

STONE BLOCKS

de-scaling lithic assemblages to reveal behavioural
variability among Neanderthal groups from the
Serpis Valley

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Doctoral Thesis by

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A mi madre y a mi hermano.

*Me gusta ir con el verano muy lejos, pero volver donde mi madre en invierno
y ver los perros que jamás me olvidaron y los abrazos que me dan mis hermanos,
me gusta,
me gusta.*

Facundo Cabral, *No soy de aquí, ni soy de allá (en vivo)*

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This Thesis is presented in the following formats:

1. Tesis doctoral presentada en una lengua diferente de las oficiales de la Universitat de València (Artículo 7)
2. Tesis doctoral presentada como compendio de publicaciones (Artículo 8)
3. Mención internacional al título de doctor o doctora (Artículo 9)

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Abstract

The length of the abstract is determined by the Doctoral School (at least 4000 characters)

This Thesis investigates how lithic assemblages are formed and how their temporal and spatial structure reflects distinct patterns of Neanderthal mobility, resource management, and spatial organisation. These questions are addressed through a theoretical and methodological framework that links artefacts, time, and space, and applies a scale-reduction approach to dissect the palimpsest nature of the archaeological record. This strategy is implemented at two sites in the Serpis Valley (eastern Iberia): Abric del Pastor and El Salt.

The central premise is that stratigraphically defined archaeological assemblages are not coherent wholes, but complex accumulations shaped by overlapping human activities and natural processes that operated both during and after the original events that generated them. Rather than treating large-scale lithic assemblages as self-contained behavioural units, this Thesis argues that the identification of discrete formation events offers a more effective route for achieving a better perception of the historical processes that shaped the lithic record. Within this framework, time is not conceived as a fixed variable but as an emergent property inferred from the relational patterns among artefacts. This model challenges the assumption of Neanderthal behavioural uniformity and seeks to demonstrate how finer-scale analyses can uncover shifting technoeconomic and spatial strategies.

The research is structured around five main objectives. First, to identify distinct archaeostratigraphic units within stratigraphic aggregates, focusing on intra-site formation processes. Second, to infer the likely extent of raw material procurement territories and reconstruct mobility patterns, addressing broader spatial dynamics in the region. Third, to analyse the introduction, modification, and discard of lithic materials across different spatial contexts, both within the site and in the landscape. Fourth, to characterise the spatial configuration of activities through detailed intra-site analysis. And fifth, to evaluate how increasing the temporal resolution of archaeological assemblages affects the interpretation of human behaviour across these different levels of analysis.

These goals are pursued through archaeostratigraphic, spatial, technoeconomic, and taphonomic analyses applied to lithic materials from stratigraphic unit V and the lower part of unit IV at El Abric del Pastor, and unit Xb at El Salt. These units serve as the basis for three peer-reviewed case studies, each highlighting distinct patterns of site formation and behavioural dynamics.

The results show that archaeostratigraphic units can be successfully defined even within complex palimpsests, particularly in the lower part of unit IV at Abric del Pastor and in the outer zone of unit Xb at El Salt, where well-defined material beds and vertical discontinuities are supported by refits and hearth associations. By contrast, resolution proves more limited in unit V at Abric del Pastor and the inner zone of unit Xb at El Salt, where sedimentary features and post-depositional alterations limit the identification of distinct formation stages.

Raw material procurement reflects a primarily local strategy centred on the upper course of the Serpis River. Flint types such as Serreta and Mariola dominate, with occasional inclusion of more distant sources as Beniaia. While El Salt displays stable procurement patterns, Abric del Pastor shows higher diachronic variability, likely tied to changing mobility and territorial strategies. The consistent absence of flint types from adjacent valleys suggests a spatial attachment to the Serpis Valley.

Lithic resource management reveals complementary patterns in both sites. At Abric del Pastor, alternating phases of intense and minimal knapping are observed, often confined to specific stages of the operational sequence. While some units reflect on-site production, others are characterised primarily by the introduction of single artefacts. El Salt, by contrast, displays a consistently higher fragmentation of operative chains, with scarce refits and a predominance of unretouched flakes. These patterns point not to a single techno-economic model, but to a diversity of overlapping strategies operating across different temporal and spatial scales.

Spatial data highlight significant intra-site variability across each formation stage. At El Abric del Pastor, spatial configurations range from hearth-related assemblages to isolated activity areas and repeated-use zones. The spatial association between flints, faunal remains, and combustion features varies from one unit to another, indicating flexible decisions, probably driven by specific techno-economic factors. El Salt appears more consistent in spatial terms, but diachronic shifts in hearth distribution and size- and weight-sorting reveal underlying behavioural variation.

In sum, this Thesis demonstrates that the relationship between scale and resolution is not merely a technical concern but a key interpretive dimension. By moving beyond stratigraphic units and focusing on discrete events and their interrelations, it becomes possible to trace shifts in techno-economic decisions within a single geological framework. Rather than reinforcing the notion of a unified behavioural model, the findings highlight variability and change as essential to the interpretation of lithic assemblage formation processes and the behavioural dynamics expressed through them.

Resumen extendido

La extensión e idioma de este resumen es el resultado de los requerimientos de la Escuela de Doctorado (mínimo 5000 palabras en una lengua oficial de la Universitat de València cuando la Tesis esté redactada en una lengua no oficial)

Introducción

La formación de los conjuntos líticos y la manera en que su estructura temporal y espacial refleja patrones de movilidad, gestión de recursos y organización del espacio constituye uno de los principales retos de la arqueología paleolítica. Esta Tesis aborda dichas cuestiones centrándose en los grupos neandertales que ocuparon el Valle del Serpis, al este de la Península ibérica, mediante el análisis de conjuntos líticos de dos yacimientos: el Abric del Pastor y El Salt. Para ello, se desarrolla un marco teórico y metodológico que vincula artefactos, tiempo y espacio, y que emplea la reducción de escala como estrategia para mitigar el efecto palimpsesto característico del registro arqueológico. Los conjuntos líticos, uno de los testimonios más persistentes y ampliamente distribuidos de la actividad humana, constituyen el núcleo empírico de esta investigación.

No obstante, el registro arqueológico presenta una complejidad inherente: los artefactos no se conservan como testigos intactos del comportamiento humano, sino que han sido modificados a lo largo del tiempo por la acción combinada de procesos culturales y naturales. A partir de este reconocimiento, la arqueología reorientó su mirada. Sin abandonar el estudio del comportamiento como objetivo central, comenzó a incorporar la investigación de los agentes y procesos que intervienen en la formación de los conjuntos, integrando estas dinámicas en las interpretaciones conductuales. Este giro analítico, reforzado por la investigación etnoarqueológica, puso de manifiesto la complejidad de los procesos de formación incluso en contextos contemporáneos observados en tiempo real. Se evidenció que, incluso bajo observación directa, la transición de la acción al residuo no sigue una trayectoria lineal.

A esta complejidad se suma el carácter fragmentario del registro arqueológico. Los conjuntos no constituyen realidades completas, sino muestras parciales y, con frecuencia, sesgadas, que se acumulan tanto en sentido vertical, como de forma lateral, sobre las superficies arqueológicas. Cuando alguno de los tres pilares interpretativos (i.e. producto, tiempo o espacio) se ve comprometido, la reconstrucción del comportamiento humano se debilita. El objetivo, por tanto, no es eliminar esta condición fragmentaria, sino mitigarla mediante estrategias de análisis que permitan afinar la escala de observación e incrementar su resolución. Solo así es posible aproximarse a las dinámicas históricas que dieron origen a los conjuntos líticos.

Sin embargo, uno de los factores que más dificulta esta reconstrucción es el efecto palimpsesto: la acumulación y transformación de múltiples episodios deposicionales, que se producen a lo largo de escalas temporales y espaciales inicialmente indeterminadas. Este

fenómeno da lugar a conjuntos en los que las secuencias originales de comportamiento quedan desdibujadas. Si no se reconoce adecuadamente, el efecto palimpsesto puede distorsionar la interpretación arqueológica, simplificando la variabilidad diacrónica en una aparente homogeneidad sincrónica y enmascarando la complejidad del cambio conductual.

Para hacer frente a este problema, la arqueología ha tendido a segmentar el tiempo en escalas (i.e. larga, media y corta duración) en función del tipo de pregunta de investigación. No obstante, estas escalas han operado como marco teórico de conveniencia bajo el “Time Perspectivism”, favoreciendo la aceptación del palimpsesto como una condición insalvable, en lugar de abordarlo como un fenómeno susceptible de ser tratado. Esta perspectiva ha derivado en el análisis de cualquier conjunto, independientemente de su historia de formación, como una unidad de análisis fiable.

Esta Tesis plantea un enfoque alternativo. En lugar de entender la escala como tiempos jerárquicos de duración fija, la concibe como una operación de zoom: un acto de ampliar o reducir el marco de observación. La resolución, en este contexto, se expresa como la densidad de información observable que resulta de dicha operación. Sin embargo, una mayor resolución no está necesariamente ligada a una escala más reducida, ni viceversa. Esta distinción permite cuestionar hasta qué punto una observación más concreta conduce realmente a interpretaciones más precisas, y si el análisis a pequeña escala garantiza una reconstrucción más fiel del comportamiento. En este sentido, la relación entre escala y resolución se plantea como una hipótesis en sí misma, con implicaciones fundamentales para el estudio de la variabilidad del comportamiento humano.

Las unidades de análisis utilizadas en la arqueología paleolítica reflejan diferentes posiciones dentro de la relación entre escala aplicada y resolución obtenida. La unidad estratigráfica, definida según principios geológicos, agrupa materiales acumulados a lo largo de amplios intervalos temporales. Esta acumulación prolongada tiende a generar promedios conductuales que pueden ocultar la variabilidad a corto plazo y proyectar una imagen excesivamente homogénea del comportamiento. Para superar esta limitación, la unidad arqueostratigráfica permite aislar episodios de formación temporalmente más acotados dentro de una misma secuencia estratigráfica, ofreciendo la posibilidad de identificar cambios o continuidades en el comportamiento, aunque el efecto palimpsesto persista horizontalmente.

Por su parte, la unidad espacial introduce una perspectiva centrada en la relación entre los artefactos, las actividades humanas y su distribución en el espacio. Así, permite identificar conjuntos asociados a hogares, áreas de desecho o zonas de descanso, siempre en función de la resolución proporcionada por la unidad de análisis original, ya sea estratigráfica o arqueostratigráfica. Finalmente, el evento se constituye como la unidad elemental mínima para interpretar la dinámica histórica: no como un “momento” inobservable perdido en el palimpsesto, sino como un episodio discreto y reconocible de acción intencional. Esta aproximación permite recuperar la variabilidad conductual y cuestionar las interpretaciones generalistas derivadas de escalas más amplias, revelando cómo variaron las decisiones tecnoeconómicas a lo largo de un tiempo y un espacio menos indeterminados.

Para respaldar este cambio de perspectiva, la Tesis adopta un modelo teórico basado en una concepción relacional del tiempo. En lugar de asumir el tiempo como una dimensión continua, lo entiende como una propiedad emergente que resulta de las interacciones entre eventos discretos. Esta idea se inspira en la Gravedad Cuántica de Bucles, que sostiene que el tiempo no es una entidad fundamental, sino el producto de correlaciones físicas entre los componentes granulares de un sistema (i.e. eventos). Trasladado al registro arqueológico, esto implica que el tiempo no preexiste a los artefactos, sino que emerge de sus relaciones tridimensionales y materiales. Así, los artefactos se conciben como indicadores de eventos, y el tiempo se infiere a partir de la forma en que estos indicadores se vinculan entre sí.

Este marco replantea el registro arqueológico no como una línea temporal, sino como una nube de correlaciones. Las discontinuidades verticales o las conexiones establecidas a partir de remontajes líticos se convierten en herramientas para inferir diacronía o contemporaneidad, reemplazando la dependencia tradicional de la datación absoluta o los criterios estratigráficos. La sincronía, en este modelo, no es una condición real, sino el producto de una resolución borrosa y desdibujada. Al centrar la atención en las relaciones entre eventos, esta Tesis pretende reconstruir secuencias de comportamiento sin recurrir a la ilusión de una unidad temporal única.

Este modelo relacional del tiempo (“Time relationalism”) no solo redefine cómo concebimos la dimensión temporal en arqueología, sino que también abre nuevas vías para captar la variabilidad de los comportamientos neandertales. En este sentido, la revisión de la producción científica pone de manifiesto diferencias tanto en las escalas aplicadas como en las interpretaciones derivadas de ellas. Cuando el análisis se realiza a escalas amplias, como la de las unidades estratigráficas, los modos de vida neandertales suelen presentarse como relativamente uniformes: preferencias constantes en el uso de materias primas, distancias medias de aprovisionamiento o pautas reiteradas de ocupación del espacio. No obstante, esta imagen es en gran medida el resultado de un promedio conductual a largo plazo: es producto del palimpsesto.

Los análisis a menor escala han revelado una realidad distinta. Las comparaciones arqueostratigráficas evidencian variabilidad en las estrategias de aprovisionamiento, en la organización del espacio y en las decisiones tecnológicas. Las unidades espaciales muestran configuraciones de ocupación diversas, que se manifiestan, por ejemplo, en distintos patrones de descarte tanto entre unidades arqueostratigráficas como dentro de una misma unidad. Por su parte, el análisis centrado en los eventos permite reconstruir con mayor precisión las decisiones tomadas en marcos temporales breves, así como la secuencia concreta de actividades realizadas. Más que un único “comportamiento neandertal”, lo que se manifiesta es una multiplicidad de estrategias y respuestas. Así, la noción de este comportamiento neandertal como un patrón uniforme pierde capacidad explicativa cuando se examina a escalas más reducidas.

En cuanto a los objetivos, esta Tesis se guía por dos propósitos fundamentales: por un lado, examinar los patrones diacrónicos del comportamiento tecnoeconómico y espacial de los grupos neandertales; y por otro, contribuir a una mejor comprensión de los procesos de

formación de los conjuntos líticos, considerando de forma conjunta tanto la acción humana como los factores naturales que intervienen en su configuración.

Para ello, se definen cinco objetivos principales. En primer lugar, identificar unidades arqueostratigráficas dentro de conjuntos definidos por criterios estratigráficos, centrándose en los procesos de formación registrados en el yacimiento. En segundo lugar, delimitar de forma aproximada los territorios de aprovisionamiento de materias primas líticas y reconstruir patrones de movilidad, atendiendo a dinámicas espaciales de ámbito regional. En tercer lugar, analizar la introducción, modificación y abandono de los materiales líticos en distintos contextos, tanto dentro del yacimiento como en el territorio en el que se enmarca. En cuarto lugar, caracterizar la organización espacial de las actividades a partir de conjuntos con y sin estructuras de combustión identificados en los yacimientos. Y en quinto lugar, evaluar cómo el incremento de la resolución temporal de los conjuntos arqueológicos incide en la interpretación del comportamiento humano desde estos distintos niveles de análisis. A través de este marco integrado, esta Tesis propone explorar la variabilidad del comportamiento de los grupos neandertales en el Valle del Serpis, a partir de los registros del Abric del Pastor y El Salt (Alcoi, este de la Península ibérica).

Contextos arqueológicos

Los yacimientos arqueológicos del Abric del Pastor y El Salt se localizan en el este de la Península ibérica, dentro del Prebético oriental de la Cordillera Bética, una unidad geológica conformada durante la orogenia Alpina. Esta región se caracteriza por un sustrato de rocas sedimentarias plegadas y fracturadas, principalmente calizas y margas de origen mesozoico, que configuran un relieve abrupto, modelado por fallas inversas y otras estructuras tectónicas. En ese contexto, el Valle del Serpis, donde se sitúan ambos yacimientos, constituye un corredor fluvial moldeado por la acción del río y sus afluentes. Dicha dinámica erosiva facilitó la movilización natural de diversos tipos de sílex, que se convirtieron en la principal materia prima lítica empleada por los grupos neandertales en la región.

El Abric del Pastor es un abrigo rocoso situado a 820 metros sobre el nivel del mar, en la margen izquierda del Barranc del Cint, dentro del Parque Natural de la Serra de Mariola. Esta sierra, modelada por pliegues anticlinales e intensos procesos kársticos, está compuesta principalmente por calizas cretácicas elevadas durante el final del Mioceno. El abrigo en sí corresponde a un paleotubo kárstico formado en calizas tortonienses, con una superficie conocida de 60 m², de los cuales se han excavado 40 m². La mayor parte del aporte sedimentario proviene de una visera principal y de una cornisa interna parcialmente colapsada.

La secuencia estratigráfica conocida alcanza un espesor de 1,5 metros y comprende seis unidades estratigráficas (de la UE VI a la UE I). Los niveles pleistocenos (UE VI–II) abarcan desde aproximadamente 62 hasta 48 ka, mientras que la SU I corresponde a un depósito holoceno con materiales en posición secundaria, que refleja alteraciones como bioturbación y removilización producida por el uso pastoril. La mayoría de la información publicada proviene de la parte superior de la UE IV, donde se han identificado episodios de ocupación

de corta duración. Los artefactos líticos están producidos principalmente con sílex de origen local, y el conjunto faunístico está dominado por cabra montés, ciervo y tortuga mediterránea.

En esta Tesis, se estudian la UE V y la base de la UE IV, con el objetivo de profundizar en el conocimiento de las ocupaciones neandertales más antiguas del yacimiento, así como ordenar y contextualizar los procesos de formación que preceden a los episodios mejor conocidos de la parte superior de la secuencia. Además, las unidades objeto de estudio se corresponden con los momentos previos a la reconfiguración estructural del abrigo provocada por el desplome de la visera interior, lo que confiere un valor añadido al análisis de las estrategias espaciales desarrolladas en este contexto.

El Salt es un abrigo rocoso situado a 680 metros sobre el nivel del mar y ubicado bajo una pared caliza paleocena de 38 metros de altura. El yacimiento se encuentra en la confluencia de los ríos Barxell y Polop que da lugar al río Serpis, sobre una terraza de travertino formada durante el estadio isotópico 5. Su depósito arqueológico, de unos 6,3 metros de espesor, está compuesto principalmente por sedimentos derivados del travertino que cubre la pared y conserva una secuencia estratigráfica de trece unidades. Los conjuntos asociados al Paleolítico medio se concentran entre las UE XII y V, en un intervalo que se estima entre aproximadamente 60 y 45 ka.

La secuencia documenta un patrón de ocupaciones neandertales recurrentes y de corta duración, frecuentemente organizadas en torno a estructuras de combustión. Esto es especialmente evidente en la UE Xa, donde los hogares están excepcionalmente bien preservados, con capas de ceniza definidas y sustratos termoalterados. El sílex domina los conjuntos líticos, mientras que el registro faunístico está compuesto principalmente por ciervo, cabra montés y caballo, con presencia ocasional de jabalí y algunos carnívoros. Los datos paleoambientales indican una tendencia general hacia una mayor aridez a lo largo de la secuencia, siendo los cambios más marcados los observados en la UE V, que contiene además las últimas evidencias de presencia neandertal en el yacimiento.

En esta Tesis se ha seleccionado la UE Xb para un análisis detallado, ya que ofrece un contexto estratigráfico y paleoambiental bien conservado para explorar la variabilidad del comportamiento en alta resolución, a la vez que complementa la historia diacrónica de los grupos neandertales ya documentada para la UE Xa.

Materiales y métodos

Los materiales empleados en esta Tesis proceden de dos fuentes principales: las coordenadas tridimensionales de los restos arqueológicos y los propios artefactos líticos. Las primeras permitieron realizar los análisis arqueostratigráficos y espaciales, mientras que los segundos proporcionaron la información necesaria para el análisis tecnoeconómico. Los materiales líticos fueron solicitados a la Generalitat Valenciana y estudiados bajo permiso de préstamo autorizado por el Museu Arqueològic Municipal d'Alcoi.

Para el análisis espaciotemporal, las coordenadas 3D fueron registradas mediante estación total para todos los restos arqueológicos, excepto el carbón. Se contó con un total de 1.712 artefactos líticos, 579 restos faunísticos y 18 estructuras de combustión. Este procedimiento, combinado con protocolos estrictos de excavación, garantizó una elevada precisión tridimensional.

Solo se incluyeron en el estudio tecnoeconómico los restos líticos con coordenadas registradas (1.702 artefactos). Estos materiales fueron sometidos a tareas de limpieza, siglado y etiquetado en la Universitat de València. Posteriormente, toda la información tridimensional y tecnoeconómica se integró en una base de datos unificada para su análisis.

Metodológicamente, esta Tesis adopta una estrategia articulada en distintos niveles de análisis, orientada a caracterizar tanto los procesos de formación como la variabilidad tecnoeconómica de los conjuntos líticos. En primer lugar, se llevó a cabo un análisis de materias primas mediante técnicas macroscópicas y microscópicas con el objetivo de identificar los tipos de sílex documentados en el Prebético oriental. Se prestó especial atención a los sílex tipo Serreta, Mariola y Beniaia, ampliamente representados en los registros arqueológicos de la región y cuyas propiedades geológicas han sido descritas con detalle en trabajos previos. Asimismo, se evaluaron posibles alteraciones postdeposicionales a través de la identificación de productos termoalterados y superficies con pátina blanca. A partir de estas variables genéticas y postgenéticas, los artefactos fueron agrupados en Unidades de Materia Prima (UMP).

Posteriormente, los conjuntos líticos fueron sometidos a un análisis detallado de atributos, incluyendo criterios morfotécnicos, dimensionales y de peso. Los artefactos se clasificaron por tipo de producto (lascas, productos retocados, núcleos y fragmentos), y para cada tipo se midieron distintas variables tecnológicas. Luego, se llevó a cabo un análisis de remontajes para reconstruir las secuencias de producción e identificar patrones de actividad en el espacio. Las conexiones entre artefactos fueron descritas y cuantificadas, lo que facilitó las interpretaciones sobre los procesos de formación del registro en los pasos posteriores.

El análisis arqueostratigráfico se realizó en tres dimensiones utilizando el software ArcGIS Pro, con el fin de identificar distintos estadios de formación dentro de las unidades estratigráficas. Este incluyó la evaluación de discontinuidades verticales de materiales, continuidad lateral de lechos de artefactos, remontajes líticos y marcadores de superficie como hogares y bloques.

Por último, se aplicó un conjunto de pruebas espaciales con el objetivo de evaluar la organización interna y la integridad de cada unidad de análisis obtenida. Estas pruebas se agruparon según su finalidad: para examinar la distribución general de los restos se emplearon el Average Nearest Neighbour y la función L de Ripley; la estimación de densidades se realizó mediante análisis Kernel; y la detección de "clustering" se abordó a través del algoritmo DBSCAN y el análisis Optimised Hot Spot. Además, se utilizaron pruebas de Chi-cuadrado como herramienta de contraste estadístico. Todos estos análisis se adaptaron a las características de cada caso de estudio e integraron, cuando fue pertinente, datos faunísticos, de estructuras de combustión y topográficos.

Resultados

Los métodos aplicados a los materiales procedentes de ambos yacimientos han dado lugar a tres artículos científicos publicados en revistas internacionales de alto impacto. A continuación, se presentan los resúmenes de cada trabajo.

Caso de estudio 1: “Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula)”. Contrastar hipótesis sobre el comportamiento neandertal requiere alcanzar una resolución espaciotemporal próxima a un único episodio de ocupación humana. Sin embargo, la mayoría de los datos disponibles provienen de contextos con cronologías imprecisas, afectados tanto por el efecto palimpsesto como por diversos procesos postdeposicionales. Esto implica que el comportamiento neandertal caracterizado en alta resolución temporal sigue siendo, en gran medida, desconocido. En este estudio se aplicó un análisis arqueostratigráfico sobre las unidades IVe, IVf, IVg, Va, Vb y Vc del Abric del Pastor (Alcoi, Península ibérica). A partir de este análisis se logró aislar una unidad arqueostratigráfica concreta, sobre la cual se realizaron estudios de materias primas, tecnología lítica, huellas de uso, arqueozoología y análisis espacial. Los resultados muestran una acumulación de baja densidad formada por productos de talla, artefactos utilizados y restos de fauna procesados en torno a un hogar. Estos datos aportan una dimensión humana a través de una resolución temporal muy alta, que complementa la información ambiental y pirotecnológica previamente obtenida para ese mismo hogar, constituyendo la primera caracterización integral de un potencial episodio de ocupación neandertal. Asimismo, el enfoque metodológico multidisciplinar empleado contribuye al avance en el conocimiento sobre los procesos de formación del registro arqueológico.

Caso de estudio 2: “The Time of the Stones: A Call for Palimpsest Dissection to Explore Lithic Record Formation Processes”. La disección de palimpsestos arqueológicos se ha consolidado como una herramienta clave para comprender la historia de los grupos humanos desde una perspectiva diacrónica. Sin embargo, su aplicación generalizada ha estado limitada por obstáculos metodológicos y teóricos, así como por las propias características del registro arqueológico. Este trabajo evalúa si superar estas barreras representa un cambio significativo en la forma de entender el comportamiento humano del pasado, y si ello justifica la exploración de escalas más reducidas. Con este fin, se analizaron los conjuntos líticos de la unidad Xb del yacimiento neandertal de El Salt (Alcoi, Península ibérica), centrándose en atributos tecnológicos y en el análisis de materias primas, lo que permitió definir Unidades de Materia Prima (UMPs) y remontajes. A partir de estas variables, se aplicaron análisis arqueostratigráficos y espaciales para generar unidades de análisis cuyos datos fueron comparados con los del total de la unidad. Las unidades arqueostratigráficas definidas presentan composiciones y distribuciones espaciales diferenciadas: algunas están asociadas a hogares e incluyen remontajes, mientras que otras se relacionan con zonas sin evidencias de combustión e incluyen productos singulares, de mayor tamaño y peso. Este enfoque demuestra que la reducción de la escala permite detectar una mayor variabilidad del comportamiento, disminuyendo los errores interpretativos inherentes al análisis del conjunto total. Asimismo, refuerza el papel de la resolución temporal en la reconstrucción

de los procesos de formación del registro y cuestiona aquellas perspectivas que consideran innecesaria o inviable la disección del palimpsesto.

Caso de estudio 3. “Knapping... sleeping and consuming? Spatial variability in the high-resolution Neanderthal context of Abric del Pastor (Alcoi, eastern Iberia)”: Secuenciar y caracterizar unidades de alta resolución en las que puedan observarse procesos antrópicos y naturales en escalas comparables resulta fundamental para comprender tanto el comportamiento espacial como los procesos de formación del registro arqueológico. Esto requiere una aproximación multidisciplinar que ya se ha aplicado previamente en el Abric del Pastor (Alcoi, este de Iberia), revelando ocupaciones cortas con alta resolución espaciotemporal en la unidad IV, especialmente a partir del estudio de los conjuntos líticos. En este trabajo, se extiende dicho marco metodológico a la unidad estratigráfica V, investigando los procesos de formación del registro lítico mediante análisis arqueostratigráficos y espaciales, que integran materias primas, atributos tecnológicos y remontajes. Además, se incorporan técnicas de micromorfología de suelos y análisis de *n*-alcanos para explorar aspectos clave de la formación sedimentaria. Estas técnicas permitieron confirmar la presencia de hogares *in situ* y descartar procesos erosivos en el sector oeste del abrigo, donde no se han recuperado materiales arqueológicos. Los resultados, con los remontajes como referencia, revelan al menos dos estadios distintos de formación antrópica, caracterizados por actividades de talla recurrentes en la zona norte. Estas actividades presentan variabilidad interna en cuanto al tipo de sílex y a la intensidad de uso. Además, esta zona de talla se encuentra espacialmente segregada de otras tres: una con un hogar aislado junto a la pared del abrigo, sin materiales asociados, posiblemente vinculada al descanso; otra con una acumulación diacrónica de restos faunísticos; y una tercera sin registro arqueológico ni signos de alteración postdeposicional. La identificación de eventos de formación discretos permite documentar un ejemplo detallado de variabilidad espacial, en el que ciertas zonas fueron utilizadas deliberadamente para actividades similares en momentos distintos. Este patrón contrasta con la organización espacial de la unidad IV y con otros contextos neandertales, evidenciando cambios en las estrategias de estructuración y uso del espacio.

Discusión

Los resultados de estos tres estudios abren nuevas posibilidades para la discusión e interpretación del registro lítico en el tiempo y el espacio.

La definición y caracterización de unidades arqueostratigráficas (UAs) resulta clave para refinar la escala desde la que interpretar el comportamiento diacrónico de los grupos neandertales. A través de una combinación de análisis tridimensional y vínculos físicos entre artefactos a partir de remontajes y unidades de materia prima (UMPs), este trabajo ha alcanzado distintos grados de resolución. Los resultados más claros se obtuvieron en el Abric del Pastor, especialmente en los niveles inferiores de la UE IV, donde la presencia de lechos materiales bien definidos y discontinuidades verticales permitió identificar UAs bien delimitadas, como IVfH17. Esta unidad se encuentra separada por un hiato de 5–6 cm y presenta un alto grado de conservación, lo que sugiere un patrón ocupacional de baja intensidad y corta duración.

En cambio, la UE V del mismo yacimiento presentó mayores dificultades metodológicas. Aunque se identificaron dos estadios de formación a partir de hiatos materiales aislados y de la relación vertical entre distintos remontajes, estas evidencias no fueron lo suficientemente consistentes en toda la superficie excavada como para justificar la definición de distintas UAs. La textura sedimentaria desempeñó un papel crucial para explicar esta limitación: los sedimentos más gruesos del sureste favorecieron la separación de eventos, mientras que los más finos del norte fueron más susceptibles a la compactación vertical, tanto natural como antrópica. Los indicadores tafonómicos, como el daño en filos y la pátina blanca, reforzaron la hipótesis de “trampling” y meteorización, en un área con mayor densidad material y mayor exposición.

En El Salt, la UE Xb presentó una complejidad añadida debido a la erosión holocena, que interrumpió la continuidad espacial entre las zonas interior y exterior de excavación. Por este motivo, la unidad fue analizada como dos entidades espaciales separadas. Se identificaron cuatro UAs, dos en cada zona, pero no se logró establecer una correlación lateral clara entre ellas. Mientras que las UAs exteriores están bien separadas por hiatos verticales y asociadas con capas de hogares, las interiores muestran un patrón de puntos más ambiguo, donde los principales criterios de separación han sido los remontajes y las asociaciones con estructuras de combustión.

A pesar de estas dificultades, la integración de datos tafonómicos y tecnoeconómicos en los tres casos ha demostrado el potencial de la arqueostratigrafía para reconstruir relaciones diacrónicas incluso en palimpsestos complejos. No obstante, también se señalan los límites actuales y se propone una aproximación más microcontextual para futuras investigaciones. En lugar de trabajar únicamente sobre superficies amplias de manera extensiva, la arqueostratigrafía debería centrarse también en zonas específicas donde puedan establecerse correlaciones entre eventos con mayor seguridad.

El aprovisionamiento de materias primas líticas constituye una vía informativa clave para examinar la movilidad de los grupos neandertales en el Valle del Serpis. Aunque esta Tesis no pretende delimitar zonas de captación concretas, la diferenciación de tipos de sílex permite reconstruir patrones generales de gestión del territorio. Así, se observa un contraste claro entre ambos yacimientos. En El Salt, el aprovisionamiento presenta una homogeneidad relativa, con predominio constante del sílex Serreta a lo largo de las UAs definidas. En cambio, el Abric del Pastor muestra una alta variabilidad diacrónica en la frecuencia y diversidad de tipos de sílex, incluyendo Mariola, Serreta y Beniaia.

En el Abric del Pastor, los sílex Mariola y Serreta predominan en las fases iniciales, mientras que el tipo Beniaia adquiere mayor protagonismo en las más recientes. Los datos sugieren un aprovisionamiento de corto alcance (3–5 km) desde la cabecera del Serpis, complementado con captación ocasional en tramos medios del valle, especialmente para los sílex Beniaia y Catamarruc (>17 km). Un patrón similar se documenta en El Salt, donde Serreta y Mariola dominan en las fases tempranas y Beniaia gana relevancia en unidades como la UE VIII.

Aunque no se realizó un análisis exhaustivo de las características postgenéticas del sílex, las correlaciones entre la frecuencia de los tipos de sílex y sus áreas de captación conocidas apuntan a un aprovisionamiento mayoritariamente local, complementado ocasionalmente con materiales de procedencia más lejana. La recurrencia de sílex de buena calidad para la talla, combinada con su accesibilidad a lo largo del valle del Serpis, habría reducido los costes de búsqueda y transporte, especialmente en un paisaje caracterizado por una notable diversidad ecológica y abundancia de recursos. Estas condiciones probablemente minimizaron la necesidad de desplazamientos hacia otros valles. La ausencia sistemática de sílex procedentes de fuera del valle del Serpis, incluidos aquellos disponibles en valles adyacentes, sugiere una explotación preferente del territorio inmediato y una orientación espacial del aprovisionamiento centrada en dicho corredor fluvial.

El análisis de la formación de los conjuntos líticos ofrece perspectivas complementarias sobre cómo los grupos neandertales gestionaron los recursos líticos en el Valle del Serpis. A pesar de ciertas similitudes estructurales, los patrones observados en El Abric del Pastor y El Salt sugieren distintos grados de fragmentación en las cadenas operativas.

En el Abric del Pastor, la secuencia arqueológica muestra una alternancia entre momentos con alta actividad de talla y otros con escasa o nula evidencia de producción *in situ*. Unidades como la UE V, UA IVd1 y IVb se caracterizan por una evidencia sustancial de talla, aunque a menudo limitada a fases específicas de la secuencia y con un número relativamente bajo de UMPs. En cambio, otras unidades como las UAs IVfH17, IVc2 o IVc1 están dominadas por la introducción singular de lascas, núcleos o productos retocados, sin evidencia clara de talla en el yacimiento. Estas diferencias no siguen una progresión diacrónica, sino que aparecen de forma intermitente a lo largo de la secuencia. En conjunto, este patrón sugiere un uso flexible y de corta duración del yacimiento, donde cada etapa de formación respondería a necesidades tecnológicas específicas.

El Salt muestra un patrón más homogéneo, con una actividad de talla sistemáticamente reducida. Los remontajes y las UMPs son escasos a lo largo de toda la secuencia, y la mayoría de los conjuntos están dominados por productos singulares. Esto sugiere un alto grado de fragmentación en las cadenas operativas, un patrón coherente con lo documentado en muchos otros yacimientos del Paleolítico medio europeo. Pese a la abundancia de entornos de captación de sílex en las proximidades, la mayoría de los materiales líticos parece haber sido introducida al yacimiento en formatos preconfigurados, principalmente como lascas sin retoque. Estas habrían formado parte de estrategias de aprovisionamiento individual, en las que los “toolkits” se compondrían de herramientas pequeñas y versátiles. No obstante, también se documenta cierta variabilidad, como el transporte esporádico de núcleos grandes y pesados del sílex más lejano o productos con un alto grado de retoque del sílex más cercano, lo que sugiere que dichas estrategias no fueron completamente homogéneas a lo largo del tiempo.

El predominio de lascas sin retoque en ambos yacimientos sugiere una estrategia tecnológica basada en la flexibilidad y la eficiencia en los costes. Más que interpretarlo como un reflejo de simplicidad tecnológica o una limitación de los recursos, parece tratarse

de una elección deliberada, adecuada para ocupaciones cortas en un entorno conocido y rico en recursos. No obstante, estos conjuntos no representan un único modo de gestión tecnoeconómica, sino múltiples estrategias superpuestas a lo largo de distintos tiempos y espacios. Esta configuración pone en cuestión las lecturas tipológicas o puramente tecnológicas del comportamiento tecnoeconómico de los grupos neandertales, y plantea la necesidad de un modelo interpretativo que integre la movilidad y el aprovisionamiento, teniendo en cuenta la naturaleza episódica de los procesos de formación del registro arqueológico.

Los datos espaciales obtenidos en esta Tesis revelan una notable variabilidad en la manera en que los grupos neandertales estructuraron sus actividades a lo largo de distintos estadios de formación, y destacan hasta qué punto el tiempo condiciona nuestra percepción del espacio. En El Abric del Pastor, donde se habían identificado principalmente conjuntos asociados a hogar, los resultados de esta Tesis permiten enriquecer esa imagen al evidenciar un patrón espacial mucho más complejo y variable. En la UE V, por ejemplo, la única estructura de combustión identificada (H19) no muestra una asociación clara con el registro material, mientras que la actividad de talla se concentra en una zona alejada del propio hogar. Esta desconexión espacial de la actividad de talla y la estructuración del espacio a partir del fuego, repetida al menos en dos etapas de formación distintas, sugiere una producción lítica anticipada, posiblemente vinculada a tareas logísticas ajenas al propio yacimiento.

Esta imagen contrasta con la UA IVfH17, donde la asociación espacial entre el hogar, los huesos de ciervo procesados, los productos de talla y las herramientas utilizadas indica un episodio breve de formación con múltiples actividades vinculadas. Esta unidad marca el inicio de un patrón de actividades en torno al fuego dentro del yacimiento. Sin embargo, dicho patrón se expresa de formas diversas a lo largo de la secuencia conocida. Mientras algunos hogares (como H8 o H6) muestran acumulaciones mixtas de productos líticos y fauna, otros parecen tener funciones más específicas: H9 y H5 se asocian claramente con actividades de talla, mientras que H14 se vincula exclusivamente al procesamiento de carcasas. La presencia de hogares sin materiales circundantes y la ausencia de fuego en ciertas unidades ilustran aún más la diversidad en el uso del espacio. Factores estructurales, como la línea de visera o la morfología del abrigo, explican parcialmente estas decisiones espaciales, pero otros aspectos, posiblemente de orden cultural, también merecen un peso interpretativo. De hecho, la introducción preferente del sílex Beniaia, de captación más lejana, se correlaciona con configuraciones espaciales distintas en IVd1 y IVb, que incluyen múltiples hogares y una intensa actividad de talla *in situ*. Estos patrones podrían revelar distintas estrategias de gestión territorial reflejadas a nivel intra-site o incluso la presencia de grupos distintos.

En El Salt, la organización espacial presenta un patrón más homogéneo, con conjuntos asociados al fuego presentes de forma constante tanto en la zona interior como en el área exterior. Sin embargo, esta aparente regularidad, producto del palimpsesto, oculta variaciones diacrónicas y diferencias localizadas en los patrones de actividad. Por ejemplo,

el mayor número de hogares en toda la secuencia aparece en el área exterior durante la UA Xb1out, mientras que en fases posteriores la actividad de combustión se concentra cada vez más en la zona interior. Estos cambios en el enfoque espacial, junto con las variaciones en la representación de tipos de sílex, reflejan la naturaleza dinámica del uso del sitio a lo largo del tiempo. Cabe destacar que, aunque los hogares funcionan como focos de organización espacial, la presencia de actividad de talla no siempre está directamente relacionada con las estructuras de combustión, lo que cuestiona cualquier suposición de patrones sistemáticos.

La identificación de una acumulación discreta de grandes núcleos de sílex de Beniaia en la UA Xb2out ejemplifica esta variabilidad. Su localización, ligeramente apartada de las áreas de actividad asociadas a hogares, y sus características de tamaño, peso y tipo de sílex abren múltiples posibilidades interpretativas. Estos núcleos podrían representar reservas de materia prima, productos desechados durante tareas de acondicionamiento del espacio, o herramientas seleccionadas para actividades específicas como el procesamiento de grandes carcasas. Un caso comparable en términos de variabilidad es el del hogar H50, cuya profundidad y complejidad de su formación sedimentaria sugieren un uso prolongado o repetido. La alternancia de tipos de combustible y la evidencia de reordenamiento interno en la capa de ceniza apuntan a una acumulación sostenida en el tiempo, añadiendo una dimensión temporal al análisis espacial. Conjuntamente, estos casos muestran que un análisis detallado del registro permite superar la aparente homogeneidad de los palimpsestos e identificar decisiones específicas más allá del comportamiento recurrente.

La comparación entre El Salt y El Abric del Pastor refuerza una idea fundamental: la organización del espacio no responde a una función predeterminada del yacimiento, sino que es el resultado de múltiples decisiones tomadas a lo largo del tiempo. La variabilidad observada, tanto a escala “intra-” como “intersite”, pone en cuestión las interpretaciones tipológicas y excesivamente simplificadoras. No es la reiteración de ciertas configuraciones espaciales, como los conjuntos vinculados a hogares, lo que define un lugar, sino la capacidad para reconocer cuándo y cómo dichas configuraciones surgen, desaparecen o se transforman. Por ello, el estudio del comportamiento espacial debe mantenerse sensible a la escala y la resolución resultante, evitando etiquetas que, en lugar de aclarar, tienden a oscurecer los procesos históricos subyacentes. En esta línea, ambos yacimientos se entienden mejor no como categorías funcionales rígidas, sino como recursos en sí mismos: espacios con determinados costes de acceso y uso, cuya ocupación dependió de dinámicas territoriales más amplias y de necesidades específicas en cada momento.

Los resultados de este estudio ponen de relieve el valor de la disección de palimpsestos arqueológicos como herramienta para afinar las interpretaciones sobre el comportamiento humano. La reducción de escala ha resultado clave para identificar tanto la continuidad como la variabilidad en los patrones de actividad, siendo dos dimensiones que suelen quedar enmascaradas cuando se trabaja desde escalas de análisis más amplias. Así, mientras en El Salt la actividad de talla se manifiesta en momentos y áreas concretas, en la UE V del Abric del Pastor se documenta un uso reiterado del mismo espacio para esta actividad. Estas diferencias no habrían sido perceptibles sin la aplicación de un mismo marco de análisis.

Lejos de imponer una única lectura, reducir la escala permite captar la diversidad y matices del comportamiento humano en el registro arqueológico.

Este planteamiento adquiere una relevancia particular en conjuntos de alta densidad, donde la combinación de eventos de formación inconexos puede dar lugar a interpretaciones erróneas, leídas en ocasiones como tendencias generales de comportamiento. Lo que a simple vista parece un patrón estructurado puede descomponerse, al observarse con mayor detalle, en una suma de eventos sin relación directa entre sí. Centrar el análisis en los eventos y en sus vínculos, en lugar de asumir que el conjunto forma una unidad coherente, permite formular interpretaciones más ajustadas a los procesos antrópicos y naturales que dieron forma al registro.

Así, el análisis confirma la estrecha relación entre escala y resolución. Las unidades estratigráficas proporcionan una visión parcial y, en muchos casos, equívoca, mientras que las unidades arqueostratigráficas, espaciales y, especialmente, los enfoques centrados en eventos permiten lecturas más precisas y matizadas del comportamiento humano. Este enfoque cuestiona la validez de un “comportamiento neandertal” homogéneo, evidenciando que esta imagen es, en gran medida, un producto del análisis a gran escala. Frente a ello, la reducción de escala no solo incrementa la resolución interpretativa, sino que permite reconocer la diversidad inherente a las estrategias y decisiones humanas. En definitiva, esta Tesis demuestra que es precisamente en la variabilidad, en el cambio, y no en la uniformidad, donde reside la clave para comprender el comportamiento de los grupos neandertales.

section



I

INTRODUCTION



I. Introduction

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I. Introduction

This Thesis is situated within the broader field of research on the formation processes of archaeological assemblages, with a particular focus on the lithic record. The very notion of “processes” inherently implies a diachronic perspective on formation: i.e. the recognition that both intentional and unintentional actions and their material results unfold over different times. Consequently, this study places a strong emphasis on temporality. Moreover, as time only unfolds within space, spatial considerations are equally central to this work. These two fundamental dimensions, arguably the most crucial in any scientific discipline, are explored through the lens of stone tools, whose three-dimensional positioning and techno-economic attributes serve not only as the object of study but also as the source of hypotheses, results, and interpretations.

Within this general framework, the research is rooted in a specific territorial context: the Serpis Valley in eastern Iberia. More precisely, the sites of Abric del Pastor and El Salt provide the archaeological deposits where these formation processes can be investigated in both time and space. By examining the lithic assemblages recovered from these sites, this study seeks to reconstruct the behavioural dynamics of our subjects of study: Neanderthal groups.

1.1. Record formation processes

How did thousands of artefacts end up here? This seemingly simple question encapsulates one of the fundamental challenges in Palaeolithic archaeology: comprehending the processes that led to the formation of archaeological assemblages. Addressing this issue is not limited to describing how these processes unfolded. It requires structuring and sequencing them as a basis for a broader objective: understanding past human behaviours.

This question, in turn, brings together the three central aspects of this study. Although they are listed here, they will be detailed throughout this chapter. First, artefacts: there can be no attempt to reconstruct behaviour without materiality (Reid et al., 1975; Schiffer, 1976; Dobres & Hoffman, 1994; Skibo & Schiffer, 2008). The empirical foundation of behavioural archaeology lies in the analysis of material traces, whether lithic artefacts, faunal remains, or features such as hearths. Although not all of these are “artefacts” in the strict sense of intentionally modified objects, they all result from human activity and contribute to the reconstruction of past behaviours. Therefore, an archaeology of behaviour must be firmly rooted in material evidence.

Second, time: materiality is cumulative and, as such, has the potential to generate time (Lucas, 2021). The study of artefacts through their capacity to produce time allows us to identify either continuity or variability in behaviour, depending on the analytical units employed. Third, space: within each unit of analysis, artefacts are distributed spatially according to both cultural components and natural transformations (Schiffer, 1972, 1975). While space is an inherent variable of artefacts, the presence or absence of meaningful spatial correlations must be considered separately, as these relationships play a key role in assessing formation processes (Schiffer, 1975; Binford, 1978; Stevenson, 1985; Vaquero & Pastó, 2001). While human behaviour emerges from materiality, its continuity or variability is inherently shaped by time and space.

“To look for differences (variations) is to take into consideration the discontinuities in particular technological traits of material culture, both through time and over space” (Lemonnier, 1992: 19).

Thus, if we wish to reconstruct past human behaviours, we must focus on materials that generate a temporal and spatial framework. But this is far from straightforward: several challenges complicate such an approach. The first is that artefacts do not exist in a pristine state; rather, they are shaped by a complex interplay of geogenic and anthropogenic processes that are constantly acting.

Understanding human behaviour and its transformations therefore requires, on the one hand, acknowledging that the archaeological record is not a perfect reflection of past systems. With this premise, the New Archaeology aimed to observe and document living systems with similar socio-economic structures (i.e. hunter-gatherer groups) through archaeological questions (e.g. technology, mobility, settlement dynamics). This gave rise to Ethnoarchaeology, which produced numerous studies such as those by John Yellen (1976) and Richard Lee (1979) on the !Kung, Lewis Binford on the Nunamiut (1977, 1978, 1980), and Binford and O’Connell on the Alyawara (Binford & O’Connell, 1984; Binford, 1986; O’Connell, 1987).

Ethnoarchaeology thus became a key tool for understanding the archaeological record, generating questions and hypotheses that could be tested. However, despite its great utility, ethnoarchaeological data were not free from uncertainty (Schiffer, 1978). The high dynamism of human-scale behaviours raised concerns: there is a constant diachrony in the formation processes of assemblages that is difficult to detect even in living systems. A clear example of this is the cautionary stance taken in Robert Ascher “Analogy in Archaeology” (1961):

“At any point in its existence some proportion of materials are falling into disuse and decomposing, while new materials are being added as replacement. In a certain sense a part of every community is becoming, but is not yet, archaeological data” (Ascher, 1961: 324).

At the same time, archaeologists began to recognise that the formation of the archaeological record was also shaped by non-human processes, which required much attention (Schiffer, 1972, 1983a; Binford, 1981). This led to a shift in focus towards identifying these processes and

assessing the extent to which cultural patterns could be distinguished from them (whether this filtering process generated a pristine record, which is the basis of the “Pompeii premise” debate). From this perspective, formation process studies started to place equal emphasis on both the sedimentary matrix that encloses artefacts and the artefacts themselves (e.g. Villa, 1982; Villa & Courtin, 1983; Gifford-González et al., 1985; Hofman, 1986). In fact, considering archaeological materials as “sedimentary components” (sensu Bertran et al., 2019) offers a more coherent framework for analysing site formation, as it allows us to better distinguish what is (and what is not) the result of intentional human activity.

Another challenge stems from the inherently fragmentary nature of the archaeological record (“the issue of incompleteness”; sensu Lucas, 2012 following “archaeological context” of Schiffer, 1972). Artefacts are not complete representations of past behaviours; they are “fragments” of a broader whole (sensu Lucas, 2012, 2014). As DeBoer (1983: 21) notes, archaeological assemblages are far from pristine behavioural records, not only due to cultural and natural transformations, as Schiffer pointed out, but also because of sampling biases.

This issue is particularly relevant when considering spatial distribution. A given assemblage may lose its interpretive strength if it does not represent a significant proportion of the total spatial context, regardless of its quantitative representation: assemblages are formed not only from bottom to top, but also from side to side. Thus, any attempt to assess behavioural variability or continuity tends to collapse if any of the three foundational pillars (i.e. artefacts, time, or space) is compromised. This does not mean that we cannot reconstruct the behaviours of past groups because of a problem of representation in any of these pillars. In fact, the challenge of the archaeological discipline must be precisely to control this bias, extract from a fragmentary sample the closest image of the operation of that system, and balance the historical inferences based on the scale of analysis and the resulting resolution.

1.2. Time and space: palimpsests, scales and resolutions

When all the factors influencing the formation of the archaeological record began to be considered, a particular phenomenon emerged; one that unites both intentional human action and natural depositional processes while simultaneously preventing a pristine image of past behaviour: **the palimpsest effect**.

At a general level, this effect arises from the accumulation and transformation of multiple depositional episodes across initially indeterminate temporal and spatial scales (Binford, 1981; Bailey, 1983, 2007, 2008; Schiffer, 1985; Vaquero, 2008, 2012; Malinsky-Buller et al., 2012). Thus, if the main obstacle to reading past human behaviours is the palimpsest effect, then the task of identifying, isolating, and sequencing the formation processes of preliminary “mixed” and blurred assemblages becomes indispensable.

Neglecting this task (ignoring the problem) leads to erroneous interpretations of diachronic behaviour, often reducing behavioural dynamism into a singular, undifferentiated package (converting behaviours into a single behaviour) and mistaking change for stasis (turning diachronic into synchronic).

“For example, the artifact groupings produced by spatial analysis of occupation floor data are traditionally interpreted as directly reflecting the composition of tool kits or the residues of specific activities. Thus, when the investigator does not seek to understand and take into account formation processes, the analysis automatically contains the implicit assumptions that formation processes had benign effects and that archaeological assemblages can be treated analytically as if they are equivalent to systemic inventories” (Schiffer, 1985: 20).

But rather than resolving it, archaeology has avoided the issue by borrowing a conceptual framework from the social sciences: Braudel division of time. Fernand Braudel had already developed a methodological approach for addressing historical change, structuring time according to the nature of the questions being asked (Knapp, 1992; Murray, 1999; Harding, 2005; Simonetti, 2018; Lucas, 2021). He proposed three analytical scales according to different “wavelengths of time” (*sensu* Bintliff, 2006):

1. “Longue durée”—long-term structural behaviours
2. “Conjoncture”—medium-term processes
3. “Événement”—short-term events

The “longue durée” or the long-term referred to large-scale processes, typically linked to geographical or climatic changes, while the “conjoncture” or medium-term encompassed historical processes that, situated within the framework of the long-term, explained the relationship between human groups and those broader transformations (Harding, 2005; Bintliff, 2006; Harris, 2017). For Braudel, both the long- and medium-term were the most reliable analytical scales, as events (short-term) contained a degree of uniqueness that made them less explicable and comparable. Thus, the two longer timescales were considered more representative of structural patterns.

In archaeology, this framework was adopted by Geoff Bailey, who initiated the Time Perspectivism approach (e.g. 1983, 2007, 2008). This perspective highlighted the issue of the palimpsest effect, drawing attention to the assumptions underlying archaeological interpretations. For Bailey or Murray (e.g. 1999; 2008), the medium- and long-term processes were the most suitable scales for deriving behavioural inferences, whereas events were largely inaccessible due to the very nature of the palimpsest effect. However, these medium- and long-term scales were themselves tied to archaeological sequences and stratigraphic units, which were, in turn, deeply affected by time-averaging. Thus, variability could be observed, but always with an inherent degree of interpretative uncertainty.

In this connection, Bailey and colleagues criticised the use of ethnographic analogies, operating at the short-term scale, to explain the archaeological record, arguing that this created an imbalance between scales (“uniformitarianism”; *sensu* Bailey, 1983; Fletcher, 1992; Smith, 1992; for similar criticism in Palaeolithic archaeology, see Vaquero, 2012; Kuhn & Clark, 2015). However, Time Perspectivism remained primarily a critique of how human behaviour was interpreted in archaeology (e.g. Holdaway & Wandsnider, 2008 and references therein). While it has had, and continues to have, a significant impact on Palaeolithic

archaeology, it also produced a certain complacency: the idea that any assemblage can be studied, regardless of scale, as long as one acknowledges its palimpsest nature, as long as one does not lose “perspective”:

“We accept the palimpsest for what it is as a general tendency, and in effect shrink the palimpsest to a single episode, a single data set, in order to examine it in the wider comparative context of other such data sets” (Bailey, 2007: 210).

Gavin Lucas (2021), having moved beyond his earlier post-processual conception of time as experience (e.g. Lucas, 2004, probably following Munn, 1992 perspective on time), now embraces a more Aristotelian view, convinced that change, rather than duration, is the key to explaining archaeological processes. In light of this, he proposes replacing Braudel tripartite division (“événement”, “conjoncture”, and “structure”) with three alternative concepts: “severance”, “recurrence”, and “persistence”, each of which could unfold at different tempos. The first entails a drastic transformation: an event as rupture, as discontinuity; the second represents cyclical patterns of change, rising and falling; and the third signifies the endurance of behaviour, or stasis (Lucas, 2021: 57).

While this approach is undoubtedly compelling (focusing primarily on variability, or what changes) these concepts fundamentally correspond to operative ontologies at the level of interpretation. In other words, they are not intrinsic properties of the archaeological record but rather emerge from the process of comparing analytical units and assessing their historical significance in terms of transformation or continuity.

In this Thesis, **the concept of scale** is employed as a synonym for proximity and distance, a form of zooming in and out. By doing so, we sidestep the issue of duration while also avoiding the need to assess historical change or permanence directly. Thus, it is conceived as a “mode of analysis” (*sensu* Lucas, 2008). At the lowest magnification, we find the stratigraphic unit. As we zoom in, we encounter progressively finer analytical units, whose capacity to represent human behaviour and its variability depends on a key factor: resolution.

The concept of resolution will be understood as the “pixel density” resulting from zooming, analogous to digital rather than optical resolution, following Simonetti (2018):

“Optical resolution refers to the capacity of an optical apparatus to differentiate between two randomly selected points. Digital resolution refers to the number of light points on a fixed two-dimensional surface” (Simonetti, 2018: 50).

The key factor distinguishing one from the other within the framework of Palaeolithic archaeology is time. Optical resolution can be linked to absolute dating methods (time as a unit of measurement) which, in our case, remain imprecise, often involving errors of thousands of years (with some exceptions: e.g. Vandeveldt et al., 2018; Herrejón-Lagunilla et al., 2024). Digital resolution, on the other hand, pertains to the capacity to observe events and their temporal relationships, even if these relationships are not strictly quantifiable. As McTaggart state it more than 100 years ago:

“It is, therefore, possible that the realities which we perceive as events in a time-series do really form a non-temporal series. It is also possible, so far as we have yet gone, that they do not form such a series, and that they are in reality no more a series than they are temporal (...) Should it be true, it will follow that in our perception of these realities as events in time, there will be some truth as well as some error. Through the deceptive form of time, we shall grasp some of their true relations” (McTaggart, 1908: 473).

Defined in this way, the relationship between scale and digital resolution promises to be one of the key factors in interpreting human behaviour, while also remaining a largely untested hypothesis in Palaeolithic archaeology. Are they inversely proportional? Does a smaller scale imply higher resolution? Does zooming in always result in a clearer image? No intrinsic proportionality has been demonstrated. It is possible to observe something at an extremely small scale without obtaining a high-resolution digital image. Thus, scale refers to the level of zoom applied to an image, but does not necessarily correlate with its quality. However, this must be tested within and across each unit of analysis employed to characterise behaviour.

1.3. Units of analysis in Palaeolithic archaeology

Palaeolithic archaeology has been constructed through different units of analysis, each operating at distinct scales and yielding varying degrees of resolution. From the largest to the smallest scale, we can identify the following:

Stratigraphic unit

The stratigraphic unit (SU) has traditionally been the most widely used analytical framework for inferring human behaviour, dating back to the early beginnings of the discipline (Droop, 1915–2010; Daniel, 1943). In Palaeolithic contexts, stratigraphic units are defined by geological rather than anthropogenic principles. By understanding large-scale geological processes, it is possible to delineate the upper and lower boundaries of these units based on granulometric and colourimetric variations in the sedimentary matrix, aggregates, and type of contacts (Harris, 1991; Brookfield, 2004). Their temporal dimension is established through absolute and relative dating methods which, in Pleistocene contexts, often carry significant error margins, sometimes spanning thousands of years (Walker, 2013).

From an interpretative standpoint, the materials contained within a stratigraphic unit are characterised as representing an “average” of past behaviour. This approach emphasises the predominance of certain patterns while also allowing for the identification of apparent structural factors and fluctuations when comparing successive or preceding units. Consequently, stratigraphic units have been the main protagonists in reconstructing long-term processes, interpreted through stratigraphic sequences.

The origins and widespread adoption of the stratigraphic unit can be traced back to principles derived from geology, which were later reinforced by the rise of neo-evolutionary or post-processualism frameworks and the concept of Deep Time, traditionally understood on a large scale (i.e. Robb & Pauketat, 2013; e.g. Hodder, 1987). Although perspectives have evolved, the stratigraphic unit remains a dominant analytical framework in Palaeolithic archaeology,

particularly through its application in comparative analyses of stratigraphic sequences. This persistence is partly due to the influence of behavioural ecology and environmental determinism, especially in terms of “adaptability” (e.g. Butzer, 1982; Winterhalder, 2001; Coddington & Bird, 2015; Saltré et al., 2024), as well as the methodological robustness provided by microcontextual geoarchaeological approaches (e.g. Karkanas & Goldberg, 2019).

Archaeostratigraphic unit

The archaeostratigraphic unit (AU) emerged as a response to concerns over the uncertain temporality inherent in the stratigraphic unit. Influenced by the New Archaeology and ethnoarchaeological data, whose temporal scale was significantly shorter than that of geological strata, researchers sought to refine units of analysis to better account for human-scale dynamics (e.g. Gasche & Tunca, 1983; Villa & Courtin, 1983; Stevenson, 1985, 1991). This unit is defined primarily by anthropogenic factors, specifically through the three-dimensional coordinates of archaeological materials (Canals et al., 2003; Martínez-Moreno et al., 2004).

The identification of vertical gaps (i.e. material gaps) between beds of artefacts is considered a key criterion for distinguishing separate units. Additional anthropogenic and geogenic markers, such as the presence of hearths, refits, or blocks, are used to refine the identification of palaeosurfaces and ensure vertical preservation and lateral continuity of material beds (e.g. Machado et al., 2013, 2019; Roy-Sunyer, 2015; Vaquero et al., 2015; Bargalló et al., 2016; Martínez-Moreno et al., 2016; Sánchez-Romero et al., 2017; Arteaga-Bribea et al., 2023).

Interpretations based on archaeostratigraphic units must be correlated with formation stages within the stratigraphic unit. This allows for comparative analyses of material assemblages across different units, enabling the testing of hypotheses regarding behavioural variability or continuity along a certain geological time-span (Vaquero, 2008; Vaquero et al., 2012). While these units still contain a degree of time-averaging due to the persistent palimpsest effect, the resolution they offer is, in principle, significantly higher than that of their parent geological units.

Spatial unit

The concept of the spatial unit gained prominence in the early 1970s, as Palaeolithic archaeology increasingly incorporated socio-economic perspectives, influenced by structural anthropology, historical materialism, and later by the anthropology of technology (e.g. Leroi-Gourhan & Brézillon, 1966, 1972; Cahen et al., 1979; Carbonell & Mora, 1985; Olive, 1988; Lemonnier, 1992; Dobres & Hoffman, 1994). These frameworks conceptualised space not as a passive scenario but as an active structure shaped by human action and social organisation. This shift led researchers to focus on how artefacts were distributed, how they related to specific activities, and how spatial organisation reflected underlying social and economic structures within occupied spaces:

“Definim el lloc d’ocupació com un espai actiu des del que l’home intervé sobre el seu entorn, convertint aquest espai en base estructural de les seves relacions de producció i reproducció” (Carbonell & Mora, 1985: 35).

Ethnoarchaeological studies played a key role in reinforcing the importance of spatial organisation, highlighting the existence of multiple spatial units. These included material accumulations around hearths (e.g. Yellen, 1976; Binford, 1978), secondary refuse deposits (e.g. Bartram et al., 1991; O’Connell et al., 1991), resting areas (e.g. Binford, 1986; Galanidou, 2000), and specialised activity zones (e.g. O’Connell, 1987).

The integration of Geographic Information Systems (GIS) and analytical techniques borrowed from geography and other disciplines provided a strong methodological foundation for spatial analysis in archaeological sites (e.g. Baena & Ríos, 2006; Connolly & Lake, 2006; Menéndez-Marsh et al., 2013; Gillings et al., 2020). This approach has gained particular attraction in Palaeolithic archaeology over the past few decades, by dividing the overall assemblage, whether stratigraphic or archaeostratigraphic, into discrete spatial units, such as clusters or high-density areas (e.g. Vaquero, 1999; Vaquero & Pastó, 2001; Spagnolo et al., 2019, 2020a, 2020b; Sánchez-Romero et al., 2020, 2021, 2023).

Unlike the previous units, the spatial unit is inherently dependent on a higher-order framework, either a stratigraphic or an archaeostratigraphic unit. Thus, its resolution is dictated by the scale of the unit it is associated with (Vaquero, 2022). Hypotetically, spatial resolution will be lower when derived from stratigraphic units and significantly higher when linked to archaeostratigraphic units. When applied to the latter, spatial analysis offers a way to mitigate, at least interpretatively, the effects of palimpsests, which persist in horizontal distributions, as observed since the beginning of the spatial analyses:

“Our examples also offer the warning that the spatial clustering of artifacts, particularly tools, does not necessarily reflect their actual association in use” (Cahen et al., 1979: 671).

Formation event

The event has been characterised as the smallest analytical unit within an assemblage (Lucas, 2008; Vaquero, 2008). Unlike other units, it is the only one that can be almost entirely isolated from the effects of time-averaging, as it represents a discrete “grain” within the deposit: an ethnographic unit (Vaquero, 2008; Vaquero et al., 2012).

For a long time, the event was largely disregarded, even within the framework of New Archaeology. It was seen as merely a fragment of a broader process, and as such, it was assumed that understanding the process itself would be sufficient to comprehend all its constituent parts (e.g. Binford, 1972). However, subsequent works have highlighted the relevance of this analytical scale.

Brooks (1982) reinforced the role of individual agency, structuring activities based on their actors. He argued that studying the event as “an activity or task” allows for a more direct analysis of the individual. While his perspective on broader systems was somewhat

underdeveloped (e.g. the concept of episode as a result of different events occurred in one day), his work made an important case for recognising that a comprehensive understanding of cultural systems must consider both the individual as an actor and the event as its material outcome. Archaeology, therefore, must account not only for the “normative patterns” observed across entire assemblages but also for the “behavioural patterns” discerned through the study of individual events.

This perspective gained further attention with the emergence of the Anthropology of Technology, which positioned intentional human action (manifested through materiality) at the core of social reconstructions of past human groups (e.g. Lemonnier, 1992; Dobres & Hoffman, 1994). Central to this approach was the agency of the individual as the creator of material culture, whose products not only reflect but also shape social relations and interactions within the group. In this sense, the artefact is not merely an object but also a subject, an active component in the construction of social dynamics. Consequently, the scale of observation had to be progressively narrowed, bringing the analytical focus ever closer to human action:

“The final goal of technological studies is not (only) to describe microscale prehistoric activities, but to understand microscale social processes” (Dobres & Hoffman, 1994: 213).

Similarly, Vaquero (2008), following the idea of the event as an intentional action (Vaquero, 2001), developed a model for the lithic record that distinguished two types of technical events, conceiving the event as an activity. According to him:

“A technical event is an activity episode related to the manipulation of lithic resources that is developed continuously, without location changes or temporal interruptions” (Vaquero, 2008: 3179).

Within this framework, two main categories of lithic events have been defined according to Vaquero (2008):

- 1. Introducing events:** Singular products input into the site already knapped.
- 2. Knapping events:** Products resulting from the anthropic modification of an original mass within the site.

A crucial consideration when working with technical events is the role of recycling. The modification of previously discarded artefacts introduces both temporal and spatial discontinuities, implying the existence of distinct events based on his definition (i.e. Vaquero, 2008, 2011; Vaquero et al., 2015, 2017; Amick, 2014; Baena et al., 2015).

Regardless of its specific ontology, it is evident that no smaller analytical scale is possible; the event is the minimum unit. But is it observable? Previous definitions challenge Braudelian and Time Perspectivism positions (e.g. Bailey, 2007), which assume intrinsic singularity and impossible detection of events, probably because both conceive events as episodes (e.g. “human occupations”, “living floors”), not activities. But even being able to discern them, why isolate individual pieces in deposits composed of thousands of artefacts? As Lucas (2008) pointed out, the goal is not simply to reconstruct other analytical units, but

to establish relationships between events, to determine whether certain behaviours recur while others remain unique.

1.4. Theoretical framework

The study of lithic record formation processes requires a careful consideration of both scale and temporality. While scale defines the resolution at which archaeological processes are examined, time governs the way we perceive and interpret behavioural variability and continuity. Given its central role in this Thesis, it is essential to develop a critical ontological approach to the concept of time and determine how it will be addressed in our analysis.

Time relationalism

One of the main pathologies in archaeological research is the tendency to treat time as an implicit, self-evident variable rather than a concept requiring theoretical definition. In this Thesis, time, which exists, is not conceived as a uniform or linear framework but as a relational construct that emerges from the interaction between events, which in turn provide insight into formation processes. This perspective moves beyond stratigraphic units and absolute chronologies, focusing instead on how temporal relationships are generated from the archaeological record and how they shape the identification of behavioural dynamics.

The foundations of this approach are rooted in Loop Quantum Gravity (LQG), a theoretical framework that emerged in the 1990s within quantum physics (e.g. Rovelli & Smolin, 1990; Rovelli, 1996, 2004, 2024; Ashtekar & Lewandowski, 2004; Brahma, 2020). Unlike traditional conceptions of time in physics, such as Newtonian time, which assumes an independent and continuous temporal flow (the “time’s arrow”; *sensu* Eddington, 1929), LQG proposes a radically different view:

1. Time is not an inherent variable, nor does it flow continuously or independently.
2. Instead, it is a relational property that emerges from the interactions between fundamental components of a system: the events.

This means that time does not exist as an independent dimension but emerges from the intrinsic properties or variables of events and their interactions. In this sense, if instead of conceiving time as a pre-existing variable, we focus on describing the characteristics of these events and the relationships they establish with one another, time manifests as a consequence of these interactions between the fundamental components.

These components, often referred to as “grains” or “events”, are the smallest units of analysis. They are discrete and discontinuous, meaning that their identification, and the relationships between them, from which time emerges, requires an extremely fine observational scale (Rovelli, 1996, 2024). According to Rovelli (2024), “macroscopic blurring” prevents the observation of events and their relationships on a larger scale, creating the illusion of continuous time. Reducing the scale allows for a higher resolution and more

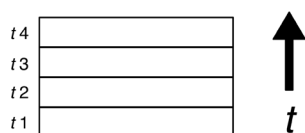
precise spatiotemporal perception, but this perception remains inherently incomplete and fragmentary.

This is because events do not occur in a sequentially ordered manner, nor do they form a puzzle that can be fully reconstructed. Instead, as Smolin (2020: 143) argues, “foundational puzzles are consequences of an incompleteness of our understanding of nature”, a limitation imposed by our macroscopic perspective, an issue that directly resonates with the fragmentary nature of the archaeological record.

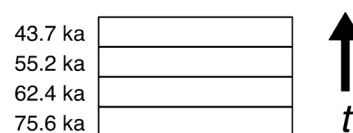
Once we accept this, relationships between events do not necessarily involve all events. In this regard, the concept of “partial order” becomes crucial, as it allows for defining “before” and “after” relationships between some events without requiring all events to be sequentially connected (Rovelli, 2024). This perspective is particularly relevant to Palaeolithic archaeology, where attempts to understand formation processes tend to focus on producing a complete and continuous picture.

However, time is not the only emergent property: change also arises. As relationships between events shift, they generate new configurations within the system. This perspective is also crucial in Palaeolithic archaeology, where the variability of the record does not follow a predefined temporal structure but rather results from the accumulation and reorganization of events. From this standpoint, the study of change should not be attached to stratigraphic units or sequences but should instead focus on the transformation of relationships between events and the detection of patterns of recurrence or singularity in the archaeological record (Fig. 1).

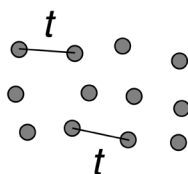
Classical conception of time in Physics



Classical conception of time in Archaeology



Loop Quantum Gravity
conception of time



Application of LQG conception of time
to Archaeology

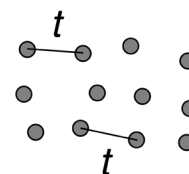


Fig. 1. Scheme of how time has been treated in Physics and Archaeology and the possible introduction of LQG as a theoretical background to time in Archaeology. Examples from physics have been modified from Rovelli (2024).

In this Thesis, we adopt this conception of time as this; as a relational property that arises only when a relationship is established between two or more events, as opposed to the continuous and macroscopic perception on which traditional Physics was based, and on which traditional Archaeology, relying on stratigraphic units and absolute datings, was also rooted. Time exists, but we have misconceived and misused it:

“Toda la evolución de la ciencia indica que la mejor gramática para concebir el mundo es la del cambio, no la de la permanencia. Del acontecer, no del ser. Se puede concebir el mundo como constituido de cosas. De sustancia. De entes. De algo que es. O bien pensar que el mundo está constituido de eventos. De acontecimientos. De procesos. La destrucción de la noción del tiempo representa el desplome de la primera de estas dos perspectivas, no de la segunda. Concebir el mundo como un conjunto de eventos, de procesos, es el modo que mejor nos permite captarlo, comprenderlo, describirlo” (Rovelli, 2024: 76).

But how can this be properly linked to the archaeological record? In our case, events are represented by the three-dimensional points corresponding to each lithic object. This is where the “event-based approach” comes into play (Vaquero, 2008; 2012; Vaquero et al., 2012), conceived as the smallest unit of analysis and the smallest grain from which the anthropogenic formation processes start:

“Increasing attention should be paid to the short-term processes, those defined by specific activity events. These activities set out the cultural formation dynamics of the archaeological assemblages upon which long-term archaeology has been traditionally developed. The deposition and characteristics of material remains depend on decisions taken by individuals at specific times and places with the aim of solving specific needs. The stratigraphically defined archaeological assemblages are simply the sum of an unknown number of such decisions” (Vaquero, 2008: 3178).

In order to establish correlations that produce a discrete rising of time, it is necessary to conduct a detailed analysis of the object of study, namely, the anthropogenically modified rock, and extract from it the variables that allow one event to be correlated with another. In this study, the variables that enable the identification of relationships between events are intrinsically related to:

1. Their position in three-dimensional space (3D coordinates), which allows for spatial relationships to be established.
2. Their physical properties, both prior to (raw materials) and following human intervention (size, weight, type of product). Predefined modern cultural constructs related to these products (e.g., typologies or styles) are not considered (Cahen et al., 1979).

In the first case, the emergence of time is defined by spatiotemporal independence: a physical gap that separates groups of events, whether or not they are interrelated. In the second case, these variables do not imply a direct correlation between events, but they may contribute to its establishment as a spatiotemporal dependence. For instance, raw material identification and technological analysis enable the recognition of lithic refits, which do establish a physical relationship between two events. With both types of relationships, it is possible to define different temporal expressions between events or groups of events:

Diachrony: two events do not produce the same temporal framework. For example, when a material gap exists between two material beds, a temporal rupture is empirically established. Events above and below the hiatus are considered diachronic.

Contemporaneity: this temporal expression is highly scale-dependent (i.e. Lucas, 2021). In this Thesis, contemporaneity is linked to activity events (e.g. a lithic refit expressing a knapping episode). However, contemporaneity must be tested and challenged even within clear events such as refits, as recycling can alter the physical properties of artefacts and their spatial location (Vaquero 2011; Vaquero et al., 2017).

Synchrony/Simultaneity: from a relativistic and quantum perspective, two events cannot be truly simultaneous or synchronous (Einstein, 1952; Rovelli, 1996). The perception of synchrony or simultaneity arises from a blurred macroscopic interpretation of events and their relationships.

This interdisciplinary approach provides tools for a more realistic interpretation of the nature of Pleistocene archaeological deposits, where absolute dating fails to resolve the spatiotemporal uncertainty of events at a human or near-human timescale. Thus, this theoretical framework allows for analysing events in terms of their mutual and discrete relationships, overcoming the simplistic interpretation of the record as a linear and continuous temporal sequence. Furthermore, it permits us to work with complex and fragmented records, such as archaeological palimpsests, considering the difficulty of establishing temporal relationships.

1.5. Blurred or high-resolution Neanderthals: what do we know about their techno-economic and spatial behaviour

Using the stratigraphic unit as the primary analytical framework, we have gained significant insights into Neanderthal behaviours. This approach allows for the extraction of dominant patterns across assemblages. For instance, it has enabled the identification of the most frequently used raw materials and the approximate distances between procurement locations and archaeological sites, which contribute to reconstructing mobility patterns (typically 5–30 km in most sites; e.g. Geneste, 1991; Féblot-Augustins, 1993, 1999; Fernandes et al., 2008; Roy-Sunyer, 2016; Roy-Sunyer et al., 2017; Gómez de Soler et al., 2020; Mayor et al., 2022). At the same time, within these assemblages, it is common to find artefacts whose procurement and production imply longer distances, often appearing in singular formats, with or without retouch (Kuhn, 1991, 1992, 1994; Bourguignon et al., 2006; Meignen et al., 2009; Delagnes & Rendu, 2011; Conard et al., 2012; Turq et al., 2017; Vaquero & Romagnoli, 2018). Additionally, recycled artefacts have been identified, whose recognition stems from temporally dependent alterations (e.g. modification after patination or thermal alteration; e.g. Thiébaud et al., 2010; Baena et al., 2015; Romagnoli, 2015; Mayor et al., 2024).

Lithic resource management within sites has also been assessed, revealing that even at this scale, the fragmentation of operational chains is evident: not all production stages occur

at a given site, and when they do, they are rarely completed in full (i.e. Turq et al., 2013; Moncel et al., 2014; Dibble et al., 2017). This highlights a critical limitation of this approach: an overly broad perspective that does not account for the dynamism of time and space in site formation processes can lead to misinterpretations, such as the so-called “the complete reduction sequence fallacy” (*sensu* Turq et al., 2013).

From a spatial perspective, apparent structural patterns have been recognised, such as the placement of hearths and the consequent establishment of activity zones around them. In rockshelter sites, these are more commonly found in interior spaces (e.g. Vaquero & Pastó, 2001; Henry et al., 2004; Blasco et al., 2016; Reeves et al., 2019; Sánchez-Romero et al., 2020), while external areas are typically characterised by lower material densities and singular artefacts, usually of larger size and weight (e.g. Vaquero, 1999; Vaquero et al., 2001; Neruda, 2017; Sánchez-Martínez et al., 2022). These low-resolution units can also assess adaptation to other structural features, such as the location of illuminated areas or large boulders.

Thus, the stratigraphic unit provides a global image, emphasising recurrent patterns and producing a “monolithic” view of a single Neanderthal behaviour, portraying it as uniform and unchanging. This concept, where the stratigraphic unit is treated as a long-term process reflecting an averaged behavioural picture, is evident in paper titles such as “The complementarity of luminescence dating methods illustrated on the Mousterian sequence of the Roc de Marsal: A series of reindeer-dominated, Quina Mousterian layers dated to MIS 3” (Guérin et al., 2017) or the more recent “Evidence from Tinsmet Cave in Israel suggests behavioural uniformity across Homo groups in the Levantine mid-Middle Palaeolithic circa 130,000–80,000 years ago” (Zaidner et al., 2025).

Archaeostratigraphic analysis offers a means to go beyond what can be inferred from the geological deposit alone. Firstly, it provides quantitative variability, with more or less dense units allowing inferences about settlement dynamics in terms of intensity or recurrence (e.g. Sañudo et al., 2016; Zilio et al., 2021). Secondly, it facilitates comparisons between lithic assemblages from different temporal contexts, enabling assessments of continuity or change in mobility patterns and resource management strategies, both in terms of production and spatial distribution (e.g. Machado et al., 2013, 2017; Vaquero et al., 2015; Bargalló et al., 2016, 2020; Spagnolo et al., 2019, 2020; Mora et al., 2020). From a spatial perspective, in addition to revealing changes in site occupation strategies, archaeostratigraphy aids in “dissecting” zones of apparent recurrence (e.g. activity around hearths), demonstrating that artefacts spatially associated with combustion structures are not necessarily contemporaneous but may be found above or below them in vertical, and thus temporal terms (e.g. Vaquero & Pastó, 2001; Martínez-Moreno et al., 2004, 2016).

The spatial unit has been instrumental in demonstrating the diverse ways Neanderthal groups organised their living spaces. However, its resolution is dependent on the scale of analysis (stratigraphic or archaeostratigraphic). It has enabled the identification of activity units around hearths (“hearth-related assemblages”; *sensu* Vaquero & Pastó, 2001), a

common feature in most Middle Palaeolithic sites, where knapping and carcass processing are predominant activities, resulting in volumetric patterns dominated by small artefacts (Vaquero et al., 2004; Machado et al., 2013, 2017, 2019; Clark, 2017, 2019; Vaquero, 2022; Sánchez-Romero et al., 2024). Besides hearth-related assemblages, secondary refuse zones have been identified, characterised by larger or technologically exhausted artefacts (Vaquero, 1999; Vaquero et al., 2001; Peresani, 2009; Spagnolo et al., 2019, 2020a), resting areas, typically near cave or rock shelter walls with multiple hearths and minimal evidence of productive activities (Henry et al., 2004, 2012; Vallverdú et al., 2010; Spagnolo et al., 2019), and even storage areas (Uthmeier et al., 2020). Lithic refitting has also enabled the “connection” of different spatial units, illustrating cases ranging from diachronic recycling episodes to potentially contemporaneous activity zones through the bidirectionality of refitted pieces (Vaquero et al., 2017).

With the exception of hearth-related assemblages, which leave clear material traces even in high-density deposits, other spatial units are highly scale-dependent and resolution-sensitive, often masked by the overlaying of multiple activities, suggesting their potential underrepresentation in the Middle Palaeolithic record.

Finally, event-based analysis contributes to the study and contextualisation of human-scale activities. Moreover, when these events are sequenced, they reveal shifts in territorial, technical, and spatial management. The finer the analytical grain, the more evident these changes become. The best example of this approach is provided by Vaquero et al. (2012), who characterised three vertically separated knapping events, revealing differences in raw material acquisition, management, and spatial distribution. Their findings demonstrated that each event reflects distinct techno-economic decisions over time and that event-based comparisons are more informative than assemblage-as-a-whole analyses when addressing behavioural variability. However, this type of analysis remains scarce in the literature.

For example, at El Salt, multiple events represented by different raw material units (RMUs) were identified within distinct archaeostratigraphic units, revealing changing patterns in flint procurement and management across at least three separate moments (Mayor et al., 2020). Use-wear analysis of these materials demonstrated that artefacts served different functions at each stage, including butchering, woodworking, or both (Bencomo et al., 2023). At Abric del Pastor, Machado et al. (2019) focused on specific refits, showing different events in the same core reduction, which were also displayed spatially. Similarly, Delpiano & Peresani (2017) and Baena et al. (2019) have focused on specific refits to investigate technical decisions or different skill levels within and across refitted sequences, providing a picture of behaviour at the individual level.

In this way, the event has emerged as the most suitable approach for capturing variability, demonstrating that there is no single Neanderthal behaviour. As a result, this seemingly unique behaviour is becoming increasingly less useful for characterising the human groups behind the archaeological record (Vaquero, 2012).

1.6. Objectives

This Thesis is built upon transversal objectives that serve as a framework for the detailed analytical goals outlined below. First, it seeks to explore diachronic changes and continuities in Neanderthal techno-economic and spatial behaviours. Second, it aims to contribute to a better understanding of lithic assemblage formation processes, considering both anthropogenic and natural factors that shape the archaeological record. These broader goals provide the foundation for the following specific research objectives, each coupled with two sub-targets that will contribute to achieving it. Thus, this Thesis seeks to:

1. Narrow down the analytical scale of lithic assemblages

Isolate distinct formation stages within the stratigraphic unit from the relationships of dependence and independence between events.

Use these formation stages as a baseline for characterising human behaviour.

2. Investigate Neanderthal mobility patterns

Differentiate lithic raw materials based on the regional geological framework.

Define the minimum territorial range of lithic resource procurement.

3. Examine the management of lithic resources introduced into the site

Assess how lithic products are introduced, modified, and discarded, also considering raw material variability.

Contribute to the understanding of fragmented and incomplete operative chains.

4. Characterise occupation strategies at the spatial level, with particular attention to the role of lithic assemblages

Identify the fundamental spatial units of hunter-gatherer behaviour (i.e. hearth-related assemblages).

Investigate cases of variability where lithic assemblages accumulate in the absence of fire.

5. Assess the usefulness of increasing temporal resolution in the study of past human behaviour.

Evaluate how the refinement of analytical scale affects the identification of behavioural variability.

Discuss the implications of adopting broader or narrower scales of analysis for the reconstruction of Neanderthal behaviours.

section



II

ARCHAEOLOGICAL CONTEXTS

II. Archaeological contexts

2.1. General geomorphological context

2.2. Abric del Pastor

2.3. El Salt

2.1. General geomorphological context

The archaeological sites of Abric del Pastor and El Salt, which are the focus of this Thesis, are located in the eastern part of the Iberian Peninsula, within the geological region of the Prebaetic Zone, which forms part of the eastern domain of the Baetic System (Molina, 2015).

This mountain system, formed during the Tertiary period as a result of the tectonic processes associated with the Alpine Orogeny, is composed predominantly of Mesozoic sedimentary rocks (Jurassic and Cretaceous). It is characterised by rugged relief, shaped mainly by these rocks (mostly limestones and marls) which have undergone intense tectonic folding and fracturing. These processes gave rise to a complex landscape dominated by faults, primarily reverse/thrust faults, along with other associated tectonic structures.

This geological context has produced numerous mountain ranges notable for their altitude and abrupt relief, such as the Serra de Mariola, El Menejador, La Serreta, La Serrella, Almudaina, and Benicadell (Molina, 2015; Mayor, 2023), with peaks including Aitana (1,558 m.a.s.l.) and Montcabrer (1,389 m.a.s.l.). Between these ranges lie deeply incised fluvial valleys, such as the Serpis Valley, where the sites examined in this Thesis are located (Fig. 2).

The Serpis Valley is a river corridor shaped by fluvial activity and constitutes one of the main drainage systems in the region. It extends for approximately 75 km, from the confluence of the Barxell and Polop rivers in the municipality of Alcoi (Alicante) to the municipality of Gandía (Valencia), where it flows into the Mediterranean Sea. Its tributaries (e.g. the Benissaidó, Agres, and Penàguila rivers) drain the various mountain chains that flank the valley (Mayor, 2023). This fluvial network has eroded the limestone and marl bedrocks, creating a landscape marked by ravines and river terraces.

This intense erosional activity facilitated the natural release and transport of various flint types formed within the valley, which became the primary raw material exploited by Neanderthal groups in the region (Molina et al., 2010, 2016; Mayor et al., 2022; Mayor, 2023). These flint types include, from oldest to youngest: Cretaceous Mariola flint type, Palaeocene Font Roja flint type, Eocene Serreta and Beniaia flint types, and Miocene-Pliocene Catamarruc and Polop flint types. All of these, along with less common varieties in the region, were characterised in the Thesis of Francisco Javier Molina (2015), which identified both their primary outcrops and Pleistocene redepositional contexts.

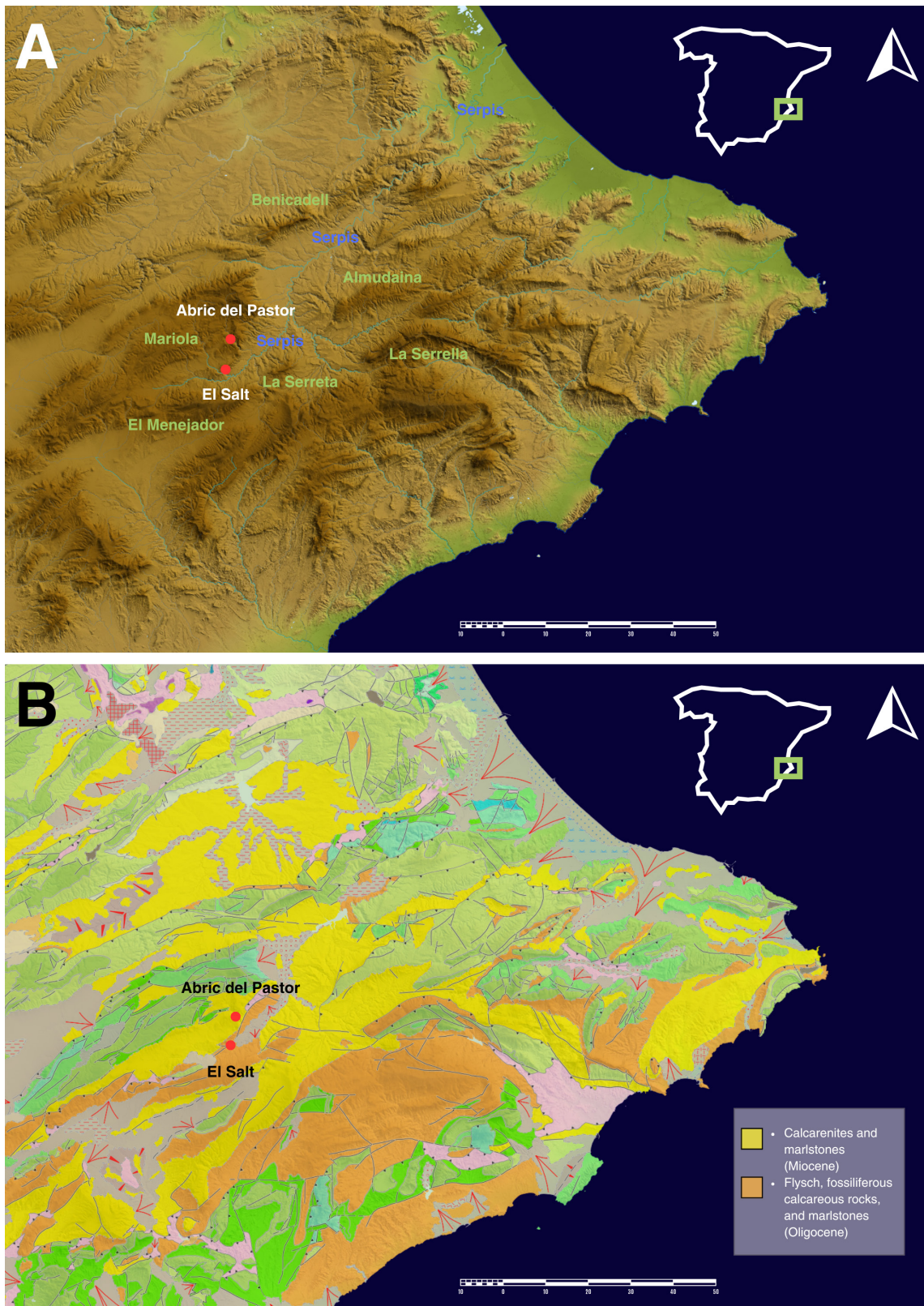


Fig. 2. Geomorphological context of the north-eastern Prebaetic. A) Relief map showing the location of the archaeological sites studied and B) geological map showing the geological strata of both sites.

2.2. Abric del Pastor

“Me permito indicarle que proceda con el máximo cuidado y procure sacar la tierra en capas delgadas y cribarla bien. Dese cuenta que unos centímetros pueden suponer varios miles de años”

“I would like to instruct you to proceed with the utmost care and take care to remove the soil in thin layers and sieve it well. Please bear in mind that a few centimetres may involve thousands of years”

Letter from Francisco Jordá Cerdá to Mario Brotons Jordá regarding the methodology to be followed at Abric del Pastor, 19 January 1953.

General context

The archaeological site of Abric del Pastor is located in the municipality of Alcoy, in the province of Alicante, on the eastern Iberian Peninsula. It is a small rock shelter with an estimated surface area of approximately 60 m². The site is situated on the left bank of the Barranc del Cint, within the boundaries of the Serra de Mariola Natural Park (Vicens-Petit, 1989; Galván et al., 2009; Molina et al., 2010; Machado et al., 2013, 2019; Mallol et al., 2019).

Research history

Abric del Pastor was discovered in 1942 by three local hikers and amateur archaeologists during the early surveys of the Barranc del Cint: Mario Brotons Jordá, Juan Pastor Femenía, and Héctor García Llácer. Among them, it was undoubtedly Mario Brotons who played the most significant role in the research and promotion of the site.

Born in Alcoy in 1922, Mario Brotons began his intellectual formation through self-education until the outbreak of the Spanish Civil War in 1936 (Fig. 3a). During the conflict, he joined the militia and served in various brigades until the end of the war, when he was arrested. Released in 1939, he helped establish a resistance group against Franco Regime in Alcoy and subsequently went into hiding in Valencia until 1942, when he returned to his hometown. There, he organised a clandestine socialist group and was imprisoned again from 1944 to 1947. Upon release, he worked as a bookseller and later as a paper and cardboard entrepreneur (Fig. 3b). It was during this period of economic stability and sustained political activism that Brotons resumed his archaeological interests, while continuing to engage in anti-fascist activities. He played a key role in the reorganisation of the Partido Socialista Obrero Español until a disagreement with the General Secretary, Rodolfo Llopis, led to his expulsion in 1974.

It was during this second phase of stability that Brotons initiated the first archaeological intervention at Abric del Pastor. Documentation of this process is preserved in the “Arxiu personal de Mario Brotons Jordá”, held at the Alcoi Municipal Archive. The archive contains extensive correspondence between Brotons and prominent archaeologists of the time, such as Lluís Pericot (Universitat de Barcelona) and his doctoral student Francisco Jordá (Museo Arqueológico Provincial de Oviedo), who provided methodological guidance.

In November 1951, Brotons began excavating a test trench measuring 1.25 x 0.75 m at Abric del Pastor. This initial intervention revealed the site archaeological potential, yielding several Palaeolithic artefacts and faunal remains. It is important to note that, at that time, the recent discoveries at Cova Negra in Xàtiva had significantly increased scholarly interest in the Middle Palaeolithic. However, as the excavation was carried out without official authorisation, Brotons was forced to pause his work until 1953. When he resumed, he discovered that the site had been looted in the meantime, with the original trench illegally expanded. The second campaign focused on cleaning and clarifying the disturbed area, as well as establishing a preliminary stratigraphic sequence (Fig. 3c). His excavation primarily

affected the upper Holocene layer, as he misidentified the compact Pleistocene deposits as sterile substratum. The introduction of Palaeolithic material into the Holocene context is addressed in detail in the section “Stratigraphic and chronological sequence”.

Although correspondence with Pericot and Jordá was consistent and both encouraged Brotons to publish his findings, no such publication was ever produced, nor was a new field campaign carried out. During this period, Brotons was also involved in the discovery of the rock art site of La Sarga, which became the focus of his subsequent efforts.

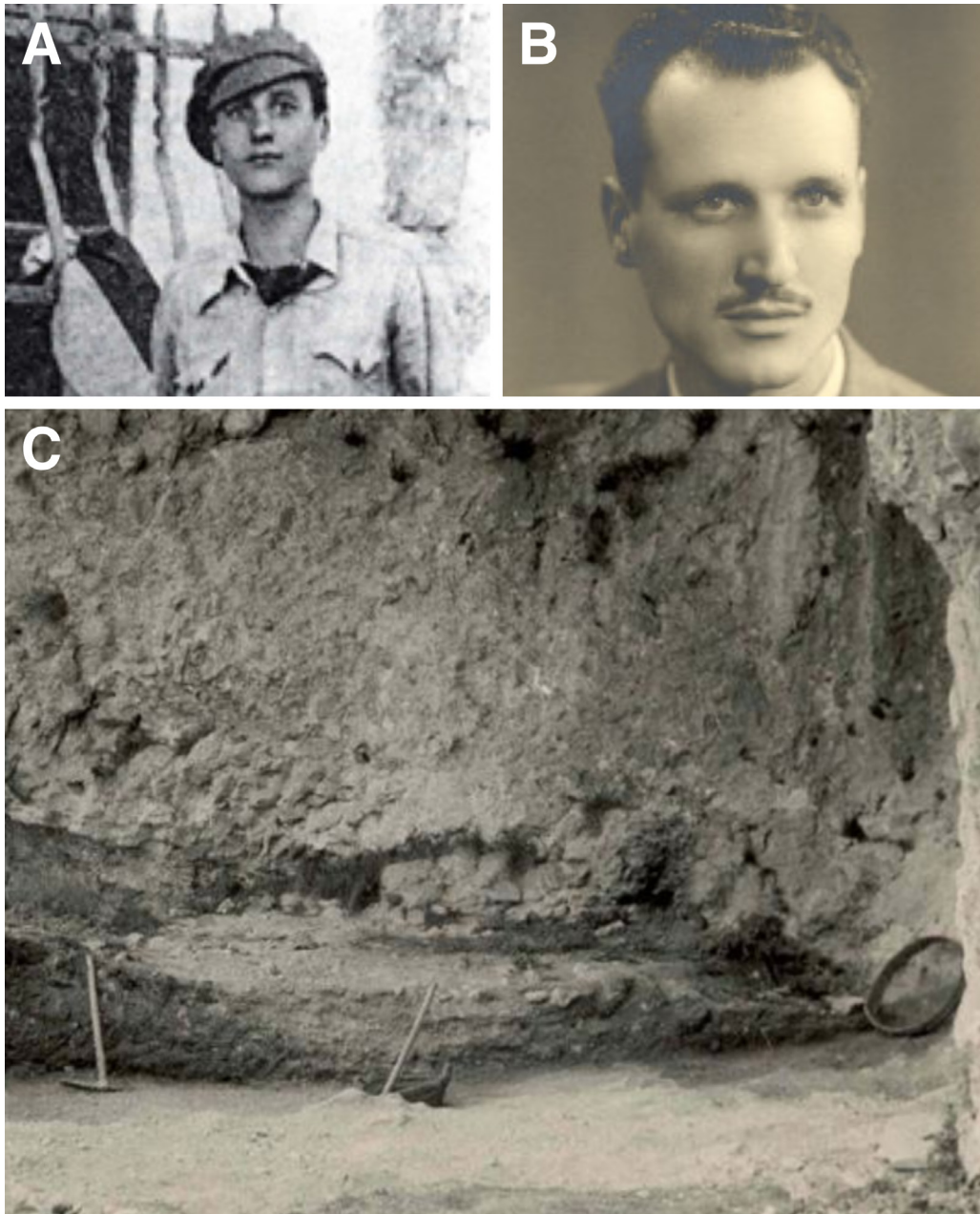


Fig. 3. A and B) Pictures of Mario Brotons and C) photo of Abric del Pastor during the 1953 season.

Several years later, two brief interventions were carried out with the aim of contextualising earlier work. The first took place in 1967 under the direction of Alfonso Seguí, and the second in 1972, led by Jose María Segura and Emili Cortell from the Museu Arqueològic Camilo Visedo Moltó, as part of broader survey efforts in the Barranc del Cint.

After several decades of inactivity, research at the site resumed in 2005. A new team from the University of La Laguna, comprising Bertila Galván, Cristo Hernández, and Carolina Mallol, launched new interventions with the preliminary goal of contextualising the materials from the Brotons collection and securing samples for dating. The analysis of the lithic assemblage, composed of 2,430 items, confirmed a clear attribution to the Middle Palaeolithic, characterised by a marked predominance of retouched tools (Galván et al., 2009). Excavations, initially carried out through a small test trench near the wall (approximately 1.8 x 1.3 m), demonstrated that the site was far from exhausted. In fact, it yielded a new and rich archaeological record within a Pleistocene deposit. Consequently, the excavation area was expanded to its current extent of 40 m². Since then, El Abric del Pastor has become a key site for high-resolution studies of Neanderthal behaviour, resulting in more than a dozen high-impact international publications.

Geomorphological context

Abric del Pastor is located at 820 metres above the sea level, on the left bank of the Barranc del Cint, within the Serra de Mariola, a mountain range designated as a Natural Park (Fig. 4a). The Serra de Mariola is characterised by an anticlinal structure, steep relief, and a strong influence of karstic processes (Fig. 4b and 4c). It is mainly composed of Cretaceous limestones deposited along the margin of an ancient marine basin. Its uplift during the Late Miocene was driven by the thrust of Triassic plastic materials (Garay, 1995). Karstic dissolution has shaped the landscape, forming internal plains and ravines such as the Barranc del Cint itself, where Abric del Pastor is situated (Molina, 2015).

The ravine, particularly in its northern sector where the site is located, exhibits intense karstic development, resulting in the formation of numerous rock shelters and caves in the area (Fig. 4b) (Vicens-Petit, 1989). This zone, marked by significant tectonic activity, hosts peaks near the highest elevations of the valley, such as Les Àguiles (1,110 m.a.s.l.), directly facing Abric del Pastor. The Cint or Benissaidó river runs through the ravine; although its current flow is minimal, the deep incision of the channel is attributed to greater energy and erosive capacity during the early Holocene (Macklin et al., 2006). Today, the site lies 60 metres above the ravine floor, although during the Upper Pleistocene this distance is presumed to have been shorter, as suggested by the development of fluvial terraces on both slopes, reflecting the evolution of the palaeokarst.

From a morphostructural perspective, Abric del Pastor is a palaeokarstic tube formed within biotrital limestones of the Tortonian Miocene (Molina, 2015) (Fig. 4d). The known surface area of the rockshelter is 60 m², of which 40 m² have been excavated.

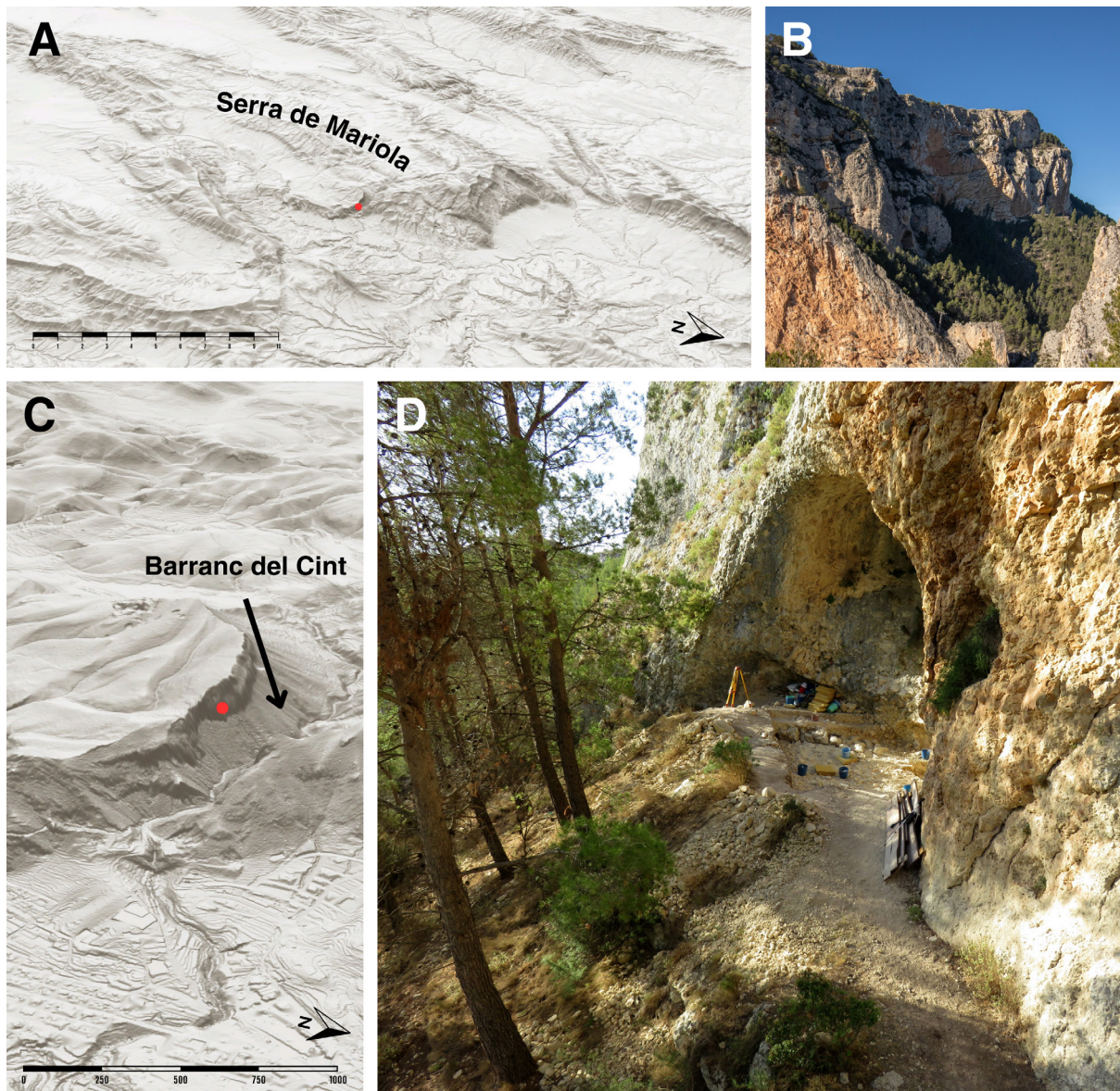


Fig. 4. A) Three-dimensional relief of the Serra de Mariola and the location of the site (red dot). Scale in kilometres. B) Typical karst landscape of the ravine (photo by Ana Fagoaga). C) Three-dimensional relief of the Barranc del Cint ravine and the location of the site (red dot). Scale in metres. D) General view of the Abric del Pastor.

The shelter features a main ledge measuring 5.5 metres in height above the unexcavated surface (7 metres from the excavated surface), which extends around the entire perimeter and constitutes the primary source of sedimentary input (Fig. 5a). The disintegration of this conglomeratic calcareous overhang, composed of blocks, cobbles, gravels, and sands, accounts, with some variation, for the formation of most of the stratigraphic units at the site during the Upper Pleistocene.

In addition, until the deposition of SU IV, the shelter featured an inner ledge in the eastern sector, approximately 1.5 metres high and covering around 7 m². A remnant of this overhang is still preserved in the southeast (ca. 3 m²) (Fig. 5b), while in the centre-east and northeast it collapsed (Fig. 5c), generating a dense concentration of large blocks within SU IV (Fig. 5d).

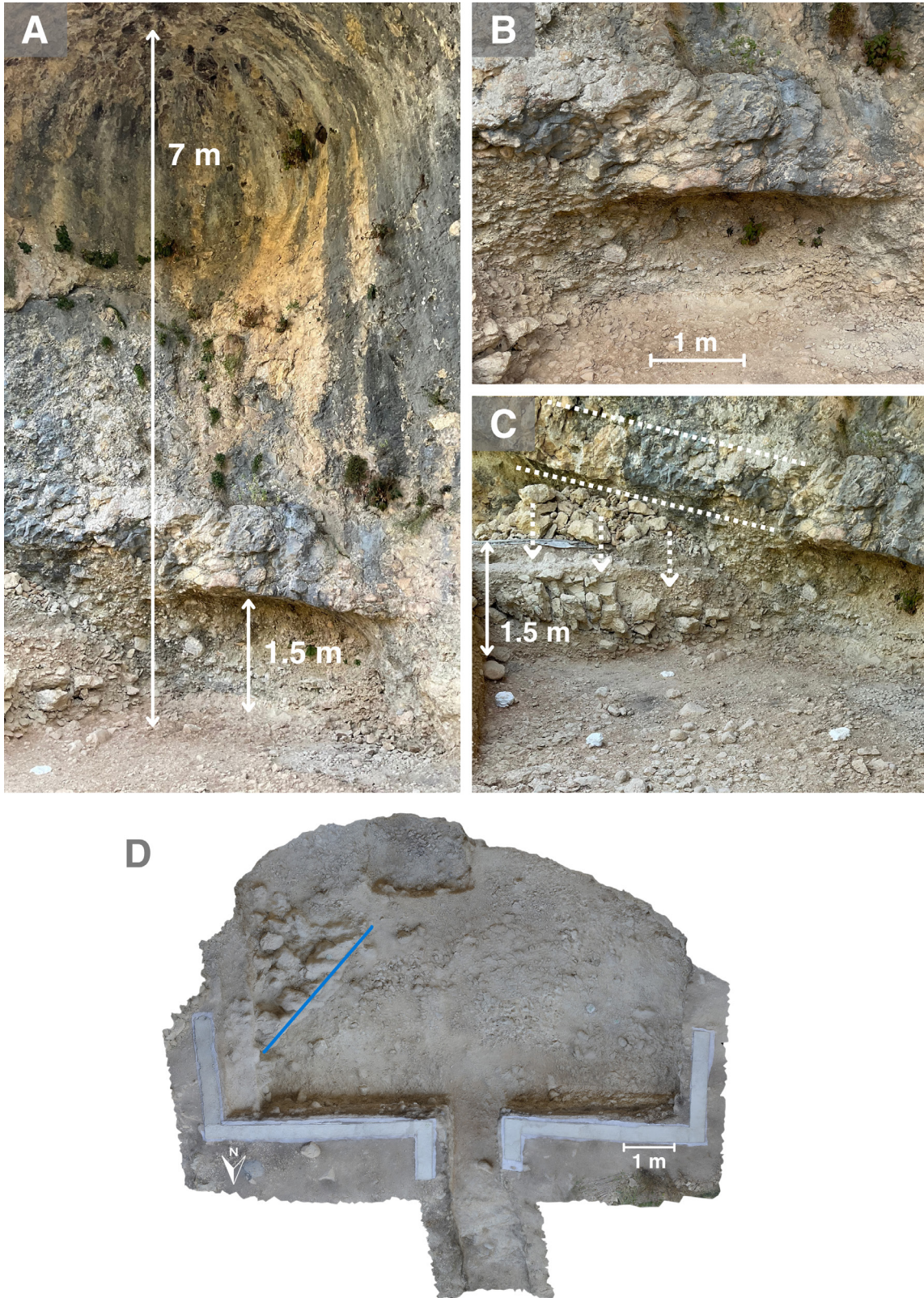


Fig. 5. A) Main ledge and inner ledge of the rock shelter. B) View of the non-collapsed area of the inner ledge. C) Scheme of the collapse of the inner ledge. D) Plan of the site during the excavation of SU IVd showing the collapsed blocks of the inner ledge.

Stratigraphic and chronological sequence

The stratigraphic sequence currently known at Abric del Pastor is divided into six units, with a total thickness of approximately 1.5 metres (Machado et al., 2013; Connolly et al., 2019; Mallol et al., 2019). Below, each unit is described from the oldest to the most recent, including its thickness, sedimentary composition, and chronological attribution where available:

SU VI: This unit is currently under excavation, and its full thickness remains undetermined. It is characterised by a loose matrix, in which fine sands and gravels predominate over coarser fractions. The sediment exhibits a greyish tone in the eastern sector, shifting to a yellowish-green colour in the central and western areas. An herbivore tooth recovered from this unit yielded an Electron Spin Resonance/Uranium-series (ESR/U-series) date of 62 ± 10 ka.

SU V: This unit, subject of study, presents a variable thickness ranging from 10 to 30 cm (Fig. 6a). It is generally defined by a sandy matrix with fine gravels, loosely compacted and with a reddish tone. However, it displays notable horizontal variability: a higher concentration of clasts in the east, greater compaction of reddish sands in the north and south, and a dominance of fine yellow sands with some blocks in the west (Fig. 6b).

SU IV: With a thickness ranging from 55 to 72 cm, this unit was subdivided into several lithostratigraphic subunits (IVg–IVa) based on grain-size differences. Subunits IVa, IVe, and IVg are predominantly clast-supported, whereas IVb, IVd, and IVf are composed mainly of yellow calcareous gravels and sands. In IVd, the collapse of the inner ledge resulted in a significant accumulation of large blocks in the eastern area (Fig. 5d). Subunits IVe, IVf, and IVg collectively reach a thickness of approximately 10 cm, and although distinguishable during excavation, they present diffuse boundaries in section (Fig. 6a). Two dates are available for SU IV: 63 ± 5 ka by optically stimulated luminescence (OSL) on sediment from IVd, and 48 ± 5 ka by ESR/U-series on an herbivore tooth from IVb.

SU III: This unit, between 1 and 12 cm thick, appears locally in the eastern part of the site. It consists of yellow sands and gravels with a high degree of carbonate cementation.

SU II: The first unit in the Pleistocene sequence, it ranges from 1 to 13 cm in thickness and is found locally in the northeast. It is composed of brown sands and gravels and is partially eroded by SU I.

SU I: This unit, between 13 and 65 cm thick, is composed of humic soils with a high content of faecal organic matter and shows clear evidence of bioturbation. The presence of Late Roman pottery and the characteristics of the sedimentary record support its attribution to the Late Holocene. It also displays several intrusions that cut into the upper Pleistocene units (SUs II and III). These may be the result of shelter use for livestock penning and dung collection or cleaning, a practice documented from the Iberian period through to Roman times (Vicens-Petit, 1989; Fernández-Eraso & Polo-Díaz, 2008; Colominas et al., 2023). Dung removal likely created trenches through which Palaeolithic material was introduced into this upper unit.



Fig. 6. A) Stratigraphic profile showing the upper limits of the studied units. White: SU IVf (approximate). Green: SU V. B) Excavation surface during the 2022 season (SU V).

Palaeoenvironmental sequence

The dates obtained suggest that the Pleistocene sequence at Abric del Pastor approximately spans Marine Isotope Stages (MIS) 4 to 3. Various analytical techniques have provided palaeoenvironmental information throughout the sequence, with most data concentrated in SU IV.

In subunit IVd, the microvertebrate assemblage, dominated by *Apodemus sylvaticus*, points to colder-than-present conditions, with a mean annual temperature (MAT) of 12.2 °C, which is 1.48 °C lower than today (Connolly et al., 2019). In contrast, palaeoecological analyses of macromammals suggest environmental conditions not drastically different from those of the present. The dominant taxa *Capra pyrenaica*, *Testudo hermanni*, and *Cervus elaphus* indicate a meso-Mediterranean thermotype for SU IV (Pérez et al., 2017) and a Type IV biome (Mediterranean) for subunit IVd (Connolly et al., 2019) (Fig. 7).



Fig. 7. Photographic representation of the different taxa identified in the Abric del Pastor that contribute to the palaeoenvironmental reconstruction. From left to right: *Juniperus sp.*, *Apodemus sylvaticus*, *Capra pyrenaica* and *Testudo hermanni*.

Anthracological data from SU IV further support arid or semi-arid supra-Mediterranean conditions (with a MAT 4 °C lower and annual precipitation 200 mm lower than present values). This is inferred from the predominance of *Juniperus sp.* across the unit (47%) and the presence of *Pinus nigra sylvestris* in subunit IVd (Vidal-Matutano et al., 2015; Connolly et al., 2019; Vidal-Matutano & Pardo-Gordó, 2020).

Finally, micromorphological and lipid biomarker analyses conducted across the full sequence also provide indicators of cooler conditions. Microscopically, evidence of cryoturbation (freeze-thaw processes) has been identified, especially in SU IV. Additionally, there is a noted decrease in organic content towards the base of the sequence, with a minimum in SU V and slightly higher values in SU VI, which may suggest arid conditions, particularly during the deposition of SUs V and IV (Connolly et al., 2019; Connolly, 2021).

Archaeological sequence

The following section presents the archaeological record across the sequence, from the oldest to the most recent units:

SU VI, currently under excavation, displays a higher density of archaeological material compared to the overlying units. The lithic assemblage is notable for the presence of thermally altered flint artefacts, increased evidence of combustion—both in the number of surface hearths and dispersed charcoal—and a lower degree of faunal fragmentation than in subsequent phases.

The lithic assemblage from **SU V** is the focus of the current Thesis and will therefore be presented in detail in the following chapters. At the moment, no published studies are available regarding the faunal record, wood resource collection, or other aspects of the assemblage.

At the **base of SU IV**, subdivided into subunits IVg–IVe, three archaeostratigraphic units (AUs) were identified: IVfH17, IVf1, and IVe1 (Sossa-Ríos, 2021). The first of these is analysed in this Thesis and will be presented in subsequent sections. Both AUs IVf1 and IVe1 are low-density units without hearths. IVf1 is distributed across the entire excavation area and consists of eight lithic products (four flakes and four fragments), with Serreta flint type predominating over Mariola flint. AU IVe1 is located in the southeast part of the site and is dominated by faunal remains, along with two flint artefacts (a core and a retouched product) both made on Mariola flint.

For **IVf**, several published studies provide contextual data. The hearth H17, the only combustion feature recorded in this initial phase of SU IV, consists of a millimetre-thick ash layer above a centimetre-thick black layer of thermally altered substrate, showing no signs of post-depositional disturbance (Mallol et al., 2019). *Juniperus sp.* was the dominant taxon in the anthracological assemblage (74%), with a clear spatial concentration around H17 (Mallol et al., 2019). Lipid and isotopic analyses of the ash layer revealed preserved animal fats, with isotopic values matching those of herbivores (Jambrina et al., 2019).

Towards the **top of SU IV**, archaeostratigraphic analysis of subunits IVd–IVa enabled the identification of four archaeostratigraphic units, each with discrete spatial concentrations (Machado et al., 2013, 2019). These show a general predominance of hearth-related assemblages, including Levallois knapping sequences and faunal processing, although substantial variability is evident within the AUs.

This variability is first apparent in lithic density, which is highest at the top (AU IVb = 446 products) and base (AU IVd = 198 products), and significantly lower in the middle units (AU IVc1 = 22 artefacts; IVc2 = 18 artefacts). Moreover, the most material-rich AUs exhibit differences in activity patterns. In AU IVb, knapping is the dominant activity, including refitting sequences of over 30 products. In contrast, AU IVd1 is mainly associated with carcass processing, a pattern also noted, though to a lesser extent, in AU IVc2. AU IVc1

shows a mixed pattern of both activities. Changes are also evident in the flint types introduced to the site: Beniaia flint dominates in IVb (73%), Serreta in IVc1 (64%), Mariola in IVc2 (66%), and a mixed predominance of Beniaia (42%) and Serreta (46%) in IVd1 (Machado et al., 2013, 2019; Molina, 2015).

Regarding the faunal record, there is clear evidence of a preference for Mediterranean tortoise (*Testudo hermanni*), especially in IVd and IVc (Sanchis et al., 2015). In these subunits, thermally altered remains account for 42% of the assemblage, while cut marks (found on the internal faces of plates, as well as on humeri and scapulae) do not exceed 6%. In addition to tortoise, anthropogenically modified remains include wild goat (*Capra pyrenaica*) and red deer (*Cervus elaphus*), with a minimal contribution from the Bovinae family. Notably, carnivores are nearly absent, with only one Canidae remain identified and no evidence of carnivore-induced taphonomic alterations (Pérez et al., 2017).

The hearths identified in subunits IVd to IVa (n = 9) are generally circular, although a few exhibit more angular morphologies (e.g. H3 or H5), and range from approximately 25 to 75 cm in diameter (Machado et al., 2019). In the field, these features typically appear as a sequence of two layers: a greyish upper layer, sometimes containing charcoal fragments, and a lower reddened layer. Micromorphologically, hearths consist of silty-sandy charred plant matter, charcoal, and thermally altered microscopic archaeological materials, mainly faunal and flint fragments. Ash is rarely preserved, likely due to its volatility, the effects of humidity, and/or post-depositional anthropogenic processes such as trampling (Machado et al., 2013; Mallol et al., 2019). The preferred fuel throughout this sequence was *Juniperus sp.*, identified in most of the charcoal samples. Lesser amounts of pine (*Pinus nigra sylvestris*) and pistachio (*Pistacia sp.*) were also present (Vidal-Matutano et al., 2015).

SUs III and II contain few remains, mainly of *Testudo hermanni*, and include a single hearth (H7) in SU II (Machado et al., 2013). The erosive impact of Holocene cuts, as well as the limited horizontal extent of these units, likely accounts for their reduced archaeological visibility.

SU I contains materials in secondary position, including Late Roman pottery, faunal remains of uncertain chronology, and Middle Palaeolithic artefacts. Notably, the lithic assemblage exhibits considerable technological complexity, including Levallois refitting sequences and a high proportion of retouched tools (Galván et al., 2009).

2.3. El Salt

“¡Que hallemos el musteriense y los más guapos neandertales de España!”

“I hope we find the Mousterian and the most beautiful Neanderthals in Spain!”

Letter from Lluís Pericot to Vicente Pascual regarding the expectations of the excavation at El Salt, 23 March 1960.

General context

The archaeological site of El Salt is located in the municipality of Alcoi, in the province of Alicante, on the eastern Iberian Peninsula. It consists of a rockshelter with a potential surface area of approximately 250 m². The site is situated at the headwaters of the Serpis River, in the confluence of the Barxell and Polop rivers (Galván et al., 1992; Fumanal, 1994; Galván et al., 2001; Mallol et al., 2013; Galván et al., 2014a; Garralda et al., 2014; Machado et al., 2017; Mayor et al., 2020).

History of research

The estate where the site is located, known as Villa Vicenta, had been the summer residence of the Alcoyan poet Juan Gil Albert until his exile in 1939. After being expropriated, the property was transferred in 1958 to the Parish of Santa María de Alcoi. One year later, the first prehistoric find at the site occurred. In July 1959, Juan Faus, an amateur archaeologist and collaborator of the Museu Arqueològic Camilo Visedo Moltó of Alcoi, reported several Palaeolithic artefacts found on the surface of the upper garden of the estate (Galván et al., 1992; Segura, 2017). Although he communicated the discovery to Vicente Pascual, then Local Delegate of the National Archaeological Excavation Service and newly appointed director of the museum (Fig. 8a), it ultimately reached Fernando Ponsell, another amateur archaeologist, who in August 1959 carried out the first excavation, despite opposition from both Pascual and Miquel Tarradell (Universitat de València). Ponsell intervention resulted in a 3.5 x 1.5 m trench, exposing the full thickness of the deposit and several archaeological remains.

Lluís Pericot, who had previously been involved remotely in the work at Abric del Pastor, learned of the discovery and contacted Pascual with the intention of excavating at El Salt in late 1959. At that time, Pericot had financial support from the Wenner-Gren Foundation and backing from the Excavation Service of the Diputació de Barcelona, of which he was director. He decided to commission Pascual to conduct the first formal excavation following Ponsell unauthorised dig, providing not only financial assistance but also sending his doctoral student Ricardo Martín and his collaborator at the University of Barcelona, Eduardo Ripoll.

After overcoming difficulties related to excavation permission, the excavation took place in April 1960 under the direction of Vicente Pascual and Ricardo Martín, who extended Ponsell original trench (Fig. 8a). Given the promising results and with Pericot approval, a second season followed in April–May 1961. Although this excavation also yielded good results, it would be the last led by this initial team. The military and professional obligations of Ricardo Martín, along with Pascual commitments at the museum, ultimately prevented the continuation of the work and the timely publication of results, paralleling the situation at Abric del Pastor.

In the case of El Salt, research activity resumed more swiftly. During her doctoral studies, Bertila Galván (Universidad de La Laguna) (Fig. 8c), supervised by Ignacio Barandiarán

(Universidad del País Vasco), began a technological study of various Palaeolithic sequences in the Valencian region (e.g. Cova Negra de Xàtiva, Cova del Cochino). However, she was forced to abandon her work at Cova Negra midway through her Thesis and was instead granted access to the materials from the 1960s excavations at El Salt. After several research stays in France with renowned Palaeolithic scholars François Bordes and Henry Laville, Galván defended her Thesis in 1985. Shortly thereafter, she obtained the first excavation permission for El Salt (1986) (Fig. 8d) and secured a permanent position at the University of La Laguna in 1987.

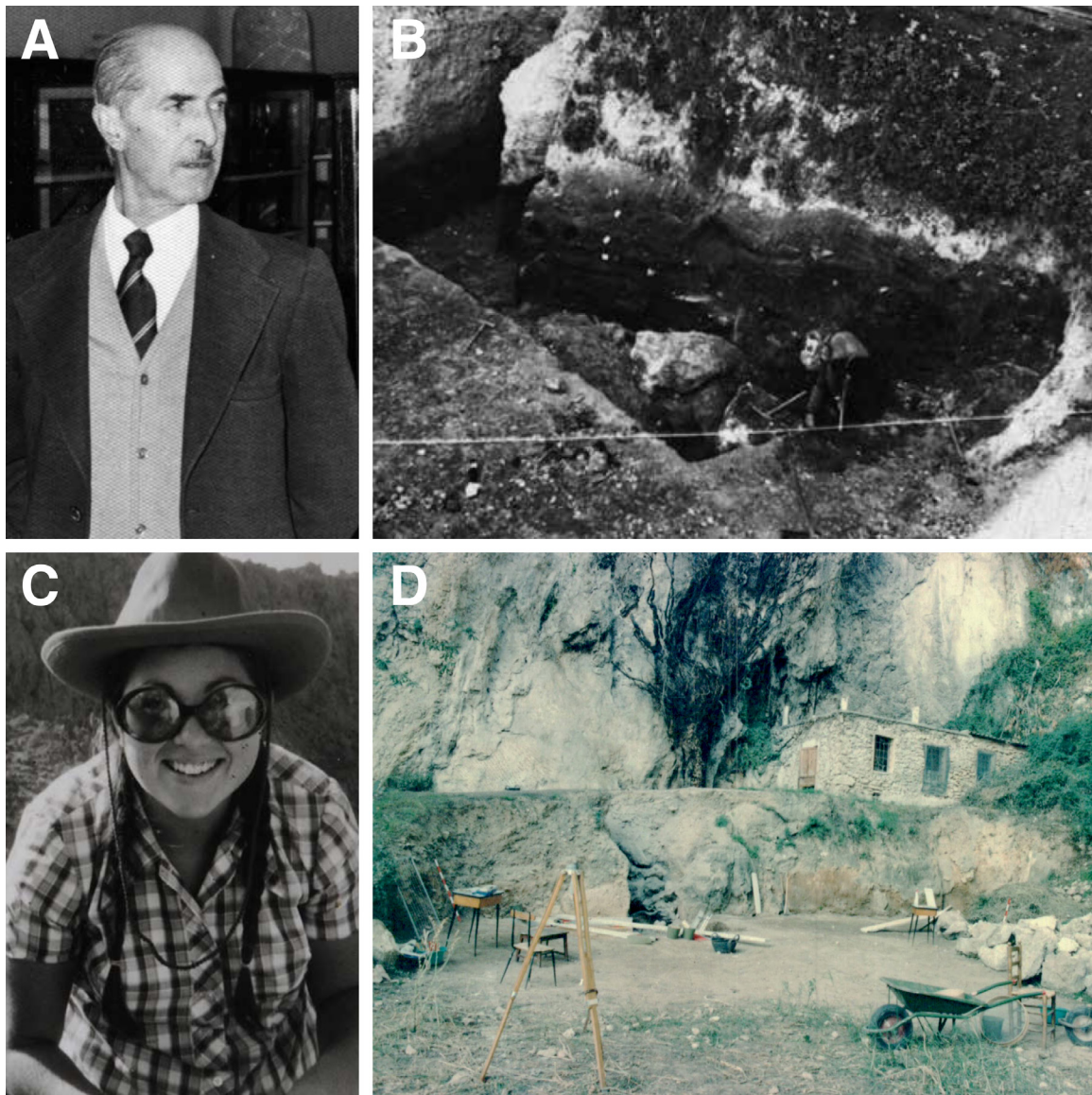


Fig. 8. A) Picture of Vicente Pascual. B) Work during the 1961 season. C) Picture of Bertila Galván. D) Work during the first excavation season of the University of La Laguna (1986).

One year after the first campaign, Cristo M. Hernández, then an undergraduate student at the same university, joined the project. After 38 years of continuous work at the site, he currently co-directs the excavations alongside Carolina Mallol (University of La Laguna). Since 1986, El Salt has been excavated annually and, after nearly four decades of research, it has become a major reference point for the study of Neanderthal groups and their palaeoenvironmental contexts.

Geomorphological context

El Salt is a rockshelter located at 680 metres above the sea level at the headwaters of the Serpis River, within a landscape defined by several prominent geomorphological features (Fig. 9a). To the north lie the mountains of Mariola, while to the south rises El Menejador, situated within the Font Roja Natural Park. To the west, the site connects with the Polop Valley, and to the east, the landscape opens towards the Serpis Valley, creating a strategic and sheltered location (Fig. 9b).

The rockshelter is located at the base of a 38-metre-high Paleocene limestone wall (Fig. 9c). During the Oligocene, conglomeratic materials were deposited, which were subsequently affected by tectonic processes. A later fault caused the uplift and separation between the limestone wall and the associated conglomerates. This complex tectonic and sedimentary history has largely shaped the present-day structure of the El Salt setting.

During the Pleistocene, the valley witnessed the formation of a travertine system, consisting of tufa platforms arranged as terraces at different elevations, as well as ramp formations, all resulting from fluvial dynamics and calcium carbonate precipitation (Fumanal, 1994). The archaeosedimentary deposit of El Salt is located on one of these terraces (T2), whose final phase of formation is associated with MIS 5. In this context, during the Late Pleistocene, the limestone wall of the rockshelter was also covered by tufa deposits. These formed through the interaction between calcium carbonate-rich water from the ancient Barxell River course, the limestone surface, and the vegetation growing on it (Molina, 2015; Ordóñez et al., 2016) (Fig. 9d). It is precisely this tufa that, through disintegration processes, contributes significantly to the formation of the sedimentary matrix of the archaeological deposit (Mallol et al., 2013; Leierer et al., 2019). During the Upper Pleistocene, the rockshelter ledge experienced several episodes of collapse and rockfall, which are recorded in the stratigraphic sequence and ultimately nuanced the site character as a shelter.

In the Holocene, a cave opened up in the upper part of the site, in the western sector of the wall (Fig. 9e). This cave, formed through the reactivation of karstic processes, expelled a high-energy gravel deposit that eroded a significant part of the pre-existing archaeological sequence. However, most of the deposit associated with the Middle Palaeolithic remained unaffected, except in the eastern area (Fig. 9f), where an erosive scar is still visible today within the current excavated zone.

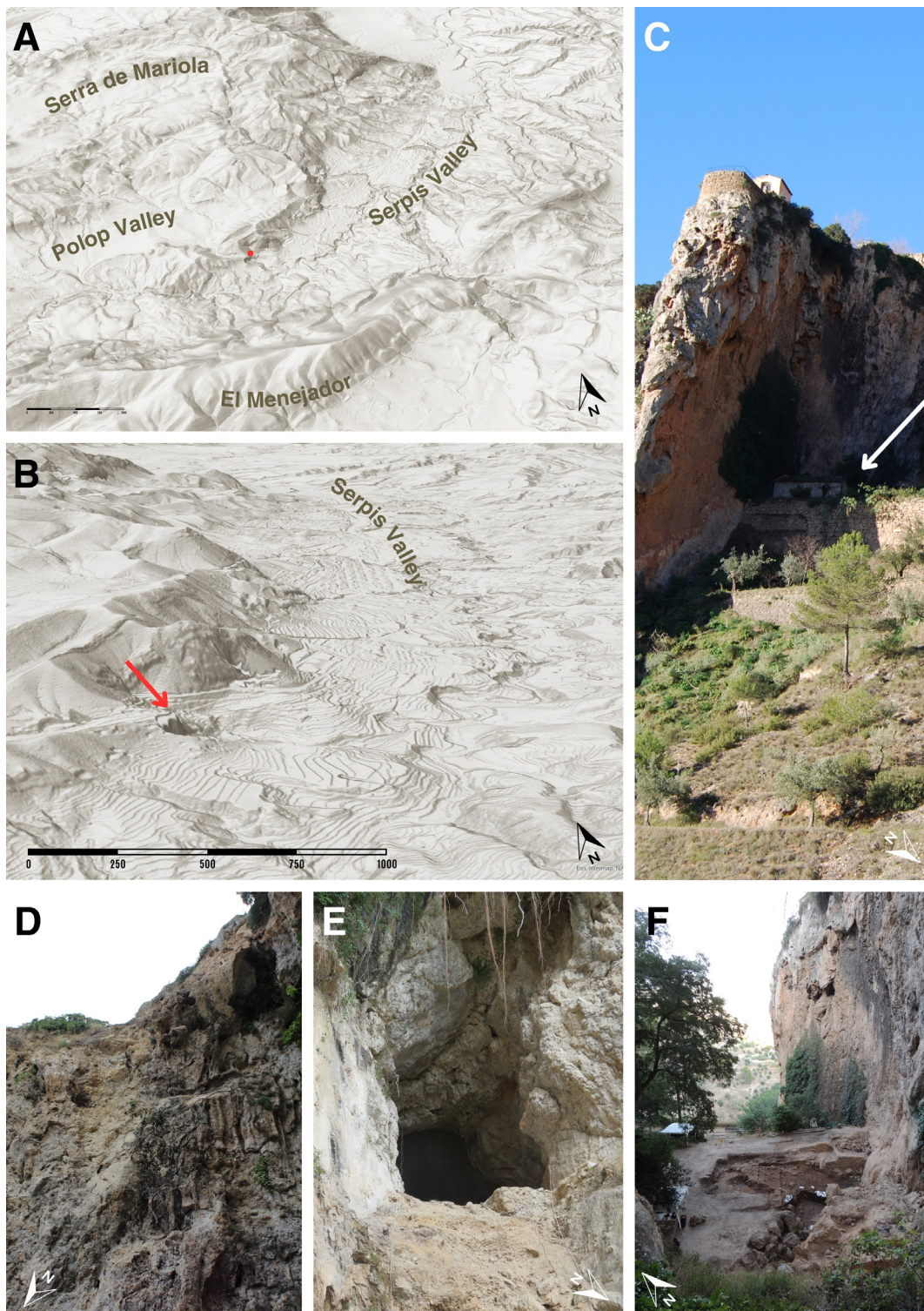


Fig. 9. A) Three-dimensional relief view of the El Salt context (red dot). Scale = 1000 metres. B) Specific three-dimensional relief showing the location of the site (red arrow). Scale in metres. C) Photograph of the 38-metre high wall that forms the shelter. D) Tuffa formation attached to the wall. E) The opening of the Holocene cave. F) View of the site from the opening of the cave.

Stratigraphic and chronological sequence

The stratigraphic sequence at El Salt is divided into thirteen units, with a total thickness of 6.3 metres (Fumanal, 1994; Mallol et al., 2013; Galván et al., 2014a, 2014b; Garralda et al., 2014) (Fig. 10). Each unit is described below, from the oldest to the most recent, including its thickness, sedimentary composition, and absolute dates where available:

SU XIII: The basal unit of the site consists of an archaeologically sterile tufa deposit, currently known to exceed one metre in thickness. Uranium-Thorium (U/Th) dating has provided ages of 81.5 ± 2.7 ka and 80.1 ± 4 ka.

SU XII: This is the first unit containing archaeological material. It is approximately 30 cm thick and lies directly atop the tufa platform, with a clear stratigraphic contact. The earliest recorded collapse of the overhang occurred during its formation, evidenced by large blocks resting directly on the platform. The matrix consists of dark brown silts and clays. Thermoluminescence (TL) dating yielded an age of 60.7 ± 8.9 ka.

SU XI: This unit has a variable thickness of 5 to 25 cm. The matrix remains brown silty clay, although small yellowish nodules of degraded limestone are also present. These indicate diagenetic processes during the formation of this unit.

SU X: This unit has been subdivided into SU Xb and SU Xa, based on colour and texture differences observed both in the field and under the microscope. SU Xb, which is subject of study of this Thesis, lies at the base and is 15 cm thick. It is characterised by a fine dark brown silty clay sediment (Fig. 10b). However, there are horizontal variations: the sediment is more orange towards the outer area (further from the wall) and darker in the inner zone (closer to the wall). This contrast reflects anthropogenic organic input, which accumulates in the inner area, where combustion structures, dispersed combustion residues, and natural organic matter are concentrated. SU Xa is 10 cm thick and lies directly above Xb, with a diffuse and undulating contact. It consists of a lighter, more sandy sediment. The average TL date for both units is 52.3 ± 4.6 ka.

SU IX: This unit is approximately 15 cm thick and is defined by a darker silty clay matrix, reflecting increased organic input of both anthropogenic and natural origin.

SU VIII: This unit has a thickness ranging between 10 and 17 cm. It is composed of orange-toned silty clay, with an irregular presence of pebbles and gravels. A significant decline in anthropogenic presence is observed at this level, a trend that continues in the overlying units.

SU VII: Ranging from 10 to 25 cm thick, this unit retains an orange silty clay matrix, but numerous clay aggregates are present. TL dating places this unit at 49.2 ± 4.8 ka.

SU VI: This unit is approximately 10 cm thick and features a more sandy matrix with an ochre-pink tone. It has been dated by TL to 47.2 ± 4.4 ka.

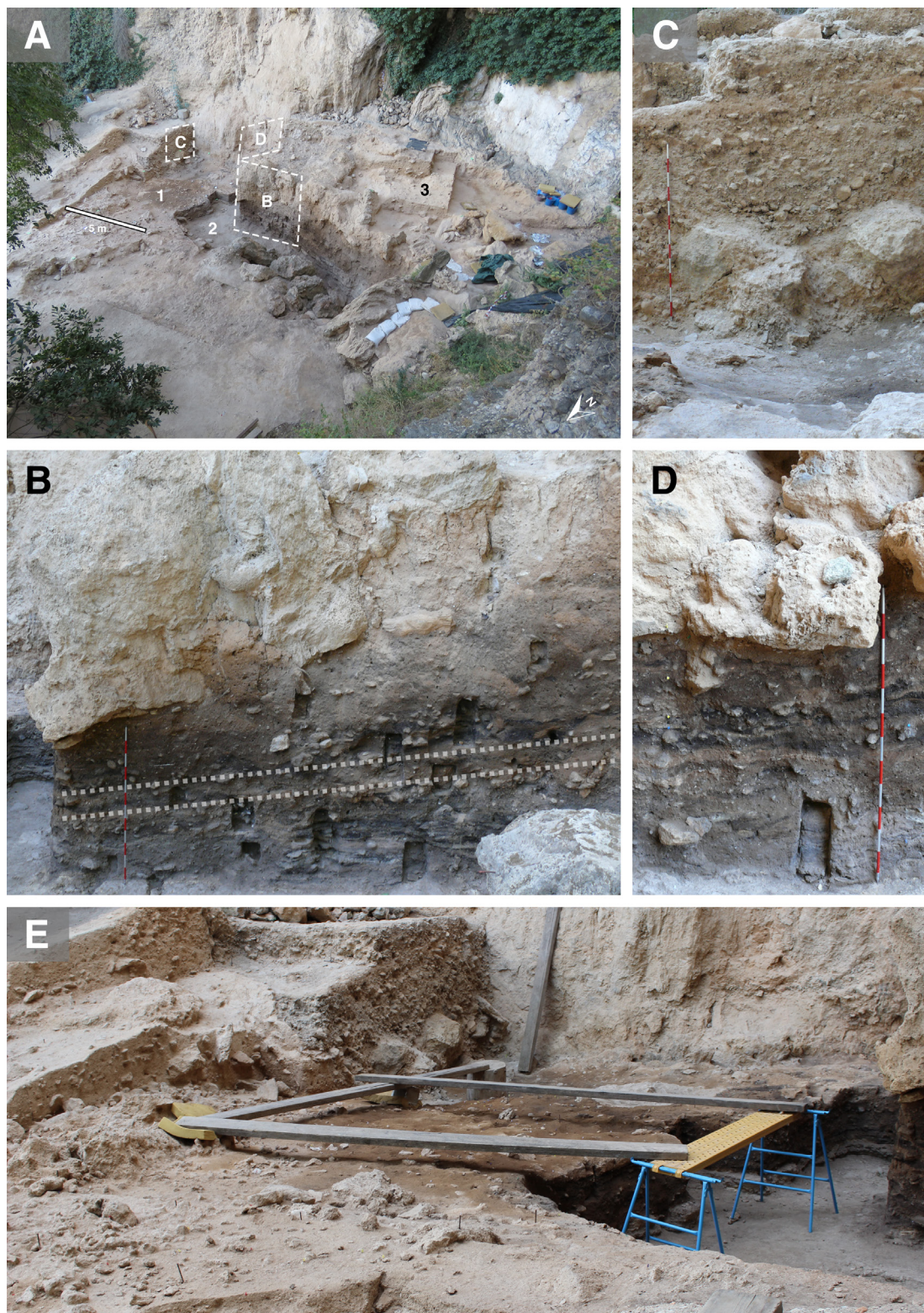


Fig. 10. A) General view of the site showing the different stratigraphic profiles (letters) and significant areas (numbers). A1) Current excavation surface, A2) trench excavated during the 1960s seasons, and A3) excavation surface of upper SU V. B) Profile 3 of the site showing the sequence attributed to the Middle Palaeolithic (SUs XII-V). The studied level is indicated by dashed lines. C) Profile 12, showing the erosive deposit of pebbles and gravels (SUs IV-I). D) Profile 2 showing another perspective of the Palaeolithic archaeological deposit (SUs XII-VI). E) Current excavation surface.

SU V: This unit has been subdivided into lower and upper subunits. The lower subunit is approximately 75 cm thick and is composed of yellow-orange silty clay. The second major collapse of the overhang is recorded at the base of this unit, evidenced by large tufa blocks. It also contains the final anthropogenic traces in the deposit, including Neanderthal human remains. The upper subunit has a minimum thickness of 50 cm, due to its erosive contact with overlying units. It consists of massive aeolian silts, yellow at the base, with an increase in gravel content towards the top (Fig. 10a). TL dating yielded an age of 45.2 ± 3.4 ka.

SUs IV–I: These units are associated with the opening of the cave. Together they reach a total thickness of 1.3 metres and consist primarily of sub-rounded blocks, cobbles, and gravels. Their contact with the older units is erosive. Due to slope dynamics, this erosive event only affected SU V in the western sector of the site, nearest the cave mouth, whereas in the eastern sector, corresponding to the current excavation area, it impacted SUs V to XI, generating an erosional cut that continues close to the wall (Fig. 10c). The presence of Early Neolithic materials in secondary position, such as Cardial pottery, allows this assemblage to be dated, thereby placing the cave-opening event at an advanced stage of the Holocene.

Unlike at Abric del Pastor, where the excavated surface nearly matches the total potential extent of the shelter, the case of El Salt requires a more detailed explanation. In addition to the trench excavated first by Ponsell and subsequently by Pascual in 1960 (2 in Fig. 10a), El Salt comprises two main areas that have been excavated under the current research direction.

The first area (1 in Fig. 10a) is an irregular surface of 38 m² that has been the primary focus of investigation, from SU I to SU XI, the latter still under excavation. This area is subdivided into two sectors that have been excavated together: an inner and an outer zone, separated by the drip line. As noted in the description of SU Xb, the differences between these sectors are primarily sedimentological, although archaeological variation is also evident, with higher densities of material and combustion features in the inner area.

The second area (3 in Fig. 10a), covering approximately 30 m², was excavated to investigate the sediment composition, palaeoenvironmental record, and potential archaeological content of the upper part of SU V.

In addition to the graphical support provided in Figure 10, a link is available for the full 3D visualisation of the site:

[El Salt \(Alcoi\) - 3D model by el.tossal.topografia \(@el.tossal.cartografies\) \[b16bb4e\]](#)

Palaeoenvironmental sequence

The site of El Salt has yielded substantial palaeoenvironmental data over the past decades, with information recovered from nearly the entire stratigraphic sequence.

Conditions identified in the basal section of the sequence (**SUs XII-Xb**), based on lipid and isotopic analyses of sediments, point to a generally humid environment (Davara, 2022). However, internal variation is evident. Isotopic data indicate a progressive reduction in humidity from the top of SU XII through to SU Xb. This trend toward aridification intensifies markedly from SU VII to SU V (Connolly, 2021).

In **SU Xb**, both microvertebrates and anthracological remains provide valuable insights into the environmental conditions during its formation. The micromammal taxa identified (*Microtus agrestis*, *Apodemus sylvaticus* and *Elyomys quercinus*) together with charred woody remains attributed to *Pinus nigra sylvestris*, *Acer sp.*, and *Quercus sp.*, suggest a landscape of open woodland under supra-Mediterranean climatic conditions (Fagoaga et al., 2018, 2019; Vidal-Matutano et al., 2018). Both proxies indicate a cooler and wetter climate than the present (14 °C and 443 mm), with an estimated drop in mean annual temperature of -3.3 °C and an increase in mean annual precipitation of 113.3 mm.

In addition, the recovery of amphibians such as *Bufo bufo*, *Epidalea calamita*, and *Alytes obstetricans*, along with reptiles (*Chalcides bedriagai*, *Acanthodactylus erythrurus*) and snakes (*Rinechis scalaris*), suggests the presence of humid zones or temporary flooded areas near the site (Marquina et al., 2017), further supporting the interpretation of a wet environment.

In the case of **SU Xa**, the macrofaunal taxa identified and considered suitable for palaeoecological analysis (*Equus ferus*, *Cervus elaphus*, and *Capra pyrenaica*) indicate an open landscape with warmer temperatures (20.05 °C) and slightly higher precipitation (457.55 mm) than in SU Xb (Pérez et al., 2017; Pérez, 2019). These data support the classification of SU Xa within a Type IV zonobiome, suggesting that the El Salt environment was dominated by Mediterranean-type vegetation (Fig. 11).



Fig. 11. Photographic representation of the different taxa identified in UE X at El Salt that contribute to the palaeoenvironmental reconstruction. From left to right: *Pinus nigra sylvestris*, *Microtus agrestis*, *Equus ferus* and *Cervus elaphus*.

From this point onward, humidity gradually declines. Micromorphological, palynological, lipid, and isotopic analyses across **SUs VIII–VI** reflect alternating wet and dry periods, as well as increased surface exposure to natural agents (Connolly, 2021). However, it is not until **SU V** that the environment becomes fully arid. The same analyses indicate a sedimentary matrix dominated by aeolian silts and a marked reduction in organic matter. Additionally, the base of this unit records the final collapse event of the rockshelter ledge.

Micromammal data reinforce this interpretation: the absence of *Arvicola sapidus*, a species present in the other units, points to an environment more open, colder, and drier than today (−2.76 °C and −13.3 mm) (Fagoaga et al., 2021). Similarly, the identification and habitat modelling of amphibian and reptile species in **SU V** align with these data, although they suggest a slightly milder cooling (−1.3 °C) (Marquina et al., 2021).

The characteristics of this final phase in the sequence have been linked to Heinrich Events 5 and 4 (ca. 45 and 38 ka, respectively), two abrupt cold climatic oscillations that chronologically coincide with the last Neanderthal presence at El Salt and most of the sites on the Iberian Peninsula (Mallol et al., 2012; Galván et al., 2014a).

Archaeological sequence

SU XII, which marks the base of the archaeological deposit, has not yet been the subject of detailed study.

SU XI is currently under excavation (2022–present). Preliminary field observations indicate the abundant presence of hearths (many of them superimposed in specific areas of the site), highly fragmented faunal remains, and a lithic assemblage dominated by flint, although numerous limestone cobbles bearing anthropogenic modifications have also been recorded.

SU Xb, part of this Thesis, has been previously studied and provides valuable insights into Neanderthal behaviour. Micromorphological analyses have identified episodes of seasonal abandonment between certain combustion events, suggesting short-term occupations spaced out over time (Leierer et al., 2019; Leierer, 2021). The hearths are generally circular, averaging 50 cm in diameter, and show exceptional preservation of both the ash layer (white layer) and the underlying thermally altered substrate (black layer) (Mallol et al., 2013; Leierer, 2021). The main fuel used was *Pinus nigra sylvestris*, likely gathered within a radius of approximately 1 km (Vidal-Matutano et al., 2018). However, other taxa such as *Buxus sempervirens*, *Acer sp.*, and *Quercus sp.*, were also identified, with the latter likely collected from more distant areas (ca. 5 km). Spatial analysis of charcoal taxa reveals discrete distributions of certain species around specific hearths, particularly for the less common taxa (Vidal-Matutano, 2017).

Our recent temporal analysis of four of these hearths, based on archaeostratigraphy and archaeomagnetism, has provided estimates of the minimum time intervals between them. The results suggest short spans between H55 and H48 (20–25 years), several decades

between H48 and H59 (70–85 years), and nearly a century between H50 and H59 (85–105 years) (Herrejón-Lagunilla et al., 2024).

In this unit and others, lagomorphs dominate the faunal assemblage, outnumbering all other taxa. Taphonomic analysis has confirmed the natural origin for these remains, with the Eurasian eagle-owl (*Bubo bubo*) identified as the main predator and accumulator of rabbit bones at the site (Marín-Monfort et al., 2021).

SU Xa is one of the best-documented units, with multiple studies attempting to dissect it into more precise units and characterising the behaviours reflected in each. Much of this work derives from the Doctoral Thesis of Jorge Machado (2016). Eight archaeostratigraphic units (AUs) were identified (Machado & Pérez, 2016; Machado et al., 2017). AUs 3.1, 3.2, 3e, and 4e are confined to the outer zone, with minimal evidence of combustion, while AUs 4.1, 5.1, 5.2, and 5.3 are restricted to the inner area, where anthropogenic activity associated with hearths is more intensive.

Lithic assemblages show both variation and continuity across this sequence, particularly in terms of flint types and their management (Molina, 2015; Machado et al., 2017). Serreta flint dominates in all AUs, generally exceeding 50% of the assemblages. Mariola and Beniaia flints follow in frequency, occupying the second and third positions respectively. Less common flints, such as Escobella, appear only in specific contexts (e.g. AU 3.2), while Font Roja flint is limited to inner AUs. Technologically, the assemblage is dominated by Levallois production, especially recurrent centripetal modalities. On-site production is most evident for Serreta and Mariola flints, which show refitting sequences, though usually with only 2–3 refitted products. Beniaia flint, as well as rarer types like Font Roja, Escobella, and Polop, appear mostly as retouched tools or single flakes.

Zooarchaeological analysis across the AUs identified some stable patterns, such as the consistent presence of *Equus ferus* and *Capra pyrenaica* (Machado & Pérez, 2016; Pérez et al., 2020). *Cervus elaphus* is present throughout most of the sequence, though absent from AU 5.1. Other, less common taxa, such as *Sus scrofa* and *Bos primigenius*, appear only in specific contexts, like AU 4e and 3e (wild boar) and AU 3e (auroch) (Machado & Pérez, 2016; Machado et al., 2017). Skeletal part representation follows size-based patterns: large-sized individuals are represented mainly by femurs, radii, and ulnae; medium-sized animals by cranial remains and tibias; and small-sized ones by femurs, tibias, cranial fragments, and scapulae (Pérez et al., 2017, 2020; Pérez, 2019). Diaphyseal fragments from deer and horse were also modified for use as retouchers (Pérez et al., 2019). Carnivore remains are also present in SU Xa, represented by three species: *Cuon sp.*, *Panthera pardus*, and *Lynx sp.* However, their numbers are low, and carnivore-induced taphonomic alterations are scarce (Pérez & Sanchis, 2021).

Archaeostratigraphic analysis was later refined through the detailed study of RMUs (raw material units), which identified two distinct formation events in AU 4.1 (4.1.1 and 4.1.2) and three in AU 5.3 (5.3.1, 5.3.2, and 5.3.3) (Mayor et al., 2020). These new units of analysis reflect short knapping episodes near hearths in the inner zone, dominated by Serreta and

Mariola flints using recurrent centripetal reduction modalities. Use-wear analysis applied to these units, included within 5.3, revealed functional variation in the lithic record over time. 5.3.1 is associated exclusively with woodworking; 5.3.2 with both wood and animal processing; and 5.3.3 solely with animal processing (Bencomo et al., 2023).

SU IX has not been specifically studied, although the Doctoral Thesis of Leopoldo Pérez (2019) on the entire faunal sequence highlights red deer as the dominant taxon, followed by wild goat and horse.

SU VIII was the focus of the Doctoral Thesis of Alejandro Mayor (2023). Analysis of lithic procurement dynamics identified a major shift in the El Salt sequence. In this unit, Beniaia flint (40%) surpassed the previously dominant types, Serreta (28%) and Mariola (20%), indicating new mobility patterns among Neanderthal groups in the Serpis Valley. The closest known Beniaia flint sources are approximately 21 km away. Postgenetic features in the lithic assemblage, such as fluvial alteration, further support this connection with the Serpis River (Mayor et al., 2022; Mayor, 2023). Additionally, recycled artefacts, identified by modifications after white patina or thermal alteration, appear to have been collected alongside raw material, suggesting they formed part of the procurement strategy (Mayor et al., 2024).

Zooarchaeological data for this unit show a predominance of red deer, followed by wild goat and horse. Remains of aurochs, chamois, and lynx were also identified. Among the main taxa, skeletal part representation highlights the dominance of hindlimbs in deer and forelimbs in wild goat and horse (Pérez, 2019; Mayor et al., 2022).

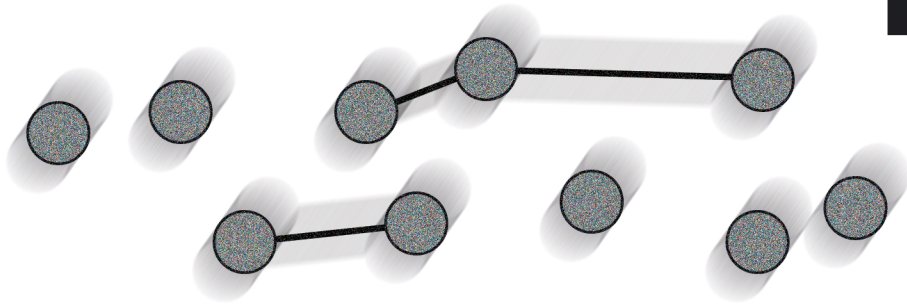
SUs VII and VI mark the beginning of a pronounced decline in anthropogenic activity. Only three hearths have been recorded, all in SU VII. In SU VI, fire use is inferred solely from thermally altered materials. Lithic and faunal records are also significantly reduced. Nonetheless, continuity in hunting and prey selection is observed, with red deer prevailing, followed by wild goat, horse, and auroch (Pérez, 2019).

SU V, particularly its lower part, contains the last evidence of Neanderthal occupation at El Salt. Human remains were discovered in the outer zone, consisting of six teeth from a juvenile individual (Garralda et al., 2014). Faunal remains indicate the continued presence of red deer, but a marked decline in wild goat and horse. Carnivores, for the first time at El Salt, are represented by the red fox (*Vulpes vulpes*) (Pérez & Sanchis, 2021).

These diminishing anthropogenic signals disappear entirely in the upper part of SU V. The archaeological record vanishes, aside from the occasional, unassignable flint fragments. This discontinuity has also been observed at other Iberian sites and is associated with a generalised hiatus between the last Neanderthals and the arrival of Anatomically Modern Humans (Mallol et al., 2012).

Finally, **SUs IV–I** contain lithic artefacts associated with the Upper Palaeolithic and pottery materials attributable to the Neolithic, although all of them are found in secondary context (Galván et al., 2014b).

section



MATERIALS AND METHODS

III. Materials and methods

3.1. Materials

3.1.1. Materials for temporal and spatial research

3.1.2. Materials for technoeconomic research

3.2. Methods

3.2.1. Raw material analysis and RMU identification

3.2.2. Lithic attribute analysis

3.2.3. Refitting analysis

3.2.4. Archaeostratigraphic analysis

3.2.5. Spatial analyses

3.2.6. Additional methods

3.1. Materials

For this Thesis, two general types of data were used. Firstly, the archaeological record coordinates, from which archaeostratigraphic and spatial data were extracted. Secondly, the lithic objects, which provided technoeconomic information. The latter were requested from the Direcció General de Patrimoni de la Generalitat Valenciana, approved by this institution, and studied within the two-year period established by the law, under a loan agreement with the Museu Arqueològic Municipal Camilo Visedo Moltó of Alcoi.

3.1.1. Materials for temporal and spatial research

The bottom of each archaeological remain, defined by the central point of its supporting surface on the sedimentary layer, was recorded using Sokkia iM-50 Series and Leica Geosystems FlexLine TS02 total stations. This procedure was carried out regardless of the object size. The only remains neither recorded with coordinates nor field collected were charcoal fragments, in order to prevent underrepresentation of the sample during water sieving. Each excavation day, the recorded points were downloaded from the total station in .txt format, peer reviewed, and transferred to an Excel 97-2003 (.xls) spreadsheet. This format is the one compatible with the software used for point processing (see sections 3.2.3 and 3.2.4).

A total of 1,712 points corresponding to lithic objects, 579 to faunal remains, and 18 to combustion structures were processed (Table 1). In the case of combustion features, the number of three-dimensional points exceeds the actual number of structures, as each hearth was recorded with multiple points. Both the ash layer and the thermally altered substrate layer were delimited using a minimum of eight perimeter points, with at least four additional internal points, usually arranged in a cross pattern, to capture the topography of each hearth layer.

	Abric del Pastor SUs IVg-e (2016-2017)	El Salt SU Xb (2013-2016)	Abric del Pastor SU V (2018-2023)	Total
Lithics	21	1,544	147	1,712
Fauna	279	-	300	579
Hearths	1	14	3	18
Total	301	1,558	450	2,309

Table 1. Number of materials considered for archaeostratigraphic and spatial analyses.

Each archaeological remain, whether lithic or faunal, was documented within a stratigraphic unit folder along with its assigned facies. This classification also applied to hearths, meaning that each excavator distinguished and recorded objects situated above or below the ash or thermally altered substrate layer using different nomenclature. This step is crucial for archaeostratigraphic analysis, as it allows for the validation or reconsideration of hypotheses regarding material correlation and the surfaces marked by each layer.

This data collection process was further enhanced by meticulous and detailed excavation at both sites (Fig. 12). However, El Salt required a greater material investment due to its sedimentary complexity, the frequent occurrence of overlapping hearths and the organic richness of the deposit. These factors necessitated the use of industrial vacuum cleaners, sterilised metal tools, and nitrile gloves throughout the excavation process. Given the coarser grained sediments, the low frequency of fires and the low organic content of the deposit, these materials were not used daily at Abric del Pastor.



Fig. 12. Excavation and data acquisition process (photos by Sven Kleinhapl). A) Excavation of a combustion area at El Salt B) Detail of the excavation process C) 3D coordinate acquisition using a light stick and D) 3D coordinates acquisition using a total station.

3.1.2. Materials for technoeconomic research

For this study, only lithic remains with recorded 3D coordinates were considered. This decision stems from the necessity of three-dimensional spatial data to define units of analysis within the whole assemblage. Although sieved material is associated with a stratigraphic unit and facies, this level of contextual information is insufficient for a high-resolution approach based on vertical and horizontal distribution.

As a result, the study comprises 1,702 lithic remains distributed across different units, both specific (i.e. AU IVfH17 at Abric del Pastor) and general (i.e. SU Xb at El Salt and SU V at Abric del Pastor) (Table 2).

	Abric del Pastor AU IVfH17 (2016-2017)	El Salt SU Xb (2013-2016)	Abric del Pastor SU V (2018-2023)	Total
Lithics	11	1,544	147	1,702

Table 2. Number of lithic remains considered for raw materials and lithic attributes analyses.

Once coordinates had been recorded, each lithic artefact was stored in a zip-lock plastic bag along with a label documenting the site name, recording date, stratigraphic unit, facies, inventory number, as well as its orientation and slope. Following this, the materials associated with each facies were organised in the excavation laboratory and stored in large plastic bags labeled with the corresponding unit and facies. At the end of each field season, the artefacts from each facies were stored at the municipal archaeological museum in cardboard boxes.

The next step was to apply for the legal loan and, once accepted (3-6 months), to transport the cardboard boxes to the research laboratory at the Departament de Prehistòria, Arqueologia i Història Antiga of the Universitat de València (UV). There, each lithic object was washed with water, air-dried, and subsequently labelled. The labelling process involved applying a transparent nail varnish base coat, followed by permanent ink coding. This was done in non-critical areas to avoid obstructing the analysis: preferably on proximal ventral areas in flakes and retouched pieces, and on cortical surfaces in cores, except in cases where cortex was minimal, in which case large scars were used instead.

After all these processes were completed, a database was created using Microsoft Excel 365 (version 97-2003), provided by the UV. This database compiled both the temporal and spatial data alongside the technoeconomic information for each artefact. The variables included will be explained in the methods section.

3.2. Methods

3.2.1. Raw material analysis and RMU identification

In the Eastern Prebaetic Zone, previous research has established a well-defined framework for identifying and characterising flint types, as well as for assessing potential procurement contexts. In this regard, the work of Francisco Javier Molina et al. (2010, 2015, 2016) laid the foundation for distinguishing eight flint types within the Serpis Valley, to which four additional lithotypes identified in the neighbouring Vinalopó Valley have been added (Table 3), an area also known to have been occupied by Neanderthal groups (Torregrosa et al., 2018; Molina et al., 2019). Although no lithotypes from the Vinalopó Valley have been identified in previously studied units at both Abric del Pastor and El Salt (Machado et al., 2013, 2017, 2019; Mayor et al., 2022), they were nonetheless considered in the present analysis in case they were part of our assemblages.

	Flint type	Period	Stage
Serpis Valley			
	Escobella	Cretaceous	Cenomanian
	Marxuquera	Cretaceous	Coniacian
	Mariola	Cretaceous	Maastrichtian
	Font Roja	Palaeocene	Selandian-Thanetian
	Serreta	Eocene	Ypresian
	Beniaia	Eocene	Ypresian
	Polop	Miocene	Tortonian
	Catamarruc	Miocene/Pliocene	Tortonian-Gelasian
Vinalopó Valley			
	Cámara	Jurassic	Tithonian
	Xinorla	Palaeocene-Miocene	Danian-Serravallian
	Umbría	Oligocene	Rupelian-Chattian
	Cabrera	Miocene	Langhian-Serravallian

Table 3. Flint types identified in both valleys according to period and stage of formation (modified from Molina et al., 2016 and Mayor et al., 2022).

Although this study considers the characteristics of all known flint types from the Eastern Prebaetic, three particular varieties from the Serpis Valley have predominated in the previously studied units from both sites (Machado et al., 2013, 2017, 2019; Mayor et al., 2022). Given their relevance, a brief description of each is provided below, accompanied by a figure (Fig. 13), while for a comprehensive characterisation of the remaining types, the reader is referred to Molina (2015).

Serreta flint: This type is typically found in subprimary positions, predominantly in the form of nodules. It exhibits a colour range from dark grey to deep brown, with an extremely fine texture. In terms of translucency, it tends to be more transparent than opaque, and its knapping quality is excellent, making it a highly suitable raw material for tool production. It can be gathered from 3 to 45 km from both sites, depending on the natural transport of the flint from its outcrop to the river mouth.

Mariola flint: This type occurs mainly in primary and subprimary positions, also with nodules as the predominant format. Its colour palette spans from ochre to grey, and it features a fine microcrystalline texture with characteristic carbonate fossil inclusions. Compared to Serreta flint, Mariola is more opaque than translucent, with a well-developed cortex often exceeding 1 cm in thickness. Its knapping quality is generally good. It can be collected from 3 to 45 km from both sites, according to the natural displacement of the flint from its original outcrop to the coastline.

Beniaia flint: Among the three, this is the most heterogeneous type, displaying significant variability in its characteristics. It is primarily found in subprimary positions and also takes the form of nodules. Its colour spectrum ranges from brown to grey, with a texture that varies from microcrystalline to macrocrystalline. This flint exhibits extreme differences in opacity, being either highly translucent or almost entirely opaque. It is particularly notable for its internal megaquartz formations and high content of bioclasts and biogenic structures. Due to its heterogeneity, the knapping quality of Beniaia flint is highly variable, depending on the specific attributes of each nodule. It can be procured from 17 to 45 km from both sites, based on the natural movement of the flint from its source outcrop to the river mouth.

Once the characteristics of the different flints were known, the analysis process could begin. The lithic assemblages were analysed using a combination of macroscopic and microscopic techniques (Turq, 2005; Tarriño & Terradas, 2013; Gómez de Soler et al., 2020). The primary objective was to identify the raw materials present in the assemblages and assess their variability across archaeostratigraphic and spatial units.

The first stage of analysis involved a macroscopic (naked-eye) examination of each artefact, focusing on fundamental attributes such as grain size, texture, colour, translucency, and the presence of inclusions (e.g. fossils, carbonate formations, recrystallisations, detrital quartz, and megaquartz geodes). Additionally, cortex characteristics (colour, texture, and thickness), as well as subcortical and endocortical halos, were also considered. When macroscopic identification proved insufficient, a more detailed microscopic examination

was conducted using stereomicroscopes (Euromex DZ 1600, Euromex EduBlue 1802-S, and Euromex Novex AR-Zoom), with observations recorded using the Euromex ImageFocus Plus software (version 2.4.9.0).

Following the description of these attributes, each artefact was compared with the reference collection developed by Molina (2015), which provided a framework for identifying and distinguishing different flint types within the region.

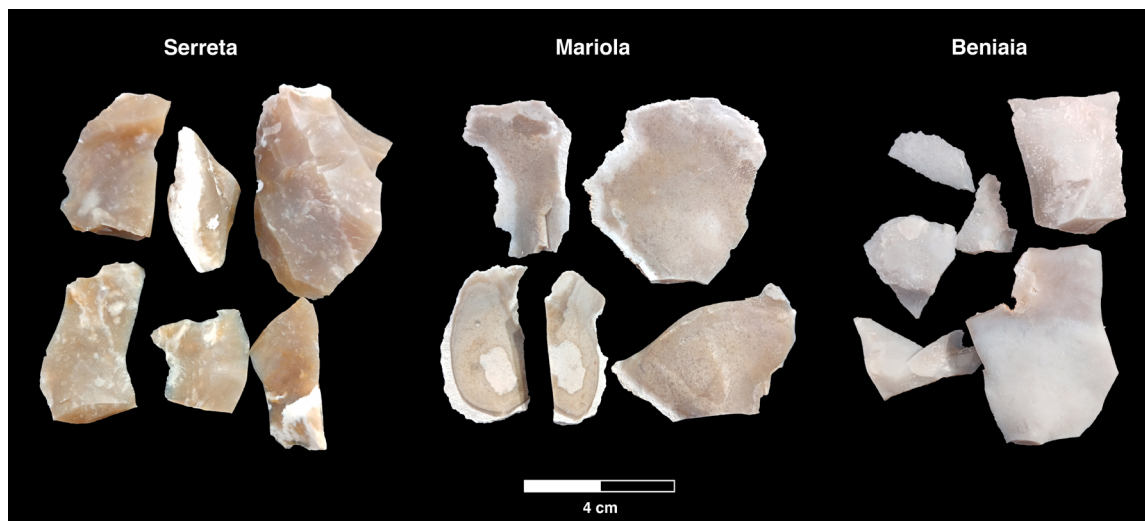


Fig. 13. Reference samples of the main flint types: Serreta, Mariola and Beniaia. Although this image shows the most common varieties, there is a great diversity within each type.

Previous studies at Abric del Pastor and El Salt have applied the concept of the “chaîne évolutive” (*sensu* Fernandes & Raynal, 2006; Fernandes et al., 2008; Fernandes, 2012), which reconstructs the geological life cycle of siliceous raw materials based on stigmata preserved on cortical surfaces. This approach has proven essential for refining the identification of procurement contexts and offering a more detailed perspective on Neanderthal mobility patterns, as demonstrated in previous research at both sites (Molina, 2015; Machado et al., 2017; Mayor et al., 2022). In this Thesis, this methodology was incorporated in the analysis of the lithic assemblage from Abric del Pastor AU IVfH17 and reviewed by other researcher (see section 3.2.6), allowing for a more nuanced interpretation of flint procurement. However, for the remaining assemblages, the focus was placed solely on the recognition of flint types to evaluate their temporal and spatial distribution within the site.

Another key component of the analysis involved evaluating post-depositional alterations that could affect raw material identification. Thermally altered products were identified based on experimentally established indicators for flint types from the Serpis Valley, such as colour shifts, surface textural changes, reticular fissures, thermal domes, irregular fractures, and glossy surfaces (Dorta et al., 2010). In addition, the presence of white patina and its location on the product surface were recorded, as this phenomenon is associated with prolonged exposure to weathering in calcite-rich deposits. (Rottländer, 1975; Burrioni et al., 2002; Caux et al., 2018) and can inform about post-depositional processes in the territory and/or on the site (e.g. Mayor et al., 2024).

Once the lithic artefacts were classified by lithotype and potential alteration processes, the next step was the identification of raw material units (RMUs) (Roebroeks, 1988; Conard & Adler, 1997; Vaquero, 2008; Moncel et al., 2014). This approach, following Roebroeks (1988: 29), aimed to determine whether artefacts originated from the same original flint nodule. To establish RMUs, each lithic element was systematically compared to the rest of the assemblage, assessing shared genetic traits. When multiple artefacts exhibited strong correspondences, they were grouped into set RMUs (S-RMUs), whereas isolated products were classified as single-element RMUs (SE-RMUs), indicating they could derive from unique nodules. This process was facilitated by the features of the flints in this region, characterised by high internodular variability, and low intranodular variability (Molina, 2015).

3.2.2. Lithic attribute analysis

Once the raw materials were identified, the lithic assemblage was subjected to a morphotechnical attribute analysis (Andrefsky, 2005; Baena & Cuartero, 2006; Vaquero, 2013). The first step involved classifying each artefact into one of four technological categories: flakes, retouched products, cores, and fragments.

The identification of flakes was based on the presence of a striking platform, bulb, and ripple marks on the ventral surface. Even when one or two of these attributes were absent (due to fractures, for instance) flakes could still be recognised. Once identified, their morphology (rectangular, quadrangular, triangular, trapezoidal, semicircular, or irregular) was recorded, along with amount of cortex (0, 0–25%, 25–50%, 50–75%, 75–100%, and 100%) and the location of the cortex (proximal, lateral, distal, or total). Additional recorded attributes included platform type (cortical, flat, dihedral, faceted—either flat or convex—punctiform, linear, removed, or fractured), bulb prominence (smooth, pronounced, removed, or fractured), number of dorsal negatives, direction of dorsal scar patterns (unidirectional, bidirectional, centripetal, orthogonal, or indeterminate), and fractures (proximal, ventral, or lateral).

For retouched products (i.e. artefacts with intentionally modified edges), the morphotechnical characterisation depended on whether they were flakes, cores, or fragments. The description of retouch followed Laplace (1972) classification, considering its type (simple, abrupt, flat, or over-elevated), extent (marginal or invasive), direction (direct, inverse, or alternate), delineation (continuous, notched, or denticulated), orientation (lateral or transversal), position (left, right, proximal, medial, or distal), and shape (straight, convex, concave, or sinuous).

Cores, defined here as any product modified for the extraction of another product, were described in terms of blank type (cobble, block, flake, fragment or indeterminate), number of striking platforms, polarity (unipolar, bipolar, peripheral, or semi-peripheral), number of negatives, direction of removals (unidirectional, bidirectional, orthogonal, or centripetal), and fractures.

Lastly, fragments included all lithic pieces lacking the diagnostic attributes necessary for classification as either flakes or cores.

Once the morphotechnical criteria were recorded, dimensional and weight attributes were analysed as these are key attributes in the study of site formation processes (DeBoer, 1983). For the dimensional analysis (in mm), flake (retouched or not) measurements were taken based on the technical axis rather than the morphological axis (Fig. 14). In contrast, for cores and fragments, the longest morphological axis was measured first, followed by the second axis based on its orientation. Length and width were obtained this way, while thickness was measured at the intersection of both axes.

To classify artefacts according to size, the product of length and width (in mm²) was calculated, allowing comparison with the dimensional groups established by Vaquero (2008):

1. Very small: <500 mm²
2. Small: <1000 mm²
3. Medium: <1500 mm²
4. Large: <2000 mm²
5. Very large: >2000 mm²

Additionally, for unbroken flakes, two indices were calculated: the Elongation Index, obtained by dividing length by width, and the Thickness Index, calculated by dividing the smaller value between length and width by thickness.

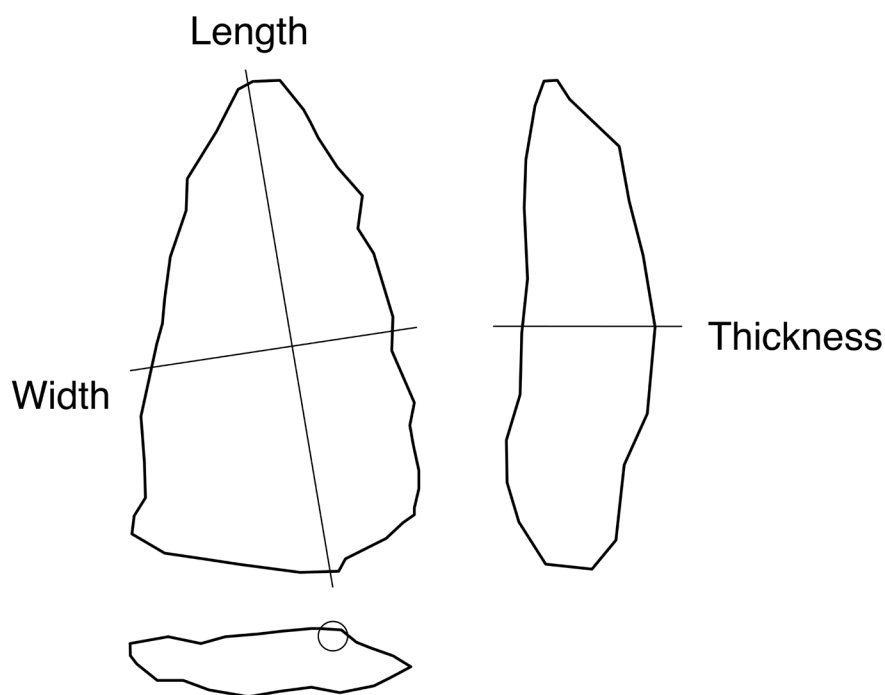


Fig. 14. Example of how measures have been obtained from flakes.

All artefacts were then weighed (in grams), as weight serves as a complementary indicator of the state of the mass introduced into the site (Shott, 1994; Mears et al., 2022). In the third study, weight data was classified using Jenks natural breaks method, generating five groups based on the sample distribution. This classification helped track variations in weight across archaeostratigraphic cross-sections and spatial distributions (Jenks, 1967; Benito-Calvo et al., 2015; Sánchez-Romero et al., 2021).

Finally, it is important to note that many of these attributes were recorded in the database to complete the learning process and to address possible questions that might arise during the research. However, not all were directly used in hypothesis generation and discussion, leaving data for further exploration in subsequent studies.

3.2.3. Refitting analysis

Lithic refits, or R-RMUs, represent raw material units that share physical connections, reinforcing the validity of S-RMUs through direct material linkage (Machado et al., 2019; Romagnoli & Vaquero, 2019; Vaquero et al., 2019). In this sense, refitting plays a crucial role in reconstructing site formation processes. The moment two pieces are joined, they establish a tangible relationship that introduces the dimension of time, allowing for the identification of contemporaneity between one or more technical actions, as well as other processes unrelated to the anthropogenic formation of the deposit. This opens numerous avenues for research:

“Refitting is an analytical bridge to a stage from which realistic behavioral studies may begin. Piecing things together is not an analytical end point, but it should put us in a position to develop and evaluate increasingly sophisticated models of past behavior and culture change” (Hofman, 1986: 170).

Beyond its significance for understanding lithic technology and the fragmentation of “chaînes opératoires” (e.g. Takakura, 2018; Baena et al., 2019; Martínez-Moreno et al., 2019; Zangrossi et al., 2019), refitting analysis is fundamental for establishing vertical relationships between material assemblages (e.g. Machado et al., 2013, 2019; Bargalló et al., 2016; Arteaga-Brieba et al., 2023), detecting postdepositional processes both vertically and horizontally (e.g. Villa, 1982; Hofman, 1986; Bertran et al., 2012, 2019; López-Ortega et al., 2019; Bel, 2022), and investigating knapping areas as well as the movement of lithic products between activity zones within the site (e.g. Newcomer & Sieveking, 1980; Vaquero et al., 2017, 2019; Bargalló et al., 2020).

In our methodological approach, lithic products were tested for refitting through two independent trials over a period of one week for the first study (carried out in the UV), three months in the second (conducted at the UV), and two months in the third case of study (carried out at both UV and the Interdisciplinary Center for Archaeology and the Evolution of Human Behaviour - ICArEHB), ensuring an exhaustive search for possible connections. We distinguished between two types of physical links:

Refits, which correspond to production sequences (“refitting of production sequences”; *sensv* Cziesla, 1990: 15).

Conjoins, resulting from syndepositional or postdepositional fractures, whether natural or anthropogenic (“refitting of breaks” and “inserts”; *sensv* Cziesla, 1990: 15).

For both refits and conjoins, connection lines were mapped, following either the chronological sequence of removal events (for refits) or the artefact surface contact (for conjoins). Each R-RMU was analysed by calculating the number of elements involved, the number of connections per line and their respective lengths (minimum, maximum, mean and standard deviation) using ArcGIS ArcMap version 10.5 for the first and second study cases, while ArcGIS Pro version 3.1.0 was used for the third case.

3.2.4. Archaeostratigraphic analysis

Once the lithic assemblage had been analysed and the techno-economic variables recorded, the next step was to examine the vertical formation of the assemblages. Archaeostratigraphy, which focuses on this aspect, has yielded valuable results for identifying and sequencing different formation stages of the archaeological record (e.g. Canals et al., 2003; Machado et al., 2013, 2019; Roy-Sunyer, 2015; Vaquero et al., 2015; Bargalló et al., 2016; Sánchez-Romero et al., 2017; Spagnolo et al., 2020a; Arteaga-Bribea et al., 2023), as well as detecting taphonomic alterations that may have affected the integrity of the deposit (e.g. Baker, 1978; Villa, 1982; Villa & Courtin, 1983; Stevenson, 1985, 1991; Mielgo et al., 2024; Rose et al., 2025).

The first step involved a three-dimensional examination of the general point-pattern, serving as an initial assessment of the deposit integrity (Fig. 15). This preliminary evaluation was conducted using ArcGIS ArcScene 10.5 in the first and second studies, and ArcGIS Pro 3.1.0 in the third.

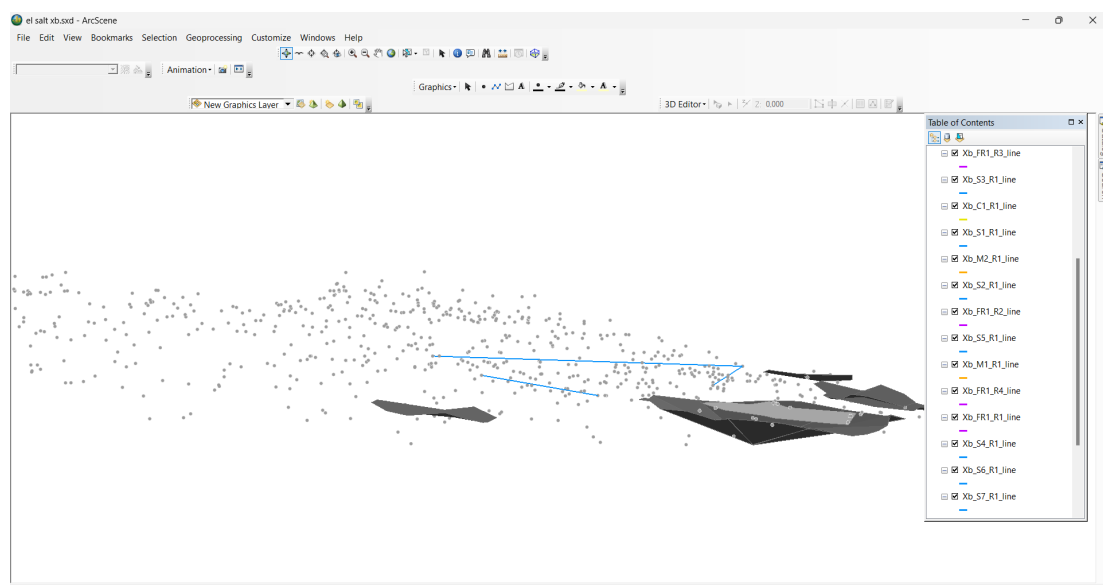


Fig 15. Example of 3D visualisation of the point-pattern, along with refits and hearths.

Subsequently, the most suitable width for cross-sections was determined through a trial-and-error process aimed at optimising the number of points represented while maintaining visual perspective. It is important to emphasise that this process was also carried out in 3D, as selecting an appropriate width in 2D could introduce significant bias depending on the site topography.

Once the optimal width had been established, cross-section sampling was performed across the entire site in each case, both transversal and longitudinal. Each cross-section was evaluated in 3D; however, the selection and association of points (where the identification of AUs was feasible) were conducted in 2D, using ArcGIS ArcMap 10.5 for the first and second cases, and ArcGIS Pro 3.1.0 for the third.

The identification of AUs is guided by four fundamental criteria (Fig. 16). First, the vertical separation between material beds (material gap/hiatus), which indicates periods of absence of anthropogenic deposition. Second, the lateral continuity of material beds, ensuring a robust representation of AUs and the hiatuses that separate them. It is worth noting that a material bed does not need to cover the entire site surface. In fact, under optimal formation conditions (at a human scale) this is unlikely. Cases where archaeological material extends across the entire surface are more likely to be the result of palimpsest effect. Third, lithic refits within the same material bed, which reinforce both the integrity of the studied record and the consistency of the AU as a unit of analysis. Finally, surface markers provide additional support for distinguishing between material beds. These include hearths, where the top (the ash layer) represents a surface, and the base (the underlying thermally altered substrate) indicates previous formation events (Mallol et al., 2013; Aldeias et al., 2016). Other markers include blocks, whose bases, except in cases where a violent fall has significantly altered the deposit, may also define archaeological surfaces.

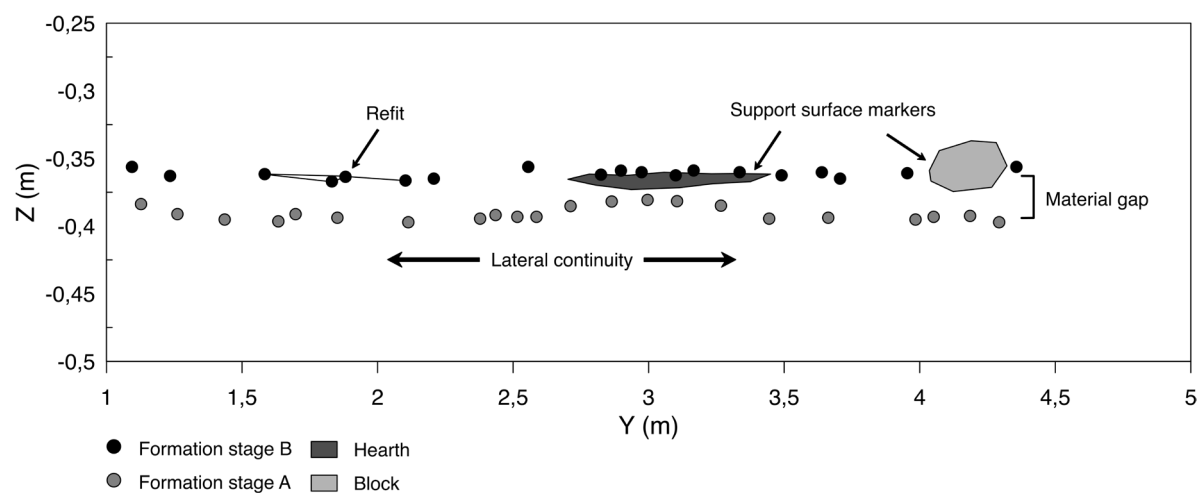


Fig 16. Example of an archaeostratigraphic cross-section illustrating the main criteria for distinguishing anthropogenic formation stages (i.e. AUs).

Furthermore, the third study incorporated taphonomic variables into the vertical dispersion of the lithic assemblage (e.g. Rose et al., 2025). Specifically, cases of edge damage and patina formation on edges were documented, as they could provide further insights into the diachronic formation of SU V at Abric del Pastor.

To determine the cross-sections that best illustrate the point pattern for each study, spatial analysis was employed. Although the horizontal distribution analyses are detailed in the following subsection, a brief explanation is provided here. A Kernel Density Estimation (KDE) was applied to the entire assemblage to identify areas with higher material density, which were then selected for the cross-section illustration (e.g. Sánchez-Romero et al., 2023).

In addition to KDE, the second and third studies implemented an Ordinary Kriging Interpolation Method to approximate the palaeotopography of each unit within each site (e.g. Sánchez-Romero et al., 2023; Arteaga-Briebea, 2024). This method utilised 3D excavation surface points recorded at 50 cm intervals, along with the coordinates of the archaeological materials themselves. The aim of this test was to improve the understanding of archaeostratigraphic sections and their lateral topographic variations.

3.2.5. Spatial analyses

Throughout this Thesis, various spatial tests have been employed to evaluate the anthropogenic formation processes in each unit of analysis. The diversity of applied tests (Table 4) reflects the specific research questions and requirements of each case study, the characteristics of the sample, and the progressive learning process that unfolded from the first study to the third. As the research advanced, new tests were gradually incorporated, a progression further enriched by my research stay at the Universitat Autònoma de Barcelona (UAB) in early 2023, where I worked with Laura Sánchez Romero and Rafael Mora Torcal.

	Abric del Pastor AU IVfH17	El Salt SU Xb	Abric del Pastor SU V
Qualitative point-pattern description	Yes	Yes	Yes
Average Nearest Neighbour	Yes	Yes	Yes
Ripley L-Function	No	No	Yes
Kernel Density Estimation	Yes	Yes	Yes
Kriging interpolation method	No	Yes	Yes
Density-Based Clustering	No	No	Yes
Optimised Hot Spot Analysis	No	No	Yes
Chi-square	No	Yes	Yes

Table 4. Different tests applied in each case.

For all the spatial analyses detailed below, two main software programs were used: ArcGIS ArcMap 10.5 for the first and second case studies and ArcGIS Pro 3.1.0 for the third. In every case, the initial step involved a qualitative assessment and description of the overall point-pattern distribution. This preliminary evaluation was conducted by integrating various lithic record variables (e.g. size, weight, type of product, type of flint, amount of cortex, refits) and analysing their spatial arrangement.

To characterise the spatial distribution of the lithic assemblages, we applied a series of spatial tests in a structured manner, moving from the most general to the most detailed analyses.

First, Average Nearest Neighbour (ANN) was applied in all cases to the lithic assemblages considering the excavated area. This test provides a general overview of the spatial pattern exhibited by the X-Y points, discerning whether the distribution is clustered, random, or dispersed (Whallon, 1974; Romagnoli & Vaquero, 2016; Sánchez-Romero et al., 2022). ANN serves as the foundation for further spatial analyses, offering an initial classification of the dataset.

Second, the homogeneous Ripley L -function was used in the third study to refine the understanding of clustering and dispersion at different spatial scales (Besag, 1977). While ANN provides a global characterisation, Ripley L allows the detection of deviations from randomness at varying distances (Ripley, 1977). The observed $L(d)$ values were compared against an envelope created by simulating random spatial distributions, offering a more detailed perspective on the intensity of clustering at different scales (Lee, 2023).

Third, Kernel Density Estimation (KDE) was conducted in every study with Euclidean distance and a search radius variable depending on the sample analysed. This method estimates the distribution of archaeological remains across the excavated space, creating a continuous raster that highlights areas of higher and lower concentration (Spagnolo et al., 2019, 2020a, 2020b; Sánchez-Romero et al., 2022; Zilio et al., 2021). It was applied to both lithic and faunal remains in the first and third cases, and only to lithic assemblages in the second study. In all cases, KDE allows us to visualise the intensity of material distribution and to assist in defining the placement of archaeostratigraphic cross-sections.

Following KDE, we applied the ordinary Kriging interpolation method in the second and third cases to generate a palaeosurface that enhances the understanding of the archaeostratigraphic cross-sections. This method estimates values at unsampled points by considering spatial autocorrelation (Oliver & Webster, 1990; Hageman & Bennett, 1999) using both the coordinates of the archaeological remains and the coordinates obtained to control the topography of the surface, recorded horizontally at 0.5 m intervals. By integrating Kriging with KDE, we can also contextualise the material concentrations in relation to topographic variability (Sánchez-Romero et al., 2020, 2023; Arteaga-Brieba, 2024).

To further explore spatial clustering, Density-Based Clustering (DBSCAN) was performed in the third case using the self-adjustment clustering method (HDBSCAN) and considering a minimum of 10 points for clustering. This method identifies both clusters and outliers (“noise”) by evaluating the spatial distribution of the dataset without predefining the number of clusters (Mikhailova et al., 2019; Murugesan et al., 2021; Díaz-Rodríguez & Fábregas-Valcarce, 2022). The probability threshold for clustering was set at ≥ 0.66 to ensure a balance between inclusivity and precision.

Building on the clustering results, Optimised Hot Spot Analysis (Getis-Ord G_i^*) was applied in the third case to detect statistically significant clusters of artefacts. This test was employed by calculating the number of artefacts per grid square, using a fishnet composed of 0.74 m² squares, following the Quadrat Method (Getis, 1964; Lee & Wong, 2001; Sánchez-Romero, 2019). This method was also applied to artefact weight to detect possible sorting by mass. The Optimised Getis-Ord G_i^* test provides high statistical confidence in identifying spatial clustering without requiring a predefined radius or number of clusters (Sánchez-Romero et al., 2022; Arteaga-Briebe, 2024).

Finally, we conducted Chi-square tests in the second and third cases to assess the interdependence between the archaeological remains and their spatial positioning. These tests determine whether the observed distribution of materials significantly deviates from a random expectation, offering an additional layer of validation to the previous analyses.

This structured approach, moving from general spatial characterisation (ANN) to scale-sensitive clustering (Ripley L), intensity mapping (KDE), palaeotopographic reconstruction (Kriging), and advanced clustering methods (DBSCAN and Getis-Ord G_i^*), ensures a comprehensive understanding of spatial relationships of lithic products within the assemblages.

3.2.6. Additional methods

In contemporary research, the questions posed by the archaeological record and addressed in scientific papers rarely find solid answers without drawing on other disciplines. Consequently, this Thesis has incorporated multiple approaches, each selected to address specific analytical challenges, through collaboration with colleagues specialising in different fields.

Thus, this research has been complemented by data from six disciplines, either directly or indirectly related to the scope of this study. In the first study, an in-depth technological reassessment of the lithic assemblage was conducted by Alejandro Mayor (Universitat d’Alacant - UA), Cristo Hernández (Universidad de La Laguna - ULL), and Manuel Vaquero (Institut de Paleoecologia Humana i Evolució Social - IPHES), with Alejandro Mayor also reviewing post-genetic data. Additionally, use-wear analysis was carried out by Mariel Bencomo (UV), while zooarchaeological and taphonomic analyses were performed by Leopoldo Pérez (UV).

In the third study, soil micromorphology was undertaken by Laura Tomé (ULL) and Carolina Mallol (ULL), alongside lipid biomarker analysis conducted by Javier Davara (ULL). Both analyses were carried out at the Archaeological Micromorphology and Biomarkers Lab at the ULL. For a detailed description of each additional method, refer to the methodology sections within the corresponding articles (sections 4.1 and 4.3).

section

IV

RESULTS

PUBLISHED OR ACCEPTED PAPERS

4.1. Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula)



OPEN

Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula)

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Testing Neanderthal behavioural hypotheses requires a spatial–temporal resolution to the level of a human single occupation episode. Yet, most of the behavioural data on Neanderthals has been obtained from coarsely dated, time-averaged contexts affected by the archaeological palimpsest effect and a diversity of postdepositional processes. This implies that time-resolved Neanderthal behaviour remains largely unknown. In this study, we performed archaeostratigraphic analysis on stratigraphic units IVE, IVf, IVg, va, vb and vc from Abric del Pastor (Alcoi, Iberian Peninsula). Further, we isolated the archaeological remains associated with the resulting archaeostratigraphic unit and applied raw material, technological, use-wear, archaeozoological and spatial analyses. Our results show a low-density accumulation of remains from flintknapping, flint tool-use and animal processing around a hearth. These data provide a time-resolved human dimension to previous high-resolution environmental and pyrotechnological data on the same hearth, representing the first comprehensive characterisation of a Neanderthal single occupation episode. Our integrated, multidisciplinary method also contributes to advance our understanding of archaeological record formation processes.

Recent research on Neanderthal settlement dynamics has revealed that their occupations were short-termed^{1–3} and the long-term campsite paradigm is no longer sustained⁴. The current focus is on isolating higher time-resolution units concealed in time-averaged archaeological deposits, but relatively little attention has been paid to the pursuit and characterisation of single occupation episodes as a means to approach Neanderthal behavioural variability^{5–7}. Isolating single Neanderthal occupation events and exploring behavioural cues hidden in their material components and in their interrelationships may bring to light aspects, such as group mobility, technology or demography, relevant to advance ongoing debates on the Neanderthals, usually based on low-resolution temporal data.

A key challenge in approaching the single occupation episode is to assess the role of the different natural and anthropogenic processes leading to the formation of the archaeological record, since we still do not know to what extent these formation processes condition our inferences on behaviour⁸. For hunter-gatherer societies, the issue has been investigated in ethnoarchaeological studies, which take place at human narrow timescales. These allow for observations on the transformations of the material remains generated by specific human actions during single occupation episodes^{8–11}. However, these minimal analytical units, which are the only to own this scale, are particularly difficult to be identified in Palaeolithic contexts because of the palimpsest effect, which implies an absence of examples¹². Although time-averaged assemblages may be useful to recognise long-term

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Figure 1. (a) Location of the Abric del Pastor site in the context of the Iberian Peninsula. The map was obtained with Google Earth Pro version 7.3 [Versiones de Earth—Google Earth]. (b) Location of the site in the context of the Mariola mountain range. (c) Site overview.

trends, human behavioural variability is difficult to be assessed from mixed diachronic events. In the field of lithic technology, one of the best-known consequences of time-averaging is the complete reduction sequence fallacy, as pointed out by Dibble et al.¹³. This misconception could be also reflected in other analytical domains, such as hunting-related behaviour (i.e. the entire carcass transport fallacy) or palaeoenvironmental reconstruction (i.e. the mosaic landscape fallacy)^{14,15}.

The Abric del Pastor site (Alcoi, Iberian Peninsula) (Fig. 1) is a small rockshelter with a Middle Palaeolithic archaeological deposit dated roughly between 63 ± 5 ky BP and 48 ± 5 ky BP and composed of granulometrically organised sandy, gravelly and clastic layers shaping a concave morphology^{16–18}. The material record is integrated by low-density, stratigraphically discrete assemblages, whose features are favourable towards effective palimpsest dissection^{16,17}. This is supported by the current excavation surface, which covers a major part of the rockshelter (40 of 60 m²).

Unit ivf is an example of this. It was investigated using a high-resolution interdisciplinary methodology that yielded palaeoenvironmental and pyrotechnological data, including the presence of a well preserved, simple, in situ, open hearth (i.e. H17), fueled with juniper wood¹⁸. The ash layer preserves molecular traces of herbivore fat¹⁹. These data show that this context is ideal for further investigations of behavioural aspects through a time-resolving approach.

Here, we present an interdisciplinary study that has allowed to recognise and characterise a low-density hearth-related accumulation representing a high-resolution human event within unit ivf. This study has combined archaeostratigraphic, raw-material, technological, use-wear, archaeozoological, and spatial analyses. Our integrated results, coupled with the previous data, become a chance of providing the features of a Neanderthal occupation episode.

Results

Archaeostratigraphy. The archaeostratigraphic analysis resulted in identification of three AUs: ivf, ivf and ivfH17 (Fig. 2). From these, we are going to focus on the latter, which is partially located in the western part of the site and consists of 11 lithic products, 78 faunal remains and a combustion structure (i.e. H17). It has been defined by the following observations. The distinction between ivfH17 and ivf is better observed in the east–west general section, while its difference regarding SU v is more noticeable in the north–south general section, due to the natural slope of the SUs forming a slightly concave shape (Fig. 2). It should be noted that, in the western part of the site, no more remains have been recovered in the 5 cm below. This absence results in an archaeological gap beneath AU ivfH17.

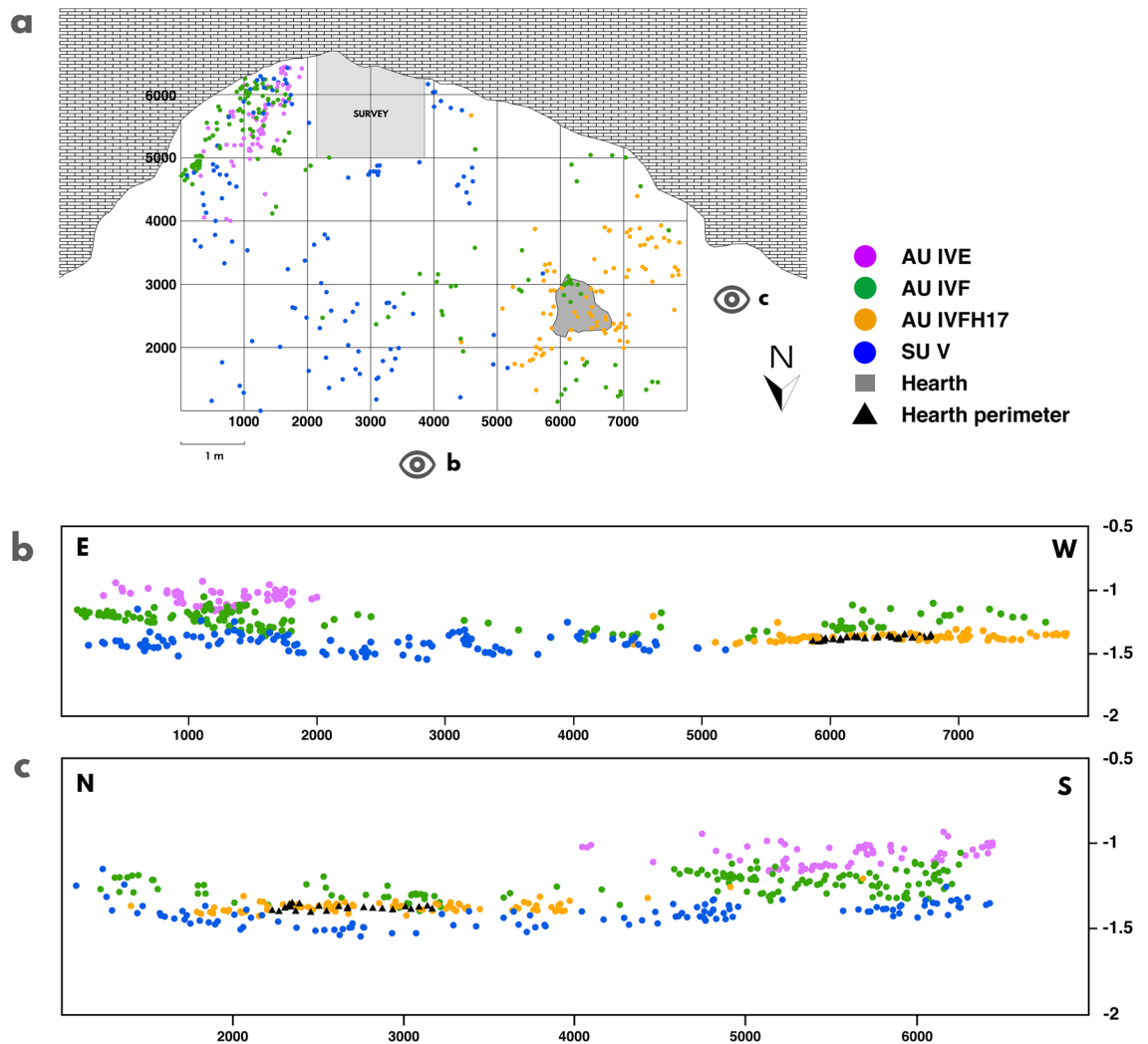


Figure 2. Representation of the archaeostratigraphic units (AU). (a) Horizontal plot. (b) Vertical plot (east–west). (c) Vertical plot (north–south).

In particular, the 40 cm-wide cross-sections were oriented to illustrate the separation of AU ivfH17 from ivf (Fig. 3a). The vertical distinction between AU ivfH17 and SU v is observed in the general north–south section (Fig. 2c). We plotted the assemblages from ivf and ivfH17, and distinguished, in the second case, the record components: the hearth surface, the partially refitted set raw material unit (RMU), the single-element RMUs, and the faunal bones, both heated and unburnt. On the one hand, the east–west cross-section shows the vertical connection between the set RMU and the faunal assemblage, as well as the vertical difference with regards to the upper assemblage (i.e. minimal vertical distance: 6 cm) (Fig. 3b). On the other hand, the north–south and the northeast–southwest cross-sections display the vertical contact among the faunal assemblage, particularly those burnt bones, and the hearth perimeter, as well as the vertical difference between ivfH17 and ivf assemblages (i.e. minimal vertical distance: 5 cm) (Fig. 3c, d).

Raw materials. The 11 lithic products are made on previously characterised flint types^{20,21}: nine on Mariola flint and two on Serreta flint (Table S2; Figs. 4, 5). The Mariola assemblage is composed of four single-element RMUs and one set RMU comprising five artefacts. It shows different signs of natural postgenetic alterations linked to polishing and abrasion occurring after its release from bedrock and prior to its gathering. One product displays slight colour change from anthropogenic thermal alteration (i.e. yellow to pink) and small scales. No postgenetic features were observed on the Serreta flint objects, which were grouped into two single-element RMUs.

Technology. The lithic assemblage is composed of 11 flakes (Table S3; Figs. 4, 5), five of which belong to the set RMU, and six are single-element RMUs. These latter are: one Mariola non-cortical centripetal flake (Fig. 4a), one Mariola cortical retouched flake (Fig. 4b), one Serreta *débordante*-like centripetal flake (Fig. 4c), and three small flakes, two on Mariola and one on Serreta flint (Fig. 4d–f). These six artefacts correspond to six different knapping sequences displaying distinct phases (Table S3).

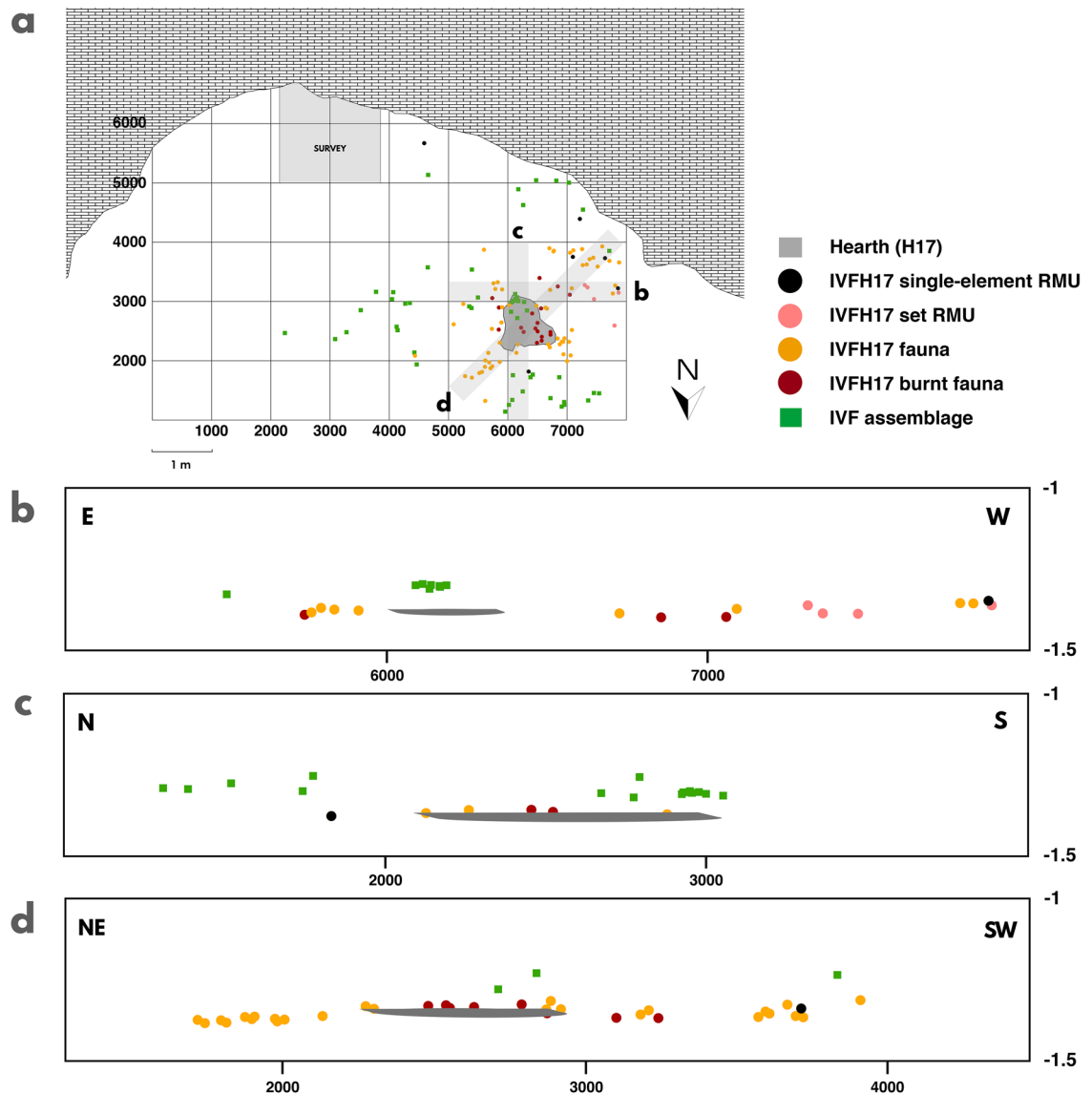


Figure 3. Archaeostratigraphic representation of the AU ivfH17 assemblage in comparison to the AU ivf assemblage. (a) Horizontal plot. (b) Cross-section (east–west). (c) Cross-section (north–south). (d) Cross-section (northeast–southwest).

The Mariola set RMU, here onwards ivf.M1, is composed of a surpassed flake showing centripetal core features (Fig. 5a), a flake with a cortical back (Fig. 5b), and three small flakes (Fig. 5c–e). The cortical flake, which is also the largest one, displays a series of small, flat, unipolar removals in the proximal area that led to bulb and butt removal, as well as dorsal face modification. One of these removals has been refitted with one of the three small flakes mentioned above (ivf.M1-R1; Fig. 5b,e). In the opposite side of the large flake, there is a rebounded fracture affecting the ventral face and departing from the distal area. This fracture, together with the above mentioned characteristics, are common features among splintered pieces (i.e. *pièces esquillées*)²², so its complete characterisation will be given in the next section being that these features have not been considered technical, but use-related (vid. use-wear for further information).

RMU ivf.M1 represents an operational chain on a Mariola flint nodule. The elements within it are representative of different stages of a Levallois recurrent centripetal knapping sequence (Table S3). This statement is supported by the features of the surpassed flake (Fig. 5a), which preserves the hierarchical edge between both striking and flaking platforms. It also shows several dorsal negatives characterised by a centripetal direction and a peripheral polarity. Furthermore, the technical features of the small flakes are along the same lines (Fig. 5c,d; Table S3), excepting the refitted one.

Use-wear. Six elements (54.5%) were analysed for use-wear traces, which were identified in four of them related to the work of semihard/hard materials, and animal materials (Table S4).

Concerning the single-element RMUs, we report two artefacts displaying use-wear. One is the Mariola centripetal flake, which has traces of working on a hard or semihard material. In this case, thermal alteration only

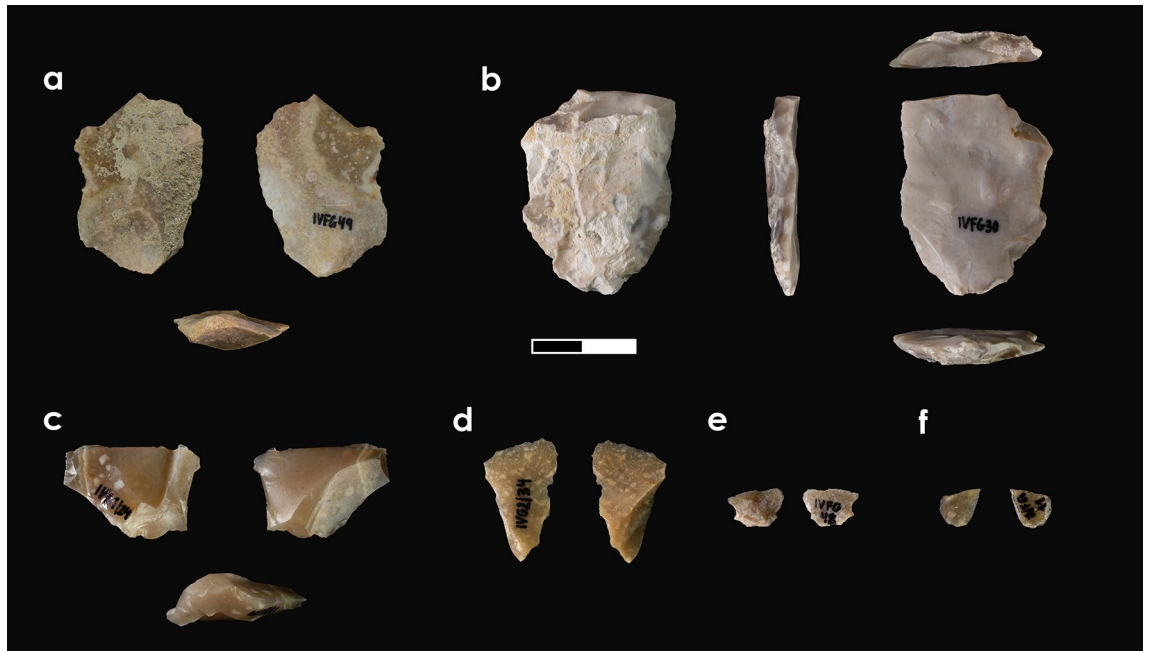


Figure 4. Single-element RMUs.

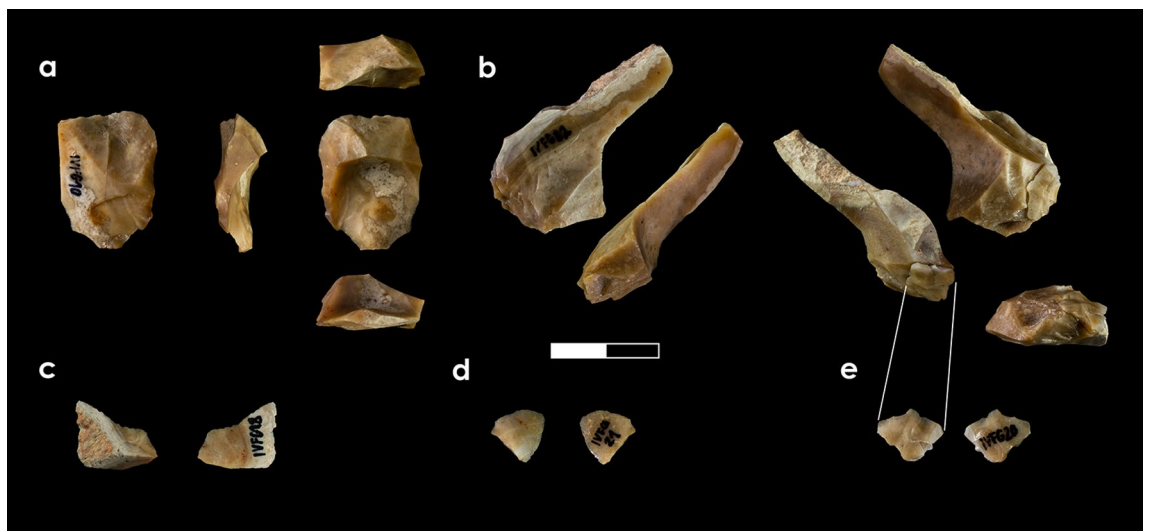


Figure 5. Set RMU. The refitting connection is indicated by parallel lines.

allowed us to characterise the scars, which are large, semicircular, both aligned and superposed, and exhibit a feather termination (Fig. 6a). Its distribution on one side of the edge and its perpendicular orientation indicate a transversal motion related to a scraping action. The second one is the Mariola retouched flake, which shows traces of cutting of animal tissue (Fig. 6b). The flake edge is rounded, with long striations, and at the apex, there is a dull, rough-textured, domed polished exhibiting medium-large scars. These are, both aligned and superposed, with feather and step terminations associated with well-developed polished spots in the highest parts of the topography which indicates a contact with hard material (e.g. cartilage, bone). The distribution of the polish, scars and striations on both sides of the edge suggest a longitudinal motion, related to a cutting action.

RMU ivf.M1 contains two elements with use-wear traces. One is linked to bone cutting and exhibits a very bright polish, parallelly aligned to the edge, with a smooth texture and a flat topography (Fig. 6c). The scars are large, quadrangular and with step terminations, along with medium-sized, semicircular and feather terminations. The presence of short and deep striations with a parallel orientation on the edge, as well as the distribution of polishing on both sides of the edge, indicate a longitudinal movement of the tool related to a cutting action. The second one displays large, superposed, quadrangular and irregular scars, with a step termination and with a perpendicular orientation to the edge (Fig. 6d). These features, together with previously described technological features, suggest that the flake represents a splintered tool associated with percussion activity on hard material.

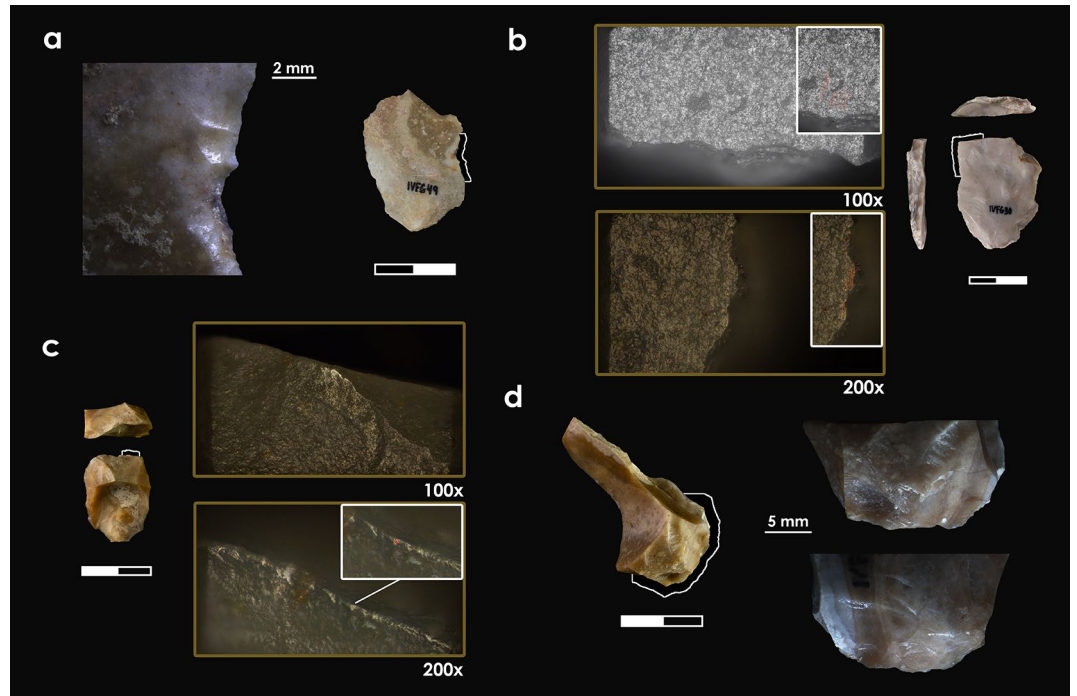


Figure 6. Tools displaying use-wear traces and detailed photos.

Taxa	Element	NR	Cut marks	Thermal alterations	Weathering	Erosion	Concreteness	Corrosion	Manganese	Sediment pressure	Roots marks
Caprinae	Metapodial	2									1
<i>Capra pyrenaica</i>	Tibia	1					1		1		1
<i>Cervus elaphus</i>	Metapodial	1					1			1	
	First phalanx	1					1				
Medium size	Vertebra	1			1					1	
	Thoracic vertebra	1			1					1	
	Ribs	3		1			2	1	2		2
	Ulna	1					1				
	Splinter	21	1	3	2		14	3	8		2
	Diaphysis	25	4	5	2		22	2	20		8
Small size	Ribs	1					1		1		
	Diaphysis	1		1		2	1				
Indeterminate	Splinter	16		3			21		9		
	Cancellous bone	3		5			3				

Table 1. Archaeozoological data from the ivfH17 assemblage.

Archaeozoology. The faunal assemblage is composed of 78 bone fragments, among which we have been able to recognise two species (*Cervus elaphus*, n2; *Capra pyrenaica*, n1) and one subfamily (*Caprinae*, n2). These remains represent at least three individuals (Table 1). However, this minimum number of individuals can be reduced to two, if we base ourselves on the fact that anatomical parts identified as belonging to the *Caprinae* subfamily are not repeated amongst the elements determined as *Capra pyrenaica*. The taxonomically undetermined bones were classified by weight categories. The medium-size group predominates (n56: 70.88%), followed by indeterminate (n15: 18.98%) and small-size remains (n2: 2.53%). Since medium and small sizes in SU IV are represented only by red deer and wild goat, respectively²³, we assume that they correlate with these taxa.

There is a predominance of postcranial remains, of which almost all are appendicular. The taxonomically classified remains are a red deer (*Cervus elaphus*) metapodial and a first phalanx, a wild goat (*Capra pyrenaica*) tibia and two *Caprinae* metapodials. In the medium-size group, skeletal representation is dominated by diaphysis

fragments, splinters and ribs (Table 1). The small-size group is integrated by a diaphysis and rib fragment. Lastly, we report several splinters and cancellous bone fragments in the indeterminate group.

The entire assemblage shows a high degree of fragmentation (97.46%), of which 68.35% was old fresh-fractured, mostly into the medium-size group. Additional anthropogenic modifications include thermal alteration (24.05%) and cut-marks (6.33%). Burnt bones exhibit different degrees of heating, mostly charring (i.e. black surfaces), followed by mild heating (i.e. from brown to black) and near calcination (i.e. from black to grey). Cut-marks were identified on four diaphysis fragments and a splinter belonging to a medium-sized individual. No predator damage alterations, such as carnivores or raptors were observed. The degree of postdepositional alteration is high, and numerous bone surfaces display secondary carbonate and manganese oxide precipitation, corrosion, weathering, sedimentary pressure or root-marks.

Spatial analysis results. Spatially, the AU ivfH17 assemblage is distributed over ca. 20 m² and constrained to the western part of the rockshelter (Fig. 7). The kernel density map displays two high-density spots adjacent to the hearth in the northern area, and another medium to high density spot in the southwest, which is 1.14 m from the hearth perimeter (Fig. 7a). The Serreta single-element RMUs are completely excluded from the spots. The average nearest neighbour (ANN) analysis applied to this group confirms its dispersion (ratio: 1.8941). For the rest of the assemblage, the ANN shows clustering ratios (Table S5).

Specifically, the lithic assemblage (Fig. 7b) is clustered in the western area with no remains inside the hearth. The Mariola set RMU is in the west of the fire, with a 0.56 m distance between the two refitted elements. The four Mariola single-element RMUs are found in the southwest area. In this group, the heated flake is 1.96 m away from the hearth centre and 1.59 m from the hearth perimeter (Fig. 7d). The two Serreta single-element RMUs are separated from the rest of the lithic assemblage. One of them is in the northern area and the other one is in the southeast.

Regarding the used tools (Fig. 7b), the retouched flake associated with butchering activity is 0.98 m to the southwest of the hearth perimeter. It is surrounded by bone fragments without cut-marks, including those belonging to *Cervus elaphus* and to medium-sized animals. The thermoaltered centripetal flake used to work on a hard or semihard material has a similar position (1.59 m to the southwest of the hearth perimeter). Nevertheless, there is a material gap of 0.5 m-radius around this piece. In the case of the set RMU, the flake used to work on a hard material is 1.26 m to the southwest of the hearth perimeter, while the splintered tool is 1.09 m west of it. Considering a 0.5 m radius for each case, the former artefact is more strongly related to the deer and medium-sized animal remains in the southwest. Regarding the distance from the nearest bone with cut-marks to the two used tools, the splintered piece is 0.89 m away from it, whereas the other one is 1.27 m.

The faunal assemblage is located around the hearth, with a minor distribution in the eastern area (Fig. 7c). The assemblage located inside the hearth (n16) is composed of medium-sized taxa (n9: 56.25%), indeterminate remains (n6: 37.50%) and small-sized taxa (n1: 6.25%). The assemblage located outside the fire (n62) shows predominance of medium-sized taxa (n43: 69.35%), followed by indeterminate (n13: 20.97%), *Cervus elaphus* (n2: 3.23%), *Caprinae* (n2: 3.23%), *Capra pyrenaica* (n1: 1.61%), and small-sized taxa (n1: 1.59%). The burnt remains are mostly situated inside the hearth (n11: 61.11%), but some are also found also outside of it (n7: 38.89%) (Fig. 7d). Finally, the bone fragments with cut-marks are distributed in the north of the assemblage, near to the hearth perimeter. Two of them are further than 0.5 m from the hearth perimeter, whereas the other three are closer than 0.5 m.

Discussion

The integrated, interdisciplinary data presented in this paper offer the possibility of isolating and characterising human high-resolution events.

Archaeostratigraphic dissection reveals a vertically discrete assemblage of archaeological remains (lithic, faunal and combustion remains) framed between AU ivf at the top and SU v at the base. This deposit has been labelled AU ivfH17. This unit is composed of a hearth (H17) in the west, and different anthropogenic materials around it: 11 flint remains, both on Mariola and Serreta types, four of them showing use-wear traces, and 78 bone remains of red deer and wild goat.

The postgenetic alterations observed on the Mariola flint objects indicate fluvial source procurement, more specifically the upper course of the Serpis river (~3–5 km southeast)^{20,21}. Even though Serreta flint could be gathered in the same contexts, we did not observe postgenetic alterations to support this possibility. The observed technological features reveal fragmentation of the operational chain even in high resolution contexts^{24,25}. We identified the presence of elements that were introduced, used and abandoned, and others that were introduced, modified and taken out. These features allow considering cores and unretouched flakes as mobile toolkits.

In this sense, the bone assemblage shows a highly fragmentary input of appendicular and axial parts of red deer (n2) and wild goat (n5). Most of the cut-marks and burnt elements are related to the single red deer individual, possibly indicating direct consumption on site. The presence of herbivore fat lipid residues in the hearth sediment supports this hypothesis¹⁹. Use-wear analysis on lithics suggests low-intensity activities related to animal exploitation (i.e. butchery activity and bone processing). The use-wear traces observed on the splintered piece could be associated either to bone or to wood processing²⁶. However, the exclusive use of the other tools on animal tissue and the high fragmentation degree of the faunal assemblage points to a bone processing activity, perhaps related to marrow extraction²⁷.

Spatially, the ANN concentrated ratios observed in the entire assemblage and in almost all the material groups indicate a low postdepositional impact, as well as a short connection distance of the refitted set²⁸. The distribution of remains clustered around the fire suggest the existence of a hearth-related assemblage^{29–33}. The activities performed around H17 hearth (butchering, bone processing) are represented, on the one hand, by the

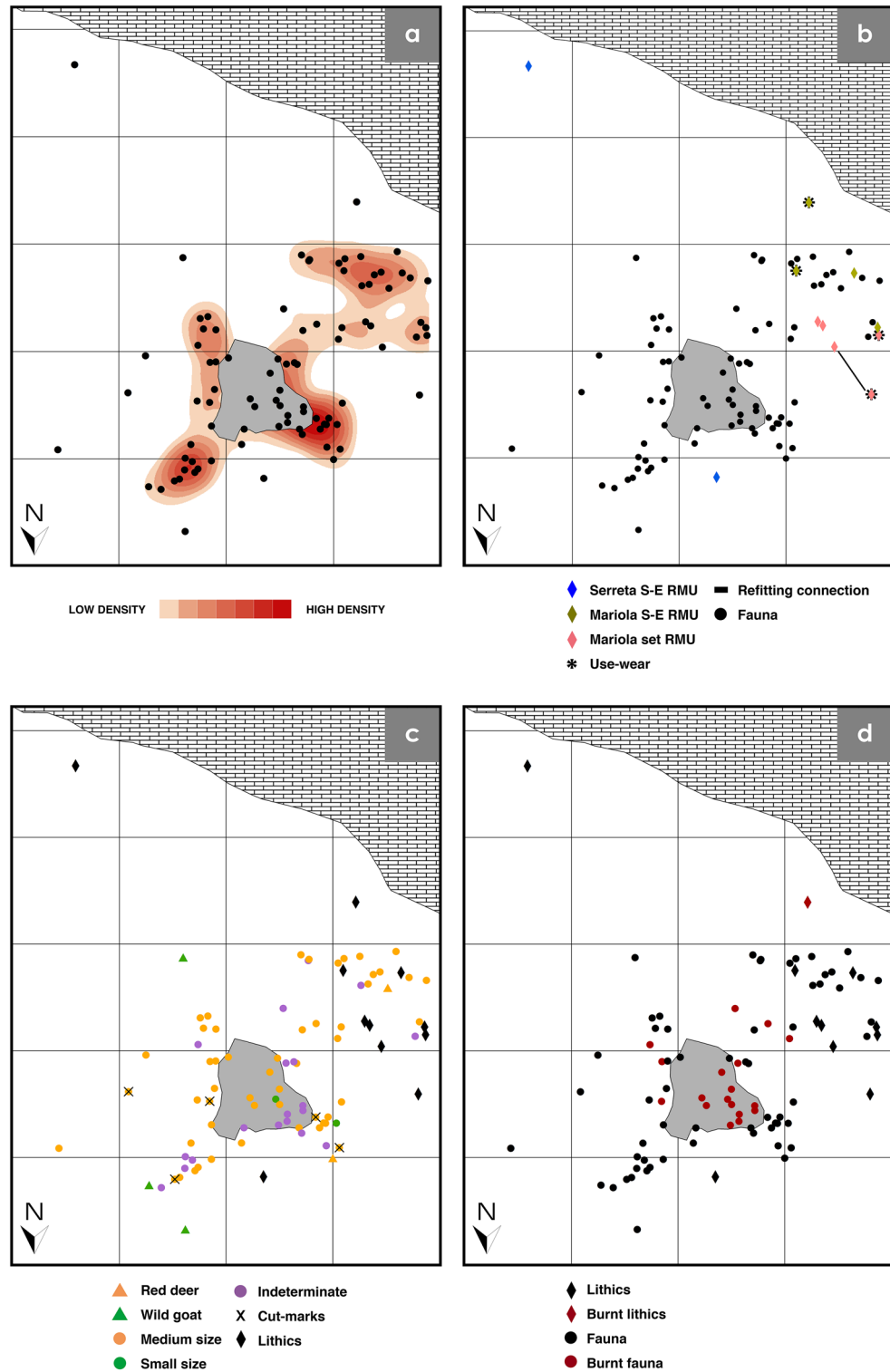


Figure 7. Horizontal plots of the AU rvfH17 assemblage used for spatial analysis. All the plots were generated with ArcGIS Desktop ArcMap version 10.5.1 [Esri Support ArcMap 10.5 (10.5.1)] (a) Kernel density map. (b) Lithic elements by RMU, flint type, use-wear traces and refitting connection. Single-element RMUs are abbreviated as S-E. (c) Faunal assemblage by taxa, size and cut-marks. (d) Burnt elements.

bulk of the deer remains and the used tools in the southwest area, and on the other hand, by the cut-marked deer remains in the northern area.

Even isolating this short assemblage in the vertical deposit, we cannot assume synchrony in the horizontal plane. In this sense, there are some indications of possible diachrony amongst the H17 hearth-related assemblage inferred from taphonomic, anthropogenic and spatial features of: (1) the wild goat bones; (2) the burnt Mariola flint flake, and (3) the two isolated Serreta flint flakes.

First, the absence of anthropogenic modifications on the wild goat bones, might indicate a different moment and/or agent of deposition. Second, the burnt Mariola flint flake presents two distinguishing features from the rest of the assemblage. One is that thermal alteration affects the use-wear traces, indicating that it was used, subsequently heated and then discarded at the southern area of the rockshelter. The other feature is the postdepositional calcium carbonate cement on its surface, not observed on any other lithic object. Finally, the dispersed character of the wild goat assemblage, the burnt Mariola flake and the only two Serreta flints differs from the rest of the assemblage. Cross-checking this information with the clustered groups and their characteristics enables us to propose that diachrony exists between both assemblages: the main accumulation would be linked to a single moment, whereas these scattered materials might be the result of another or more depositional events.

Thus, excluding the two Serreta single-element RMUs, together with the wild goat remains and the burnt Mariola flake, we interpret the resulting assemblage as a potential single occupation episode. This event involved an input, use, transformation and abandonment/output of four Mariola RMUs and the processing-consumption of appendicular and axial parts of a red deer around the fire. The presence of animal fat in the hearth sediment is indirect evidence of deer meat consumption and/or tossing of meat in the fire.

The integrated, interdisciplinary method applied in this study allowed achieving the optimal spatiotemporal resolution that permits us to read Neanderthal behaviours. Regarding group mobility, the input record displays a movement from the southeast (~3–5 km), where the Mariola flint was gathered and deer hunting was more feasible due to ecological conditions^{18,20,21}. Absence of Beniaia flint, which is a more distant flint type (~25–30 km) present in other AUs within Abric del Pastor¹⁷, strengthens the nearby character of the movements in this case. In this study, we also show that the difficulty in considering cores and unretouched flakes as mobile toolkits is a consequence of low resolution approaches. In the lithic assemblages affected by palimpsest, features interpreted as mobility indicators have been only recognised in some retouched single tools or in allochthonous raw materials^{9,34–37}. Therefore, identifying mobile toolkits needs high-resolution contexts in order to observe the potential heterogeneity of technofunctional and raw material features.

We have brought to light partial evidence of use of a single flint toolkit (i.e. presence of a retouched tool and ten unretouched flakes), as well as indirect evidence of exported cores (i.e. absence of flint cores and on-site knapping). In parallel, there is evidence of transport to the rockshelter and on site butchery and consumption of selected anatomical parts of medium-sized prey. Such transportation patterns have been documented ethnoarchaeologically (e.g. Hazda populations)^{38,39}, but not verified in Pleistocene archaeological contexts due to their low degree of spatiotemporal resolution^{40,41}. Likewise, our time-resolved use-wear data indicates relationships between lithic and bone records linked to an animal-processing activity. This connection is scarcely observable in time-averaged contexts⁵.

By narrowing down the time scale of the archaeological framework, we have identified a possible single Neanderthal occupation episode representing a brief stay in a rockshelter. Our results raise the possibility that the small size of the archaeological assemblage, made up of few lithic and bone remains and a single simple hearth, its fragmented character and its spatial distribution might be representative of a Neanderthal single occupation episode. Are record formation processes in larger assemblages produced by a sum of single occupation events such as the one represented by AU ivfH17? This possibility could be investigated in Neanderthal contexts comprising time-averaged dense palimpsests, such as caves and rockshelters, but also in open-air sites where the anthropogenic deposits are vertically separated but the horizontal diachrony must be tested⁴². Approaches aimed at palimpsest dissection allow us to identify the elementary units of which the archaeological assemblages are composed and, therefore, to assess a behavioural variability that can be hidden in the assemblage-as-a-whole inferences.

Materials and methods

In this work, we have taken into account the three-dimensional georeferences of 67 lithic elements, 356 faunal remains and 1 combustion structure belonging to SUs ive, ivf, ivg, va, vb and vc for archaeostratigraphic analysis (Table S1). After the vertical dissection had been carried out, we have focused on one from those higher-resolution analytical frameworks that have been obtained: AU ivfH17. This new unit comprises 11 flint remains and 78 faunal bones and a simple hearth. The lithic and faunal assemblage have been analysed through raw material, technological, use-wear, archaeozoological and taphonomic methodologies. Ultimately, we integrated the record information from this new analytical framework for consolidating the archaeostratigraphic dissection and achieving spatial distribution patterns (see Supplementary Information for methodological details).

Site overview. The Abric del Pastor site is located in Alcoi (Alacant, eastern Iberian Peninsula). It is a rockshelter situated at 820 m above sea level, on an escarpment at the eastern foothills of Mariola mountain range. It is specifically found on the right bank of El Cint ravine, which connects to the upper and middle courses of the Benissaidó river. Geomorphologically, the rockshelter is a partially eroded karstic tube formed during the Miocene on alternating beds of Cretaceous dolomitic limestone and Serravallian Miocene limestone cobble conglomerates⁴³. Erosion of the karstic tube resulting in the rockshelter occurred during the Pleistocene and is connected with incision and phreatic activity of the Benissaidó river¹⁶.

The site has a potential occupation surface area of 60m², of which 40m² are included in the excavation surface. The stratigraphic sequence is 1.5 m-thick and has been subdivided into six units: I-VI from top to base. (Fig. S2) (see Supplementary Information for site details). SU IVf (Fig. S1) is a gravitational gravelly-sandy deposit derived from roof spall. It was excavated during the 2016 and 2017 archaeological field seasons. Previous studies of SU IVf have provided chronometric OSL data indicating that this unit dates roughly to 63 ± 5ky BP¹⁸. Anthracological, archaeozoological (i.e. microfaunal and macrofaunal), biomolecular and micromorphological data available from SU IVd (overlying IVf) indicate supramediterranean semiarid-cool environmental conditions²³.

Data availability

All data produced and used in this paper are available under reasonable request to the corresponding author.

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References

- Moncel, M. H. *et al.* Late Neanderthal short-term and specialized occupations at the Abri du Maras (South-East France, level 4.1, MIS 3). *Archaeol. Anthropol. Sci.* **13**, 45. <https://doi.org/10.1007/s12520-021-01285-5> (2021).
- Picin, A. & Cascalheira, J. Introduction to short-term occupations in Palaeolithic archaeology. In *Short-Term Occupations in Paleolithic Archaeology* (eds Cascalheira, J. & Picin, A.) 1–15 (Springer, 2020).
- Spagnolo, V. *et al.* Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto Rockshelter (Ginosa, Southern Italy). *Archaeol. Anthropol. Sci.* **12**, 54. <https://doi.org/10.1007/s12520-019-00971-9> (2020).
- Machado, J., Mallol, C. & Hernández, C. M. Insights into Eurasian Middle Palaeolithic settlement dynamics: The palimpsest problem. In *Settlement dynamics of the Middle Paleolithic and Middle Stone Age IV* (eds Conard, N. J. & Delagnes, A.) 361–382 (Kerns Verlag, 2015).
- Mayor, A., Hernández, C. M., Machado, J., Mallol, C. & Galván, B. On identifying Palaeolithic single occupation episodes: Archaeostratigraphic and technological approaches to the Neanderthal lithic record of stratigraphic unit xa of El Salt (Alcoi, eastern Iberia). *Archaeol. Anthropol. Sci.* **12**, 84. <https://doi.org/10.1007/s12520-020-01022-4> (2020).
- Spagnolo, V. *et al.* Neanderthal camps and hyena dens: Living floor 150A at Grotta dei Santi (Monte Argentario, Tuscany, Italy). *J. Archaeol. Sci. Rep.* **30**, 102249. <https://doi.org/10.1016/j.jasrep.2020.102249> (2020).
- Bargalló, A., Gabucio, M. J., Gómez, B., Chacón, M. G. & Vaquero, M. Rebuilding the daily scenario of Neanderthal settlement. *J. Archaeol. Sci. Rep.* **29**, 102139. <https://doi.org/10.1016/j.jasrep.2019.102139> (2020).
- Schiffer, M. B. Toward the identification of formation processes. *Am. Antiq.* **48**, 4. <https://doi.org/10.2307/279771> (1983).
- Binford, L. R. Forty-seven trips: A case study in the character of archaeological formation processes. In *Stone Tools as Cultural Markers: Change, Evolution and Complexity* (ed. Wright, R. V.) 24–36 (Australian Institute of Aboriginal Studies, 1977).
- Binford, L. R. Behavioral archaeology and the “Pompeii premise”. *J. Anthropol. Res.* **37**, 195–208. <https://doi.org/10.1086/jar.37.3.3629723> (1981).
- Brooks, A. S. & Yellen, J. E. The preservation of activity areas in the archaeological record: Ethnoarchaeological and archaeological work in northwest Ngamiland, Botswana. In *Method and Theory for Activity Area Research: An Ethnoarchaeological Approach* (ed. Kent, S.) 63–106 (Columbia University Press, London, 1987).
- Vaquero, M. Introduction: Neanderthal behavior and temporal resolution of archaeological assemblages. In *High Resolution Archaeology and Neanderthal Behavior: Time and Space in Level J of Abric Romaní (Capellades, Spain)* (ed. Carbonell, E.) 1–16 (Springer, 2012).
- Dibble, H. *et al.* Major fallacies surrounding stone artifacts and assemblages. *J. Archaeol. Method Theory* **24**, 813–851. <https://doi.org/10.1007/s10816-016-9297-8> (2017).
- Morin, E. & Ready, E. Foraging goals and transport decisions in Western Europe during the Paleolithic and Early Holocene. In *Zooarchaeology and Modern Human Origins. Vertebrate and Paleoanthropology* (eds Clark, J. & Speth, J.) (Springer, 2013).
- Lyman, R. L. Paleoenvironmental reconstruction from faunal remains: Ecological basics and analytical assumptions. *J. Archaeol. Res.* **25**, 315–371. <https://doi.org/10.1007/s10814-017-9102-6> (2017).
- Machado, J., Hernández, C. M., Mallol, C. & Galván, B. Lithic production, site formation and Middle Palaeolithic palimpsest analysis: In search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). *J. Archaeol. Sci.* **40**, 2254–2273. <https://doi.org/10.1016/j.jas.2013.01.002> (2013).
- Machado, J., Mayor, A., Hernández, C. M. & Galván, B. Lithic refitting and the analysis of Middle Palaeolithic settlement dynamics: A high-temporal resolution example from El Pastor rock shelter (Eastern Iberia). *Archaeol. Anthropol. Sci.* **11**, 4539–4554. <https://doi.org/10.1007/s12520-019-00859-8> (2019).
- Mallol, C. *et al.* Fire and brief human occupations in Iberia during MIS 4: Evidence from Abric del Pastor (Alcoy, Spain). *Sci. Rep.* **9**, 18281. <https://doi.org/10.1038/s41598-019-54305-9> (2019).
- Jambrina, M. *et al.* *n*-Alkyl nitriles and compound-specific carbon isotopes analysis of lipid combustion residues from Neanderthal and experimental hearths: Identifying sources of organic compounds and combustion temperatures. *Quat. Sci. Rev.* **222**, 105899. <https://doi.org/10.1016/j.quascirev.2019.105899> (2019).
- Molina, F. J., Tarrío, A., Galván, B. & El Hernández, C. M. Sílex del Prebético de Alicante: Tipos, variabilidad y áreas de captación y talla del Pleistoceno. *Cuad. Prehist. Arqueol. Univ. Granada* **26**, 283–311 (2016).
- Mayor, A. *et al.* An instance of Neanderthal mobility dynamics: A lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt rockshelter (Alcoi, eastern Iberia). *J. Archaeol. Sci. Rep.* **44**, 103544. <https://doi.org/10.1016/j.jasrep.2022.103544> (2022).
- Le Brun-Ricalens, F. Les pièces esquillées: État des connaissances après un siècle de reconnaissance. *Paleo* **18**, 95–114. <https://doi.org/10.4000/paleo.181> (2006).
- Connolly, R. *et al.* A multiproxy record of palaeoenvironmental conditions at the Middle Palaeolithic site of Abric del Pastor (Eastern Iberia). *Quat. Sci. Rev.* **225**, 106023. <https://doi.org/10.1016/j.quascirev.2019.106023> (2019).
- Turq, A., Roebroeks, J. W., Bourguignon, L. & Faivre, J. P. The fragmented character of Middle Palaeolithic stone tool technology. *J. Hum. Evol.* **65**, 641–655. <https://doi.org/10.1016/j.jhev.2013.07.014> (2013).
- Moncel, M. H. *et al.* Fragmented reduction processes: Middle Palaeolithic technical behaviour in the Abri du Maras shelter, southeastern France. *Quat. Int.* **350**, 180–204. <https://doi.org/10.1016/j.quaint.2014.05.013> (2014).
- Vadillo-Conesa, M., Ricci, G., Bencomo, M., Aura, J. E. & Martini, F. A review of splintered pieces from two lithic assemblages in Mediterranean Europe: Grotta della Serratura (Marina di Camerota, Italy) and Cueva de Nerja (Málaga, Spain). *Lithic Technol.* **46**, 270–285. <https://doi.org/10.1080/01977261.2021.1924477> (2021).
- de la Peña, P. Sobre la identificación macroscópica de las piezas astilladas: Propuesta experimental. *Trab. Prehist.* **68**, 79–98. <https://doi.org/10.3989/tp.2011.11060> (2011).

28. Bargalló, A., Gabucio, M. J. & Rivals, F. Puzzling out a palimpsest: Testing an interdisciplinary study in level O of Abric Romani. *Quat. Int.* **417**, 51–65. <https://doi.org/10.1016/j.quaint.2015.09.066> (2016).
29. Vaquero, M. & Pastó, I. The definition of spatial units in Middle Palaeolithic sites: The hearth-related assemblages. *J. Archaeol. Sci.* **28**, 1209–1220. <https://doi.org/10.1006/jasc.2001.0656> (2001).
30. Vaquero, M. The organisation of living spaces in Neanderthal campsites. In *Updating Neanderthals* (eds Romagnoli, F. et al.) 207–225 (Academic Press, 2022).
31. Stevenson, M. G. Beyond the formation of hearth-associated artifact assemblages. In *The Interpretation of Archaeological Spatial Patterning* (eds Kroll, E. M. & Price, T. D.) 269–299 (Springer, 1991).
32. Spagnolo, V. et al. Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscuruscuito (Ginosa – Taranto, Southern Italy). *Quat. Sci. Rev.* **217**, 169–193. <https://doi.org/10.1016/j.quascirev.2018.06.024> (2019).
33. Binford, L. R. Dimensional analysis of behavior and site structure: Learning from an Eskimo hunting stand. *Am. Antiq.* **43**, 330–361. <https://doi.org/10.2307/279390> (1978).
34. Kuhn, S. L. A formal approach to the design and assembly of mobile toolkits. *Am. Antiq.* **59**, 426–442. <https://doi.org/10.2307/282456> (1994).
35. Morrow, T. A. Bigger is better: Comments on Kuhn's formal approach to mobile toolkits. *Am. Antiq.* **61**, 581–590. <https://doi.org/10.2307/281842> (1996).
36. Bourguignon, L., Delagnes, A. & Meignen, L. Systèmes de production lithique, gestion des outillages et territoires au Paléolithique moyen: Où se trouve la complexité? In *Normes techniques et pratiques sociales: De la simplicité des outillages pré- et protohistoriques* (eds Astruc, L. et al.) 75–86 (Éditions APDCA, 2006).
37. Picin, A. et al. Neanderthal mobile toolkit in short-term occupations at Teixoneres Cave (Moià, Spain). *J. Archaeol. Sci. Rep.* **29**, 102165. <https://doi.org/10.1016/j.jasrep.2019.102165> (2020).
38. Monahan, C. M. The Hadza carcass transport debate revisited and its archaeological implications. *J. Archaeol. Sci.* **25**, 405–424. <https://doi.org/10.1006/jasc.1997.0241> (1998).
39. Schoville, B. J. & Otárola, E. A model of hunter-gatherer skeletal element transport: The effect of prey body size, carriers, and distance. *J. Hum. Evol.* **73**, 1–14. <https://doi.org/10.1016/j.jhevol.2014.06.004> (2014).
40. Pérez, L. et al. A high temporal resolution zooarchaeological approach to Neanderthal subsistence strategies on the southeastern Iberian Peninsula: El Salt stratigraphic unit xa (Alicante, Spain). In *Short-Term Occupations in Paleolithic Archaeology* (eds Cascalheira, J. & Picin, A.) 237–289 (Springer, 2020).
41. Marin, J., Saladié, P., Rodríguez, A. & Carbonell, E. Ungulate carcass transport strategies at the Middle Palaeolithic site of Abric Romani (Capellades, Spain). *C. R. Palevol.* **16**, 103–112. <https://doi.org/10.1016/j.crpv.2015.11.006> (2017).
42. Bailey, G. & Galanidou, N. Caves, palimpsests and dwelling spaces: Examples from the Upper Palaeolithic of south-east Europe. *World Archaeol.* **41**, 215–241. <https://doi.org/10.1080/00438240902843733> (2009).
43. Martínez, W., Benzaquén, M., Cabañas, I. & Uralde, M. Á. *Mapa geológico de España (e. 1:50.000): Onteniente* (Instituto Geológico y Minero de España, 1975).

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Author contributions

S.S.R. performed raw material, technological, archaeostratigraphic and spatial analyses. A.M. developed raw material and technological analyses. M.B. carried out the use-wear analysis. L.P. performed the archaeozoological analysis. C.M., B.G., C.M.H. are responsible for archaeological excavation. S.S.R., C.M.H. and M.V. developed the research design. All authors contributed to data interpretation and manuscript preparation.

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4.2. The time of the stones: a call for palimpsest dissection to explore lithic record formation processes



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

Manuel Vaquero and Cristo M. Hernández contributed equally to this work.

Extended author information available on the last page of the article

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; Vandavelde *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

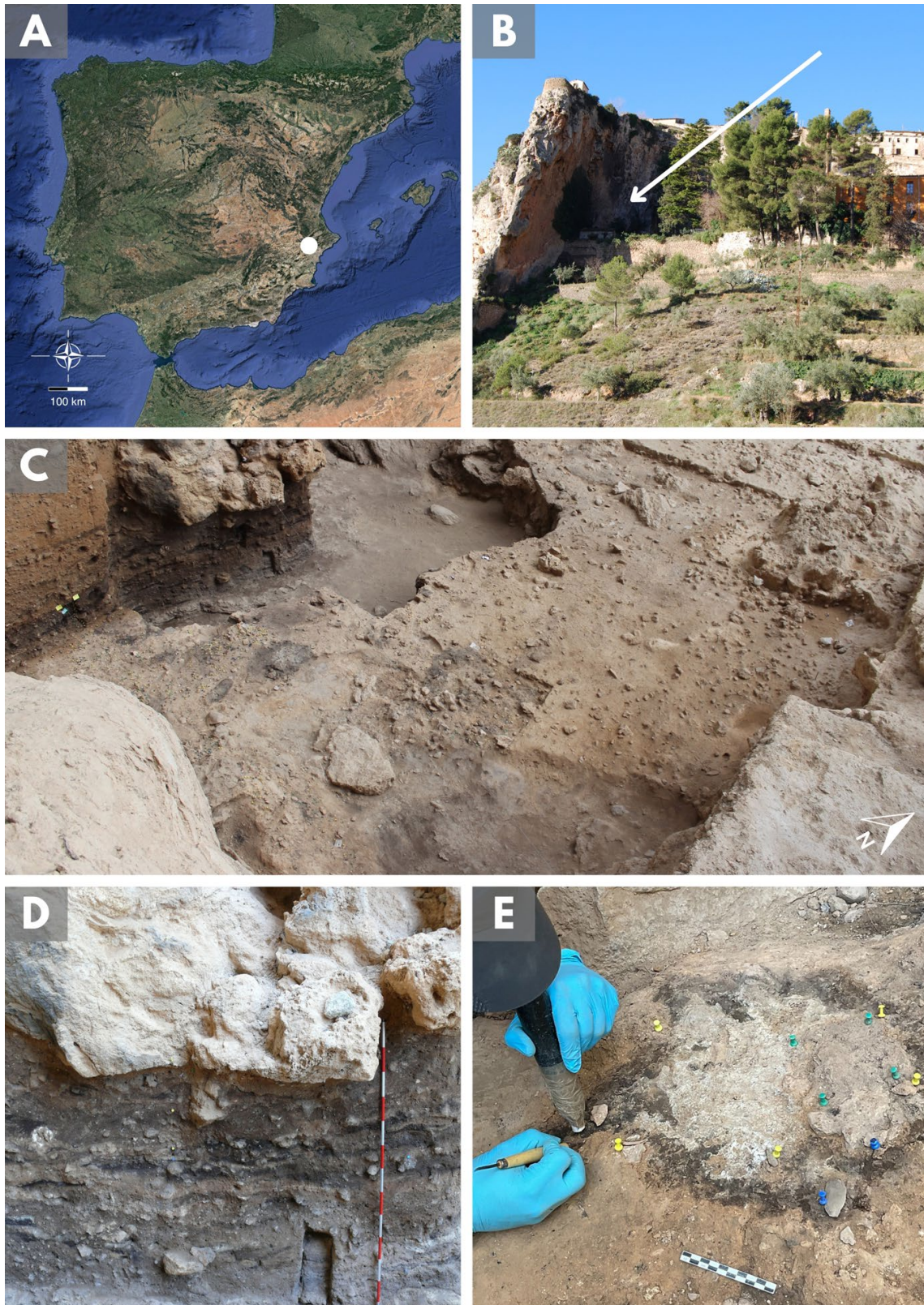


Fig. 1 Overview of El Salt. **A** Location of the site. **B** El Salt under the tufa formation. **C** Excavation surface of SU Xb. **D** Stratigraphic profile of El Salt. **E** Hearth preservation and excavation process of SU Xb

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 m² within a larger archaeology-bearing area of 250 m² (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 *Elyomys 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.* $< 500 \text{ mm}^2$), small (*i.e.* ≥ 500 to $< 1000 \text{ mm}^2$), medium (*i.e.* ≥ 1000 to $< 1500 \text{ mm}^2$), large (*i.e.* ≥ 1500 to $< 2000 \text{ mm}^2$) and very large (*i.e.* $< 2000 \text{ mm}^2$). 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; Tarrío & 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-Bribea *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

Outer area	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%)		
	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%)			
Total	866 (100%)			866 (100%)			866 (100%)			

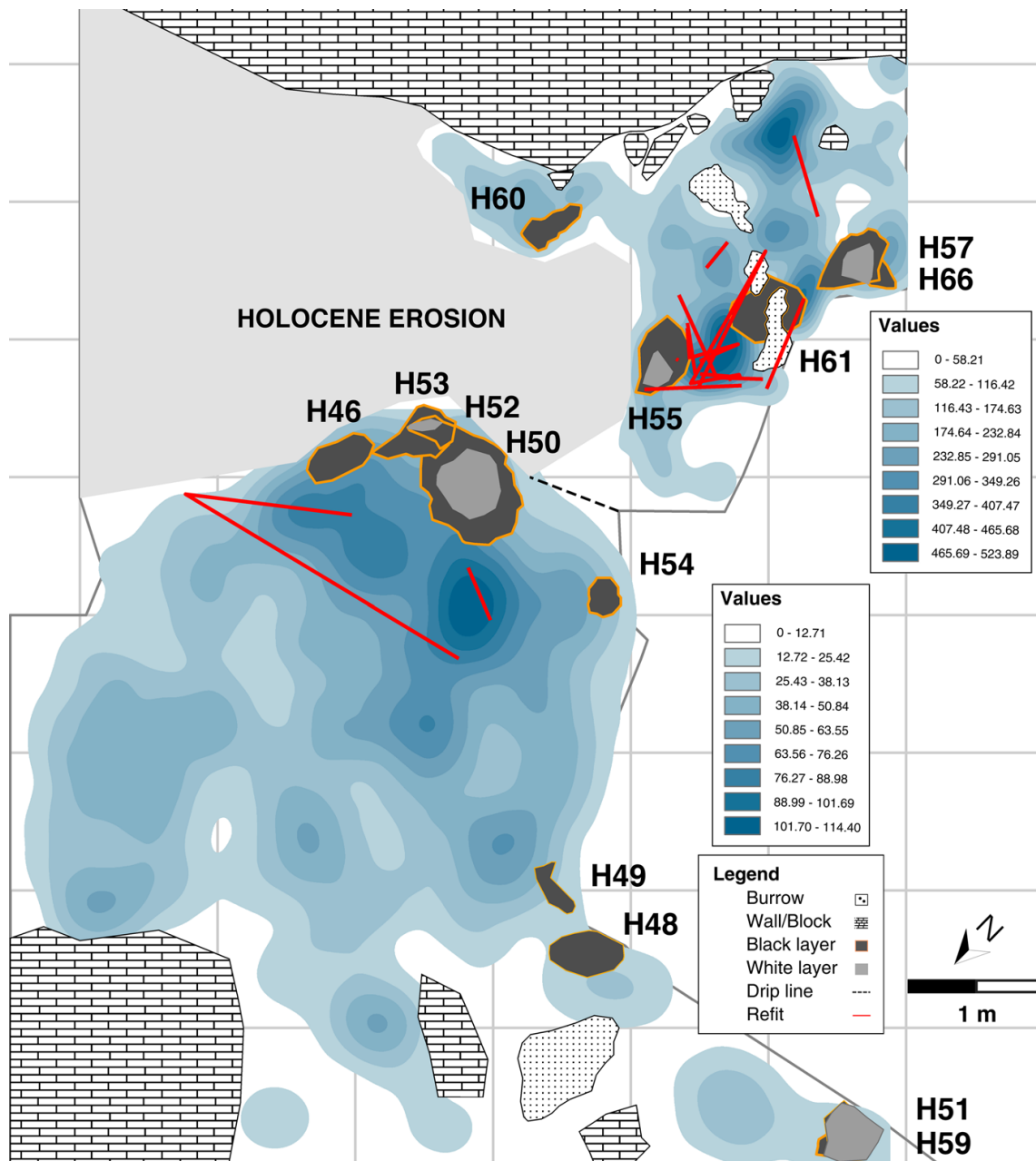


Fig. 2 General plan of El Salt displaying Kernel Density results for the SU Xb lithic record, refits and hearths

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 m²) 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

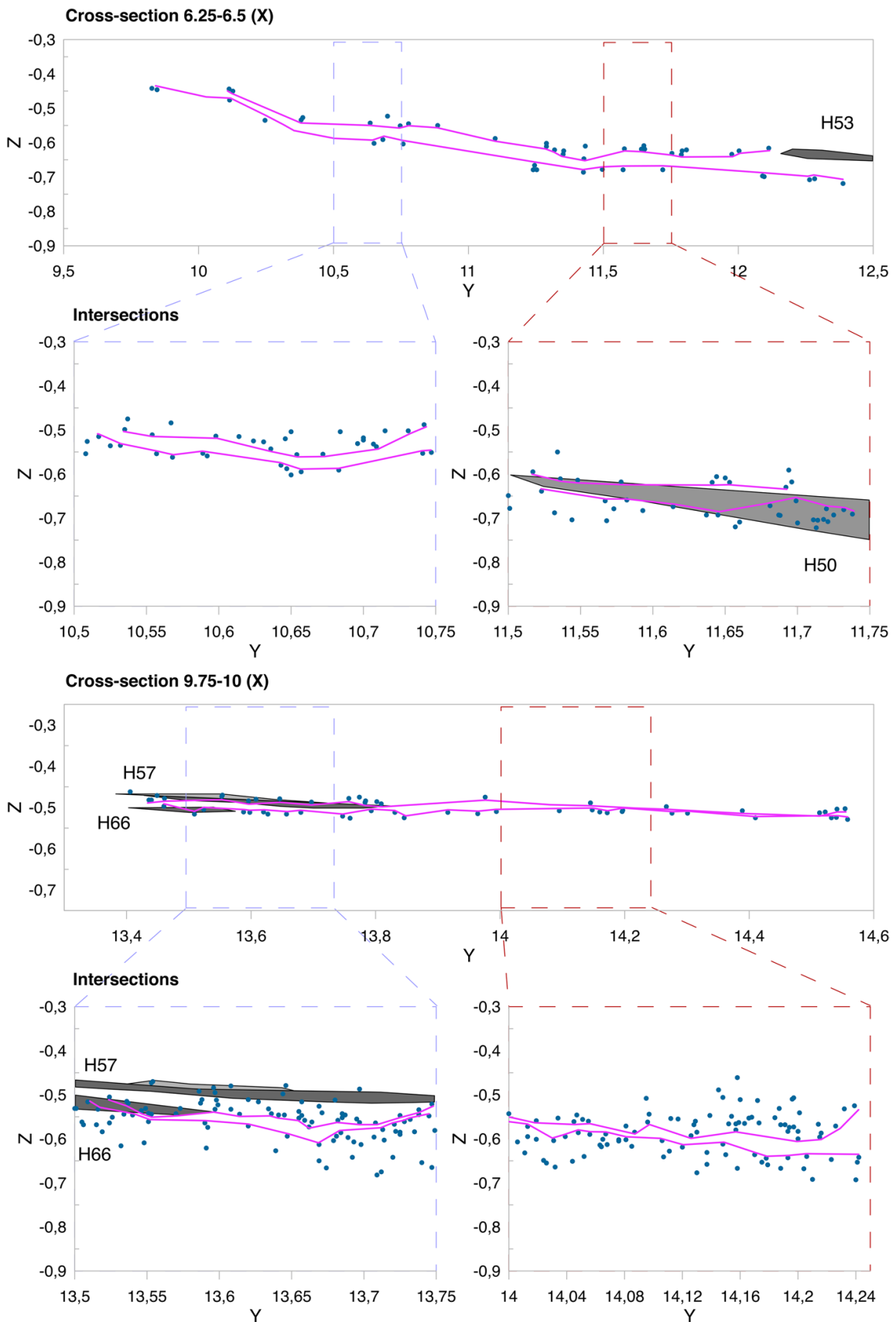


Fig. 3 Archaeostratigraphic sections and intersections showing the identified material gap: outer area (top), inner area (bottom)

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

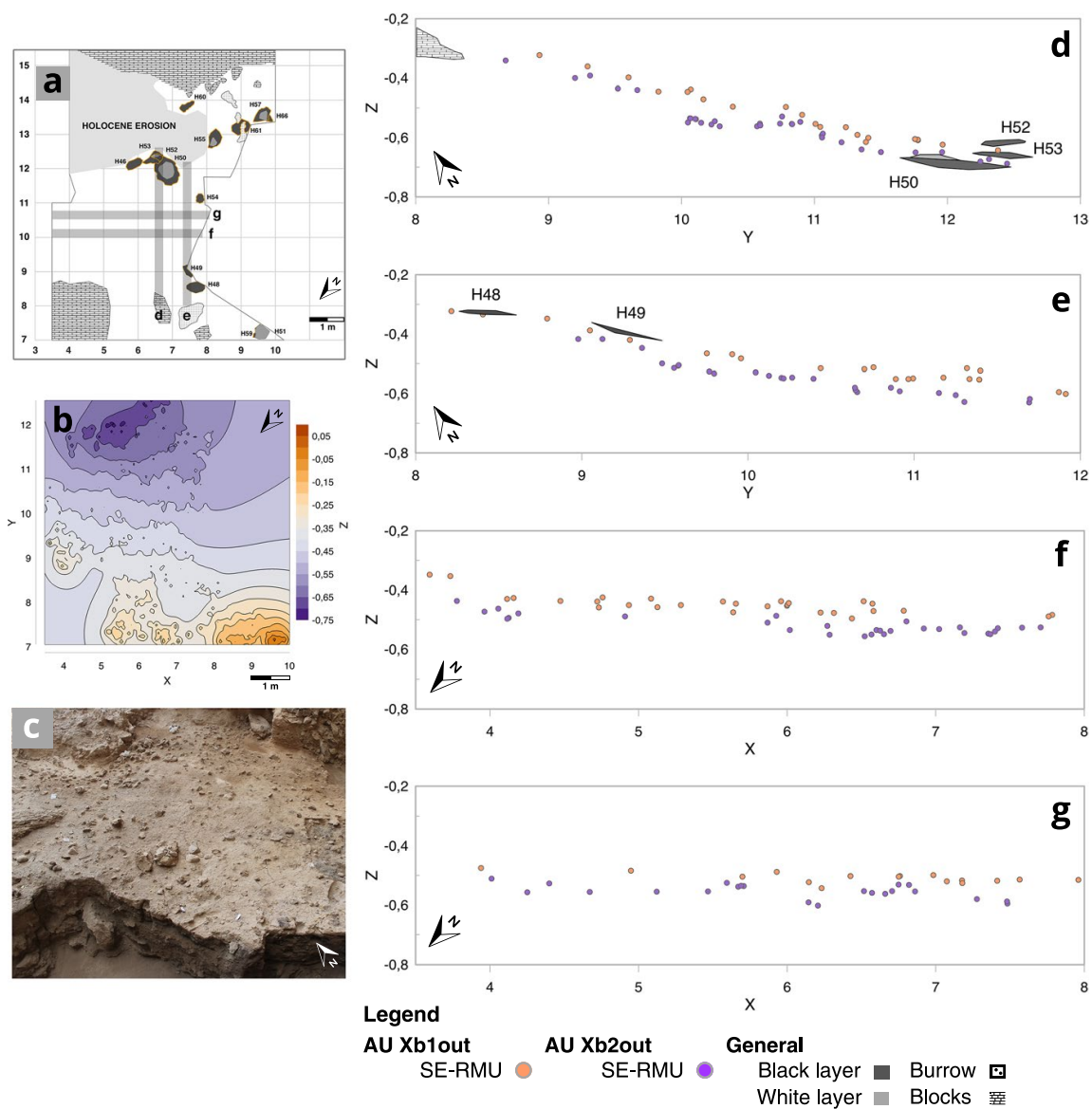


Fig. 4 Archaeostratigraphic profiles of the outer area: **a** plan of the El Salt Xb excavation surface highlighting the cross-sections of the outer area, **b** contour map of the excavation surface created to depict the topographical variations in the outer area, **c** photo of the excavation surface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

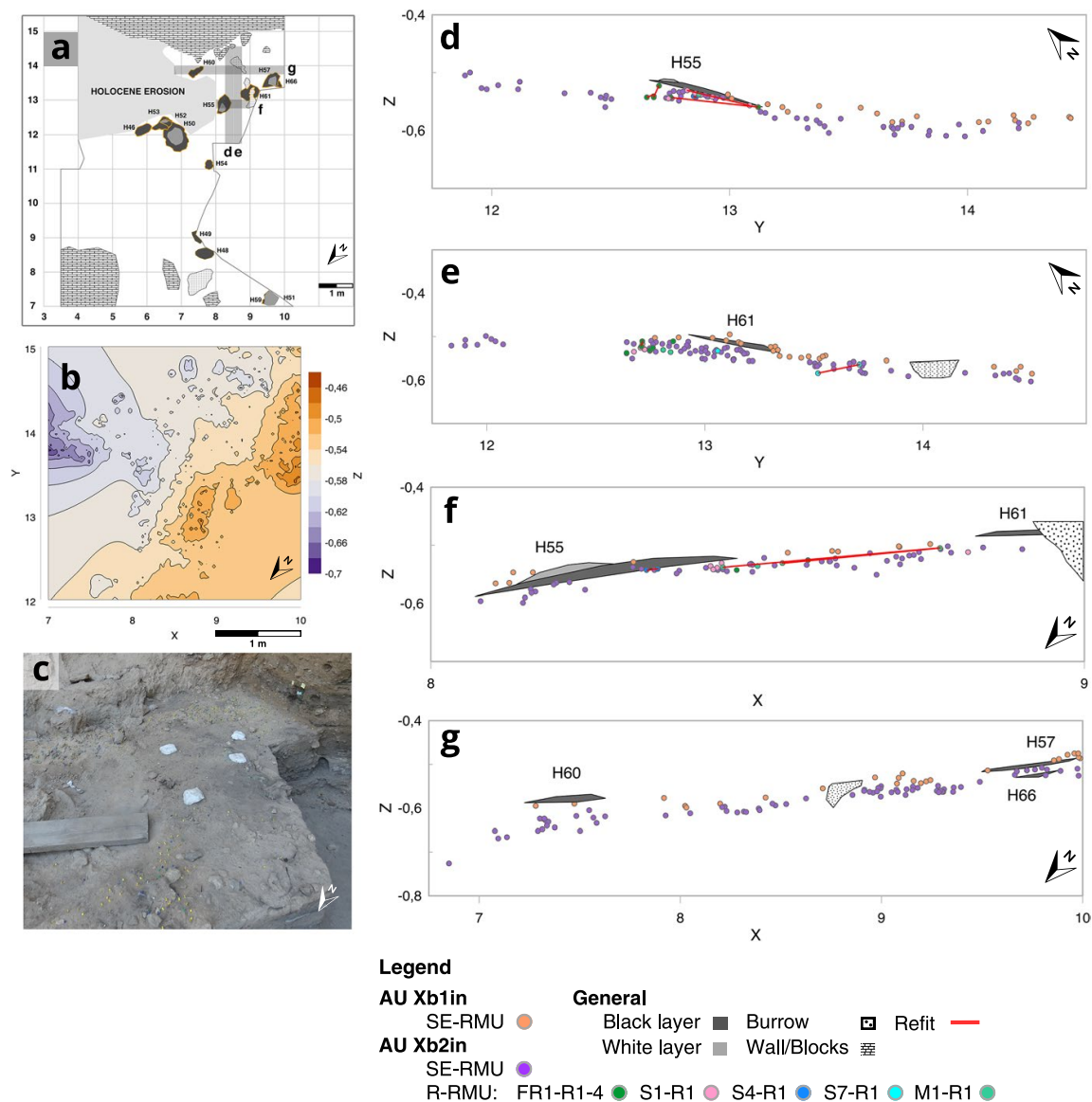


Fig. 5 Archaeostratigraphic profiles of the inner area: **a** plan of the El Salt Xb excavation surface highlighting the cross-sections of the inner area, **b** contour map of the excavation surface created to depict the topographical variations in the inner area, **c** photo of the excavation surface 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 m²) 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).

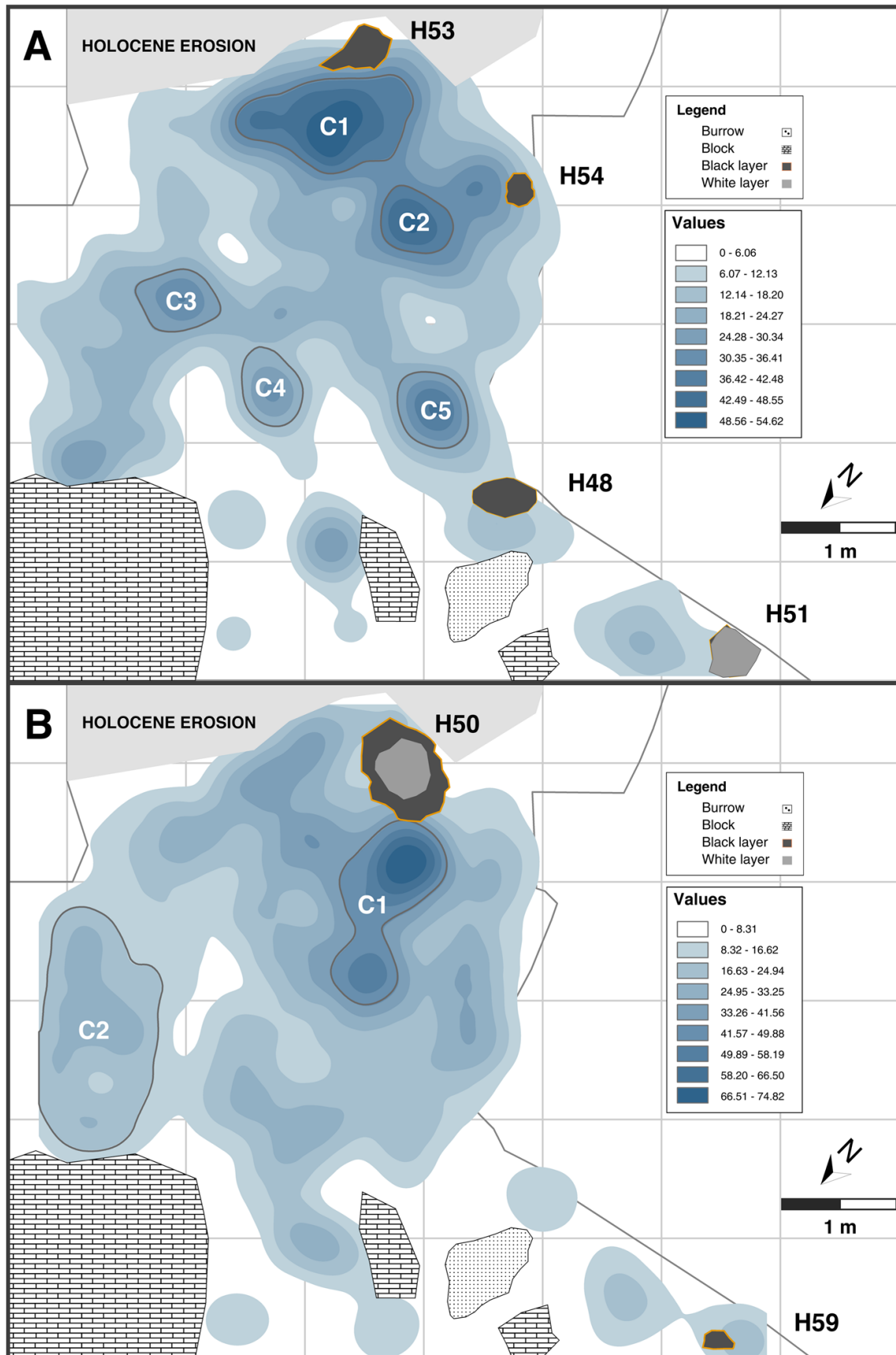


Fig. 6 Kernel density analysis results for the outer area divided into **A** lithic assemblage from the AU Xb1out and **B** lithic assemblage from the AU Xb2out

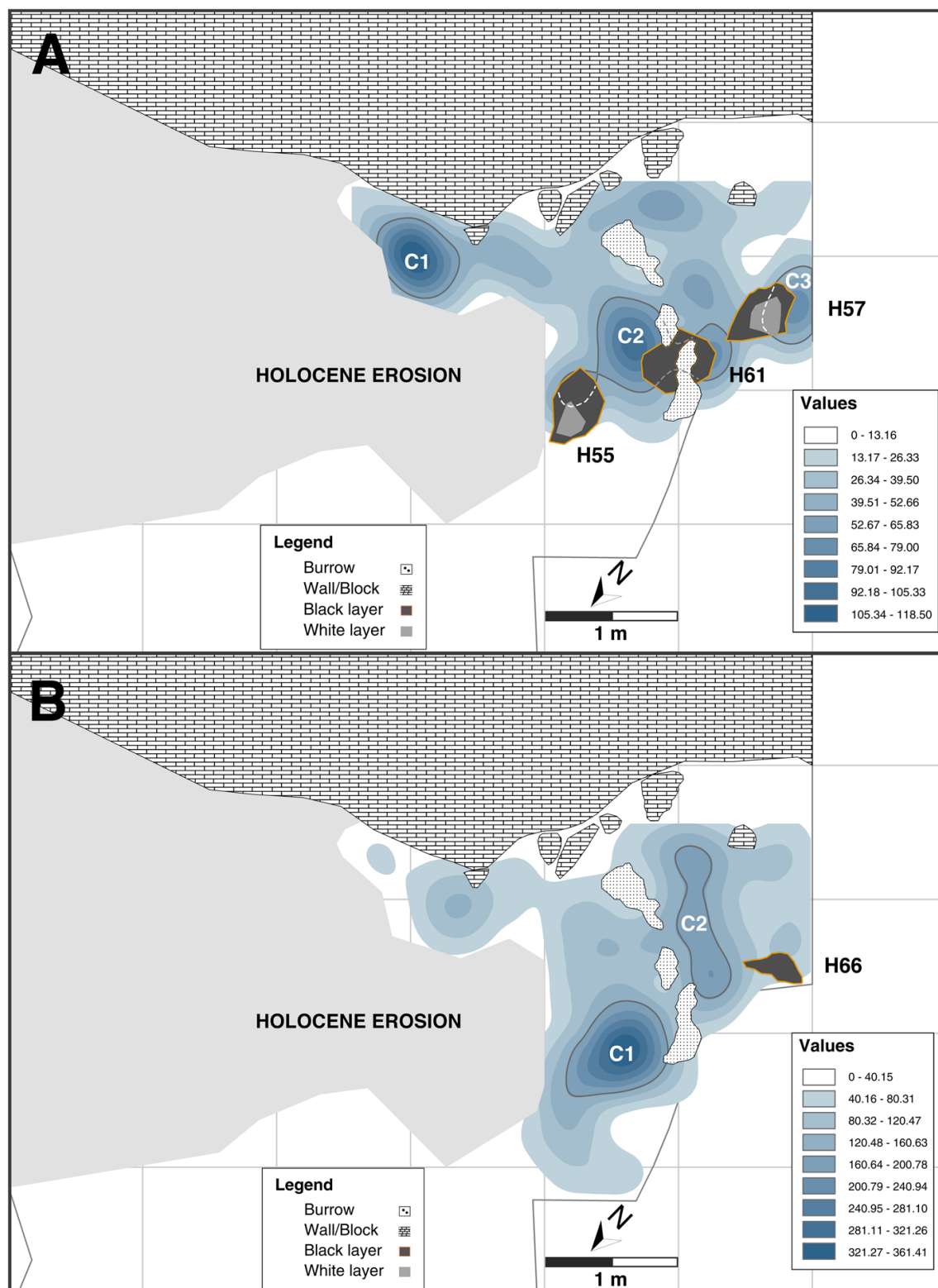


Fig. 7 Kernel density analysis results for the inner area divided into **A** lithic assemblage from the AU Xb1in and **B** lithic assemblage from the AU Xb2in

Outer Area

Within this area, 2 AUs were determined (Xb1out and Xb2out). These units are distributed across the whole outer area (ca. 30 m²), 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. “Archeostratigraphic 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

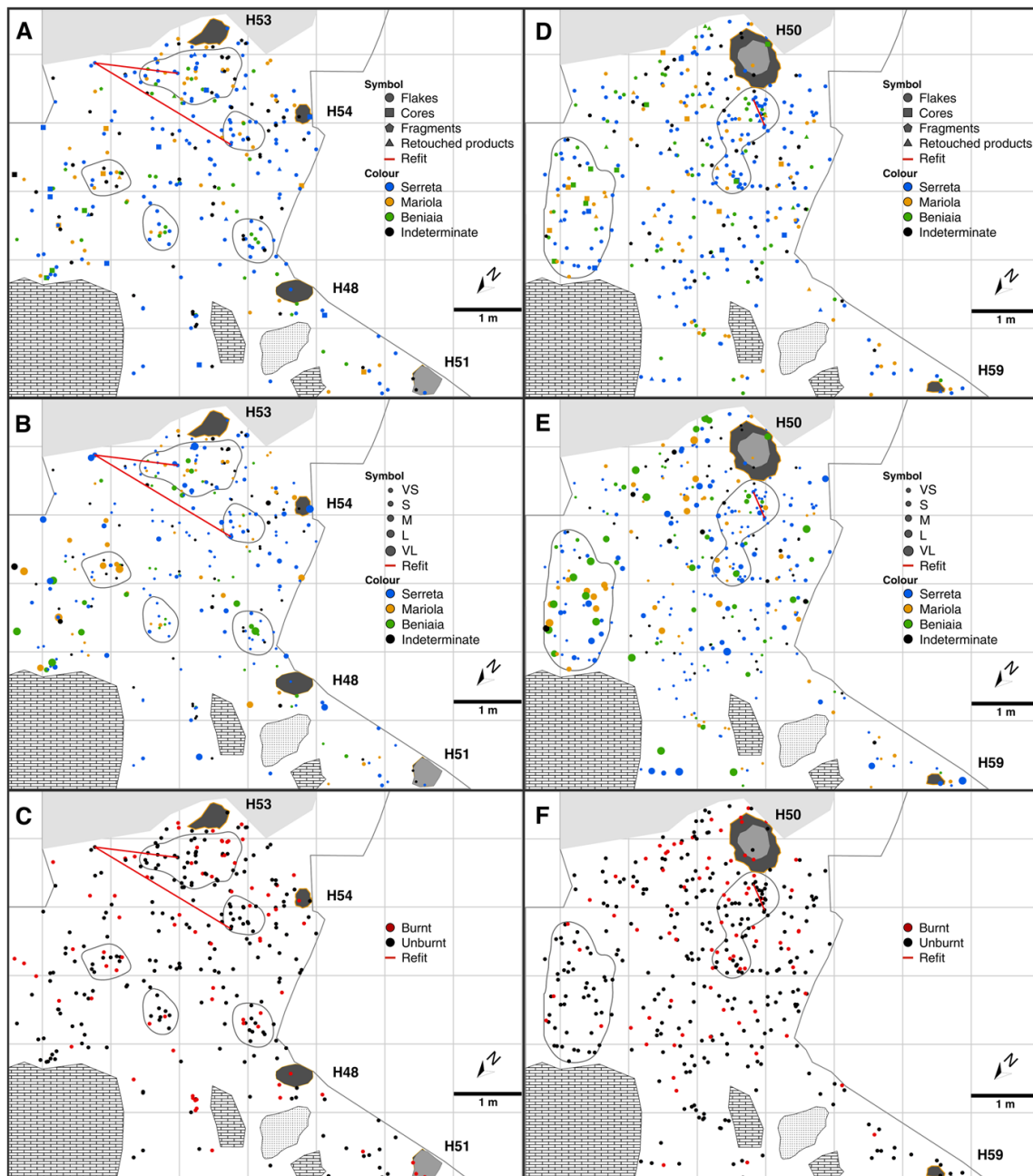


Fig. 8 Spatial distribution of the lithic assemblages based on flint type (colours), type of product, size class, thermoalteration and refits. **A–C** AU Xb1out, **D–F** AU Xb2out

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

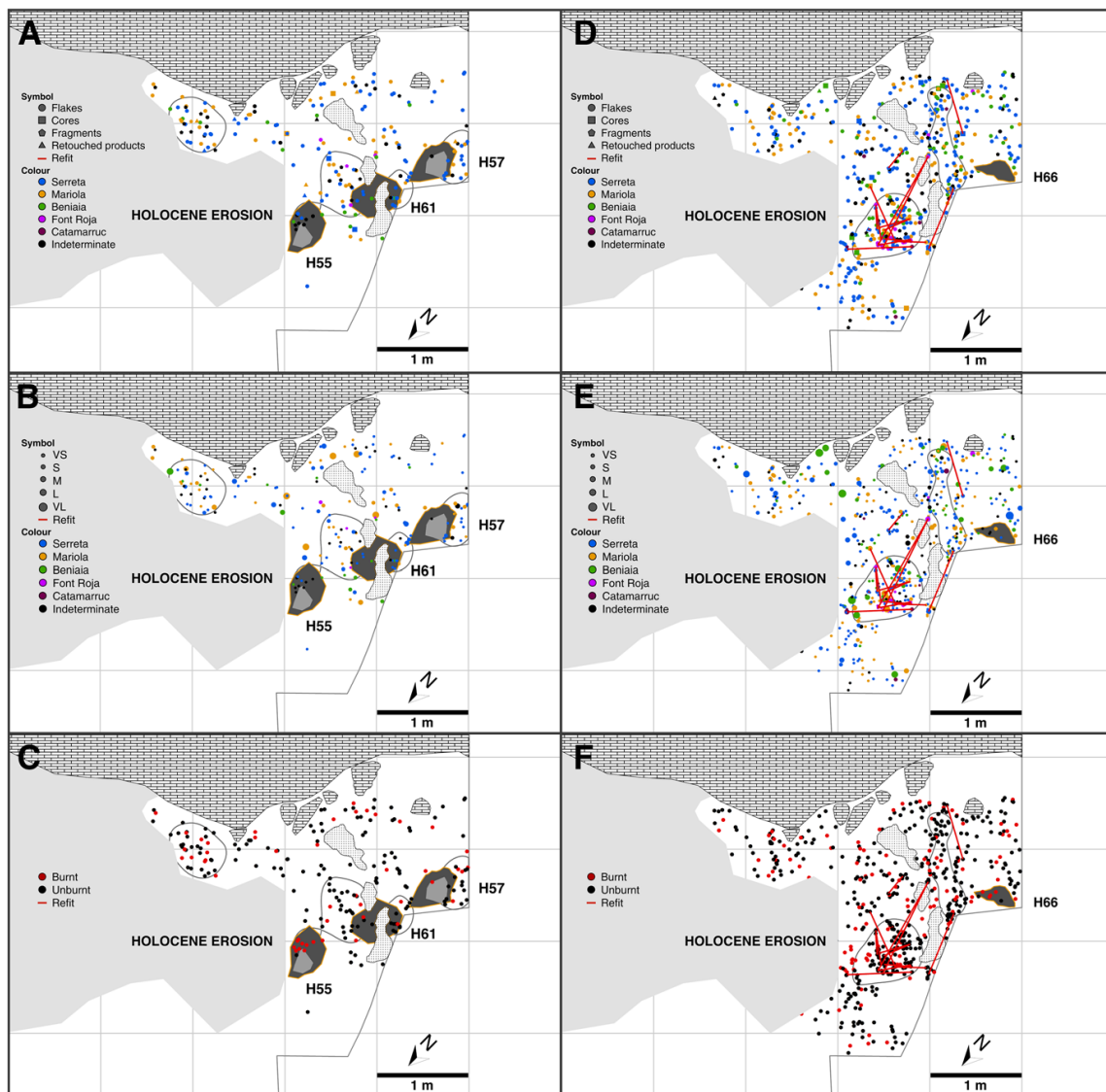


Fig. 9 Spatial distribution of the lithic assemblages based on flint type (colours), type of product, size class, thermoalteration and refits. **A–C** AU Xb1in, **D–F** AU Xb2in

(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,

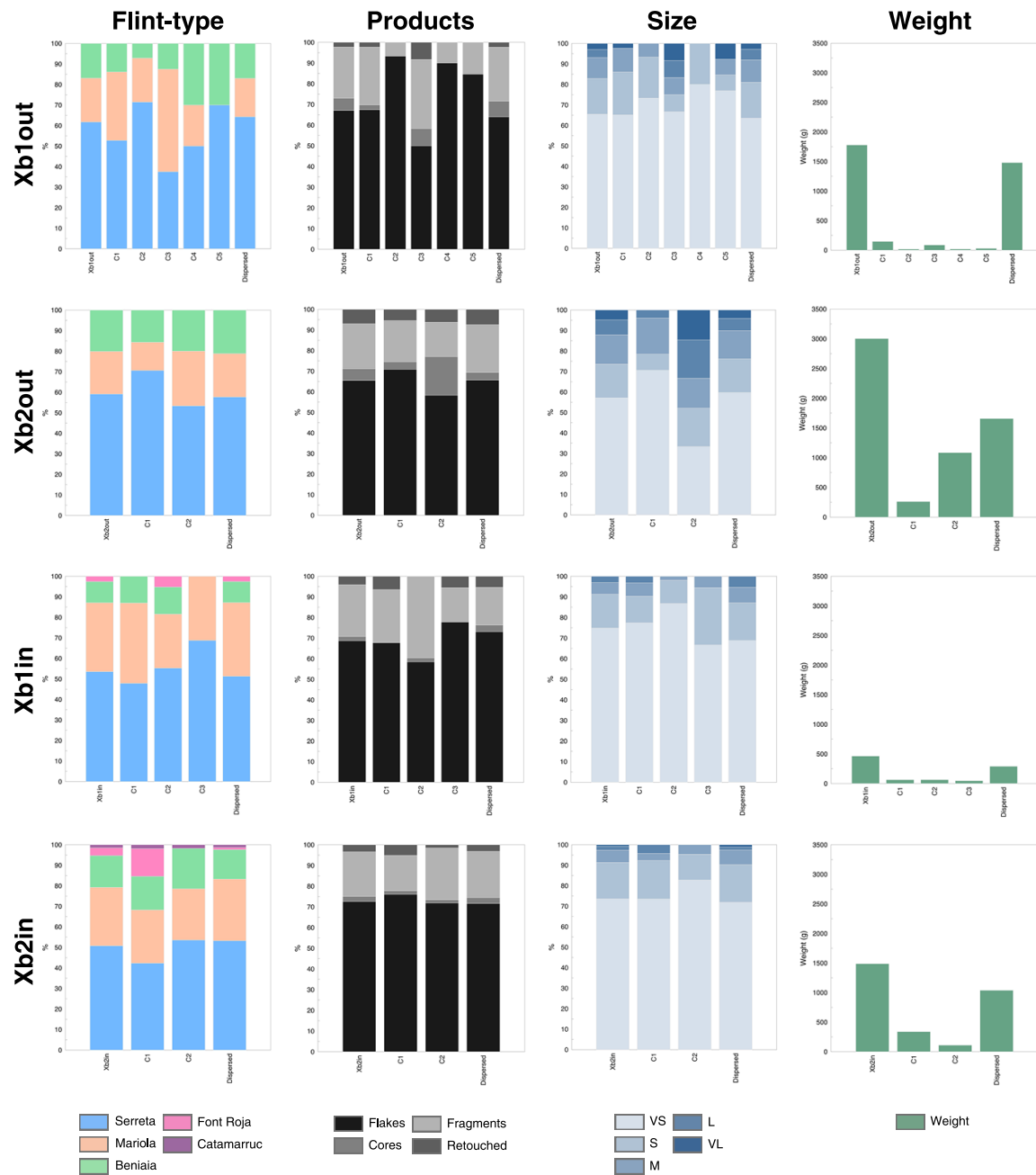


Fig. 10 Bar charts comparing the content of the defined AUs, based on flint type, type of product, size class and weight

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

AU	Serreta		Mariola		Beniaia		Font Roja		Catamarruc
	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

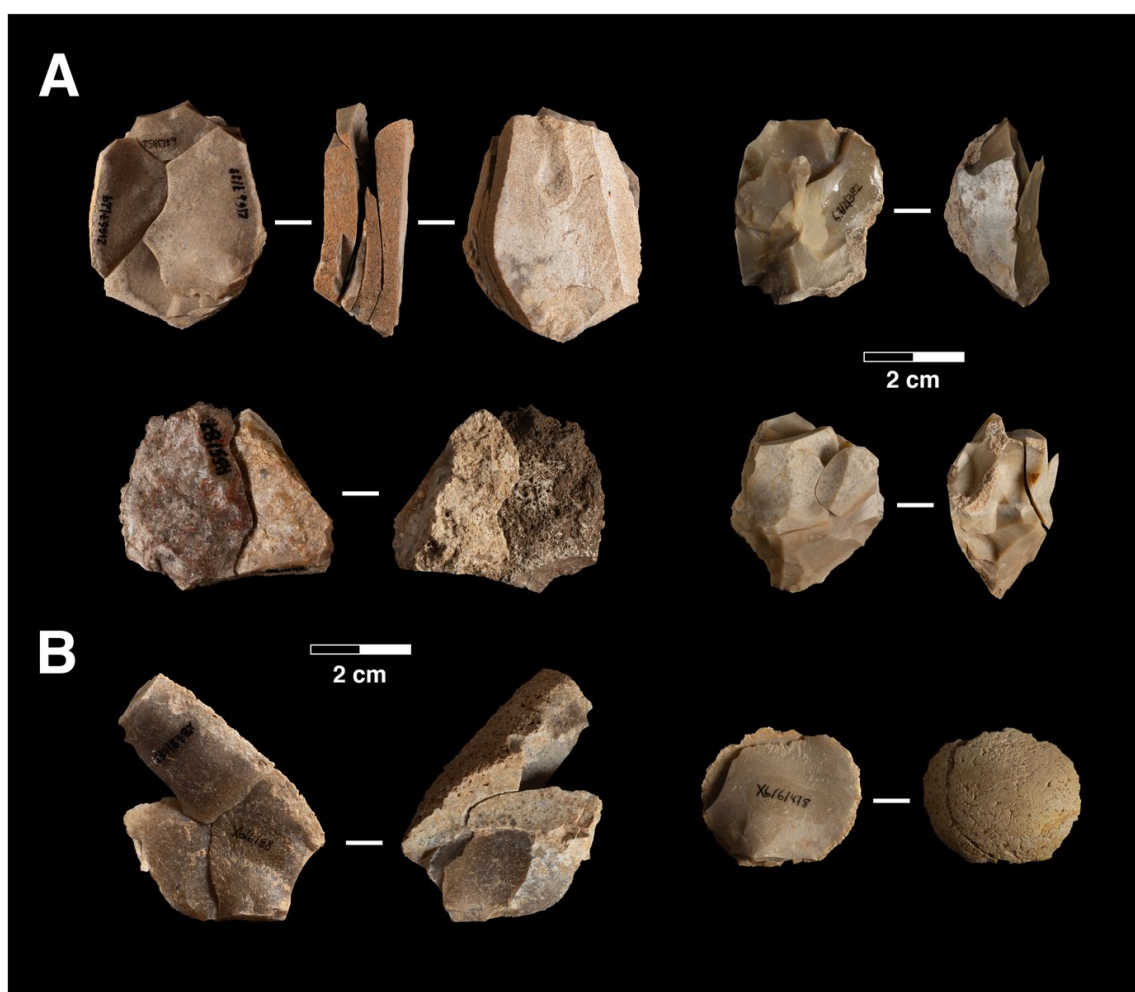


Fig. 11 Refitted sequences from El Salt SU Xb. **A** Some examples of R-RMUs from the inner area and **B** R-RMUs from the outer area. Photography: Maria Guillén (IPHES)

(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

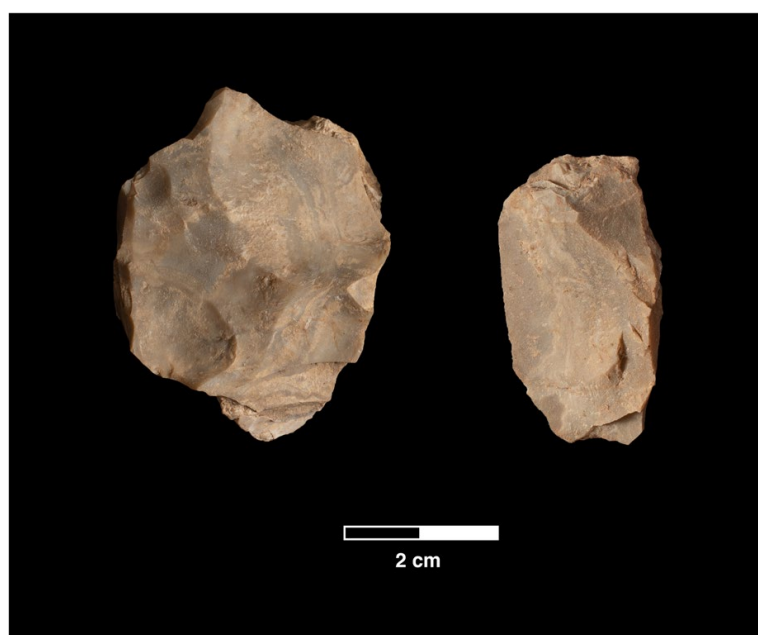
regular gaps between them, facilitating their vertical definition despite having fewer R-RMUs. Even here, where we have a more defined picture, the archaeostratigraphic analysis proved crucial for separating events, as illustrated by the case of H52 or H60. They were initially considered part of the 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 Beniaia 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 m² 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

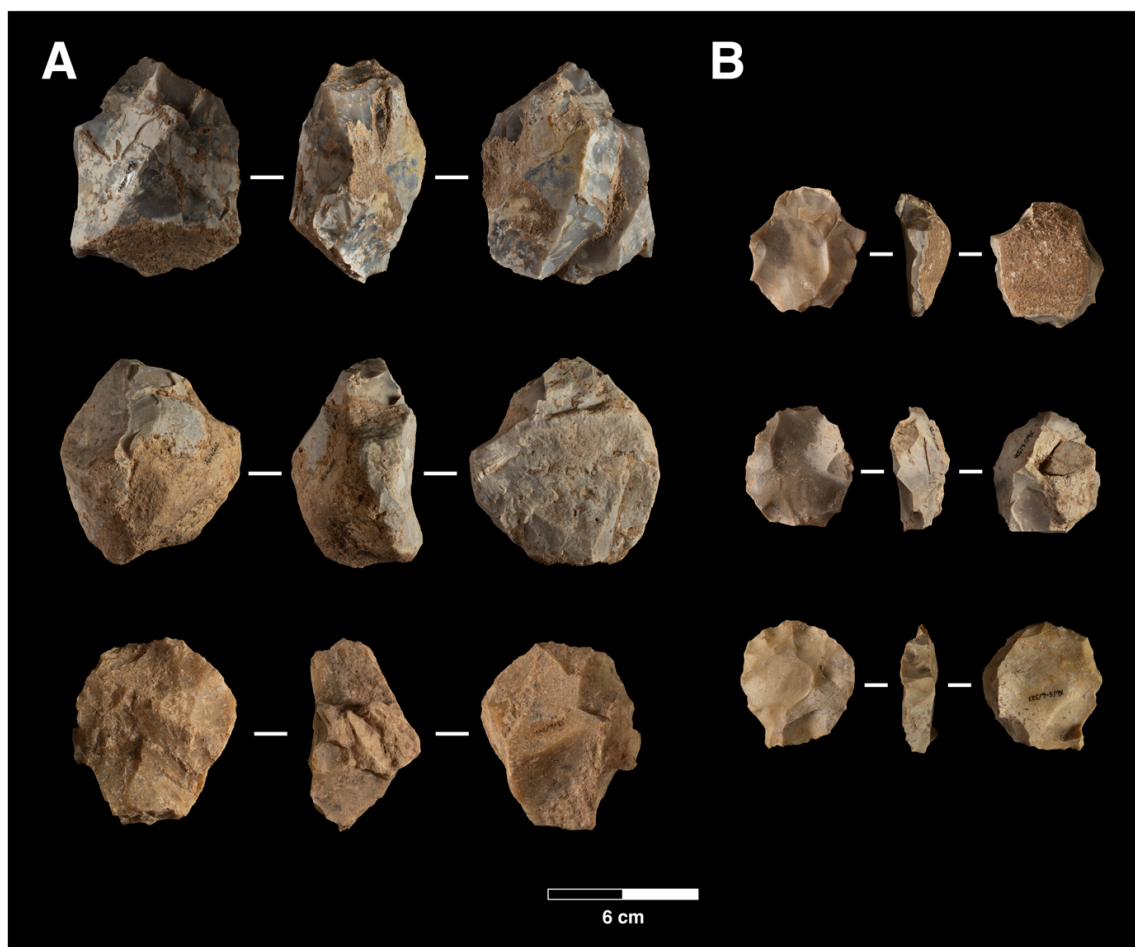


Fig. 13 Representation of the lithic assemblage contained in C2 from Xb2out. **A** Beniaia large cores and **B** Mariola exhausted cores. Photography: Maria Guillén (IPHES)

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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References

- Adler, D., Prindiville, T., & Conard, N. J. (2003). Patterns of spatial organization and land use during the Eemian interglacial in the Rhineland: New data from Wallertheim, Germany. *Eurasian Prehistory*, 1(2), 25–78.
- Aldeias, V., Dibble, H. L., Sandgathe, D., Goldberg, P., & McPherron, S. J. (2016). How heat alters underlying deposits and implications for archaeological fire features: A controlled experiment. *Journal of Archaeological Science*, 67, 64–79. <https://doi.org/10.1016/j.jas.2016.01.016>
- Arteaga-Brieba, A., Courtenay, L., Cobo-Sánchez, L., Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., & Mosquera, M. (2023). An archaeostratigraphic consideration of the Gran Dolina TD10.2 cultural sequence from a quantitative approach. *Quaternary Science Reviews*, 309, 108033. <https://doi.org/10.1016/j.quascirev.2023.108033>
- Bailey, G. N. (1983). Concepts of time in Quaternary Prehistory. *Annual Review of Anthropology*, 12, 165–192. <https://doi.org/10.1146/annurev.an.12.100183.001121>
- Bailey, G. N. (2007). Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology*, 26(2), 198–223. <https://doi.org/10.1016/j.jaa.2006.08.002>
- Bailey, G. N. (2008). Time perspectivism: Origins and consequences. In S. Holdaway & L. Wandsnider (Eds.), *Time in Archaeology: Time perspectivism revisited* (pp. 13–30). Utah University Press.
- Bailey, G. N., & Galanidou, N. (2009). Caves, palimpsests and dwelling spaces: Examples from the Upper Palaeolithic of south-east Europe. *World Archaeology*, 41(2), 215–241. <https://doi.org/10.1080/00438240902843733>
- Baker, C. (1978). The size effect: An explanation of variability in surface artifact assemblage content. *American Antiquity*, 43(2), 288–293. <https://doi.org/10.2307/279254>
- Barciela, V., & Molina, F. J. (2005). L’Alt de la Capella (Benifallim, Alicante). Nuevos datos sobre el poblamiento musteriense al aire libre en la cuenca del río Serpis. *Recerques Del Museu D’alcoi*, 14, 7–26.
- Bargalló, A., Gabucio, M. J., & Rivals, F. (2016). Puzzling out a palimpsest: Testing an interdisciplinary study in level O of Abric Romaní. *Quaternary International*, 417, 51–65. <https://doi.org/10.1016/j.quaint.2015.09.066>
- Barton, M., & Riel-Salvatore, J. (2014). The formation of lithic assemblages. *Journal of Archaeological Science*, 46, 334–352. <https://doi.org/10.1016/j.jas.2014.03.031>

- Bencomo, M., Giner, P., Sirvent, L. M., & Hortelano, L. (2020). Understanding woodworking in Paleolithic times by means of use-wear analysis. *Journal of Archaeological Science: Reports*, 29, 102119. <https://doi.org/10.1016/j.jasrep.2019.102119>
- Bencomo, M., Mayor, A., Sossa-Ríos, S., Jardón, P., Galván, B., Mallol, C., & Hernández, C. M. (2023). Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): Working with lithic tools in a narrow timescale. *Archaeological and Anthropological Sciences*, 15, 92. <https://doi.org/10.1007/s12520-023-01787-4>
- Binford, L. R. (1978a). *Nunamiut ethnoarchaeology*. Academic Press.
- Binford, L. R. (1978b). Dimensional analysis of behavior and site structure: Learning from an Eskimo hunting stand. *American Antiquity*, 43(3), 330–361. <https://doi.org/10.2307/279390>
- Binford, L. R. (1981). Behavioural archaeology and the “Pompeii premise.” *Journal of Anthropological Research*, 37(3), 195–208. <https://doi.org/10.1086/jar.37.3.3629723>
- Blasco, R., Rosell, J., Sañudo, P., Gopher, A., & Barkai, R. (2016). What happens around a fire: Faunal processing sequences and spatial distribution at Qesem cave (300ka), Israel. *Quaternary International*, 398, 190–209. <https://doi.org/10.1016/j.quaint.2015.04.031>
- Canals, A., Vallverdú, J., & Carbonell, E. (2003). New archaeostratigraphic data for the TD6 level in relation to *Homo antecessor* (Lower Pleistocene) at the site of Atapuerca, north-central Spain. *Geochronology*, 18, 481–504. <https://doi.org/10.1002/gea.10071>
- Cenk-Yesilova, G., Ollé, A., & Vergés, J. M. (2021). Is a spatial investigation possible without long-distance refit/conjoin? Application to the MIS 11 lithic assemblage of levels E and J from La Cansaladeta site (Tarragona, Spain). *Archaeological and Anthropological Sciences*, 13, 157. <https://doi.org/10.1007/s12520-021-01384-3>
- Clark, A. (2017). From activity areas to occupational histories: New methods to document the formation of spatial structure in hunter-gatherer sites. *Journal of Archaeological Method and Theory*, 24, 1300–1325. <https://doi.org/10.1007/s10816-017-9313-7>
- Clark, A. (2019). Using spatial context to identify lithic selection behaviors. *Journal of Archaeological Science: Reports*, 24, 1014–1022. <https://doi.org/10.1016/j.jasrep.2019.03.011>
- Clark, A., Ranlett, S., & Stiner, M. (2022). Domestic spaces as crucibles of Paleolithic culture: An archaeological perspective. *Journal of Human Evolution*, 172, 103266. <https://doi.org/10.1016/j.jhevol.2022.103266>
- Conard, N.J. & Adler, D. (1997). Lithic reduction and hominid behaviour in the Middle Paleolithic of the Rhineland. *Journal of Anthropological Research*, 53(2). <https://doi.org/10.1086/jar.53.2.3631275>
- De la Peña, P., Colino, F., d’Errico, F., Wadley, L., Banks, W. E., Stratford, D., & Backwell, L. (2022). Lithic technological and spatial analysis of the final Pleistocene at Border Cave. *South Africa. Quaternary Science Reviews*, 296, 107802. <https://doi.org/10.1016/j.quascirev.2022.107802>
- Dibble, H. L., Holdaway, S. J., Lin, S. C., Braun, D. R., Douglass, M. J., Iovita, R., McPherron, S. P., Olszewski, D. I., & Sandgathe, D. (2017). Major fallacies surrounding stone artifacts and assemblages. *Journal of Archaeological Method and Theory*, 24, 813–851. <https://doi.org/10.1007/s10816-016-9297-8>
- Dietl, H., Kandel, A. K., & Conard, N. J. (2005). Middle Stone Age settlement and land use at the open-air sites of Geelbek and Anyskop. *South Africa. Journal of African Archaeology*, 3(2), 231–242. <https://doi.org/10.3213/1612-1651-10052>
- Díez-Martín, F., Sánchez, P., Domínguez, M., Mabulla, A., & Barba, R. (2009). Were Olduvai hominins making butchering tools or battering tools? Analysis of a recently excavated lithic assemblage from BK (bed II, Olduvai gorge, Tanzania). *Journal of Anthropological Research*, 28(3), 274–289. <https://doi.org/10.1016/j.jaa.2009.03.001>
- Discamps, E., Thomas, M., Dancette, C., Gravina, B., Plutniak, S., Royer, A., Angelin, A., Bachelierie, F., Beauval, C., Bordes, J. G., Deschamps, M., Langlais, M., Laroulandie, V., Mallye, J. B., Michel, A., Perrin, T., & Rendu, W. (2023). Breaking free from field layers: The interest of post-excavation stratigraphies (PES) for reproducing reliable archaeological interpretations and increasing chronological resolution. *Journal of Paleolithic Archaeology*, 6, 29. <https://doi.org/10.1007/s41982-023-00155-x>
- Dorta, R., Hernández, C. M., Molina, F. J., & Galván, B. (2010). La alteración térmica en los sílex de los valles alcoyanos (Alicante, España). Una aproximación desde la arqueología experimental en contextos del Paleolítico medio: El Salt. *Recerques del Museu d’Alcoi*, 19, 33–64.
- Eixea, A., & Sanchis, A. (2022). Reconstrucción preliminar de la secuencia del Paleolítico medio y superior inicial de la Cova Foradada (Oliva, Valencia) a partir del estudio de los materiales líticos. *Archivo De Prehistoria Levantina*, 34, 29–59.

- Eixea, A., Sanchis, A., & Martínez, Á. (2019). Nuevos datos procedentes del yacimiento del Paleolítico medio del Puntal del Gat (Benirredrà, Valencia). *Saguntum*, 51, 257–259.
- ElTossal Topografía. (2015, September 2). 3D model of the Middle Palaeolithic site of El Salt. from <https://sketchfab.com/3d-models/el-salt-alcoi-b16bb4eab477472d8ae07cfd16ce6c33>. Accessed 24 May 2024
- Fagoaga, A., Ruiz, F. J., Laplana, C., Blain, H. A., Marquina, R., Marin, M. D., & Galván, B. (2018). Palaeoecological implications of Neanderthal occupation at unit xb of El Salt (Alcoi, eastern Spain) during MIS 3 using small mammals proxy. *Quaternary International*, 481, 101–112. <https://doi.org/10.1016/j.quaint.2017.10.024>
- Fernandes, P., & Raynal, J. P. (2006). Péroarchéologie du silex: Un retour aux sources. *Comptes Rendus Palevol*, 5(6), 829–837. <https://doi.org/10.1016/j.crpv.2006.04.002>
- Fraille-Márquez, C., Diez-Martín, F., Duque-Martínez, J., Uribebarrea, D., Sánchez-Yustos, P., de Francisco, S., Baquedano, E., Mabulla, A., & Domínguez-Rodrigo, M. (2022). Facing the palimpsest conundrum: An archaeo-stratigraphic approach to the intra-site analysis of SHK Extension (Bed II, Olduvai Gorge, Tanzania). *Archaeological and Anthropological Sciences*, 14, 230. <https://doi.org/10.1007/s12520-022-01691-3>
- Fumanal, M. P. (1994). El yacimiento musteriense de El Salt (Alcoi, País Valenciano): Rasgos geomorfológicos y climatoestratigrafía de sus registros. *Saguntum*, 27, 39–56.
- Galanidou, N. (2000). Patterns in caves: Foragers, horticulturists, and the use of space. *Journal of Anthropological Archaeology*, 19(3), 243–275. <https://doi.org/10.1006/jaar.1999.0362>
- Galván, B. (1992). El Salt (Alcoi, Alicante): Estado actual de las investigaciones. *Recerques Del Museu D'alcoi*, 1, 73–80.
- Galván, B., Hernández, C. M., Mallol, C., Mercier, N., Sistiaga, A., & Soler, V. (2014). New evidence of early Neanderthal disappearance in the Iberian peninsula. *Journal of Human Evolution*, 75, 16–27. <https://doi.org/10.1016/j.jhevol.2014.06.002>
- Goldberg, P., & Macphail, R. I. (2005). Caves and rockshelters. In P. Goldberg & R. I. Macphail (Eds.), *Practical and Theoretical Geoarchaeology* (pp. 169–187). Blackwell.
- Gómez, B., Soto, M., Vallverdú, J., Vaquero, M., Bargalló, A., Chacón, M. G., Romagnoli, F., & Carbonell, E. (2020). Neanderthal lithic procurement and mobility patterns through a multi-level study in the Abric Romaní site (Capellades, Spain). *Quaternary Science Reviews*, 237, 106315. <https://doi.org/10.1016/j.quascirev.2020.106315>
- Guillemot, P., Jaillet, S., Chacón, M. G., Pois, V., & Moncel, M. H. (2023). Spatial patterning of Middle Palaeolithic lithic assemblages at the Abri du Maras, southeast France: Combining GIS analysis and 3D palaeotopographic reconstructions. *Journal of Archaeological Science: Reports*, 49, 103999. <https://doi.org/10.1016/j.jasrep.2023.103999>
- Harding, J. (2005). Rethinking the great divide: Long-term structural history and the temporality of event. *Norwegian Archaeological Review*, 38(2), 88–101.
- Herrejón-Lagunilla, Á. (2020). Estudios arqueomagnéticos en materiales quemados prehistóricos en la península Ibérica: aplicaciones geocronológicas y geoarqueológicas. *PhD dissertation*, Universidad de Burgos. <https://doi.org/10.36443/10259/5935>
- Herrejón-Lagunilla, Á., Villalaín, J.J., Pavón-Carrasco, F.J., Sánchez-Bravo, M.S., Sossa-Ríos, S., Mayor, A., Galván, B., Hernández, C.M., Mallol, C. & Carrancho, Á. (2024). The time between Palaeolithic hearths. *Nature*, 630. <https://doi.org/10.1038/s41586-024-07467-0>
- Hodder, I. (1987). The contribution of the long-term. In I. Hodder (Ed.), *Archaeology as long-term history* (pp. 1–8). Cambridge University Press.
- Iturbe, G., Fumanal, M. P., Carrión, J. S., Cortell, E., Martínez, R., Guillem, P. M., Garralda, M. D., & Vandermeersch, B. (1993). Cova Beneito (Muro, Alicante): Una perspectiva interdisciplinar. *Recerques Del Museu D'alcoi*, 2, 23–88.
- Knapp, B. (1992). Archaeology and Annales: Time, space, and change. In B. Knapp (Ed.), *Archaeology, Annales, and Ethnohistory* (pp. 1–22). Cambridge University Press.
- Kuhn, S., & Clark, A. (2015). Artifact densities and assemblage formation: Evidence from Tabun Cave. *Journal of Anthropological Archaeology*, 38, 8–16. <https://doi.org/10.1016/j.jaa.2014.09.002>
- Leierer, L. (2021). Approaching Neanderthal behavior through the geoarchaeological study of combustion structures: Investigations in soil micromorphology and lipid biomarkers. *PhD dissertation*, Universidad de La Laguna.
- Leierer, L., Jambina-Enríquez, M., Herrera-Herrera, A., Connolly, R., Hernández, C.M., Galván, B. & Mallol, C. (2019). Insights into the timing, intensity and natural setting of Neanderthal occupation from the geoarchaeological study of combustion structures: A micromorphological and biomarker

- investigation of El Salt, unit xb, Alcoy, Spain. *PloS ONE*, 14(4). <https://doi.org/10.1371/journal.pone.0214955>
- López-Ortega, E., Rodríguez, X. P., Ollé, A., & Lozano, S. (2019). Lithic refits as a tool to reinforce post-depositional analysis. *Archaeological and Anthropological Sciences*, 11, 4555–4568. <https://doi.org/10.1007/s12520-019-00808-5>
- López-Ortega, E., Rodríguez, X. P., & Vaquero, M. (2011). Lithic refitting and movement connections: The NW area of the level TD10-1 at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). *Journal of Archaeological Science*, 38(11), 3112–3121. <https://doi.org/10.1016/j.jas.2011.07.011>
- Lucas, G. (2008). Time and archaeological event. *Cambridge Archaeological Journal*, 18(1). <https://doi.org/10.1017/S095977430800005X>
- Lucas, G. (2012). *Understanding the archaeological record*. Cambridge University Press.
- Lucas, G. (2021). *Making time: The Archaeology of time revisited*. Routledge.
- Machado, J., Hernández, C. M., Mallol, C., & Galván, B. (2013). Lithic production, site formation and Middle Palaeolithic palimpsest analysis: In search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). *Journal of Archaeological Science*, 40, 2254–2273. <https://doi.org/10.1016/j.jas.2013.01.002>
- Machado, J., Mayor, A., Hernández, C. M., & Galván, B. (2019). Lithic refitting and the analysis of Middle Palaeolithic settlement dynamics: A high-temporal resolution example from El Pastor rock shelter (eastern Iberia). *Archaeological and Anthropological Sciences*, 11, 4539–4554. <https://doi.org/10.1007/s12520-019-00859-8>
- Machado, J., Molina, F. J., Hernández, C. M., Tarrío, A., & Galván, B. (2017). Using lithic assemblage formation to approach Middle Palaeolithic settlement dynamics: El Salt stratigraphic unit x (Alicante, Spain). *Archaeological and Anthropological Sciences*, 9, 1715–1743. <https://doi.org/10.1007/s12520-016-0318-z>
- Machado, J., & Pérez, L. (2016). Temporal frameworks to approach human behavior concealed in Middle Palaeolithic palimpsests: A high-resolution example from El Salt stratigraphic unit x (Alicante, Spain). *Quaternary International*, 417, 66–81. <https://doi.org/10.1016/j.quaint.2015.11.050>
- Malinsky-Buller, A., Hovers, E., & Marder, O. (2011). Making time: ‘Living floors’, ‘palimpsests’ and site formation processes - A perspective from the open-air Lower Paleolithic site of Revadim Quarry, Israel. *Journal of Anthropological Archaeology*, 30, 89–101. <https://doi.org/10.1016/j.jaa.2010.11.002>
- Mallol, C. & Hernández, C.M. (2016). Advances in palimpsest dissection. *Quaternary International*, 417. <https://doi.org/10.1016/j.quaint.2016.09.021>
- Mallol, C., Hernández, C. M., Cabanes, D., Sistiaga, A., Machado, J., Rodríguez, À., Pérez, L., & Galván, B. (2013). The black layer of Middle Palaeolithic combustion structures: Interpretation and archaeostratigraphic implications. *Journal of Archaeological Science*, 40(5), 2515–2537. <https://doi.org/10.1016/j.jas.2012.09.017>
- Marin, M. D., Fagoaga, A., García, S., Ruiz, F. J., Mallol, C., Hernández, C. M., Galván, B., & Fernández, Y. (2021). Contribution of small mammal taphonomy to the last Neanderthal occupations at the El Salt site (Alcoi, southeastern Spain). *Quaternary Research*, 103, 208–224. <https://doi.org/10.1017/qua.2021.4>
- Marquina, R., Fagoaga, A., Crespo, V. D., Ruiz, F. J., Bailon, S., Hernández, C. M., & Galván, B. (2017). Amphibians and squamate reptiles from the stratigraphic unit xb of El Salt (Middle Palaeolithic; Alcoy, Spain): Palaeoenvironmental and palaeoclimatic implications. *Spanish Journal of Palaeontology*, 32(2), 291–312. <https://doi.org/10.7203/sjp.32.2.17045>
- Martínez-Moreno, J., Mora, R., & de la Torre, I. (2004). Methodological approach for understanding Middle Palaeolithic settlement dynamics at La Roca dels Bous (Noguera, Catalunya, Northeast Spain). In N. J. Conard (Ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age*. Vol. ii(pp. 393–414). Kerns Verlag.
- Martínez-Moreno, J., Mora Torcal, R., Roy Sunyer, M., & Benito-Calvo, A. (2016). From site formation processes to human behaviour: Towards a constructive approach to depict palimpsests in Roca dels Bous. *Quaternary International*, 417, 82–93. <https://doi.org/10.1016/j.quaint.2015.09.038>
- Martín-Viveros, J. I., Ollé, A., Chacón, M. G., Romagnoli, F., Gómez, B., Vaquero, M., Saladié, P., Vallverdú, J., & Carbonell, E. (2020). Use-wear analysis of a specific mobile toolkit from the Middle Paleolithic site of Abric Romaní (Barcelona, Spain): A case study from level M. *Archaeological and Anthropological Sciences*, 12, 16. <https://doi.org/10.1007/s12520-019-00951-z>
- Massilani, D., Morley, M.W., Mentzer, S.M., Aldeias, V., Vernet, B., Miller, C., Stahlschmidt, M., Kozlikin, M.B., Shunkov, M.V., Derevianko, A.P., Conard, N.J., Wurz, S., Henshilwood, C.S., Vasquez,

- J., Essel, E., Nagel, S., Richter, J., Nickel, B., Roberts, R.G. et al. (2022). Microstratigraphic preservation of ancient faunal and hominin DNA in Pleistocene cave sediments. *Proceedings of the National Academy of Sciences*, 119. <https://doi.org/10.1073/pnas.2113666118>
- Mayor, A. (2023). *Las pistas que nos dejaron: gestión del sílex y movilidad neandertal en la unidad estratigráfica VIII del abrigo de El Salt (Alcoi, Alacant)*. PhD dissertation, Universitat d'Alacant.
- Mayor, A., Hernández, C. M., Machado, J., & Mallol, C. (2020). On identifying Palaeolithic single occupation episodes: Archaeostratigraphic and technological approaches to the Neanderthal lithic record of stratigraphic unit xa of El Salt (Alcoi, eastern Iberia). *Archaeological and Anthropological Sciences*, 12, 84. <https://doi.org/10.1007/s12520-020-01022-4>
- Mayor, A., Hernández, C. M., Machado, J., Mallol, C., & Galván, B. (2019). El estudio tecnológico de conjuntos líticos paleolíticos desde la perspectiva del episodio de ocupación humana: Los casos de El Salt y El Pastor (Alcoi, Alacant). *Recerques Del Museu D'alcoi*, 28, 7–26.
- Mayor, A., Sossa-Ríos, S., Molina, F. J., Pérez, L., Galván, B., Mallol, C., & Hernández, C. M. (2022). An instance of Neanderthal mobility dynamics: A lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt rockshelter (Alcoi, eastern Iberia). *Journal of Archaeological Science: Reports*, 44, 103544. <https://doi.org/10.1016/j.jasrep.2022.103544>
- Mayor, A., Sossa-Ríos, S., Vaquero, M. & Hernández, C.M. (2024). Recycling and implications for Neanderthal productive strategies in the stratigraphic unit VIII of the El Salt rockshelter (Alcoi, Eastern Iberia). *Lithic Technology*, 1–18. <https://doi.org/10.1080/01977261.2024.2356952>
- Mears, P., Wilson, L. & Browne, C. (2022). Number or weight? The effects and implications of quantifying lithic raw material use in two different ways. *Journal of Archaeological Science: Reports*, 43103431. <https://doi.org/10.1016/j.jasrep.2022.103431>
- Mentzer, S. M. (2017). Rockshelter settings. In A. S. Gilbert (Ed.), *Encyclopedia of geoarchaeology* (pp. 725–743). Springer.
- Molina, F.J. (2015). *El sílex del Prebético y cuencas neógenas en Alicante y sur de Valencia: su caracterización y estudio aplicado al Paleolítico medio*. PhD dissertation, Universitat d'Alacant.
- Molina, F. J., & Mayor, A. (2023). Proveïment de grups caçadors i recol·lectors en dipòsits amb sílex ressedimentat: Mas del Batle (Alcoi, Alacant), una nova àrea de captació del litotipus Mariola. *Recerques Del Museu D'alcoi*, 32, 7–24.
- Molina, F. J., Tarrío, A., Galván, B., & Hernández, C. M. (2010). Áreas de aprovisionamiento de sílex en el Paleolítico medio en torno al Abric del Pastor (Alcoi, Alicante): Estudio macroscópico de la producción lítica de la colección Brotons. *Recerques Del Museu D'alcoi*, 19, 65–80.
- Molina, F. J., Tarrío, A., Galván, B., & Hernández, C. M. (2015). Estudio geoarqueológico de áreas de aprovisionamiento de sílex en el Prebético de Alicante: Los ejemplos de Penella (Alcoi) y La Fenassosa (Onil). In L. Alapont & F. E. Tendero (Eds.), *Actuacions sobre el patrimoni arqueològic de la Comunitat Valenciana* (pp. 13–27). Ajuntament de València.
- Molina, F. J., Tarrío, A., Galván, B., & Hernández, C. M. (2016). El sílex del Prebético de Alicante: Tipos, variabilidad y áreas de captación y talla del Pleistoceno. *Cuadernos De Prehistoria y Arqueología De La Universidad De Granada*, 26, 283–311.
- Mora, R., Roy-Sunyer, M., Martínez-Moreno, J., Benito-Calvo, A. & Samper, S. (2020). Inside the palimpsest: Identifying short occupations in the 497D level of Cova Gran (Iberia). In J. Cascalheira & A. Picin (ed.), *Short-term occupations in Paleolithic archaeology* (pp. 39–69). Springer. https://doi.org/10.1007/978-3-030-27403-0_3
- Morrow, T. A. (1996a). Bigger is better: Comments on Kuhn's formal approach to mobile tool kits. *American Antiquity*, 61(3), 581–590. <https://doi.org/10.2307/281842>
- Morrow, T. A. (1996b). Lithic refitting and archaeological site formation processes: A case study from the Twin Ditch site, Greene County, Illinois. In G. H. Odell (Ed.), *Stone tools: Theoretical insights into human prehistory* (pp. 345–373). Springer.
- Murray, T. (1999). A return to the Pompeii premise. In T. Murray (Ed.), *Time and archaeology* (pp. 8–27). Routledge.
- Murray, T. (2008). Paradigms and metaphysics, or “this is the end of Archaeology as we know it?” In S. Holdaway and L. Wandsnider (eds.), *Time in Archaeology. Time perspectivism revisited* (pp. 170–180). The University of Utah Press.
- Navazo, M., Santamaría, C., & Santamaría, M. (2023). Using cores as tools: Use-wear analysis of Neanderthal recycling processes in level 4 at Prado Vargas (Cornejo, Merindad de Sotoscueva, Burgos, Spain). *Lithic Technology*, 48(2), 149–167. <https://doi.org/10.1080/01977261.2022.2108276>
- O'Connell, J. F. (1987). Alyawara site structure and its archaeological implications. *American Antiquity*, 52, 74–108. <https://doi.org/10.2307/281061>

- Pederzani, S., Aldeias, V., Dibble, H. L., Goldberg, P., Hublin, J. J., Madelaine, S., McPherron, S. J., Sandgathe, D., Steele, T. E., Turq, A., & Britton, K. (2021). Reconstructing Late Pleistocene paleoclimate at the scale of human behavior: An example from the Neandertal occupation of La Ferrassie (France). *Scientific Reports*, *11*, 1419. <https://doi.org/10.1038/s41598-020-80777-1>
- Pérez, L. (2019). *Estrategias de subsistencia y dinámicas de asentamiento en los valles de Alcoy durante el Paleolítico medio: análisis zooarqueológico, tafonómico y paleoecológico de la secuencia arqueológica de El Salt (Alcoy, Alicante)*. PhD dissertation, Universitat Rovira i Virgili.
- Pérez, L., Hernández, C. M., & Galván, B. (2020). Bone retouchers from the Middle Palaeolithic site of El Salt, stratigraphic unit xa (Alicante, Spain): First data and comparison with the Middle to Upper Pleistocene European record. *International Journal of Osteoarchaeology*, *29*(2), 238–252. <https://doi.org/10.1002/oa.2732>
- Pettitt, P. (1997). High-resolution Neanderthals? Interpreting Middle Paleolithic intrasite spatial data. *World Archaeology*, *29*(2), 208–224. <https://doi.org/10.1080/00438243.1997.9980374>
- Pettitt, P. (2000). Neanderthal lifecycles: Development and social phases in the lives of the last archaics. *World Archaeology*, *31*(3), 351–366. <https://doi.org/10.1080/00438240009696926>
- Picin, A. & Cascalheira, J. (2020). Introduction to short-term occupations in Paleolithic archaeology. In J. Cascalheira & A. Picin (eds.), *Short-term occupations in Paleolithic archaeology* (pp. 1–15). Springer. https://doi.org/10.1007/978-3-030-27403-0_1
- Pop, E., Charalampopoulos, D., Arps, C. S., Verbaas, A., Roebroeks, W., Gaudzinski-Windheuser, S., & Langejans, G. (2018). Middle Palaeolithic percussive tools from the last interglacial site Neumark-Nord 2/2 (Germany) and the visibility of such tools in the archaeological record. *Journal of Paleolithic Archaeology*, *1*, 81–106. <https://doi.org/10.1007/s41982-018-0008-8>
- Rampelli, S., Turrioni, S., Mallol, C., Hernández, C. M., Galván, B., Sistiaga, A., Biagi, E., Astolfi, A., Brigidi, P., Benazzi, S., Lewis, C. M., Warinner, C., Hofman, C. A., Schnorr, S. L., & Candela, M. (2021). Components of a Neanderthal gut microbiome recovered from fecal sediments from El Salt. *Communications Biology*, *4*, 169. <https://doi.org/10.1038/s42003-021-01689-y>
- Reeves, J., McPherron, S., Aldeias, V., Dibble, H., Goldberg, P., Sandgathe, D., & Turq, A. (2019). Measuring spatial structure in time-averaged deposits insights from Roc de Marsal, France. *Archaeological and Anthropological Sciences*, *11*, 5743–5762. <https://doi.org/10.1007/s12520-019-00871-y>
- Rezek, Z., Holdaway, S. J., Olszewski, D. I., Lin, S. C., Douglass, M., McPherron, S., Iovita, R., Braun, D., & Sandgathe, D. (2020). Aggregates, formational emergence, and the focus on practice in stone artifact archaeology. *Journal of Archaeological Method and Theory*, *27*, 887–928. <https://doi.org/10.1007/s10816-020-09445-y>
- Rivals, F., Blasco, R., Rosell, J., Efrati, B., Gopher, A., & Barkai, R. (2021). Seasonality, duration of the hominin occupations and hunting grounds at Middle Pleistocene Qesem Cave (Israel). *Archaeological and Anthropological Sciences*, *13*, 205. <https://doi.org/10.1007/s12520-021-01460-8>
- Rodríguez de Vera, C., Herrera-Herrera, A. V., Jambriña-Enríquez, M., Sossa-Ríos, S., González-Urquijo, J., Lazuen, T., Vanlandeghem, M., Alix, C., Monnier, G., Pajović, G., Tostevin, G., & Mallol, C. (2020). Micro-contextual identification of archaeological lipid biomarkers using resin-impregnated sediment slabs. *Scientific Reports*, *10*, 20574. <https://doi.org/10.1038/s41598-020-77257-x>
- Rodríguez-Cintas, Á., & Cabanes, D. (2017). Phytolith and FTIR studies applied to combustion structures: The case of the Middle Paleolithic site of El Salt (Alcoy, Alicante). *Quaternary International*, *431*, 16–26. <https://doi.org/10.1016/j.quaint.2015.09.043>
- Roebroeks, W. (1988). *From find scatters to early hominid behaviour: A study of Middle Palaeolithic riverside settlements at Maastricht-Belvédère (the Netherlands)*. Leiden University Press.
- Romagnoli, F., & Vaquero, M. (2016). Quantitative stone tools intra-site point and orientation patterns of a Middle Palaeolithic living floor: A GIS multi-scalar spatial and temporal approach. *Quartär*, *63*, 47–60. https://doi.org/10.7485/QU63_3
- Romagnoli, F., Gómez de Soler, B., Bargalló, A., Chacón, M., & Vaquero, M. (2018b). Here and now or a previously planned strategy? Rethinking the concept of ramification for micro-production in expedient contexts: Implications for Neanderthal socio-economic behaviour. *Quaternary International*, *474*, 168–181. <https://doi.org/10.1016/j.quaint.2017.12.036>
- Romagnoli, F., Nishiaki, Y., Rivals, F. & Vaquero, M. (2018a). Time uncertainty, site formation processes, and human behaviours: New insights on old issues in high-resolution archaeology. *Quaternary International*, *474*(B), 99–102. <https://doi.org/10.1016/j.quaint.2018.04.033>
- Romagnoli, F., & Vaquero, M. (2019). The challenges of applying refitting analysis in the Palaeolithic archaeology of the twenty-first century: An actualised overview and future

- perspectives. *Archaeological and Anthropological Sciences*, 11, 4387–4396. <https://doi.org/10.1007/s12520-019-00888-3>
- Rosell, J., Blasco, R., Fernández-Laso, M. C., Vaquero, M., & Carbonell, E. (2012). Connecting areas: Faunal refits as a diagnostic element to identify synchronicity in the Abric Romaní archaeological assemblages. *Quaternary International*, 252, 56–67. <https://doi.org/10.1016/j.quaint.2011.02.019>
- Roy-Sunyer, M. (2015). Deconstructing archaeological palimpsests: Applicability of GIS algorithms for the automated generation cross sections. In S. Campana, R. Scopigno & G. Carpentiero (eds.), *Keep the revolution going: Proceedings of the 43rd annual conference on computer applications and quantitative methods in archaeology* (pp. 407–414). Archaeopress.
- Sánchez-Martínez, J., Mora, R., Martínez-Moreno, J., Roda, X., & Roy-Sunyer, M. (2022). Carrying rocks: Hoarding behaviour in the gravettian occupation of Cova Gran de Santa Linya (SE Pyrenees). *Journal of Archaeological Science: Reports*, 41, 103125. <https://doi.org/10.1016/j.jasrep.2021.103125>
- Sánchez-Romero, L., Benito-Calvo, A., Iriarte, E., San Emeterio, A., Ortega, I., & Ríos, J. (2022). Unraveling Châtelperronian high-density accumulations: The open-air site of Aranbaltza II (Bizkaia, Spain). *Archaeological and Anthropological Sciences*, 14, 77. <https://doi.org/10.1007/s12520-022-01541-2>
- Sánchez-Romero, L., Benito-Calvo, A., Marín, A. B., Agudo, L., Karampaglidis, T., & Ríos, J. (2020). New insights for understanding spatial patterning and formation processes of the Neanderthal occupation in the Amalda I cave (Gipuzkoa, Spain). *Scientific Reports*, 10, 8733. <https://doi.org/10.1038/s41598-020-65364-8>
- Sánchez-Romero, L., Benito-Calvo, A., Pérez, A., & Santonja, M. (2016). Assessment of accumulation processes at the Middle Pleistocene site of Ambrona (Soria, Spain): Density and orientation patterns in spatial datasets derived from excavations conducted from 1960s to the present. *Public Library of Science One*, 11(12), e0167595. <https://doi.org/10.1371/journal.pone.0167595>
- Sánchez-Romero, L., Benito-Calvo, A., & Ríos-Garaizar, J. (2021). Defining and characterising clusters in Palaeolithic sites: A review of methods and constraints. *Journal of Archaeological Method and Theory*, 29, 305–333. <https://doi.org/10.1007/s10816-021-09524-8>
- Sánchez-Romero, L., Canals, T., Pérez-González, A., Márquez, B., Mosquera, M., Karampaglidis, T., Arsuaga, J.L. & Baquedano, E. (2017). Breaking the palimpsest: an approach to the cultural sequence of Neanderthal occupation at the Navalmaíllo rockshelter, Pinilla del Valle (Spain). *Trabajos de Prehistoria*, 74(2). <https://doi.org/10.3989/tp.2017.12192>
- Sañudo, P., Blasco, R. & Fernández-Peris, J. (2016). Site formation dynamics and human occupations at Bolomor cave (Valencia, Spain): An archeostratigraphic analysis of levels I to XII (100–200 ka). *Quaternary International*, 417. <https://doi.org/10.1016/j.quaint.2015.09.044>
- Schiffer, M. (1972). Archeological context and systemic context. *American Antiquity*, 37(2), 156–165. <https://doi.org/10.2307/278203>
- Schiffer, M. (1983). Toward the identification of formation processes. *American Antiquity*, 48(4), 675–706. <https://doi.org/10.2307/279771>
- Shott, M. J. (1994). Size and form in the analysis of flake debris: Review and recent approaches. *Journal of Archaeological Method and Theory*, 1(1), 69–110. <https://doi.org/10.1007/BF02229424>
- Sistiaga, A., Mallol, C., Galván, B., & Summons, R. E. (2014). The Neanderthal meal: A new perspective using faecal biomarkers. *Public Library of Science One*, 9(6), e101045. <https://doi.org/10.1371/journal.pone.0101045>
- Sossa-Ríos, S., Mayor, A., Hernández, C. M., Bencomo, M., Pérez, L., Galván, B., Mallol, C., & Vaquero, M. (2022). Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula). *Scientific Reports*, 12, 15883. <https://doi.org/10.1038/s41598-022-20200-z>
- Spagnolo, V., Aureli, D., Martini, I., Ekberg, I., Boschin, F., Crezzini, J., Poggi, G., Boscato, P., & Ronchitelli, A. (2020b). Short and close in time: Overlapped occupation from the layer 56 of the Molare rock shelter (southern Italy). *Archaeological and Anthropological Sciences*, 12, 92. <https://doi.org/10.1007/s12520-020-01037-x>
- Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Toniello, G., Astudillo, F., Boschin, F., Boscato, P., & Ronchitelli, A. (2019). Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa - Taranto, southern Italy). *Quaternary Science Reviews*, 217, 169–193. <https://doi.org/10.1016/j.quascirev.2018.06.024>
- Spagnolo, V., Marciani, G., Aureli, D., Martini, I., Boscato, P., Boschin, F., & Ronchitelli, A. (2020a). Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the

- Oscurusciuto rockshelter (Ginosa, southern Italy). *Archaeological and Anthropological Sciences*, 12, 54. <https://doi.org/10.1007/s12520-019-00971-9>
- Speth, J. D., Meignen, L., Bar-Yosef, O., & Goldberg, P. (2012). Spatial organization of Middle Paleolithic occupation X in Kebara cave (Israel): Concentrations of animal bones. *Quaternary International*, 247, 85–102. <https://doi.org/10.1016/j.quaint.2011.03.001>
- Stevenson, M. G. (1985). The formation of artifact assemblages at workshop/habitation sites: Models from Peace Point in northern Alberta. *American Antiquity*, 50, 63–81. <https://doi.org/10.2307/280634>
- Stevenson, M. G. (1991). Beyond the formation of hearth-associated artifact assemblages. In E. M. Kroll (Ed.), *The interpretation of archaeological spatial patterning* (pp. 269–299). Springer.
- Tarriño, A., & Terradas, X. (2013). Materias primas líticas. In M. García & L. Zapata (Eds.), *Métodos y técnicas de análisis y estudio en arqueología prehistórica: De lo técnico a la reconstrucción de los grupos humanos* (pp. 439–452). Euskal Herriko Unibertsitatearen Argitalpen Zerbitzua.
- Turq, A., Roebroeks, W., Bourguignon, L., & Faivre, J. P. (2013). The fragmented character of Middle Palaeolithic stone tool technology. *Journal of Human Evolution*, 65(5), 641–655. <https://doi.org/10.1016/j.jhevol.2013.07.014>
- Vandavelde, S., Brochier, J. É., Desachy, B., Petit, C., & Slimak, L. (2018). Sooted concretions: A new micro-chronological tool for high temporal resolution archaeology. *Quaternary International*, 474, 103–118. <https://doi.org/10.1016/j.quaint.2017.10.031>
- Vaquero, M. (1999). Intrasite spatial organization of lithic production in the Middle Palaeolithic: The evidence of the Abric Romaní (Capellades, Spain). *Antiquity*, 73(281), 493–504. <https://doi.org/10.1017/S0003598X00065054>
- Vaquero, M. (2008). The history of stones: Behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. *Journal of Archaeological Science*, 35(12), 3178–3185. <https://doi.org/10.1016/j.jas.2008.07.006>
- Vaquero, M. (2012). Introduction: Neanderthal behaviour and temporal resolution of archaeological assemblages. In E. Carbonell (ed.), *High resolution archaeology and Neanderthal behavior: Time and space in level J of Abric Romaní (Capellades, Spain)* (pp. 1–16). Springer. https://doi.org/10.1007/978-94-007-3922-2_1
- Vaquero, M., Bargalló, A., Chacón, M.G., Romagnoli, F. & Sañudo, P. (2015). Lithic recycling in a Middle Paleolithic expedient context: evidence from the Abric Romaní (Capellades, Spain). <https://doi.org/10.1016/j.quaint.2014.05.055>
- Vaquero, M., Chacón, G. M., Fernández-Laso, M. C., & Rando, J. M. (2001). Intrasite spatial patterning and transport in the Abric Romaní Middle Paleolithic site (Capellades, Barcelona, Spain). In N. J. Conard (Ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age* (pp. 573–592). Kerns Verlag.
- Vaquero, M., Chacón, M. G., García, M. D., Gómez, B., Martínez, K., & Cuartero, F. (2012). Time and space in the formation of lithic assemblages: The example of Abric Romaní level. *J. Quaternary International*, 247, 162–181. <https://doi.org/10.1016/j.quaint.2010.12.015>
- Vaquero, M., Fernández-Laso, M. C., Chacón, M. G., Romagnoli, F., Rosell, J., & Sañudo, P. (2017). Moving things: Comparing lithic and bone refits from a Middle Paleolithic sites. *Journal of Anthropological Archaeology*, 48, 262–280. <https://doi.org/10.1016/j.jaa.2017.09.001>
- Vaquero, M., & Pastó, I. (2001). The definition of spatial units in Middle Palaeolithic sites: The hearth-related assemblages. *Journal of Archaeological Science*, 28, 1209–1220. <https://doi.org/10.1006/jasc.2001.0656>
- Vaquero, M., Rando, J. M., & Chacón, G. (2004). Neanderthal spatial behaviour and social structure: Hearth-related assemblages from the Abric Romaní Middle Palaeolithic site. In N. J. Conard (Ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age II* (pp. 367–392). Kerns Verlag.
- Vaquero, M., & Romagnoli, F. (2018). Searching for lazy people: The significance of expedient behavior in the interpretation of Paleolithic assemblages. *Journal of Archaeological Method and Theory*, 25, 334–367. <https://doi.org/10.1007/s10816-017-9339-x>
- Vaquero, M., Romagnoli, F., Bargalló, A., Chacón, M. G., Gómez, B., Picin, A., & Carbonell, E. (2019). Lithic refitting and intrasite artifact transport: A view from the Middle Paleolithic. *Archaeological and Anthropological Sciences*, 11, 4491–4513. <https://doi.org/10.1007/s12520-019-00832-5>
- Vermeersch, P. (2001). Middle Paleolithic settlement patterns in West European open-air sites: Possibilities and problems. In N. J. Conard (Ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age* (pp. 395–414). Kerns Verlag.

- Vidal-Matutano, P., Henry, A., & Théry-Parisot, I. (2017). Dead wood gathering among Neanderthal groups: Charcoal evidence from Abric del Pastor and El Salt (eastern Iberia). *Journal of Archaeological Science*, 80, 109–121. <https://doi.org/10.1016/j.jas.2017.03.001>
- Vidal-Matutano, P., Pérez, G., Hernández, C. M., & Galván, B. (2018). Macrobotanical evidence (wood charcoal and seeds) from the Middle Palaeolithic site of El Salt, eastern Iberia: Palaeoenvironmental data and plant resources catchment areas. *Journal of Archaeological Science: Reports*, 19, 454–464. <https://doi.org/10.1016/j.jasrep.2018.03.032>
- Villa, P. (1982). Conjoinable pieces and site formation processes. *American Antiquity*, 47(2). <https://doi.org/10.2307/279901>
- Villa, P., & Courtin, J. (1983). The interpretation of stratified sites: A view from underground. *Journal of Archaeological Science*, 10, 267–281. [https://doi.org/10.1016/0305-4403\(83\)90011-0](https://doi.org/10.1016/0305-4403(83)90011-0)
- Yellen, J. E. (1977). *Archaeological approaches to the present: Models for reconstructing the past*. Academic Press.
- Zilio, L., Hammond, H., Karampaglidis, T., Sánchez-Romero, L., Blasco, R., Rivals, F., Rufà, A., Picin, A., Chacón, M. G., Demuro, M., Arnold, L., & Rosell, J. (2021). Examining Neanderthal and carnivore occupations of Teixoneres cave (Moià, Barcelona, Spain), using archaeostratigraphic and intra-site spatial analysis. *Scientific Reports*, 11, 4339. <https://doi.org/10.1038/s41598-021-83741-9>

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4.3. Knapping...sleeping and consuming? Spatial variability in the high-resolution Neanderthal context of Abric del Pastor (Alcoi, eastern Iberia)

Knapping... sleeping and consuming? Spatial variability in the high-resolution Neanderthal context of Abric del Pastor (Alcoi, eastern Iberia)

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Abstract

Sequencing and characterising high-resolution units in which both natural and anthropogenic records can be examined on comparable scales is essential for understanding spatial behaviour and site formation processes. This requires a multidisciplinary approach that has previously been applied to the Neanderthal site of Abric del Pastor (Alcoi, eastern Iberia), revealing short-term occupations with high spatiotemporal resolution in stratigraphic unit IV, particularly focused on the lithic assemblages. In this study, we extend this methodological framework to stratigraphic unit V, investigating lithic record formation processes by applying archaeostratigraphic and spatial analyses, incorporating raw materials, technical attributes and refits. Additionally, this research integrates soil micromorphology and sedimentary *n*-alkane analysis to explore critical aspects of sedimentary formation processes. Specifically, these techniques were used to corroborate the presence of in situ hearths and rule out the possibility of erosional processes in the western sector of the rockshelter, where no archaeological materials were recorded. Our results, with refits as a benchmark, reveal at least two distinct stages of anthropogenic formation, characterised by recurring knapping activities primarily concentrated in the northern zone. These activities display internal variability in terms of flint type usage and activity intensity. Moreover, this knapping area is spatially segregated from three other zones: one containing a single hearth, close to the rockshelter wall, with no associated archaeological materials, possibly aligned with sleeping/resting purposes; another with a diachronic accumulation of faunal remains; and a third with an absence of archaeological record, in which postdepositional processes have not been detected. By identifying discrete formation events, we provide a detailed example of Neanderthal spatial variability, highlighting the deliberate use of certain zones for similar activities over time. This pattern contrasts with the spatial organisation of stratigraphic unit IV and other Neanderthal contexts, reflecting shifting strategies in the arrangement and use of space.

Keywords Neanderthal behaviour · Palimpsest · Lithic refitting · Archaeostratigraphy · Spatial analyses

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1. Introduction

Middle Palaeolithic spatial units play a pivotal role in deciphering Neanderthal behaviour (Vaquero, 2022), as they offer a valuable framework for interpreting the organisation of activities and interactions within sites with different types of records (e.g. lithic, faunal, charcoal remains) (e.g. Vaquero et al., 2012, 2022; Vidal-Matutano, 2017; Rosell et al., 2019; Bargalló et al., 2020; Sánchez-Romero et al., 2020, 2024; Moclán et al., 2023). In this sense, the hearth-related assemblage (*sensu* Vaquero & Pastó, 2001) is the most widely recognised spatial unit within Middle and Upper Palaeolithic sites with combustion evidence, where fire acts as a focal point around which humans carried out their activities (Binford, 1978; Stevenson, 1991), at least since the Middle Palaeolithic onwards. Furthermore, other spatial units have been identified in Neanderthal contexts, exhibiting notable variability, including secondary refuse areas of faunal remains (e.g. Speth, 2006; Gabucio et al., 2018; Starkovich et al., 2020) or lithic products (e.g. Spagnolo et al., 2019; Sossa-Ríos et al., 2024), sleeping zones (e.g. Henry et al., 2004; Vallverdú et al., 2010; Spagnolo et al., 2019, 2020), or storage places (e.g. Uthmeier et al., 2020).

However, the understanding of spatial organisation remains incomplete without addressing its interplay with the temporal dimension, particularly because the palimpsest effect is inherent in nearly all archaeological sites (Bailey, 1983, 2007, 2008; Stern, 2008; Lucas, 2008; Vaquero, 2012). The accumulation of overlapping and/or interweaved events, either human or natural, hampers the process of isolating discrete spatial units within larger assemblages. As a result, it may produce a homogeneous and misleading picture of the archaeological space-time, where all activities appear to have occurred everywhere and at all times. Additionally, palimpsests can obscure spatial units with scarce material records and hinder comparisons with ethnographic data, which often operates on a human timescale. These challenges make the reconstruction of the diachronic history of archaeological deposits, and thus of the human groups that generate them, a particularly demanding task.

Specifically, when studying lithic assemblages, these temporal challenges are even more evident. We must acknowledge from the outset that their formation likely involved multiple depositional episodes, mostly represented by single products (Vaquero, 2008; Turq et al., 2013; Dibble et al., 2017). This awareness implies that any behavioural interpretations are constrained by the limitations of temporal resolution (Vaquero, 2001, 2008). Therefore, it becomes essential to search for diachrony markers within the assemblage that might help differentiate and contextualise events, or groups of events, across time and space.

But does this mean that we must only be interested in isolated events to understand past behaviour? Our recent research argues otherwise (Sossa-Ríos et al., 2024): the goal is not merely to isolate events, but to order and sequence them. This sequential understanding—determining what occurred first and what followed—is fundamental not

only for capturing the nuances of human behavioural variability, but also for detecting the continuity of certain behavioural patterns or the emergence of new behavioural dynamics. The process of analysis remains the same for both questions, offering insights into both change and persistence across time and space. For example, while one type of flint may constitute 80% of an assemblage, this does not imply that it was introduced uniformly over time. In fact, this flint could have been massively transported in only one or a few events, becoming a high but biased percentage of the total of human actions, as De Lange (2008: 155) showed in her model for faunal assemblages, and Vaquero et al. (2012) for lithic assemblages. Thus, from being the constant pattern, it would become the indicator of variability. Both behavioural continuity/staticity and variability/dynamism require testing, and any hypothesis of time averaging must be carefully scrutinised and, if possible, rejected.

Delving into more detail, when examining time within a lithic assemblage, two information flows are ideally encountered: direct and indirect diachrony indicators. The former are particularly valuable as they allow time to be observed as empirical data: several centimetres of sedimentation separate two events of human activity, one below, the other above, with those centimetres representing a temporal lapse between groups of events. However, indirect markers offer a different perspective, especially as they tend to be horizontally shaped: Does a cluster of artefacts constitute a different temporal unit from a cluster positioned two metres away? Or does a concentration of a flint type signify a distinct timeframe compared to another dispersed flint assemblage? There is no empirical basis to confirm these temporal distinctions directly. Behavioural aspects can be tentatively inferred and compared with experimental or ethnoarchaeological studies, and formation models can provide additional context (e.g. Stevenson, 1985; Sullivan, 1992), but there is no straightforward relationship between time as a variable and the observed archaeological data. However, these indirect indicators can be highly informative, particularly in cases where direct markers are scarce or absent, enabling archaeologists to develop and test hypotheses about assemblage formation, such as bidirectional movements of refitted artefacts to test contemporaneity (Vaquero et al., 2017; 2019). Thus, both direct and indirect flows of information are essential when reconstructing the formation processes of lithic assemblages, with one important nuance: not all movements within an assemblage are the result of human action.

In this regard, archaeostratigraphy has proven useful in determining these sequences by identifying material gaps within vertical point-patterns (Canals et al., 2003; Galobart & Canals, 2003; Bargalló et al., 2016; Machado et al., 2017; Sánchez-Romero et al., 2017; Spagnolo et al., 2020; Sossa-Ríos et al., 2024). However, using point-patterns alone without considering archaeological information can be problematic for the definition of units of analysis that may have undergone postdepositional alterations. To address this issue, one of the most common solutions in lithic studies is to link remains through refit

connections (Vaquero et al., 2012, 2019; López-Ortega et al., 2019; Romagnoli & Vaquero, 2019). This approach has not only refined the isolation of higher-resolution units, but has also helped to detect vertical movements, such as refit connections between different material beds (e.g. Villa, 1982; Hofman, 1986; Morrow, 1996). While refits are instrumental in identifying movements, other variables can further explain them. For instance, size and weight can help to assess whether remains have been sorted by size or weight, which would vary based on factors like the type of matrix or surface topography (e.g. Baker, 1978; Villa & Courtin, 1983; Gifford-González et al., 1985; McPherron et al., 2014; Marwick et al., 2017).

As we stated before, even within an archaeostratigraphic unit, the spatial dimension of lithic assemblages remains temporally ambiguous, with different human and non-human agents acting during the period of surface exposure, sometimes reaching more than centuries (e.g. Herrejón-Lagunilla et al., 2024). In the case of space, there have been a growth of contributions investigating not only the distribution of activities and their interrelationships (e.g. López-Ortega et al., 2011; Vaquero et al., 2017; Spagnolo et al., 2019, 2020; Sánchez-Romero et al., 2020, 2024), but also the postdepositional processes that may have occurred horizontally. Here, lithic orientation, size and weight, when correlated with more general factors such as palaeosurface reconstructions, can be useful for assessing the taphonomy of the record involved (e.g. Bertran et al., 2012, 2019; Sánchez-Romero et al., 2023). On the other hand, we have seen that hearths are the most common focus for human activities. However, fire can also act as a spatial modifier, as fire activity is capable of displacing lithics up to 3 metres from their original location when they are on the surface at the time of combustion (Dorta et al., 2010; Nieto-Márquez & Baena, 2015; Frank & Baridón, 2021).

These advances have significantly improved our understanding of how hunter-gatherers managed the site, shedding light on the variability between areas and activities developed within them over time. Additionally, they have highlighted that both vertical and horizontal distributions are influenced by non-human factors, which can be recognised and isolated through lithic and spatial taphonomy. However, this is not always enough. Other alterations affecting the record must also be considered when analysing and interpreting lithic assemblages. Both macroscopic and microscopic geoarchaeological observations are critical for evaluating the general and specific sedimentary contexts in which lithics are found (Karkanas & Goldberg, 2018). This approach has gained much attention, for instance, by warning of the possibility of vertical movements not only from top to bottom (e.g. Canti, 2003; Araujo, 2013) but also from bottom to top (e.g. Luria et al., 2020).

Even with the aforementioned advances, few lithic studies have successfully integrated the human-generated record with the sedimentary context in which it is embedded (e.g. Machado et al., 2013; Spagnolo et al., 2019; Sánchez-Romero et al., 2022). This task is essential before exploring any behavioural insights occurring

at the site (Bertran et al., 2019; Sánchez-Romero et al., 2022), especially when lithic data alone may offer limited information. Moreover, tracing the dynamic composition and spatiotemporal dimension of the lithic record requires specific contextual conditions that mitigate the intrinsic uncertainties of archaeological assemblages. In this regard, two factors are particularly advantageous. First, sites where nearly complete surfaces have been excavated enable us to reconstruct more reliable scenarios, such as the intrasite movement of artefacts connecting different areas. Second, assemblages characterised by low material density inherently reduce the degree of time averaging, thus facilitating the isolation of high-resolution units. Together, these conditions allow for a more accurate integration of lithic data with its spatiotemporal context, building a robust foundation for exploring behavioural patterns.

The Middle Palaeolithic site of Abric del Pastor (Alcoi, eastern Iberia) meets these essential criteria, making it particularly well-suited for tackling the challenges posed by the palimpsest effect. In previous studies, SU IV was defined as an example of low-density assemblages in which high-resolution units were isolated and characterised using various methods, at different scales, over a representative area (Machado et al., 2013, 2019; Mallol et al., 2019; Sossa-Ríos et al., 2022). In this study, we present a multidisciplinary investigation focusing on the formation processes of the lithic assemblages of SU V. This includes the analysis of lithic attributes, raw material sourcing, refitting, archaeostratigraphy and spatial distribution.

Additionally, we have incorporated geoarchaeological techniques: soil micromorphology and sedimentary *n*-alkane analysis. The application of these multiscale methods is critical for accurately interpreting the formation and distribution of lithic assemblages, and particularly for assessing specific key field questions. First, the western part of the surface displays an apparently homogeneous deposit, primarily composed of massive, calcitic yellow sand, and calcareous gravel. This area showed no evidence of anthropogenic activity, with only a few isolated archaeological materials recorded over the 2018-2023 excavation seasons (ca. 20 cm-depth). Thus, understanding the geoarchaeological genesis of this deposit is essential for exploring the possible reasons behind the lack of anthropogenic activity in this area. By disentangling the main sedimentary formation processes, we could gain a clearer understanding of the actual agency/role played by human groups that occupied the site (Schiffer, 1972, 1983, 1985). Second, fire activity was only recognised in a limited area near the wall, where a clear combustion structure consisting of black and red layers (i.e. H19) was documented during excavation. However, additional traces of combustion were detected above and below this hearth (i.e. H18 and H20), although these were less well-defined. Therefore, determining the number of fire episodes within the SU V is crucial for two main purposes: 1) associating specific lithic assemblages with one or more fire events, both vertically and horizontally, and 2) evaluating the possibility of multiple hearths existing in the same space, but linked with different moments. Investigating fire,

known as the primary spatial organiser of hunter-gatherer groups (e.g. Binford, 1978; Stevenson, 1991; Vaquero & Pastó, 2001), through its sedimentary record can help complement and refine the scale offered by the vertical point-pattern and the features of associated materials.

By addressing the challenges posed by the temporal and spatial dimensions of lithic assemblages, alongside the complexities of the sedimentary record, this study seeks to advance the interpretative frameworks for understanding Neanderthal spatial behaviour and the formation processes of archaeological assemblages.

2. The Abric del Pastor Middle Palaeolithic site

The Abric del Pastor site is located within the Serra de Mariola natural park, in the municipality of Alcoi (eastern Iberia) (Fig. 1). Positioned at an elevation of 820 m.a.s.l., this rockshelter lies on an escarpment within the eastern foothills of the Mariola mountain range. It is situated on the left side of the El Cint ravine, which links to the upper and middle courses of the Benissaidó river (Galván et al., 2009; Machado et al., 2013, 2019). From a geomorphological perspective, the rockshelter is a partially eroded karstic tube generated during the Tortonian Miocene, characterised by alternating layers of Cretaceous dolomitic limestone and Serravallian Miocene limestone-cobble conglomerates (Molina et al., 2010). The erosion process that led to the formation of the rockshelter took place during the Pleistocene, associated with the incision and phreatic activities of the Benissaidó river.

The first intervention was conducted by M. Brotons, who excavated the site in 1951 and 1953. These excavations, restricted to a few square metres, revealed several Middle Palaeolithic remains coming from the SU I, a reworked Holocene unit that partially eroded the upper sections of SUs II and III (Galván et al., 2009). After this, two other interventions were carried out with the aim of contextualising the work previously developed by Brotons, the excavation of A. Seguí in 1967 and that of J.M. Segura and E. Cortell in 1972 by the Museu Arqueològic Municipal Camilo Visedo Moltó. In 2005, the excavations were restarted by B. Galván, C.M. Hernández and C. Mallol covering the current area. Since that time, the site has been excavated every year so far by the University of La Laguna and national and international researchers.

The site offers a potential occupation surface of 60 m², with 40 m² currently under excavation. Up to now, the stratigraphic sequence measures 1.6 m-thick and is divided into six stratigraphic units (SUs), labelled VI-I from bottom to top, with a chronometric range for the Pleistocene sequence (SU VI to II) of 63 ± 5 ky BP to 48 ± 5 ky BP (see Connolly et al., 2019 and Mallol et al., 2019 for a detailed description of each unit).

SU V was excavated between the 2018 and 2023 field seasons. Although SU V lacks direct chronometric data, it is presumably older than the OSL date from SU IVd (63 ± 5 ky BP). With a thickness varying from 15 to 30 cm, this unit consists of matrix-supported blocks, gravels and reddish calcareous sands in the southeastern and central zones, with gravels and reddish sands in the northern

and southern parts, while the western zone is composed of calcareous, yellowish massive sands. Previous micromorphological analysis on a thin section from the test pit showed that SU V is composed of a calcitic matrix, with the occasional presence of iron oxides and clay coatings. On the other hand, this unit presents the lowest organic content of the archaeological sequence, based on the concentration of *n*-alkanes and the total organic carbon index (TOC) (Connolly et al., 2019).

At the time of formation of this unit, the site featured, inside the main 6.95 m-high shelter covering almost the entire surface (i.e. Drip Line in Fig. 2), a limestone ledge in the east (1.5 m-high), which collapsed during the early stages of SU IV formation (i.e. Collapsed Ledge in Fig. 2 and Fig. S1). From the latter, a small sheltered zone is still preserved in the southeast (3 m²).

3. Materials and methods

For this work, we analysed the lithic assemblage from SU V, consisting of 147 products. Additionally, we considered the X, Y, Z coordinates of the lithic (*n* = 147) and faunal (*n* = 300) assemblages, as well as the potential combustion structures for archaeostratigraphic and spatial analyses, recorded using Sokkia iM-50 Series and Leica Geosystems FlexLine TS02 total stations. While our objective was to record all lithic artefacts regardless of their size, some pieces were recovered through water screening. None of these pieces exceed 20 mm, and despite conducting two separate refitting attempts, none could be linked to the established refitting sequences. Moreover, given that this study focuses primarily on the temporal dimension provided by the Z coordinate, we decided not to include these materials in the analysis.

On the other hand, five sediment blocks were taken for soil micromorphology, and six sediment samples were collected for *n*-alkane analysis.

3.1. Lithic record

Raw material analysis

The entire lithic assemblage was analysed both macroscopically and by means of a Euromex DZ 1600 and a Euromex EduBlue 1802-S stereomicroscopes, both visualised using the Euromex ImageFocus Plus software, version 2.4.9.0. The first step involved examining the primary genetic traits exhibited by each lithic element (*sensu* Fernandes & Raynal, 2006). For the limestone, these characteristics were just described. For the flint, these traits allowed us to identify the specific lithotypes to which the lithic specimens belonged. These siliceous lithotypes had been previously recognised, described, and defined in studies conducted in the eastern Prebaetic system and associated Neogene basins, such as the Serpis or the Vinalopó river valleys (Molina, 2016; Molina et al., 2010, 2014, 2016). Additionally, we have also observed the postgenetic traits, that is, those produced by alterations occurred after the flint release from the host-rock, in order to use them in the identification of raw material units (i.e.

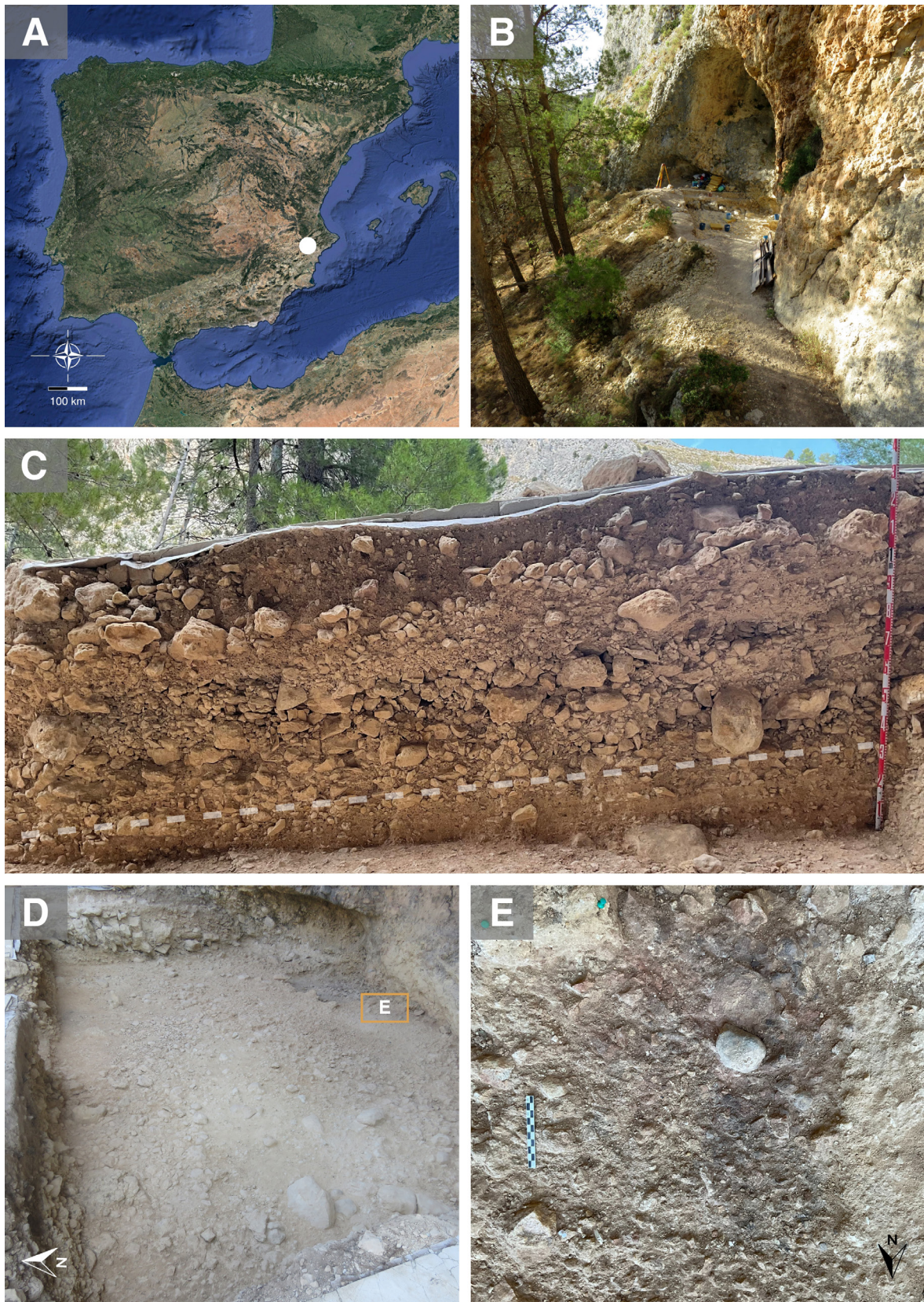


Fig. 1 Location of the Abric del Pastor site in the Iberian Peninsula (A), General view of the rockshelter from the west (B), View of the North profile. SU V is the brown, finer-grained layer at the bottom (C), 2022 excavation surface (D), Dark gray area classified as H19 (E).

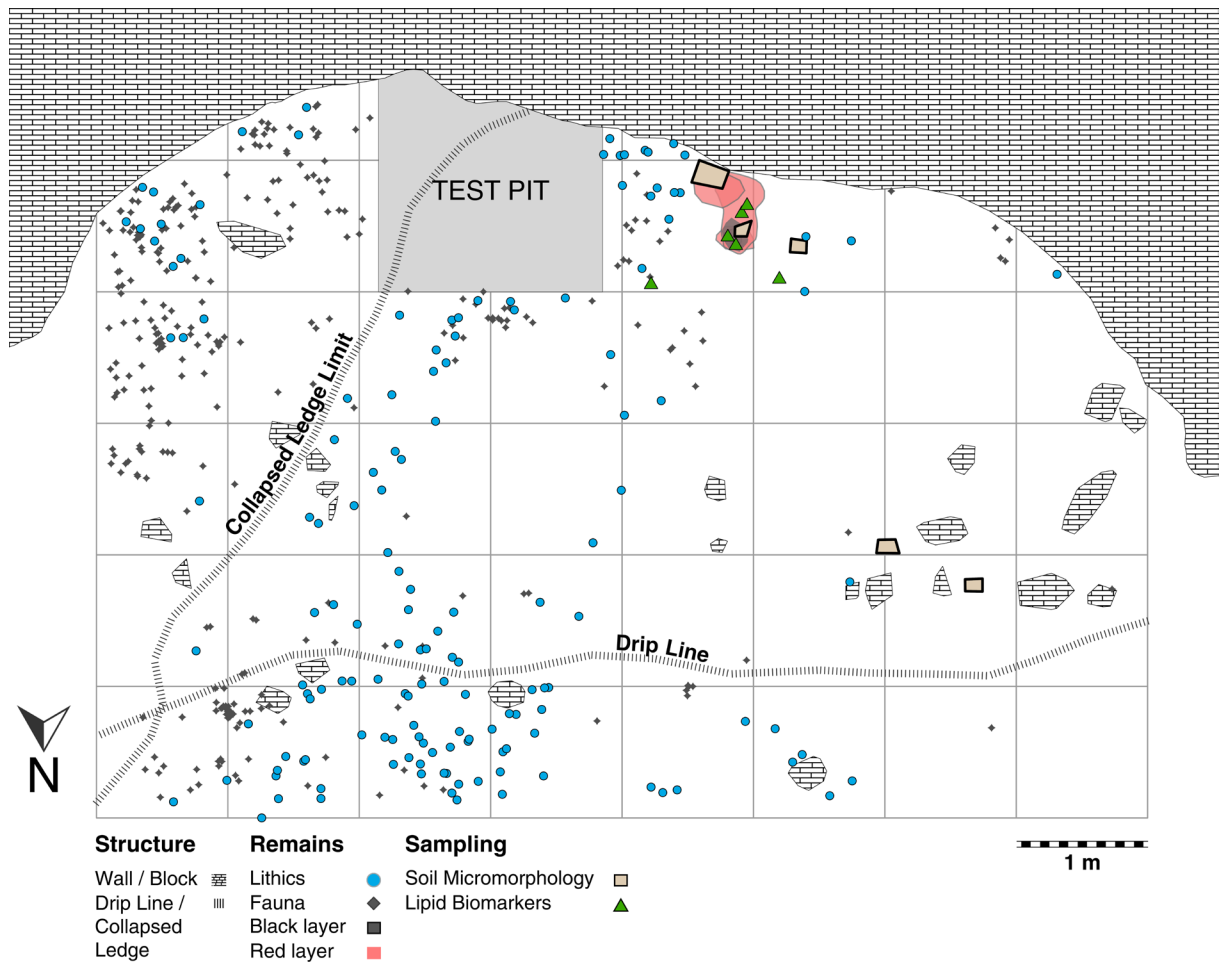


Fig. 2 Plan of the site showing the position of structural elements, archaeological remains and sediment samples.

RMU), as explained below.

In this vein, the genetic features used to identify the flint lithotypes within the assemblage included matrix colour and texture; cortex colour, texture, and thickness; subcortical and endocortical halos; inclusions (e.g. fossils and microfossils, biogenic structures, megaquartz). The characteristics of the siliceous lithotypes appearing in this paper (i.e. Serreta, Mariola, Beniaia, and Catamarruc) have already been published, as mentioned earlier (see Machado et al., 2017; Mayor et al., 2022; Molina et al., 2016).

Additionally, we focused on two types of alterations observed in some flint elements: thermal alteration and white patina formation. On the first hand, thermoalterations were identified based on macroscopic indicators that had been previously defined through experimental studies, compared with the archaeological record, and published (Dorta et al., 2010). These features include chromatic and textural changes, reticular fissures, thermal domes, irregular fractures, and glossy surfaces. On the other hand, the formation of white patina has been associated with the exposure of flint to weathering processes (Fiers et al., 2018; Thiry et al., 2014), as well as its presence in acidic, calcite-rich deposits (Rottländer, 1975). In the Serpis river basin, this phenomenon has been

notably observed in flint that has redeposited in colluvial environments, where it occurs with particular intensity (Mayor et al., 2024; Molina & Mayor, 2023; Molina et al., 2015).

Once the genetic traits and the aforementioned signs of alteration were described, we proceeded with the RMU identification (Roebroeks, 1988; for minimum analytical nodule, see Larson & Kornfeld, 1997). Each element was compared to the rest of the assemblage to recognise matches in their traits, whether geogenic or postgenetic. When two or more flint artefacts exhibited a high degree of similarity and coincidence, they were grouped together as a set RMU (i.e. S-RMU). Since an RMU represents the outcome of knapping a single raw material nodule, any element that did not match with others was classified as a single-element RMU (i.e. SE-RMU), and thus considered as the potentially sole product of a single raw material nodule (Sossa-Ríos et al., 2022, 2024).

Lithic attribute analysis

The lithic assemblage was analysed based on specific qualitative and quantitative attributes. First, each lithic element was classified according to artefact type (i.e. flake, retouched product, core, fragment, or unmodified nodule).

The next step involved acquiring metric data from the artefacts. For flakes, maximum length, width, and thickness were measured, considering their technical axes. For the remaining elements, the maximum possible dimension was recorded as the length. Taking this axis as reference, the widest horizontally transversal line was considered the width, and the thickest vertically transversal measure was taken as the thickness. These measurements allowed us to establish different typometric groups based on the product of length and width: very small (i.e. <500 mm²), small (i.e. 500-1,000 mm²), medium-sized (i.e. >1,000-1,500 mm²), large (i.e. >1,500-2,000 mm²), and very large (i.e. >2,000 mm²), following the criteria outlined by one of us (Vaquero, 2008).

Additionally, each element was weighed and grouped according to the results of the Jenks natural breaks classification method, which identifies groups in the data by maximising the differences between classes and minimising the variance within them (Jenks, 1967). Weight has proven to be a more appropriate variable to investigate changes in mass introduction (Sossa-Ríos et al., 2024).

Subsequently, the approximate proportion of cortex present on flakes was estimated. These percentages were grouped into ranges based on quarters: 0%, >0-25%, >25-50%, >50-75%, >75-<100%, and 100% (Mayor et al., 2022).

In the case of cores and flakes, we followed established technological approaches aimed at reconstructing knapping methods, strategies, and modalities (Boëda, Geneste & Meignen, 1990; Pelegrin, 1990; Boëda, 1995). For flakes, the analysis focused on variables such as the number and orientation of dorsal scars, and platform and bulb characteristics. Cores underwent a more detailed evaluation, considering the organisation and hierarchy of surfaces, the type and preparation of striking platforms, and the number and orientation of removals. This analytical framework enabled the general identification of knapping systems, including the presence and variability of Levallois and non-Levallois methods, as well as the degree of fragmentation in the operative sequences.

Lithic refitting analysis

Once the assemblage was separated into SE-RMUs and S-RMUs, we undertook the task of connecting lithic products. This process is critical to gain confidence in the identification of S-RMUs by physical joining, but also to increase our knowledge of technical and technological aspects, as well as the vertical and horizontal distribution of knapping activities (Cziesla, 1990; Vaquero et al., 2017, 2019; Machado et al., 2019; Romagnoli & Vaquero, 2019; Martínez-Moreno et al., 2019; Baena et al., 2019).

We distinguish between two types of connections. Refits, which are considered to be links associated with production sequences, and conjoins, understood as product joints resulting from either syndepositional or postdepositional fractures. We generated connection lines for both refits and conjoins, and calculated the number of elements involved, the number of connections by lines, and their lengths (minimum, maximum, mean, and

standard deviation) for each flint type and R-RMU (i.e., products physically connected within an S-RMU, whether refits or conjoins).

The connection lines were drawn based on the chronological sequence of removal events for refits, and on the artefact surface contact for conjoins. All this information may provide clues, for example, to the movement of certain products between activity areas, the position of the knapper (e.g. standing or sitting), or postdepositional disturbances (e.g. Vaquero et al., 2017; Newcomer & Sieveking, 1980; Bertran et al., 2012; Arilla et al., 2020).

For the refitting task, we spent two months, the first at Universitat de València and the second at the Interdisciplinary Center of Archaeology and the Evolution of Human Behaviour (i.e. ICArEHB), with different attempts for each product and involving different people.

Archaeostratigraphic analysis

The archaeostratigraphic analysis was applied with the aim of detecting possible material hiatuses that can separate the entire assemblage into higher resolution units of analysis (e.g. Martínez-Moreno et al., 2004, 2016; Sánchez-Romero et al., 2017, 2023; Spagnolo et al., 2020; Arteaga-Briebea et al., 2023). All the following steps were performed using ArcGIS Pro 3.1.0.

First, the entire assemblage was plotted in 3D for visualising the overall and specific point-pattern, since 2D analysis implies a serious lack of perspective (Roy-Sunyer, 2015; Sánchez-Romero et al., 2017). This process continues throughout the entire vertical examination, as each cross-section is constantly visualised and subjected to a qualitative analysis in this manner (Machado et al., 2013; Sossa-Ríos et al., 2024). Second, Kernel Density Estimation (KDE) (see Spatial analyses for further explanation) was horizontally conducted for lithic and faunal assemblages in order to observe the areas where most materials were involved and thus placing the 2D cross-sections. Taking into account the areas of major accumulation of artefacts, we selected the profiles and applied a thickness of 0.50 m due to the low density of the assemblage, in order to represent the largest possible number of materials without losing perspective. For the lithic assemblage, we combined the visualisation of RMUs, both single and refitted, with weight, patina and edge damage within the 2D cross-sections, for compositional and taphonomic assessments (Baker, 1978; Villa, 1982; Stevenson, 1985; Gifford-González et al., 1985; Rose et al., 2024). For analysing the vertical relationships of R-RMUs, the connecting lines were also displayed in 3D, as this visualisation saves the need to generate many 2D cross-sections when including all the refitted sets (e.g. Sánchez-Romero et al., 2024).

Finally, we applied the ordinary Kriging interpolation method to generate a palaeosurface that enhances the understanding of the archaeostratigraphic cross-sections (e.g. Oliver & Webster, 1990; Hageman & Bennett, 1999; Sánchez-Romero et al., 2020, 2023; Arteaga-Briebea, 2024). This method estimates values at unsampled points by considering spatial autocorrelation, using both

the coordinates of the archaeological remains and the coordinates obtained to control the topography of the surface, recorded horizontally at 0.5 m intervals.

Spatial analyses

The spatial analyses were applied to determine the distribution patterns of the lithic record and establish units of analysis that can offer insights into spatial assemblage variability (Clark, 2017, 2019; Sánchez-Romero et al., 2022, 2024; Arteaga-Bribea et al., 2023). All the following tests were performed using Esri ArcGIS Pro, version 3.1.0.

First, Average Nearest Neighbour (ANN) was applied to the lithic assemblages considering the excavated area (i.e. 40 m²). This test shows the general spatial pattern exhibited by the X-Y points, discerning between clustered, random, or dispersed (Whallon, 1974; Romagnoli & Vaquero, 2016; Sánchez-Romero et al., 2022). The homogeneous Ripley *L*-function was then applied to the lithic record to identify the spatial scale, in terms of distance, at which clustering or dispersion occurs (Besag, 1977). This transformation of the *K*-function (Ripley, 1977) linearised the results, making it easier to detect deviations from randomness. The observed *L*(*d*) values are compared against an envelope created by simulating random spatial distributions. This provides a more comprehensive view of clustering and dispersion across different spatial scales, allowing the identification of statistically significant patterns (Lee, 2023). Third, Kernel Density Estimation (KDE) was conducted with Euclidean distance with a search radius of 0.9 m. This method estimates the distribution of archaeological remains over a defined space, creating a continuous raster that highlights areas with higher and lower concentrations of materials (Spagnolo et al., 2019, 2020; Sánchez-Romero et al., 2022; Zilio et al., 2021). We applied this for lithics, but also for faunal remains, since their analysis was necessary for placing the archaeostratigraphic cross-sections, and also for allowing comparisons in the use of space.

Two additional tests were applied to detect spatial clusters with the aim of exploring in depth the composition of the lithic assemblages. On the one hand, Density-Based Clustering (DBSCAN) was performed using the self-adjustment clustering method (HDBSCAN) and considering a minimum of 10 points for clustering. This analysis identifies both clusters and “noise” (i.e. artefacts located in areas where local point density is too low to meet the clustering criteria) by evaluating the spatial distribution of the dataset without predefine the number of clusters (Mikhailova et al., 2019; Murugesan et al., 2021; Díaz-Rodríguez & Fábregas-Valcarce, 2022). The probability threshold for clustering was set at ≥ 0.66 , considering the need to balance inclusivity and precision in identifying significant clusters within this low-density assemblage. This threshold provides a moderate level of stringency that captures a substantial number of points while minimising the inclusion of “noise”. On the other hand, Optimised Hot Spot Analysis (Getis-Ord *G*_i^{*}) was applied to calculate the number of artefacts by square, considering a fishnet composed of 0.74 m² squares. This grid measure was calculated following the Quadrat

Method, in which the size of each of the quadrants is calculated based on the extent of the area and the number of artefacts (Getis, 1964; Lee & Wong, 2001; Sánchez-Romero, 2019). This method was also applied to the weight variable to detect possible sorting by mass. The Optimised Getis-Ord *G*_i^{*} offers a high statistical confidence in the identification of spatial clustering also without having to define the radius and the number of clusters in advance (Sánchez-Romero et al., 2022; Arteaga-Bribea, 2024).

Moreover, we conducted a Chi-square, Fisher exact and Cramer’s V tests to explore the interdependence between the archaeological remains (both lithics and fauna) and their positioning in certain areas of the site. These tests were conducted to assess whether the observed distribution of materials was significantly different from what would be expected by chance.

Finally, several variables were displayed for qualitative analyses: white patina and edge damage, weight, raw material, type of product and thermal alteration. Furthermore, we applied the Jenks natural breaks classification method to categorise lithic artefacts by weight, forming groups that minimise variance within each class, while maximising variance between classes, based on the dataset itself (e.g. Jenks, 1967; Benito-Calvo et al., 2015; Sánchez-Romero et al., 2021).

3.2. Sedimentary record

Soil micromorphology

Five undisturbed, oriented sediment blocks were collected from two different locations of the rockshelter (Fig. 2). Three blocks were collected from the combustion area, in order to assess the presence of a single or multiple combustion structures (H18, H19 and H20). Two other blocks were sampled from the massive sandy deposit located at the western area of the site, with the aim of assessing its main formation processes and integrity. This selection of sampling areas was specifically designed to address these targeted field questions. Broader geoarchaeological data regarding the general formation processes at SU V have already been published by Connolly et al. (2019).

The micromorphology blocks were processed at the Archaeological Micromorphology and Biomarkers Lab (AMBILAB, University of La Laguna, Tenerife, Spain). First, the blocks were dried for 48h at 60 °C, and then impregnated with a 7:3:0.1 v/v/v/ ratio mixture of polyester resin (palatal cast resin UN1866, TNK compounds), styrene (styrene monomer (CAS: 100–42–5) UN2055, TNK compounds) and catalyst (methyl ethyl ketone (Luperox, CAS: 78–93–3), TNK compounds). The hardened blocks were cut into 1-cm-thick slabs using a Euro-Shatal M31100 radial saw. These slabs were then transformed into 8 thin sections (7cm x 4cm x 30µm) at Spectrum Petrographics (Vancouver, Washington, USA).

For micromorphological analysis, petrographic microscopes Nikon E600-POL and Nikon AZ100 were used, both located at AMBILAB. The samples were analysed under plane-polarised light (PPL) and cross-polarised light (XPL). Microphotographs were taken using

a Basler acA2400 camera. Thin sections were analysed and described following the standard guidelines provided by Stoops (2003), and Nicosia & Stoops (2017).

n-alkanes

Bulk sediment samples were collected from the black layer (BL) and red layer (RL) of H19. For H20, a blackish sediment beneath H19 was identified and sampled as a possible black layer, with the underlying sediment sampled as a potential red layer. Control samples were also collected from the natural substrates of the potential combustion structures. No samples were collected from H18 due to insufficient sediment with signs of combustion for analysis. All the samples were recovered with solvent-washed metal tools using nitrile gloves, packed in aluminium foil, and stored at $-20\text{ }^{\circ}\text{C}$ until further processing.

Sediment samples were oven-dried at $60\text{ }^{\circ}\text{C}$ for 48h and homogenised using an agate mortar and pestle. Lipids were extracted from 10 g of sediment using a dichloromethane and methanol mixture (DCM: MeOH, 3:1, v/v, 40 mL) through ultrasound-assisted extraction in 3 cycles of 30 minutes each. The total lipid extract was fractionated into three different polarity fractions through a silica gel column (1 g activated silica 70-230 mesh, 0.1 g sand 50-70 mesh and glass wool in a Pasteur pipette) using several mobile phases. In this study, we present results of fraction 1 (F1: *n*-alkanes), which was eluted with $\frac{3}{8}$ of the dead volume ($\sim 1.5\text{ mL}$) in hexane. The fraction extracts were subsequently evaporated under a stream of N_2 at $40\text{ }^{\circ}\text{C}$ and re-dissolved in $50\text{ }\mu\text{L}$ of hexane. Prior to measurement, $1\text{ }\mu\text{L}$ of 5α -androstane (8 mg/L in DCM) was added as an internal standard (IS). The extracts were analysed by gas chromatography-mass spectrometry (GC-MS) (see Supplementary material). Even/odd numbered *n*-alkanes distribution was evaluated by calculating the carbon preference index (CPI) (see Supplementary material).

4. Results

The assemblage as-a-whole: a simple lie

The lithic assemblage comprises four flint types alongside a single limestone artefact. Thirteen S-RMUs were identified, six of which include almost complete or partial refits. When counted by RMUs rather than by individual artefacts, Mariola flint emerges as the most represented, followed by Serreta, Beniaia, and a minor presence of Catamarruc flint. Technologically, the assemblage is dominated by Levallois production, with a preference for recurrent centripetal modalities. Additionally, a smaller proportion of the assemblage reflects unidirectional and bidirectional reduction patterns not strictly following Levallois principles. Flakes are generally very small and small-sized with a low amount of cortex, suggesting that most of the core exploitation and initial decortication occurred elsewhere. Retouched products are scarce and all correspond to sidescrapers, only one of which is associated with an R-RMU, suggesting that most were likely

introduced to the site already fully knapped and modified.

Spatially, lithic materials are concentrated in the northern sector, which also contains all refitted sequences. This distribution contrasts with the faunal remains, primarily located in the southeast, and a combustion area to the south, where a single hearth lacks associated materials and only a few remains are found nearby. The western sector remains empty, with no evidence of either human activity or natural disturbance.

While this summary offers a useful overview, it reflects only the apparent pattern at the stratigraphic unit level. To fully understand the formation of this assemblage and the behavioural variability it captures, it is essential to move beyond this static view and explore the diachronic relationships between discrete formation events.

4.1. Lithic record

Archaeostratigraphic results

Based on KDE results, lithic products are concentrated in the north, while faunal remains are primarily located in the northeast and southeast, with a noticeable absence of archaeological materials in the west and certain central areas (Fig. 3a). Consequently, the 50 cm-thick cross-sections illustrating vertical distribution are focused on these zones where most material is concentrated. Given that the point-pattern exhibits a concave morphology from north to south (Fig. 3b), cross-sections were oriented along this axis, except for one 35 cm-thick oblique cross-section, which was used to analyse the relationship between H19 and archaeological remains (Fig. 3g).

The SU V point-pattern is well organised, with vertical gaps of materials identified, including differences of up to 10 cm between material beds in the southeast (Fig. 3c), and 1 to 3 cm between Serreta and Mariola R-RMUs line sets in the north (Fig. 4). Additionally, the refitting line sets show similar slopes, with no line crossings between vertically separated refitted products (Fig. 4). Similarly, there is no evidence of vertical weight sorting. Light-weight classes (W1 and W2) are evenly distributed, especially in the central and northern zones, where these classes predominate (Fig. 3e). Furthermore, considering the Kriging results (Fig. 3b), most of these lightweight products are positioned in the higher parts, decreasing in number as the surface becomes more concave. On the other hand, although the presence of some heavy materials at the bottom is noticeable in the east (Fig. 3c), lighter materials are found on top of the assemblage in the same profile. Regarding other taphonomic features, such as patina and edge damage, both conditions are observed particularly at the bottom of the assemblage (Fig. 3f), with some exceptions such as a product with patina and edge damage situated at the top (Fig. 3d).

Despite the absence of major vertical movements, we were unable to subdivide the assemblage into distinct archaeostratigraphic units for several reasons. First, there are horizontal gaps in the central zone, hampering the association of material beds across different areas of the site. Second, these material beds are not continuous,

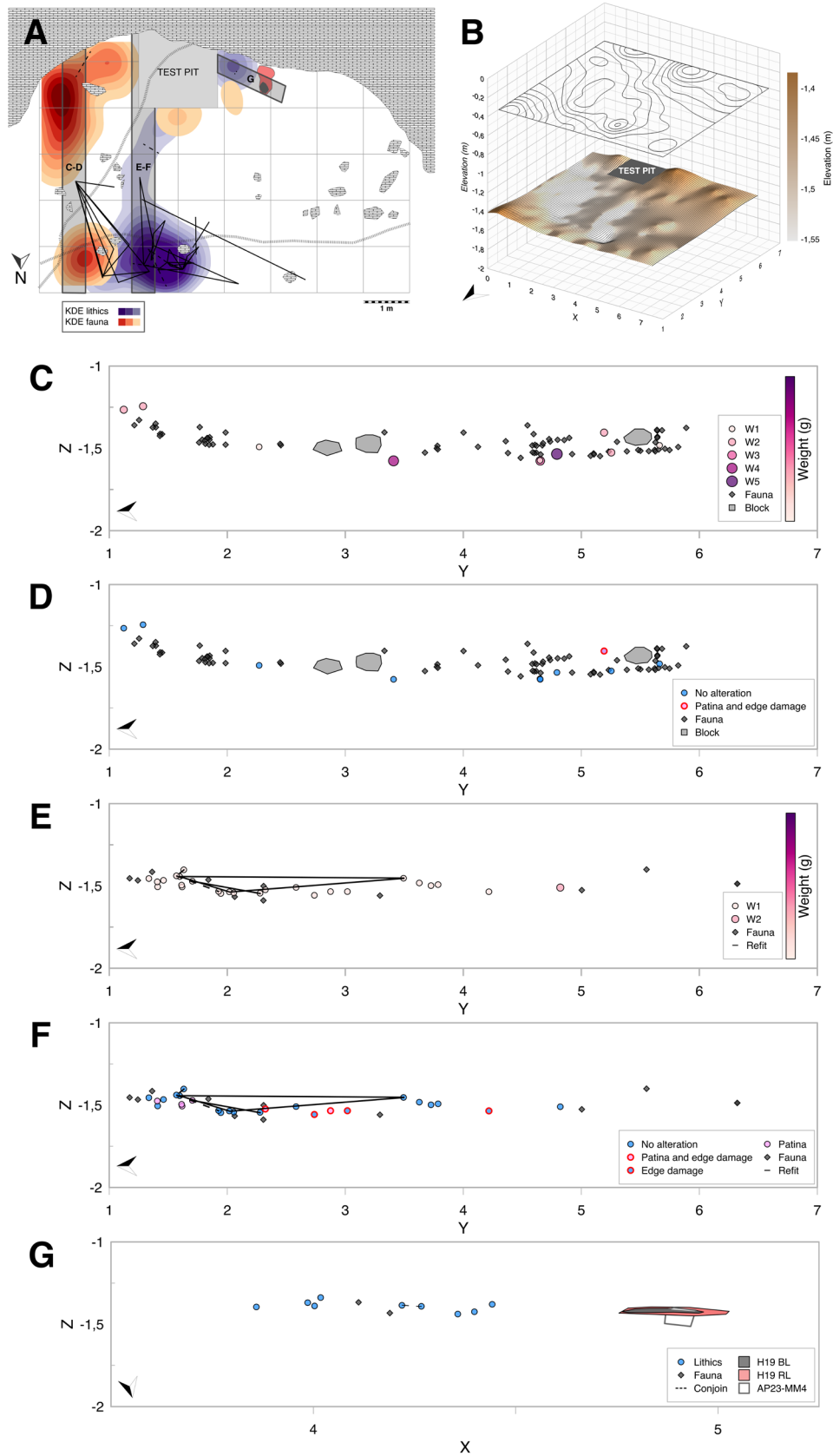


Fig. 3 Site plan indicating the most dense concentrations of lithic and faunal remains, and the location of the cross-sections (A), palaeotopographic reconstruction of SU V (B), north-to-south C cross-section by weight class (C), north-to-south D cross-section by taphonomy (D), north-to-south E cross-section by weight class (E), north-to-south F cross-section by taphonomy (F), and northeast-to-southeast cross section (G). Weight classes in grams: W1 = 0-3.58; W2 = 3.59-18.62; W3 = 18.63-46.40; W4 = 46.41-88.93; W5 = 88.94-1239.

with certain materials bridging existing gaps after 10 to 20 cm horizontally. Finally, the compaction of the record, which spans a short vertical range, particularly in the north where most materials are concentrated, hinders any reliable archaeostratigraphic correlation.

In the case of H19, the only identified combustion structure (see Discussion, subsection 5.4), it was not possible to establish an archaeostratigraphic correlation between any of its layers (black or red) and the point-pattern. This is due to the ca. 25 cm horizontal gap between the hearth and the lithic and faunal record (Fig. 3g).

Spatial results

The ANN (Table S1) and homogeneous Ripley's L -function (Fig. S2) analyses indicate a clustering pattern for the lithic assemblage. Both methods also show clustering for the Serreta and Mariola flint types. However, for the Beniaia flint type, ANN suggests a clustering pattern but with higher p value (0.23), indicating weaker statistical

significance due to the low sample size. Additionally, the L -function did not produce reliable results for the Beniaia flint, as the test requires at least 30 points for robust analysis.

In the case of KDE (Fig. 5a), the lithic products exhibit a major concentration in the northern area. Other zones with lower densities were identified in the southeast and in the south, near the wall and H19. However, there is a notable absence of archaeological materials in the western part of the site, where no concentrations are observed. HDBSCAN identified clusters in the same three areas (Fig. 5a), resulting in three clusters and a "noise" assemblage with varying numbers of lithic products. Thus, Cluster 1 (C1) has been identified in the southeast ($n=9$), Cluster 2 (C2) in the north ($n=42$), and Cluster 3 (C3) in the south ($n=14$). In addition to these, there are scattered materials ("noise") across the surface ($n=82$) that were not classified within any cluster by HDBSCAN. While Cluster 1 and 3 aligned with their respective KDE density ranges, Cluster 2 encompassed the lithic products extending into the

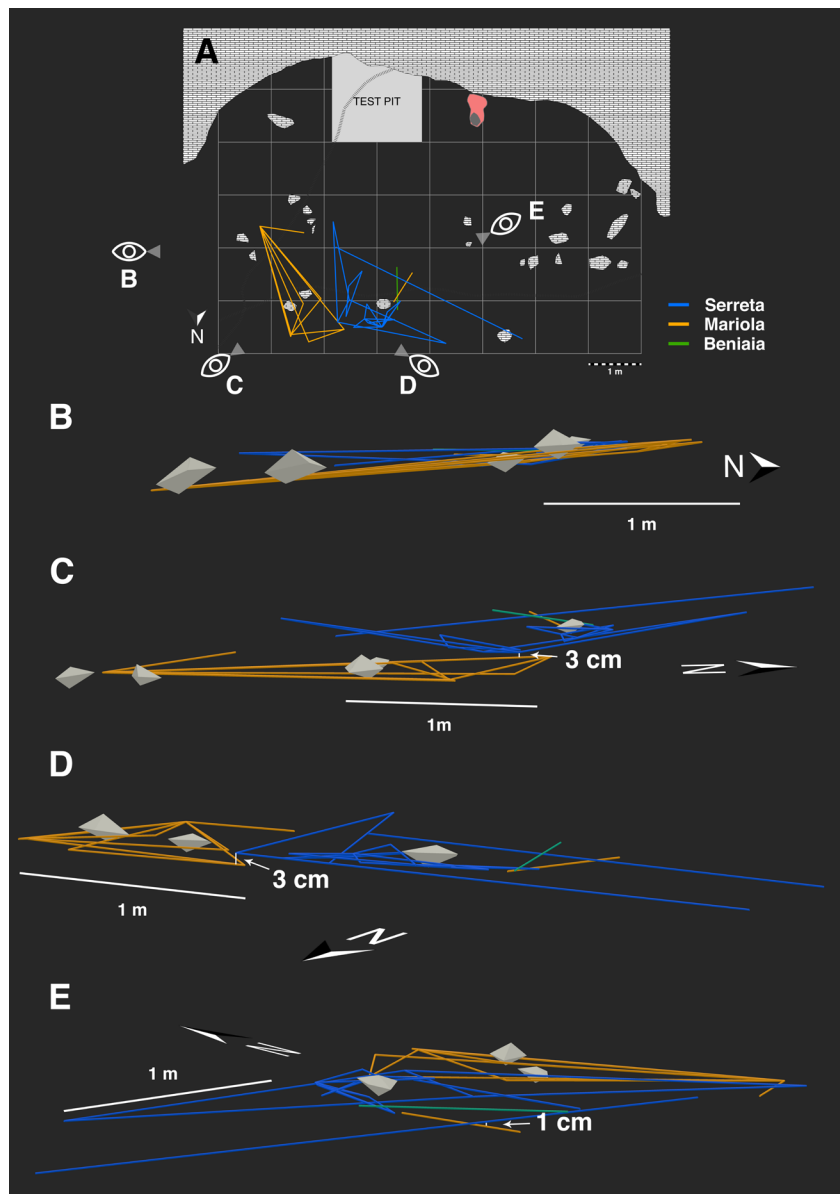


Fig. 4 Site plan showing refitting lines by flint type (A), and 3D visualisation of the refitting lines from different perspectives and angles (B-E).

fourth most dense range of values. Considering both the KDE ranges and the HDBSCAN cluster boundaries, the sizes of the clusters were similar for cluster 1 (0.87x0.68 m) and cluster 3 (0.87x0.79 m), while cluster 2 (1.81x1.66 m) was approximately double their dimensions.

On the other hand, Optimised Hot Spot Analysis only identified one hot-spot cluster in the northern area, with eight quadrats showing a 99% confidence level and one quadrat 95% confidence (Fig. 5b). No cold-spots clusters were detected. In the case of weight, Optimised Hot Spot Analysis shows a clustering pattern of heavyweight products with 95% of confidence in the southeastern area, all under the Ledge (Fig. S4).

The Chi-square test revealed a statistically significant relationship between the distribution of lithic and faunal remains in relation to the Ledge ($\chi^2 = 87.67$, $p < 0.0001$). Similarly, Fisher's exact test further confirmed this association ($p < 0.0001$), with Cramer's V indicating a moderately strong effect size ($V = 0.44$) (Table S2).

Finally, the KDE analysis of faunal remains shows concentrations in areas distinct from the lithic distributions (Fig. 5c). These concentrations are particularly high in the southeast and the northeast, with smaller concentrations in the south. Again, the western part of the site exhibits a notable absence of faunal remains, consistent with the pattern observed for lithic materials.

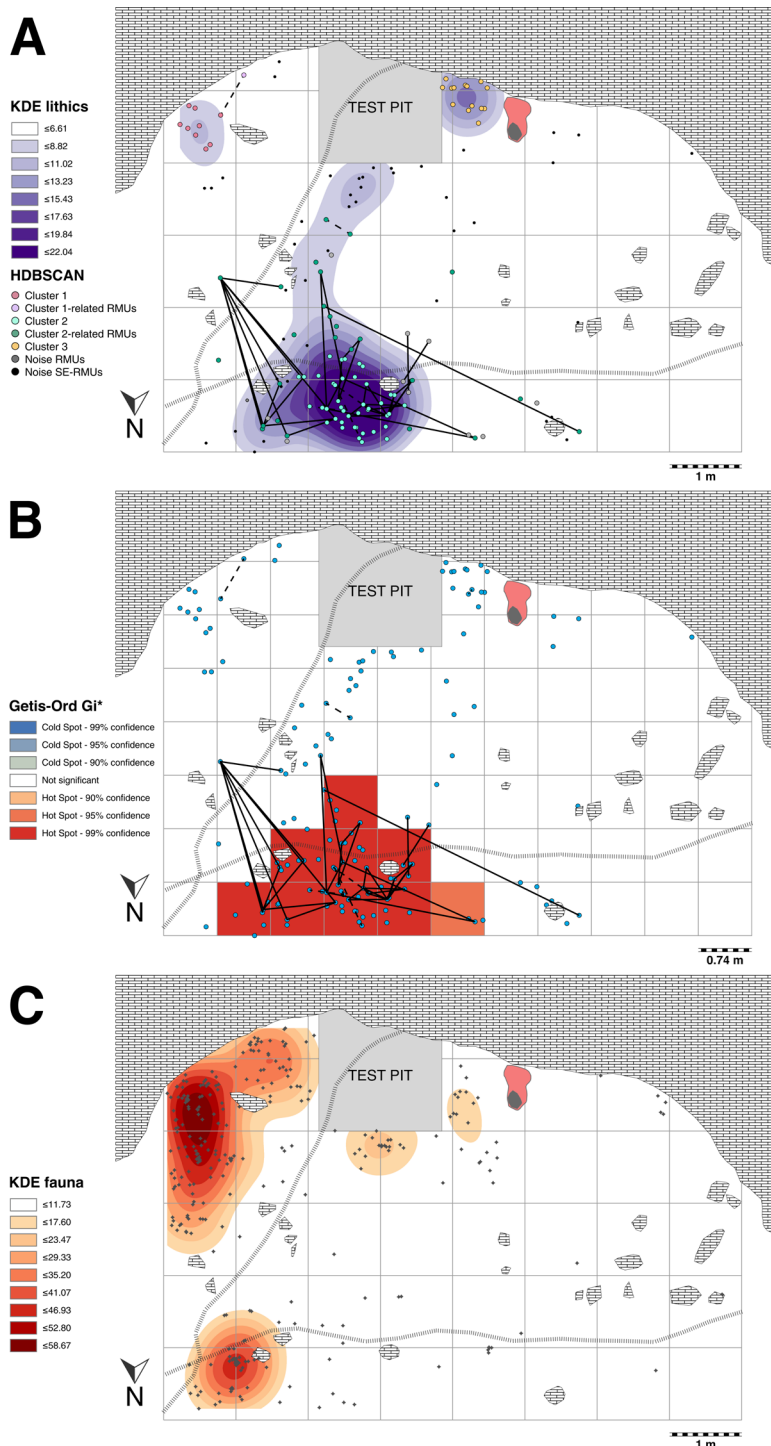


Fig. 5 KDE and HDBSCAN results of the lithic assemblage (A), Getis-Ord Gi* results of the lithic assemblage by 0.74m² squares using the Quadrat method (B), KDE results of the faunal assemblage (C).

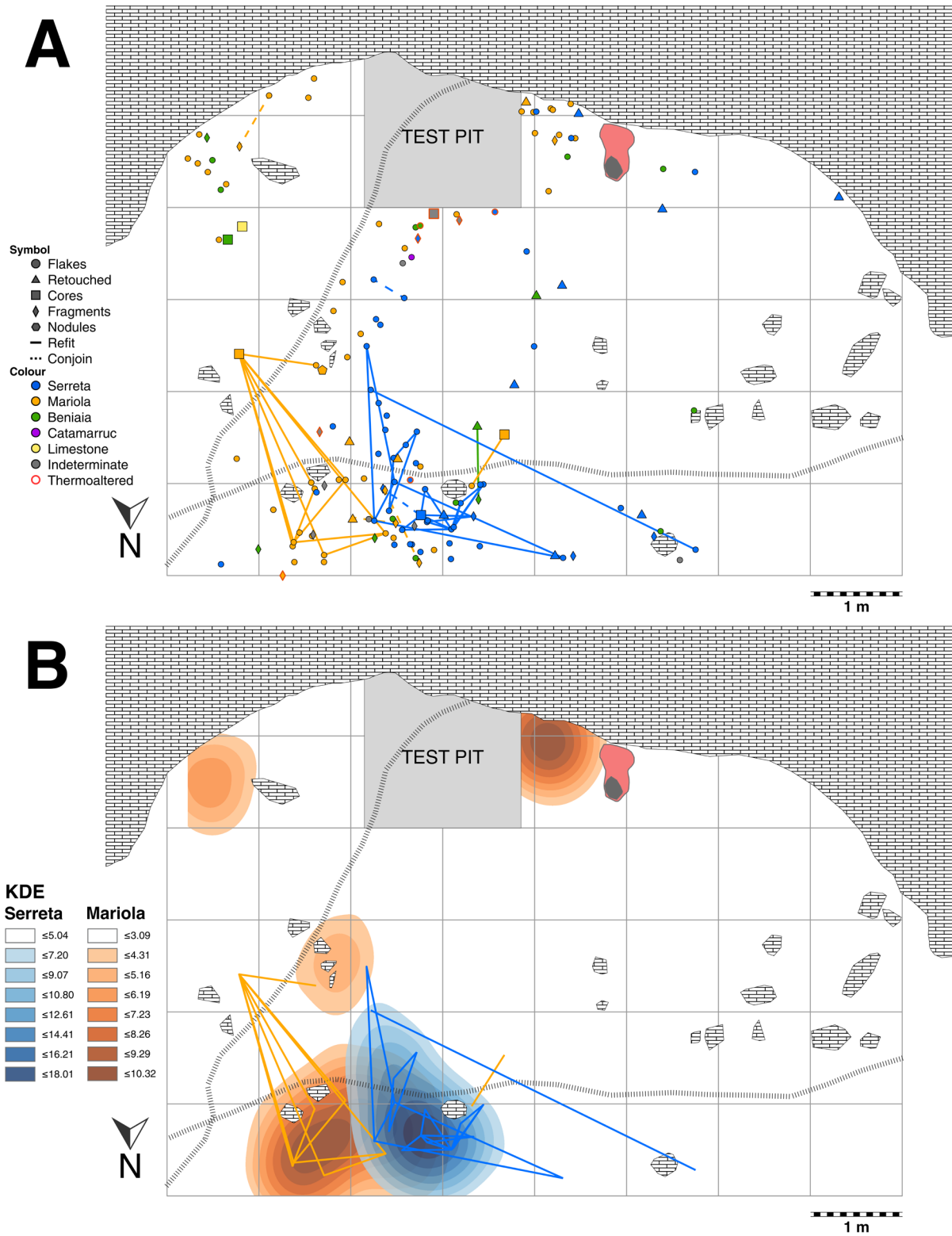


Fig. 6 Spatial distribution of the SU V lithic assemblage by product type (symbol), flint type (colour) and thermoalteration (red contour) (A), and KDE results of Serreta and Mariola flint types (B).

Raw material results

The lithological data obtained will be presented here by distinguishing between the material record associated with each cluster (i.e. C1, C2 and C3), and the scattered assemblage (i.e. “noise”) (Fig. 7). Lithic artefacts that fall outside any cluster but belong to an S-RMU included in any of them will be incorporated in the analysis of the corresponding cluster (Fig. 5a). Furthermore, this is supported by the spatial distribution of flint types (Fig. 6) and recognised alterations (Fig. S3b).

C1 consists of 10 lithic artefacts, all made of flint. Three are made of Beniaia flint, while seven, including one outside the cluster, are made of Mariola flint. The only S-RMU identified (V-M6) is made of Mariola flint and includes two elements, one located outside the cluster. This reduces the total number of anthropogenic inputs in C1 from 10 to nine. In the Beniaia flint assemblage, none of the artefacts show thermal alterations, but one artefact has initial stages of white patina and edge damage. The Mariola flint set lacks signs of thermal alteration, with two artefacts showing white patina in advanced stages on natural surfaces, and one artefact (from V-M6) displaying edge damage.

C2 contains 67 flint artefacts, with Serreta being the most represented (n=40), followed by Mariola (n=21),

and Beniaia (n=4), and two undetermined products. Six S-RMUs were identified: three made of Mariola flint (V-M3, V-M5, and V-M7) and three of Serreta flint (V-S1, V-S2, and V-S4). These S-RMUs comprise 53 products (79% of C2), reducing the potential anthropogenic inputs from 67 to 20. Although this cluster is dominated by both Serreta and Mariola, they exhibit a slight spatial differentiation, with minimal overlap between the two flint types (Fig. 6b). In the Beniaia assemblage, none of the artefacts show thermal alteration, but three have white patina and one has edge damage. In the Mariola assemblage, no thermal alteration was observed, but three artefacts show advanced white patina and no edge damage. The Serreta assemblage has one thermally altered artefact and 11 products with white patina, mostly at early stages. It also has the most artefacts with edge damage (n=11). Spatially, the KDE concentrations of both patina and edge damage coincide with the C2 perimeter (Fig. S3b).

C3 comprises 14 flint artefacts, predominantly of Mariola flint (n=10), with three made of Serreta and one of Beniaia flint. One S-RMU (V-M1) was identified in C3, consisting of five Mariola flint artefacts, reducing the number of potential anthropogenic inputs from 14 to 10. None of the artefacts show thermal alteration or edge damage, although one Mariola product exhibits white patina development in the subcortical area.

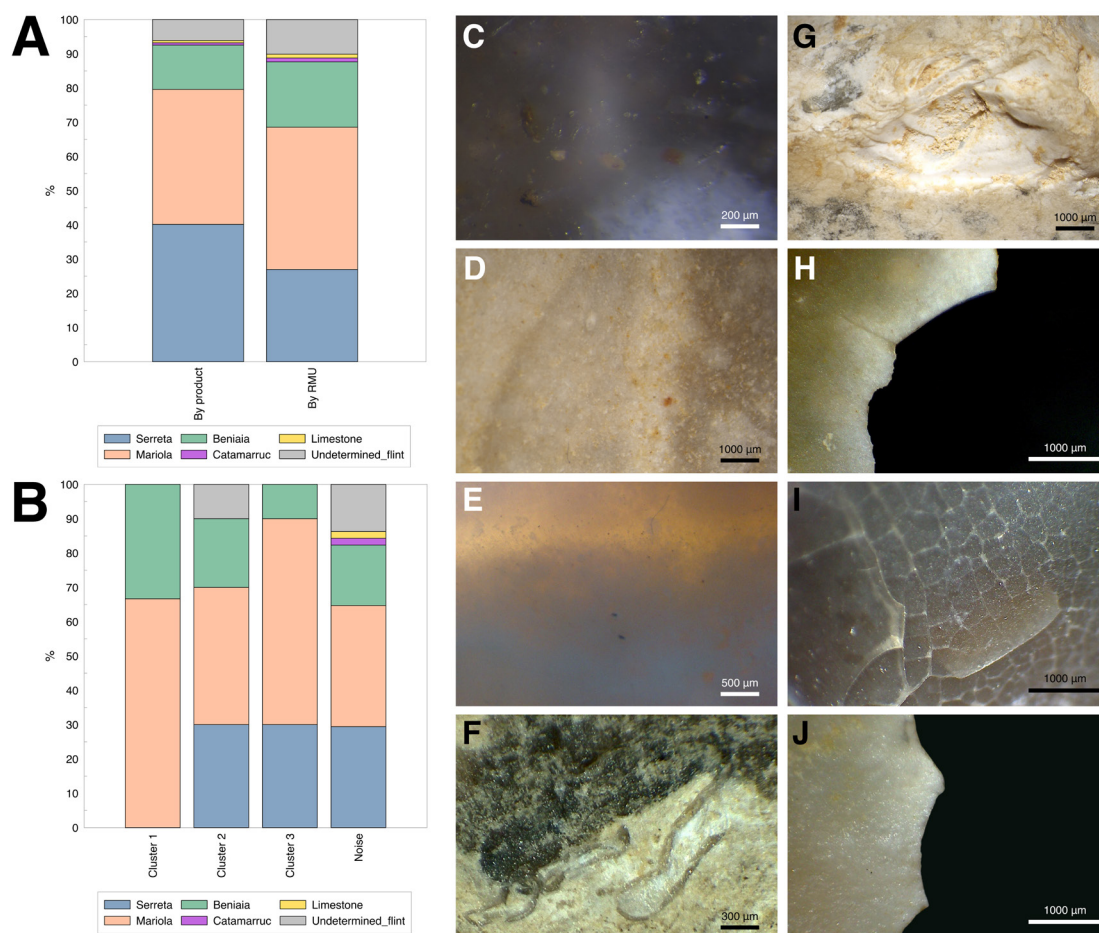


Fig. 7 Bar graph showing the representation of raw materials by product type and RMU (A) and by clusters (B), microphotograph of the the Serreta flint matrix, displaying figured elements and texture (C), Microphotograph of the Mariola flint matrix, which contains carbonate inclusions (D), Photograph of the a Beniaia flint surface displaying a biogenic structure using light contrast (E), Photograph of a Catamarruc flint flake surface, including a subcortical area (i.e. upper black part) with biogenic structures and recrystallised fossils (F), Photograph showing the presence of white patina on natural crashmarks (G), Photograph of the patinated edge of a flint flake (H), photograph of the surface of a flint flake showing reticular fissures as sign of thermal alteration (I), and edge fractures on a flint flake (J).

The scattered assemblage includes 56 artefacts, with one made of limestone (bioclastic calcarenite) and the remaining 55 of flint. Among the flint assemblage, 20 products were made on Mariola flint, 17 on Serreta, 10 on Beniaia, and only one on Catamarruc lithotype. Seven artefacts remain undetermined. Five S-RMUs were identified: two made of Mariola (V-M2 and V-M4), two of Serreta (V-S3 and V-S5), and one of Beniaia (V-B1), accounting for 17.85% of the total scattered assemblage. The Beniaia assemblage shows one thermally altered artefact and two with white patina formation. In the Mariola assemblage, one element is thermally altered, and three display white patina. The Serreta assemblage has two thermally altered artefacts and six with white patina, mostly at advanced stages. One artefact shows edge damage. Finally, the single Catamarruc product shows no postgenetic alterations.

Lithic attributes

Following the results presentation scheme of raw materials, the lithic attributes will be described by differentiating between the artefacts linked to each cluster (i.e. C1, C2 and C3), and the dispersed products (i.e. “noise”) (Table 1, 2, 3, 4) (Fig. 8). Likewise, any lithic artefact that lies outside a cluster but is part of an S-RMU included in one of them will be analysed as part of the corresponding cluster (Fig. 5a). This is further supported by the spatial representation of type of products (Fig. 6a), and weight classification (Fig. S3a).

C1 contains 10 lithic artefacts (Table 1), with a combined weight of 35.92 g. The Mariola artefacts (n=7) mainly consist of very small to small non-cortical flakes. The S-RMU V-M1 includes one flake (located outside the cluster) and one fragment that conjoin. The Beniaia products (n=3) are also very small to small flakes and fragments, with a low amount of cortex.

C2 includes 67 artefacts weighing 247.06g (Table 2). Among them, 25 artefacts (37%) belong to S-RMUs outside the cluster, although most are found within 1 m of it. C2 is dominated by S-RMU related products (79%, n=53), with 34 artefacts refitted (64%). Only 14 products were identified as single elements.

The Mariola assemblage within C2 (n=21) consists largely of very small to small flakes with a low amount of cortex. These include several flakes that belong to RMU V-M3, which refit with a core (88 g) located to the east. One small fragmented retouched artefact forms RMU V-M5 (n=4), and another larger retouched product is present. Single elements are primarily small flakes with 0-25% of cortex.

The Serreta flint assemblage (n=40) is mainly distributed within S-RMUs (n=37), with only three being single products (two flakes and one very small non cortical retouched product). The general trend within S-RMUs is very small to small flakes (n=34), with 0-25% of cortex. The only documented core is linked with RMU V-S1, which is refitted with 7 flakes and a fragment with a medium to high percentage of cortex. RMU V-S2 and V-S4 consist of very small to small flakes, non-cortical in the first case

and with a non-cortical to medium cortical proportion in the second. Beniaia flint type is represented by three very small flakes and a fragment with low amount of cortex.

C3 contains 14 artefacts weighing 76.4 g (Table 3). Mariola artefacts (n=10) are mainly very small to small flakes with a low to medium amount of cortex. Within these, RMU V-M1 (n=5) is composed of very small to small products with a low amount of cortex (four flakes and one fragment). From these, two artefacts conjoin, being one flake and one fragment. The Serreta assemblage (n=3) includes two very small flakes and a small, retouched product with low cortical proportions, while the Beniaia flint type is represented by a single small non-cortical flake.

“Noise” or dispersed materials show a more heterogeneous composition (Table 4). It consists of 56 products, weighing 1671.02 g. Mariola products (n=20) include mostly flakes (n=16), predominantly very small to small with varying cortex (up to 75-100%). Some exceptions include two large flakes, one large core, one medium-sized retouched artefact, and a medium-sized nodule with no evidence of technical exploitation. S-RMU V-M2 is integrated by one large core and one small flake that refit, and V-M4 is composed by two very small non-cortical flakes.

Table 1 Type of products of Cluster 1 by raw material.

	Mariola		Serreta		Beniaia	
	n	%	n	%	n	%
Flakes	6	86			2	67
Retouched						
Cores						
Fragments	1	14			1	33
Nodules						
Total	7	100			4	100

Table 2 Type of products of Cluster 2 by raw material.

	Mariola		Serreta		Beniaia	
	n	%	n	%	n	%
Flakes	15	71	36	90	3	75
Retouched	2	10	1	2.5		
Cores	1	5	1	2.5		
Fragments	3	14	2	5	1	25
Nodules						
Total	21	100	40	100	4	100

Table 3 Type of products of Cluster 3 by raw material.

	Mariola		Serreta		Beniaia	
	n	%	n	%	n	%
Flakes	8	80	2	67	1	100
Retouched	1	10	1	33		
Cores						
Fragments	1	10				
Nodules						
Total	10	100	3	100	1	100

The Serreta assemblage (n=17) exhibits primarily flakes (n=8), although there is a relevant presence of retouched artefacts (n=6). The flakes are very small to small products with a low amount of cortex, while the retouched products tend to be larger and have higher cortical proportions. S-RMU V-S3 includes a small flake and one very small fragment with medium proportion of cortex, and V-S5 consists of two very small fragmented retouched products with no cortex.

Beniaia flint type (n=10) includes small non-cortical flakes (n=4), a large full cortical flake, a large core, fragments and two retouched artefacts. Of these, one small, retouched product and a very small fragment refit (V-B1). Lastly, there is one medium-sized Catamarruc flake with no cortex and a very large limestone core weighing 1239 g, which significantly contributes to the overall weight of the dispersed materials (Fig. 6a and Fig. S3a).

Refitting results

The 28.57% of the lithic assemblage is refitted, comprising 42 products (Table 5). Of these, 71.43% are technical refits, while 28.57% are conjoins. In total, seven technical refits within six R-RMUs were identified, involving 30 lithic products and creating 37 lines (Fig. 9). The average distance between refitted artefacts is 1.01 m, with a standard deviation of 0.87 m. The shortest distance recorded is 0.03 m, while the longest is 3.94 m.

Following on technical refits, Serreta flint type exhibits four refits within three R-RMUs, involving 18 products that form 24 refitting lines. The average distance for these lines is 0.80m, with a maximum of 3.94 m, a minimum of 0.03 m and a standard deviation of 0.89 m. The R-RMU V-S1 (n=9), located in C2, represents a core reduction sequence progressing from initial to full production, following a

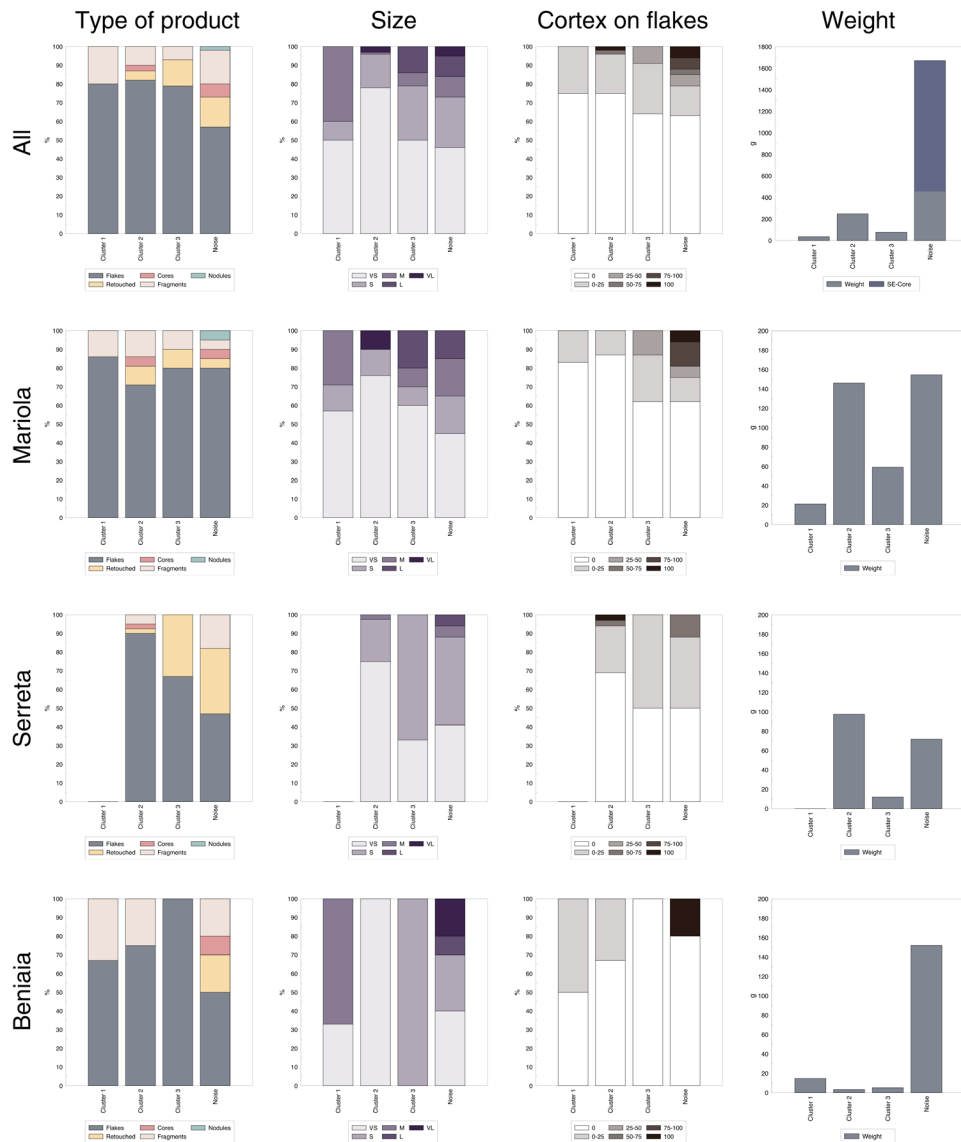


Fig 8 Bar charts showing flint type presence within the spatial units, based on type of product, size-class, amount of cortex and weight.

Table 4 Type of products of the “Noise” assemblage by raw material.

	Mariola		Serreta		Beniaia		Catamarruc		Limestone	
	n	%	n	%	n	%	n	%	n	%
Flakes	16	80	8	47	5	50	1	100		
Retouched	1	5	6	35	2	20				
Cores	1	5			1	10			1	100
Fragments	1	5	3	18	2	20				
Nodules	1	5								
Total	20	100	17	100	10	100	1	100	1	100

recurrent centripetal Levallois modality. The sequence is distributed over a small area in the northern sector (1.01 × 0.51 m) (Fig. 9f). The R-RMU V-S2 contains two separate refits, both related to C2, and reflecting advanced stages in the knapping sequence: one composed of two centripetal flakes located 3.94 m apart (Fig. 9c), and the other comprising three flakes from a centripetal knapping sequence, with distances of 0.91, 0.58, and 0.38 m between them (Fig. 9d). R-RMU V-S4, linked with C2, consists of an advanced knapping sequence of four centripetal flakes distributed across an area of 1.93 m.

Mariola flint type shows two R-RMUs comprising 10 products, generating 12 refitting lines. The average distance of these lines is 1.45 m, with a standard deviation of 0.72 m. The minimum distance recorded is 0.66 m, while the maximum distance reaches 2.52 m. R-RMU V-M2, located in the “noise” assemblage, consists of a core and a flake, separated by 0.66 m, which together display a bidirectional reduction pattern (Fig. 9e). In contrast, R-RMU V-M3, related to C2, reflects a recurrent centripetal Levallois sequence that includes one core and seven flakes, covering both full production and the preparation of striking platforms (Fig. 9b). From these artefacts, six flakes are located within a small area (0.88x0.74 m) in the northeast, while the core and the remaining flake are spaced further apart, with distances ranging from 1.3 m to 2.5-2 m towards the east, and the core positioned under the Ledge.

Beniaia flint type shows one R-RMU (V-B1), located in the “noise” assemblage, consisting of two products that form a single refitting line over a distance of 0.81 m. These artefacts reflect a brief orthogonal knapping episode and consist of one retouched product and one fragment.

The 12 conjoined products form seven lines, distributed within five R-RMUs (two from Serreta and three from Mariola flint type). These exhibit a smaller spatial spread than technical refits, with an average distance of 0.49 m, a minimum of 0.08 m, a maximum of 0.87 m, and a lower standard deviation of 0.25 m.

4.2. Sedimentary record

Soil micromorphology

The micromorphological samples from the combustion and western areas of the rockshelter (Fig. 10, Fig. S5) exhibit a stratified sequence of alternating beds of loose, clast-supported sediment and slightly compact, matrix-supported sediment. Throughout the samples, the coarse fraction is composed of frequent (~30-40%), unsorted, subrounded and subangular fossiliferous limestone sand and gravel and minor amounts of quartz (<5%). The micromass is composed of micritic calcite and clay and it is predominantly arranged in a loose, granular and/or crumbly microstructure with vughs, simple and compound packing voids. A porphyric c/f related distribution has also been occasionally documented. Iron mottles and iron staining (<5%) have been detected. For a more detailed description of the micromorphological features documented in each sample, see Table 6.

The micromorphological samples from the possible combustion structures show few microscopic combustion residues at the top part of sample AP-23-4 and bottom part of AP-23-3, a segment stratigraphically associated with H19 (Fig. 10). The combustion residues comprise: 1) scatters of unidentified, rounded silt-to-fine sand-sized

Table 5 Refitting composition and distances according to flint type.

	Flint type	Refits	R-RMU (n)	Products (n)	Lines (n)	Average distance (m)	Minimum distance (m)	Maximum distance (m)	Standard deviation
Refits	All	7	6	30	37	1.01	0.03	3.94	0.87
	Serreta	4	3	18	24	0.80	0.03	3.94	0.89
	Mariola	2	2	10	12	1.45	0.66	2.52	0.72
	Beniaia	1	1	2	1	0.81	0.81	0.81	-
Conjoins	All	5	5	12	7	0.49	0.08	0.87	0.25

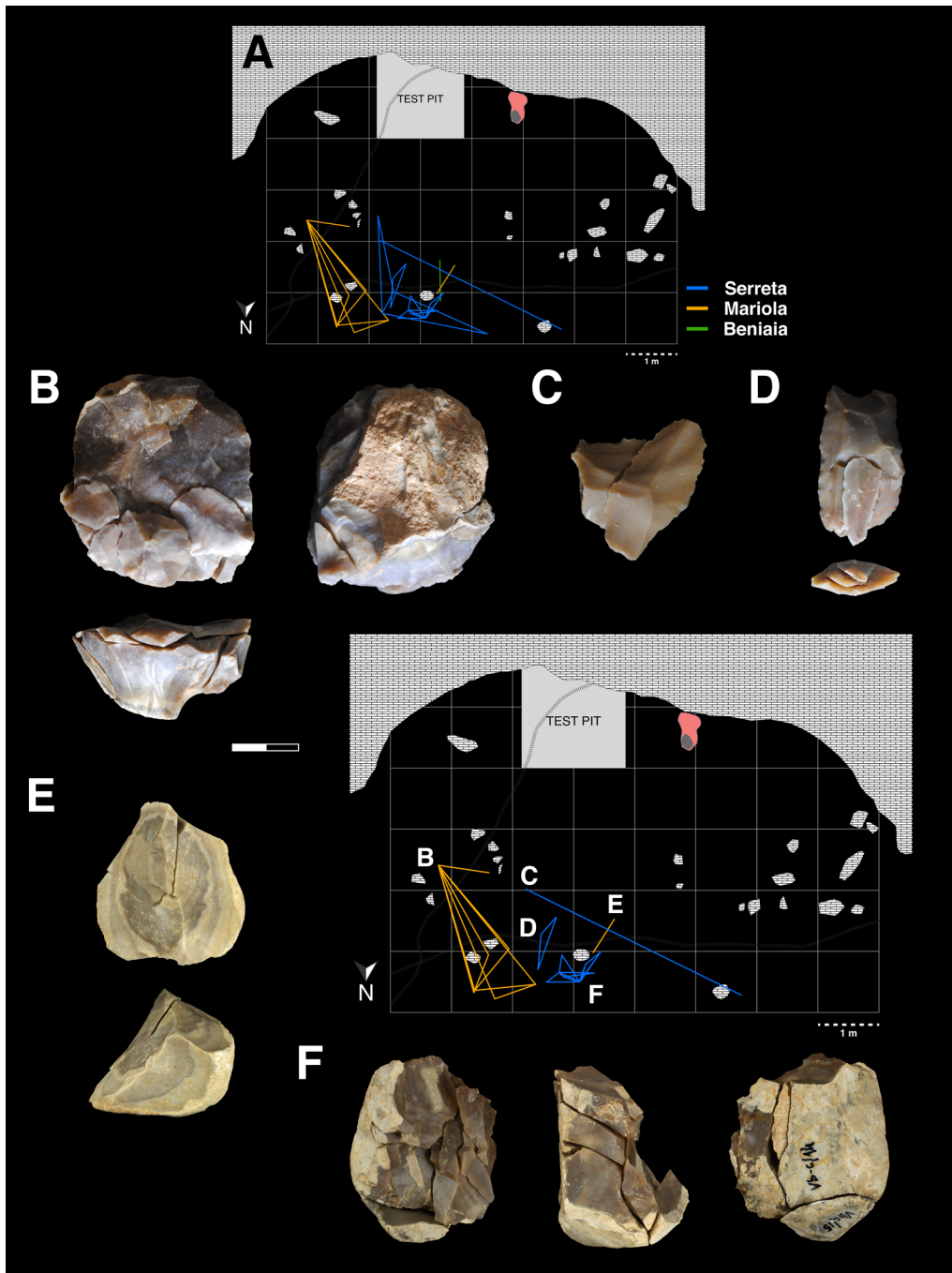


Fig. 9 Site plan showing refitting lines by flint type (A), R-RMU V-M3 (B), refit 1 from RMU V-S2 (C), refit 2 from RMU V-S2 (D), R-RMU V-M2 (E), and R-RMU V-S1 (F).

charred plant matter; 2) few subrounded, fissured, sand-sized charcoal fragments; and 3) few subrounded, fissured, rubified limestone gravel.

n-Alkanes

The natural substrate of the combustion structures, collected as control samples, was characterised by the prevalence of odd-numbered, long-chain *n*-alkanes (i.e., C27, C29, and C31), although mid-chain compounds lacking an odd-over-even predominance were also present (Fig. 11a, Table S3). Similar results were observed in the

sediment sampled as the potential red layer of H20, and to a lesser extent, in the sediment identified in the field as its black layer (Fig. 11a, Table S3). The control samples yielded CPI values of 3.2 and 3.0, while H20 samples returned values of 3.9 for the red layer (RL) and 2.5 for the black layer (BL) (Fig. 11b, Table S3).

In contrast, in both BL and RL of H19, mid-chain *n*-alkanes without an odd-over-even predominance (maximising at C21, C22 and C20) dominated, with a minimal presence of long-chain, odd-numbered compounds (Fig. 11a, Table S3). This is reflected in CPI values below 2 for both samples (Fig. 11b, Table S3).

Table 6 Summary of the lithological composition and main micromorphological features documented in each sample.

Sample ID	Location	Lithology	Micromass	Microstructure	Porosity	Anthropogenic components	Other relevant features
AP-23-1	Massive sands	Subangular, subrounded and angular silt, sand and gravel-sized fossiliferous limestone (~40-45%), quartz fine sand (<5%)	Micritic calcite with iron mottles (<5%) and iron staining	Medium compaction, crumb / granular Upper section: Compact, crumb, porphyric Lower section: Medium compaction, crumb / granular	Vughs, simple and compound packing voids		Very scarce fresh root tissue
AP-23-2	Massive sands	Subangular, subrounded and angular silt, sand and gravel-sized fossiliferous limestone (~50-55%), quartz fine sand (<5%)	Micritic calcite with iron mottles (<5%) and iron staining	Upper section: Compact, crumb, porphyric Lower section: Medium compaction, crumb / granular	Vughs, simple and compound packing voids		
AP-23-3	Combustion area (H18, H19)	Subangular and angular silt, sand and gravel-sized fossiliferous limestone (~30-40%), fossiliferous limestone subangular and subrounded coarse gravel and clasts (~15-20%), quartz fine sand (<5%)	Micritic calcite with iron mottles (<5%) and iron staining	Upper section: Compact, subangular blocky, porphyric Lower section: Loose, crumb / Granular	Vughs, simple and compound packing voids	Lower section: Rubbified limestone gravel and clast	Weakly developed iron coating around a gravel-sized limestone
AP-23-4	Combustion area (H19, H20)	Subangular and angular silt, sand and gravel-sized fossiliferous limestone (~30-40%), fossiliferous limestone subangular clasts (~10-15%), quartz fine sand (<5%)	Micritic calcite with iron mottles (<5%) and iron staining	Upper section: Loose, crumb / granular. Gefuric Middle-lower section: Compact, porphyric	Vughs, simple and compound packing voids, few channels	Upper section: Sand-sized subrounded, fissured charcoal Silt to fine sand-sized, rounded charred plant matter Rubbified, fissured limestone gravel	
AP-23-5	Combustion	Subangular	Micritic calcite	Loose	Vughs, simple		Scarce fresh

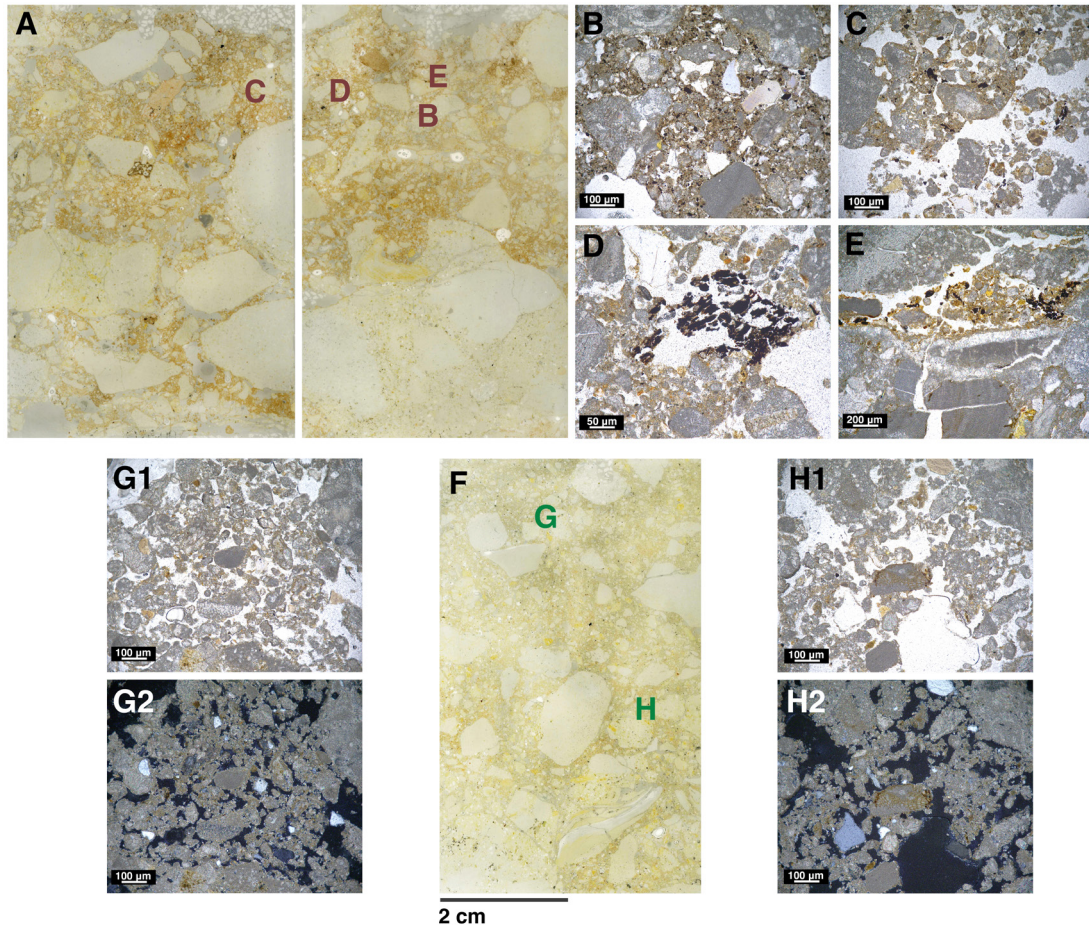


Fig. 10 Micromorphological scans of thin sections from sample AP-23-4, representing the H19 combustion structure (A) and sample AP-23-1, representing the archaeologically sterile zone at the western area of the rock shelter (F). The location of selected microphotographs for each sample are labeled with capital letters. (B) PPL (plane-polarised light). Accumulation of silt-to-fine sand-sized unidentified charred matter in a single-spaced porphyric, vughy, calcitic clay matrix with subangular-subrounded limestone sand and gravel. (C) PPL. Similar matrix as B and presence of silt-to-sand-sized charred matter and charcoal but more loose, with a granular-crumbly microstructure. (D) PPL. Sand-sized fissured charcoal. (E) PPL. Silt and sand-sized charred matter between two limestone clasts. (G) PPL (G1) and XPL (cross-polarised light) (G2) microphotographs displaying loose, granular sediment with vughs and packing voids, composed of unsorted limestone clasts and calcitic clay cement. (H) PPL (H1) and XPL (H2) Similar to G1. Here, some of the limestone clasts are iron-stained.

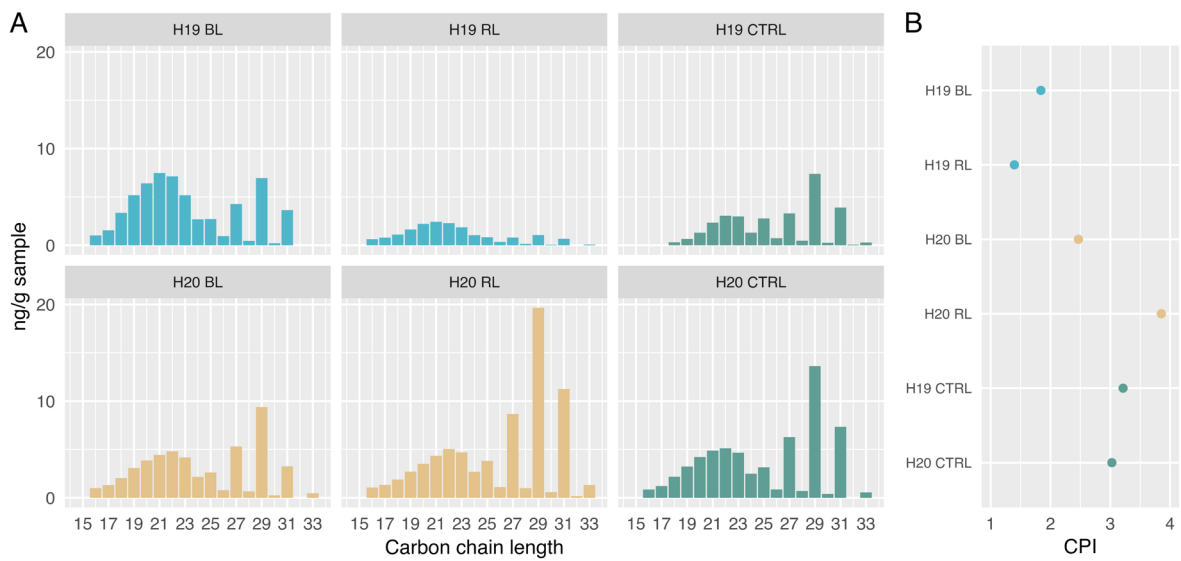


Fig. 11 Bar charts showing the distribution and abundance of the n-alkanes identified in the sedimentary samples (A), CPI (Carbon Preference Index) values of n-alkanes (C19 to C33) from the sedimentary samples (B). BL: potential black layer; RL: potential red layer; CTRL: control sample.

5. Discussion

Our results reveal the presence of four distinct archaeological areas in Abric del Pastor SU V, as determined through spatial analyses. The northern area is predominantly composed of lithic products, with multiple refits. These refitting sequences show a vertical discontinuity, separating distinct episodes of different flint type exploitations. In contrast, the southeastern area features a diachronic accumulation of faunal remains under the ledge. The southern zone, situated near the wall, presents the single combustion structure of SU V (i.e. H19), as evidenced by micromorphological and *n*-alkane data, with limited anthropogenic activity in its surroundings. Lastly, for the western area, where no archaeological remains were detected, geoarchaeological data show the absence of severe postdepositional disturbances that may have affected the integrity of the deposit.

In the following paragraphs, we address the taphonomic aspects of the lithic assemblage to assess its potential for building behavioural interpretations and, subsequently, the temporal and spatial formation dynamics are evaluated.

5.1. Lithic taphonomy

With the aim of evaluating the integrity of SU V lithic assemblage, three variables could provide valuable insights: white patina on edges, edge damage and refitting connections. White patina on edges is concentrated in the northern part of the site, beyond the Drip Line. This position likely increases exposure to water and moisture, which, along with mechanical stress in coarse-grained deposits such as Abric del Pastor, may cause and accelerate patina formation (Rotlländer, 1975; Burrioni et al., 2002; Caux et al., 2018; Berruti & Arzarello, 2020). For edge damage, while it is possible that different fractions (sand, pebbles, blocks) falling from the roof of the shelter could naturally contribute to this alteration, the concentration of artefacts with damaged edges and its coincidence with Cluster 2, where most of the human activity has been identified, suggest that trampling is the most plausible factor (McBrearty et al., 1998; Weitzel & Sánchez, 2021). Furthermore, both factors may be correlated. Experimental work by McPherron et al. (2014) indicates a significant difference in trampling damage between fine-grained and coarse-grained deposits, with damage being more pronounced in the latter.

Both trampling and exposure could have caused minor vertical or horizontal movements, although such slight displacements could remain undetected in our study. In the archaeostratigraphic profiles crossing the northern area, point-pattern analysis did not reveal any significant movement. Refitted sets exhibit minimal vertical separation, spanning no more than 1 to 4 cm, a much lower range than in other sites where refitted pieces display vertical displacements of up to 20–40 cm (e.g. Villa, 1982; Hofman, 1986; Morrow, 1996). Furthermore, our refits generally show horizontal connections of short distance (average: 1.01 m), suggesting a low incidence of any of such postdepositional processes. In fact, in some

cases, they are concentrated in very small areas of less than 1 m², as in the case of V-S1. However, we can not entirely rule out vertical displacement. Experimental studies on trampling, such as Villa & Courtin (1983), demonstrate that assemblages initially separated by 3 cm can converge within a short vertical span due to small downward and upward movements of 0.9 to 2.9 cm. Similar short-range vertical displacements have also been observed by Marwick et al. (2017), within time frames much shorter (5 to 15 minutes) than those used by Villa & Courtin (1983) of 21 to 38 days, or Driscoll et al. (2016) of 12 days.

In experimental works, the influence of artefact size/weight on vertical displacement due to trampling remains debated. Some experiments suggest that small products tend to move downward, preserving their original horizontal positions, while medium to large artefacts exhibit more horizontal than vertical displacement (Stockton, 1973; Nielsen, 1991). Conversely, other studies report no correlation between size/weight and vertical movement (e.g. Gifford-González et al., 1985; Marwick et al., 2017) or note preferential movement of larger products over smaller ones (Moeyersons, 1978). In our case, the densest lithic area (Cluster 2), where edge damage is observed, does not show evidence of weight-sorting. However, this area is predominantly composed of lightweight products in weight class 1 (0–3.58 g). While it is possible that some differences exist within Class 1, experimental data suggest that artefacts up to 9 g exhibit similar behaviours (Villa & Courtin, 1983). Finally, a greater concentration of these lightweight products towards the centre of the deposit is also not observed as a function of slope, which is also a key variable in identifying postdepositional movements (Bertran et al., 2012).

Having regard to taphonomy and composition, we consider that it is feasible to interpret the archaeological record of SU V in terms of human behavioural variability.

5.2. Squeezing the time out

While the identification of the distinct events contributing to the formation of the entire assemblage is often possible due to the distinction of clear vertical gaps between material beds, the situation in SU V is challenging. Although material hiatuses are indeed present, they lack lateral continuity and are predominantly observed in the southeast area, where the highest concentration of faunal remains is located. Thus, without a detailed taxonomic and taphonomic analysis of the faunal assemblage, relying solely on these vertical gaps as indicators of diachronic events would be premature and potentially misleading.

Therefore, in cases like this, where clear stratigraphic separations involving the entire record are ambiguous, a more in-depth analysis that includes the study of raw materials, RMUs and lithic refits can provide valuable insights. The event-based approach has proven valuable in isolating discrete formation episodes in the absence of general archaeostratigraphic gaps. At Abric del Pastor SU IV, even archaeostratigraphic units were initially established based on homogeneous vertical hiatuses, yet further refinement was achieved through RMUs and

refits (Machado et al., 2013, 2019; Sossa-Ríos et al., 2022). Multiple refitted sequences from distinct RMUs and flint types enabled the identification of three depositional events within a single AU (i.e. AU IVb), establishing spatial associations between specific knapping events and certain hearths (Machado et al., 2019).

Comparable examples from other Palaeolithic sites further validate this approach. At Abric Romani level J, three diachronic events linked to the introduction and exploitation of different chert types have been documented, revealing distinct technical behaviours and spatial distributions (Vaquero et al., 2012). Similarly, at Cova Gran level 497D, spatial clustering of refitted chalcedony RMUs within a 3 m² area (i.e. cluster HL1) contrasted with the broader distribution of chert RMUs, suggesting diachronic inputs and knapping activities (Mora et al., 2020; Sánchez-Romero et al., 2024). At Abri du Maras level 4.1, comparing RMUs of different raw materials revealed that, even in the northern part of the site where most lithic activities occurred, flint and quartz RMUs show different spatial distributions (Guillemot et al., 2023). The archaeostratigraphic analysis of RMUs and refits has also been instrumental at El Salt, where distinct formation events have been recognised within SUs Xa and Xb, enabling the linkage of each knapping episode with different hearth layers (Machado et al., 2017; Mayor et al., 2020; Sossa-Ríos et al., 2024).

Following this approach, our analysis of SU V reveals similar diachronic patterns. The most compelling evidence lies in the vertical differentiation between the refitting sequences of Mariola and Serreta flint types. Although both refitting sets are largely associated with Cluster 2, their knapping sequences are vertically distinct, with Mariola refits placed at the bottom, and those of Serreta positioned above (Fig. 4). Furthermore, this remark is also evident spatially: while both refitting sets are concentrated in the same general area, they do not completely overlap but are instead slightly separated. Beyond the refits, the overall assemblage, when examined by flint types, also reveals spatial variability. Mariola flint type is predominantly found in the eastern area, where Serreta is absent. This spatial segregation provides further indirect evidence of diachrony within SU V, supporting the hypothesis of at least two formation stages as indicated by both direct (i.e. vertical separation of refits) and indirect (i.e. distinct flint types with different spatial distributions) temporal markers.

Accepting this hypothesis implies a recurrent pattern in activities that warrants spatial examination. The spatial distribution of SU V is characterised by distinct separations between clusters and a lack of interconnections among them. In the northern area, despite the presence of numerous refits, these connections do not extend beyond two metres from Cluster 2, and they do not reach the perimeters of Clusters 1 or 3. For the latter clusters, there is no evidence to suggest any association, either with each other or with Cluster 2. Given this spatial segmentation, we must examine the behavioural patterns within each zone separately.

5.3. Knapping here... again

So far, our data indicate that the northern zone was repeatedly selected for knapping at different times, with Mariola flint knapped first and Serreta flint later. However, does separating these two events reveal other variations beyond the use of different raw materials? In fact, there is a noticeable distinction between the two assemblages. While both flint types were knapped, Serreta appears more prominently in recent knapping events, suggesting an intensification of activity over time. This shift is evident in the change of raw material percentages, with Serreta dominating when counted by artefact, but being surpassed by Mariola when counted by RMU. A similar trend continues in the overlying AUs IVfH17 and IVc2, which also show a dominance of Mariola flint (Machado et al., 2013, 2019; Sossa-Ríos et al., 2022). In contrast, later units such as AU IVb1 and El Salt SU VIII—both dated to around 48 ka—display a marked shift, with Beniaia flint becoming the principal introduced raw material (Machado et al., 2013, 2019; see Mayor et al., 2022 for further discussion).

Therefore, the zone where Cluster 2 is located appears to function as a recurring knapping area. This idea is principally based on the vertical relations of the refitting sets, and reinforced by the raw material changes between upper and lower segments of the sequence, which strengthen the diachrony interpretation by representing the different visits to potentially distinguishable lithic provisioning areas.

This use of specific areas for knapping at different moments has also been documented in other Neanderthal contexts, such as the northeastern zone of Oscurusciuto in SUs 11a, 11b and 13 (Spagnolo et al., 2019; Spagnolo et al., 2020), the M2 accumulation in sublevel M or the A accumulation in archaeolevel Oa at Abric Romani (Vaquero et al., 2015; Bargalló et al., 2020), the Cluster HL1 of level 497D at Cova Gran (Mora et al., 2020; Sánchez-Romero et al., 2024), the northern area of level 4.1 and Area 1 of level 4.2 at Abri du Maras site (Moncel et al., 2021; Guillemot et al., 2023), or the inner area of El Salt (Machado et al., 2017; Mayor et al., 2020; Sossa-Ríos et al., 2024).

However, there are several aspects in which our case diverges from these examples. On the one hand, our knapping events are not associated with any combustion structure, which contrasts with the hearth-related assemblage model frequently observed where knapping activity is recurrent (Yellen, 1976; Brooks & Yellen, 1987; Stevenson, 1991; Vaquero & Pastó, 2001), including SU IV at Abric del Pastor (Machado et al., 2013, 2019). On the other hand, our refitting sets display shorter connection distances (average of 1.01 m) compared to, for example, almost all levels of Abric Romani, except for levels H and N (Vaquero et al., 2019). Moreover, although there are examples where the averages are even lower such as those from levels H and N, or the present at Cova Gran 497D (0.85 m; Sánchez-Romero et al., 2024), they all show refit connections that reach 5 m or more. In general, our case exhibits minimal intra-site movement. While some of our

connections extend 3 to 4 m, there are limitations to their interpretation.

Firstly, medium-to-long distance refitting lines are scarce. In some cases, such as R-RMU-vM3, the core is located the farthest from refitted artefacts, standing alone underneath the Ledge in the northeast. This reminds us of similar cases at Abric del Pastor SU IV where cores within refits R12 and R14b appear isolated, possibly indicating discard after knapping rather than intentional movement between areas (Machado et al., 2019). Secondly, our maximum refit distances of around 4 m could result from the natural scattering effect of knapping when standing upright (i.e. Newcomer & Sieveking, 1980), which complicates the identification of spatiotemporal relationships that typically requires at least a 5 m threshold (Vaquero et al., 2017, 2019). Lastly, artefacts found outside Cluster 2 but related to it are not associated with any specific activity areas but rather appear mixed with other dispersed material.

This recurrent and concentrated lithic production, spatially unrelated to other activities, also exhibits a high degree of fragmentation. Although a detailed technological analysis of SU V is ongoing, refits further highlight that aspect. The predominance of small products with a low amount of cortex in both flint types suggest advanced stages of the knapping sequence, as both product size and cortex percentage typically diminish with reduction progress (Ahler, 1989; Kvamme, 1997; Vaquero, 2008; Bertran et al., 2012). These features point to significant fragmentation of the operative chains (Turq et al., 2013), contrasting sharply with the almost complete sequences frequently observed in some of the abovementioned sites. The only exception to this pattern is R-RMU-vS1, which shows evidence of earlier stages in the reduction sequence. Moreover, the procurement of lithic resources identified in this case points to mobility from the Serpis valley towards the ravine. This would indicate different knapping events carried out across the territory, beginning with raw material acquisition from at least 3 km away for Serreta and Mariola flints, and from at least 35 km for Beniaia and Catamarruc (Molina et al., 2016).

Taking all these attributes into consideration, our findings seem more consistent with anticipatory lithic production for use in activities carried out elsewhere, fitting with Kent's (1991) concept of "anticipated mobility" or the "What I will have to do in terms of the goals of the expedition" notion of Lewis, R. Binford (1977). Therefore, this pattern may reflect the time before resource gathering typical of this environment during SU IV, such as the collection of juniper (*Juniperus sp.*) (Vidal-Matutano et al., 2015), or goat hunting in the steep terrain of the Cint ravine (Connolly et al., 2019).

This repetition of knapping in the northern area, coupled with the hearth positioned near the shelter wall, could give us a pristine image of a "special-purpose camp" (*sensu* Bartram et al., 1991: 90) or a "work camp" (*sensu* Binford & Binford, 1966: 269), very similar to the "Alyawara men's bush camp" described by Binford (1986: 558). However, the persistent palimpsest effect and the lack of spatiotemporal relationships between this

zone and others, where hearths and faunal remains are present, advise caution in drawing definitive, and illusory, behavioural conclusions. In this case, it is necessary to continue the discussion area by area.

5.4. A possible resting area?

The southern part of the site, close to the rockshelter wall, exhibited lower material density than either the north and southeast areas. In this context, our proxies for detecting anthropogenic combustion in SU V yielded positive results for H19. Micromorphological analysis revealed the absence of anthropogenic components in association with H18 or H20. These were exclusively documented within the stratigraphic section associated with H19 (Fig. 10), specifically in the lower part of sample AP-23-3 and the upper part of sample AP-23-4. These components, which include silt to fine sand-sized charred plant remains, fragmented charcoal, and fissured, rubified limestone gravel, are indicative of combustion (Mallol et al. 2017; Mentzer, 2014) and likely represent the burnt substrate—the black/red layer—on which the fire was lit (Mallol et al. 2017; 2013a). The absence of distinct, well-defined black layers in combustion structures at Abric del Pastor is a recurrent feature, which is likely associated with the scarcity of organic matter present on the surface prior to ignition (Mallol et al., 2013b) and the overall poor preservation of organic matter at the site, and particularly at SU V (Connolly et al., 2019). On the other hand, calcitic wood ash—typically stratigraphically associated with a white layer, corresponding to fuel input (Mallol et al., 2017)—was not detected, aligning with findings from other combustion structures at Abric del Pastor SU IV (Mallol et al., 2019). The absence of an ash layer may be attributed to wind erosion, due to its volatility, and/or moisture-induced dissolution. Human activities, such as trampling, may have also contributed to its disappearance (Mallol et al., 2017; 2013b), as previously suggested for other combustion structures at Abric del Pastor SU IV (Mallol et al., 2019).

n-Alkane data provide additional evidence that H19 represents a combustion structure, and that this is the sole evidence of anthropogenic fire within Abric del Pastor SU V. Control samples representing the natural sediment of SU V showed a predominance of odd-numbered, long-chain *n*-alkanes (Fig. 11a). This pattern indicates that waxes derived from terrestrial higher plants are the primary source of sedimentary *n*-alkanes in Abric del Pastor SU V (Bush and McInerney, 2013; Eglinton and Hamilton, 1967; Ficken et al., 2000). CPI values above two in these samples (Fig. 11b) suggest relatively well-preserved sedimentary organic matter (Ortiz et al., 2013), although the presence of mid-chain compounds lacking an odd-over-even predominance suggests some degradation, likely from bacterial activity in which longer hydrocarbons are broken down, resulting in a restructured distribution that lacks odd-over-even predominance (Brittingham et al., 2017; Grimalt et al., 1988; Zech et al., 2011). Similar results have been previously found in the sediments of Abric del Pastor SU IV (Mallol et al., 2019). This pattern is also

observed in H20 RL and, to a lesser extent, in the H20 BL (Fig. 11a,b). Together with the soil micromorphology data, these findings allow us to exclude H20 as a combustion structure. In contrast, the red and black layers from H19 exhibited a pronounced dominance of mid-chain *n*-alkanes without an odd-over-even predominance, while long-chain, odd-numbered compounds were present only minimally in this case (Fig. 11a). This *n*-alkane profile with CPI values lower than two indicates a significantly more intense degradation process (Ortiz et al., 2013) (Fig. 11b), which more likely aligns with the occurrence of a combustion event, i.e., H19, and the consequent thermal breakdown of the molecules (Diefendorf et al., 2015; Knicker et al., 2013; Leierer et al., 2019; Tomé et al., 2022, 2024; Wiesenberg et al., 2009).

The marginal *n*-alkane degradation observed in H20 BL can be explained not as an individual combustion structure, as noted above, but rather as a result of heat transfer from H19, since the H20 BL sample was located beneath H19 RL. In fact, micromorphological observations identified silt and fine sand-sized charred plant material slightly below H19, supporting this interpretation. Therefore, both micromorphological and molecular data underscore H19 as the only Neanderthal combustion structure documented at Abric del Pastor SU V.

Macroscopically, this combustion structure (i.e. H19) is placed just 5 cm from the wall, with no archaeological materials documented in its red and black layers. Archaeological record was found about 25 cm to the east of the hearth, consisting of a S-RMU (n=5) and 9 single elements, but there is no evidence of archaeostratigraphic correlation with H19, nor any evidence of thermally altered artefacts. This example diverges from most Palaeolithic contexts, where hearths and their perimeters commonly contain different and abundant burnt remains (e.g. bones, lithic fragments) (e.g. Fernández-Peris et al., 2012; Blasco et al., 2016; Machado & Pérez, 2016; Spagnolo et al., 2016; Barkai et al., 2017; Pérez et al., 2017a), consistent with the hearth-related assemblage model (*sensu* Vaquero & Pastó, 2001). This model works independently from the palimpsest effect, being always archaeologically visible, since it has been verified in high resolution examples, such as AU IVc1 or IVfH17 of Abric del Pastor SU IV (Machado et al., 2019; Sossa-Ríos et al., 2022) or Horizon A of Wallertheim (Adler et al., 2003), as well as in time-averaged contexts like the H50 hearth-related assemblage from El Salt SU Xb (Sossa-Ríos et al., 2024).

As discussed above, micromorphological data showed that silt-sized charred plant matter, few sand-sized charcoal fragments and burnt limestone gravel are the solely anthropogenic components associated with H19. Experimental and archaeological studies suggest that human activities around a fire, such as production or consumption, would likely leave more abundant microscopic anthropogenic residues, even if the hearth area has been trampled, dumped or swept (Mallol et al., 2013b; Miller et al., 2010; Marcazzan et al., 2022; Goldberg et al., 2009; Starkovich et al., 2020).

This set of evidence aligns with some of the characteristics commonly associated with resting/sleeping

zones, as identified in ethnoarchaeological, archaeological and experimental studies (Galanidou, 2000; Henry et al., 2004; Mallol et al., 2007; Goldberg et al., 2009; Vallverdú et al., 2010; Wadley et al., 2011, 2020; Bargalló et al., 2020; Spagnolo et al., 2020). The recent state of the art on this topic, provided by Spagnolo et al. (2019), proposes the evaluation of certain parameters to infer the existence of such spaces: 1) spatial segregation from high-activity areas, 2) spatial proximity to the wall, 3) presence of hearths at roughly equal distance intervals, and 4) potential traces of bedding. In addition, recent investigations on smoke density simulation indicate that fires positioned within 0.5 m from the wall generate a smoke-free space, providing ideal conditions for resting activities rather than domestic tasks (Kedar et al., 2024). Our case fulfils the first two requirements: a microscopic absence of archaeological remains, similar to Spagnolo et al. (2019) soil micromorphology sample 172; a low concentration of unburnt macroscopic remains around the hearth, with the uncertainty about their correlation with the fire; and the proximity of the hearth to the wall (<0.5 m). However, it lacks multiple hearths and evidence of bedding. While the presence of multiple hearths can be ruled out, bedding, if present, would be very difficult to identify considering the grain size and overall composition of the deposit (Mallol et al., 2019; Connolly et al., 2019), and the poor preservation of phytoliths in SU V (D. Papavasiliou, comm. pers.).

Ultimately, whether this area was used for sleeping, resting or for some other purpose, it seems clear that this example does not fit the hearth-related assemblage model, showcasing a distinct form of variability within Abric del Pastor, as well as potentially within broader Palaeolithic contexts.

5.5. More areas, less evidence

Once we have reviewed the southern and northern zones, the remaining areas within the site should be addressed. The southeastern sector, covering everything under the Ledge, is an area dominated by faunal remains, with no detected hearths and scarce lithic artefacts, forming what we refer to as Cluster 1. This composition stands in contrast to Cluster 2 and, indeed, to the entirety of the site surface. Statistical tests, including Chi-square, Fisher and Cramer's V, underscore this distinctiveness, highlighting a significant disparity between the record within the area sheltered by the Ledge and the record outside of it. Moreover, it is worth noting that the roof of the Ledge was positioned approximately 1.5 m above the ground level, potentially restricting the range of activities that could be carried out within this confined space.

The current data concerning Cluster 1 and artefacts under the Ledge include predominantly small to medium-sized flakes, two cores (one medium-sized and one very large), and a notable absence of retouched products and refitting sets. The statistically significant presence of heavyweight products was also noted. However, due to the small number of lithic remains, this information can only support the inference of limited or absent knapping activities, while the potential interaction between these

artefacts and the faunal remains requires a use-wear analysis to confirm or refute this hypothesis. This being the case, we must shift our focus to the faunal assemblage.

The observed concentration of faunal remains in this manner, spatially differentiated from domestic activities, mirrors patterns noted in other Neanderthal contexts (e.g. Speth, 2006; Gabucio et al., 2018; Spagnolo et al., 2019; Starkovich et al., 2020). This pattern has often been interpreted as a secondary refuse zone, with size sorting favouring the accumulation of larger bones away from activity areas, which in this case would be reinforced by the presence of heavyweight lithic products. Such “cleaning behaviour” is ethnoarchaeologically associated with extended occupations in residential contexts, where domestic tasks are concentrated around the hearth and the perimeter needs a continuous refurbishment (Binford, 1978; O’Connell, 1987; Bartram et al., 1991; Galanidou, 2000). However, intriguing questions arise in our case: If H19 shows no evidence of domestic activity, were these bones cooked? If they were cooked, from what central focus were they displaced? Further zooarchaeological analyses could provide crucial insights on this matter.

While this area could align with a designated refuse disposal zone, our data remains limited, constrained by the lack of taxonomic and taphonomic analyses on the faunal assemblage. This gap prevents us from ruling out alternative explanations, such as the deposition of bones by carnivores, a phenomenon documented in other Middle Palaeolithic sites (e.g. Sánchez-Romero et al., 2020; Zilio et al., 2021; Spagnolo et al., 2020, 2024), despite there is no previous evidence of carnivore activity in the analysed sequence (Sanchis et al., 2015; Pérez et al., 2017b; Connolly et al., 2019; Sossa-Ríos et al., 2022).

On the other hand, micromorphological data offer valuable insights into the depositional dynamics of the western area of the site, where no archaeological remains were identified. Micromorphological observations revealed that what appeared to be a massive sandy-gravelly deposit in the field consists of a crudely bedded sequence of sandy-gravelly layers with variable micritic calcite cement (Fig. 10). The coarse fraction is unsorted and there are no signs of lamination, sharp contacts or any other feature indicative of surface transport or erosion. The lithology and fabric at this part of the rock shelter is similar to what was observed in the micromorphological samples from the combustion area (AP-23-3, AP-23-4 and AP-23-5) and to previously documented samples from SU V and SU IV (Connolly et al., 2019; Mallol et al., 2019) and suggest a gravitational, accretional depositional dynamic, a pattern typical of rockshelter environments (Mentzer, 2017).

Therefore, severe postdepositional processes affecting the archaeological record can be ruled out. This implies that this area was not used for performing any of the activities detected in other zones of the rockshelter (e.g., knapping, fire use), and that this choice was consistent over time, creating a non-activity palimpsest. Similar cases have been reported at Abric Romani level N (Vallverdú et al., 2010), Oscuruscuito unit 13 (Spagnolo et al., 2019), Tor Faraj (e.g., floor II; Henry et al., 2004), and Roca dels Bous level 10 (Martínez-Moreno et al., 2004). However,

in these examples, the empty spaces are typically located near the wall with aligned fires, and have been interpreted as sleeping or resting areas; in the case of Roca dels Bous, the empty zone lies between hearth-related assemblages. To our knowledge, no previously documented cases exist in which almost half of a rockshelter surface lacks archaeological remains, as observed in the western sector of Abric del Pastor, where the persistence of an unused space suggests a deliberate and recurrent spatial decision. In this sense, the reasons why Neanderthals did not leave any record in this area remain ambiguous. Various possibilities could be considered, including structural/environmental factors, such as exposure to wind or rain in this less sheltered part of the site, or cultural factors, like the preference for reoccupying the same spaces previously used by earlier groups.

6. Conclusions

By adopting an event-based approach, we have shifted the unit of analysis from broad stratigraphic containers to discrete, temporally constrained episodes of activity. Events, as the minimal components of the assemblage, provide the most precise window into human behaviour. Their identification and the study of their interrelationships have clarified the diachronic organisation of space, resource management, and behavioural variability. This approach also offers a methodological reference for interpreting more complex palimpsests where such high spatiotemporal resolution cannot be fully achieved. Through refitting analysis and the principle of diachrony, we were able to separate certain events, thereby reducing the spatiotemporal uncertainty that typically characterises stratigraphic units. This allowed us not only to demonstrate that certain areas were used for the same purpose at different times, but also to refute the hypothesis of a singular, extensive knapping episode involving distinct flint types in the same zone.

Nevertheless, this study also highlights that even in high-resolution contexts, the issue of palimpsests remains prevalent. The temporally separated activity events may represent multiple occupation events, potentially linked with materials whose association with the same temporal context cannot be proven, as in the case of single products. Thus, time, understood as an emergent property, continues to pose challenges, regardless of the resolution of archaeological assemblages, making it difficult to assume contemporaneity. While some degree of time averaging persists, albeit in a reduced form, the methodological framework applied here has significantly improved our understanding of the temporal and spatial structuring of Neanderthal behaviours.

Similarly, our interpretations have been also refined thanks to the integration of geoarchaeological techniques, enabling us to avoid potential inferential errors, such as the misinterpretation of repeated fires in the southern area, and to rule out geogenic/biogenic postdepositional factors as an explanation for the absence of materials in the western sector.

On the other hand, the spatial units examined notably lack the typical hearth-related assemblages. This discrepancy may indicate a positive correlation between temporal resolution and behavioural variability, suggesting that finer temporal distinctions allow for a more nuanced understanding of diverse site use patterns. In other words, these cases accentuate the differences, making common behaviours less apparent. However, we also observed continuity in spatial organisation, exemplified by the repeated knapping activity in the northern sector. This highlights that palimpsest dissection is essential not only for detecting short-term changes, but also for identifying persistent and structural behaviours. While explaining this recurrence will require additional examples and, consequently, a more robust hypothesis, this study establishes a valuable precedent.

Furthermore, the low degree of interaction observed between the distinct areas suggests that activities were short-term, likely more aimed at planning economic tasks than at fully executing them on site, which reinforces the notion of spatial fragmentation of activities within the landscape. However, this limited interaction also restricts the temporal linkage across areas, compelling us to interpret each area as a discrete behavioural unit without assuming direct/indirect connections. Precisely for this reason, identifying discrete events allows us to move beyond conceiving space as a uniform whole, thus avoiding hasty or inaccurate interpretations that fail to align with the temporal scale of the data.

In this sense, zooarchaeological analysis will be crucial for examining potential spatiotemporal inferences, particularly concerning refitting links between zones, and the possible presence of a secondary waste deposit in the southern area. Such deposits are generally associated with long-term residential contexts, and any contradictions here, interpreted as a short-term context, could open possibilities for more complex site formation processes. Lastly, a more detailed technological analysis of the lithic record will provide further insights into spatiotemporal variability, allowing us, for instance, to test the differences between the Mariola and Serreta assemblages, or to assess the role of the minor flint types and limestone.

Finally, this case highlights the limitations of applying uniformitarianism as an interpretative framework in archaeology. When confronted with archaeological cases that lack robust ethnoarchaeological parallels, our explanatory capacity becomes significantly constrained, diminishing what Bailey (1983: 173) describes as the “creative role” of our discipline. The issue is not merely the challenge of reconciling different temporal scales, but also the limited capacity to address research questions without forcing our data to fit existing examples. More data from high-resolution Palaeolithic contexts are required in order to build strong hypotheses about Neanderthal spatial behaviour.

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References

- Adler, D., Prindiville, T. & Conard, N. (2003). Patterns of spatial organization and land use during the Eemian interglacial in the Rhineland: new data from Wallertheim, Germany. *Eurasian Prehistory*, 1(2), 25–78.
- Ahler, S. (1989). Mass analysis of flaking debris: studying the forest rather than the tree. *Archaeological Papers of the American Anthropological Association*, 1(1), 85–118. <https://doi.org/10.1525/ap3a.1989.1.1.85>
- Araujo, A.G. (2013). Bioturbation and the upward movement of sediment particles and archaeological materials: comments on Bueno et al. *Journal of Archaeological Science*, 40, 2124–2127. <https://doi.org/10.1016/j.jas.2012.12.035>
- Arilla, M., Rosell, J. & Blasco, R. (2020). A neo-taphonomic approach to human campsites modified by carnivores. *Scientific Reports*, 10, 6659. <https://doi.org/10.1038/s41598-020-63431-8>
- Arteaga-Bribea, A., Courtenay, L., Cobo-Sánchez, L., Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., & Mosquera, M. (2023). An archaeostratigraphic consideration of the Gran Dolina TD10.2 cultural sequence from a quantitative approach. *Quaternary Science Reviews*, 309, 108033. <https://doi.org/10.1016/j.quascirev.2023.108033>
- Arteaga-Bribea, A. (2024). *Among stones and bison. The lithic assemblage of Gran Dolina TD10.2 (Atapuerca). Technological and spatial implications*

- of a specialised Middle Pleistocene kill-butcherer site. PhD dissertation, Universitat Rovira i Virgili.
- Baena, J., Ortiz, I. & Torres, C. (2019). Good and bad knappers among Neanderthals. In: Yoshihiro, N. & Jöris, O. (eds) *Learning among Neanderthals and Paleolithic Modern Humans*, 95–117, Springer.
- Baker, C. M. (1978). The size effect: an explanation of variability in surface artifact assemblage content. *American Antiquity*, 43(2), 288–293. <https://doi.org/10.2307/279254>
- Bailey, G. (1983). Concepts of time in Quaternary Prehistory. *Annual Review of Anthropology*, 12, 165–192. <https://doi.org/10.1146/annurev.an.12.100183.001121>
- Bailey, G. (2007). Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology*, 26(2), 198–223. <https://doi.org/10.1016/j.jaa.2006.08.002>
- Bailey, G. (2008). Time perspectivism: origins and consequences. In Holdaway, S. & Wandsnider, L. (eds.), *Time in Archaeology: Time perspectivism revisited*, 13–30, Utah University Press.
- Bargalló, A., Gabucio, M.J. & Rivals, F. (2016). Puzzling out a palimpsest: Testing an interdisciplinary study in level O of Abric Romaní. *Quaternary International*, 417, 51–65. <https://doi.org/10.1016/j.quaint.2015.09.066>
- Bargalló, A., Gabucio, M. J., Gómez de Soler, B., Chacón, G. & Vaquero, M. (2020). Rebuilding the daily scenario of Neanderthal settlement. *Journal of Archaeological Science: Reports*, 29, 102139. <https://doi.org/10.1016/j.jasrep.2019.102139>
- Barkai, R., Rosell, J., Blasco, R. & Gopher, A. (2017). Fire for a reason: barbecue at Middle Pleistocene Qesem Cave, Israel. *Current Anthropology*, 58(16), S163–S370. <https://doi.org/10.1086/691211>
- Bartram, L., Kroll, E. & Bunn, H. (1991). Variability in camp structure and bone food refuse patterning at Kua San hunter-gatherer camps. In: Ellen, K. & Douglas, P. (eds) *The interpretation of archaeological spatial patterning*, 77–144, Springer.
- Benito-Calvo, A., Carvalho, S., Arroyo, A., Mastusawa, T. & de la Torre, I. (2015). First GIS analysis of modern stone tools used by wild chimpanzees (*Pan troglodytes verus*) in Bossou, Guinea, West Africa. *PLoS One*, 10(3): e0121613. <https://doi.org/10.1371/journal.pone.0121613>
- Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P. & Sorensen, M. (2012). Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites. *Journal of Archaeological Science*, 39(10), 3148–3166. <https://doi.org/10.1016/j.jas.2012.04.055>
- Bertran, P., Lenoble, A., Todisco, D., Bordes, J. G., Discamps, E. & Vallin, L. (2019). Perturbation assessment in archaeological sites as part of taphonomic study: a review of methods used to document the impact of natural processes on site formation and archaeological interpretations. *Paleo*, 30, 52–75. <https://doi.org/10.4000/paleo.4378>
- Berruti, G. & Arzarello, M. (2020). Talking stones: taphonomy of the lithic assemblage of Pirro Nord 13 (Apricena, FG, Italy). A new approach to the study of the post depositional alterations on lithic tools. *Journal of Archaeological Science: Reports*, 31, 102282. <https://doi.org/10.1016/j.jasrep.2020.102282>
- Besag, J.E. (1977). Comment on modeling spatial point processes by B.D. Ripley. *Journal of Royal Statistical Society*, 39, pp. 193–195.
- Binford, L. R. & Binford, S. R. (1966). A preliminary analysis of functional variability in the mousterian of levallois facies. *American Anthropologist*, 68(2), 238–295.
- Binford, L. R. (1977). Forty-seven trips: a case study in the character of archaeological formation processes. In: Wright, R. (ed.) *Stone Tools as cultural markers: change, evolution and complexity*, 24–36, Australian Institute of Aboriginal Studies, Canberra.
- Binford, L. R. (1978). Dimensional analysis of behavior and site structure: learning from an Eskimo hunting stand. *American Antiquity*, 43(3), 330–361. <https://doi.org/10.2307/279390>
- Binford, L. R. (1986). An Alyawara day: making men's knives and beyond. *American Antiquity*, 51(3), 547–562. <https://doi.org/10.2307/281751>
- Blasco, R., Rosell, J., Sañudo, P., Gopher, A. & Barkai, R. (2016). What happens around a fire: faunal processing sequences and spatial distribution at Qesem cave (300ka), Israel. *Quaternary International*, 398, 190–209. <https://doi.org/10.1016/j.quaint.2015.04.031>
- Boëda, E., Geneste J.M., Meignen, L. (1990). Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen. *Paléo*, 2, 43–80.
- Boëda, E. (1995). Levallois: a volumetric construction, methods, a technique. In: H. Dibble & O. Bar-Yosef (eds.), *The definition and interpretation of Levallois technology*, 23, 41–68. Prehistory Press, Michigan.
- Brittingham, A., Hren, M.T. & Hartman, G. (2017). Microbial alteration of the hydrogen and carbon isotopic composition of n-alkanes in sediments. *Organic Geochemistry*, 107, 1–8. <https://doi.org/10.1016/j.orggeochem.2017.01.010>
- Brooks, A. & Yellen, J. (1987). The preservation of activity areas in the archaeological record: ethnoarchaeological and archaeological work in Northwest Ngamiland, Botswana. In: Susan, K. (ed.) *Method and theory for activity area research: an ethnoarchaeological approach*, 63–106, Columbia University Press, New York.
- Burroni, D., Donahue, R., Pollard, M. & Mussi, M. (2002). The surface alteration features of flint artefacts as record of environmental processes. *Journal of Archaeological Science*, 29(11), 1277–1287. <https://doi.org/10.1006/jasc.2001.0771>
- Bush, R.T. & McInerney, F.A. (2013). Leaf wax n-alkane distributions in and across modern plants: Implications for paleoecology and chemotaxonomy. *Geochimica et Cosmochimica Acta*, 117, 161–179. <https://doi.org/10.1016/j.gca.2013.04.016>
- Canals, A., Vallverdú, J. & Carbonell, E. (2003). New archaeostratigraphic data for the TD6 level in relation to Homo Antecessor (Lower Pleistocene) at the site of Atapuerca, north-central Spain. *Geochronology*, 18, 481–504. <https://doi.org/10.1002/gea.10071>
- Canti, M.G. (2003). Earthworm activity and archaeological stratigraphy: a review of products and processes. *Journal of Archaeological Science*, 30, 135–148. <https://doi.org/10.1006/jasc.2001.0770>
- Caux, S., Galland, A., Queffelec, A. & Bordes, J. G. (2018). Aspects and characterization of chert alteration in an archaeological context: a qualitative to quantitative pilot study. *Journal of Archaeological Science: Reports*, 20, 210–219. <https://doi.org/10.1016/j.jasrep.2018.04.027>
- Clark, A.E. (2017). From activity areas to occupational histories: new methods to document the formation of spatial structure in hunter-gatherer sites. *Journal of Archaeological Method and Theory* 24, 1300–1325. <https://doi.org/10.1007/s10816-017-9313-7>
- Clark, A.E. (2019). Using spatial context to identify lithic selection behaviors. *Journal of Archaeological Science: Reports* 24, 1014–1022. <https://doi.org/10.1016/j.jasrep.2019.03.011>
- Connolly, R., Jambriña-Enríquez, M., Herrera-Herrera, A., Vidal-Matutano, P., Fagoaga, A., Marquina-Blasco, R., Marin-Monfort, M., Ruiz-Sánchez, F. J., Laplana, C., Bailon, S., Pérez, L., Leierer, L., Hernández, C. M., Galván, B. & Mallol, C. (2019). A multiproxy record of palaeoenvironmental conditions at the Middle Palaeolithic site of Abric del Pastor (Eastern Iberia). *Quaternary Science Reviews*, 225, 106023. <https://doi.org/10.1016/j.quascirev.2019.106023>
- Cziesla, E. (1990). On refitting of stone artefacts. In: E. Cziesla, S. Eickhoff, N. Arts & D. Winter (eds.), *The big puzzle: international symposium on refitting stone artefacts*, 9–44. Bonn
- De Lange, L. (2008). Time perspectivism and the structure of archaeological records: a case study. In Holdaway, S. & Wandsnider, L. (eds.), *Time in Archaeology: Time perspectivism revisited*, 149–160, Utah University Press.
- Díaz-Rodríguez, M. & Fábregas-Valcarce, R. (2022). Evaluating the effectiveness of three spatial cluster analysis methods on Palaeolithic site location distributions in Galicia, NW Iberian Peninsula. *Journal of Archaeological Science: Reports* 41, 103323. <https://doi.org/10.1016/j.jasrep.2021.103323>
- Dibble, H.L., Holdaway, S.J., Lin, S.C., Braun, D.R., Douglass, M.J., Iovita, R., McPherron, S.P., Olszewski, D.I. & Sandgathe, D. (2017). Major fallacies surrounding stone artifacts and assemblages. *Journal of Archaeological Method and Theory* 24, 813–851. <https://doi.org/10.1007/s10816-016-9297-8>
- Diefendorf, A.F., Sberna, D.T. & Taylor, D.W. (2015). Effect of thermal maturation on plant-derived terpenoids and leaf wax n-alkyl components. *Organic Geochemistry*, 89–90, 61–70. <https://doi.org/10.1016/J.ORGGEOCHEM.2015.10.006>
- Dorta, R.J., Hernández, C.M., Molina, F.J. & Galván, B. (2010). La alteración térmica en los sílex de los valles alcoyanos (Alicante, España). Una aproximación desde la arqueología experimental en contextos del Paleolítico medio: El Salt. *Recerques del Museu d'Alcoi* 19, 33–64.
- Driscoll, K., Alcaina, J., Égüez, N., Mangado, X., Fullola, J. M., Tejero, J. M. (2016). Trampled under foot: a quartz and chert human trampling experiment at the Cova del Parco rock shelter, Spain. *Quaternary International*, 424, 130–142. <https://doi.org/10.1016/j.quaint.2015.04.054>
- Eglinton, G. & Hamilton, R.J. (1967). Leaf epicuticular waxes. *Science*, 156, 1322–1335. <https://doi.org/10.1126/science.156.3780.1322>
- Fernandes, P. & Reynal, J.P. (2006). Péroarchéologie du silex: un retour aux sources. *Comptes Rendus Palevol* 5(6), 829–837. <https://doi.org/10.1016/j.crpv.2006.04.002>
- Fernández-Peris, J., Barciela, V., Blasco, R., Cuartero, F., Fluck, H., Sañudo, P. & Verdasco, C. (2012). The earliest evidence of hearths in southern Europe: the case of Bolomor Cave (Valencia, Spain). *Quaternary International*, 247, 267–277. <https://doi.org/10.1016/j.quaint.2010.10.014>
- Ficken, K.J., Li, B., Swain, D.L. & Eglinton, G. (2000). An n-alkane proxy for the sedimentary input of submerged/floating freshwater aquatic macrophytes. *Organic Geochemistry*, 31, 745–749. [https://doi.org/10.1016/S0146-6380\(00\)00081-4](https://doi.org/10.1016/S0146-6380(00)00081-4)

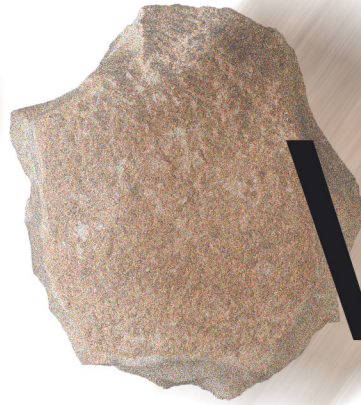
- Fiers, G., Halbrucker, É., De Kock, T., Laforce, B., Vandendriessche, H., Messiaen, L., Vincze, L., Crombé, P. & Cnudde, V. (2018). Preliminary characterization of flint raw material used on prehistoric sites in NW Belgium. *Gearchaeology* 34(4), 400–412. <https://doi.org/10.1002/geo.21719>
- Franck, A. & Baridón, J. (2021). The effect of fire in the distribution of lithic assemblages: an experimental approach. *Lithic Technology*, 47(2), 133–146. <https://doi.org/10.1080/01977261.2021.1981653>
- Gabucio, M. J., Fernández-Laso, M. C. & Rosell, J. (2018). Turning a rock shelter into a home. Neanderthal use of space in Abric Romani levels M and O. *Historical Biology*, 30(6), 743–766 <https://doi.org/10.1080/08912963.2017.1340470>
- Galanidou, N. (2000). Patterns in caves: foragers, horticulturists, and the use of space. *Journal of Anthropological Archaeology*, 19(3), 243–275. <https://doi.org/10.1006/jaar.1999.0362>
- Galobart, Á. & Canals, A. (2003). Arqueostratigrafia y reconstrucción de la dinámica sedimentaria en los yacimientos del Pleistoceno inferior de Incaurcal I e Incaurcal V. *Paleontologia i Evolució*, 34, 221–232.
- Galván, B., Hernández, C. M., Francisco-Ortega, M. I., Molina, J. & Tarrío, A. (2009). La producción lítica del Abric del Pastor (Alcoy, Alicante). Un ejemplo de variabilidad musteriense. *Tabona*, 17, 11–61.
- Getis, A. (1964). Temporal land-use pattern analysis with the use of Nearest Neighbor and Quadrat methods. *Annals of the Association of American Geographers*, 54(3), 391–399. <https://doi.org/10.1111/j.1467-8306.1964.tb00497.x>
- Gifford-González, D., Damrosch, D., Damrosch, D., Pryor, J. & Thunen, R. (1985). The third dimension in site structure: an experiment in trampling and vertical dispersal. *American Antiquity*, 50(4), 803–818. <https://doi.org/10.2307/280169>
- Goldberg, P., Miller, C., Schiegl, S., Ligouis, B., Berna, F., Conard, N. & Wadley, L. (2009). Bedding, hearths, and site maintenance in the Middle Stone Age of Sibudu Cave, KwaZulu-Natal, South Africa. *Archaeological and Anthropological Sciences*, 1, 95–122. <https://doi.org/10.1007/s12520-009-0008-1>
- Grimalt, J.O., Torras, E. & Albaigés, J. (1988). Bacterial reworking of sedimentary lipids during sample storage. *Organic Geochemistry*, 13, 741–746. [https://doi.org/10.1016/0146-6380\(88\)90096-4](https://doi.org/10.1016/0146-6380(88)90096-4)
- Guillemot, P., Jaillet, S., Chacón, M.G., Pois, V. & Moncel, M.H. (2023). Spatial patterning of Middle Palaeolithic lithic assemblages at the Abri du Maras, southeast France: combining GIS analysis and 3D palaeotopographic reconstructions. *Journal of Archaeological Science: Reports*, 49, 103999. <https://doi.org/10.1016/j.jasrep.2023.103999>
- Hageman, J. & Bennett, D. (1999). Construction of digital elevation models for archaeological applications. In: Konnie W. & Joe B. (eds.) *Practical applications of GIS for archaeologists*, 121–136, CRC Press, London.
- Henry, D., Hietala, H., Rosen, A., Demidenko, Y., Usik, V. & Armagan, T. (2004). Human behavioral organization in the Middle Paleolithic: were Neanderthals different? *American Anthropologist*, 106(1), 17–31. <https://doi.org/10.1525/aa.2004.106.1.17>
- Herrejón-Lagunilla, Á., Villalain, J. J., Pavón-Carrasco, F. J., Sánchez-Bravo, M., Sossa-Ríos, S., Mayor, A., Galván, B., Hernández, C. M., Mallol, C. & Carrancho, Á. (2024). The time between Palaeolithic hearths. *Nature*, 630, 667–670. <https://doi.org/10.1038/s41586-024-07467-0>
- Hofman, J. (1986). Vertical movement of artifacts in alluvial and stratified deposits. *Current Anthropology*, 27(2), 163–171. <https://doi.org/10.1086/203414>
- Jenks, G.F. (1967). The data model concept in statistical mapping. In: K. Frenzel (ed.), *International yearbook of cartography VII*, 186–190. Liverpool
- Karkanas, P. & Goldberg, P. (2018). *Reconstructing Archaeological Sites: Understanding the Geoarchaeological Matrix*. John Wiley & Sons.
- Kedar, Y., Kedar, G., Kadowaki, S. & Barkai, R. (2024). Hearth management at a Middle Palaeolithic rockshelter site: smoke density analysis at Tor Faraj, Jordan. *Journal of Archaeological Science*, 172, 106107. <https://doi.org/10.1016/j.jas.2024.106107>
- Kent, S. (1991). The relationship between mobility strategies and site structure. In: Ellen, K. & Douglas, P. (eds) *The interpretation of archaeological spatial patterning*, 33–57, Springer.
- Knicker, H., Hilscher, A., de la Rosa, J.M., González-Pérez, J.A. & González-Vila, F.J. (2013). Modification of biomarkers in pyrogenic organic matter during the initial phase of charcoal biodegradation in soils. *Geoderma*, 197–198, 43–50. <https://doi.org/10.1016/j.geoderma.2012.12.021>
- Kvamme, K. (1997). Patterns and models of debitage dispersal in percussion flaking. *Lithic Technology*, 22(2), 122–138. <https://doi.org/10.1080/01977261.1997.11754538>
- Larson, M.L. & Kornfeld, M. (1997). Chipped stone nodules: theory, method, and examples. *Lithic Technology* 22(1), 4–18. <https://doi.org/10.1080/01977261.1997.11754530>
- Lee, J. & Wong, D. (2001). *Statistical analysis with ArcView GIS*. John Wiley & Sons.
- Lee, J. (2023). Spatiotemporal Ripley's *K* and *L* functions. In Jay L. (ed.) *Spatiotemporal Analytics*, 77–90, CRC Press.
- Leierer, L., Jambriña-Enríquez, M., Herrera-Herrera, A.V., Connolly, R., Hernández, C.M., Galván, B. & Mallol, C. (2019). Insights into the timing, intensity and natural setting of Neanderthal occupation from the geoarchaeological study of combustion structures: A micromorphological and biomarker investigation of El Salt, unit Xb, Alcoy, Spain. *PLoS One*, 14: e0214955 <https://doi.org/10.1371/journal.pone.0214955>
- López-Ortega, E., Rodríguez, X.P. & Vaquero, M. (2011). Lithic refitting and movement connections: the NW area of the level TD10-1 at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). *Journal of Archaeological Science*, 38(11), 3112–3121. <https://doi.org/10.1016/j.jas.2011.07.011>
- López-Ortega, E., Rodríguez, X.P., Ollé, A. & Lozano, S. (2019). Lithic refits as a tool to reinforce postdepositional analysis. *Archaeological and Anthropological Sciences*, 11, 4555–4568. <https://doi.org/10.1007/s12520-019-00808-5>
- Lucas, G. (2008). Time and archaeological event. *Cambridge Archaeological Journal*, 18(1), 59–65. <https://doi.org/10.1017/S095977430800005X>
- Luria, D., Fantalkin, A., Zilberman, E. & Ben-Dor, E. (2020). Identifying the Brazil nut effect in archaeological site formation processes. *Mediterranean Geoscience Reviews*, 2, 267–281. <https://doi.org/10.1007/s42990-020-00023-8>
- Machado, J., Hernández, C.M., Mallol, C. & Galván, B. (2013). Lithic production, site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor stratigraphic unit IV (Alicante, Spain). *Journal of Archaeological Science*, 40(5), 2254–2273. <https://doi.org/10.1016/j.jas.2013.01.002>
- Machado, J. & Pérez, L. (2016). Temporal frameworks to approach human behavior concealed in Middle Palaeolithic palimpsests: a high-resolution example from El Salt stratigraphic unit x (Alicante, Spain). *Quaternary International*, 417, 66–81. <https://doi.org/10.1016/j.quaint.2015.11.050>
- Machado, J., Molina, F.J., Hernández, C.M., Tarrío, A. & Galván, B. (2017). Using lithic assemblage formation to approach Middle Palaeolithic settlement dynamics: El Salt stratigraphic unit x (Alicante, Spain). *Archaeological and Anthropological Sciences* 9, 1715–1743. <https://doi.org/10.1007/s12520-016-0318-z>
- Machado, J., Mayor, A., Hernández, C.M. & Galván, B. (2019). Lithic refitting and the analysis of Middle Palaeolithic settlement dynamics: a high-temporal resolution example from El Pastor rock shelter (eastern Iberia). *Archaeological and Anthropological Sciences* 11, 4539–4554. <https://doi.org/10.1007/s12520-019-00859-8>
- Mallol, C., Marlowe, F., Wood, B. & Porter, C. (2007). Earth, wind, and fire: ethnoarchaeological signals of Hadza fires. *Journal of Archaeological Science*, 34(12), 2035–2052. <https://doi.org/10.1016/j.jas.2007.02.002>
- Mallol, C., Hernández, C.M., Cabanes, D., Sistiaga, A., Machado, J., Rodríguez, Á., Pérez, L. & Galván, B. (2013a). The black layer of Middle Palaeolithic combustion structures. Interpretation and archaeostratigraphic implications. *Journal of Archaeological Science*, 40, 2515–2537. <https://doi.org/10.1016/j.jas.2012.09.017>
- Mallol, C., Hernández, C.M., Cabanes, D., Machado, J., Sistiaga, A., Pérez, L. & Galván, B. (2013b). Human actions performed on simple combustion structures: An experimental approach to the study of Middle Palaeolithic fire. *Quaternary International*, 315, 3–15. <https://doi.org/10.1016/j.quaint.2013.04.009>
- Mallol, C., Mentzer, S.M. & Miller, C.E. (2017). Combustion features. In: Nicosia, C. & Stoops, G. (eds.), *Archaeological Soil and Sediment Micromorphology*, 299–330, Wiley Blackwell, Oxford.
- Mallol, C., Hernández, C., Mercier, N., Falguères, C., Carrancho, A., Cabanes, D., Vidal-Matutano, P., Connolly, R., Pérez, L., Mayor, A., Ben-Arous, E. & Galván, B. (2019). Fire and brief human occupations in Iberia during the MIS 4: Evidence from the Abric del Pastor (Alcoy, Spain). *Scientific Reports*, 9, 18281. <https://doi.org/10.1038/s41598-019-54305-9>
- Marczazan, D., Miller, C. & Conard, N. (2022). Burning, dumping, and site use during the Middle and Upper Palaeolithic at Hohle Fels Cave, SW Germany. *Archaeological and Anthropological Sciences*, 14, 178. <https://doi.org/10.1007/s12520-022-01647-7>
- Martínez-Moreno, J., Mora, R. & de la Torre, I. (2004). Methodological approach for understanding Middle Palaeolithic settlement dynamics at La Roca dels Bous (Noguera, Catalunya, Northeast Spain). In: N. Conard (ed.), *Settlement dynamics of the Middle Palaeolithic and Middle Stone Age*, 2, 393–413. Kerns Verlag.
- Martínez-Moreno, J., Mora, R., Roy, M. & Benito-Calvo, A. (2016). From site formation processes to human behaviour: towards a constructive approach to depict palimpsests in Roca dels Bous. *Quaternary*

- International*, 417, 82–93. <https://doi.org/10.1016/j.quaint.2015.09.038>
- Martínez-Moreno, J., Mora, R., Benito-Calvo, A., Roy, M. & Sánchez-Martínez, J. (2019). A bunch of refits: 497D blade knapping assemblage of the Early Upper Paleolithic in Cova Gran (Northeast Iberia). *Archaeological and Anthropological Sciences*, 11, 4585–4600. <https://doi.org/10.1007/s12520-018-0726-3>
- Marwick, B., Hayes, E., Clarkson, C. & Fullagar, R. (2017). Movement of lithics by trampling: an experiment in the Madjedbebe sediments, northern Australia. *Journal of Archaeological Science*, 79, 73–85. <https://doi.org/10.1016/j.jas.2017.01.008>
- Mayor, A., Hernández, C.M., Machado, J. & Mallol, C. (2020). On identifying Palaeolithic single occupation episodes: archaeostratigraphic and technological approaches to the Neanderthal lithic record of stratigraphic unit xa of El Salt (Alcoi, eastern Iberia). *Archaeological and Anthropological Sciences*, 12, 84. <https://doi.org/10.1007/s12520-020-01022-4>
- Mayor, A., Sossa-Ríos, S., Molina, F.J., Pérez, L.J., Galván, B., Mallol, C. & Hernández, C.M. (2022). An instance of Neanderthal mobility dynamics: a lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt rockshelter (Alcoi, eastern Iberia). *Journal of Archaeological Science: Reports* 44, 103544. <https://doi.org/10.1016/j.jasrep.2022.103544>
- Mayor, A., Sossa-Ríos, S., Vaquero, M. & Hernández, C.M. (2024). Recycling and implications for Neanderthal productive strategies in the stratigraphic unit VIII of the El Salt rockshelter (Alcoi, eastern Iberia). *Lithic Technology*, 50(1), 82–99. <https://doi.org/10.1080/01977261.2024.2356952>
- McBrearty, S., Bishop, L., Plummer, T., Dewar, R. & Conard, N. (1998). Tools underfoot: human trampling as an agent of lithic artifact edge modification. *American Antiquity*, 63(1), 108–129. <https://doi.org/10.2307/2694779>
- McPherron, S., Braun, D., Dogandzic, T., Archer, W., Desta, D. & Lin, S. (2014). An experimental assessment of the influences on edge damage to lithic artifacts: a consideration of edge angle, substrate grain size, raw material properties, and exposed face. *Journal of Archaeological Science*, 49, 70–82. <https://doi.org/10.1016/j.jas.2014.04.003>
- Mentzer, S.M. (2017). Rockshelter settings. In: Gilbert, A. S. (ed.) *Encyclopedia of Geoarchaeology*, 725–741, Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-4409-0_159
- Mentzer, S.M. (2014). Microarchaeological approaches to the identification and interpretation of combustion features in prehistoric archaeological sites. *Journal of Archaeological Method and Theory*, 21, 616–668. <https://doi.org/10.1007/s10816-012-9163-2>
- Mikhailova, N., Mikhailova, E., & Grafeeva, N. (2019). The application of clustering techniques to group archaeological artifacts. In: A. Rocha, H. Adeli, L. Reis & S. Costanzo (eds.), *New Knowledge in Information Systems and Technologies*, 930, 50–57. Springer, Cham. https://doi.org/10.1007/978-3-030-16181-1_5
- Miller, C.E., Conard, N.J., Goldberg, P. & Berna, F. (2010). Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modified combustion features. *Palaeolithic*, 2. <https://doi.org/10.4000/paethnologie.8197>
- Moclán, A., Huguet, R., Márquez, B., Álvarez-Fernández, A., Laplana, C., Arsuaga, J.L., Pérez-González, A. & Baquedano, E. (2023). Identifying activity areas in a neanderthal hunting camp (the Navalmaillo rock shelter, Spain) via spatial analysis. *Archaeological and Anthropological Sciences*, 15, 44. <https://doi.org/10.1007/s12520-023-01746-z>
- Moeyersons, J. (1978). The behaviour of stones and stone implements buried in consolidated and creeping Kalahari sands. *Earth Surface Processes*, 3, 115–128.
- Molina, F.J., Tarrío, A., Galván, B. & Hernández, C.M. (2010). Áreas de aprovisionamiento de sílex en el Paleolítico medio en torno al Abric del Pastor (Alcoi, Alicante): estudio macroscópico de la producción lítica de la colección Brotons. *Recerques del Museu d'Alcoi* 19, 65–80.
- Molina, F.J., Tarrío, A., Galván, B. & Hernández, C.M. (2014). Prospección geoarqueológica del Prebético de Alicante: primeros datos acerca del abastecimiento de sílex durante la prehistoria. *Revista del Museu Arqueològic Provincial d'Alacant* extra 1, 154–163.
- Molina, F.J., Tarrío, A., Galván, B. & Hernández, C.M. (2015). Estudio geoarqueológico de áreas de aprovisionamiento de sílex en el Prebético de Alicante: los ejemplos de Penella (Alcoi) y La Fenasaosa (Onil). In: L. Alapont, J. Martí & F.E. Tendero (eds.), *Actuacions sobre el patrimoni arqueològic de la Comunitat Valenciana: actes de les I Jornades d'Arqueologia de la Comunitat Valenciana*, 13–27. València
- Molina, F.J. (2016). Estudio geoarqueológico de entornos sedimentarios fluvio-lacustres y endorreicos con industrias del Paleolítico medio en el norte de la provincia de Alicante (España). *Recerques del Museu d'Alcoi* 25, 7–30.
- Molina, F.J., Tarrío, A., Galván, B. & Hernández, C.M. (2016). El sílex del Prebético de Alicante: tipos, variabilidad y áreas de captación y talla del Pleistoceno. *Cuadernos de Prehistoria y Arqueología de la Universidad de Granada* 26, 283–311. <https://doi.org/10.30827/cpag.v26i0.7403>
- Molina, F.J. & Mayor, A. (2023). Proveïment de grups caçadors i recol·lectors en dipòsits amb sílex ressedimentat: Mas del Batle (Alcoi, Alacant), una nova àrea de captació del litotipus Mariola. *Recerques del Museu d'Alcoi* 32, 7–24.
- Moncel, M.H., Chacón, M.G., Vettesse, D., Courty, M.A., Daujeard, C., Eixea, A., Fernandes, P., Allué, E., Hardy, B., Rivals, F., Béarez, P., Gallotti, R. & Puaud, S. (2021). Late Neanderthal short-term and specialized occupations at the Abri du Maras (south-east France, level 4.1, MIS 3). *Archaeological and Anthropological Sciences*, 13, 45. <https://doi.org/10.1007/s12520-021-01285-5>
- Mora, R., Roy-Sunyer, M., Martínez-Moreno, J., Benito-Calvo, A. & Samper, S. (2020). Inside the palimpsest: Identifying short occupations in the 497D level of Cova Gran (Iberia). In J. Cascalheira & A. Picin (ed.), *Short-term occupations in Paleolithic archaeology*, 39–69, Springer. https://doi.org/10.1007/978-3-030-27403-0_3
- Morrow, T. (1996). Lithic refitting and archaeological site formation processes: a case study from the Twin Ditch site, Greene county, Illinois. In G.H. Odell (ed.), *Stone tools: theoretical insights into human prehistory*, 345–373, Springer.
- Murugesan, N., Cho, I. & Tortora, C. (2021). Benchmarking in cluster analysis: a study on spectral clustering, DBSCAN, and K-means. In: T. Chadjipadelis, B. Lausen, A. Markos, T.R. Lee, A. Montanari & R. Nugent (eds.), *Data analysis and rationality in a complex world*, 175–185. Springer, Cham. https://doi.org/10.1007/978-3-030-60104-1_20
- Newcomer, M. & Sieveking, G. (1980). Experimental flake scatter-patterns: a new interpretative technique. *Journal of Field Archaeology*, 7(3), 345–352. <https://doi.org/10.1179/009346980791505392>
- Nielsen, A. (1991). Trampling the archaeological record: an experimental study. *American Antiquity*, 56(3), 483–503. <https://doi.org/10.2307/280897>
- Nicosia, C. & Stoops, G. (2017) (eds.). *Archaeological Soil and Sediment Micromorphology*. Oxford
- Nieto-Márquez, I. & Baena, J. (2015). Experiments around the fire, discovering human and natural processes in Middle Paleolithic hearths. *Anthropologie*, 53(3), 501.
- O'Connell, J. (1987). Alyawara site structure and its archaeological implications. *American Antiquity*, 52(1), 74–108. <https://doi.org/10.2307/281061>
- Oliver, M. & Webster, R. (1990). Kriging: a method of interpolation for geographical information systems. *International Journal of Geographical Information Systems*, 4(3), 313–332. <https://doi.org/10.1080/02693799008941549>
- Ortiz, J.E., Moreno, L., Torres, T., Vegas, J., Ruiz-Zapata, B., García-Cortés, Á., Galán, L. & Pérez-González, A. (2013). A 220 ka palaeoenvironmental reconstruction of the Fuentillejo maar lake record (Central Spain) using biomarker analysis. *Organic Geochemistry*, 55, 85–97. <https://doi.org/10.1016/j.orggeochem.2012.11.012>
- Pelegrin, J. (1990). Prehistoric lithic technology: some aspects of research. *Archaeological Review from Cambridge*, 9(1), 116–125.
- Pérez, L., Sanchis, A., Hernández, C. M., Galván, B., Sala, R. & Mallol, C. (2017a). Hearths and bones: an experimental study to explore temporality in archaeological contexts based on taphonomical changes in burnt bones. *Journal of Archaeological Science: Reports*, 12(1), 287–309. <https://doi.org/10.1016/j.jasrep.2016.11.036>
- Pérez, L., Sanchis, A., Hernández, C. M. & Galván, B. (2017b). Paleocología de micromamíferos aplicada a los conjuntos zooarqueológicos de El Salt y el Abric del Pastor (Alcoi, Alicante). *Preses petites i grups humans en el passat. III Jornades d'arqueozoologia*, 327–353.
- Ripley, B. D. (1977). Modelling spatial patterns. *Journal of Royal Statistical Society*, 39(2), 172–192. <https://doi.org/10.1111/j.2517-6161.1977.tb01615.x>
- Roebroeks, J.W. (1988). *From find scatters to early hominid behaviour: a study of Middle Palaeolithic riverside settlements at Maastricht-Belvédère (the Netherlands)*. Leiden University.
- Romagnoli, F. & Vaquero, M. (2016). Quantitative stone tools intra-site point and orientation patterns of a Middle Palaeolithic living floor: a GIS multi-scalar spatial and temporal approach. *Quartär* 63, 47–60. https://doi.org/10.7485/QU63_3
- Romagnoli, F. & Vaquero, M. (2019). The challenges of applying refitting analysis in the Palaeolithic archaeology of the twenty-first century: an actualised overview and future perspectives. *Archaeological and Anthropological Sciences* 11, 4387–4396. <https://doi.org/10.1007/s12520-019-00888-3>
- Rose, J., Hilbert, Y., Usyk, V., Bebbler, M., Beshkani, A., Buchanan, B., Cascalheira, J., Chlachula, D., Dellmour, R., Eren, M., Garba, R., Hallinan, E., Li, L., Walker, R. & Marks, A. (2024). Mapping lateral

- stratigraphy at Palaeolithic surface sites: A case study from Dhofar, Oman. *Journal of Archaeological Science*, 173, 106117. <https://doi.org/10.1016/j.jas.2024.106117>
- Rosell, J., Modesto-Mata, M., Fernández-Laso, M.C., Modolo, M. & Blasco, R. (2019). Refitting bones to reconstruct the diversity in Middle Palaeolithic human occupations: the case of the Abric Romani site (Capellades, Barcelona, Spain). *Archaeological and Anthropological Sciences*, 11, 4601–4619. <https://doi.org/10.1007/s12520-019-00887-4>
- Rottländer, R.C. (1975). The formation of patina on flint. *Archaeometry* 17, 106–110. <https://doi.org/10.1111/j.1475-4754.1975.tb00120.x>
- Roy, M. (2015). Deconstructing archaeological palimpsests: Applicability of GIS algorithms for the automated generation of cross-sections. In: S. Campana, R. Scopigno & G. Carpentiero (eds.), *Keep the revolution going: Proceedings of the 43rd annual conference on computer applications and quantitative methods in Archaeology*, 407–414. Archaeopress.
- Sánchez-Romero, L., Canals, A., Pérez-González, A., Márquez, B., Mosquera, M., Karampaglidis, T., Arsuaga, J. L., & Baquedano, E. (2017). Breaking the palimpsest: an approach to the cultural sequence of Neanderthal occupation at the Navalmaillo rockshelter, Pinilla del Valle (Spain). *Trabajos de Prehistoria*, 74(2), 225–237. <https://doi.org/10.3989/tp.2017.12192>
- Sánchez-Romero, L. (2019). *Desarrollo y aplicación metodológica para el análisis espacial de yacimientos paleolíticos al aire libre y en cueva*. PhD dissertation, Universidad de Burgos.
- Sánchez-Romero, L., Benito-Calvo, A., Marín, A.B., Agudo, L., Karampaglidis, T. & Rios, J. (2020). New insights for understanding spatial patterning and formation processes of the Neanderthal occupation in the Amalda I cave (Gipuzkoa, Spain). *Scientific Reports*, 10, 8733. <https://doi.org/10.1038/s41598-020-65364-8>
- Sánchez-Romero, L., Benito-Calvo, A. & Rios-Garaizar, J. (2021). Defining and characterising clusters in Palaeolithic sites: a review of methods and constraints. *Journal of Archaeological Method and Theory* 29, 305–333. <https://doi.org/10.1007/s10816-021-09524-8>
- Sánchez-Romero, L., Benito-Calvo, A., Iriarte, E., San Emeterio, A., Ortega, I. & Rios, J. (2022). Unraveling Châtelperronian high-density accumulations: the open-air site of Aranbaltza II (Bizkaia, Spain). *Archaeological and Anthropological Sciences*, 14, 77. <https://doi.org/10.1007/s12520-022-01541-2>
- Sánchez-Romero, L., Benito-Calvo, A., De Loecker, D., & Pope, M. (2023). Spatial analysis and site formation processes associated with the Middle Pleistocene hominid teeth from Q1/B waterhole, Boxgrove (West Sussex, UK). *Archaeological and Anthropological Sciences*, 15, 98. <https://doi.org/10.1007/s12520-023-01790-9>
- Sánchez-Romero, L., Martínez-Moreno, J., Benito-Calvo, A., Sánchez-Martínez, J. & Mora, R. (2024). Not only domestic spaces: dismantling short-term occupations in level 497D of Cova Gran de Santa Linya (pre-Pyrenees, Spain). *Journal of Quaternary Science*, 39(7), 1078–1097. <https://doi.org/10.1002/jqs.3648>
- Sanchis, A., Pérez, L., Hernández, C.M. & Galván, B. (2015). La tortuga mediterránea en yacimientos valencianos del Paleolítico medio: distribución, origen de las acumulaciones y nuevos datos procedentes del Abric del Pastor (Alcoi, Alacant). *Preses petites i grups humans en el passat. II Jornades d'arqueozoologia*, 97–120.
- Schiffer, M. B. (1972). Archaeological context and systemic context. *American Antiquity*, 37(2), 156–165. <https://doi.org/10.2307/278203>
- Schiffer, M. B. (1983). Toward the identification of formation processes. *American Antiquity*, 48(4), 675–706. <https://doi.org/10.2307/279771>
- Schiffer, M. B. (1985). Is there a “Pompeii premise” in Archaeology? *Journal of Anthropological Research*, 41(1), 18–41. <https://doi.org/10.1086/jar.41.1.3630269>
- Sossa-Ríos, S., Mayor, A., Hernández, C.M., Bencomo, M., Pérez, L.J., Galván, B., Mallol, C. & Vaquero, M. (2022). Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula). *Scientific Reports* 12, 15883. <https://doi.org/10.1038/s41598-022-20200-z>
- Sossa-Ríos, S., Mayor, A., Sánchez-Romero, L., Mallol, C., Vaquero, M. & Hernández, C.M. (2024). The time of the stones: a call for palimpsest dissection to explore lithic record formation processes. *Journal of Archaeological Method and Theory*, 31, 2188–2238. <https://doi.org/10.1007/s10816-024-09666-5>
- Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Boscato, P., Rinaldo, F. & Ronchitelli, A. (2016). Between hearts and volcanic ash: the SU 13 palimpsest of the Oscurusciuto rock shelter (Ginosa - Southern Italy): analytical and interpretative questions. *Quaternary International*, 417, 105–121. <https://doi.org/10.1016/j.quaint.2015.11.046>
- Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Toniello, G., Astudillo, F., Boschin, F., Boscato, P. & Ronchitelli, A. (2019). Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa - Taranto, southern Italy). *Quaternary Science Reviews* 217, 160–193. <https://doi.org/10.1016/j.quascirev.2018.06.024>
- Spagnolo, V., Marciani, G., Aureli, D., Martini, I., Boscato, P., Boschin, F. & Ronchitelli, A. (2020). Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto rockshelter (Ginosa, southern Italy). *Archaeological and Anthropological Sciences* 12, 54. <https://doi.org/10.1007/s12520-019-00971-9>
- Spagnolo, V., Crezzini, J., Falguères, C., Tombret, O., Garbe, L., Bahrain, J. J., Giaccio, B., Arrighi, S., Aureli, D., Eckberg, I., Boscato, P., Ronchitelli, A. & Boschin, F. (2024). Grotta Grande (southern Italy). Disentangling the Neanderthal and carnivore interaction in a short-term palimpsest at the last glacial onset (116–109 ka). *Quaternary Science Reviews*, 331, 108628. <https://doi.org/10.1016/j.quascirev.2024.108628>
- Speth, J. (2006). Housekeeping. Neanderthal-style: hearth placement and midden formation in Kebara Cave (Israel). In: Erella, H. & Steven, K. (eds) *Transitions before transitions: evolution and stability in the Middle Paleolithic and Middle Stone Age*, 171–188, Springer.
- Starkovich, B., Elefanti, P., Karkanas, P. & Panagopoulou, E. (2020). Site use and maintenance in the Middle Palaeolithic at Lakonis I (Peloponnes, Greece). *Journal of Paleolithic Archaeology*, 3, 157–186. <https://doi.org/10.1007/s41982-018-0006-x>
- Stern, N. (2008). Time averaging and the structure of Late Pleistocene archaeological deposits in southwest Tasmania. In Holdaway, S. & Wandsnider, L. (eds), *Time in Archaeology: Time perspectivism revisited*, 134–178, Utah University Press.
- Stevenson, M. (1985). The formation of artifact assemblages at workshop/habitation sites: models from Peace Point in northern Alberta. *American Antiquity*, 50, 63–81. <https://doi.org/10.2307/280634>
- Stevenson, M. (1991). Beyond the formation of hearth-associated artifact assemblages. In: E. M. Kroll (ed.), *The interpretation of archaeological spatial patterning*, 269–297. Springer.
- Stockton, E. (1973). Shaw's creed shelter: human displacement of artefacts and its significance. *The Australian Journal of Anthropology*, 9(2), 112–117.
- Stoops, G. (2003). *Guidelines for analysis and description of soil and regolith thin sections*. Soil Science Society of America.
- Sullivan, A. (1992). Investigating the archaeological consequences of short-duration occupations. *American Antiquity*, 57(1), 99–115. <https://doi.org/10.2307/2694837>
- Thiry, M., Fernandes, P., Milnes, A. & Raynal, J.P. (2014). Driving forces for the weathering and alteration of silica in the regolith: implications for studies of prehistoric flint tools. *Earth-Science Reviews* 136, 141–154. <https://doi.org/10.1016/j.earscirev.2014.05.008>
- Tomé, L., Iriarte, E., Blanco-González, A., Fernández-Palacios, E., Martín-Seijo, M., Carrancho, Á., Herrera-Herrera, A.V. & Mallol, C. (2024). Fire use and waste management in an Iberian Iron Age village: Geoarchaeological insights into midden formation processes. *Journal of Archaeological Science: Reports*, 59, 104773. <https://doi.org/10.1016/j.jasrep.2024.104773>
- Tomé, L., Jambrina-Enríquez, M., Égüez, N., Herrera-Herrera, A.V., Davara, J., Marrero Salas, E., Arnay de la Rosa, M. & Mallol, C. (2022). Fuel sources, natural vegetation and subsistence at a high-altitude aboriginal settlement in Tenerife, Canary Islands: Microcontextual geoarchaeological data from Roques de García Rockshelter. *Archaeological and Anthropological Sciences*, 14, 195. <https://doi.org/10.1007/s12520-022-01661-9>
- Turq, A., Roebroeks, W., Bourguignon, L. & Faivre, J.P. (2013). The fragmented character of Middle Palaeolithic stone tool technology. *Journal of Human Evolution*, 65(5), 641–655. <https://doi.org/10.1016/j.jhevol.2013.07.014>
- Uthmeier, T., Chabai, V.P., & Veselsky, A.P. (2020). From the apron into the pit: the deposition of the complete debris from the manufacture of a bifacial preform at the Middle Palaeolithic site of Kabazi V, level III/4-2. *Archaeological and Anthropological Sciences*, 12, 71. <https://doi.org/10.1007/s12520-019-00968-4>
- Vallverdú, J., Vaquero, M., Cáceres, I., Allué, E., Rosell, J., Saladié, P., Chacón, G., Ollé, A., Canals, A., Sala, R., Courty, M. & Carbonell, E. (2010). Sleeping activity area within the site structure of archaic human groups: evidence from Abric Romani level N combustion activity areas. *Current Anthropology*, 51(1), 137–145. <https://doi.org/10.1086/649499>
- Vaquero, M. (2001). Contextos de acción intencional y perspectivas historicistas en la interpretación de los conjuntos arqueológicos. *Krei*, 6, 79–104.
- Vaquero, M. & Pastó, I. (2001). The definition of spatial units in Middle Palaeolithic sites: the hearth-related assemblages. *Journal of Archaeological Science*, 28(11), 1209–1220. <https://doi.org/10.1006/jasc.2001.0656>
- Vaquero, M. (2008). The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. *Journal of Archaeological Science* 35(12), 3178–3185.

- <https://doi.org/10.1016/j.jas.2008.07.006>
- Vaquero, M. (2012). Introduction: Neanderthal behavior and temporal resolution of archeological assemblages. In: E. Carbonell (ed.), *High resolution archaeology and Neanderthal behavior. Vertebrate paleobiology and paleoanthropology*, 1–16. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-3922-2_1
- Vaquero, M., Chacón, M.G., García, M.D., Gómez, B., Martínez, K. & Cuartero, F. (2012). Time and space in the formation of lithic assemblages: the example of Abric Romaní level J. *Quaternary International*, 247, 162–181. <https://doi.org/10.1016/j.quaint.2010.12.015>
- Vaquero, M., Bargalló, A., Chacón, M.G., Romagnoli, F. & Sañudo, P. (2015). Lithic recycling in a Middle Paleolithic expedient context: evidence from the Abric Romaní (Capellades, Spain). *Quaternary International*, 361, 212–228. <https://doi.org/10.1016/j.quaint.2014.05.055>
- Vaquero, M., Fernández-Laso, M.C., Chacón, M.G., Romagnoli, F., Rosell, J. & Sañudo, P. (2017). Moving things: comparing lithic and bone refits from a Middle Paleolithic site. *Journal of Anthropological Archaeology* 48, 262–280. <https://doi.org/10.1016/j.jaa.2017.09.001>
- Vaquero, M., Romagnoli, F., Bargalló, A., Chacón, M. G., Gómez de Soler, B., Picin, A. & Carbonell, E. (2019). Lithic refitting and intrasite artifact transport: a view from the Middle Paleolithic. *Archaeological and Anthropological Sciences*, 11, 4491–4513. <https://doi.org/10.1007/s12520-019-00832-5>
- Vaquero, M. (2022). The organisation of living spaces in Neanderthal campsites. In: Francesca, R. Stefano, B. & Florent, R. (eds.) *Updating Neanderthals. Understanding behavioural complexity in the Late Middle Palaeolithic*. Chapter 11, Academic Press, 207–225. <https://doi.org/10.1016/B978-0-12-821428-2.00001-9>
- Vidal-Matutano, P. (2017). Firewood and hearths: Middle Palaeolithic woody taxa distribution from El Salt, stratigraphic unit Xb (Eastern Iberia). *Quaternary International*, 457, 74–84. <https://doi.org/10.1016/j.quaint.2016.07.040>
- Villa, P. (1982). Conjoinable pieces and site formation processes. *American Antiquity*, 47(2), 276–290. <https://doi.org/10.2307/279901>
- Villa, P. & Courtin, J. (1983). The interpretation of stratified sites: a view from underground. *Journal of Archaeological Science*, 10(3), 263–281. [https://doi.org/10.1016/0305-4403\(83\)90011-0](https://doi.org/10.1016/0305-4403(83)90011-0)
- Wadley, L., Sievers, C., Bamford, M., Goldberg, P., Berna, F. & Miller, C. (2011). Middle Stone Age bedding construction and settlement patterns at Sibudu, South Africa. *Science*, 334(6061), 1388–1391. <https://doi.org/10.1126/science.1213317>
- Weitzel, C. & Sánchez, A. (2021). A trampling experiment to assess fractures and edge damage in quarry's lithic assemblages. *Lithic Technology*, 46(4), 286–301. <https://doi.org/10.1080/01977261.2021.1926702>
- Whallon, R. (1974). Spatial analysis of occupation floors II: The application of Nearest Neighbor Analysis. *American Antiquity*, 39(1), 16–34. <https://doi.org/10.2307/279216>
- Wiesenberg, G.L.B., Lehndorff, E. & Schwark, L. (2009). Thermal degradation of rye and maize straw: Lipid pattern changes as a function of temperature. *Organic Geochemistry*, 40, 167–174. <https://doi.org/10.1016/j.ORGGEOCHEM.2008.11.004>
- Yellen, J. (1976). Settlement patterns of the !Kung: an archaeological perspective. In: Richard, L. & Irven, D. *Kalahari hunter-gatherers*, 47–72, Harvard.
- Zech, M., Pedentchouk, N., Buggle, B., Leiber, K., Kalbitz, K., Marković, S.B. & Glaser, B. (2011). Effect of leaf litter degradation and seasonality on D/H isotope ratios of n-alkane biomarkers. *Geochimica et Cosmochimica Acta*, 75, 4917–4928. <https://doi.org/10.1016/j.gca.2011.06.006>
- Zilio, L., Hammond, H., Karampaglidis, T., Sánchez-Romero, L., Blasco, R., Rivals, F., Rufà, A., Picin, A., Chacón, M.G., Demuro, M., Arnold, L.J. & Rosell, J. (2021). Examining Neanderthal and carnivore occupations at Teixoneres cave (Moià, Barcelona, Spain) using archaeostratigraphic and intra-site spatial analysis. *Scientific Reports* 11, 4339. <https://doi.org/10.1038/s41598-021-83741-9>

section



V



DISCUSSION



V. Discussion

5.1. De-scaling lithic assemblages

5.2. Raw material procurement in the Serpis Valley

5.3. Breaking the chains: lithic resource management in Neanderthal groups from the Serpis Valley

5.4. Reading the space, considering the time

5.5. Evaluating palimpsest dissection

V. Discussion

The discussion is structured to address the key research questions guiding this study, progressively integrating the analytical outcomes to evaluate their broader implications. It begins by assessing the potential for reducing the analytical scale of lithic assemblages beyond the stratigraphic unit (5.1), examining its methodological constraints and the extent to which this approach reveals meaningful differences in formation processes. This is followed by an exploration of lithic resource procurement strategies in the Serpis Valley (5.2), considering whether diachronic variations in flint type distribution reflect shifts in Neanderthal mobility patterns. The focus then turns into the formation processes of lithic assemblages (5.3), investigating how the management of introduced resources varied across contexts, and intrasite time and space. Subsequently, the discussion expands to a spatial perspective (5.4), assessing whether differences in raw material procurement and management influenced site organisation and use over time. Finally, the validity and implications of palimpsest dissection as a methodological framework are critically evaluated (5.5), considering whether downscaling the analytical unit provides higher-resolution insights into Neanderthal behavioural dynamics.

5.1. De-scaling lithic assemblages

The identification of AUs, which represent the most suitable starting point for examining human behaviour and its variability, has yielded heterogeneous results across the archaeological contexts studied. Our approach, based on event correlation through three-dimensional positioning and physical links (i.e. RMUs and refits), has generated high-resolution units of analysis, such as AU IVfH17 at Abric del Pastor, while also revealing units with greater uncertainty, as seen in the AUs from SU V at Abric del Pastor and SU Xb at El Salt.

Abric del Pastor: an easy task?

In SU V, the results were promising, although it was not possible to define AUs. Nevertheless, we identified two formation stages, both in the north, evidenced by refits (with a vertical distance of 3 cm), and southeast, where a hiatus of almost 10 cm was observed (Sossa-Ríos et al., 2025). Despite these indications, the inability to define AUs can be explained by the localised nature of the hiatuses in the southeast, which lack continuity towards the central area. Meanwhile, in the north, single products do not exhibit a vertical correlation with the position of Serreta (upper) or Mariola (lower) refits, but instead appear highly compacted in the vertical profiles. The presence or absence of these material gaps is likely influenced by both natural and anthropogenic factors in the formation of the deposit.

From a geogenic perspective, the southeastern area is characterised by a coarser sediment fraction throughout the unit. This feature is recurrent in nearly all identified AUs of SU IV, where material hiatuses reach or exceed 10 cm (e.g. IVc1-IVb; Machado et al., 2013, 2019). Such patterns suggest rapid and sufficiently large-scale sedimentation processes (involving blocks, pebbles, etc.) capable of clearly separating earlier events from later ones (Mallol et al., 2019; Connolly et al., 2019). In contrast, the rest of SU V surface is composed of a finer fraction. Additionally, a difference in depth between both units is observed (60–80 cm for SU IV; 15–30 cm for SU V). This variation in the thickness of the deposit, which is likely associated with such textural changes, may explain the difficulty in precisely linking single introduction events with certain knapping events in SU V, although human activity and other natural processes must also be considered.

In the northern area, where sediments are even finer (sands and gravels), factors such as trampling (considering the location of recurring knapping area) and weathering (due to its location beyond the drip line) may have sufficiently contributed to slight vertical dispersion. This is suggested by the taphonomic alterations observed on artefacts concentrated in this area (e.g. through edge damage and patina on edge), aligning with experimental studies (e.g. Villa & Courtin, 1983; Gifford-González et al., 1985; Caux et al., 2018; Burrioni et al., 2002; McPherron et al., 2014; Weitzel & Sánchez, 2017).

Thus, although we were unable to define vertical units of analysis beyond SU V, we could establish diachronic correlations between events, allowing us to observe certain aspects of variability in the formation of the record. A similar approach has been applied, for example,

at Roca dels Bous level 10 or Cova Gran level 497D, where, despite the inability to formally group events into AUs, distinctions were still identified based on the vertical positioning of hearths, refits, and blocks (Martínez-Moreno et al., 2016; Sánchez-Romero et al., 2024).

Conversely, the study of the basal levels of SU IV produced highly conclusive results, following the upper part of this unit (Machado et al., 2013, 2019). Here, we identified continuous artefacts beds and hiatuses, enabling us to distinguish AU IVfH17 and AU IVf1 as spatially and temporally independent units, separated by 5–6 cm (Sossa-Ríos et al., 2022), similar to the high-resolution unit reported by Adler et al. (2003) in Wallertheim A site. This area (western sector) has consistently displayed a sandier composition throughout the deposit, suggesting that the vertical distinction between these sets of events could be linked to an extended formation period without anthropogenic activity.

In this regard, experimental studies on trampling in compact sandy silt (similar to that of the western sector) conducted by Gifford-González et al. (1985) recorded vertical displacements of up to 3–4 cm after just two hours of activity. Given that no such displacements were detected in our case, and that the material gap itself spans a similar distance, this may indicate a brief duration or low intensity of activities in both AUs, alongside a favourable state of preservation. However, other factors such as the penetrability of the sediment need to be assessed (McBrearty et al., 1998), for example, by further experimentation taking into account the specific characteristics of the Abric del Pastor and its granulometric differences.

These examples from Abric del Pastor highlight the complexity and dynamism of formation processes. While low-density assemblages appear to be the most suitable for inferring behaviour and spatio-temporal patterns (Binford, 1980; Roebroeks, 1988; Conard & Adler, 1997; Adler et al., 2003; Vaquero, 2008), additional factors, such as geogenic formation processes, syn- or post-depositional anthropogenic alterations, or the absence of fire, introduce significant challenges, further complicating the identification of discrete formation stages, as reported in other archaeostratigraphic attempts (e.g. Cuesta de la Bajada; Moclán et al., 2023).

In this regard, fire plays a crucial role in establishing spatial and temporal relationships between events. In SU IV, the upper limits of each hearth served as a reliable reference, allowing lithic artefacts to be associated both vertically and horizontally within a hearth-related assemblage. Conversely, in SU V, where only a single hearth is present, no material associations could be established. This underlines the dual nature of fire: beyond its role in structuring social behaviour, it also acts as a key surface marker in archaeological contexts, aiding in the recognition of event depositional “times” and activity patterns (Stevenson, 1991; Vaquero & Pastó, 2001; Mallol et al., 2013).

These findings build upon previous data, resulting in a total of seven AUs and a SU with at least two distinct formation stages. In the following chapters, we will explore the content of these units and address key questions regarding intra- and inter-site diachronic variability.

El Salt: a challenging puzzle

The case of El Salt Xb presents both advantages and challenges compared to Abric del Pastor. First, a structural difficulty arises: Holocene erosion has significantly limited the correlations between the inner area, closer to the rockshelter wall, and the outer area, further away. This erosion has directly affected the contact between these two zones, disrupting continuity within the general point pattern. As a result, we had to treat them as separate assemblages, relying solely on physical linkages between events (i.e. refits) as the only means of emerging temporal relationships.

When treated as isolated assemblages, we were able to distinguish two formation stages in the outer area (AU Xb2out and Xb1out) and two in the inner area (AU Xb2in and Xb1in) (Sossa-Ríos et al., 2024). However, no direct correlations could be established between inner and outer formation stages due to the absence of refits connecting both areas. The only potential link was a two-piece RMU, which, while tentatively suggesting a connection between the older AUs, was considered insufficient. This spatially constrained approach was also applied to SU Xa, where four AUs were identified in the outer area and four in the inner area. Here too, only a single two-piece RMU was found linking two of these AUs, but this was again judged not enough (Machado & Pérez, 2016; Machado et al., 2017). Therefore, while the general count suggests four AUs in SU Xb and eight in SU Xa, this should not be interpreted as a straightforward sequence in which each AU directly overlies the previous one. Instead, we must conceive these sequences as independent within each area, with the unresolved uncertainty regarding inner-outer temporal relationships.

In SU Xb, the identification of two distinct groups of events in the outer area was facilitated by the regularity and gentle slope of the material beds, as well as by the hiatus separating them (1–5 cm). Their differentiation was further supported by vertical associations with well-preserved hearth features (Leierer et al., 2019), but was also reinforced by an archaeostratigraphic analysis of the leporid assemblages conducted in a recent undergraduate thesis (Mir-Lápido, 2024). This study found that rabbit remains, predominantly of natural origin (Marín-Monfort et al., 2021), were particularly distributed within the hiatus between AUs Xb2out and Xb1out, effectively filling the identified gap. This finding presents both an advancement and a challenge for archaeostratigraphy, demonstrating that occupational hiatuses are not necessarily displayed as material gaps.

This area exposes similarities to other Palaeolithic contexts where hiatuses are clearly evidenced, and material beds exhibit good lateral continuity. Examples include level 11 at Oscurusciuto rockshelter by a continuous 2-3 cm material gap (Spagnolo et al., 2020a), level F at Navalmaíllo, where a distinct 5-7 cm hiatus allows differentiation between two assemblages (Sánchez-Romero et al., 2017), and level O at Abric Romaní, which has been further subdivided not only between Oa and Ob but also within the latter (Ob1 and Ob2) (Bargalló et al., 2016; Gabucio et al., 2018). A similar pattern is observed in level M, where a clear distinction is made between M and MInf (Vaquero et al., 2015; Gabucio et al., 2018). This latter case is particularly relevant to our outer area, as much like our observations, a greater

separation between formation stages is evident towards the outer zone of the rockshelter (e.g. profile L5; Vaquero et al., 2015: 216). Such differential archaeostratigraphic separation based on the site surface is even more pronounced in level J at Abric Romani, divided into Ja and Jb, though this distinction is only perceptible across part of the excavated area (Vaquero et al., 2012).

In this line, the inner area of El Salt SU Xb presented significantly more difficulties. Here, material beds were irregular in shape, and while hiatuses were present, they were more localised and thinner (1–3 cm). In this case, the tridimensional properties of events and their interrelations were substituted by their associations with hearths and the connections revealed through refits. This allowed us, despite considerable challenges, to differentiate earlier events from later ones.

These differences in the arrangement and distribution of 3D points between the inner and outer areas were not observed in SU Xa, where the regularity and separation between discrete formation stages were also detected near the shelter wall (Machado et al., 2017), similar to the archaeostratigraphic results of Bolomor (Sañudo et al., 2016). This suggests that the inner area underwent more complex formation processes during SU Xb, particularly in its earlier stage.

At the base of the sequence, the oldest assemblage (AU Xb2in) exhibits a more irregular distribution, with vertical refit connections spanning some centimetres. This prevented us from identifying clear subdivisions within the lower part of the point-pattern. The evidence from hearth H66, the only fire structure associated with this AU, provides further support for this blurred image. Archaeomagnetic analysis on thin sections has revealed vertical mixing of magnetic particles within this hearth, which has been interpreted as the result of trampling (Dinckal et al., 2024), in line with previous archaeomagnetic experiments aimed at understanding hearth formation processes at El Salt (Herrejón-Lagunilla et al., 2019).

In contrast, the more recent formation stage (AU Xb1in) shows lower density, less vertical displacement and greater regularity in lateral continuity along the material bed. This apparently good preservation of the last moments is also evident in the associated hearths. Fires from this most recent formation stage exhibit well-preserved microstructures in both black and white layers (e.g. H55, H57, H61; Leierer et al., 2019).

What factors might explain these differences in point pattern distribution between the two AUs? On the one hand, this may be linked to a lower sedimentation rate during the initial stages of SU Xb, resulting in prolonged exposure to both natural and anthropogenic agents, which in turn could have shaped the observed point pattern distribution. While such low sedimentary conditions have been proposed for SU Xb, no clear change has been identified between the upper and lower segments of the unit (Leierer et al., 2019).

With this picture, we cannot dismiss the presence of distinct formation stages within the broader pattern of AU Xb2in, generated without direct hearth associations and characterised by high-intensity activities (e.g. *in situ* knapping). Such activities may have contributed to the

vertical displacement of materials. It is therefore possible that not all events within AU Xb2in correspond to the upper limit of H66; instead, some later events may be interweave with those from the earliest moments of SU Xb formation processes. This scenario was already highlighted by Martínez-Moreno et al. (2004) at level 10 of Roca dels Bous, where several artefacts were found above a hearth but lacked lateral association with any other. While hearths serve as reliable surface markers, they do not necessarily account for all activity surfaces, as events may also occur in areas without combustion structures.

According to Stevenson (1991: 279), this scenario could have resulted in a size-sorting effect, with smaller artefacts being more susceptible to downward displacement into the sedimentary matrix. However, it would be difficult to determine whether size-sorting actually occurred, as this area is already dominated by small and very small lithic products. A vertical analysis incorporating taphonomic variables (e.g. edge damage), similar to our approach in SU V at Abric del Pastor, may have provided further insight into this issue.

Regarding natural formation processes, we identified an irregular point pattern in the area closest to the shelter wall, which may be the result of deposit deformation caused by a fallen block, potentially accompanied by wall-effect deformations (Goldberg & Macphail, 2005; Mentzer, 2017). This deformation event must have occurred after the formation of the upper AU, as it ultimately modified the morphological pattern of all events (Fig. 17). This finding underscores the limited explanatory capacity of archaeostratigraphy when dealing with non-anthropogenic formation events. A stronger emphasis on experimental research could help address these uncertainties (Bertran et al., 2019). For example, controlled experiments could be used to assess the extent to which block falls (ubiquitous in almost all cave and rock shelter contexts) alter vertical and horizontal point patterns. Further experimentation in this area is needed for a better understanding of archaeological formation processes.

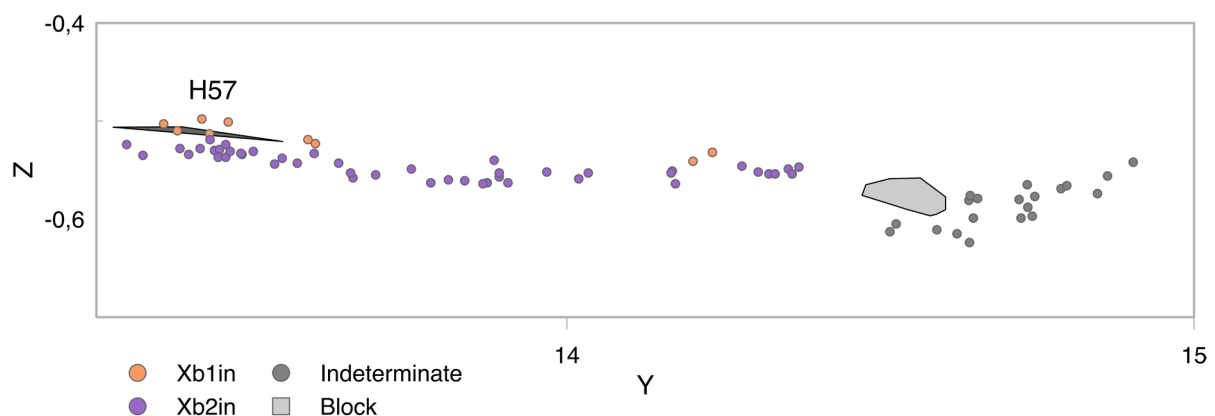


Fig. 17. 25-cm-thick cross-section corresponding to the inner area of El Salt SU Xb. This section exhibits the good lateral correlation of certain events of AU Xb1in with H57; the more irregular pattern of AU Xb2in, as well as the natural processes affecting the preservation of the point pattern near the wall, presumably due to the fall of the block and the wall effect.

Towards a microcontextual archaeostratigraphy

As we have seen, archaeostratigraphy has allowed us to reveal temporal dynamics through different correlations between events and/or groups of events in both sites. However, it is crucial to highlight that the resulting units of analysis still lack the resolution necessary to accurately correlate and characterise most human behaviours.

In both our case studies and others documented in the literature, the ability to segment stratigraphic units rarely exceeds two, three, or four formation stages (AUs). Each of these stages encompasses multiple events of material introduction and management, condensing processes that may, in reality, have occurred over an extended period. This level of resolution remains insufficient. This suggests that our difficulty in defining finer analytical units may stem from an inadequate scale of analysis, one that generates a macroscopic blur and prevents us from identifying correlations between events occurring at much smaller scales.

Geoarchaeology has already confronted this challenge and responded by focusing on characterising formation processes at a fine-grained scale (Courty, 2001; Nicosia & Stoops, 2017; Karkanas & Goldberg, 2018). Within this discipline, it would be entirely inadequate to attempt to identify abandonment events within a stratigraphic unit solely by observing a section profile. In fact, many abandonment processes, defined as episodes of natural sedimentation without anthropogenic activity (what we consider a hiatus), have been identified through micromorphology in layers less than a centimetre thick.

For example, at Roc de Marsal, micromorphological analyses revealed that natural sedimentation events covering apparently superimposed hearths were less than one centimetre thick (Aldeias et al., 2012). A similar phenomenon was observed at Theopetra Cave, where thin lenses of natural sedimentation, only a few millimetres thick, separated successive hearths (Karkanas & Kyparissi-Apostolika, 2024). Likewise, at Roques de García Rockshelter, microfacies containing abundant anthropogenic residues were interspersed with layers of natural sedimentation measuring approximately one to three centimetres in thickness (Tomé et al., 2022).

Archaeostratigraphy must follow a similar path. We are searching for these same hiatuses, yet we do so by analysing point patterns composed of thousands of artefacts, often with depths of analysis reaching or exceeding one metre. Unlike geoarchaeology, however, we have the advantage of working in three dimensions, with the ability to sample any area of the site without modifying its structure. Moreover, we can integrate a broad range of techno-economic and taphonomic variables into the point-pattern, providing a richer and more nuanced perspective on formation processes, especially in high-density palimpsests (Fig. 18).

This does not mean abandoning an archaeostratigraphic analysis based on 3D cross-sections spanning the entire site. On the contrary, such analyses remain essential for assessing the lateral continuity of material beds. However, this should be complemented by a detailed examination of specific zones within the studied unit, allowing for the identification of relationships or independent events that may then be extended to the broader area.

Whether this approach will lead to a more precise reconstruction of past human behaviour remains uncertain. We may ultimately find that the complexity of formation processes exceeds our ability to resolve them archaeostratigraphically. It is also possible that the lack of lateral correlation between certain events will prevent us from defining distinct AUs. However, even in that scenario, this approach would still contribute to a deeper understanding of formation processes, helping to refine our perception of how archaeological deposits accumulate and transform over time.

This proposal aligns with recent efforts to renew archaeostratigraphic methodologies, such as the study of Arteaga-Briebe et al. (2023), which integrates Machine Learning to quantitatively associate points with specific AUs. Both their approach and our future proposal share an additional objective: reducing the high-time costs associated with archaeostratigraphic analysis. Given the labour-intensive nature of this technique, the density of palimpsests can easily saturate analytical capacity, especially considering that traditional assessments are predominantly qualitative. By incorporating new analytical strategies, we aim to mitigate these limitations, making archaeostratigraphy more efficient without sacrificing interpretative depth.

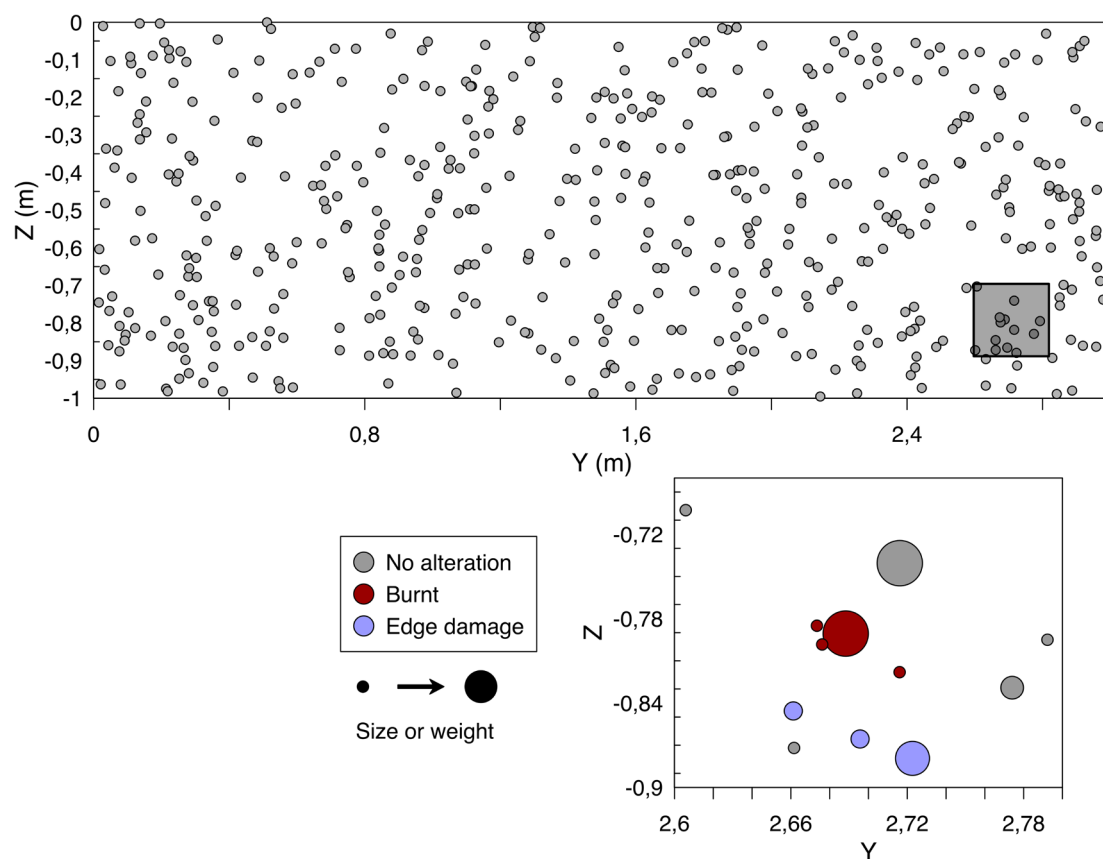


Fig. 18. Hypothetical example of a very irregular point pattern with few visible and regular hiatuses or lateral connections between beds. Archaeostratigraphy on such pattern would probably produce very discouraging results, even more so without the inclusion of any structural variables (e.g. fires, blocks). However, zooming in to a smaller window of analysis (e.g. 20x20 cm) with the integration of techno-economic or taphonomic variables allows some relationships between points to be observed. Points were randomly generated with Python 3.12 and Spyder 6.0.3.

5.2. Raw material procurement in the Serpis Valley

Although this Thesis does not aim to define specific procurement zones of lithic resources, the differentiation of flint types, supported by their characterisation in terms of composition and territorial distribution by Francisco Javier Molina (2015), provides a solid foundation for interpreting mobility and behavioural patterns in this study.

The analysis of raw materials from both sites, across the various analytical units defined in this Thesis (Sossa-Ríos et al., 2022, 2024, 2025), as well as those previously studied (Machado et al., 2013, 2017, 2019; Sossa-Ríos, 2021; Mayor et al., 2022), has enabled the observation of structural behaviours and the identification of variability in lithic resource procurement patterns.

When analysing the distribution of different flint types in both sequences, the first notable feature is the heterogeneity observed at the Abric del Pastor, in contrast to the considerable overall homogeneity at El Salt.

Variability in flint type introduction at the Abric del Pastor

The data presented in this work pertain to the earliest part of the known sequence at the Abric del Pastor (Fig. 19). This lower section is characterised by a predominance of Mariola flint in both analytical units, particularly in AU IVfH17, where it exceeds 80% in a quantitatively small assemblage ($n = 11$) (Sossa-Ríos et al., 2022). In SU V, this predominance was identified through RMU and refitting analysis, since a product-based approach rather than an original nodule-based one would have positioned Serreta flint as the most represented type (Sossa-Ríos et al., 2025).

While this approach successfully adjusted the percentages, we recognise that this representation still has a temporal dimension problem, which, however, we managed to mitigate. Although we could not establish finer temporal analytical units beyond the stratigraphic unit, we know that Mariola refitting sets are associated with the earlier phases of SU V, while Serreta refits, the second most represented type, dominate in later phases. As discussed in the previous chapter, our hypothesis is that SU V formed during at least two depositional stages, each coinciding with the input of different flint types (Sossa-Ríos et al., 2025).

When comparing Mariola flint from our analytical units, associated with the earliest phases, with previously defined units corresponding to later phases, significant variability over time becomes evident, with no apparent trend. While this flint predominates in SU V and AU IVfH17, it alternates between periods of low representation (e.g. AU IVf1, AU IVd1, AU IVc1) and episodes where it dominates or fully constitutes the assemblage (e.g. AU IVe1, AU IVc2) (Machado et al., 2019; Sossa-Ríos, 2021). Nonetheless, its recurring presence across all defined units highlights its sustained procurement and introduction into the site.

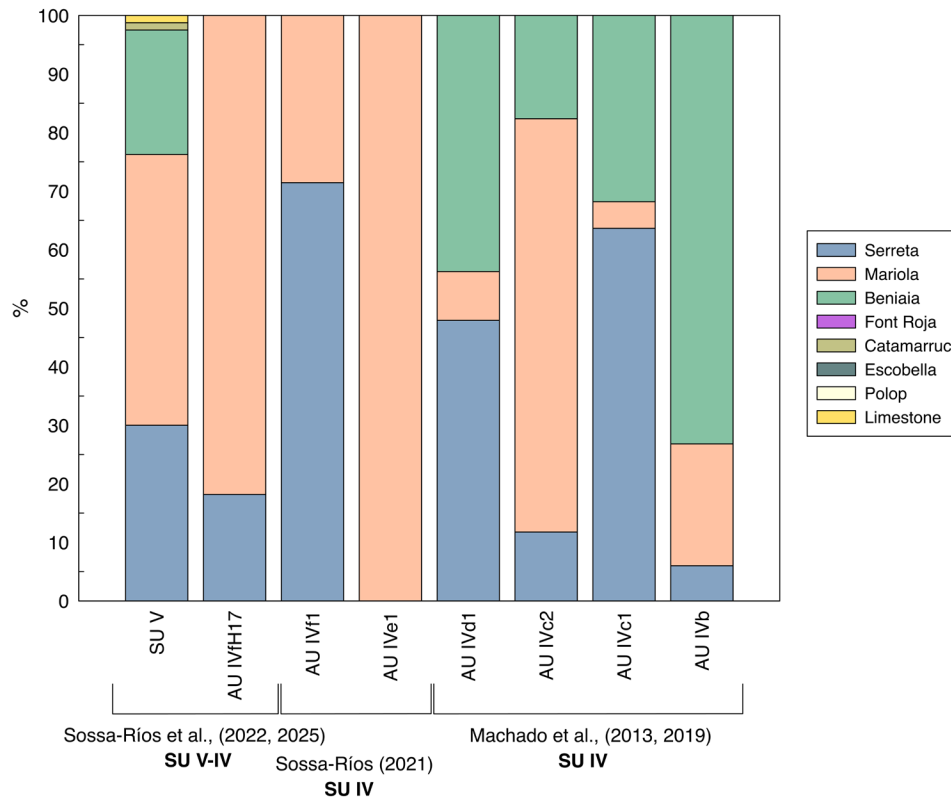


Fig. 19. Raw material distribution by units of analysis along the studied sequence of Abric del Pastor. Indeterminate products were excluded from the representation.

The second most represented type, Serreta flint, exhibits a similar pattern to Mariola flint, with abrupt oscillations throughout the sequence. This type dominates in some units (e.g. AU IVf1, AU IVd1, AU IVc1) but registers low (AU IVfH17, AU IVc2, AU IVb) or even null representation in others (AU IVe1) (Machado et al., 2013, 2019; Sossa-Ríos, 2021). This diachronic variability contrasts with the pattern observed at El Salt, where, except for SU VIII, Serreta flint dominates in each archaeostratigraphic unit within SU Xb and SU Xa, as discussed in following sections.

For Beniaia flint, the results from SU V and AU IVfH17 offer an interesting perspective on the general sequence of the Abric del Pastor. These results reveal a moderate and presumably diachronic introduction during SU V, followed by an abrupt change in AU IVfH17, marked by a prolonged stasis in its introduction (AU IVfH17, AU IVf1, and AU IVe1) (Sossa-Ríos, 2021). In the later phases, Beniaia flint becomes increasingly prominent, dominating the assemblage in the most recent AU (IVb) and showing significant representation in AU IVd1 and AU IVc1, at the expense of Mariola flint (Machado et al., 2013, 2019).

Finally, we could also identify previously unrecognised raw materials and flint types in the sequence. One example is Catamarruc flint, represented solely by a flake in SU V. This introduction is accompanied by another single element: the limestone core. The presence of these materials in SU V suggests a behaviour whose significance in earlier periods remains unknown, but which evidently diminished further over time.

Mobility dynamics based on lithic resources: Abric del Pastor

In terms of mobility, we rely on inferences of varying precision. For SU V, the absence of a post-genetic analysis prevents the correlation of each element with specific procurement contexts (Fernandes & Raynal, 2006; Fernandes, 2012). This limitation is particularly significant for Serreta flint, whose potential procurement contexts are mainly located in the upper course of the Serpis River but are also relatively abundant in the middle course and coastal areas (Molina, 2015). The ongoing study on this topic is expected not only to help establish approximate procurement zones but also to provide indirect indicators of diachronic variability within this stratigraphically complex unit.

For Mariola, Beniaia, and Catamarruc flints in SU V, the task of identifying procurement contexts is more straightforward. Potential sources Mariola flint type are primarily located in the upper course of the Serpis river, which limits mobility ranges to a radius of 3–5 km (Molina, 2015; Molina et al., 2016; Mayor et al., 2022). Similarly, the potential procurement sites for Beniaia and Catamarruc flints are located near the Barranc de L'Encantà in the middle course of the Serpis, at a minimum distance of approximately 17 km (Molina, 2015; Molina et al., 2016; Mayor et al., 2022).

With this information and considering the distribution of flint types throughout the sequence, we can propose hypotheses regarding mobility dynamics and Serreta flint procurement in SU V. For instance, in AUs IVd1, IVc1, and IVb, Beniaia flint represents 30–70% of the assemblage, coinciding with a significant decrease in Mariola flint, which reaches its lowest representation in the sequence. This pattern could suggest a shift in mobility dynamics, moving away from the upper course (Mariola flint) and focusing on the middle course of the Serpis, where both Beniaia and Serreta flints could be procured.

Following this logic, we might hypothesise the reverse relationship: in units dominated by Mariola flint, with little or no presence of Beniaia flint, Serreta flint was likely sourced mainly from the upper course, where its procurement contexts slightly overlap with those of Mariola flint. This hypothesis may apply to SU V, where such a relationship is suggested.

In AU IVfH17, we have post-genetic data, albeit restricted to Mariola flint due to the absence of cortical surfaces in the Serreta assemblage. Observations of polishing and abrasion on Mariola flint indicate procurement near the Serra de Orens, specifically in the Oligocene conglomerates located about 3 km from the Abric del Pastor (Sossa-Ríos et al., 2022). For SU IVd-a, the cortical and neo-cortical surfaces of Mariola flint display stigmata predominantly associated with these Oligocene resedimentation deposits, as well as nearby slope deposits adjacent to the country rock (Molina, 2015). These findings reinforce the hypothesis of recurrent procurement of Mariola flint from these contexts, persisting throughout the earlier sequence until Beniaia flint became predominant in the more recent units. For Serreta flint in AU IVfH17, the hypothesis proposed for SU V could also apply, supported by the complete absence of Beniaia flint in this unit.

Despite differences in the temporal resolution of our units of analysis, and based solely on lithic resources, a recurrent mobility pattern is evident. This pattern suggests short-range mobility (3–5 km) from the south in both units, combined with presumably sporadic and diachronic visits to more distant areas (>17 km) from the northeast during SU V.

Variability in flint type introduction at El Salt

At El Salt, the defined and characterised units correspond to the basal layers of the excavated sequence (Fig. 20) (Sossa-Ríos et al., 2024). In these earlier moments, there is a sustained predominance of Serreta flint, followed by Mariola and Beniaia flints. This trend observed in our data continues throughout all the AUs defined in SU Xa (Machado et al., 2017) until SU VIII, where the dynamics shift in favour of Beniaia flint type (Mayor et al., 2022).

Despite the apparent homogeneity in the early phases, certain relationships emerge between the proportional representation of lithotypes and the specific areas of the site. For example, while Serreta flint predominates across all AUs, there is a slight reduction in its representation in the inner zone, accompanied by an increase in Mariola and Beniaia flints, as well as minor flint types. This reduction of Serreta flint in the inner area seems consistent throughout SU Xa, except in AU 5.3, where it reaches its highest representation (Machado et al., 2017).

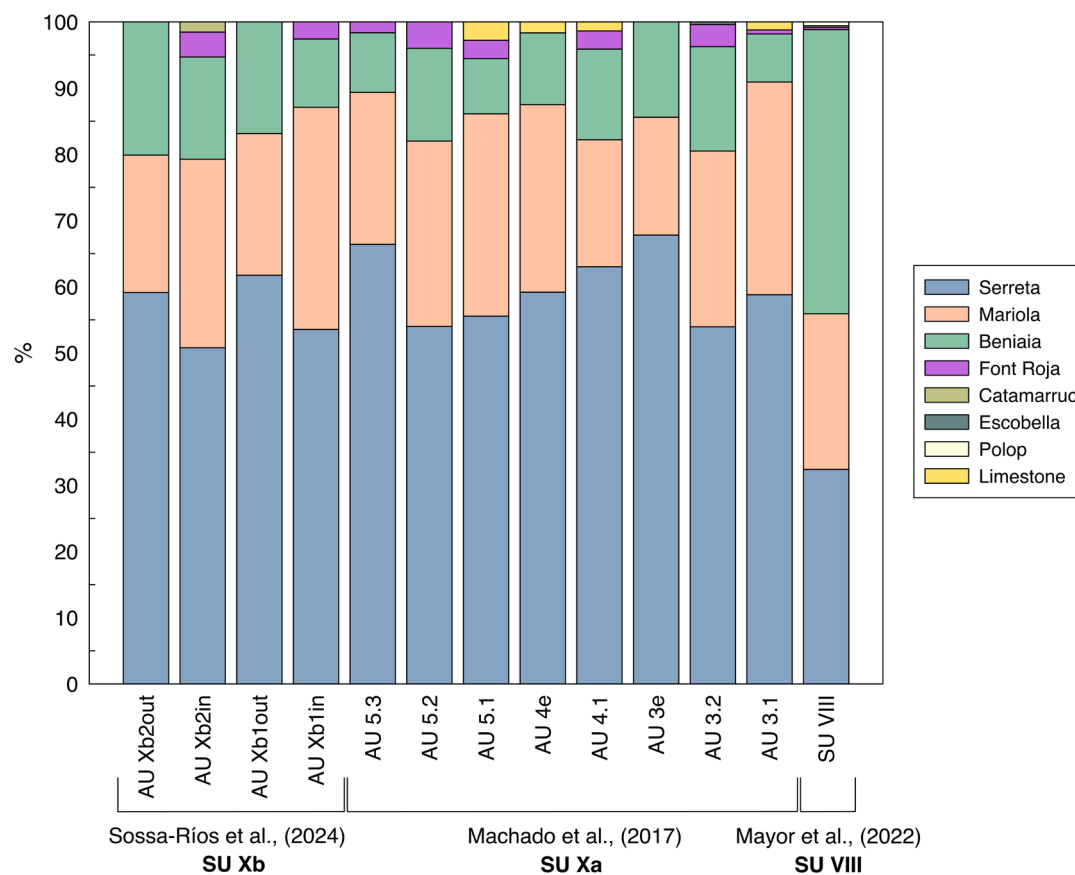


Fig. 20. Raw material distribution by units of analysis along the studied sequence of El Salt. Indeterminate products were excluded from the representation.

Mariola flint consistently remains the second most represented lithotype (except in SU VIII), yet it exhibits fluctuations within our units, peaking at 33% in AU Xb1in. In the more recent phases (AUs 5.2 and 3e), Mariola flint shows a slight downward trend, contrasting with Serreta flint, which increases in representation over the same units.

Beniaia flint demonstrates a similar pattern but primarily in the earlier phases of the exterior zone, reaching 20% representation. Subsequently, its representation decreases, hitting a low of 9% in AU 5.3. It will be in later times that this flint will clearly dominate the assemblage of SU VIII (Mayor et al., 2022).

The minor flint types identified in our sample (Font Roja and Catamarruc) are present in low percentages and only in the units associated with the inner part of the shelter. Font Roja flint appears in both AUs Xb2in and Xb2in, while Catamarruc flint is restricted to the older unit, Xb2in. This pattern seems to persist, as these lithotypes are absent in the oldest outer AUs of SU Xa (AUs 4e and 3e), until they appear in AUs 3.2 and 3.1. The presence of minor flint types remains scarce across all AUs from SU Xa and SU VIII, generally accounting for less than 10% of the assemblage.

Lastly, it is worth noting the presence of limestone in four AUs of SU Xa. However, limestone is very poorly represented and it is predominantly associated with its use as hammers and certain flakes (Machado et al., 2017). However, the exclusion of limestone from the analysis of our units precludes any detailed comparison.

Mobility dynamics based on lithic resources: El Salt

The study of lithic resources at El Salt allows us to hypothesise about mobility dynamics, even though post-genetic data is unavailable for the analysed sample. For SU Xa, previous research has identified a predominance of provisioning activities in colluvial contexts near the site, particularly for Serreta flint, with catchment ranges estimated at 3–5 km (Molina, 2015). By contrast, SU VIII exhibits distinct mobility patterns, characterised by the predominant acquisition of Beniaia flint from alluvial contexts in the mid-course of the Serpis River, over 21 km away (Mayor et al., 2022).

Assuming a correlation between the predominance of Serreta flint and its procurement contexts, we propose that the units analysed in this study mark the onset of the dynamics observed in SU Xa, with activities focused on the upper course of the Serpis. This hypothesis is further supported by the consistent presence of Mariola flint as the second most represented lithotype, as its primary catchment areas are also located in the upper course of the river (Molina, 2015; Mayor et al., 2022).

As proposed for El Abric del Pastor, these patterns contrast with phases when other mobility routes predominate, such as SU VIII, where Beniaia flint becomes dominant. According to our previous work (Mayor et al., 2022), the predominance of Beniaia flint type in these units may be attributed to either paleoenvironmental factors reducing the availability of Serreta and Mariola flints in the upper course, to a shift in mobility dynamics, with groups focusing on the mid-course of the Serpis River, or a combination of both.

The consistent, albeit low, presence of minor lithotypes at El Salt, particularly Font Roja flint, can be linked to the proximity of its catchment areas, some less than 3 km from the site (Molina, 2015). In contrast, the Catamarruc flint, estimated to originate from at least 21 km away, may have been acquired alongside Beniaia flint, as they share similar catchment locations in the mid-course of the Serpis (Molina, 2015; Mayor et al., 2022).

The low representation of Font Roja and Catamarruc flints may be explained by differing factors. For Font Roja, its limited availability could result from its late exposure to erosive processes, delaying its release and accessibility until the Pleistocene. Meanwhile, the scarcity of Catamarruc flint, beyond the challenge of its distance, could be attributed to its quality. As a recently formed lithotype (Miocene), similar to Polop flint, it may not have undergone sufficient crystallization to be easily knapped (Molina et al., 2010; Mayor et al., 2022).

Based on this analysis, we propose that the mobility patterns for the studied units were predominantly short-range (3–5 km), focused on the upper course of the Serpis River, where both Serreta and Mariola flints were sourced. These short-range patterns were complemented by presumably diachronic yet sporadic visits from/to the northeast (>21 km), targeting the acquisition of Beniaia flint and occasionally Catamarruc flint. Finally, two distinct moments in time, represented by the two RMUs of Font Roja flint, suggest nearly immediate catchment events in the vicinity of the site (1–3 km).

However, these interpretations must be approached cautiously. The characterised AUs still have indeterminate temporal resolution. Mobility patterns could vary between individual provisioning events, which remain undetectable in archaeostratigraphic units like these, where potentially diachronic events are immersed.

Neanderthals on the move: mobility patterns in the Serpis Valley

After analysing the lithic resource procurement strategies and mobility dynamics at Abric del Pastor and El Salt, it is essential to consider both sites in a broader framework, assessing their place within the Serpis Valley and their relationship with other European territories regarding the “techniques d’acquisition” (*sensu* Geneste, 1991).

At both sites, flint dominates as the primary raw material, consistently representing over 90% of the assemblages in all units of analysis. This predominance can be explained by several factors linked to the characteristics of the Serpis Valley (Molina, 2015; Molina et al., 2016). Firstly, erosional processes, prior and contemporaneous to the Pleistocene, facilitated the release of flint from its country rock, making it accessible in fluvial, alluvial, and colluvial contexts. Secondly, its widespread distribution across the valley, from the headwaters of the river to its mouth, ensured its availability to human groups. Thirdly, the main flint types (Serreta, Mariola, and Beniaia) generally exhibit high knappable quality, reinforcing their preference over other materials. Finally, the absence of other raw materials, such as quartzite or quartz, within the territory (apart from limestone) further highlights the dominance of flint.

Limestone, while less represented, is present at both sites, reaching its peak in AU 5.1 from El Salt, where it accounts for 5% of the assemblage. At this site, limestone appears to have been procured locally from the shelter conglomerates and is mainly associated with percussion activities (Abreu, 2011). In the case of Abric del Pastor, we need to add a nuance to the representation of this material, which is that the deposit is mainly composed of limestone cobbles. This is both a challenge and a logistical problem, as it is in other Palaeolithic contexts such as Sibudu with sandstone (Will, 2021) or Lagar Velho with limestone cobbles, which, although not from the shelter itself, predominate within the record (Alonso-Fernández et al., 2023). However, the single core identified in SU V, made of esparitic limestone, indicates an external source distinct from the micritic limestone characteristic of the shelter.

The patterns observed in our units of analysis, defined by the dominant procurement of flint from close sources near the river (mainly within a 3–5 km radius), combined with occasional and diachronic incorporation of materials from more distant origins (>15 km), find parallels in other Neanderthal mediterranean contexts.

For instance, at Roca dels Bous, Neanderthal groups associated with Unit N12 primarily exploited black quartzite, sourced locally (<5 km) from secondary fluvial deposits of the Segre River (Roy-Sunyer et al., 2017). However, the presence of Garumnian chalcedony and Serra Llarga flint, exceeding 10 km in distance, indicates occasional procurement of more distant resources. Nearby, at Cova Gran, the late Middle Palaeolithic level S1B exhibits a similar pattern, albeit centred on chalcedony, with nearby sources dominating the assemblage. In contrast, black quartzite, sourced from Segre terraces (>10 km), appears in smaller quantities (Roy-Sunyer, 2016; Mora et al., 2018).

At Abri du Maras, the comparison of Levels 4.2 and 4.1 highlights a strong relationship between Neanderthal groups and the Ardèche River, with resource procurement in secondary conglomeratic contexts (Moncel et al., 2024). Nonetheless, variations in mobility routes are evident. In Level 4.2, resources were obtained both north and south of the river, while in Level 4.1, procurement predominantly occurred to the south. Although specific mobility ranges remain undefined, distances of 3–30 km are suggested for northern routes, while southern routes range from 2–20 km.

This close relationship between Palaeolithic hunter-gatherer groups and specific territories is also observed in other European regions. In the Aquitaine Basin, Neanderthal sites are preferentially located in the middle valleys of the Dordogne, an area rich in biotic resources and abundant Senonian flint. Although evidence exists for lithic resource procurement beyond 50 km, such contributions are minimal compared to the diachronic use of local resources within these valleys (Turq et al., 2017).

Abric Romaní presents a contrasting case. In Levels M, Oa, and P, the predominant flint types reflect broader mobility dynamics unrelated to the course of the Anoia River (Gómez de Soler et al., 2020). In Levels M and Oa, Sant Martí de Tous flint predominates (93% and 84%), sourced approximately 16 km away. In Level P, mobility extended to 16–24 km, as Panadella flint (43%) is equivalent to Sant Martí de Tous (54%) as a primary material. These

regional itineraries from the southwest exceed local ranges, despite the availability of other flint types near the site (<10 km), such as Serra and Muschelkalk.

Faunal evidence provides further insights into these broader ranges in Level P, where mobility was focused on hunting large ungulates, which were dispersed across the territory. Lithic resource procurement, in this case, appears imbricated within hunting activities (Marín et al., 2019; Gómez de Soler et al., 2020).

This observation highlights an important aspect: mobility cannot be explained solely by lithic resource availability (Kelly, 1983). Instead, hunter-gatherer mobility often involves “embedded procurement” (sensu Binford, 1979), where raw materials are indirectly gathered during movements targeting other resources.

Consequently, our analysis emphasises the significance of territory and its resource diversity, and spatial congruency, in interpreting Neanderthal mobility (Garvey, 2015; Picin, 2022). This is particularly relevant in contexts like the upper Serpis Valley, where various resources share similar procurement ranges (Fig. 21). The upper valley offers abundant resources, aligning with the ranges defined by lithic procurement, within a context of benign palaeoenvironmental conditions in SU Xb of El Salt and IVd of El Abric del Pastor. Alongside high-quality flint (Molina, 2015), the upper valley provides ample water sources near El Salt, where the Serpis River originates. The combination of water availability and the smooth relief would have supported horse and deer populations in the basin area (Pérez et al., 2017; Pérez, 2019).

Moreover, the Barranc del Cint offers distinct resources, including water from the Benissaidó River, an ideal habitat for wild goat and Mediterranean tortoises (Connolly et al., 2019). The presence of juniper (*Juniperus*) in this area further highlights the diversity of immediate resources (Vidal-Matutano et al., 2015). This diversity helps explain the general short-range mobility observed at both sites (5–10 km), supported by the high habitat quality, where temperate conditions favoured a rich primary and secondary biomass (Kelly, 1983; Grove, 2009; Daffara et al., 2019).

This does not diminish the significance of lithic raw materials in mobility itineraries, as they have been shown to be fundamental in both quantity and quality (Andrefsky, 1994). Indeed, the upper Serpis Valley exhibits both attributes, facilitating the interpretation of broader behavioural patterns. In a context such as this, the travel and search costs (i.e. time) involved in selecting high-quality flint types would have been relatively low (Vaquero & Romagnoli, 2018). Even when accounting for the middle course and the Beniaia flint procurement, the distances remain within a manageable range, without much costs for hunter-gatherer groups. Among the Hadza, for instance, men typically travel an average of 14 km per day, with daily movements of 15–25 km being quite common (Wood et al., 2021).

Such patterns are characteristic of Mediterranean Neanderthals, whose more localised mobility was favoured by relatively benign palaeoenvironmental conditions compared to central Europe (Féblot-Augustins, 1993, 1999; Turq et al., 2013; Picin, 2022). This raises a crucial question: could such a mobility dynamic be sustained over long periods?

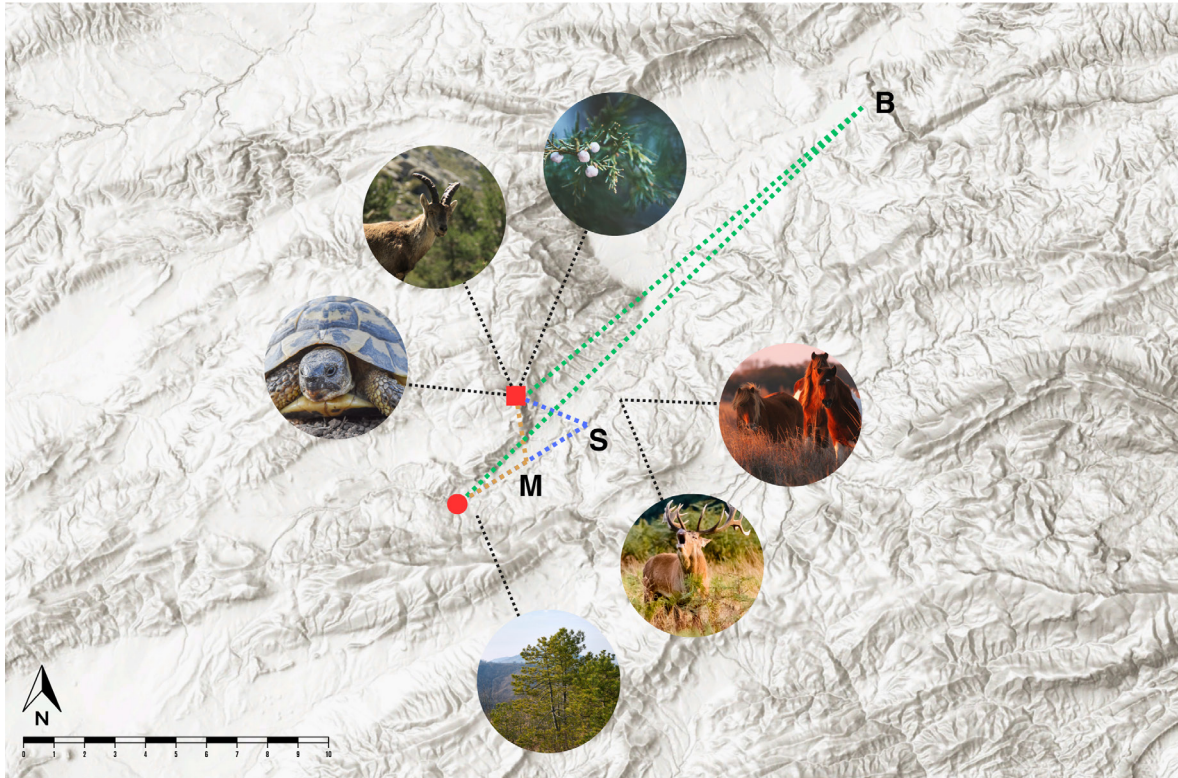


Fig. 21. Approximate distribution of main resources and their relationship to the studied sites (circle: El Salt; square: Abric del Pastor) (scale in kilometres). The data considered for El Salt come from units Xb and Xa (Molina, 2015; Machado et al., 2017; Vidal-Matutano et al., 2018; Pérez et al., 2020), while for Abric del Pastor they come from units IVf and IVd (Machado et al., 2013; 2019; Vidal-Matutano et al., 2015; Sossa-Ríos et al., 2022).

Why leave home? Explaining the lack of inter-valley interaction

One of the most striking structural aspects of the lithic record at El Salt and El Abric del Pastor is the strong connection between Neanderthal groups and the Serpis Valley. To date, no type of flint has been identified in these assemblages that could be associated with silicifications from other valleys. For instance, the neighbouring Vinalopó Valley contains outcrops of quartzite and flint types such as Umbría, Cámara, Cabrera, and Xinorla, as well as redeposited Subbaetic Veleta flint (Molina et al., 2016). These lithotypes have been identified in both Middle Palaeolithic contexts (e.g. Cueva del Cochino and Cova dels Calderons; Molina, 2015; Torregrosa et al., 2018) and Upper Palaeolithic sites (e.g. Abrigo de la Horna and Alto de Alcaná; Belmonte et al., 2018). However, they are entirely absent in the lithic assemblages from the Serpis Valley sites, suggesting a diachronic reliance on the same flint resources of the same territory.

This pattern of resource use, confined to a single valley without evidence of inter-territorial interaction, is not unique. In the Rhône Valley, raw material studies combined with isotopic analyses of human remains at Payre indicate that individuals spent their entire growth period within the same territory (Moncel et al., 2019). Similarly, at Saint-Anne I and Baume-

Vallée in the Massif Central, some lithic materials were transported between valleys, but they represent a minimal percentage of the assemblage, suggesting limited inter-valley mobility (Fernandes et al., 2008; Daujeard et al., 2012). In southwest France, although lithic evidence shows regional movement, settlement patterns were concentrated in the Périgord, with only sporadic contacts with neighbouring regions (Turq et al., 2017). The recurrent and stable connection between different territories in southern France would not be reached until the Mesolithic (Delvigne et al., 2019).

The absence or highly sporadic nature of inter-territorial interaction raises important questions about the behavioural and ecological strategies of Neanderthals in the Serpis Valley. Robert Kelly (2003) highlights the stability of familiar habitats as a key factor: known landscapes that consistently provide subsistence resources reduce the need for exploration. However, such stability requires significant intergenerational effort to accumulate and transmit territorial knowledge. This “resource monitoring” refers to the ability of human groups to identify, track, and predict the availability of resources over time. It is a long-term social process that is never fully complete, particularly in dynamic environments where resources fluctuate (Kelly, 1983).

As McCall (2012) pointed out, information is handled in a group manner and acquires important social significance, as in the case of the Gamo and Konso groups, where the location and use of procurement contexts are passed down from generation to generation through specific individuals of the same lineage.

Abandoning a well-understood landscape entails discarding accumulated knowledge, disrupting established information networks within the valley (Whallon, 2006), and initiating a new learning process that could take generations. While logistical mobility (unconstrained by the slower pace of children or older individuals) might facilitate the exploration of new territories, venturing into unfamiliar areas still involves significant risks. This is especially true for small groups, where uncertainties about resource availability and safe return routes can pose existential threats (Kelly, 2003).

The physical geography of the region must also be considered. However, in the case of the Serpis and Vinalopó Valleys, physical barriers do not explain the lack of connection. Natural corridors, such as the ring road of Alcoi, Cocentaina, Muro, and Agres, would have been accessible to Pleistocene hunter-gatherers (Aura et al., 1993). This suggests that the decision to remain within the Serpis Valley was not driven by geographical constraints but by other ecological, social, or genetic factors.

During the earlier phases of both sequences, the Serpis Valley likely provided not only abundant subsistence resources but also sufficient genetic diversity. This abundance may have minimised the need for inter-valley movement and reinforced a focus on the upper Serpis. In later phases, however, increased movement from the northeast becomes evident, as indicated by the predominant use of Beniaia flint type. While previous research hypothesised that palaeoenvironmental factors reduced the availability of Serreta and Mariola flint, or alternatively suggested distinct mobility patterns for certain groups (Mayor

et al., 2022), genetic factors may also play a role. These movements could reflect a need for genetic exchange during periods of population stress.

This pattern aligns with broader trends observed in hunter-gatherer groups. MacDonald and Hewlett (1999) found that mating distances between groups tend to increase during demographic declines. They also emphasised the role of reproductive strategies in shaping mobility, challenging interpretations based solely on subsistence. Evidence from Neanderthal sites like El Sidrón shows that Neanderthals were aware of the risks of inbreeding and mitigated them through patrilocal mobility patterns (Lalueza-Fox et al., 2010). However, in later phases at El Sidrón, signs of malformations and diseases linked to inbreeding suggest that such strategies were not always sufficient (Ríos et al., 2015).

The strong connection between Neanderthal groups and the Serpis Valley can be attributed to a combination of ecological stability, accumulated territorial knowledge, and genetic factors. Furthermore, the abundant available resources within this territory made it an optimal habitat, reducing the need for inter-valley movement. However, changes in lithic procurement patterns in later phases suggest increased mobility, potentially driven by demographic pressures and the need for genetic exchange. These findings highlight the complex interplay between environmental, social, and genetic factors in shaping Neanderthal mobility strategies.

5.3. Breaking the chains: lithic resource management in Neanderthal groups from the Serpis Valley

Having analysed the introduction of flint and the mobility associated with it, it is time to delve into how Neanderthal groups managed this resource. While this thesis does not aim to focus extensively on technological behaviour, there are certain general and specific traits that can be discerned at both sites.

Lithic resource management at Abric del Pastor

As with the introduction of flint types, the Abric del Pastor also displays significant heterogeneity in the representation of technological categories throughout the known sequence.

The units studied in this Thesis, placed at the base of the sequence, exhibit marked differences among themselves (Fig. 22). While both are dominated by flakes, especially AU IVfH17 where flakes account for 100%, SU V includes a more diverse representation, with retouched tools and fragments comprising similar percentages (9% and 11%, respectively), followed by cores and an unworked nodule (Sossa-Ríos et al., 2022, 2025).

This strong emphasis on specific products, as seen in AU IVfH17, continues into AUs IVf1 and IVe, with flakes and fragments initially predominating, followed later by cores and retouched tools. However, this clear distinction between the two assemblages is largely explained

by the small number of remains, as both AUs are characterised by low archaeological representation ($n = 8$ and $n = 2$, respectively) (Sossa-Ríos, 2021).

Later, this trend is disrupted in AU IVD1, where, despite the presence of all technological categories, flakes clearly dominate the assemblage. However, this is followed by a renewed emphasis on the representation of other products, particularly retouched tools, in AUs IVC2 and IVC1. In AU IVC1, there is also an increase in the proportion of cores. Finally, AU IVb, much like SU V and AU IVD1, shows a significant component of flakes, accompanied by cores, retouched tools, and fragments, albeit in reduced proportions (Machado et al., 2013, 2019).

As we have seen, our units and their different composition also form the basis of a trend that is repeated in the sequence: units in which only one or two types of product are present, and units in which all products are present, with flakes being predominant.

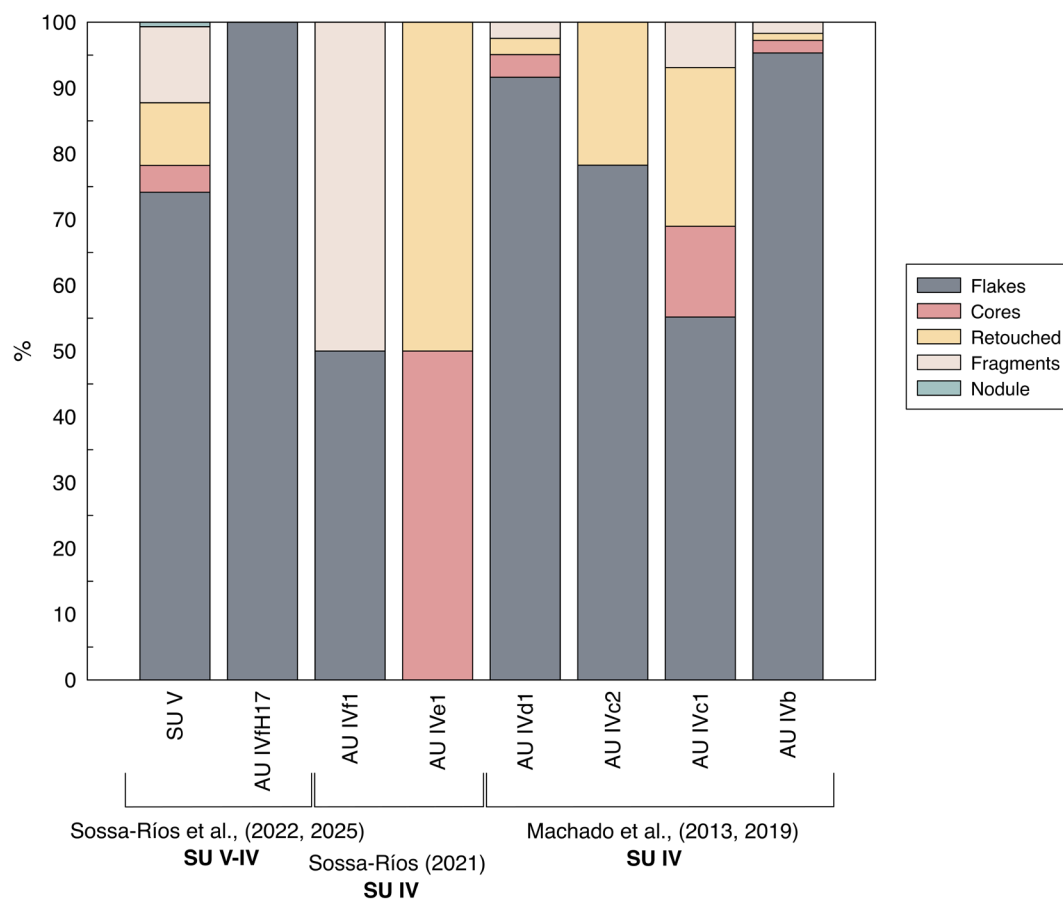


Fig. 22. Distribution of technological categories by units of analysis along the studied sequence of Abric del Pastor. To see the representation by flint types, the reader is referred to the publications.

Knapping at the site, identified primarily through refits but also by S-RMUs, exhibits changes throughout the sequence (Table 5). In this regard, our units display variability among themselves. SU V demonstrates significant knapping activity throughout its formation, comprising nearly half of the assemblage in terms of the number of pieces involved in technical sequences (Sossa-Ríos et al., 2025). This contrasts with the brief episode of knapping and use associated with a single RMU in IVfH17 (Sossa-Ríos et al., 2022).

These data contribute to a highly intriguing dynamic. Episodes of predominant knapping are followed by others where it is almost absent, a pattern that seems to occur throughout the formation of the Abric del Pastor. AU IVfH17 marks the beginning of a series of occupation episodes, succeeded within AUs IVf1 and IVe1, in which knapping had minimal or no impact on the formation of the archaeological record (Sossa-Ríos, 2021).

These phases give way to a unit where knapping once again becomes prominent. AU IVd1 displays data comparable to those recorded in SU V, with knapping activity distributed across several RMUs. However, this dynamic is interrupted by two anthropogenic formation processes, represented by AUs IVc2 and IVc1, which show almost no evidence of knapping (Machado et al., 2013, 2019).

The sequence at the Abric del Pastor concludes with a unit where knapping is the main activity. While SU V and AU IVd1 presented significant evidence, AU IVb stands out with 445 pieces involved in knapping activity (Machado et al., 2013, 2019). An interesting point to note is that, despite tripling the number of pieces and doubling the number of refits, AU IVb exhibits a similar number of RMUs compared to the two previously mentioned units.

	RMU (n)	R-RMU (refits) (n)	Products involved (n)
AU IVb	7	15	445
AU IVc1	6	0	20
AU IVc2	3	0	13
AU IVd1	6	11	132
AU IVe1	0	0	0
AU IVf1	0	0	0
AU IVfH17	1	1	5
SU V	13	7	71

Table 5. RMU and R-RMU representation by units of analysis along the studied sequence of Abric del Pastor. The products involved are the total account of elements within RMUs, whether refitted or not. Data were extracted from Machado et al. (2013; 2019), Sossa-Ríos (2021) and Sossa-Ríos et al. (2022; 2025).

Despite observing differences within the sequence, particularly between units that are more or less closely associated with knapping episodes, it is also possible to identify distinctions between the episodes themselves.

The stronger association with technical activities recorded in SU V (exclusively in the northern area), AU IVd1, and AU IVb reveals slight similarities between the first two and a more marked contrast with the latter. AU IVb, despite its high volume of knapping activity, involves relatively few RMUs, which can be explained by its specific technological management. This unit exhibits significant intensity, with nearly complete reduction sequences focused on a small number of nodules, occasionally showing separate reduction stages derived from the same nodule (Machado et al., 2019). In contrast, SU V and AU IVd1 display incomplete knapping sequences, associated with specific stages, whether initial or final, and involve a similar number of original nodules.

The selection of flint types for knapping at the site also shows notable differences across these units. While knapping activities in SU V predominantly used Mariola flint first, followed by Serreta flint, AU IVd1 is characterised by a predominance of Serreta flint, followed by Beniaia. In AU IVb, there is a greater heterogeneity of flint types, with knapping sequences involving Serreta, Mariola, and Beniaia flint, the latter being the most represented. In this sense, SU V stands out particularly due to the role of Beniaia flint, which is almost entirely restricted (apart from a refit of two artefacts) to its introduction as single products (Sossa-Ríos et al., 2025).

Similarly, despite the predominance of knapping activity in all these units of analysis, the introduction of single artefacts is evident across all technological categories and flint types (Fig. 23). Notably, the uncertainty surrounding the singularity of these items is greatly reduced in the case of the Abric del Pastor, where the low number of artefacts and the high spatial representation provide a high degree of confidence in the analysis and its interpretation.

In contrast to the aforementioned units, AU IVfH17, IVf1, IVe1, IVc2, and IVc1 represent the opposite case, with little to no evidence of knapping activity. These units are instead dominated by single products, which appear in almost every format: cores, flakes, or retouched artefacts, but almost never as fragments. Fragments are only observed in AU IVc1, which is also the unit with the highest number of RMUs among those with low knapping activity. Interestingly, unlike units with knapping presence, AU IVc1 shows a very low percentage of flakes, linked to very short reduction sequences (Machado et al., 2019).

Likewise, these events associated with the single abandonment of products show some correlation with the types of flint observed. In the earlier phases, these units with a low archaeological record lack Beniaia flint, whereas in AU IVc2 and IVc1, this flint type is present, and then is heavily knapped (AU IVb). This might suggest that the introduction of Beniaia flint to the site is more closely linked to mobility dynamics and increased itinerancy along the mid-course of the Valley rather than to specific management strategies for this material. There does not appear to be a correlation between Beniaia flint and knapping activity, nor between Beniaia flint and retouched products throughout the sequence. Nor does this seem to be the case for the more local flints (Serreta and Mariola), where, in addition to knapping sequences, there is also a significant component of retouched products and single flakes.

However, to complete this picture, the ongoing comprehensive analysis of SU V technology may shed light on possible technical differences within the unit itself, as well as between this older unit and more recent ones.

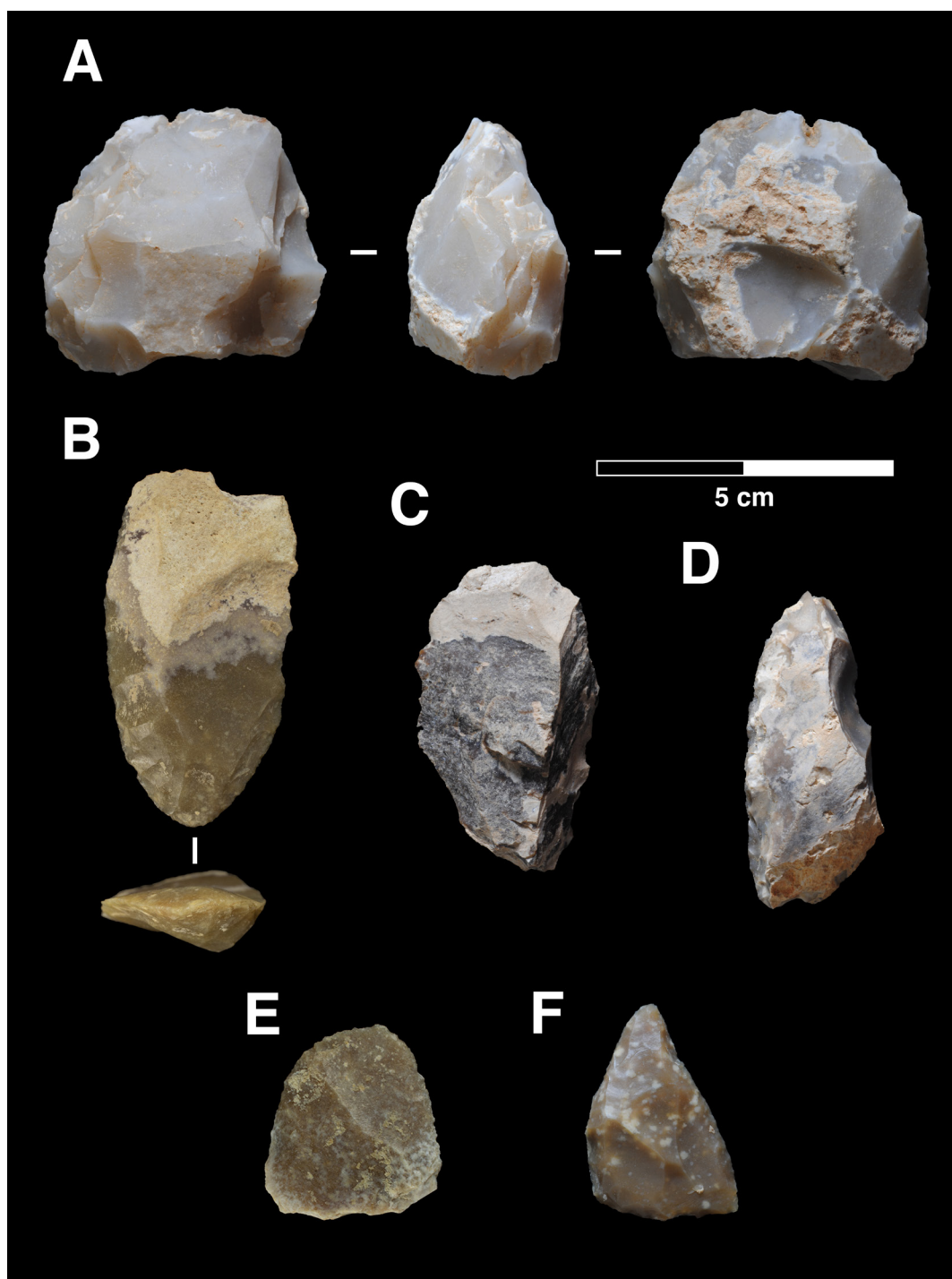


Fig. 23. Single core, retouched products and flakes from Abric del Pastor SU V. A) Beniaia core. B and E) Retouched products made up of Mariola. C) Flake representing the only Catamarruc introduction to the sequence. D and F) Retouched products made up of Serreta.

Lithic resource management at El Salt

As with raw materials, El Salt maintains its homogeneous character in the representation of technological categories, with flakes predominating throughout the sequence, consistently accounting for over 60% of the assemblage. Nevertheless, certain diachronic changes can be observed across the sequence (Fig. 24).

In our units, flakes represent around 65% of the assemblage, with slightly lower proportions recorded in the outer zone during both formation stages (Sossa-Ríos et al., 2024). Subsequently, their representation increases significantly in AU 5.3, reaching the maximum of the sequence (81%). This unit marks the beginning of a period of high flake representation, which continues until AU 4.1 (Machado et al., 2017).

The lower representation of flakes in the outer area, as observed in our units, is repeated in the external AUs of SU Xa (4e, 3e, 3.2, and 3.1), where flakes reach the minimum of the sequence in AU 3e (61%). This unit marks an abrupt decline in flake representation but simultaneously initiates an upward trend in the more recent units, culminating in SU VIII, where flakes represent 75% of the assemblage.

For cores, a discernible pattern seems to emerge throughout the sequence. These products are represented in higher percentages in the exterior of the shelter. While the representation in our outer units is similar to that recorded in the immediately subsequent moments marking the beginning of SU Xa in the inner zone (AUs 5.3–5.1), our units share the outer-inner relationship observed in SU Xa. In this phase, AUs 4e, 3e, 3.2, and 3.1 exhibit higher percentages than the inner AUs of Xa. In our case, the inner units (Xb2in and Xb1in) record the lowest representation of cores in the entire sequence (2%). The decline in flake representation noted in AU 3e coincides with an increase in cores. This higher representation remains relatively stable in the outer area (16–13%) until the more recent phases of the studied deposit (SU VIII; Mayor et al., 2022).

Retouched products, on the other hand, fluctuate within our units, showing greater representation in the earlier moments of the exterior zone (7%). After this phase, particularly following the first AU of SU Xa (5.3), these products exhibit an upward trend, reaching their peak in AU 3e (16%).

Fragments also display a relatively clear pattern. From their significant representation in our units (ca. 20%), an abrupt change is observed, marked by substantial reduction in the basal AUs of Xa, which subsequently start a diachronic decline from this point onward, reaching their minimum in the two most recent analytical units (3–4% in AU 3.1 and SU VIII).

Knapping activity at El Salt shows diachronic presence throughout the sequence, with stages of greater or lesser intensity (Table 6). This is particularly evident from the RMUs and the products involved in them. However, it is notable that refittings are scarce, often numbering fewer than five within AUs.

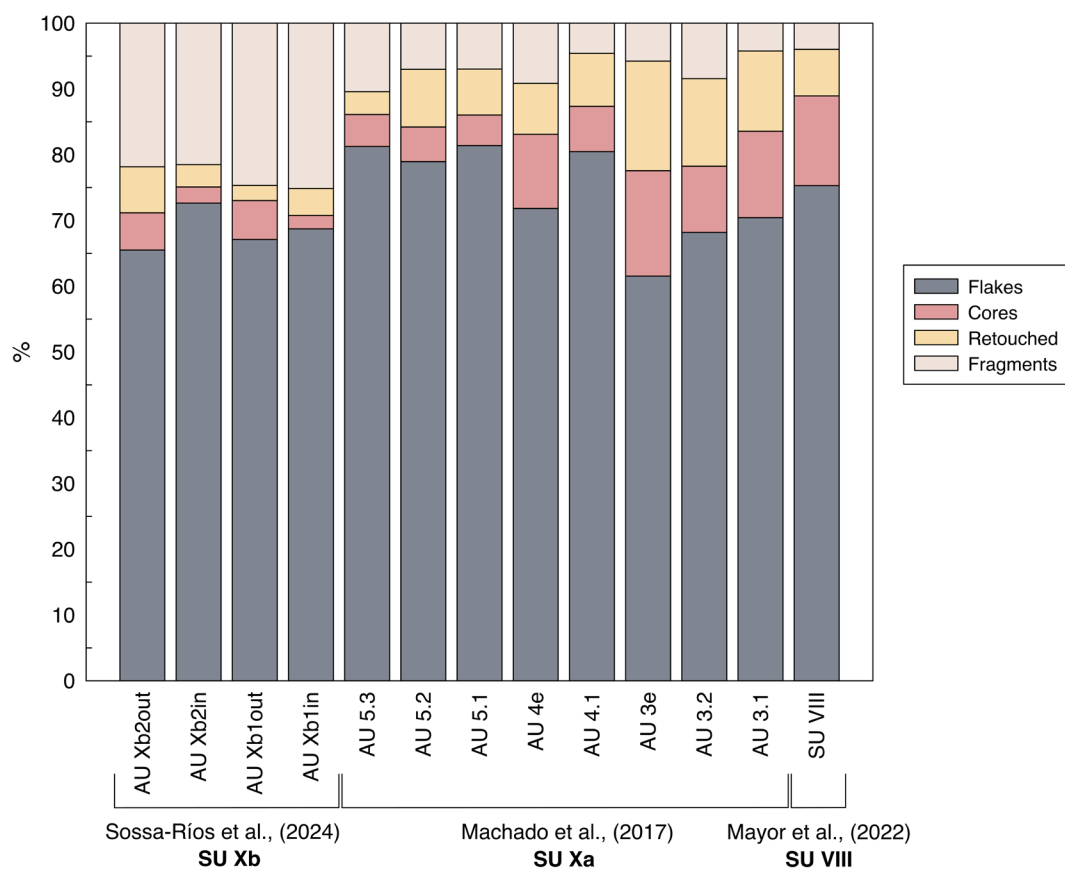


Fig. 24. Distribution of technological categories by units of analysis along the studied sequence of El Salt.

The only moment where a higher number of refittings is recorded occurs in AU Xb2in, characterised in this Thesis ($n = 12$). Subsequently, the numbers drop considerably. This is evident within SU Xb itself, where, following the basal units ($n = 13$), only one refitting is identified both inside and outside. The onset of SU Xa shows certain similarities, particularly in the inner area. At the base, five refittings are distributed between AUs 5.3 and 5.2, but none are recorded in AUs 5.1 and 4.1. Conversely, the outer zone of SU Xa exhibits the opposite pattern, with no sequences recorded at the base but six refittings identified in the more recent units (AUs 3.2 and 3.1) (Machado et al., 2017).

Regarding the RMUs, a slight upward trend can be observed throughout the sequence, both in their number and in the associated products. However, the products involved never exceed 100 artefacts per AU, and when a high general number of products is observed in a single AU, these are typically associated with a large number of RMUs (e.g. 82 products from 33 RMUs in AU 3.2). An exception to this pattern is the oldest AU in the internal zone, where a considerable number of products are linked to a few RMUs but with more refittings. This could reflect greater intensity in the knapping sequences, as observed, for example, in the refitting of Font Roja flint (Sossa-Ríos et al., 2024), which is not reflected in later moments.

	RMU (n)	R-RMU (refits) (n)	Products involved (n)
SU VIII	30	1	86
AU 3.1	29	3	74
AU 3.2	33	3	82
AU 3e	13	0	30
AU 4.1	14	0	36
AU 4e	19	0	47
AU 5.1	8	0	19
AU 5.2	9	2	25
AU 5.3	22	3	56
AU Xb1in	3	0	7
AU Xb1out	5	1	17
AU Xb2in	13	12	70
AU Xb2out	7	1	22

Table 6. RMU and R-RMU representation by units of analysis along the studied sequence of El Salt. The products involved are the total account of elements within RMUs, whether refitted or not. Data were extracted from Mayor (2023), Machado et al. (2017) and Sossa-Ríos et al. (2024).

Despite these minor differences, there is no clear relationship at El Salt between knapping activity and the predominance of specific products. For instance, although AU Xb2in shows a higher proportion of flakes presumably associated with knapping activity, this correlation is not observed in other AUs where refittings or an increase in RMUs and associated products are recorded. In fact, the AU with the lowest impact from this activity (AU 5.1) exhibits the highest percentage of flakes in the entire sequence. The same applies to cores. While AU Xb2in shows a very low percentage of these products (a trend shared, to some extent, with AUs 5.3 and 5.2), the same is true for Xb1in, where no refittings exist. Conversely, the opposite pattern is also observed, with an increase in cores in AUs 3.2 and 3.1, where refitted sequences are also present.

Knapping activity shows variations in the types of flint selected. The base of the internal sequence, marked by AU Xb2in, exhibits a range of different flint types, although Serreta flint is the most represented. However, the refits identified for this flint involve few pieces, indicating highly specific moments in the knapping sequence between cores and flakes. Serreta is accompanied by other flints, such as Mariola, which exhibits similar behaviour. The opposite is observed, for example, with Font Roja flint, which is extensively exploited in sequences of up to 14 pieces. This pattern is complemented by Catamarruc flint, represented by a single refit between two flakes.

After this, Xb begins to exhibit the characteristics that persist throughout the rest of the sequence: a marked scarcity of refits. In the external AUs (Xb2out and Xb1out), refits are quantitatively reduced to one per unit, involving connections between two or three flakes in both cases. In the most recent inner AU, there are no connections at all.

In SU Xa, this trend continues but reveals interesting changes. In the inner zone, knapping activities are strictly associated with Serreta and Beniaia flints in equal numbers, with Mariola absent in both AU 5.3 and AU 5.2 (Machado et al., 2017). In contrast, the outer area exhibits refits involving Serreta and Mariola flints in its upper part, but not Beniaia (AUs 3.2 and 3.1). By SU VIII, the sole refit identified involves Serreta flint, connecting a flake and a core (Mayor et al., 2022; Mayor, 2023).

Although refits and RMUs are few represented throughout most of the El Salt sequence, the opposite observable trend is the dominance of single products over time (Fig. 25). Despite their consistent presence, these products dominate specific units, such as AUs Xb1in, 5.1, and 4.1 in the inner zone, or AUs 4e and 3e in the outer area, all of which lack refitting sequences and have very few RMUs.

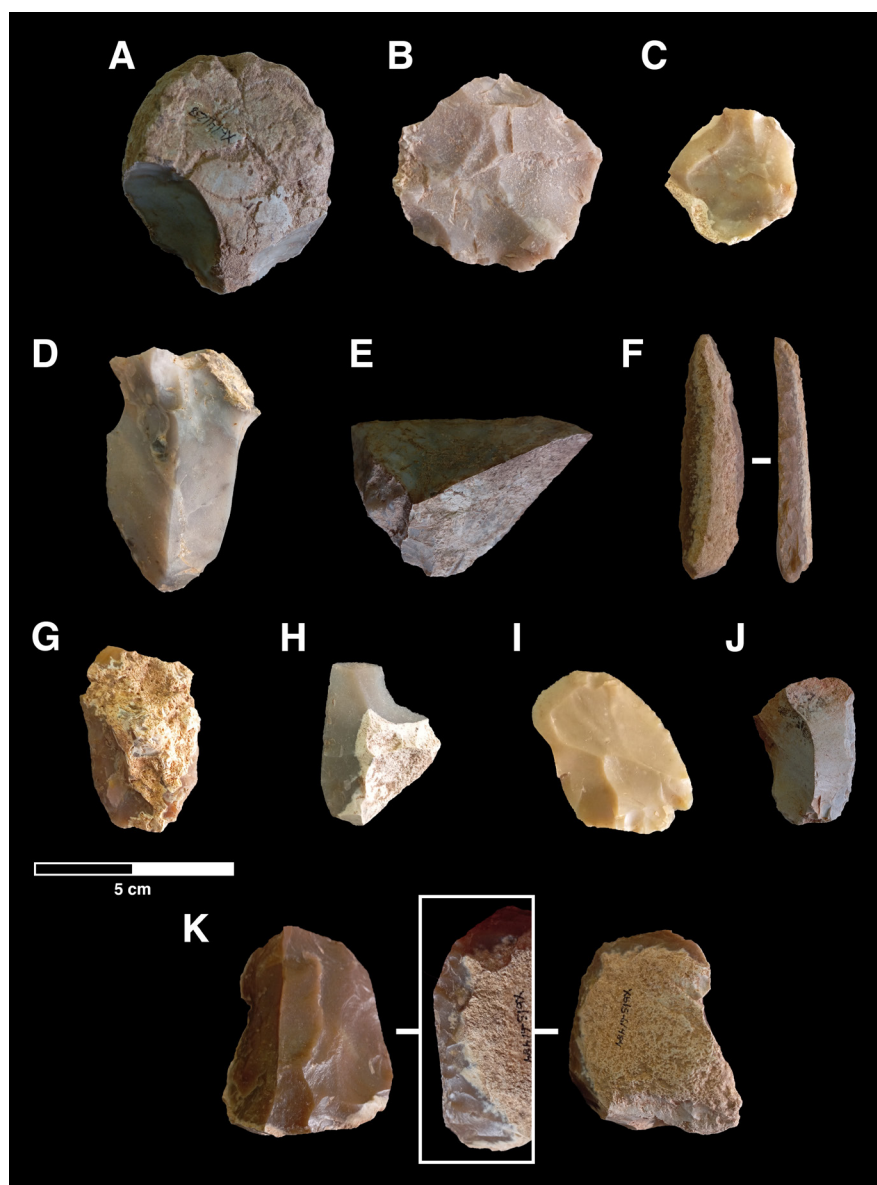


Fig. 25. Cores and retouched products from El Salt SU Xb. Cores in different stages, from initial to almost final stages: **A)** Beniaia core, **B)** Beniaia core, **C)** Serreta core. Retouched products made up of Beniaia (**D, E, G**) and Serreta (**F, H, I**). **J)** Retouched product with two different white patinas (unknown flint type). **K)** Retouched core made up of Serreta.

These single products appear in various formats, ranging from cores at different stages to flakes of varying sizes, with or without retouch, and in nearly all flint types. The only noteworthy observation regarding this in our units and the AUs of SU Xa is the lower representation of retouched products on Mariola flint compared to Serreta and Beniaia flints (Machado et al., 2017; Sossa-Ríos et al., 2024). On the other hand, the representation of minor flint types seems to change in terms of their format at the site. In our case, Font Roja flint is associated with knapping activities, while in SU Xa and SU VIII, it appears more linked to isolated introductions.

Patterns of lithic resource management in Neanderthal groups from the Serpis Valley

The image of lithic resource management provided by our data from both sites reveals similarities as well as certain differences in each archaeological sequence.

At Abric del Pastor, we observe a changing context, where no single management dynamic prevails. Instead, two distinct patterns seem to emerge: one associated with the introduction of single products and short knapping sequences, and another in which, in addition to singular products, longer sequences are present, though never complete. The former is exemplified by AU IVfH17, IVc2, and IVc1, while the latter is observed in SU V, AU IVd1, and IVb. Notably, these dynamics do not follow a clear trend within the sequence but instead occur intermittently throughout the archaeological deposit.

SU V deserves particular attention, as its lower spatiotemporal resolution requires further nuance. In this regard, Cluster 2 exhibits a greater presence of knapping activity, whereas Clusters 1 and 3 are dominated by single products (Sossa-Ríos et al., 2025). Despite the temporal uncertainty associated with this unit, spatial clustering provides analytical subdivisions that, while not necessarily indicating diachrony, help avoid overgeneralised interpretations of the unit-as-a-whole.

At El Salt, the observed pattern is more homogeneous. Although one of our units (Xb2in) yielded the highest number of refits recorded within a single AU, knapping activity remains a very minor component of lithic management dynamics at the site (e.g. 5.47% refitted in AU Xb2in) (Sossa-Ríos et al., 2024). This characteristic is shared with sites such as Abric Romani, where refitting percentages across some archaeological levels range from 5% to 9%, with sequences often consisting of just two or three pieces (e.g. I, K, N, Oa; Chacón & Fernández-Laso, 2007; Vaquero et al., 2019; Bargalló et al., 2020).

Having reviewed and ruled out severe taphonomic biases at El Salt (see Section 5.1), one might consider spatial constraints as a limiting factor in the identification of refits. However, this situation cannot be solely attributed to an underrepresented surface. Rather than viewing it as a problem, we should interpret it, albeit blurred by the palimpsest effect, as evidence of a distinct and diachronic management model:

“The absence of refits within an assemblage, for example, may not be due to natural site formation processes, such as reworking of a site, per se, but to repetitive transport behaviour that led to the accumulation of the assemblage in question” (Turq et al., 2013: 652).

It is precisely the introduction of single products that characterises the formation of lithic assemblages at this site. Thus, El Salt exhibits a greater fragmentation of operative chains, with a consistent predominance of products introduced across multiple events and only sporadic, limited knapping activity. This model has already been identified as a common trend among most Neanderthal lithic assemblages (Vaquero, 2008; Turq et al., 2013 e.g. Chacón, 2009; Moncel et al., 2014; Marciani et al., 2016; Picin et al., 2020), with the exception of those primarily focused on raw material acquisition and exploitation in primary or sub-primary contexts (e.g. Gramly, 1980; Rosen, 2010; Baena et al., 2015; 2019; Nieto-Márquez & Baena, 2017).

This perspective could also apply to units IVfH17, IVc2, and IVc1 at Abric del Pastor, where this type of management predominates. However, the scenario changes with units IVb, IVd, and V. What do these signify in terms of lithic management? Are they simply the same pattern, but with knapping evidence that has not yet been obscured by an accumulation of single products from multiple events? This question may be closely related to spatiotemporal factors, which will be revisited later in the discussion.

As previously noted, the procurement of lithic resources would have involved a low cost for groups occupying the upper Serpis valley. The question now is whether this economic accessibility also extended to how flint was managed within the territory and at the sites themselves (Vaquero & Romagnoli, 2018).

At both sites, these single (and dominant) products consist mostly of small, unretouched flakes with low cortical percentages, produced on flint collected from nearby sources (3–5 km from the sites). This “planned” behaviour (*sensu* Kuhn, 1992) aligns with the mass reduction/utility increase model, in which the transport of multiple, lightweight small-sized blanks, primarily retouched and unretouched flakes, prevails (Kuhn, 1992; 1994). This corresponds to the “provisioning individuals” model, where each person carries their own pre-made artefacts suited to anticipated activities (Kuhn, 1992).

However, we are dealing with assemblages that encompass broad temporal spans, and there are indicators of variability in the “personal gear” (*sensu* Binford, 1977) of Neanderthal groups. This variability is first evident in size and weight. At both Abric del Pastor and El Salt, certain cases deviate from the rule proposed by Kuhn. For instance, the large and heavyweight (1,200 g) limestone artefact from Cluster 1 of SUV, or the Cluster 2 concentration of large, heavy Beniaia cores in El Salt AU Xb2out. Although Kuhn does not dismiss the role of such items in transport and management dynamics, researchers like Morrow (1996a), Close (1996), and Roth and Dibble (1998) argue that these products may be the most economically viable, extending tool longevity and facilitating the production of new artefacts as needed, what Bourguignon et al. (2006) term “matrices de production”.

This concept helps to explain the presence of both single and knapped small to medium-sized cores, as well as large cortical flakes (“provisioning places”; *sensu* Kuhn, 1992). However, it does not account for the transport of large volumes that were not subsequently knapped at the sites. In this regard, Gould et al. (1971) highlighted the advantage of collecting large, low-quality raw material products for use as multipurpose tools, such as hammerstones or anvils, particularly in the context of large-animal butchering. While not directly based on this idea, recent experimental research on similarly heavy-duty tools has yielded positive results in marrow extraction (Assaf et al., 2025).

Variability is also evident in the management of different flint types. While nearby sources were preferentially collected, introduced, and more frequently knapped, the less represented and more distant Beniaia flint follows a similar management pattern. Its presence varies from single flakes (both retouched and unretouched) to highly developed knapping sequences (Machado et al., 2013, 2019; Sossa-Ríos et al., 2025). Additionally, Serreta and Mariola flint also appear at both sites as retouched products. This contrasts with the some proposals, in which minor or regionally sourced flint types would typically occur as single retouched tools (e.g. Geneste, 1991; Kuhn, 1994). In the case of Beniaia, the difference seems to be purely quantitative, linked to mobility and provisioning dynamics, as its transport would have incurred a higher cost (Geneste, 1991; Vaquero & Romagnoli, 2018). As noted by Vaquero et al. (2012), different techno-economic choices can coexist within the same assemblage, forming a palimpsest of decisions with varying degrees of cost implications.

Regarding modified flake products, it appears that retouch loses its interpretive value as an indicator of transport cost. According to Bamforth (1986), retouch is primarily related to raw material availability and tool efficiency at the moment of use rather than the classical notion of “curated” products (*sensu* Binford, 1977, 1979). The low overall incidence of retouched artefacts, particularly at El Salt, can be interpreted within this framework, given the broad availability of lithic resources within a short distance.

Furthermore, a recent functional analysis of tools from SU Xa identified use on different materials (e.g. woodworking, butchering) across unretouched flakes of various sizes, including very small ones (Bencomo et al., 2023). This aligns with use-wear data from Level M of Abric Romani, where informal expedient tools played a significant role (Martín-Viveros et al., 2020). The preference for transporting and using single products, particularly flakes, has also been observed among modern Australian Indigenous groups (Holdaway & Douglass, 2012). This perspective challenges the traditional primacy of retouched products, which have long guided behavioural interpretations in Middle Palaeolithic studies and continue to do so in much of Upper Palaeolithic research.

Thus, a broader view of transported assemblages emerges: one that includes not only unretouched flakes but also cores, which functioned as mobile “matrices” for further exploitation across the landscape (Bourguignon et al., 2006; Meignen et al., 2009). The high fragmentation of operative chains observed in our sites and in other Neanderthal contexts may reflect transport cost reduction, as suggested by Geneste (1991). This is particularly relevant in regions where flint occurs in large, heavy nodules, favouring *in situ* knapping at

workshops before being transported in smaller, more manageable formats (e.g. Bergeracois; Courbin et al., 2020). However, the nodules from the Serpis valley are notably smaller, with maximum dimensions of 5–15 cm (Molina, 2015), meaning that knapping at procurement locations would not have significantly reduced transport costs.

Nevertheless, the management of this resource follows a similar pattern at different regions, with raw materials arriving in pre-configured formats. This phenomenon could be explained by:

1. The need to transport other resources, necessitating a reduction of flint volume at procurement sites; or
2. A widely shared cultural framework dictating how lithic resources should be managed, regardless of transport cost.

This cultural framework aligns with the concept of “savoir-faire” (*sensv* Karlin, 1991a, 1991b), which extends beyond technical skill to encompass the relationship between artefacts and landscapes, including raw material procurement, modification, and transport.

These patterns, alongside inferences about raw material provisioning strategies, suggest that Neanderthal groups operated within a relatively small territory but moved frequently, occupying each site intermittently and for short durations. This interpretation is reinforced by archaeomagnetic data of combustion features, which indicates that some SU Xb burning events, some of them from the same “surface”, are separated by decades or even centuries (Herrejón-Lagunilla et al., 2024).

Accepting this hypothesis entails a discouraging scenario, particularly in the case of El Salt. If most formation events consisted of single, isolated products, our ability to distinguish and separate one event from another would diminish considerably. As a result, analysis would have to rely more heavily on indirect inferential approaches, including spatial organisation (e.g. clustering), geological indicators (e.g. post-genetic data differentiating raw material sources), and technological markers (e.g. shifts in lithic management strategies).

5.4. Reading the space, considering the time

The data presented in this Thesis introduce new insights into human behavioural variability, complementing previous research. This variability is expressed to a greater or lesser extent depending on the scale of analysis, and it is particularly evident in spatial organisation.

Changing spaces: Abric del Pastor

At Abric del Pastor, spatial management dynamics have been characterised by the predominance of “hearth-related assemblages” (*sensv* Vaquero & Pastó, 2001) throughout the upper part of SU IV and its defined AUs (Machado et al., 2013, 2019). If fire is considered the primary space organiser, our data suggest both continuity and rupture in this pattern.

SU V contains only one combustion structure (i.e. H19), with minimal or no material association around its perimeter (Sossa-Ríos et al., 2025). The main material accumulations, both lithic and faunal, are located several metres away from this hearth. The presumed diachrony between these accumulations and the hearth itself, along with its proximity to the wall and lack of macro- and microscopic material, led us to interpret this area as a possible resting space, following other cases (e.g. Henry et al., 2004; Vallverdú et al., 2010; Spagnolo et al., 2019; Gabucio et al., 2023).

In addition, the data support that the knapping area was used repeatedly over at least two formation stages, with a different type of flint being introduced and knapped at each stage. While the precise timescale within this deposit remains unknown, at least two episodes and a maximum of seven have occurred, based on the observed refits alone. The lack of spatial and temporal connection with other activities and the very composition of Cluster 2 led us to interpret this zone as a recurring knapping area related to activities to be carried out elsewhere in the territory: an anticipatory production strategy (Binford, 1977, 1986; Kent, 1991).

If these activities were embedded within logistical movements related to hunting wild goat (*Capra pyrenaica*) or collecting juniper (*Juniperus sp.*), both present in the surrounding area, an appropriate toolkit would have been necessary and had to be prepared in advance, as there were no potential provisioning contexts within the Barranc del Cint. This aligns not only with the types of higher-quality flint represented, but also with the brief duration of the activities and their lack of intrasite association with butchering or other tasks. However, a use-wear analysis of these knapped remains could shed further light on this hypothesis and their potential use.

This way of managing lithic resources in time and space could be aligned with the final phase of the site formation model proposed by Stevenson (1985). In this “final or abandonment phase,” the group would prepare the necessary artefacts for their next stop after two preceding phases: one in which they would arrange the space and prepare their equipment for occupation (“initial settling-in space”) and another in which they would carry out their economic activities (“occupational or exploitative phase”). According to this model, two expectations arise for the final phase: first, that the accumulation of knapped remains would be the most spatially clustered, and second, that this production would have no relationship with previously conducted activities.

This interpretation could lead to the temptation of viewing SU V as a spatial whole, justifying the absence of connections (e.g. through refits). However, given the lack of direct evidence, another possibility emerges: visits to the site did not necessarily always follow all three phases. In our case, Cluster 2 would reflect the recurrent use of this external space solely for production, with immediate departure following this task. This model itself exemplifies Neanderthal behavioural variability expressed in spatial terms and restricted to these specific occupational moments.

Subsequently, our next case, recorded in AU IVfH17, marks the beginning of a new model at the site and a rupture with the previous one. This instance consists of a flat hearth fuelled by *Juniperus sp.*, where appendicular parts of red deer were cooked. The resulting bone fragments are distributed within and around the fire, accompanied by knapping remains and single tools used on bone and meat (Mallol et al., 2019; Jambrina et al., 2019; Sossa-Ríos et al., 2022). This case, which is close to human timescales and discernible due to the low-density archaeological record and interdisciplinary research, represents the start of a long sequence of hearths associated with “domestic” activities. However, differences in their number, activity, and spatial positioning indicate variability in recurrence.

Before moving on to similar cases, it is important to note that after AU IVfH17, a period of spatial management followed in which fire was not the central element. During the formation of AUs IVf1 and IVe1, groups visiting the site did not generate hearths or knapping sequences (Sossa-Ríos, 2021). Instead, both formation stages are characterised by the limited introduction of single artefacts, which do not form accumulations but rather dispersions in different areas of the site (east and west: IVf1; east: IVe1) (Sossa-Ríos, 2021; Sossa-Ríos et al., 2022).

Following this, the model of activity around hearths re-emerges. The “mixed” behaviour observed in H17, with both lithic and faunal remains present without a clear predominance of a single activity, is also evident in H8 (AU IVd1) and H6 (AU IVc1). All of these are located towards the western part of the site, in an area where the shelter provided by the main drip line was more limited.

These cases differ from other hearths whose surrounding activities exhibit greater specificity (Fig. 26). For example, H9 (AU IVd1) and H5 (IVb) are associated with significant knapping activity (Machado et al., 2019) and are located in the southwest and central-east of the site, respectively. Others, such as H14 (AU IVb), are strictly associated with faunal remains, making it the only hearth positioned in the southeast, coinciding with the inner ledge. Finally, some hearths have no recorded activity within their strict perimeter, yet they are near material accumulations, either associated (H11 in AU IVd1 and H3 and H4 in AU IVb) or unassociated (H15 in AU IVc2) with other fires.

Thus, due to the temporal resolution of space at Abric del Pastor, it is possible to observe a certain variability within the very concept of hearth-related assemblage. The presence or absence of fire and the variability of associated material assemblages lead us to several key observations:

1. A hearth is not always present. This is something we have already proposed for El Salt based on the singular introduction model (Sossa-Ríos et al., 2024), but here it is easier to test due to the spatial representation.
2. When a hearth is present, it is not always located in the same place. Although fires predominantly occur in the central-western zone, there is no overlap throughout the entire sequence.

- When present, a hearth does not always structure the same behaviour. We can find fires devoid of material record and linked to a possible use as resting areas; fires associated with at least two activities (e.g. knapping and consumption); and fires around which activities are more focused on one resource or another (knapping or consumption).

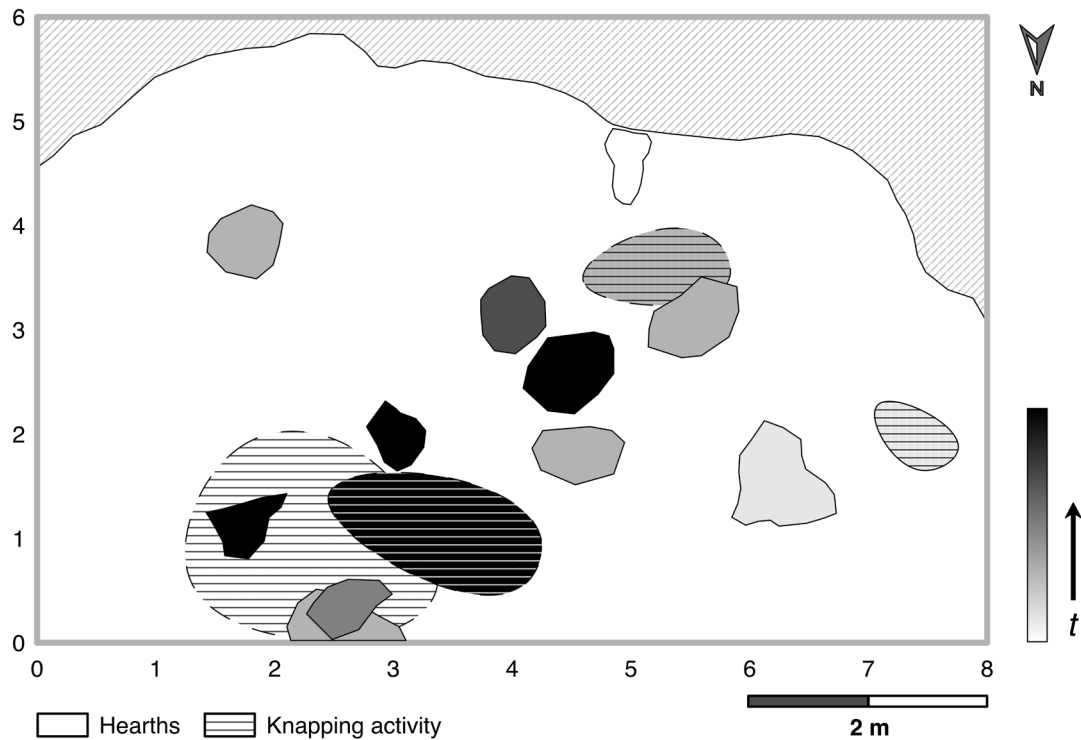


Fig. 26. Eighties-inspired spatial distribution of all combustion structures and associated knapping areas at Abric del Pastor (SU V - AU IVb). The diachrony among them is represented by colours (from white to black). Knapping areas are approximate. For an accurate visualisation of the distribution of the refitted remains, please see: Machado et al. (2019); Sossa-Ríos et al. (2022, 2025).

Structural factors of the rockshelter itself must be conditioning certain behaviours, such as the near absence of fires in the southeast due to the height of the inner ledge or the location of resting fires near the wall to smoke control (Galanidou, 2000; Kedar et al., 2024). However, other factors, possibly cultural, related to group dynamics and territorial/resource management, are also evident.

The first of these, general and structural in nature, concerns the organisation of activities around fire, regardless of type and intensity, although we recognise that variability exists. However, other factors manifest only in specific moments, such as the recurrent knapping activity in the northern and uncovered area of the shelter throughout the formation of SU V. This recurrence of knapping in the same space, without association with a hearth or faunal remains, could be explained by the cultural connection of certain groups whose management of the Barranc del Cint was not linked to domestic activities, at least in this site.

Additionally, in later moments, space management appears to be linked to Beniaia flint. In the case of this flint, which is sourced from the most distant location, it is worth questioning whether perceptible spatial changes are associated with its introduction. As Vaquero et al. (2001) suggested, data must be interrelated to assess the level of connection between the site and the territory:

“Intrasite occupation patterns may be related to settlement strategies at a regional level” (Vaquero et al., 2001: 592).

It is noticeable that when Beniaia flint dominates in terms of introduction, spatial management differs slightly. For example, H9 in IVd1 and H5 in IVb show accumulations around the fire associated with the near-complete exploitation of Beniaia flint nodules. In both AUs, this flint predominates, and in both cases, the spatial units of “fire and knapping” are accompanied by nearby hearths with lower material accumulation. While we must maintain the presumption of diachrony for these fires, it is striking that only in the AUs where Beniaia is most frequently introduced do we find more than one combustion structure.

The difference between IVd1 and IVb, compared to other AUs where knapping is conducted fragmentarily on local flints, suggests possible cultural explanations for the units dominated by Beniaia. Groups arriving from the north, based on the provenance of this flint, may not have had detailed control over this part of the territory. Facing this uncertainty, they may have transported large production matrices to meet potential needs as they arose (“provisioning places” model; *sensv* Kuhn, 1992). This difference is spatially evident, being the only cases where knapping is more prominent than other activities and where, albeit cautiously, multiple hearths are observed. The possibility that different groups managed and generated a different spatial outcome remains open, though we must acknowledge that establishing precise temporal correlations between these elements is highly challenging.

Another noteworthy element, albeit due to its absence, is size-sorting. This phenomenon, described as the McKellar Hypothesis (McKellar, 1973-1983; Schiffer, 1983b), in which small products tend to be refused near the activity area (“primary refuse”; *sensv* Schiffer, 1972, 1983a) and large products are displaced to another area far from the activity place (“secondary refuse”; *sensv* Schiffer, 1972; 1983a), has been recognised in both ethnoarchaeological and archaeological contexts (e.g. Yellen, 1977; O’Connell, 1987; Binford, 1978; Vaquero, 1999; Vaquero et al., 2001, 2012, 2015; Spagnolo et al., 2020a; Sánchez-Martínez et al., 2022). Considering only the lithic record, no accumulations of large or heavy material have been identified in our units or in previously published ones. Coinciding with Murray (1980), this could correlate with brief site-use events, that did not require investment in an “initial settling-in space” (*sensv* Stevenson, 1985).

However, beyond the lithic record, faunal remains in SU V exhibit a significant concentration in the southeastern zone, which also appears diachronic, judging by the material vertical hiatuses recorded in this area (Sossa-Ríos et al., 2025). Moreover, this is not the only moment where such an isolated accumulation is observed, as it is also evident in IVf1, IVe1 and IVc2 (Machado et al., 2019; Sossa-Ríos, 2021; Sossa-Ríos et al., 2022). Investigating this assemblage

could shed light on the accumulating agent which, if human, might be correlated with surface cleaning (“secondary refuse”) or “dumping” (*sensu* Binford, 1978), given its abundance and the absence of knapping or combustion activity in that zone (O’Connell et al., 1991; Speth, 2006; Gabucio et al., 2018; Spagnolo et al., 2019; Starkovich et al., 2020). Further work may shed light on this issue, particularly by integrating taphonomic and spatial analyses to assess whether the pattern reflects deliberate human agency or alternative depositional processes.

A suspicious homogeneity: El Salt

In the case of El Salt, the results presented in this Thesis reveal certain continuities with previous studies (Machado & Pérez, 2016; Machado et al., 2017), but also aspects that have only emerged in our analysis.

Among the regular or static aspects, we highlight, first, the constant presence of hearth-related assemblages throughout the inner zone and the southern sector of the outer area, usually bordering the excavation profiles (Sossa-Ríos et al., 2024). These units are accumulations near fires observed in all our analytical units and also identified in SU Xa (Machado & Pérez, 2016; Machado et al., 2017). This material reflection of behaviour in space is dominant in most contexts associated with hunter-gatherer groups, whether prehistoric or ethnoarchaeological (e.g. Yellen, 1977; Binford, 1978; Stevenson, 1991; Vaquero & Pastó, 2001; Martínez-Moreno et al., 2004; Henry, 2012; Blasco et al., 2016; Spagnolo et al., 2019, 2020a). Its diachronic expression throughout the studied sequence indicates structural factors that guide interactions between individuals and the resources they manage.

This apparent recurrence is also evident in the types of products introduced into the site and their spatial distribution, with a clear predominance of very small to small single flakes made of Serreta flint across the entire surface, followed by Mariola and Beniaia flints. This pattern is accompanied by the scarce presence of refits across the AUs of both units SU Xb and Xa, which prevents establishing potential contemporaneity or diachrony relationships between the inner and outer area, which are already difficult to correlate due to the surface representation. Only two RMUs, each consisting of two artefacts (one between AU Xb2in and Xb2out, and another between AU 4.1 and 4e) suggest a possible connection between the two zones, although this evidence remains insufficient (Machado & Pérez, 2016; Sossa-Ríos et al., 2024).

This monotonous image exhibited by the lithic record at El Salt is also perceptible in the anthracological record of SU Xb, with the predominance of *Pinus nigra* (Vidal-Matutano, 2017; Vidal-Matutano et al., 2018), or in the presence of medium-sized taxa in SU Xa (Machado & Pérez, 2016; Pérez et al., 2020). However, we cannot rely solely on these dominant factors, as they may be masking episodic realities that deviate from the average due to the palimpsest effect:

“The apparent monotony is the result of the temporal depth of archeological assemblages. As the resolution of analysis increases, Neanderthal behavior becomes more variable” (Vaquero et al., 2012: 177).

In some cases, it is possible to access these accumulations with greater resolution and less spatiotemporal uncertainty, especially after the refinement of archaeostratigraphic analysis, which allowed for the rejection of potentially erroneous inferences. This is the case for concentration C1 in AU Xb2in, characterised by a predominance of knapping activity. An analysis of the unit-as-a-whole would have associated this activity with hearths H55 and H61, aligning with hearth-related assemblage models. While it is not possible to entirely rule out the possibility that these knapping events were linked to a combustion structure (due to the low spatial representation in this area), it can be ruled out that they were specifically associated with these two hearths. Furthermore, it is evident that while more knapping occurred more frequently in the inner zone, this was not always the case, as there is no evidence of knapping in AU Xb1in. Conversely, while knapping was less frequent in the outer zone, it took place during both formation stages. These temporal nuances help refine certain generic assumptions about Neanderthal spatial behavior.

In this regard, another case is the very position of the hearths, which organise many activities. It is often assumed that combustion evidence is more prevalent inside due to structural factors (e.g. shelter protection; Galanidou, 2000; Bailey & Galanidou, 2009); however, this is not always the case (Fig. 27). Comparing the presence-absence of hearths across the AUs of SU Xb and Xa, diachronic changes in space become evident. For example, in the most recent moments of the outer zone in SU Xb (AU Xb1out), we find the highest concentration of fires in the entire sequence. Additionally, from that point onward, the inner zone begins to gain prominence in combustion activity, maintaining this trend over time until the end of SU Xa, when the outer area once again surpasses the inner zone in the number of hearths (Sossa-Ríos et al., 2024; Machado et al., 2017). Another changing element is the presence of hearths in the outer zone, which remains positive in our units but records null values in three AUs of Xa (4e, 3e, and 3.2).

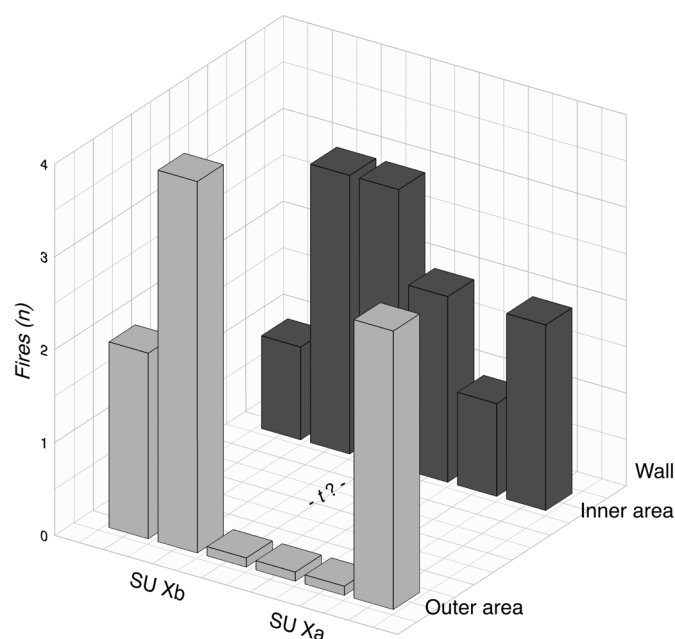


Fig. 27. 3D vertical bar chart regarding the number and spatial location of fires. X axis represents the time, from the AUs defined in this Thesis (SU Xb) to the AUs belonging to SU Xa.

This leads to an interesting observation regarding the formation of lithic assemblages. The data confirmed that a higher number of fires does not necessarily correlate with a larger archaeological record. This had already been suggested by Sorensen & Scherjon (2018) through modeling approach, and we can now test it archaeologically. Moreover, anthropogenic accumulations can form without a direct association with fire, aligning with data from AUs IVe1 and IVf1 at Abric del Pastor (Sossa-Ríos, 2021; Sossa-Ríos et al., 2022). This hypothetical formation of lithic assemblages at El Salt, mainly composed of single products without direct association with combustion structures, further complicates the identification of diachrony between events, leaving an uncertain scenario for future research.

Another seemingly “regular” aspect that we have been able to unravel is the diachronic predominance of single cores in the outer area, a pattern also noted in the AUs of SU Xa (Machado et al., 2017). One possible explanation is that the outer zone operated diachronically as a “toss” area (*sensu* Binford, 1978). However, none of the cores identified in this zone have been refitted with artifacts from the inner area in any of the studied units, preventing any spatiotemporal correlation between knapping and discard activities (Vaquero et al., 2017).

In this regard, the spatial analysis conducted for each AU in SU Xb was crucial in developing alternative hypotheses. This allowed us to observe that, in the earliest phase (AU Xb2out), these cores were concentrated in a highly specific area, separate from the activity zones associated with hearths (concentration C2). Furthermore, these cores displayed variability in both size, weight and flint type. Specifically, the accumulation was dominated by large and heavy cores of Beniaia flint, alongside small to medium-sized and lighter cores of Mariola flint (Sossa-Ríos et al., 2024).

This opens up several interpretative possibilities. The first is that it represents a secondary refuse area, where incoming groups relocated products from previous occupations to prepare the space, thereby generating a visible size-sorting pattern (Schiffer, 1972, 1983a; Binford, 1978; Stevenson, 1985; Bartram et al., 1991; Vaquero et al., 2012) or even sorting by technology pattern in the case of small and exhausted cores as observed in Oscurusciuto 13, 11b and 11a (i.e. Spagnolo et al., 2019, 2020a). This scenario would suggest a longer duration for the events recorded in this AU, as ethnoarchaeological data indicate that such behaviors typically occur when a group anticipates a prolonged stay (i.e. Yellen, 1977). However, the absence of connections between these cores and very small products, presumably discarded in primary activity zones, urges caution in accepting this interpretation.

An alternative explanation, specifically regarding the Beniaia flint cores, is that they were stored as raw material reserves for future visits, a practice documented among hunter-gatherers as “caching” or “hoarding behavior” (e.g. Binford, 1979; Peresani, 2009; Spagnolo et al., 2020b; Sánchez-Martínez et al., 2022). In this sense, McCall (2012), in his review of lithic resource management in ethnoarchaeological contexts, pointed out that such behavior is more common when raw material procurement is independent of other subsistence activities, thus optimizing transport costs. In this case, transporting these cores would have entailed a higher cost than other types of flint, which naturally occur in smaller formats,

potentially supporting this hypothesis. However, this reasoning alone would only explain the accumulation of Beniaia cores.

A further explanatory avenue, also linked to Beniaia flint, is that these were not discard or storage products but rather associated with a specific activity area. Experimental studies have shown that large and heavy lithic products are highly effective for percussion and the fracturing of large bones (e.g. Assaf, 2025), reinforcing archaeological hypotheses in this regard (e.g. Pop et al., 2018; Navazo et al., 2023). In our case, a use-wear analysis of these cores, combined with a zooarchaeological and taphonomic study of the faunal remains within this concentration, could shed light on this behavior, potentially related to carcass processing. This would be consistent, for example, with accumulation K3 from level K, or M6 from level M of Abric Romani, which are also located in the outer zone (Chacón & Fernández-Laso, 2007; Gabucio et al., 2018).

Finally, the event-based approach and the multidisciplinary work carried out in El Salt, allowed us to detect variability in the formation of some events, as the case of H50. It represents a key case for assessing spatiotemporal variability in archaeological formation processes. While its lithic assemblage, dominated by small and medium-sized Serreta flint flakes, offers limited potential for distinguishing discrete diachronic events, the combustion structure itself provides critical temporal inferences. The alternation between *Pinus nigra* and *Acer sp.* as firewood (Vidal-Matutano, 2017; Vidal-Matutano et al., 2018), alongside evidence of reworking in the white layer (Leierer et al., 2019), displacing the first but keeping inside the second fuel, suggests a sequential rather than contemporaneous formation event, allowing here for the proposal of at least two distinct fire-use episodes.

The distinctive morphology of H50 adds further data to the interpretation of the time and duration of the combustion event. Unlike most hearths at El Salt, which rarely exceed 50 cm in diameter and 2 cm in black layer depth (Mallol et al., 2013), H50 reaches a depth of 13 cm, suggesting prolonged burning. Experimental data indicate that such deep penetration is typically associated with extended heating periods under specific environmental conditions, possibly pointing to longer-term use (Aldeias et al., 2016). This raises the question of whether H50 represents a single, sustained combustion event, or multiple, closely episodes.

If a more prolonged event is supported by these data, then concentration C2 could be interpreted as evidence of a more extended occupation, during which the group may have cleared the surface of large or technologically unexploitable products, starting an “initial settling-in space” (*sensu* Stevenson, 1985). However, this hypothesis must be approached with caution, and further avenues should be explored to detect diachrony. Potential strategies include post-genetic analysis of raw materials to infer different procurement places, zooarchaeological examination and refitting of faunal remains in this area (C1 and C2), as well as reassessing potential reignition processes through magnetic susceptibility analysis. While there is a consensus on the short-term nature of Neanderthal occupations, we cannot overlook the possibility of investigating possible off-average patterns.

Methodological considerations on El Salt results

The analysis of intrasite settlement dynamics based on the lithic record yielded positive results, particularly those that stood out above the behavioural average and indicated signs of variability. However, certain methodological considerations should be addressed, especially in the case of El Salt.

In this regard, the generation of spatial analysis units in SU Xb warrants some reflection. For each of the defined AUs, a Kernel density analysis was conducted. Subsequently, based on qualitative criteria, the highest-density assemblages were selected for a detailed lithic analysis (Sossa-Ríos et al., 2024; following Clark, 2017).

This approach does not inherently pose any methodological issues or errors. However, the problem in our case lies in the designation of the resulting units of analysis as “clusters.” These units actually represent areas of higher density but lack statistical significance to support their classification as such (Silverman, 1998; O’Sullivan & Unwin, 2010; Gong et al., 2023). To properly establish them as clusters, we should have employed additional geostatistical tests, as was done for SU V at Abric del Pastor, such as Optimised Hotspot Analysis (Getis-Ord G_i^*) or Density-Based Clustering (HDBSCAN). Alternatively, these areas should have been considered and referred to as “concentrations” or “high-density zones.”

On the other hand, it is necessary to rethink the role of burnt artefacts and how we handle them in relation to space. In this line, one of the most striking aspects of the spatial distribution of the lithic record at El Salt, which remains open to further discussion, is the location of thermally-altered products. While it is true that in many cases these products are associated with combustion structures, we observe a significant group of burnt elements located more than a metre away from hearths (Sossa-Ríos et al., 2024), which has also been noted for SU Xa (Dorta et al., 2010).

Research on unintentional and therefore uncontrolled heat alteration has provided valuable insights in this regard. The experiments conducted by Dorta et al. (2010) identified significant differences among the flint types from the Serpis Valley, which were later compared with the archaeological record of SU Xa. In this context, Mariola flint exhibited more intense colour alterations at lower temperatures (>300 °C) and a greater tendency to fragment in oxidising atmospheres. In contrast, Serreta flint required higher temperatures to initiate colour changes (>500 °C) and was more susceptible to explode and fragment in reducing atmospheres, limiting its displacement.

In SU Xa, most of the burnt remains are concentrated in the inner area of the rockshelter. There, products predominantly show alterations related to colour changes, gloss, or mud cracks. Conversely, in the outer area, although fewer remains are present, there is a higher proportion of irregular fragments with colour changes (42%), presumably resulting from the explosive separation of the siliceous matrix.

In this line, but in other experimental and archaeological contexts, it has been observed that pieces located within the fuel context (whether or not they are contemporary with the fire) can be projected up to three metres from their primary position (Nieto-Márquez & Baena, 2015). However, this does not always occur. The susceptibility of flint to be altered in mass and position largely depends on its volume or flint type (Bustos-Pérez & Baena, 2016).

This highlights important methodological considerations when including burnt products in research on spatial organisation. Firstly, experimental studies are necessary to understand how each flint type behaves under different thermal and sedimentary conditions in the specific study site, in order to assess the reliability of its spatiotemporal position. This approach allows for two lines of research: one of construction and another of refinement. The first involves using “non-displaced” products as activity markers, both vertically and horizontally, which is particularly useful in contexts where fire is not macroscopically visible, either due to natural or anthropogenic reasons (e.g. Alperson-Afil & Goren-Inbar, 2017; Sorensen & Scherjon, 2018). The second entails discriminating and isolating “mobile” materials when aiming to reconstruct the systemic context of these human groups, as including products that may have bounced can distort spatial tests and behavioural inferences. This latter aspect is particularly relevant at El Salt, where hearths are well-preserved and thermally-altered materials are abundant. A spatial analysis of the different lithic records within SU Xb, considering the features of these products and filtering them based on existing experimental data (i.e. Dorta et al., 2010), could have provided a clearer picture of each lithic assemblage.

No country for old types

One of the key questions that arose when analysing the accumulation around H17 at Abric del Pastor (Sossa-Ríos et al., 2022) was whether other deposits more affected by the palimpsest effect, such as SU Xb at El Salt, would have been formed by repeating this pattern.

At this stage, the evidence suggests otherwise. In fact, this pattern is not even consistently observed at Abric del Pastor, where high spatial-temporal resolution has revealed spatial units that deviate from this model. While both sites exhibit hearth-related assemblages, they also display internal and inter-site differences. For instance, the concentration of large, heavy lithic remains identified in AU Xb2out has no equivalent at Abric del Pastor, but neither in other AUs at El Salt. Similarly, the recurrent knapping area without an associated hearth recorded in SU V at Abric del Pastor has no counterpart at El Salt, but neither elsewhere within the Abric del Pastor itself.

This variability complicates the development of theoretical models to explain lithic assemblage formation, beyond the recurring introduction of single products, accompanied by relatively few, more or less complete, knapping events (Vaquero et al., 2001). But at the same time this variability warns us of something important: beware of labels. It is therefore worth highlighting the strength of spatial analysis in lithic studies, which has largely avoided functionalist typologies linked to units of analysis, or worse: entire sites.

While labelling remains a useful ontological resource in cases where productive activity is intrinsically tied to the primary or subprimary location of an exploited resource (e.g. quarrying sites; Baena et al., 2015, 2019; Torres & Baena, 2020; or kill-butchered sites; Rodríguez-Hidalgo et al., 2017; Arteaga-Briebe et al., 2023), this is not the rule, especially when the only natural resource to be exploited is the shelter itself. Abric del Pastor, for instance, could have functioned as a resting place, an observation point, a long-term residential camp, or a specific short-term stay. Given this variability, imposing historicist-cultural interpretations on a field so profoundly shaped by time averaging proves scientifically limiting. When resolution allows, the record has consistently demonstrated a high degree of variability. As such, the recurrence of technological patterns should not be mistaken for the construction of rigid site types, as doing so overlooks the spatial and temporal complexity within and between sites.

“Types are associations of variables resulting from patterned behavior; it is the behavior behind the patterns, not the types themselves, that is important. Typological analysis allows us to identify and describe relationships in specific contexts. To reify the types as universally applicable labels is to lose the context, to lay constructs over behavioral remains where they may not be appropriate” (Nelson, 1991: 84).

Why, then, should we be so quick to label? Especially when resolution often prevents us from making definitive claims. Labelling risks creating a false sense of completion and triumph, as if the settlement patterns of these groups were already fully understood. But are they? A more productive approach lies in seeking connections between events, refining methods that help mitigate the distortions of time averaging, and finding ways to address, however imperfectly, the challenges posed by the palimpsest nature of the archaeological record.

Furthermore, in the broader effort to understand the role of archaeological sites from a diachronic perspective and to explain, for instance, the discontinuous and shifting occupational patterns at Abric del Pastor or the apparent sustained homogeneity of El Salt, additional factors must be considered. One of the most crucial aspects is the perception of these sites within the landscape, shifting the focus from their material content to their geographical positioning and geomorphological configuration (Binford, 1982; Galanidou, 2000). This perspective challenges the conventional view of archaeological sites as mere repositories of products and instead considers them as natural resources in their own right: resources that could be strategically exploited by past human groups at high or low cost (Vaquero & Romagnoli, 2018).

In this regard, Abric del Pastor is not strictly open to the Serpis Valley and its associated resources, positioned within a narrow ravine that, while offering specific advantages such as water availability, and access to juniper, Mediterranean tortoise and wild goat, presents certain geomorphological constraints in terms of smooth mobility due to the ruggedness of this context (Vicens-Petit, 1989; Molina, 2015). Its location in the halfway of the Barranc del Cint also limits its visual control over the surrounding landscape, as lateral views (east-west) are obstructed by the sinuous topography of the ravine, while frontal visibility to the north is blocked by the Pic de les Àguiles. Moreover, the site itself is difficult to detect from the

ravine base considering the steep nature of this environment, reducing its prominence as a landmark in the landscape. The potential occupation surface is also relatively small (60 m²), which may have further influenced how the site was used over time.

By contrast, El Salt is situated on elevated terrain with unobstructed visibility, providing an extensive monitoring point over the valley (Galván et al., 2001). This strategic location would have facilitated long-distance observation of the landscape, aiding in the planning of movements and resource acquisition. Additionally, its proximity to the Serpis River headwaters ensured direct and consistent access to water, as well as to the various animal species drawn to this resource. Beyond its views from the site itself, El Salt would have been a highly visible landmark in the landscape. The travertine wall, which rises more than 38 metres, would have made it recognisable from great distances within the valley, potentially serving as a reference point for mobile groups. Furthermore, the potential occupation area at El Salt is substantially larger (ca. 250 m²), offering greater spatial flexibility for structuring activities compared to the more confined space available at Abric del Pastor.

Considering the archaeological record associated with the studied analytical units, it appears that the use of Abric del Pastor as a resource entailed a higher cost, primarily due to its challenging accessibility and the potential redundancy of the resources from the Barranc del Cint, many of which were already widely available in the Serpis Valley, both biotic and abiotic. Conversely, El Salt would represent a lower cost of use, with easier accessibility, especially during the Upper Pleistocene, when a lateral connection existed between the tufa terraces now found both in the valley and at the base of the site (Fumanal, 1994). This would have created a more gradual slope, facilitating movement to and from the rockshelter. At the same time, the expansive visual control over the valley from the site would have provided a strategic advantage, allowing for the efficient planning of mobility and thus, reducing costs in the exploitation of other resources across the broader landscape.

Ultimately, rather than reflecting predefined functional categories, the differences between Abric del Pastor and El Salt suggest variations in how Neanderthal groups engaged with these locations depending on broader mobility dynamics, landscape constraints, and resource needs. Recognising that sites were not inherently tied to fixed roles, but instead formed part of a flexible network of resource exploitation, in which the site itself functioned as a resource, is essential for refining interpretations of Neanderthal settlement strategies and the processes that shaped the archaeological record.

5.5. Evaluating palimpsest dissection

The findings of this study highlight broader implications that extend beyond the specific case studies examined. They provide key insights into the potential and limitations of palimpsest dissection as a means of investigating formation processes and interpreting human behaviours in the archaeological record.

A crucial observation is that without this downscaling approach, we would not have detected the same behavioural patterns. Reducing the scale of analysis has revealed spatial variability

in activity events over time. For example, at El Salt, knapping events were predominantly located in the earliest formation stage of the inner area, indicating that lithic production was not always carried out in the same location. Conversely, at Abric del Pastor, the same analytical framework allowed us to test and confirm the opposite: in the northern area of the site, knapping activity repeatedly took place over at least two formation stages of SU V. Thus, we were able to observe both variability and continuity: two fundamental aspects of human behaviour that require the same methodological approach to be properly recognised.

This is a key point, particularly when working with high-density deposits. It is essential to avoid assuming that large-scale observations inherently capture structural patterns that persist over time. The presence of recurrent elements in a given assemblage does not necessarily imply behavioural continuity. What appears as a stable pattern at a broader scale may, in fact, be the outcome of distinct, unrelated events when examined in finer detail. By reducing the scale of analysis, we make visible the relational nature of time in the archaeological record, revealing that events are not merely stacked upon one another but embedded within complex sequences of interaction. Thus, instead of treating deposits as homogeneous units, it is more productive to focus on events and their correlations. Even some events may appear quantitatively insignificant, it is better to focus on them, as they may offer a more realistic historical inferences than can be drawn from the assemblage-as-a-whole.

Our results also reinforce the correlation between scale and resolution. As the scale of analysis was progressively increased, higher-resolution behavioural patterns emerged (Fig. 28). Archaeostratigraphic units provided different insights than stratigraphic units, spatial units revealed additional variability within archaeostratigraphic units, and events, in turn, exposed further distinctions shaped by technoeconomic variables. This demonstrates that rather than being a purely methodological exercise, reducing the scale of analysis actively enhances our ability to detect behavioural dynamics.

Following this approach, the concept of a homogeneous “Neanderthal behaviour” begins to lose its coherence. The more the scale of analysis is reduced, the greater the behavioural variability observed, demonstrating that the traditional image of Neanderthals as groups with fixed behavioural patterns is the product of large scale approaches. Paradoxically, this image is then used as justification for not reducing the scale: if Neanderthals are assumed to behave the same way across time and space, then there seems little reason to refine the scale of study, since we would always observe the same patterns, in the same places, with the same materials.

This Thesis has sought to challenge that assumption. That reducing the scale of analysis does not merely enhance resolution but also reveals a greater diversity in Neanderthal behaviours, as evidenced through the study of lithic assemblages. Moreover, it has highlighted the risks of remaining at a broader scale. This approach not only leads to a loss of interpretative accuracy, but also risks producing entirely erroneous readings, generating what we might call a “Frankenstein behaviour”: an artificial construct that merges disparate events into a single, distorted narrative of human groups.

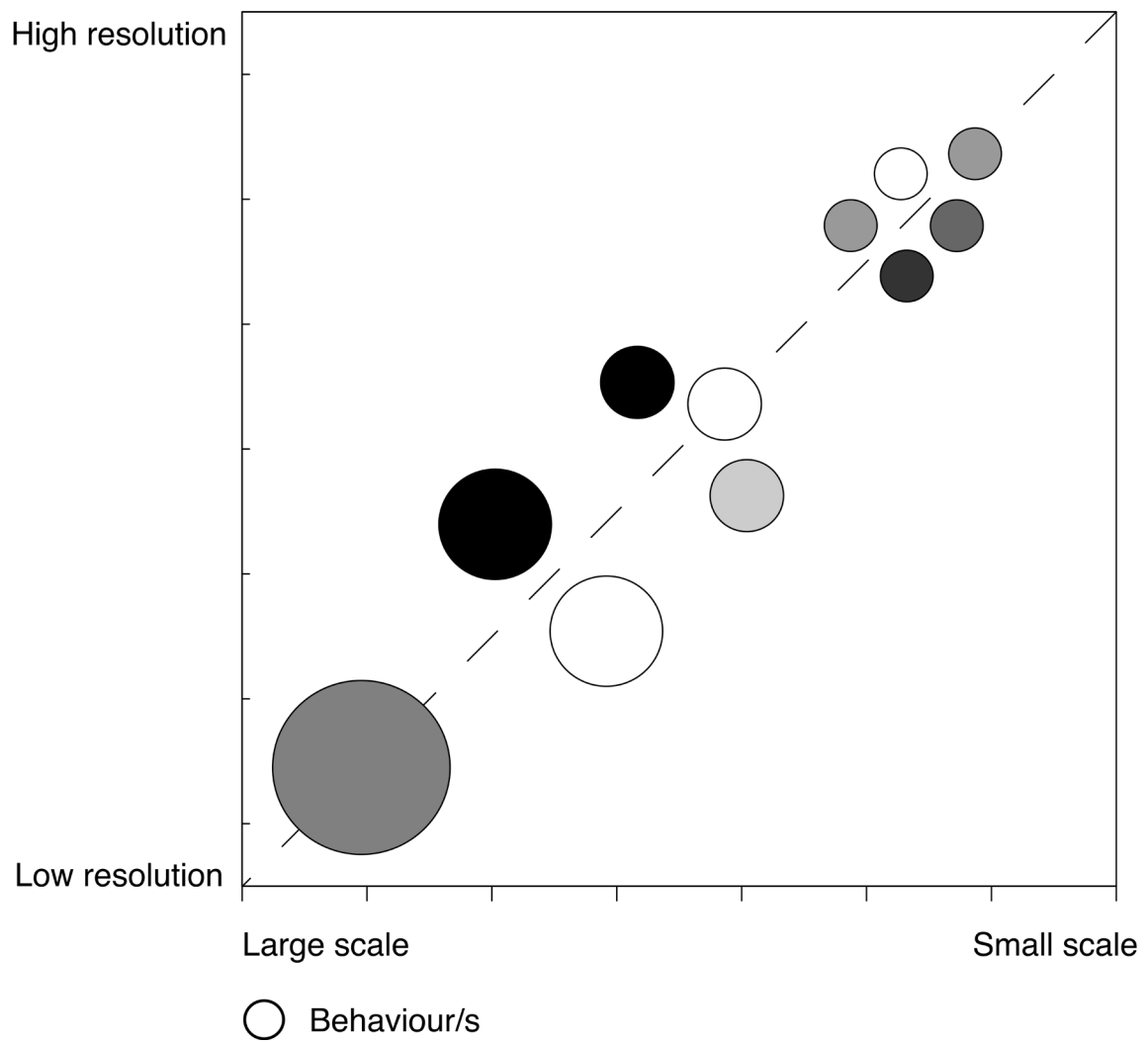
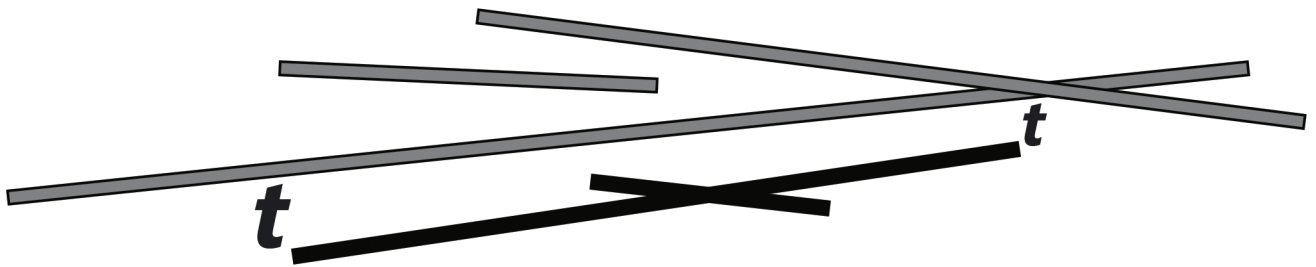


Fig. 28. General scheme of how scale is related to resolution based on our results on behavioural variability.

section

VIII



CONCLUSIONS

VI. Conclusions

VI. Conclusions

The results of this Thesis demonstrate a positive correlation between the reduction of analytical scale and the increase in spatiotemporal resolution when characterising human behaviour. This relationship is evident in both high-density contexts, such as El Salt, and in lower-density assemblages, such as those from Abric del Pastor. In both sites, scale reduction enabled the isolation of more discrete units of analysis, leading to more accurate reconstructions of technoeconomic practices and spatial management.

At the same time, the application of broader scales leads to lower-resolution outcomes, introducing interpretive biases that give rise to rigid, homogenised views of the human groups subject of study. In this sense, the ontological proposal on archaeological time outlined in this Thesis offers a more realistic perspective on the fragmentary and dynamic nature of the Palaeolithic record. Through this approach, it has been possible to identify both changes and continuities in behavioural patterns of the Neanderthal groups who inhabited and exploited the Serpis Valley during the Upper Pleistocene.

Mobility patterns, reconstructed through the procurement of siliceous raw materials within the Serpis Valley, show considerable variability depending on the resolution achieved. This variability is particularly evident at Abric del Pastor, where the representation and spatial distribution of different flint types (mainly Mariola, Serreta, and Beniaia) vary significantly across archaeostratigraphic and spatial units, reflecting shifting strategies of resource acquisition and landscape use over time.

With regard to lithic resource management, both sites exhibit a high degree of fragmentation in the operative chains, although this pattern is more pronounced at El Salt. Most assemblages there consist of single products, which poses greater challenges for identifying event-level correlations. At Abric del Pastor, by contrast, this fragmentation is more variable across the sequence: while some units present similar patterns, others show clear evidence of extensive knapping activity.

The reduction in scale also led to a direct improvement in spatial resolution. At both sites, significant variability in spatial organisation was documented. Combustion structures are not consistently associated with material assemblages, nor are they located in the same areas across different formation stages. Likewise, knapping activity shows no fixed spatial distribution, reflecting flexible and context-dependent spatial decisions. Beyond hearth-related assemblages, spatial analysis enabled the identification of secondary refuse zones and specific knapping areas with no association to fire. The diachronic dynamism revealed in the spatial distribution of lithic assemblages invites a critical reconsideration of typological

classifications in the interpretation of occupied spaces, and even more so in the broader characterisation of archaeological sites.

This approach has allowed us to obtain a clearer picture of the behaviours of the Neanderthal groups that inhabited the Serpis Valley. Far from displaying repetitive or rigid patterns, these behaviours reflect a wide range of decisions that varied over time, not only in response to economic factors but also informed by culturally embedded practices, some of which appear to have been deliberately disrupted at certain times. The results highlight a strong degree of control over the upper valley and its resources, alongside more sporadic, long-range movements from the middle valley. Similarly, raw material management was far from uniform: while heavily reduced artefacts were commonly introduced, in other cases, extensive knapping was carried out on-site, or larger, minimally modified flint cores were transported over greater distances. The hearth-related assemblage emerges as the primary spatial unit structuring many formation events at both sites. However, it is not always present, pointing to alternative modes of spatial organisation. Taken together, these patterns reflect not isolated behaviours but historical processes through which Neanderthal groups organised their activities, structured their use of resources, and negotiated economic and social decisions over time.

By consistently incorporating the temporal dimension throughout the research, it was possible to identify patterns of variability alongside those of continuity. At Abric del Pastor, for example, the identified knapping zone shows repeated use across multiple formation events, highlighting the value of this approach in tracing not only variation but also persistence in behavioural practices. This finding supports the idea that long-term histories can be more robustly reconstructed when discrete events and their diachronic relationships are taken as the starting point. As concluded in one of our published case studies:

“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”
(Sossa-Ríos et al., 2024: 42).

As part of future research, this Thesis outlines three lines of work that the author intends to pursue in the coming years, some of which are already underway. First, the application of this theoretical and methodological framework to lithic assemblages with higher material density, where the palimpsest effect tends to blur behavioural signals more strongly. Second, future research could integrate taphonomic variables, such as thermal alteration, white patinas, edge damage, and size-sorting, into the analysis of formation processes. Supported by a dedicated experimental programme, this approach would aim to identify diachronic patterns through variations in the intensity of post-depositional alterations, particularly in contexts where clear vertical gaps are absent. Lastly, the author plans to develop an archaeostratigraphic application handbook that offers a foundation for analysis and description, ultimately enhancing the clarity of the data and the interpretative discussions built upon it.

section

VIII

Con la Sarga se consiguieron las primeras pinturas rupestres, con el Abrigo del Pastor, en el Barranco del Cine, se descubrió la primera estación paleolítica de esta zona a la que sucederían por los años el yacimiento de el Salt(VER si hay bibliografía)(3) y la Cova Benedito en Muro de Alcoy(Alicante).(4).

REFERENCES

A

- Abreu, I. (2011). *Aproximación tecnofuncional a los cantos de caliza en el yacimiento paleolítico de El Salt (Alcoi, Alacant, España)*. Master Dissertation, Universidad de La Laguna.
- Adler, D., Prindiville, T. & Conard, N.J. (2003). Patterns of spatial organization and land use during the Eemian interglacial in the Rhineland: new data from Wallertheim, Germany. *Eurasian Prehistory*, 1(2), 25-78.
- Aldeias, V., Goldberg, P., Sandgathe, D., Berna, F., Dibble, H., McPherron, S., Turq, A. & Rezek, Z. (2012). Evidence for Neandertal use of fire at Roc de Marsal (France). *Journal of Archaeological Science*, 39(7). <https://doi.org/10.1016/j.jas.2012.01.039>
- Aldeias, V., Dibble, H., Sandgathe, D., Goldberg, P. & McPherron, S. (2016). How heat alters underlying deposits and implications for archaeological fire features: a controlled experiment. *Journal of Archaeological Science*, 67, 64-79. <https://doi.org/10.1016/j.jas.2016.01.016>
- Alonso-Fernández, E.S., Vaquero, M., Daura, J., Costa, A., Sanz, M. & Araujo, A. (2023). Refits, cobbles, and fire: approaching the temporal nature of an expedient Gravettian lithic assemblage from Lagar Velho (Leiria, Portugal). *PLoS ONE*, 18(12). <https://doi.org/10.1371/journal.pone.0294866>
- Alperson-Afil, N., Richter, D. & Goren-Inbar, N. (2017). Evaluating the intensity of fire at the Acheulian site of Gesher Benot Ya'aqov—Spatial and thermoluminescence analyses. *PLoS One*, 12(11). <https://doi.org/10.1371/journal.pone.0188091>
- Amick, D.S. (2014). Reflection on the origins of recycling: a Paleolithic perspective. *Lithic technology*, 39(1), 64-69. <https://doi.org/10.1179/0197726113Z.00000000025>
- Andrefsky, W. (1994). Raw material availability and the organization of technology. *American Antiquity*, 59(1). <https://doi.org/10.2307/3085499>
- Andrefsky, W. (2005). *Lithics: macroscopic approaches to analysis*. Cambridge University Press, Cambridge.
- Arteaga-Briebe, A., Courtenay, L., Cobo-Sánchez, L., Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., & Mosquera, M. (2023) An archaeostratigraphic consideration of the Gran Dolina TD10.2 cultural sequence from a quantitative approach. *Quaternary Science Reviews*, 309, 108033. <https://doi.org/10.1016/j.quascirev.2023.108033>
- Arteaga-Briebe, A. (2024). *Among stones and bison. The lithic assemblage of Gran Dolina TD10.2 (Atapuerca). Technological and spatial implications of a specialised Middle Pleistocene kill-butcherer site*. PhD Dissertation, Universitat Rovira i Virgili.
- Ascher, R. (1961). Analogy in archaeological interpretation. *Southwestern journal of anthropology*, 17(4), 317-325. <https://doi.org/10.1086/soutjanth.17.4.3628943>
- Ashtekar, A. & Lewandowski, J. (2004). Background independent quantum gravity: a status report. *Classical and Quantum Gravity*, 21(15). [10.1088/0264-9381/21/15/R01](https://doi.org/10.1088/0264-9381/21/15/R01)
- Assaf, E., Pérez, S. D., Bruner, E., Torres, C., Blasco, R., Rosell, J. & Preysler, J.B. (2025). The use of shaped stone balls to extract marrow: a matter of skill? Experimental-traceological approach. *Archaeological and Anthropological Sciences*, 17(1). <https://doi.org/10.1007/s12520-024-02138-7>
- Aura, J.E., Fernández-Peris, J. & Fumanal, M.P. (1993). Medio físico y corredores naturales: notas sobre el poblamiento

paleolítico del País Valenciano. *Recerques del Museu d'Alcoi*, II, 89-107.

B

- Baena, J. & Cuartero, F. (2006). Más allá de la tipología lítica: lectura diacrítica y experimentación como claves para la reconstrucción del proceso tecnológico. In: J.M. Maíllo & Baquedano, E. (eds.), *Miscelánea en homenaje a Victoria Cabrera*, 144-161. *Zona Arqueológica*, 7(1).
- Baena, J. & Ríos, P. (2006). Realidad y abstracción: límites de la integración de datos en los SIG. In: I. Grau (ed.), *La aplicación de los SIG en la Arqueología del paisaje*, 15-28. Servicio de Publicaciones de la Universidad de Alicante, Alicante.
- Baena, J., Nieto-Márquez, I., Torres, C. & Báñez, S. (2015). Recycling in abundance: re-use and recycling processes in the Lower and Middle Paleolithic contexts of the central Iberian Peninsula. *Quaternary International*, 361, 142-154. <https://doi.org/10.1016/j.quaint.2014.07.007>
- Baena, J., Ortiz, I. & Torres, C. (2019). Good and bad knappers among Neanderthals. In: Y. Nishiaki & O. Jöris (eds.), *Learning among Neanderthals and Paleolithic Modern Humans*, 95-117. Springer, New York. https://doi.org/10.1007/978-981-13-8980-1_7
- Bailey, G. N. (1983). Concepts of time in Quaternary prehistory. *Annual Review of Anthropology*, 165-192.
- Bailey, G. (2007). Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology*, 26(2), 198-223. <https://doi.org/10.1016/j.jaa.2006.08.002>
- Bailey, G. (2008). Time perspectivism: origins and consequences. In: S. Holdaway & L. Wandsnider (eds.), *Time in archaeology: Time perspectivism revisited*, 13-30. University of Utah Press, Utah.
- Bailey, G. & Galanidou, N. (2009). Caves, palimpsests and dwelling spaces: examples from the Upper Palaeolithic of south-east Europe. *World archaeology*, 41(2), 215-241. <https://doi.org/10.1080/00438240902843733>
- Baker, C.M. (1978). The size effect: an explanation of variability in surface artifact assemblage content. *American Antiquity*, 43(2), 288-293. <https://doi.org/10.2307/279254>
- Bargalló, A., Gabucio, M.J. & Rivals, F. (2016). Puzzling out a palimpsest: Testing an interdisciplinary study in level O of Abric Romaní. *Quaternary International*, 417, 51-65. [10.1016/j.quaint.2015.09.066](https://doi.org/10.1016/j.quaint.2015.09.066)
- Bargalló, A., Gabucio, M. J., Gómez de Soler, B., Chacón, M.G. & Vaquero, M. (2020). Rebuilding the daily scenario of Neanderthal settlement. *Journal of Archaeological Science: Reports*, 29. <https://doi.org/10.1016/j.jasrep.2019.102139>
- Bartram, L., Kroll, E. & Bunn, H. (1991). Variability in camp structure and bone food refuse patterning at Kua San hunter-gatherer camps. In: E. Kroll & D. Price (eds.), *The interpretation of archaeological spatial patterning*, 77-144. Springer, New York.
- Bamforth, D.B. (1986). Technological efficiency and tool curation. *American antiquity*, 51(1), 38-50. <https://doi.org/10.2307/280392>
- Bel, M.Á. (2022). Lithic taphonomy and the use of the spatial information: assessing Palaeolithic sequence of Covadepes Cendres (Teulada-Moraira, Spain). *Archaeological and Anthropological Sciences*, 14(9), 173. <https://doi.org/10.1007/s12520-022->

[01642-y](#)

- Belmonte, D., Molina, F.J. & Satorre, A. (2018). Nuevos yacimientos del Paleolítico superior y del Eneolítico en la Sierra de la Horna (Vinalopó medio, Aspe, Alicante). *Lucentum*, 37, 9-32. <https://doi.org/10.14198/LVCENTVM2018.37.01>
- Bencomo, M., Mayor, A., Sossa-Ríos, S., Jardón, P., Galván, B., Mallol C. & Hernández, C.M. (2023). Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale. *Archaeological and Anthropological Sciences*, 15(92). <https://doi.org/10.1007/s12520-023-01787-4>
- Benito-Calvo, A., Carvalho, S., Arroyo, A., Mastusawa, T. & de la Torre, I. (2015). First GIS analysis of modern stone tools used by wild chimpanzees (*Pan troglodytes verus*) in Bossou, Guinea, West Africa. *PLoS One*, 10(3). <https://doi.org/10.1371/journal.pone.0121613>
- Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P. & Sorensen, M. (2012). Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites. *Journal of Archaeological Science*, 39(10). <https://doi.org/10.1016/j.jas.2012.04.055>
- Bertran, P., Lenoble, A., Todisco, D., Bordes, J. G., Discamps, E. & Vallin, L. (2019). Perturbation assessment in archaeological sites as part of taphonomic study: a review of methods used to document the impact of natural processes on site formation and archaeological interpretations. *Paleo*, 30. <https://doi.org/10.4000/paleo.4378>
- Besag, J.E. (1977). Comment on modeling spatial point processes by B.D. Ripley. *Journal of Royal Statistical Society*, 39, 193-195.
- Binford, L.R. (1972). Directionality in archaeological sequences. In: L.R. Binford (ed.), *An Archaeological Perspective*. Seminar Press, London.
- Binford, L.R. (1977). Forty-seven trips: a case study in the character of archaeological formation processes. In: R. Wright (ed.), *Stone Tools as cultural markers: change, evolution and complexity*, 24-36. Australian Institute of Aboriginal Studies, Canberra.
- Binford, L.R. (1978). Dimensional analysis of behavior and site structure: learning from an Eskimo hunting stand. *American Antiquity*, 43(3), 330-361. <https://doi.org/10.2307/279390>
- Binford, L.R. (1979). Organization and formation processes: looking at curated technologies. *Journal of Anthropological Research*, 35(3), 255-273.
- Binford, L.R. (1980). Willow smoke and dog's tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity*, 45(1). <https://doi.org/10.2307/279653>
- Binford, L.R. (1981). Behavioral archaeology and the "Pompeii premise". *Journal of Anthropological Research*, 37(3), 195-208. <https://doi.org/10.1086/jar.37.3.3629723>
- Binford, L.R. & O'Connell, J.F. (1984). An Alyawara day: The stone quarry. *Journal of Anthropological Research*, 40(3), 406-432. <https://doi.org/10.1086/jar.40.3.3629763>
- Binford, L.R. (1986). An Alyawara day: making men's knives and beyond. *American Antiquity*, 51(3). <https://doi.org/10.2307/281751>
- Bintliff, J. (2006). Time, structure, and agency: the Annales, emergent complexity, and archaeology. In: J. Bintliff (ed.), *A companion to Archaeology*, 174-194. Blackwell, Oxford.

Blasco, R., Rosell, J., Sañudo, P., Gopher, A. & Barkai, R. (2016). What happens around a fire: faunal processing sequences and spatial distribution at Qesem cave (300ka), Israel. *Quaternary International*, 398, 190-209. <https://doi.org/10.1016/j.quaint.2015.04.031>

Bourguignon, L., Delagnes, A. & Meignen, L. (2006). Systèmes de production lithique, gestion des outillages et territoires au Paléolithique moyen: où se trouve la complexité? *Normes techniques et pratiques sociales. De la simplicité des outillages pré- et protohistoriques*, 75-86. APDCA, Antibes.

Brahma, S. (2020). Emergence of time in Loop Quantum Gravity. In: N. Hugget et al. (eds.), *Beyond spacetime: the foundations of Quantum Gravity*, 53-78. Cambridge University Press, Cambridge.

Brookfield, M. (2004). *Principles of stratigraphy*. Blackwell, Oxford.

Brooks, R.L. (1982). Events in the archaeological context and archaeological explanation. *Current Anthropology*, 23(1), 67-75. <https://doi.org/10.1086/202779>

Burroni, D., Donahue, R., Pollard, M. & Mussi, M. (2002). The surface alteration features of flint artefacts as record of environmental processes. *Journal of Archaeological Science*, 29(11). <https://doi.org/10.1006/jasc.2001.0771>

Bustos-Pérez, G. & Baena, J. (2016). Preliminary experimental insights into differential heat impact among lithic artifacts. *Journal of Lithic Studies*, 3(2), 73-90. <https://doi.org/10.2218/jls.v3i2.1396>

Butzer, K.W. (1982). *Archaeology as human ecology: method and theory for a contextual approach*. Cambridge University Press, Cambridge.

C

Canals, A. Vallverdú, J. & Carbonell, E. (2003). New archaeostratigraphic data for the TD6 level in relation to Homo Antecessor (Lower Pleistocene) at the site of Atapuerca, north-central Spain. *Geoarchaeology*, 18, 481-504. <https://doi.org/10.1002/gea.10071>

Cahen, D., Keeley, L.H. & Van Noten, F.L. (1979). Stone tools, toolkits, and human behavior in prehistory. *Current Anthropology*, 20(4), 661-683. <https://doi.org/10.1086/202371>

Carbonell, E., & Mora, R. (1985). Anàlisi espacial d'un campament prehistòric del Post-Glacial. Sota Palou (Campdevàrol). *Cypsela: revista de prehistòria i protohistòria*, 35-45.

Caux, S., Galland, A., Queffelec, A. & Bordes, J. G. (2018). Aspects and characterization of chert alteration in an archaeological context: a qualitative to quantitative pilot study. *Journal of Archaeological Science: Reports*, 20. <https://doi.org/10.1016/j.jasrep.2018.04.027>

Chacón, M.G. & Fernández-Laso, M.C. (2007). Modelos de ocupación durante el Paleolítico medio: el nivel K del Abric Romaní (Capellades, Barcelona, España). *Complutum*, 18, 47-60.

Chacón, M.G. (2009). *El Paleolítico medio en el suroeste europeo: Abric Romaní (Capellades, Barcelona, España), Payre (Rompón, Ardèche, Francia) y Tournal (Bize, Aude, Francia). Análisis comparativo de los conjuntos líticos y los comportamientos humanos*. PhD Dissertation, Universitat Rovira i Virgili and Muséum National d'Histoire Naturelle.

Clark, A.E. (2017). From activity areas to occupational histories: new methods

- to document the formation of spatial structure in hunter-gatherer sites. *Journal of Archaeological Method and Theory*, 24, 1300-1325. <https://doi.org/10.1007/s10816-017-9313-7>
- Clark, A.E. (2019). Using spatial context to identify lithic selection behaviors. *Journal of Archaeological Science: Reports*, 24, 1014-1022. <https://doi.org/10.1016/j.jasrep.2019.03.011>
- Close, A. (1996). Carry what weight: the use and transportation of stone tools. *Current Anthropology*, 37(3).
- Codding, B.F., & Bird, D.W. (2015). Behavioral ecology and the future of archaeological science. *Journal of Archaeological Science*, 56, 9-20. <https://doi.org/10.1016/j.jas.2015.02.027>
- Colominas, L., Portillo, M., Morera, J. Oller, J., Berrocal-Barberà, A., Gallego-Valle, A. López-Bultó, O., Messana, C., Sisa-López de Pablo, J., Tornero, C. & Olesti, O. (2023). Livestock management at the Late Iron Age of Baltarga (eastern Pyrenees): an integrated bioarchaeological approach. *Archaeological and Anthropological Sciences*, 15, 159. <https://doi.org/10.1007/s12520-023-01848-8>
- Conard, N.J. & Adler, D. (1997). Lithic reduction and hominid behaviour in the Middle Paleolithic of the Rhineland. *Journal of Anthropological Research*, 53(2). [10.1086/jar.53.2.3631275](https://doi.org/10.1086/jar.53.2.3631275)
- Conard, N. J., Bolus, M., & Münzel, S.C. (2012). Middle Paleolithic land use, spatial organization and settlement intensity in the Swabian Jura, southwestern Germany. *Quaternary International*, 247, 236-245. <https://doi.org/10.1016/j.quaint.2011.05.043>
- Conolly, J. & Lake, M. (2006). *Geographical Information Systems in Archaeology*. Cambridge University Press, Cambridge.
- Connolly, R., Jambrina-Enríquez, M., Herrera-Herrera, A., Vidal-Matutano, P., Fagoaga, A., Marquina-Blasco, R., Marin-Monfort, M., Ruíz-Sánchez, F. J., Laplana, C., Bailon, S., Pérez, L., Leierer, L., Hernández, C. M., Galván, B. & Mallol, C. (2019). A multiproxy record of palaeoenvironmental conditions at the Middle Palaeolithic site of Abric del Pastor (Eastern Iberia). *Quaternary Science Reviews*, 225, 106023. <https://doi.org/10.1016/j.quascirev.2019.106023>
- Connolly, R. (2021). *Investigating microscopic and molecular organic matter to explore the role of climate in Neanderthal social and cultural evolution at a regional scale*. PhD Dissertation, Universidad de La Laguna.
- Courbin, P., Brenet, M., Michel, A. & Gravina, B. (2020). Spatial analysis of the late Middle Palaeolithic open-air site of Bout-des-Vergnes (Bergerac, Dordogne) based on lithic technology and refitting. *Journal of Archaeological Science: Reports*, 32, 102373. <https://doi.org/10.1016/j.jasrep.2020.102373>
- Courty, M.A. (2001). Microfacies analysis assisting archaeological stratigraphy. In: P. Goldberg, V.T. Holliday, & C.R. Ferring (eds.), *Earth Sciences and Archaeology*, 205-239. Springer, Boston. https://doi.org/10.1007/978-1-4615-1183-0_8
- Cziesla, E. (1990). On refitting of stone artefacts. In: E. Cziesla, S. Eickhoff, N. Arts & D. Winter (eds.), *The big puzzle: international symposium on refitting stone artefacts*, 9-44. Bonn.

D

- Daffara, S., Berruti, G., Berruto, G., Eftekhari, N., Vaccaro, C. & Arzarello, M. (2019). Raw

- materials procurement strategies at the Ciota Ciara cave: new insight on land mobility in north-western Italy during Middle Palaeolithic, *Journal of Archaeological Science: Reports*, 26, 101882. <https://doi.org/10.1016/j.jasrep.2019.101882>
- Daniel, G. (1943). *The three ages*. Cambridge University Press, Cambridge.
- Daujeurd, C., Fernandes, P., Guadelli, J.L., Moncel, M.H., Santagata, C. & Raynal, J.P. (2012). Neanderthal subsistence strategies in Southeastern France between the plains of the Rhone Valley and the mid-mountains of the Massif Central (MIS 7 to MIS 3). *Quaternary International*, 252. <https://doi.org/10.1016/j.quaint.2011.01.047>
- Davara, J. (2022). *Reconstrucción hidroclimática del yacimiento paleolítico de El Salt (Alcoy, España) durante los MIS 5-3. Análisis molecular, isotópico y elemental de los registros sedimentario y lítico*. Master Dissertation, Universidad de Burgos.
- DeBoer, W.R. (1983). The archaeological record as preserved death assemblage. In: J. Moore & A. Keene (eds.), *Archaeological hammers and theories*, 19-36. Academic Press, New York.
- Delagnes, A. & Rendu, W. (2011). Shifts in Neanderthal mobility, technology and subsistence strategies in western France. *Journal of Archaeological Science*, 38(8), 1771-1783. <https://doi.org/10.1016/j.jas.2011.04.007>
- Delpiano, D. & Peresani, M. (2017). Exploring Neanderthal skills and lithic economy. The implication of a refitted Discoid reduction sequence reconstructed using 3D virtual analysis. *Comptes Rendus Palevol*, 16(8). <https://doi.org/10.1016/j.crpv.2017.06.008>
- Delvigne, V., Fernandes, P., Piboule, M., Bindon, P., Chomette, D., Defive, E., Lafarge, A., Liabeuf, R., Moncel, M.H., Vaissié, E., Wragg-Sykes, R. & Raynal, J.P. (2019). Barremian-Bedoulian flint humanly transported from the west bank of the Rhone to the Massif Central highlands - A diachronic perspective. *Comptes Rendus Palevol*, 18(1). 90-112. <https://doi.org/10.1016/j.crpv.2018.06.005>
- Díaz-Rodríguez, M. & Fábregas-Valcarce, R. (2022). Evaluating the effectiveness of three spatial cluster analysis methods on Palaeolithic site location distributions in Galicia, NW Iberian Peninsula. *Journal of Archaeological Science: Reports* 41, 103323. <https://doi.org/10.1016/j.jasrep.2021.103323>
- Dibble, H. L., Holdaway, S. J., Lin, S. C., Braun, D. R., Douglass, M. J., Iovita, R., McPherron, S., Olszewski, D. & Sandgathe, D. (2017). Major fallacies surrounding stone artifacts and assemblages. *Journal of Archaeological Method and Theory*, 24, 813-851. <https://doi.org/10.1007/s10816-016-9297-8>
- Dinckal, A., Herrejón-Lagunilla, Á., Carrancho, Á., Hernández, C.M. & Mallol, C. (2024). Improving archaeomagnetic interpretations by reusing magnetically oriented samples for micromorphological analysis. *Journal of Archaeological Science*, 171, 106081. <https://doi.org/10.1016/j.jas.2024.106081>
- Dobres, M. A., & Hoffman, C. R. (1994). Social agency and the dynamics of prehistoric technology. *Journal of Archaeological Method and Theory*, 1, 211-258. <https://doi.org/10.1007/BF02231876>
- Dorta, R., Hernández, C. M., Molina, F. J., & Galván, B. (2010). La alteración térmica en los sílex de los valles alcoyanos (Alicante, España). Una aproximación desde la arqueología experimental en contextos del Paleolítico medio: El Salt. *Recerques del*

Museu d'Alcoi, 19, 33–64.

Droop, J.P. (1915-2010). *Archaeological excavation*. Cambridge University Press, Cambridge.

E

Eddington, A.S. (1929). *The nature of physical world*. Cambridge University Press, Cambridge.

Einstein, A. (1952). On the electrodynamics of moving bodies. In: A. Einstein et al. (eds.), *The principle of relativity*, 35-65. Dover Publications, New York.

F

Fagoaga, A., Ruiz, F.J., Laplana, C., Blain, H.A., Marquina, R., Marin, M.D. & Galván, B. (2018). Palaeoecological implications of Neanderthal occupation at unit xb of El Salt (Alcoi, eastern Spain) during MIS 3 using small mammals proxy. *Quaternary International*, 481, 101-112. [10.1016/j.quaint.2017.10.024](https://doi.org/10.1016/j.quaint.2017.10.024)

Fagoaga, A., Blain, H.A., Marquina-Blasco, R., Laplana, C., Sillero, N., Hernández, C.M., Mallol, C., Galván, B. & Ruiz-Sánchez, F.J. (2019). Improving the accuracy of small vertebrate-based palaeoclimatic reconstruction derived from the Mutual Ecogeographic Range. A case study using geographic information systems and UDA-ODA discrimination methodology. *Quaternary Science Reviews*, 223, 105969. <https://doi.org/10.1016/j.quascirev.2019.105969>

Fagoaga, A., Laplana, C., Marquina-Blasco, R., Machado, J., Marín-Monfort, M.D., Crespo, V., Hernández, C.M., Mallol, C., Galván, B. & Ruiz-Sánchez, F.J. (2021). Palaeoecological context for the extinction of the Neanderthals: a small mammal

study of Stratigraphic Unit V of the El Salt site, Alcoi, eastern Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 569, 110222. <https://doi.org/10.1016/j.palaeo.2021.110222>

Féblot-Augustins, J. (1993). Mobility strategies in the Late Middle Palaeolithic of Central Europe and Western Europe: elements of stability and variability. *Journal of Anthropological Archaeology*, 12(3). <https://doi.org/10.1006/jaar.1993.1007>

Féblot-Augustins, J. (1999). La mobilité des groupes paléolithiques. *Bulletins et Mémoires de la Société d'anthropologie de Paris*, 11(3), 219-260.

Fernandes, P. & Raynal, J.P. (2006). Pétroarchéologie du silex: un retour aux sources. *Comptes Rendus Palevol*, 5(6). <https://doi.org/10.1016/j.crpv.2006.04.002>

Fernandes, P., Raynal, J.P. & Moncel, M.H. (2008). Middle Palaeolithic raw material gathering territories and human mobility in the southern Massif Central, France: first results from a petro-archaeological study on flint. *Journal of Archaeological Science*, 35(8). <https://doi.org/10.1016/j.jas.2008.02.012>

Fernandes, P. (2012). *Itinéraires et transformations du silex: une pétroarchéologie refondée, application au Paléolithique moyen*. PhD Dissertation, Université de Bordeaux.

Fernández-Eraso, J. & Polo-Díaz, A. (2008). Establos en abrigos bajo roca en la Prehistoria reciente: su formación, caracterización y procesos de estudio. Los casos de Los Husos y de San Cristóbal. *Krei*, 10, 39-51.

Fletcher, R. (2006). Materiality, space, time, and outcome. In: J. Bintliff (ed.), *A companion to Archaeology*, 110-140.

Blackwell, Oxford.

Fumanal, M.P. (1994). El yacimiento musteriense de El Salt (Alcoi, País Valenciano): rasgos geomorfológicos y climatoestratigrafía de sus registros. *Saguntum*, 27, 39-56.

G

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

Gabucio, M.J., Bargalló, A., Saladié, P., Romagnoli, F., Chacón, M.G., Vallverdú, J. & Vaquero, M. (2023). Using GIS and geostatistical techniques to identify Neanderthal campsites at archaeolevel Ob at Abric Romaní. *Archaeological and Anthropological Sciences*, 15(3), 24. <https://doi.org/10.1007/s12520-023-01715-6>

Galanidou, N. (2000). Patterns in caves: foragers, horticulturists, and the use of space. *Journal of Anthropological Archaeology*, 19(3). <https://doi.org/10.1006/jaar.1999.0362>

Galván, B. (1992). El Salt (Alcoi, Alicante): estado actual de las investigaciones. *Recerques del Museu d'Alcoi*, 1, 73-80.

Galván, B., Hernández-Gómez, C.M., Alberto, V., Barro, A., Francisco-Ortega, I. & Rodríguez, A. (2001). Las sociedades cazadoras-recolectoras neandertalianas en los valles de Alcoi (Alicante, España). El Salt como un centro de intervención referencial. *Tabona*, 10, 7-33.

Galván, B., Hernández, C. M., Francisco-Ortega, M. I., Molina, J. & Tarrío, A. (2009). La producción lítica del Abric del Pastor (Alcoi, Alicante). Un ejemplo de variabilidad

musteriense. *Tabona*, 17, 11-61.

Galván, B., Hernández, C.M., Mallol, C., Mercier, N., Sistiaga, A. & Soler, V. (2014a). New evidence of early Neanderthal disappearance in the Iberian peninsula. *Journal of Human Evolution*, 75, 16-27. [10.1016/j.jhevol.2014.06.002](https://doi.org/10.1016/j.jhevol.2014.06.002)

Galván, B., Hernández, C.M., Mallol, C., Machado, J., Sistiaga, A., Molina, F.J., Pérez, L., Afonso, R., Garralda, M.D., Mercier, N., Morales, J.V., Sanchis, A., Tarrío, A., Gómez, J.A., Rodríguez-Cintas, Á., Abreu, I. & Vidal-Matutano, P. (2014b). El Salt, últimos neandertales de la montaña alicantina (Alcoi, España). In: Robert, S. (ed.), *Los cazadores recolectores del Pleistoceno y del Holoceno en Iberia y el Estrecho de Gibraltar: estado actual del conocimiento del registro arqueológico*, 380-388. Fundación Atapuerca, Universidad de Burgos.

Garay, P. (1995). El marco geográfico reciente. In: Vicenç, R. (ed.), *El Cuaternario del País Valenciano*, 31-73. Universitat de València, Valencia.

Garralda, M.D., Galván, B., Hernández, C.M., Mallol, C., Gómez, J. & Maureille, B. (2014). Neanderthals from El Salt (Alcoi, Spain) in the context of the latest Middle Palaeolithic populations from the southeast of the Iberian Peninsula. *Journal of Human Evolution*, 75, 1-15. <https://doi.org/10.1016/j.jhevol.2014.02.019>

Garvey, R. (2015). A model of lithic raw material procurement. In N. Goodale & Andrefsky, W. (eds.), *Lithic technological systems and Evolutionary Theory*, 156-171. Cambridge University Press, New York.

Gasche, H., & Tunca, Ö. (1983). Guide to archaeostratigraphic classification and terminology: definitions and principles. *Journal of Field*

- Archaeology*, 10(3), 325-335. <https://doi.org/10.1179/009346983791504318>
- Geneste, J.M. (1991). L'approvisionnement en matieres premieres dans les systemes de production litique: la dimension spatiale de la technologie. *Treballs d'Arqueologia*, 1, 1-36.
- Getis, A. (1964). Temporal land-use pattern analysis with the use of Nearest Neighbor and Quadrat methods. *Annals of the Association of American Geographers*, 54(3). <https://doi.org/10.1111/j.1467-8306.1964.tb00497.x>
- Gifford-González, D., Damrosch, D., Damrosch, D., Pryor, J. & Thunen, R. (1985). The third dimension in site structure: an experiment in trampling and vertical dispersal. *American Antiquity*, 50(4). <https://doi.org/10.2307/280169>
- Gillings, M., Hacigüzeller, P. & Lock, G. (2020). *Archaeological spatial analysis: a methodological guide*. Routledge, London.
- Goldberg, P. & Macphail, R.I. (2005). Caves and rockshelters. In P. Goldberg & R.I. Macphail (eds.), *Practical and Theoretical Geoarchaeology* (pp. 169-187). Blackwell.
- Gómez de Soler, B., Soto, M., Vallverdú, J., Vaquero, M., Bargalló, A., Chacón, G., Romagnoli, F. & Carbonell, E. (2020). Neanderthal lithic procurement and mobility patterns through a multi-level study in the Abric Romaní site (Capellades, Spain). *Quaternary Science Reviews*, 237. <https://doi.org/10.1016/j.quascirev.2020.106315>
- Gong, J., Zeng, Z., Wan, B., Li, S. (2023). Spatiotemporal Kernel Density Estimation. In: J. Lee. (ed.), *Spatiotemporal Analytics*, 127-144. CRC Press, New York.
- Gould, R.A., Koster, D. & Sontz, A. (1971). The lithic assemblage of the Western Desert Aborigines of Australia. *American Antiquity*, 36(2). <https://doi.org/10.2307/278668>
- Gramley, R.M. (1980). Raw materials source areas and "curated" tool assemblages. *American Antiquity*, 45(4). <https://doi.org/10.2307/280152>
- Grove, M. (2009). Hunter-gatherer movement patterns: causes and constraints. *Journal of Anthropological Archaeology*, 28(2). <https://doi.org/10.1016/j.jaa.2009.01.003>
- Guérin, G., Frouin, M., Tuquoi, J., Thomsen, K.J., Goldberg, P., Aldeias, V., Lahaye, C., Mercier, N., Guibert, P., Jain, M., Sandgathe, D., McPherron, S., Turq, A. & Dibble, H. L. (2017). The complementarity of luminescence dating methods illustrated on the Mousterian sequence of the Roc de Marsal: A series of reindeer-dominated, Quina Mousterian layers dated to MIS 3. *Quaternary International*, 433, 102-115. <https://doi.org/10.1016/j.quaint.2016.02.063>

H

- Hageman, J. & Bennett, D. (1999). Construction of digital elevation models for archaeological applications. In: K. Wescott & J. Brandon (eds.), *Practical applications of GIS for archaeologists*, 121-136. CRC Press, London.
- Harding, J. (2005). Rethinking the great divide: long-term structural history and the temporality of event. *Norwegian Archaeological Review*, 38, 88-101. <https://doi.org/10.1080/00293650510032707>
- Harris, E. (1991). *Principios de estratigrafía arqueológica*. Crítica, Barcelona.
- Harris, O.J. (2017). Assemblages and scale in archaeology. *Cambridge Archaeological Journal*, 27(1), 127-139. <https://doi.org/10.1017/S0959774316000597>

- Henry, D., Hietala, H., Rosen, A., Demidenko, Y., Usik, V. & Armagan, T. (2004). Human behavioral organization in the Middle Paleolithic: were Neanderthals different? *American Anthropologist*, 106(1). <https://doi.org/10.1525/aa.2004.106.1.17>
- Henry, D. (2012). The palimpsest problem, hearth pattern analysis, and Middle Paleolithic site structure. *Quaternary International*, 247, 246-266. <https://doi.org/10.1016/j.quaint.2010.10.013>
- Herrejón-Lagunilla, Á., Carrancho, Á., Villalaín, J.J., Mallol, C. & Hernández, C.M. (2019). An experimental approach to the preservation potential of magnetic signatures in anthropogenic fires. *PloS ONE*, 14(8). <https://doi.org/10.1371/journal.pone.0221592>
- Herrejón-Lagunilla, Á., Villalaín, J.J., Pavón-Carrasco, F.J., Sánchez-Bravo, M.S., Sossa-Ríos, S., Mayor, A., Galván, B., Hernández, C.M., Mallol, C. & Carrancho, Á. (2024). The time between Palaeolithic hearths. *Nature*, 630. <https://doi.org/10.1038/s41586-024-07467-0>
- Hodder, I. (1987). The contribution of the long-term. In: I. Hodder (ed.), *Archaeology as a long-term history*, 1-8. Cambridge University Press, Cambridge.
- Hofman, J. (1986). Vertical movement of artifacts in alluvial and stratified deposits. *Current Anthropology*, 27(2). <https://doi.org/10.1086/203414>
- Holdaway, S. & Wandsnider L. (2008). *Time in archaeology: Time perspectivism revisited*. University of Utah Press, Utah.
- Holdaway, S. & Douglass, M. (2012). A twenty-first century archaeology of stone artifacts. *Journal of Archaeological Method and Theory*, 19, 101-131. <https://doi.org/10.1007/s10816-011-9103-6>
- J**
- Jambrina, M., Herrera-Herrera, A., Rodríguez de Vera, C., Leierer, L., Connolly, R. & Mallol, C. (2019). n-Alkyl nitriles and compound specific carbon isotope analysis of lipid combustion residues from Neanderthal and experimental hearths: identifying sources of organic compounds and combustion temperatures. *Quaternary Science Reviews*, 222, 105899. <https://doi.org/10.1016/j.quascirev.2019.105899>
- Jenks, G.F. (1967). The data model concept in statistical mapping. In: K. Frenzel (ed.), *International yearbook of cartography VII*, 186-190. Liverpool.
- K**
- Karkanas, P. & Goldberg, P. (2019). *Reconstructing archaeological sites: Understanding the geoarchaeological matrix*. John Wiley & Sons, Oxford.
- Karkanas, P. & Kyparissi-Apostolika, N. (2024). Revisiting palaeolithic combustion features of Theopetra Cave: a diachronic use of dung and peat as fuel. *Journal of Archaeological Science*, 165, 105958. <https://doi.org/10.1016/j.jas.2024.105958>
- Karlin, C. (1991a). Connaissances et savoir-faire: comment analyser un processus technique en préhistoire introduction. *Treballs d'Arqueologia*, I, 99-123.
- Karlin, C. (1991b). Analyse d'un processus technique: le débitage laminaire des magdaleniens de Pincevent. *Treballs d'Arqueologia*, I, 125-162
- Kedar, Y., Kedar, G., Kadowaki, S. & Barkai, R. (2024). Hearth management at a Middle Palaeolithic rockshelter site: smoke density analysis at Tor Faraj, Jordan. *Journal of Archaeological Science*, 172. <https://doi.org/10.1016/j.jas.2024.105958>

[org/10.1016/j.jas.2024.106107](https://doi.org/10.1016/j.jas.2024.106107)

- Kelly, R. (1983). Hunter-gatherer mobility strategies. *Journal of Anthropological Research*, 39(3), 277-306.
- Kelly, R. (2003). Colonization of new land by hunter-gatherers. Expectations and implications based on ethnographic data. In M. Rockman & J. Steele (eds.), *Colonization of unfamiliar landscapes: the archaeology of adaptation*, 44-58. Routledge, London.
- Kent, S. (1991). The relationship between mobility strategies and site structure. In: E. Kroll & D. Price (eds.), *The interpretation of archaeological spatial patterning*, 33-57. Springer, New York.
- Knapp, A.B. (1992). Archaeology and Annales: time, space and change. In: A.B. Knapp (ed.), *Archaeology, Annales, and Ethnohistory*, 1-22. Cambridge University Press, Cambridge.
- Kuhn, S.L. (1991). "Unpacking" reduction: lithic raw material economy in the Mousterian of west-central Italy. *Journal of Anthropological Archaeology*, 10(1), 76-106. [https://doi.org/10.1016/0278-4165\(91\)90022-P](https://doi.org/10.1016/0278-4165(91)90022-P)
- Kuhn, S.L. (1992). On planning and curated technologies in the Middle Paleolithic. *Journal of Anthropological Research*, 48(3), 185-214.
- Kuhn, S.L. (1994). A formal approach to the design and assembly of mobile toolkits. *American Antiquity*, 59(3), 426-442. <https://doi.org/10.2307/282456>
- Kuhn, S.L., & Clark, A.E. (2015). Artifact densities and assemblage formation: Evidence from Tabun Cave. *Journal of Anthropological Archaeology*, 38, 8-16. <https://doi.org/10.1016/j.jaa.2014.09.002>
- Lalueza-Fox, C., Rosas, A., Estalrich, A., Gigli, E., Campos, P., García-Taberner, A., García-Vargas, S., Sánchez-Quinto, F., Ramírez, O., Civit, S., Bastir, M., Hugué, R., Santamaría, D., Gilbert, T., Willerslev, E. & de la Rasilla, M. (2010). Genetic evidence of patrilocal mating behavior among Neanderthal groups, *Proceedings of the National Academy of Sciences*, 108(1), 250-253. <https://doi.org/10.1073/pnas.1011553108>
- Laplace, G. (1972). La typologie analytique et structurale. Base rationnelle d'étude des Industries lithiques et osseuses. *Colloques nationaux*, 932, 91-143.
- Lee, J. & Wong, D. (2001). *Statistical analysis with ArcView GIS*. John Wiley & Sons, New York.
- Lee, J. (2023). Spatiotemporal Ripley's *K* and *L* functions. In J. Lee (ed.), *Spatiotemporal Analytics*, 77-90. CRC Press, London.
- Lee, R.B. (1979). *The !Kung San: Men, women and work in a foraging society*. Cambridge University Press, Cambridge.
- Leierer, L., Jambriña-Enríquez, M., Herrera-Herrera, A., Connolly, R., Hernández, C.M., Galván, B. & Mallol, C. (2019). Insights into the timing, intensity and natural setting of Neanderthal occupation from the geoarchaeological study of combustion structures: a micromorphological and biomarker investigation of El Salt, unit xb, Alcoy, Spain. *PLoS ONE*, 14(4). [10.1371/journal.pone.0214955](https://doi.org/10.1371/journal.pone.0214955)
- Leierer, L. (2021). *Approaching Neanderthal behavior through the geoarchaeological study of combustion structures: investigations in soil micromorphology and lipid biomarkers*. PhD Dissertation, Universidad de La Laguna.
- Lemonnier, P. (1992). *Elements for an Anthropology of Technology*. University of

L

Michigan Press, Michigan.

Leroi-Gourhan, A. & Brézillon, M. (1966). L'habitation magdalénienne n° 1 de Pincevent près Montereau (Seine-et-Marne). *Gallia préhistoire*, 9(2), 263-385.

Leroi-Gourhan, A. & Brézillon, M. (1972). *Fouilles de Pincevent. Essai d'analyse ethnographique d'un habitat magdalénien (la section 36)*, 7-327. Éditions CNRS, Paris.

López-Ortega, E., Rodríguez, X.P., Ollé, A. & Lozano, S. (2019). Lithic refits as a tool to reinforce postdepositional analysis. *Archaeological and Anthropological Sciences*, 11, 4555-4568. <https://doi.org/10.1007/s12520-019-00808-5>

Lucas, G. (2004). *The Archaeology of Time*. Routledge, London.

Lucas, G. (2008). Time and archaeological event. *Cambridge Archaeological Journal*, 18(1), 59-65. <https://doi.org/10.1017/S095977430800005X>

Lucas, G. (2012). *Understanding the archaeological record*. Cambridge University Press, Cambridge.

Lucas, G. (2014). Evidence of what? On the possibilities of archaeological interpretation. In: R. Chapman & A. Wylie (eds.), *Material evidence. Learning from archaeological practice*, 311-323. Routledge, London.

Lucas, G. (2021). *Making time. The archaeology of time revisited*. Routledge, London.

M

MacDonald, D.H. & Hewlett, B.S. (1999). Reproductive interests and forager mobility. *Current Anthropology*, 40(4), 501-524.

Machado, J., Hernández, C.M., Mallol, C. & Galván, B. (2013). Lithic production,

site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor stratigraphic unit IV (Alicante, Spain). *Journal of Archaeological Science*, 40(5), 2254-2273. <https://doi.org/10.1016/j.jas.2013.01.002>

Machado, J. (2016). *Palimpsestos, dinámicas de asentamiento y gestión de los recursos líticos durante el Paleolítico medio en la montaña alicantina (España)*. PhD Dissertation, Universidad de La Laguna.

Machado, J. & Pérez, L. (2016). Temporal frameworks to approach human behavior concealed in Middle Palaeolithic palimpsests: a high-resolution example from El Salt stratigraphic unit X (Alicante, Spain). *Quaternary International*, 417, 66-81. [10.1016/j.quaint.2015.11.050](https://doi.org/10.1016/j.quaint.2015.11.050)

Machado, J., Molina, F.J., Hernández, C.M., Tarriño, A. & Galván, B. (2017). Using lithic assemblage formation to approach Middle Palaeolithic settlement dynamics: El Salt stratigraphic unit X (Alicante, Spain). *Archaeological and Anthropological Sciences*, 9, 1715-1743. <https://doi.org/10.1007/s12520-016-0318-z>

Machado, J., Mayor, A., Hernández, C.M. & Galván, B. (2019). Lithic refitting and the analysis of Middle Palaeolithic settlement dynamics: a high-temporal resolution example from El Pastor rock shelter (eastern Iberia). *Archaeological and Anthropological Sciences* 11, 4539-4554. <https://doi.org/10.1007/s12520-019-00859-8>

Macklin, M.G., Benito, G., Gregory, K., Johnstone, E., Lewin, J., Michczynska, D., Soja, R., Starkel, L. & Thorndycraft, V. (2006). Past hydrological events reflected in the Holocene fluvial record of Europe. *CATENA*, 66(1), 145-154. <https://doi.org/10.1016/j.catena.2005.07.015>

- Mallol, C., Hernández, C.M. & Machado, J. (2012). The significance of stratigraphic discontinuities in Iberian Middle-to-Upper Palaeolithic transitional sites. *Quaternary International*, 275, 4-13. <https://doi.org/10.1016/j.quaint.2011.07.026>
- Mallol, C., Hernández, C.M., Cabanes, D., Sistiaga, A., Machado, J., Rodríguez, Á., Pérez, L. & Galván, B. (2013). The black layer of Middle Palaeolithic combustion structures. Interpretation and archaeostratigraphic implications. *Journal of Archaeological Science*, 40, 2515–2537. <https://doi.org/10.1016/j.jas.2012.09.017>
- Mallol, C., Hernández, C., Mercier, N., Falguères, C., Carrancho, A., Cabanes, D., Vidal-Matutano, P., Connolly, R., Pérez, L., Mayor, A., Ben-Arous, E. & Galván, B. (2019). Fire and brief human occupations in Iberia during the MIS 4: Evidence from the Abric del Pastor (Alcoi, Spain). *Scientific Reports*, 18281. <https://doi.org/10.1038/s41598-019-54305-9>
- Marciani, G., Spagnolo, V., Aureli, D., Ranaldo, F., Boscato, P. & Ronchitelli, A. (2016). Middle Palaeolithic technical behaviour: material import-export and Levallois production at the SU 13 of Oscuruscituo rock shelter, Southern Italy. *Journal of Lithic Studies*, 3(2). <https://doi.org/10.2218/jls.v3i2.1414>
- Marín, J., Rodríguez-Hidalgo, A., Vallverdú, J., Gómez de Soler, B., Rivals, F., Rabuñal, J.R., Pineda, A., Chacón, M.G., Carbonell, E. & Saladié, P. (2019). Neanderthal logistic mobility during MIS 3: zooarchaeological perspective of Abric Romaní level P (Spain). *Quaternary Science Reviews*, 225(1). <https://doi.org/10.1016/j.quascirev.2019.106033>
- Marín-Monfort, M.D., Fagoaga, A., García-Morato, S., Ruiz, F.J., Mallol, C., Hernández, C.M., Galván, B. & Fernández-Jalvo, Y. (2021). Contribution of small mammal taphonomy to the last Neanderthal occupations at the El Salt site (Alcoi, southeastern Iberia). *Quaternary Research*, 103. <https://doi.org/10.1017/qua.2021.4>
- Marquina, R., Fagoaga, A., Crespo, V.D., Ruiz, F.J., Bailon, S., Hernández, C.M. & Galván, B. (2017). Amphibians and squamate reptiles from the stratigraphic unit xb of El Salt (Middle Palaeolithic; Alcoi, Spain): palaeoenvironmental and palaeoclimatic implications. *Spanish Journal of Palaeontology*, 32(2), 291-312. [10.7203/sjp.32.2.17045](https://doi.org/10.7203/sjp.32.2.17045)
- Marquina-Blasco, R., Fagoaga, A., Crespo, V., Bailon, S., Mallol, C., Hernández, C.M., Galván, B. & Ruiz-Sánchez, F.J. (2021). Amphibians and reptiles as palaeoenvironmental proxies during the Late Pleistocene (MIS3): the case of Stratigraphic Unit V of El Salt, Alcoi, Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 571, 110372. <https://doi.org/10.1016/j.palaeo.2021.110372>
- Martín-Viveros, J. I., Ollé, A., Chacón, M. G., Romagnoli, F., Gómez de Soler, B., Vaquero, M., Saladié, P., Vallverdú, J. & Carbonell, E. (2020). Use-wear analysis of a specific mobile toolkit from the Middle Paleolithic site of Abric Romaní (Barcelona, Spain): a case study from level M. *Archaeological and Anthropological Sciences*, 12, 1-25. <https://doi.org/10.1007/s12520-019-00951-z>
- Martínez-Moreno, J., Mora, R. & de la Torre, I. (2004). Methodological approach for understanding Middle Palaeolithic settlement dynamics at La Roca dels Bous (Noguera, Catalunya, Northeast Spain). In N. Conard (ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age II*, 393-414. Kerns Verlag.
- Martínez-Moreno, J., Mora, R., Roy-Sunyer, M. & Benito-Calvo, A. (2016). From site

- formation processes to human behaviour: Towards a constructive approach to depict palimpsests in Roca dels Bous. *Quaternary International*, 417, 82–93. [10.1016/j.quaint.2015.09.038](https://doi.org/10.1016/j.quaint.2015.09.038)
- Martínez-Moreno, J., Mora, R., Benito-Calvo, A., Roy-Sunyer, M. & Sánchez-Martínez, J. (2019). A bunch of refits: 497D blade knapping assemblage of the Early Upper Paleolithic in Cova Gran (Northeast Iberia). *Archaeological and Anthropological Sciences*, 11, 4585–4600. <https://doi.org/10.1007/s12520-018-0726-3>
- Mayor, A., Hernández, C.M., Machado, J. & Mallol, C. (2020). On identifying Palaeolithic single occupation episodes: archaeostratigraphic and technological approaches to the Neanderthal lithic record of stratigraphic unit xa of El Salt (Alcoi, eastern Iberia). *Archaeological and Anthropological Sciences*, 12, 84. <https://doi.org/10.1007/s12520-020-01022-4>
- Mayor, A., Sossa-Ríos, S., Molina, F.J., Pérez, L.J., Galván, B., Mallol, C. & Hernández, C.M. (2022). An instance of Neanderthal mobility dynamics: a lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt rockshelter (Alcoi, eastern Iberia). *Journal of Archaeological Science: Reports* 44, 103544. <https://doi.org/10.1016/j.jasrep.2022.103544>
- Mayor, A. (2023). *Las pistas que nos dejaron: gestión del sílex y movilidad neandertal en la unidad estratigráfica VIII del abrigo de El Salt (Alcoi, Alacant)*. PhD Dissertation, Universitat d'Alacant.
- Mayor, A., Sossa-Ríos, S., Vaquero, M. & Hernández, C.M. (2024). Recycling and implications for Neanderthal productive strategies in the Stratigraphic Unit VIII of the El Salt rockshelter (Alcoi, Eastern Iberia). *Lithic Technology*, 1-18. <https://doi.org/10.1080/01977261.2024.2356952>
- McBrearty, S., Bishop, L., Plummer, T., Dewar, R. & Conard, N. (1998). Tools underfoot: human trampling as an agent of lithic artifact edge modification. *American Antiquity*, 63(1). <https://doi.org/10.2307/2694779>
- McCall, G. (2012). Ethnoarchaeology and the organization of lithic technology. *Journal of Archaeological Research*, 20, 157-203. <https://doi.org/10.1007/s10814-011-9056-z>
- McKellar, J.A. (1973-1983). Correlations and the Explanation of Distributions. *Arizona Anthropologist*, 4, 2-5.
- McPherron, S., Braun, D., Dogandzic, T., Archer, W., Desta, D. & Lin, S. (2014). An experimental assessment of the influences on edge damage to lithic artifacts: a consideration of edge angle, substrate grain size, raw material properties, and exposed face. *Journal of Archaeological Science*, 49. <https://doi.org/10.1016/j.jas.2014.04.003>
- McTaggart, J. E. (1908). The unreality of time. *Mind*, 17(68), 457-474.
- Mears, P., Wilson, L., & Browne, C.L. (2022). Number or weight? The effects and implications of quantifying lithic raw material use in two different ways. *Journal of Archaeological Science: Reports*, 43, 103431. <https://doi.org/10.1016/j.jasrep.2022.103431>
- Meignen, L., Delagnes, A. & Bourguignon, L. (2009). Patterns of lithic material procurement and transformation during the Middle Paleolithic in Western Europe. In: B. Adams & B.S. Blades (eds.), *Materials and Paleolithic societies*, 15-24. Blackwell, Chichester.
- Menéndez-Marsh, F., Al-Rawi, M., Fonte, J., Dias, R., Gonçalves, L.J., Seco, L.G., Hipólito, J., Machado, J.P., Medina, J., Moreira, J., Pereiro, T., Vázquez, M. & Neves, A.

- (2023). Geographic information systems in archaeology: A systematic review. *Journal of Computer Applications in Archaeology*, 6(1). <https://doi.org/10.5334/jcaa.104>
- Mentzer, S.M. (2017). Rockshelter settings. In A.S. Gilbert (ed.), *Encyclopedia of geoarchaeology*, 725-743. Springer, New York.
- Mielgo, C., Huguet, R., Laplana, C., Martín-Perea, D.M., Moclán, A., Márquez, B., Arsuaga, J.L., Pérez-González, A. & Baquedano, E. (2024). Intra-site spatial approaches based on taphonomic analyses to characterize assemblage formation at Pleistocene sites: a case study from Buena Pinta Cave (Pinilla del Valle, Madrid, Spain). *Archaeological and Anthropological Sciences*, 16, 5. <https://doi.org/10.1007/s12520-023-01913-2>
- Mikhailova, N., Mikhailova, E., & Grafeeva, N. (2019). The application of clustering techniques to group archaeological artifacts. In: A. Rocha, H. Adeli, L. Reis & S. Costanzo (eds.), *New Knowledge in Information Systems and Technologies*, 50-57. Springer, Cham. https://doi.org/10.1007/978-3-030-16181-1_5
- Mir-Lápido, J. (2024). *Arqueoestratigrafía y análisis espacial en los conjuntos de leporidos del yacimiento Neandertal de El Salt (Alcoi, Alicante)*. Undergraduate Dissertation, Universidad de La Laguna.
- Moclán, A., Cobo-Sánchez, L., Domínguez-Rodrigo, M., Méndez-Quintas, E., Rubio-Jara, S., Panera, J., Pérez-González, A. & Santonja, M. (2023). Spatial analysis of an Early Middle Palaeolithic kill/butchering site: the case of the Cuesta de la Bajada (Teruel, Spain). *Archaeological and Anthropological Sciences*, 15(91). <https://doi.org/10.1007/s12520-023-01792-7>
- Molina, F.J., Tarriño, A., Galván, B. & Hernández, C.M. (2010). Áreas de aprovisionamiento de sílex en el Paleolítico medio en torno al Abric del Pastor (Alcoi, Alicante): estudio macroscópico de la producción lítica de la colección Brotons. *Recerques del Museu d'Alcoi* 19, 65-80.
- Molina, F.J. (2015). *El sílex del Prebético y cuencas neógenas en Alicante y sur de Valencia: su caracterización y estudio aplicado al Paleolítico medio*. PhD Dissertation, Universitat d'Alacant.
- Molina, F.J., Tarriño, A., Galván, B. & Hernández, C.M. (2016). El sílex del Prebético de Alicante: tipos, variabilidad y áreas de captación y talla del Pleistoceno. *Cuadernos de Prehistoria y Arqueología de la Universidad de Granada* 26, 283-311. <https://doi.org/10.30827/cpag.v26i0.7403>
- Molina, F.J., Belmonte, D., Satorre, A., Hortelano, L. & Fernández-Peris, J. (2019). El Paleolítico medio en el litoral de la sierra de Santa Pola (El Baix Vinalopó, Alicante). *Recerques del Museu d'Alcoi*, 28, 27-48.
- Moncel, M.H., Chacón, M.G., La Porta, A., Fernandes, P., Hardy, B. & Gallotti, R. (2014). Fragmented reduction processes: Middle Palaeolithic technical behaviour in the Abri du Maras rockshelter, southeastern France. *Quaternary International*, 350(6). <https://doi.org/10.1016/j.quaint.2014.05.013>
- Moncel, M.H., Fernandes, P., Willmes, M., James, H. & Grün, R. (2019). Rocks, teeth, and tools: new insights into early Neanderthal mobility strategies in South-Eastern France from lithic reconstructions and strontium isotope analysis. *PLoS ONE*, 14(4). <https://doi.org/10.1371/journal.pone.0214925>
- Moncel, M.H., Guillemot, P., Chacón, M., Abrunhosa, A., Richard, M., Fernandes, P., Hardy, B., Allué, E. & Pois, V. (2024). Site

Settlement Patterns During MIS 3 in the Southeast of France: the Lithic Assemblages of Two Phases of Occupation (Levels 4.1 and 4.2) at the Abri du Maras. *Journal of Paleolithic Archaeology*, 7(23). <https://doi.org/10.1007/s41982-024-00190-2>

Mora, R., Martínez-Moreno, J., Roy-Sunyer, M., Benito-Calvo, A., Polo-Díaz, A. & Samper-Carro, S. (2018). Contextual, technological and chronometric data from Cova Gran: their contribution to discussion of the Middle-to-Upper Paleolithic transition in northeastern Iberia. *Quaternary International*, 474(25). <https://doi.org/10.1016/j.quaint.2016.05.017>

Morrow, T.A. (1996a). Bigger is better: comments on Kuhn's formal approach to mobile tool kits. *American Antiquity*, 61(3), 581-590. [10.2307/281842](https://doi.org/10.2307/281842)

Morrow, T.A. (1996b). Lithic refitting and archaeological site formation processes: a case study from the Twin Ditch site, Greene County, Illinois. In G.H. Odell (ed.), *Stone tools: theoretical insights into human prehistory*, 345-373. Springer, New York.

Munn, N.D. (1992). The cultural anthropology of time: A critical essay. *Annual Review of Anthropology*, 21, 93-123.

Murray, T. (1999). A return to the "Pompeii premise". In: T. Murray (ed.), *Time and Archaeology*, 8-27. Routledge, London.

Murray, T. (2008). Paradigms and metaphysics, or "Is this the end of Archaeology as we know it?" In: S. Holdaway & L. Wandsnider (eds.), *Time in archaeology: Time perspectivism revisited*, 170-180. University of Utah Press, Utah.

Murugesan, N., Cho, I. & Tortora, C. (2021). Benchmarking in cluster analysis: a study on spectral clustering, DBSCAN, and K-means. In: T. Chadjipadelis, B. Lausen, A. Markos,

T.R. Lee, A. Montanari & R. Nugent (eds.), *Data analysis and rationality in a complex world*, 175-185. Springer, Cham. https://doi.org/10.1007/978-3-030-60104-1_20

N

Navazo, M., Santamaría, C. & Santamaría, M. (2023). Using cores as tools: Use-wear analysis of Neanderthal recycling processes in level 4 at Prado Vargas (Cornejo, Merindad de Sotocueva, Burgos, Spain). *Lithic Technology*, 48(2), 149-167. <https://doi.org/10.1080/01977261.2022.2108276>

Nelson, M.C. (1991). The study of technological organization. *Archaeological Method and Theory*, 3, 57-100.

Neruda, P. (2017). GIS analysis of the spatial distribution of Middle Palaeolithic artefacts in Kůlna Cave (Czech Republic). *Quaternary International*, 435, 58-76. <https://doi.org/10.1016/j.quaint.2015.10.028>

Newcomer, M. & Sieveking, G. (1980). Experimental flake scatter-patterns: a new interpretative technique. *Journal of Field Archaeology*, 7(3). <https://doi.org/10.1179/009346980791505392>

Nicosia, C. & Stoops, G. (2017). *Archaeological soil and sediment micromorphology*. John Wiley & Sons, Oxford.

Nieto-Márquez, I. & Baena, J. (2017). Did stones speak about people? Flint catchment and Neanderthal behaviour from Area 3 (Cañaverál, Madrid-Spain). *Quaternary International*, 435(12). <https://doi.org/10.1016/j.quaint.2016.01.019>

O

Oliver, M. & Webster, R. (1990). Kriging: a method of interpolation for geographical information systems. *International Journal of Geographical*

Information Systems, 4(3). <https://doi.org/10.1080/02693799008941549>

Ordóñez, S., Cuevas, J., Benavente, D. & García-del-Cura, M.Á. (2016). Architecture of Pleistocene fluvial tufa systems associated with waterfalls: El Salt (Alcoy, Spain). *GEOGACETA*, 59, 7-10.

O'Connell, J. (1987). Alyawara site structure and its archaeological implications. *American Antiquity*, 52(1). <https://doi.org/10.2307/281061>

O'Connell, J., Hawkes, K. & Blurton, N. (1991). Distribution of refuse-producing activities at Hadza residential base camps: implications for analyses of archaeological site structure. In: E. Kroll & D. Price (eds.), *The interpretation of archaeological spatial patterning*, 61-76. Springer, New York.

Olive, M. (1988). *Une habitation magdalénienne d'Étiolles. L'unité P15*. Société Préhistorique Française (Mémoire 20), Paris.

O'Sullivan, D. & Unwin, D. (2010). *Geographic Information Analysis*. Wiley & Sons, New Jersey.

P

Peresani, M. (2009). The range of caching behavior among the past hunter-gatherers of Europe. In: S. Bonnardin, C. Hamon, M. Lauwers & B. Quilliec (eds.), *Du matériel au spirituel. Réalités archéologiques et historiques des «dépôts» de la Préhistoire à nos jours. XXIXe rencontres internationales d'archéologie et d'histoire d'Antibes*, 87-95. APDCA, Antibes.

Pérez, L., Sanchis, A., Hernández, C. M. & Galván, B. (2017). Paleoecología de micromamíferos aplicada a los conjuntos zooarqueológicos de El Salt y el Abric del Pastor (Alcoy, Alicante). *Preses petites i*

grups humans en el passat. III Jornades d'arqueozoologia, 327-353.

Pérez, L. (2019). *Estrategias de subsistencia y dinámicas de asentamiento en los valles de Alcoy durante el Paleolítico medio. Análisis zooarqueológico, tafonómico y paleoecológico de la secuencia arqueológica de El Salt (Alcoy, Alicante)*. PhD Dissertation, Universitat Rovira i Virgili.

Pérez, L., Hernández, C.M. & Galván, B. (2019). Bone retouchers from the Middle Palaeolithic site of El Salt, stratigraphic unit xa (Alicante, Spain): first data and comparison with the Middle to Upper Pleistocene European record. *International Journal of Osteoarchaeology*, 29(2), 238-252. [10.1002/oa.2732](https://doi.org/10.1002/oa.2732)

Pérez, L., Machado, J., Sanchis, A., Hernández, C.M., Mallol, C. & Galván, B. (2020). A high temporal resolution zooarchaeological approach to Neanderthal subsistence strategies on the southeastern Iberian Peninsula: El Salt Stratigraphic Unit Xa (Alicante, Spain). In J. Cascalheira & A. Picin (eds.), *Short-term occupations in Paleolithic archaeology*, 237-289. Springer, Dordrecht. [10.1007/978-3-030-27403-0_3](https://doi.org/10.1007/978-3-030-27403-0_3)

Pérez, L. & Sanchis, A. (2021). Taxonomía, biometría e incidencia tafonómica de carnívoros - cánidos, félidos y úrsidos - en la secuencia arqueológica de El Salt (Alcoy, Alicante). *Recull d'estudis de fauna de jaciments valencians. V Jornades d'arqueozoologia*, 87-126.

Picin, A., Chacón, M.G., Gómez de Soler, B., Blasco, R., Rivals, F. & Rosell, J. (2020). Neanderthal mobile tool kit in short-term occupations at Teixoneres Cave (Moia, Spain). *Journal of Archaeological Science: Reports*, 29, 102165. <https://doi.org/10.1016/j.jasrep.2019.102165>

Picin, A. (2022). Deconstructing Neanderthal's mobility from an environmental perspective. In: I. Sobkowiak-Tabaka, A. Diachenko & A. Wiśniewski (eds.), *Quantitative Archaeology and Archaeological Modelling*, 13-45. Springer, New York. https://doi.org/10.1007/978-3-030-94368-4_2

Pop, E., Charalampopoulos, D., Arps, C. S., Verbaas, A., Roebroeks, W., Gaudzinski-Windheuser, S., & Langejans, G. (2018). Middle Palaeolithic percussive tools from the Last Interglacial Site Neumark-Nord 2/2 (Germany) and the visibility of such tools in the archaeological record. *Journal of Paleolithic Archaeology*, 1, 81-106. <https://doi.org/10.1007/s41982-018-0008-8>

R

Reeves, J. S., McPherron, S. P., Aldeias, V., Dibble, H. L., Goldberg, P., Sandgathe, D. & Turq, A. (2019). Measuring spatial structure in time-averaged deposits insights from Roc de Marsal, France. *Archaeological and Anthropological Sciences*, 11, 5743-5762. <https://doi.org/10.1007/s12520-019-00871-y>

Reid, J., Schiffer, M.B. & Rathje, W. (1975). Behavioral archaeology: four strategies. *American Anthropologist*, 77(4), 864-869. <https://doi.org/10.1525/aa.1975.77.4.02a00090>

Ríos, L., Rosas, A., Estalrich, A., García-Tabernero, A., Bastir, M., Huguet, R., Pastor, F. Sanchís-Gimeno, J.A. & de la Rasilla, M. (2015). Possible further evidence of low genetic diversity in the El Sidrón (Asturias, Spain) Neanderthal group: congenital clefts of the Atlas. *PLoS ONE*, 10(9). <https://doi.org/10.1371/journal.pone.0136550>

Ripley, B.D. (1977). Modelling spatial patterns. *Journal of Royal Statistical Society*, 39(2).

<https://doi.org/10.1111/j.2517-6161.1977.tb01615.x>

Robb, J. & Pauketat, T. (2013). *Big Histories, Human Lives: Tackling Problems of Scale in Archaeology*. School for Advanced Research (SAR) Press, Santa Fe.

Rodríguez-Hidalgo, A., Saladie, P., Olle, A., Arsuaga, J.L., Bermúdez de Castro, J.M. & Carbonell, E. (2017). Human predatory behavior and the social implications of communal hunting based on evidence from the TD10. 2 bison bone bed at Gran Dolina (Atapuerca, Spain). *Journal of Human Evolution*, 105, 89-122. <https://doi.org/10.1016/j.jhevol.2017.01.007>

Roebroeks, W. (1988). *From find scatters to early hominid behaviour: a study of Middle Palaeolithic riverside settlements at Maastricht-Belvédère (the Netherlands)*. Leiden University Press, Leiden.

Romagnoli, F. (2015). A second life: Recycling production waste during the Middle Palaeolithic in layer L at Grotta del Cavallo (Lecce, Southeast Italy). *Quaternary International*, 361, 200-211. <https://doi.org/10.1016/j.quaint.2014.07.033>

Romagnoli, F. & Vaquero, M. (2016). Quantitative stone tools intra-site point and orientation patterns of a Middle Palaeolithic living floor: a GIS multi-scalar spatial and temporal approach. *Quartär* 63, 47-60. https://doi.org/10.7485/QU63_3

Romagnoli, F. & Vaquero, M. (2019). The challenges of applying refitting analysis in the Palaeolithic archaeology of the twenty-first century: an actualised overview and future perspectives. *Archaeological and Anthropological Sciences* 11, 4387-4396. <https://doi.org/10.1007/s12520-019-00888-3>

Rose, J., Hilbert, Y., Usyk, V., Bebbler, M.,

- Beshkani, A., Buchanan, B., Cascalheira, J., Chlachula, D., Dellmour, R., Eren, M., Garba, R., Hallinan, E., Li, L., Walker, R. & Marks, A. (2025). *Journal of Archaeological Science*, 173. <https://doi.org/10.1016/j.jas.2024.106117>
- Rosen, S.A. (2010). Activity areas, workshops, and variations on the theme from a Near Eastern lithic perspective. *Journal of the Israel Prehistoric Society*, 40, 167-182.
- Roth, B. & Dibble, H. (1998). Production and transport of blanks and tools at the French Middle Palaeolithic site of Combe-Capelle Bas. *American Antiquity*, 63(1). <https://doi.org/10.2307/2694775>
- Rottländer, R.C. (1975). The formation of patina on flint. *Archaeometry* 17, 106-110. <https://doi.org/10.1111/j.1475-4754.1975.tb00120.x>
- Rovelli, C. & Smolin, L. (1990). Loop space representation of quantum general relativity. *Nuclear Physics B*, 331(1), 80-152. [https://doi.org/10.1016/0550-3213\(90\)90019-A](https://doi.org/10.1016/0550-3213(90)90019-A)
- Rovelli, C. (1996). Relational quantum mechanics. *International Journal of Theoretical Physics*, 35, 1637-1678. <https://doi.org/10.1007/BF02302261>
- Rovelli, C. (2004). *Quantum gravity*. Cambridge University Press, Cambridge.
- Rovelli, C. (2024). *El orden del tiempo*. Anagrama, Barcelona.
- Roy-Sunyer, M., Tarriño, A., Benito-Calvo, A., Mora, R. & Martínez-Moreno, J. (2013). Aprovechamiento de sílex en el Prepirineo oriental durante el Paleolítico superior antiguo: el nivel arqueológico 497C de Cova Gran (Santa Linya, Lleida). *Trabajos De Prehistoria*, 70(1), 7-27. <https://doi.org/10.3989/tp.2013.12100>
- Roy-Sunyer, M. (2015). Deconstructing archaeological palimpsests: Applicability of GIS algorithms for the automated generation of cross-sections. In: S. Campana, R. Scopigno & G. Carpentiero (eds.), *Keep the revolution going: Proceedings of the 43rd annual conference on computer applications and quantitative methods in Archaeology*, 407-414. Archaeopress.
- Roy-Sunyer, M. (2016). *Materias primas líticas y su explotación durante la Prehistoria en el Prepirineo oriental (NE de Iberia)*. PhD Dissertation, Universitat Autònoma de Barcelona.
- Roy-Sunyer, M., Mora, R., Plasencia, F.J., Martínez-Moreno, J. & Benito-Calvo, A. (2017). Quartzite selection in fluvial deposits: the N12 level of Roca dels Bous (Middle Palaeolithic, southeastern Pyrenees). *Quaternary International*, 435(12). <https://doi.org/10.1016/j.quaint.2015.09.010>
- ## S
- Saltré, F., Chadœuf, J., Higham, T., Ochocki, M., Block, S., Bunney, E., Llamas, B. & Bradshaw, C.J. (2024). Environmental conditions associated with initial northern expansion of anatomically modern humans. *Nature Communications*, 15(1), 4364. <https://doi.org/10.1038/s41467-024-48762-8>
- Sánchez-Martínez, J., Torcal, R., Martínez-Moreno, J., Gilabert, X.R. & Roy-Sunyer, M. (2022). Carrying rocks: Hoarding behaviour in the Gravettian occupation of Cova Gran de Santa Linya (SE Pyrenees). *Journal of Archaeological Science: Reports*, 41, 103125. <https://doi.org/10.1016/j.jasrep.2021.103125>
- Sánchez-Romero, L., Canals, A., Pérez-González, A., Márquez, B., Mosquera, M., Karampaglidis, T., Arsuaga, J. L.,

- & Baquedano, E. (2017). Breaking the palimpsest: an approach to the cultural sequence of Neanderthal occupation at the Navalmaíllo rockshelter, Pinilla del Valle (Spain). *Trabajos de Prehistoria*, 74(2), 225-237. <https://doi.org/10.3989/tp.2017.12192>
- Sánchez-Romero, L. (2019). *Desarrollo y aplicación metodológica para el análisis espacial de yacimientos paleolíticos al aire libre y en cueva*. PhD Dissertation, Universidad de Burgos.
- Sánchez-Romero, L., Benito-Calvo, A., Marín, A.B., Agudo, L., Karampaglidis, T. & Rios, J. (2020). New insights for understanding spatial patterning and formation processes of the Neanderthal occupation in the Amalda I cave (Gipuzkoa, Spain). *Scientific Reports*, 10, 8733. <https://doi.org/10.1038/s41598-020-65364-8>
- Sánchez-Romero, L., Benito-Calvo, A. & Rios-Garaizar, J. (2021). Defining and characterising clusters in Palaeolithic sites: a review of methods and constraints. *Journal of Archaeological Method and Theory* 29, 305-333. <https://doi.org/10.1007/s10816-021-09524-8>
- Sánchez-Romero, L., Benito-Calvo, A., Iriarte, E., San Emeterio, A., Ortega, I. & Rios, J. (2022). Unraveling Châtelperronian high-density accumulations: the open-air site of Aranbaltza II (Bizkaia, Spain). *Archaeological and Anthropological Sciences*, 14, 77. <https://doi.org/10.1007/s12520-022-01541-2>
- Sánchez-Romero, L., Benito-Calvo, A., De Loecker, D., & Pope, M. (2023). Spatial analysis and site formation processes associated with the Middle Pleistocene hominid teeth from Q1/B waterhole, Boxgrove (West Sussex, UK). *Archaeological and Anthropological Sciences*, 15, 98. <https://doi.org/10.1007/s12520-023-01790-9>
- Sánchez-Romero, L., Martínez-Moreno, J., Benito-Calvo, A., Sánchez-Martínez, J. & Mora, R. (2024). Not only domestic spaces: dismantling short-term occupations in level 497D of Cova Gran de Santa Linya (pre-Pyrenees, Spain). *Journal of Quaternary Science*. 1-20. <https://doi.org/10.1002/jqs.3648>
- Sanchis, A., Pérez, L., Hernández, C.M. & Galván, B. (2015). La tortuga mediterránea en yacimientos valencianos del Paleolítico medio: distribución, origen de las acumulaciones y nuevos datos procedentes del Abric del Pastor (Alcoi, Alacant). *Preses petites i grups humans en el passat. II Jornades d'arqueozoologia*, 97-120.
- Sañudo, P., Blasco, R. & Fernández-Peris, J. (2016). Site formation dynamics and human occupations at Bolomor cave (Valencia, Spain): an archeostratigraphic analysis of levels I to XII (100-200 ka). *Quaternary International*, 417. [10.1016/j.quaint.2015.09.044](https://doi.org/10.1016/j.quaint.2015.09.044)
- Schiffer, M.B. (1972). Archaeological context and systemic context. *American Antiquity*, 37(2), 156-165. <https://doi.org/10.2307/278203>
- Schiffer, M.B. (1975). Behavioral chain analysis: activities, organization, and the use of space. *Fieldiana Anthropology*, 65(4), 103-119.
- Schiffer, M.B. (1976). *Behavioral archaeology*. Cambridge University Press, Cambridge.
- Schiffer, M. B. (1978). Methodological issues in ethnoarchaeology. In: R. Gould (ed.), *Explorations in ethnoarchaeology*, 230-248. University of Mexico Press, Albuquerque.
- Schiffer, M.B. (1979). A preliminary consideration of behavioral change. In: C. Renfrew & K. Cooke (eds.), *Transformations: mathematical approaches to culture*

- change, 353-368. Academic Press, New York.
- Schiffer, M.B. (1983a). Toward the identification of formation processes. *American Antiquity*, 48(4), 675-706. <https://doi.org/10.2307/279771>
- Schiffer, M.B. (1983b). Forward to McKellar Paper. *Arizona Anthropologist*, 4, 1.
- Schiffer, M.B. (1985). Is there a "Pompeii Premise" in archaeology?. *Journal of Anthropological Research*, 41(1), 18-41. <https://doi.org/10.1086/jar.41.1.3630269>
- Schiffer, M.B. (1995). *Behavioral archaeology: first principles*. University of Utah Press, Utah.
- Segura, J.M. (2017). El arqueólogo Vicente Pascual Pérez (Alcoi, 1917-1976). Una aportación a su biografía a través del testimonio epistolar de sus colegas. *Recerques del Museu d'Alcoi*, 26, 153-196.
- Shott, M.J. (1994). Size and form in the analysis of flake debris: review and recent approaches. *Journal of archaeological method and theory*, 1, 69-110. <https://doi.org/10.1007/BF02229424>
- Silverman, B.W. (1998). *Density Estimation for statistics and data analysis*. Chapman & Hall, New York.
- Simonetti, C. (2018). Timescales and telescopes. Optics in the study of Prehistory. In: S. Souvatzi et al. (eds.), *Time and History in Prehistory*, 42-57. Routledge, London.
- Skibo, J. & Schiffer, M.B. (2008). *People and things. A behavioral approach to material culture*. Springer, New York.
- Smith, C.D. (1992). The Annales for archaeology? *Antiquity*, 66(251), 539-541. <https://doi.org/10.1017/S0003598X00081710>
- Smolin, L. (2020). Temporal relationalism. In: N. Hugget et al. (eds.), *Beyond spacetime: the foundations of Quantum Gravity*, 143-175. Cambridge University Press, Cambridge.
- Speth, J. (2006). Housekeeping, Neanderthal-style: hearth placement and midden formation in Kebara Cave (Israel). In: E. Hovers & S. Kuhn (eds.), *Transitions before transitions: evolution and stability in the Middle Paleolithic and Middle Stone Age*, 171-188. Springer, New York.
- Sorensen, A.C. & Scherjon, F. (2018). fiReproxies: A computational model providing insight into heat-affected archaeological lithic assemblages. *PLoS One*, 13(5). <https://doi.org/10.1371/journal.pone.0196777>
- Sossa-Ríos, S. (2021). *Comportamiento humano en tiempo y espacio. Disección de palimpsestos, captación de recursos líticos y gestión tecnológica en las unidades IV y V del Abric del Pastor (Alcoi, Alicante)*. Master Dissertation, Universitat Rovira i Virgili.
- Sossa-Ríos, S., Mayor, A., Hernández, C.M., Bencomo, M., Pérez, L.J., Galván, B., Mallol, C. & Vaquero, M. (2022). Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian Peninsula). *Scientific Reports* 12, 15883. <https://doi.org/10.1038/s41598-022-20200-z>
- Sossa-Ríos, S., Mayor, A., Sánchez-Romero, L., Mallol, C., Vaquero, M. & Hernández, C.M. (2024). The time of the stones: a call for palimpsest dissection to explore lithic record formation processes. *Journal of Archaeological Method and Theory*, 31, 2188-2238. <https://doi.org/10.1007/s10816-024-09666-5>
- Sossa-Ríos, S., Mayor, A., Tomé, L., Davara, J., Kleinhapl, S., Sánchez-Romero, L., Mallol, C., Vaquero, M. & Hernández, C.M. (2025).

- Knapping... sleeping and consuming? Spatial variability in the high-resolution Neanderthal context of Abric del Pastor (Alcoi, eastern Iberia). *Journal of Paleolithic Archaeology*, X(X).
- Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Toniello, G., Astudillo, F., Boschín, F., Boscato, P. & Ronchitelli, A. (2019). Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa - Taranto, southern Italy). *Quaternary Science Reviews*, 217, 169-193. [10.1016/j.quascirev.2018.06.024](https://doi.org/10.1016/j.quascirev.2018.06.024)
- Spagnolo, V., Marciani, G., Aureli, D., Martini, I., Boscato, P., Boschín, F. & Ronchitelli, A. (2020a). Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto rockshelter (Ginosa, southern Italy). *Archaeological and Anthropological Sciences*, 12, 54. [10.1007/s12520-019-00971-9](https://doi.org/10.1007/s12520-019-00971-9)
- Spagnolo, V., Aureli, D., Martini, I., Ekberg, I., Boschín, F., Crezzini, J., Poggi, G., Boscato, P. & Ronchitelli, A. (2020b). Short and close in time: overlapped occupation from the layer 56 of the Molare rock shelter (southern Italy). *Archaeological and Anthropological Sciences*, 12, 92. [10.1007/s12520-020-01037-x](https://doi.org/10.1007/s12520-020-01037-x)
- Starkovich, B., Elefanti, P., Karkanias, P. & Panagopoulou, E. (2020). Site use and maintenance in the Middle Palaeolithic at Lakonis I (Peloponnes, Greece). *Journal of Paleolithic Archaeology*, 3. <https://doi.org/10.1007/s41982-018-0006-x>
- Stevenson, M. (1985). The formation of artifact assemblages at workshop/habitation sites: models from Peace Point in northern Alberta. *American Antiquity*, 50, 63-81. <https://doi.org/10.2307/280634>
- Stevenson, M. (1991). Beyond the formation of hearth-associated artifact assemblages. In: E. Kroll & D. Price (eds.), *The interpretation of archaeological spatial patterning*, 269-297. Springer, New York.
- ## T
- Takakura, J. (2018). Lithic refitting and its implication for the integrity and duration of site occupation: The case of the Late Upper Paleolithic site of Kiusu-5 in Hokkaido, Northern Japan. *Quaternary International*, 474, 156-167. <https://doi.org/10.1016/j.quaint.2018.03.013>
- Tarriño, A. & Terradas, X. (2013). Materias primas líticas. In M. García & L. Zapata (eds.), *Métodos y técnicas de análisis y estudio en arqueología prehistórica: de lo técnico a la reconstrucción de los grupos humanos*, 439-452. Euskal Herriko Unibertsitatearen Argitalpen Zerbitzua.
- Thiébaud, C., Claud, É., Mourre, V., Chacón, M.G., Asselin, G., Brenet, M. & Paravel, B. (2010). The recycling and reuse of cores and bifaces during the Middle Paleolithic in Western Europe: functional and cultural interpretations. *Paleoethnologie. Archéologie et Sciences Humaines*. <https://doi.org/10.4000/paleoethnologie.641>
- Tomé, L., Jambrina-Enríquez, M., Éguez, N., Herrera-Herrera, A., Davara, J., Marrero, E., Arnay de la Rosa, M. & Mallol, C. (2022). Fuel sources, natural vegetation and subsistence at a high-altitude aboriginal settlement in Tenerife, Canary Islands: microcontextual geoarchaeological data from Roques de García rockshelter. *Archaeological and Anthropological Sciences*, 14(195). <https://doi.org/10.1007/s12520-022-01661-9>
- Torregrosa, P., Jover, F.J. & Molina, F.J. (2018). Nuevos datos sobre el Paleolítico medio en el valle del Vinalopó: la ocupación

musteriense de la Cova dels Calderons (La Romana, Alicante). *Archivo de Prehistoria Levantina*, 18, 9-37.

Torres, C. & Baena, J. (2020). Experts also fail: A new methodological approach to skills analysis in lithic industries. *Journal of Paleolithic Archaeology*, 3(4), 889-917. <https://doi.org/10.1007/s41982-020-00063-4>

Turq, A. (2005). Réflexions méthodologiques sur les études de matières premières lithiques. *Paléo*, 17, 111-132. <https://doi.org/10.4000/paleo.883>

Turq, A., Roebroeks, W., Bourguignon, L. & Faivre, J.P. (2013). The fragmented character of Middle Palaeolithic stone tool technology. *Journal of Human Evolution*, 65(5), 641-655. <https://doi.org/10.1016/j.jhevol.2013.07.014>

Turq, A., Faivre, J.F., Gravina, B. & Bourguignon, L. (2017). Building models of Neanderthal territories from raw material transports in the Aquitaine Basin (southwestern France). *Quaternary International*, 433(17). <https://doi.org/10.1016/j.quaint.2016.02.062>

U

Uthmeier, T., Chabai, V.P. & Veselsky, A.P. (2020). From the apron into the pit: the deposition of the complete debris from the manufacture of a bifacial preform at the Middle Paleolithic site of Kabazi V, level III/4-2. *Archaeological and Anthropological Sciences*, 12, 1-28. <https://doi.org/10.1007/s12520-019-00968-4>

V

Vallverdú, J., Vaquero, M., Cáceres, I., Allué, E., Rosell, J., Saladié, P., Chacón, G., Ollé, A., Canals, A., Sala, R., Courty, M. & Carbonell, E. (2010). Sleeping activity

area within the site structure of archaic human groups: evidence from Abric Romaní level N combustion activity areas. *Current Anthropology*, 51(1). <https://doi.org/10.1086/649499>

Vandavelde, S., Brochier, J.É., Desachy, B., Petit, C. & Slimak, L. (2018). Sooted concretions: A new micro-chronological tool for high temporal resolution archaeology. *Quaternary International*, 474, 103-118.

Vaquero, M. (1999). Intrasite spatial organization of lithic production in the Middle Palaeolithic: the evidence of the Abric Romaní (Capellades, Spain). *Antiquity*, 73. <https://doi.org/10.1017/S0003598X00065054>

Vaquero, M. (2001). Contextos de acción intencional y perspectivas historicistas en la interpretación de los conjuntos arqueológicos. *Krei*, 6, 79-104.

Vaquero, M. & Pastó, I. (2001). The definition of spatial units in Middle Palaeolithic sites: the hearth-related assemblages. *Journal of Archaeological Science*, 28(11), 1209-1220. <https://doi.org/10.1006/jasc.2001.0656>

Vaquero, M., Chacón, G. M., Fernández-Laso, M. C., & Rando, J. M. (2001). Intrasite spatial patterning and transport in the Abric Romaní Middle Paleolithic site (Capellades, Barcelona, Spain). In N.J. Conard (ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age*, 573-592. Kerns Verlag.

Vaquero, M., Rando, J.M. & Chacón, G. (2004). Neanderthal spatial behaviour and social structure: hearth-related assemblages from the Abric Romaní Middle Palaeolithic site. In N.J. Conard (ed.), *Settlement dynamics in the Middle Palaeolithic and Middle Stone Age II*, 367-392. Kerns Verlag.

- Vaquero, M. (2008). The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. *Journal of Archaeological Science*, 35(12), 3178-3185. <https://doi.org/10.1016/j.jas.2008.07.006>
- Vaquero, M. (2012). Introduction: Neanderthal behavior and temporal resolution of archaeological assemblages. In: E. Carbonell (ed.), *High resolution archaeology and Neanderthal behavior. Vertebrate paleobiology and paleoanthropology*, 1-16. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-3922-2_1
- Vaquero, M., Chacón, M.G., García, M.D., Gómez, B., Martínez, K. & Cuartero, F. (2012). Time and space in the formation of lithic assemblages: the example of Abric Romaní level J. *Quaternary International*, 247, 162-181. <https://doi.org/10.1016/j.quaint.2010.12.015>
- Vaquero, M. (2013). Tipología y tecnología lítica. In M. García & L. Zapata (eds.), *Métodos y técnicas de análisis y estudio en arqueología prehistórica: de lo técnico a la reconstrucción de los grupos humanos*, 453-477. Euskal Herriko Unibertsitatearen Argitalpen Zerbitzua.
- Vaquero, M., Bargalló, A., Chacón, M.G., Romagnoli, F. & Sañudo, P. (2015). Lithic recycling in a Middle Paleolithic expedient context: evidence from the Abric Romaní (Capellades, Spain). *Quaternary International*, 361. <https://doi.org/10.1016/j.quaint.2014.05.055>
- Vaquero, M., Fernández-Laso, M.C., Chacón, M.G., Romagnoli, F., Rosell, J. & Sañudo, P. (2017). Moving things: comparing lithic and bone refits from a Middle Paleolithic site. *Journal of Anthropological Archaeology* 48, 262-280. <https://doi.org/10.1016/j.jaa.2017.09.001>
- Vaquero, M. & Romagnoli, F. (2018). Searching for lazy people: the significance of expedient behavior in the interpretation of Paleolithic assemblages. *Journal of Archaeological Method and Theory*, 25, 334-367. [10.1007/s10816-017-9339-x](https://doi.org/10.1007/s10816-017-9339-x)
- Vaquero, M., Romagnoli, F., Bargalló, A., Chacón, M. G., Gómez de Soler, B., Picin, A. & Carbonell, E. (2019). Lithic refitting and intrasite artifact transport: a view from the Middle Paleolithic. *Archaeological and Anthropological Sciences*, 11, 4491-4513. <https://doi.org/10.1007/s12520-019-00832-5>
- Vaquero, M. (2022). The organisation of living spaces in Neanderthal campsites. In: F. Romagnoli, S. Benazzi & F. Rivals (eds.), *Updating Neanderthals. Understanding behavioural complexity in the Late Middle Palaeolithic*, 207-225. Academic Press. <https://doi.org/10.1016/B978-0-12-821428-2.00001-9>
- Vicens-Petit, J.M. (1989). Estudio arqueológico del Barranc del Sint (Alcoi). *Lucentum*, 7, 57-78.
- Vidal-Matutano, P., Hernández-Gómez, C.M., Galván, B. & Mallol, C. (2015). Neanderthal firewood management: evidence from stratigraphic unit IV of Abric del Pastor (eastern Iberia). *Quaternary Science Reviews*, 111, 81-93. <https://doi.org/10.1016/j.quascirev.2015.01.010>
- Vidal-Matutano, P., Pérez-Jordá, G., Hernández, C.M. & Galván, B. (2018). Macrobotanical evidence (wood charcoal and seeds) from the Middle Palaeolithic site of El Salt, Eastern Iberia: palaeoenvironmental data and plant resources catchment areas. *Journal of Archaeological Science: Reports*, 19, 454-464. <https://doi.org/10.1016/j.jasrep.2018.03.032>

Vidal-Matutano, P. & Pardo-Gordó, S. (2020). Predictive Middle Palaeolithic climatic conditions from Eastern Iberia: a methodological approach based on charcoal analysis and modelling. *Archaeological and Anthropological Sciences*, 12(36). <https://doi.org/10.1007/s12520-019-00993-3>

Villa, P. (1982). Conjoinable pieces and site formation processes. *American Antiquity*, 47(2), 276-290. <https://doi.org/10.2307/279901>

Villa, P. & Courtin, J. (1983). The interpretation of stratified sites: a view from underground. *Journal of Archaeological Science*, 10(3). [https://doi.org/10.1016/0305-4403\(83\)90011-0](https://doi.org/10.1016/0305-4403(83)90011-0)

W

Walker, M. (2013). *Quaternary dating methods*. Wiley, Chichester.

Weitzel, C. & Sánchez, A. (2021). A trampling experiment to assess fractures and edge damage in quarry's lithic assemblages. *Lithic Technology*, 46(4). <https://doi.org/10.1080/01977261.2021.1926702>

Whallon, R. (1974). Spatial analysis of occupation floors II: The application of Nearest Neighbor Analysis. *American Antiquity*, 39(1). <https://doi.org/10.2307/279216>

Whallon, R. (2006). Social networks and information: non-"utilitarian" mobility among hunter-gatherers. *Journal of Anthropological Archaeology*, 25(2). <https://doi.org/10.1016/j.jaa.2005.11.004>

Will, M. (2021). The role of different raw materials in lithic technology and settlement patterns during the Middle Stone Age of Southern Africa. *African Archaeological Review*, 38, 477-500. <https://doi.org/10.1007/s10437-021-09446-6>

doi.org/10.1007/s10437-021-09446-6

Winterhalder, B. (2001). The behavioural ecology of hunter gatherers. In: C. Panther et al. (eds.), *Hunter-Gatherers: An Interdisciplinary Perspective*, 13-38. University of Davis, California.

Wood, B., Harris, J., Raichlen, D., Pontzer, H., Sayre, K., Sancilio, A., Berbesque, C., Crittenden, A., Mabulla, A., McElreath, R., Cashdan, E. & Holland, J. (2021). Gendered movement ecology and landscape use in Hadza hunter-gatherers. *Nature Human Behaviour*, 5, 436-446. <https://doi.org/10.1038/s41562-020-01002-7>

Y

Yellen, J. (1976). Settlement patterns of the !Kung: an archaeological perspective. In: R. Lee & I. DeVore (eds.), *Kalahari hunter-gatherers*, 47-72, Harvard University Press.

Z

Zaidner, Y., Prévost, M., Shahack-Gross, R., Weissbrod, L., Yeshurun, R., Porat, N., Guérin, G., Mercier, N., Galy, A., Pécheyran, C., Barbotin, G., Tribolo, C., Valladas, H., White, D., Timms, R., Blockey, S., Frumkin, A., Gaitero-Santos, D., Ilani, S., Ben-Haim, S., Pedergnana, A., Pietraszek, A., Nicosia, C., Lagle, S., Varoner, O., Zeigen, C., Langgut, D., Crouvi, O., Borgel, S., Sarig, R., May, H. & Hershkovitz, I. (2025). Evidence from Tinsmet Cave in Israel suggests behavioural uniformity across Homo groups in the Levantine mid-Middle Palaeolithic circa 130,000–80,000 years ago. *Nature Human Behaviour*, 1-16. <https://doi.org/10.1038/s41562-025-02110-y>

Zilio, L., Hammond, H., Karampaglidis, T., Sánchez-Romero, L., Blasco, R., Rivals, F., Rufà, A., Picin, A., Chacón, M.G., Demuro, M., Arnold, L.J. & Rosell, J. (2021). Examining

Neanderthal and carnivore occupations at Teixoneres cave (Moià, Barcelona, Spain) using archaeostratigraphic and intra-site spatial analysis. *Scientific Reports* 11, 4339. <https://doi.org/10.1038/s41598-021-83741-9>

Zangrossi, F., Delpiano, D., Cocilova, A., Ferrari, F., Balzani, M. & Peresani, M. (2019). 3D visual technology applied for the reconstruction of a Paleolithic workshop. *Journal of Archaeological Science: Reports*. 28, 102045. <https://doi.org/10.1016/j.jasrep.2019.102045>

“We can perhaps express this tension between simultaneity and contemporaneity by contrasting two different moments of temporal wonder, experiences we can probably all relate to. On a clear and starry night if you cast your eyes upward, you see a myriad of twinkling lights, each one a luminous globe like our own sun, or a planet lit up by such a sun. When you gaze at these stars you are directly observing the past in the present. Because it takes time for light to travel, the image you see is not the ‘now’ of the star but its past. When I first heard about this, it was mind blowing. What are ‘contemporary’ events to us are past for the objects caught up in those events” (Lucas, 2021: 16-17).

VIII. APPENDICES

Appendix I

Appendix II

Appendix III

Appendix I

Supplementary Information

for

Multidisciplinary evidence of an isolated Neanderthal occupation in Abric del Pastor (Alcoi, Iberian peninsula)

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Contents

- Extended site background
- Extended methods
- Extended data

Extended site background

The Abric del Pastor is located within the Serra de Mariola natural park, specifically in an area belonging to the municipality of Alcoi, headtown of L'Alcoià county, in the Valencian province of Alacant. The first archaeological excavation was performed by Mario Brotons in 1952 and 1953, exposing the stratigraphic units (SUs) I, II and III [1]. After this, it has been excavated yearly and sometimes even twice a year from 2005 to 2021, except for 2020. The 1.5m-thick stratigraphic sequence comprises six SUs with three absolute dates (48 ± 5 ky BP in IVb, 63 ± 5 ky BP in IVd and 62 ± 12 ky BP in VI) [2] (Fig. S2):

SU I is a Holocene deposit with a very high content of caprine faecal matter, whereas SUs II, III, IV, V and VI correspond to the Late Pleistocene deposit identified to date and contain a smaller or larger density of Neanderthal material record.

Excepting SU II, which is a dark-brownish sedimentary relict truncated by SU I, the Late Pleistocene deposit formation process is based on the fall of the limestone conglomerate in different size ranges (i.e. blocks, clasts, gravels and sands), due to gravitational effects probably caused by gelifraction or other weathering effects occurred during cold and dry climatic periods [2]. SUs IV and V have been additionally subdivided into other SUs responding to distinguishable episodes of roof-fall and the consequent alternation of fine and coarse granulometric standards occurring postdepositionally (i.e. blocks and clasts, gravels and sands): IVa to IVg and Va to Vc, which is currently under excavation.

Fig. S1. a) excavation surface of SU Ⅳf. b) H17 hearth on field. c) excavation surface of SU Ⅳf with the H17 hearth.



Fig. S2. Stratigraphic sequence of Abric del Pastor (modified from Mallol et al. [2]).

Depth (cm)	Stratigraphic Unit	Lithology	Texture								Dates	Combustion structures		
			Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Granules			Pebbles	Cobbles
0-20	I	[Pattern]												
20-40	II	[Pattern]												7
40-45	III	[Pattern]												
45-55	IVa	[Pattern]												1 2
55-65	IVb	[Pattern]											48 kya ±5	3 4 5
65-85	IVc	[Pattern]												6 15
85-100	IVd	[Pattern]												
100-105	IVe	[Pattern]												
105-110	IVf	[Pattern]												
110-115	IVg	[Pattern]												8 9 10 11 12 13 14 16
115-125	V	[Pattern]												17
125-140	VI	[Pattern]											62 kya ±12	S1 S2 S3

Extended methods

Archaeostratigraphic and spatial analyses

All the assemblage has been georeferenced on field using both a Sokkia® iM-50 Series and a Leica Geosystems® FlexLine TS-02 total stations. Afterwards, vertical cross-sections and horizontal plotting have been generated using Environmental Systems Research Institute® (ESRI) ArcGIS Desktop ArcMap version 10.5. Three-dimensional observation and correlation of archaeological materials have been made using ESRI® ArcGIS Desktop ArcScene version 10.5.

Three-dimensional data (X, Y, Z) has served for establishing new analytical units through palimpsest dissection, focusing on vertical material gaps and relationships between the archaeological record features (e.g. burnt bones and hearth perimeter) [3,4]. One of these units individualised through archaeostratigraphic analysis has been taken here (i.e. the hearth-related assemblage associated with H17) to be studied in depth. The archaeological record belonging to this one comprises 11 flint artefacts, 78 faunal remains and 1 hearth. Two-dimensional georeferences (X-Y) regarding this assemblage, including the hearth, have been utilised in order to observe scattering or concentration dynamics on the surface and spots of high frequency of materials [5-7]. For this, we have applied the Kernel density analysis and the Average Nearest Neighbour using ESRI® ArcGIS Desktop ArcMap version 10.5.

Raw material analysis

Here, we have performed a three-step analysis in order to recognise geogenic and postgenetic features, and to individualise RMUs within the assemblage of the above-mentioned 11 flint elements.

Both macroscopic and microscopic observations have been carried out in order to achieve the identification of flint types following Molina et al. [8]. For doing this, we take into account the translucence degree (i.e. translucent or opaque), the grain size (i.e. fine, medium or coarse), the internal structure (i.e. microcrystalline, cryptocrystalline or opaline), the presence or absence of internal fissures and recrystallisations, the type and quantity of inclusions (i.e. geodes, sands or bioclasts), the cortex features (i.e. texture, colour and thickness), the thickness of

halos within subcortical and endocortical areas, and the broad colour spectrum. The microscopic analysis was developed using a Euromex® DZ Series binocular loupe between 0.8 and 80 magnifications.

We have carried through also the postgenetic approach defined by Fernandes and Raynal [9], which was utilised by Molina et al. [8] and Mayor et al. [10] for the Serpis riverbed, from the upper course, subsidiary watercourses and mountainous surroundings to the seashore. In this way, it is possible to recognise potential provisioning areas visited by Neanderthal groups through the signs of physical and chemical alterations occurring on flint (e.g. crashing, polishing, abrasion, round-shaping, patination, permeation). An extensive representation of these postgenetic alterations for the Serpis riverbed context is in Mayor et al. [10] Supplementary Material.

Additionally, we used this information (i.e. geogenic and postgenetic data) for the identification of RMUs. We observed the assemblage in order to establish set RMUs (i.e. two or more flint elements belonging to the same original nodule) in order to address the anthropogenic input dynamics of siliceous raw material masses into the site [11-13]. In the same way, the elements that we could not associate with other pieces, are single-element RMUs since they equally represent single original nodules.

Technological analysis

Morphometric and technical features of the 11 lithic remains were studied by the next means:

- Measuring length for flakes and major axis for cores, width for flakes and minor axis for cores, thickness for both, and weight for all the products.
- Observing the main morphological characteristics of each flake (i.e. shape, section, butts, edge outlines and bulbs) and core (i.e. shape, section, striking platforms and debitage surfaces), and the cortical percentages.
- Reading the diacritic schemes of flakes and cores, as a tool for diachronically ordering and qualitatively characterising the technical actions performed within the knapping sequences (i.e. number and direction of negatives, superpositions, degree of invasiveness or marginality and surface hierarchy).

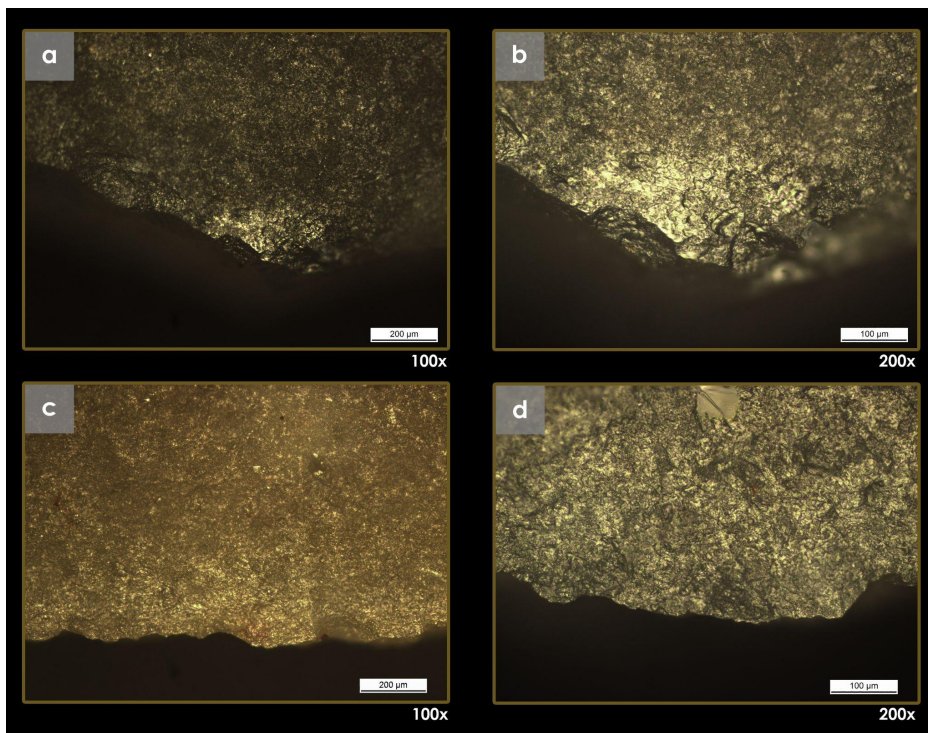
Furthermore, we aimed to look for refits through the whole assemblage, since the refitted sequences allow us to better understand technical strategies and technological conceptions utilised for exploitation [14,15].

Use-wear analysis

Use-wear analysis was developed on 6 of the 11 lithic remains. The other 5 pieces were not analysed due to their reduced size. The observation of use-wear traces was compared with references [16-21] and with an experimental program (Fig. S3) for a better interpretation.

The 6 lithic tools were analysed under the Leica M165C stereo microscope (3.65x-60x) and the Leica DM6000M metallographic microscope (50x-500x). Before the analysis, the tools were cleaned with warm water and neutral soap (Hygenia, Magnum Blue).

Fig. S3. Use-wear traces from the experimental program. a) Traces after 7 minutes cutting bone (100x). b) Traces after 7 minutes cutting bone (200x). c) Traces after 75 minutes working on butchery activity (meat and bone). d) Traces after 20 minutes working on butchery activity (skin and meat).



Archaeozoological and taphonomic analyses

Archaeozoological analysis was performed on the 78 faunal remains using standard methods [22,23]. All faunal remains were taxonomically and anatomically identified, except for bone fragments without anatomical characters or a high degree of taphonomic modifications. Non-identified specimens were classified into long bone, flat bone or articular and associated with a weight-size category based on bone density, circumference and the thickness of the cortical surface: large-sized (>300kg), medium-sized (100-300kg), small-sized (5-<100kg) and very small-sized (<5kg) [24,25]. The abundance measures employed are reduced to the number of remains (NR), number of identified specimens (NISP), the minimal number of elements (MNE) and the minimal number of individuals (MNI), due to the taphonomic conditions of the sample.

All remains were analysed under microscope Leica M165C stereo light. All dimensions (length, width, thickness) were measured for each bone fragment and the fracture analysis followed the criteria established by Villa and Mahieu [26] and the morphotypes created by Real et al. [27]. Bone surface modifications were observed and quantified to identify damage caused by anthropogenic activity (thermal alteration, percussion and butchering marks) or predator damage (tooth marks, digestion), as well as the diverse diagenetic processes that produce alterations on bone surfaces (erosion, sediment concreteness, roots marks, weathering, pigmentation, trampling) [28-34].

Supplementary data

Table S1. Total remains and combustion structures from the SUs studied in this work.

Stratigraphic unit	Lithic remains	Faunal remains	Combustion structures
ive	5	46	
ivf	6	92	1 (H17)
ivg	11	134	
va	0	16	
vb	11	17	
vc	34	52	
Total	67	357	1

Table S2. Main raw material features of the assemblage.

Flint type	Flint type representation (%)		Total/cortical elements	Proportion (%)	Number of elements by approximate percentage of cortical surface (%)					Cortex type	Number of elements with signs of postgenetic processes
	By number of elements	By raw material units			>0 - 25	>25 - 50	>50 - 75	>75 - <100	100		
Mariola	81.81	71.43	9/3	33.33	1	0	1	1	0	3	3
Serreta	18.19	28.57	2/0	0.00	0	0	0	0	0	0	0
Total	100	100	11/3	27.27	1	0	1	1	0	3	3

Table S3. Main technological features of the assemblage.

Raw material unit	Nomenclature in Fig. 4 and 5	Flint type	Refitting set	Size	Weight (g)	Butt	Flaking-face blanks	Striking polarity	Flaking direction	Technical phase	Retouch following Laplace [35]
Single element (Fig. 4)	a	Mariola	-	Small	4.09	Faceted	4	Peripheral	Centripetal	Full production	-
	b	Mariola	-	Medium	7.72	Point-shaped	2	Undiagnosed	Undiagnosed	Decortication	lat.dex.[Smd cconv]
	c	Serreta	-	Very small	1.99	Nonexistent	6	Peripheral	Centripetal	Convexity recovering	-
	d	Mariola	-	Very small	0.27	Flat	3	Undiagnosed	Unidirectional	Core reconfiguration	-
	e	Mariola	-	<10mm ²	0.09	Line-shaped	3	Undiagnosed	Unidirectional	Core reconfiguration	-
	f	Serreta	-	<10mm ²	-	Line-shaped	Undetermined	Undiagnosed	Unidirectional	Core or flake reconfiguration	-
Set RMU ivf.M1 (Fig. 5)	a	Mariola	-	Very small	2.77	Flat	4	Peripheral	Centripetal	Full production	-
	b	Mariola	ivf.M1-R1	Small	6.28	Removed	Undetermined	Undiagnosed	Undiagnosed	Full production	-
	c	Mariola	-	Very small	0.44	Flat	1	Undiagnosed	Unidirectional	Decortication	-
	d	Mariola	-	<10mm ²	0.16	Flat	-	Undiagnosed	Unidirectional	Core or flake reconfiguration	-
	e	Mariola	ivf.M1-R1	<10mm ²	0.15	Flat	-	Undiagnosed	Undiagnosed	Tool use	-

Table S4. Use-wear characterisation of the tools presenting traces.

Nomenclature in Fig. 6	Tool morphology	Edge morphology	Worked material	Action
a	Rectangular	Concave	Semi-hard/hard material	Scraping
b	Rectangular	Apex	Animal tissue	Cutting
c	Rectangular	Straight	Bone	Cutting
d	Irregular	Convex	Hard material	Percussion

Table S5. Average Nearest Neighbour analysis results from the total assemblage and the different material groups. Single-element RMUs are abbreviated as S-E RMUs.

Group	Expected mean distance	Observed mean distance	Ratio	<i>p</i>-value
AU vfh17	0.3352	0.1538	0.4590	0,0001
Mariola set RMU	1.7320	0.2670	0.1541	0.0002
Mariola S-E RMUs	1.5811	0.5730	0.3624	0.0147
Serreta S-E RMUs	2.2360	4.2354	1.8941	0.0155
Deer	0.4303	0.1445	0.3359	0.0001
Wild goat	1.4142	0.7765	0.5491	0.0537

References

1. Galván, B. Hernández, C. M., Francisco, M. A., Molina, F. J. & Tarriño, A. La producción lítica del Abric del Pastor (Alcoy, Alicante). Un ejemplo de variabilidad musteriense. *Revista Tabona*, **17**, 11-61.
2. Mallol, C. *et al.* Fire and brief human occupations in Iberia during MIS 4: evidence from Abric del Pastor (Alcoy, Spain). *Sci. Rep.* **9**, 18281; [10.1038/s41598-019-54305-9](https://doi.org/10.1038/s41598-019-54305-9) (2019).
3. Machado, J., Hernández, C. M., Mallol, C. & Galván, B. Lithic production, site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). *J. Archaeol. Sci.* **40**, 2254-2273; [10.1016/j.jas.2013.01.002](https://doi.org/10.1016/j.jas.2013.01.002) (2013).
4. Mora, R. Roy, M., Martínez, J., Benito, A. & Samper, S. Inside the palimpsest: identifying short occupations in the 497D level of Cova Gran (Iberia) in *Short-term occupations in Paleolithic archaeology* (eds. Cascalheira, J. & Picin, A.) 39-69 (Springer, 2020).
5. Sánchez-Romero, L. *et al.* New insights for understanding spatial patterning and formation processes of the Neanderthal occupation in the Amalda I cave (Gipuzkoa, Spain). *Sci. Rep.* **10**, 8733; [10.1038/s41598-020-65364-8](https://doi.org/10.1038/s41598-020-65364-8) (2020).
6. Spagnolo, V. *et al.* Neandertal camps and hyena dens: living floor 150A at Grotta dei Santi (Monte Argentario, Tuscany, Italy). *J. Archaeol. Sci. Rep.* **30**, 102249; [10.1016/j.jasrep.2020.102249](https://doi.org/10.1016/j.jasrep.2020.102249) (2020).
7. Hammond, H., Zilio, L., Peralta, S. & Moreno, J. E. Intra-site spatial analysis of lithic assemblage and refitting of an open-air site in a lacustrine landscape from central Patagonia. *J. Archaeol. Sci. Rep.* **42**: 103367; [10.1016/j.jasrep.2022.103367](https://doi.org/10.1016/j.jasrep.2022.103367) (2022).
8. Molina, F. J., Tarriño, A., Galván, B. & Hernández, C. M. El sílex del Prebético de Alicante: tipos, variabilidad y áreas de captación y talla del Pleistoceno. *Cuad. Prehist. Arqueol. Univ. Granada* **26**, 283-311 (2016).
9. Fernandes, P. & Raynal, J. P. Pétroarchéologie du silex: un retour aux sources. *Comptes Rendus Palevol* **5**: 829-837; [10.1016/j.crpv.2006.04.002](https://doi.org/10.1016/j.crpv.2006.04.002) (2006).
10. Mayor, A. *et al.* An instance of Neanderthal mobility dynamics: a lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt

- rockshelter (Alcoi, eastern Iberia). *J. Archaeol. Sci. Rep.* **44**, 103544; [10.1016/j.jasrep.2022.103544](https://doi.org/10.1016/j.jasrep.2022.103544) (2022).
11. Roebroeks, J. W. *From find scatters to early hominid behaviour: a study of Middle Palaeolithic riverside settlements at Maastricht-Belvédère (the Netherlands)* (Leiden University Press, 1988).
 12. Vaquero, M. The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. *J. Archaeol. Sci.* **35**, 3178-3185; [10.1016/j.jas.2008.07.006](https://doi.org/10.1016/j.jas.2008.07.006) (2008).
 13. Vaquero, M. Introduction: Neanderthal behavior and temporal resolution of archaeological assemblages in *High resolution archaeology and Neanderthal behavior: time and space in level J of Abric Romaní (Capellades, Spain)* (ed. Carbonell, E.) 1-16 (2012).
 14. Czesla, E. On refitting of stone artefacts in *The big puzzle: international symposium on refitting stone artefacts* (eds. Czesla, E., Eickhoff, S., Arts, N. & Winters, D.) 9-44 (Holos, 1990).
 15. Romagnoli, F. & Vaquero, M. The challenges of applying refitting analysis in the Palaeolithic archaeology of the twenty-first century: an actualised overview and future perspectives. *Archaeol. Anthropol. Sci.* **11**, 4387-4396; [10.1007/s12520-019-00888-3](https://doi.org/10.1007/s12520-019-00888-3) (2019).
 16. Tringham, R., Cooper, G., Odell, G., Voytek, B. & Whitman, A. Experimentation in the formation of edge damage: a new approach to lithic analysis. *J. Field Archaeol.* **1**, 171-196; [10.1179/jfa.1974.1.1-2.171](https://doi.org/10.1179/jfa.1974.1.1-2.171) (1974).
 17. Hayden, B. Snap, shatter, and superfractures: use-wear of Stone skin scrapers in *Lithic use-wear analysis* (ed. Hayden, B.) 207-229 (Academic Press, 1979).
 18. Keeley, L. H. *Experimental determination of stone tool uses* (University of Chicago Press, 1980).
 19. Vaughan, P. C. *Use-wear analysis of flaked stone tools* (University of Arizona Press, 1985).
 20. Anderson-Gerfaud, P. Aspects of behavior in the Middle Palaeolithic: functional aspects of stone tools from southwest France in *The emergence of modern humans: an archaeological perspective* (ed. Mellars, P. A.) 303-326 (Cornell University Press, 1990).

21. González, J. E. & Ibáñez, J. J. The quantification of use-wear polish using image analysis: first results. *J. Archaeol. Sci.* **30**, 481-489; [10.1006/jasc.2002.0855](https://doi.org/10.1006/jasc.2002.0855) (1994).
22. Lyman, R. L. *Vertebrate taphonomy* (Cambridge Manuals in Archaeology, 1994).
23. Reitz, E. J. & Wing, E. S. (eds.) *Zooarchaeology* (Cambridge University Press, 2008).
24. Uerpmann, H. P. Animal bone finds and economic archaeology: a critical study of osteo-archaeological method. *World Archaeol.* **4**, 307-322; [10.1080/00438243.1973.9979541](https://doi.org/10.1080/00438243.1973.9979541) (1973).
25. Bunn, H. T. Patterns of skeletal representation and hominid subsistence activities at Olduvai Gorge, Tanzania, and Koobi Fora, Kenya. *J. Hum. Evol.* **15**, 673-690; [10.1016/S0047-2484\(86\)80004-5](https://doi.org/10.1016/S0047-2484(86)80004-5) (1986).
26. Villa, P. & Mahieu, É. Breakage patterns of human long bones. *J. Hum. Evol.* **21**, 27-48; [10.1016/0047-2484\(91\)90034-S](https://doi.org/10.1016/0047-2484(91)90034-S) (1991).
27. Real, C. *et al.* Abrigo de la Quebrada level IV (Valencia, Spain): interpreting a Middle Palaeolithic palimpsest from a zooarchaeological and lithic perspective. *J. Palaeolithic Archaeol.* **3**, 187-224; [10.1007/s41982-018-0012-z](https://doi.org/10.1007/s41982-018-0012-z) (2020).
28. Shipman, P. *Life history of a fossil: an introduction to taphonomy and paleoecology* (Harvard University Press, 1981).
29. Shipman, P. & Rose, J. Early hominid hunting, butchering, and carcass-processing behaviors: approaches to the fossil record. *J. Anthropol. Archaeol.* **2**, 57-98; [10.1016/0278-4165\(83\)90008-9](https://doi.org/10.1016/0278-4165(83)90008-9) (1983).
30. Blasco, M. F. *Tafonomía y prehistoria: métodos y procedimientos de investigación* (Servicio de Publicaciones de la Universidad de Zaragoza, 1992).
31. Yravedra, J. Acumulaciones biológicas en yacimientos arqueológicos: Amalda VII y Esquilleu III-IV. *Trab. Prehist.* **63**, 55-78; [10.3989/tp.2006.v63.i2.17](https://doi.org/10.3989/tp.2006.v63.i2.17) (2006).
32. Domínguez, M. & Yravedra, J. Why are cut mark frequencies in archaeofaunal assemblages so variable? A multivariate analysis. *J. Archaeol. Sci.* **36**, 884-894; [10.1016/j.jas.2008.11.007](https://doi.org/10.1016/j.jas.2008.11.007) (2009).
33. Denys, C. & Patou-Mathis, M. *Manuel de taphonomie* (Errance, 2014).

34. Fernández-Jalvo, Y. & Andrews, P. *Atlas of taphonomic identification: 1001+ images of fossil and recent mammal bone modification* (Springer, 2016).
35. Laplace, G. *La typologie analytique et structurale: base rationnelle d'étude des industries lithiques et osseuses* (Centre National de la Recherche Scientifique, 1974).

Appendix II

Journal of Archaeological Method and Theory

Supplementary material for:

The time of the stones: a call for palimpsest dissection to explore lithic record formation processes

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Fig. S1. Relief map showing the position of the site in relation to the Serpis valley, mountain ranges and river courses (Mayor et al., 2022).



Fig. S2. Aerial photo showing the position of the site in the context of the Serpis valley (Google Earth).

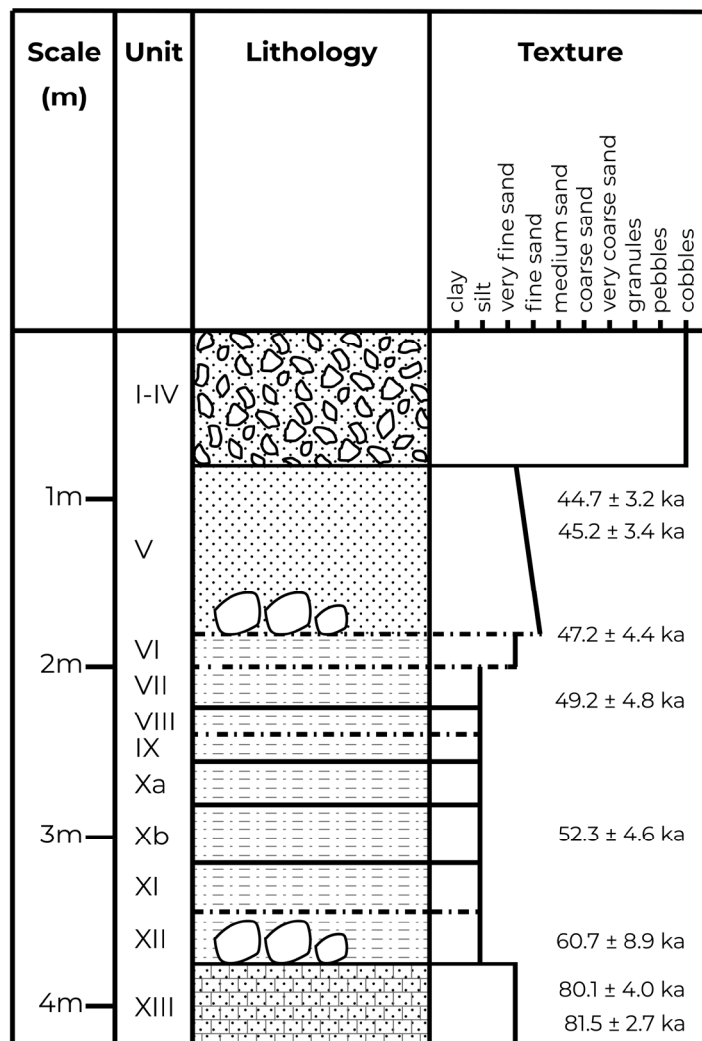


Fig. S3. Stratigraphic sequence modified from Galván et al. (2014).

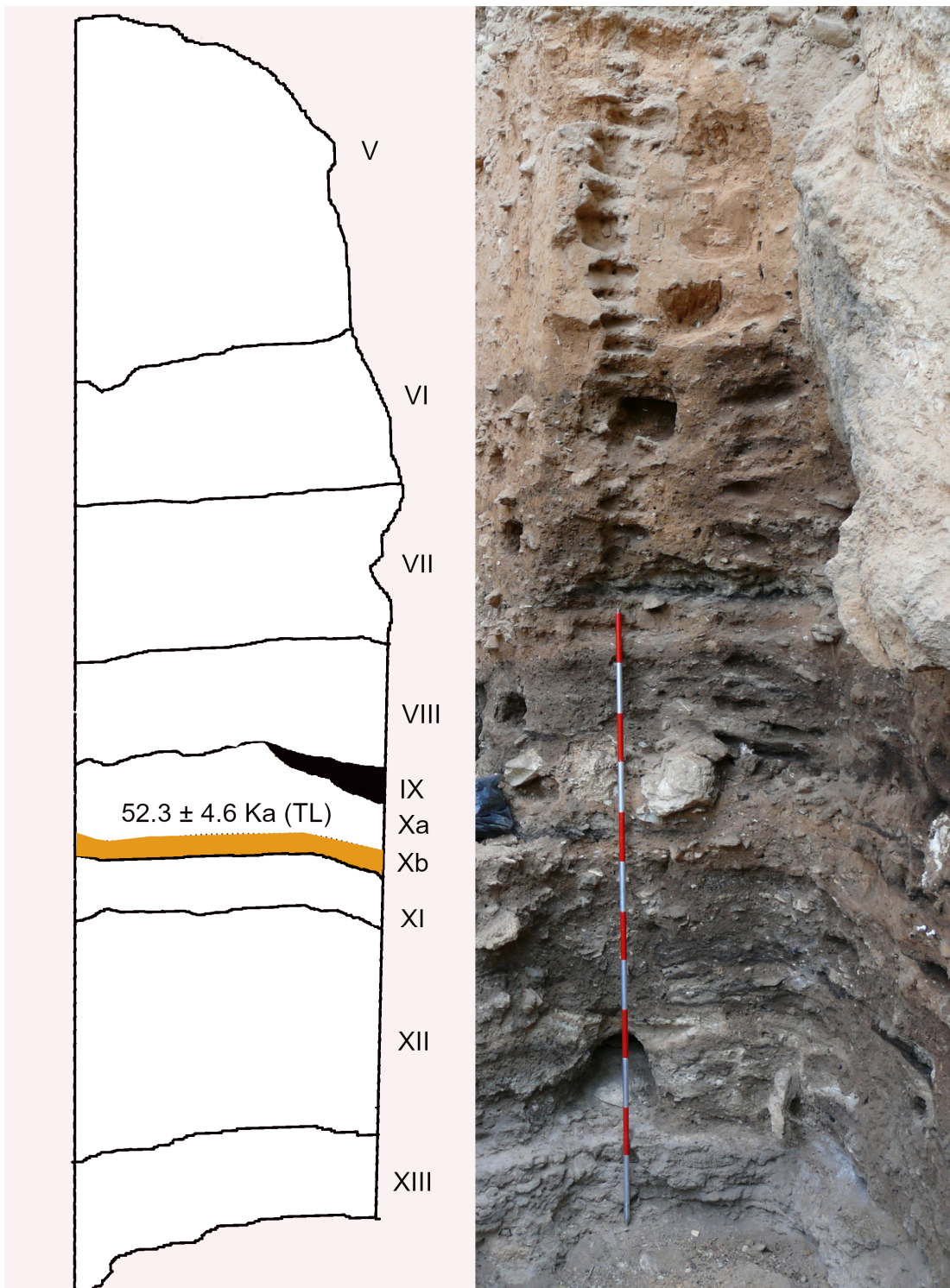


Fig. S4. Stratigraphic drawing (left) and image (right) of the Pleistocene deposit of El Salt.

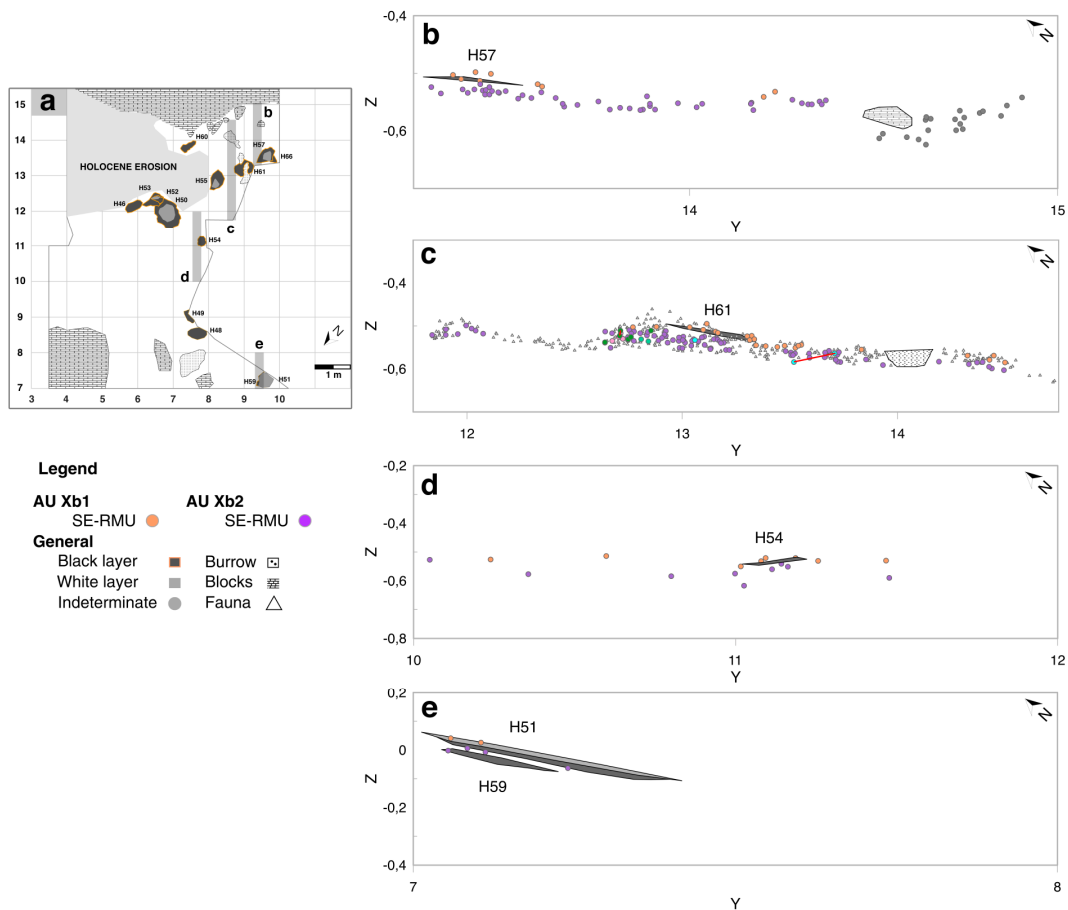


Fig. S5. Archaeostratigraphic profiles illustrating **b)** the vertically disordered point pattern adjacent to the travertine wall **c)** the faunal points filling the lithic gap to the left of H61 **d)** the vertical association of H54 to Xb1out assemblage **e)** the vertical association of H51 to Xb1out and H59 to Xb2out assemblages.

Table S1. Average Nearest Neighbour results for the defined Archaeostratigraphic Units (AUs).

Archaeostratigraphic unit	Ratio	Expected Mean Distance	Observed Mean Distance	z-score	p-value
AU Xb1out	0,6941	0,1553	0,1078	-10.2027	0
AU Xb2out	0,7098	0,1414	0,1004	-10.6910	0
AU Xb1in	0,6285	0,0994	0,0624	-9.9220	0
AU Xb2in	0,6622	0,0647	0,0428	-14.8734	0

		Xb1out	Xb2out	Xb1in	Xb2in
Size	Xb1out		0.06	0.03	
	Xb2out	0.06			<0.01
	Xb1in	0.03			0.62
	Xb2in		<0.01	0.62	
Weight	Xb1out		<0.01	<0.01	
	Xb2out	<0.01			<0.01
	Xb1in	<0.01			<0.01
	Xb2in		<0.01	<0.01	
Flint type	Xb1out		0.61	<0.01	
	Xb2out	0.61			<0.01
	Xb1in	<0.01			0.29
	Xb2in		<0.01	0.29	
Products	Xb1out		0.04	0.14	
	Xb2out	0.04			<0.01
	Xb1in	0.14			0.66
	Xb2in		<0.01	0.66	
Cortex on flakes	Xb1out		0.55	0.92	
	Xb2out	0.55			0.96
	Xb1in	0.92			0.36
	Xb2in		0.96	0.36	
Thermoalteration	Xb1out		0.24	0.92	
	Xb2out	0.24			0.52
	Xb1in	0.92			0.65
	Xb2in		0.52	0.65	

■ Dependency ■ Independency

Fig. S6. Chi-square results generated through tests for the defined AUs and different variables. The p -values from each test are indicated within the respective cells.

Table S2. Type of product distribution from the concentrations and dispersed materials in Xb1out unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%
Flakes	29	67.44	85.86	58.37	Flakes	14	93.33	17	99.94
Cores	1	2.33	13.39	9.10	Cores				
Fragments	12	27.91	25.43	17.29	Fragments	1	6.67	0.01	0.06
Retouched products	1	2.33	22.42	15.24	Retouched products				
Total	43	100.00	147.1	100.00	Total	15	100.00	17.01	100.00
C3	<i>n</i>	%	Weight (g)	%	C4	<i>n</i>	%	Weight (g)	%
Flakes	6	50.00	18.43	21.26	Flakes	9	90.00	17.59	95.91
Cores	1	8.33	37.63	43.41	Cores				
Fragments	4	33.33	3.61	4.16	Fragments	1	10.00	0.75	4.09
Retouched products	1	8.33	27.02	31.17	Retouched products				
Total	12	100.00	86.69	100.00	Total	10	100.00	18.34	100.00
C5	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Flakes	11	84.62	27.73	95.13	Flakes	135	63.98	450.63	30.46
Cores					Cores	16	7.58	764.58	51.68
Fragments	2	15.38	1.42	4.87	Fragments	55	26.07	221.76	14.99
Retouched products					Retouched products	5	2.37	42.45	2.87
Total	13	100.00	29.15	100.00	Total	211	100.00	1479.42	100.00

Table S3. Size-class distribution from the concentrations and dispersed materials in Xb1out unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%
VS	28	65.12	30.55	20.77	VS	11	73.33	3.31	19.46
S	9	20.93	56.46	38.38	S	3	20.00	10.42	61.26
M	5	11.63	37.67	25.61	M	1	6.67	3.28	19.28
L					L				
VL	1	2.33	22.42	15.24	VL				
Total	43	100.00	147.1	100.00	Total	15	100.00	17.01	100.00
C3	<i>n</i>	%	Weight (g)	%	C4	<i>n</i>	%	Weight (g)	%
VS	8	66.67	7.53	8.69	VS	8	80.00	6.24	34.02
S	1	8.33	9.24	10.66	S	2	20.00	12.1	65.98
M	1	8.33	5.27	6.08	M				
L	1	8.33	37.63	43.41	L				
VL	1	8.33	27.02	31.17	VL				
Total	12	100.00	86.69	100.00	Total	10	100.00	18.34	100.00
C5	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
VS	10	76.92	10.56	36.23	VS	134	63.51	115.46	7.80
S	1	7.69	3.78	12.97	S	37	17.54	192.17	12.99
M	1	7.69	4.62	15.85	M	23	10.90	292.04	19.74
L					L	11	5.21	299.98	20.28
VL	1	7.69	10.19	34.96	VL	6	2.84	579.77	39.19
Total	13	100.00	29.15	100.00	Total	211	100.00	1479.42	100.00

Table S4. Type of flint distribution from the concentrations and dispersed materials in Xb1out unit. Sums and percentages are not considering indeterminate materials.

C1	n	%	Weight (g)	%	C2	n	%	Weight (g)	%
Serreta	19	52.78	83.64	62.17	Serreta	10	71.43	15.28	91.72
Mariola	12	33.33	32.64	24.26	Mariola	3	21.43	0.82	4.92
Beniaia	5	13.89	18.26	13.57	Beniaia	1	7.14	0.56	3.36
Font Roja					Font Roja				
Catamarruc					Catamarruc				
Indeterminate	7		12.56		Indeterminate	1		0.35	
Total	36	100.00	134.54	100.00	Total	14	100.00	16.66	100.00
C3	n	%	Weight (g)	%	C4	n	%	Weight (g)	%
Serreta	3	37.50	9.97	12.19	Serreta	5	50.00	8.8	47.98
Mariola	4	50.00	71.06	86.85	Mariola	2	20.00	7.57	41.28
Beniaia	1	12.50	0.79	0.97	Beniaia	3	30.00	1.97	10.74
Font Roja					Font Roja				
Catamarruc					Catamarruc				
Indeterminate	4		4.87		Indeterminate				
Total	8	100.00	81.82	100.00	Total	10	100.00	18.34	100.00
C5	n	%	Weight (g)	%	Dispersed	n	%	Weight (g)	%
Serreta	7	70.00	9.93	35.87	Serreta	106	64.24	452.1	32.79
Mariola					Mariola	31	18.79	336.16	24.38
Beniaia	3	30.00	17.75	64.13	Beniaia	28	16.97	590.71	42.84
Font Roja					Font Roja				
Catamarruc					Catamarruc				
Indeterminate	3		1.47		Indeterminate	46		100.45	
Total	10	100.00	27.68	100.00	Total	165	100.00	1378.97	100.00

Table S5. Cortex on flakes distribution from the concentrations and dispersed materials in Xb1out unit.

C1	n	%	C2	n	%	C3	n	%
0	11	37.93	0	12	85.71	0	2	33.33
0-25	8	27.59	0-25	1	7.14	0-25	2	33.33
25-50	6	20.69	25-50			25-50	1	16.67
50-75	2	6.90	50-75			50-75		
75-100			75-100	1	7.14	75-100	1	16.67
100	2	6.90	100			100		
Total	29	100.00	Total	14	100.00	Total	6	100.00
C4	n	%	C5	n	%	Dispersed	n	%
0	3	33.33	0	7	63.64	0	61	45.19
0-25	2	22.22	0-25	2	18.18	0-25	44	32.59
25-50	2	22.22	25-50	1	9.09	25-50	9	6.67
50-75			50-75			50-75	6	4.44
75-100			75-100			75-100	6	4.44
100	2	22.22	100	1	9.09	100	9	6.67
Total	9	100.00	Total	11	100.00	Total	135	100.00

Table S6. Thermoaltered material distribution from the concentrations and dispersed materials in Xb1out unit.

C1	<i>n</i>	%	C2	<i>n</i>	%	C3	<i>n</i>	%
Thermoaltered	11	25.58	Thermoaltered	1	6.67	Thermoaltered	4	33.33
No thermoaltered	32	74.42	No thermoaltered	14	93.33	No thermoaltered	8	66.67
Total	43	100.00	Total	15	100.00	Total	12	100.00
C4	<i>n</i>	%	C5	<i>n</i>	%	Dispersed	<i>n</i>	%
Thermoaltered	2	20.00	Thermoaltered	4	30.77	Thermoaltered	54	25.59
No thermoaltered	8	80.00	No thermoaltered	9	69.23	No thermoaltered	157	74.41
Total	10	100.00	Total	13	100.00	Total	211	100.00

Table S7. Elongation (EI) and carination (CI) indexes from the concentrations and dispersed materials in Xb1out unit.

C1	<i>n</i>	EI	CI	C2	<i>n</i>	EI	CI
Flakes	29	1.13	3.19	Flakes	14	1.06	4.17
Retouched products	1	0.93	4.09	Retouched products			
C3	<i>n</i>	EI	CI	C4	<i>n</i>	EI	CI
Flakes	6	1.54	5.43	Flakes	9	1.5	2.76
Retouched products	1	1.6	4.1	Retouched products			
C5	<i>n</i>	EI	CI	Dispersed	<i>n</i>	EI	CI
Flakes	11	1.14	4.87	Flakes	135	1.16	4.01
Retouched products				Retouched products	5	1.17	3.73

Table S8. Comparison of flint types and type of products from the concentrations and dispersed materials in Xb1out unit.

C1	Serreta		Mariola		Beniaia		Total		C2	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
Flakes	14	41.56	11	29.28	4	15.02	29	85.86	Flakes	9	15.27	3	0.82	1	0.56	13	16.65
Cores	1	13.39					1	13.39	Cores								
Fragments	3	6.27	1	3.36	1	3.24	5	12.87	Fragments	1	0.01					1	0.01
Retouched products	1	22.42					1	22.42	Retouched products								
Total	19	83.64	12	32.64	5	18.26	36	134.54	Total	10	15.28	3	0.82	1	0.56	14	16.66
C3	Serreta		Mariola		Beniaia		Total		C4	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
Flakes	2	9.41	2	6.41	1	0.79	5	16.61	Flakes	5	8.8	1	6.82	3	1.97	9	17.59
Cores			1	37.63			1	37.63	Cores								
Fragments	1	0.56					1	0.56	Fragments			1	0.75			1	0.75
Retouched products			1	27.02			1	27.02	Retouched products								
Total	3	9.97	4	71.06	1	0.79	8	81.82	Total	5	8.8	2	7.57	3	1.97	10	18.34
C5	Serreta		Mariola		Beniaia		Total		Dispersed	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
Flakes	7	9.93			3	17.75	10	27.68	Flakes	80	193.6	23	119.83	19	109.22	122	422.65
Cores									Cores	8	211.56	4	146.69	3	359.84	15	718.09
Fragments									Fragments	14	19.39	4	69.64	5	106.75	23	195.78
Retouched products									Retouched products	4	27.55			1	14.9	5	42.45
Total	7	9.93			3	17.75	10	27.68	Total	106	452.1	31	336.16	28	590.71	165	1378.97

Table S9. Comparison of flint types and size-classes from the concentrations and dispersed materials in Xb1out unit.

C1	Serreta		Mariola		Beniaia		Total		C2	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
VS	11	8.64	8	10.84	3	3.95	22	23.43	VS	6	1.58	3	0.82	1	0.56	10	2.96
S	4	29.22	4	21.8			8	51.02	S	3	10.42					3	10.42
M	3	23.36			2	14.31	5	37.67	M	1	3.28					1	3.28
L									L								
VL	1	22.42					1	22.42	VL								
Total	19	83.64	12	32.64	5	18.26	36	134.54	Total	10	15.28	3	0.82	1	0.56	14	16.66
C3	Serreta		Mariola		Beniaia		Total		C4	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
VS	2	0.73	1	1.14	1	0.79	4	2.66	VS	4	3.52	1	0.75	3	1.97	8	6.24
S	1	9.24					1	9.24	S	1	5.28	1	6.82			2	12.1
M			1	5.27			1	5.27	M								
L			1	37.63			1	37.63	L								
VL			1	27.02			1	27.02	VL								
Total	3	9.97	4	71.06	1	0.79	8	81.82	Total	5	8.8	2	7.57	3	1.97	10	18.34
C5	Serreta		Mariola		Beniaia		Total		Dispersed	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
VS	6	6.15			1	2.94	7	9.09	VS	66	56.08	15	19	15	21.44	96	96.52
S	1	3.78					1	3.78	S	23	122.83	6	32.25	3	22.09	32	177.17
M					1	4.62	1	4.62	M	11	107.61	5	90.96	5	73.45	21	272.02
L									L	5	135.22	3	84.72	2	33.55	10	253.49
VL					1	10.19	1	10.19	VL	1	30.36	2	109.23	3	440.18	6	579.77
Total	7	9.93			3	17.75	10	27.68	Total	106	452.1	31	336.16	28	590.71	165	1378.97

Table S10. Comparison of flint types by type of products (F: flakes; R: retouched products; C: cores) and size-classes from the concentrations and dispersed materials in Xb1out unit.

C1	Serreta			Mariola			Beniaia			C2	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C		F	R	C	F	R	C	F	R	C
VS	9			7			2			VS	5			3			1		
S	3		1	4						S	3								
M	2						2			M	1								
L										L									
VL		1								VL									
Total	14	1	1	11			4			Total	9			3			1		
C3	Serreta			Mariola			Beniaia			C4	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C		F	R	C	F	R	C	F	R	C
VS	1			1			1			VS	4								3
S	1									S	1			1					
M				1						M									
L						1				L									
VL					1					VL									
Total	2			2	1	1	1			Total	5			1			3		
C5	Serreta			Mariola			Beniaia			Dispersed	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C		F	R	C	F	R	C	F	R	C
VS	6						1			VS	52			13			12		
S	1									S	20	2	1	5		1	2		
M							1			M	7	2	2	3		1	2	1	2
L										L	1		4	2		1	2		
VL							1			VL			1			1	1		1
Total	7						3			Total	80	4	8	23	4	19	1	3	

Table S11. Comparison of flint types and cortical groups from the concentrations and dispersed materials in Xb1out unit.

C1	Serreta		Mariola		Beniaia		Total		C2	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
0	4	7.84	4	9.11	3	9.68	11	26.63	0	7	9.99	3	0.82	1	0.56	11	11.37
0-25	3	8.95	4	6.17	1	5.34	8	20.46	0-25	1	2					1	2
25-50	4	2.64	2	8.78			6	11.42	25-50								
50-75	1	5.11	1	5.22			2	10.33	50-75								
75-100									75-100	1	3.28					1	3.28
100	2	17.02					2	17.02	100								
Total	14	41.56	11	29.28	4	15.02	29	85.86	Total	9	15.27	3	0.82	1	0.56	13	16.65
C3	Serreta		Mariola		Beniaia		Total		C4	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
0	1	0.17	1	5.27	1	0.79	3	6.23	0	1	5.28			2	0.34	3	5.62
0-25	1	9.24	1	1.14			2	10.38	0-25	1	1.52			1	1.63	2	3.15
25-50									25-50	2	1.15					2	1.15
50-75									50-75								
75-100									75-100								
100									100	1	0.85	1	6.82			2	7.67
Total	2	9.41	2	6.41	1	0.79	5	16.61	Total	5	8.8	1	6.82	3	1.97	9	17.59
C5	Serreta		Mariola		Beniaia		Total		Dispersed	Serreta		Mariola		Beniaia		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
0	4	6.73			2	7.56	6	14.29	0	38	42.1	5	11.13	9	25.88	52	79.11
0-25	1	0.64			1	10.19	2	10.83	0-25	30	109.01	4	14.2	8	52.17	42	175.38
25-50	1	0.75					1	0.75	25-50	2	3.78	5	15.99	2	31.17	9	50.94
50-75									50-75	3	6.6	2	21.68			5	28.28
75-100									75-100	3	16.34	3	46.68			6	63.02
100	1	1.81					1	1.81	100	4	15.77	4	10.15			8	25.92
Total	7	9.93			3	17.75	10	27.68	Total	80	193.6	23	119.83	19	109.22	122	422.65

Table S12. Type of product distribution from the concentrations and dispersed materials in Xb2out unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Flakes	39	70.91	104.9	40.06	Flakes	28	58.33	235.29	21.70	Flakes	176	65.67	768.19	46.35
Cores	2	3.64	66.2	25.28	Cores	9	18.75	695.54	64.14	Cores	10	3.73	306.22	18.48
Fragments	11	20.00	45.48	17.37	Fragments	8	16.67	115.72	10.67	Fragments	62	23.13	268.06	16.17
Retouched products	3	5.45	45.25	17.28	Retouched products	3	6.25	37.8	3.49	Retouched products	20	7.46	314.78	18.99
Total	55	100.00	261.83	100.00	Total	48	100.00	1084.35	100.00	Total	268	100.00	1657.25	100.00

Table S13. Size-class distribution from the concentrations and dispersed materials in Xb2out unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
VS	36	70.59	24.44	9.33	VS	16	33.33	24.44	2.25	VS	160	59.70	126.88	7.66
S	4	7.84	34.94	13.34	S	9	18.75	54.74	5.05	S	44	16.42	193.71	11.69
M	9	17.65	129	49.27	M	7	14.58	117.89	10.87	M	37	13.81	472.88	28.53
L	2	3.92	73.45	28.05	L	9	18.75	198.59	18.31	L	16	5.97	431.9	26.06
VL					VL	7	14.58	688.69	63.51	VL	11	4.10	431.88	26.06
Total	51	100.00	261.83	100.00	Total	48	100.00	1084.35	100.00	Total	268	100.00	1657.25	100.00

Table S14. Type of flint distribution from the concentrations and dispersed materials in Xb2out unit. Sums and percentages are not considering indeterminate materials.

C1					C2					Dispersed				
	<i>n</i>	%	Weight (g)	%		<i>n</i>	%	Weight (g)	%		<i>n</i>	%	Weight (g)	%
Serreta	36	70.59	149.09	58.99	Serreta	24	53.33	160.33	15.31	Serreta	128	57.66	543.25	34.72
Mariola	7	13.73	31.25	12.36	Mariola	12	26.67	185.17	17.69	Mariola	47	21.17	329.84	21.08
Beniaia	8	15.69	72.41	28.65	Beniaia	9	20.00	701.43	67.00	Beniaia	47	21.17	691.54	44.20
Indeterminate	4		9.08		Indeterminate	3		37.42		Indeterminate	46		92.62	
Total	51	100.00	252.75	100.00	Total	45	100.00	1046.93	100.00	Total	222	100.00	1564.63	100.00

Table S15. Cortex on flakes distribution from the concentrations and dispersed materials in Xb2out unit.

C1	<i>n</i>	%	C2	<i>n</i>	%	Dispersed	<i>n</i>	%
0	21	53.85	0	13	46.43	0	98	55.68
0-25	8	20.51	0-25	10	35.71	0-25	40	22.73
25-50	2	5.13	25-50	3	10.71	25-50	14	7.95
50-75	2	5.13	50-75			50-75	5	2.84
75-100	4	10.26	75-100			75-100	10	5.68
100	2	5.13	100	2	7.14	100	9	5.11
Total	39	100.00	Total	28	100.00	Total	176	100.00

Table S16. Thermoaltered material distribution from the concentrations and dispersed materials in Xb2out unit.

C1	<i>n</i>	%	C2	<i>n</i>	%	Dispersed	<i>n</i>	%
Thermoaltered	13	23.64	Thermoaltered	5	10.42	Thermoaltered	61	22.76
No thermoaltered	42	76.36	No thermoaltered	43	89.58	No thermoaltered	207	77.24
Total	55	100.00	Total	48	100.00	Total	268	100.00

Table S17. Elongation (EI) and carination (CI) indexes from the concentrations and dispersed materials in Xb2out unit.

C1	<i>n</i>	EI	CI	C2	<i>n</i>	EI	CI	Dispersed	<i>n</i>	EI	CI
Flakes	39	1.23	4.23	Flakes	28	1.32	3.59	Flakes	176	1.22	4.16
Retouched products	3	1.73	2.24	Retouched products	3	1.24	3.54	Retouched products	20	1.42	3.4

Table S18. Comparison of flint types and type of products from the concentrations and dispersed materials in Xb2out unit.

C1	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	26	64.49	4	6.04	7	30.34	37	100.87
Cores	1	24.13			1	42.07	2	66.2
Fragments	8	39.97	1	0.46			9	40.43
Retouched products	1	20.5	2	24.75			3	45.25
Total	36	149.09	7	31.25	8	72.41	51	252.75
C2	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	18	69.06	5	40.29	5	125.94	28	235.29
Cores	2	46.41	3	73.64	4	575.49	9	695.54
Fragments	3	37.55	2	40.75			5	78.3
Retouched products	1	7.31	2	30.49			3	37.8
Total	24	160.33	12	185.17	9	701.43	45	1046.93
Dispersed	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	98	356.36	34	132.38	29	247.16	161	735.9
Cores	3	72.07	4	94.94	3	139.21	10	306.22
Fragments	19	20.97	5	59.12	9	154.33	33	234.42
Retouched products	8	93.85	4	43.4	6	150.84	18	288.09
Total	128	543.25	47	329.84	47	691.54	222	1564.63

Table S19. Comparison of flint types and size-classes from the concentrations and dispersed materials in Xb2out unit.

C1	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	25	15.75	4	1.95	4	1.59	33	19.29
S	5	19.21	1	4.55	1	7.25	7	31.01
M	5	82.75	2	24.75	2	21.5	9	129
L	1	31.38			1	42.07	2	73.45
VL								
Total	36	149.09	7	31.25	8	72.41	51	252.75
C2	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	13	14.24	1	3.11			16	31.02
S	5	23.24	2	17.83	2	13.67	7	41.07
M	4	68.25	3	49.64			8	143.71
L	2	54.6	5	87.84	1	25.82	13	804.38
VL			1	26.75	6	661.94	10	728.18
Total	24	160.33	12	185.17	9	701.43	36	345.5
Dispersed	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	77	62.31	25	15.91	20	20.62	122	98.84
S	23	89.73	12	62.33	6	31.81	41	183.87
M	20	260.82	4	39.86	8	117.46	32	418.14
L	5	68.49	5	170.53	6	192.88	16	431.9
VL	3	61.9	1	41.21	7	328.77	11	431.88
Total	128	543.25	47	329.84	47	691.54	222	1564.63

Table S20. Comparison of flint types by type of products (F: flakes; R: retouched products; C: cores) and size-classes from the concentrations and dispersed materials in Xb2out unit.

C1	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C
VS	19			3			4		
S	4			1			1		
M	3	1	1		2		2		
L									1
VL									
Total	26	1	1	4	2		7		1
C2	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C
VS	11			1					
S	5			1			2		
M	1	1	1	1	1	1			
L	1		1	2	1	1			1
VL						1	3		3
Total	18	1	2	5	2	3	5		4
Dispersed	Serreta			Mariola			Beniaia		
	F	R	C	F	R	C	F	R	C
VS	59			21			14		
S	21	1		10	1	1	5	1	
M	12	5	3	1	2	1	7		1
L	3	2		1	1	2	1	3	1
VL	3			1			2	2	1
Total	98	8	3	34	4	4	29	6	3

Table S21. Comparison of flint types and cortical groups from the concentrations and dispersed materials in Xb2out unit.

C1	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	12	31.15	3	1.49	4	8.58	19	41.22
0-25	5	9	1	4.55	2	12.53	8	26.08
25-50	2	0.71					2	0.71
50-75	2	3.58					2	3.58
75-100	3	14.27			1	9.23	4	23.5
100	2	5.78					2	5.78
Total	26	64.49	4	6.04	7	30.34	37	100.87
C2	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	10	29.48	2	7.76	1	7.7	13	44.94
0-25	6	10.7	2	18.97	2	53.72	10	83.39
25-50	2	28.88			1	5.97	3	34.85
50-75								
75-100								
100			1	13.56	1	58.55	2	72.11
Total	18	69.06	5	40.29	5	125.94	28	235.29
Dispersed	Serreta		Mariola		Beniaia		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	53	95.51	14	19.92	22	81.8	89	197.23
0-25	26	152.77	10	29.77	2	16.66	38	199.2
25-50	8	56.7	4	49.7			12	106.4
50-75	3	10.51			1	18.96	4	29.47
75-100	3	13.19	4	25.23	2	69.07	9	107.49
100	5	27.68	2	7.76	2	60.67	9	96.11
Total	98	356.36	34	132.38	29	247.16	161	735.9

Table S22. Type of product distribution from the concentrations and dispersed materials in Xb1in unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%
Flakes	21	67.74	50.16	79.30	Flakes	31	58.49	35.4	55.42
Cores					Cores	1	1.89	12.3	19.25
Fragments	8	25.81	2.43	3.84	Fragments	21	39.62	16.18	25.33
Retouched products	2	6.45	10.66	16.85	Retouched products				
Total	31	100.00	63.25	100.00	Total	53	100.00	63.88	100.00
C3	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Flakes	14	77.78	18.28	39.53	Flakes	68	73.12	126.89	43.71
Cores					Cores	3	3.23	85.03	29.29
Fragments	3	16.67	24.87	53.78	Fragments	17	18.28	30.26	10.42
Retouched products	1	5.56	3.09	6.68	Retouched products	5	5.38	48.11	16.57
Total	18	100.00	46.24	100.00	Total	93	100.00	290.29	100.00

Table S23. Size-class distribution from the concentrations and dispersed materials in Xb1in unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%
VS	24	77.42	15.34	24.25	VS	46	86.79	29.65	46.42
S	4	12.90	15.72	24.85	S	6	11.32	26.88	42.08
M	2	6.45	16.78	26.53	M	1	1.89	7.35	11.51
L	1	3.23	15.41	24.36	L				
VL					VL				
Total	31	100.00	63.25	100.00	Total	53	100.00	63.88	100.00
C3	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
VS	12	66.67	6.85	14.81	VS	64	68.82	46.86	16.14
S	5	27.78	15.37	33.24	S	17	18.28	69.72	24.02
M	1	5.56	24.02	51.95	M	7	7.53	60.7	20.91
L					L	5	5.38	113.01	38.93
VL					VL				
Total	18	100.00	46.24	100.00	Total	93	100.00	290.29	100.00

Table S24. Type of flint distribution from the concentrations and dispersed materials in Xb1in unit. Sums and percentages are not considering indeterminate materials.

C1	<i>n</i>	%	Weight (g)	%	C3	<i>n</i>	%	Weight (g)	%
Serreta	11	47.83	20.9	34.10	Serreta	11	68.75	8.35	42.86
Mariola	9	39.13	23.88	38.96	Mariola	5	31.25	11.13	57.14
Beniaia	3	13.04	16.51	26.94	Beniaia				
Font Roja					Font Roja				
Indeterminate	8		1.96		Indeterminate	2		26.76	
Total	23	100.00	61.29	100.00	Total	16	100.00	19.48	100.00
C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Serreta	21	55.26	42.08	75.28	Serreta	40	51.28	90.93	32.53
Mariola	10	26.32	3.86	6.91	Mariola	28	35.90	160.91	57.57
Beniaia	5	13.16	6.5	11.63	Beniaia	8	10.26	18.9	6.76
Font Roja	2	5.26	3.46	6.19	Font Roja	2	2.56	8.78	3.14
Indeterminate	15		7.98		Indeterminate	15		10.77	
Total	38	100.00	55.9	100.00	Total	78	100.00	279.52	100.00

Table S25. Cortex on flakes distribution from the concentrations and dispersed materials in Xb1in unit.

C1	<i>n</i>	%	C2	<i>n</i>	%
0	11	52.38	0	17	54.84
0-25	5	23.81	0-25	9	29.03
25-50	1	4.76	25-50	1	3.23
50-75	1	4.76	50-75	1	3.23
75-100	1	4.76	75-100	1	3.23
100	2	9.52	100	2	6.45
Total	21	100.00	Total	31	100.00
C3	<i>n</i>	%	Dispersed	<i>n</i>	%
0	9	64.29	0	32	47.06
0-25	3	21.43	0-25	17	25.00
25-50			25-50	7	10.29
50-75	1	7.14	50-75	4	5.88
75-100			75-100	3	4.41
100	1	7.14	100	5	7.35
Total	14	100.00	Total	68	100.00

Table S26. Thermoaltered material distribution from the concentrations and dispersed materials in Xb1in unit.

C1	<i>n</i>	%	C2	<i>n</i>	%
Thermoaltered	9	29.03	Thermoaltered	17	32.08
No thermoaltered	22	70.97	No thermoaltered	36	67.92
Total	31	100.00	Total	53	100.00
C3	<i>n</i>	%	Dispersed	<i>n</i>	%
Thermoaltered	4	22.22	Thermoaltered	18	19.35
No thermoaltered	14	77.78	No thermoaltered	75	80.65
Total	18	100.00	Total	93	100.00

Table S27. Elongation (EI) and carination (CI) indexes from the concentrations and dispersed materials in Xb1in unit.

C1	n	EI	CI	C2	n	EI	CI
Flakes	21	1.14	3.81	Flakes	31	1.16	2.9
Retouched products	2	1.77	3.35	Retouched products			
C3	n	EI	CI	Dispersed	n	EI	CI
Flakes	14	1.31	3.74	Flakes	68	1.13	3.47
Retouched products	1	1.57	2.11	Retouched products	4	1.23	3.01

Table S28. Comparison of flint types and type of products from the concentrations and dispersed materials in Xb1in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Total		C2	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
Flakes	10	14.61	6	18.3	3	16.51			19	49.42	Flakes	14	23.41	8	3.25	4	5.6	1	0.77	27	33.03
Cores											Cores	1	12.3							1	12.3
Fragments			2	1.21					2	1.21	Fragments	6	6.37	2	0.61	1	0.9	1	2.69	10	10.57
Retouched products	1	6.29	1	4.37					2	10.66	Retouched products										
Total	11	20.9	9	23.88	3	16.51			23	61.29	Total	21	42.08	10	3.86	5	6.5	2	3.46	38	55.9
C3	Serreta		Mariola		Beniaia		Font Roja		Total		Dispersed	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
Flakes	9	7.5	4	8.04					13	15.54	Flakes	31	50.1	19	44.1	8	18.9	2	8.78	60	121.88
Cores											Cores	1	14.75	2	70.28					3	85.03
Fragments	2	0.85							2	0.85	Fragments	6	5.38	5	21					11	26.38
Retouched products			1	3.09					1	3.09	Retouched products	2	20.7	2	25.53					4	46.23
Total	11	8.35	5	11.13					16	19.48	Total	40	90.93	28	160.91	8	18.9	2	8.78	78	279.52

Table S29. Comparison of flint types and size-classes from the concentrations and dispersed materials in Xb1in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Total		C2	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
VS	8	9.55	6	2.73	2	1.1			16	13.38	VS	16	12.64	9	2.18	4	3.39	2	3.46	31	21.67
S	3	11.35	1	4.37					4	15.72	S	4	22.09	1	1.68	1	3.11			6	26.88
M			2	16.78					2	16.78	M	1	7.35							1	7.35
L					1	15.41			1	15.41	L										
VL											VL										
Total	11	20.9	9	23.88	3	16.51			23	61.29	Total	21	42.08	10	3.86	5	6.5	2	3.46	38	55.9
C3	Serreta		Mariola		Beniaia		Font Roja		Total		Dispersed	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
VS	10	5.74	2	1.11					12	6.85	VS	28	19.19	15	11.59	5	4.84	1	0.47	49	36.09
S	1	2.61	3	10.02					4	12.63	S	7	32.4	7	20.3	2	8.71	1	8.31	17	69.72
M											M	5	39.34	1	16.01	1	5.35			7	60.7
L											L			5	113.01					5	113.01
VL											VL										
Total	11	8.35	5	11.13					16	19.48	Total	40	90.93	28	160.91	8	18.9	2	8.78	78	279.52

Table S30. Comparison of flint types by type of products (F: flakes; R: retouched products; C: cores) and size-classes from the concentrations and dispersed materials in Xb1in unit.

C1	Serreta			Mariola			Beniaia			Font Roja			C2	Serreta			Mariola			Beniaia			Font Roja		
	F	R	C	F	R	C	F	R	C	F	R	C		F	R	C	F	R	C	F	R	C	F	R	C
VS	8			4			2						VS	11			7			3			1		
S	2	1			1								S	2	1	1			1						
M				2									M	1											
L							1						L												
VL													VL												
Total	10	1		6	1		3						Total	14	1	8			4			1			
C3	Serreta			Mariola			Beniaia			Font Roja			Dispersed	Serreta			Mariola			Beniaia			Font Roja		
	F	R	C	F	R	C	F	R	C	F	R	C		F	R	C	F	R	C	F	R	C	F	R	C
VS	8			2									VS	23			11			5			1		
S	1			2	1								S	6	1	7			2			1			
M													M	2	2				1						
L													L			1	2	2							
VL													VL												
Total	9			4	1								Total	31	2	1	19	2	2	8			2		

Table S31. Comparison of flint types and cortical groups from the concentrations and dispersed materials in Xb1in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Total		C2	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
0	6	10.45	2	7.36	1	1.06			9	18.87	0	6	4.72	7	1.57	2	0.67			15	6.96
0-25	2	2.15	2	1	1	0.04			5	3.19	0-25	6	11.17	1	1.68			1	0.77	8	13.62
25-50			1	0.27					1	0.27	25-50	1	0.71			1	3.11			2	3.82
50-75			1	9.67					1	9.67	50-75										
75-100	1	0.33							1	0.33	75-100										
100	1	1.68			1	15.41			2	17.09	100	1	6.81			1	1.82			2	8.63
Total	10	14.61	6	18.3	3	16.51			19	49.42	Total	14	23.41	8	3.25	4	5.6	1	0.77	27	33.03
C3	Serreta		Mariola		Beniaia		Font Roja		Total		Dispersed	Serreta		Mariola		Beniaia		Font Roja		Total	
	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)		n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)
0	5	2.38	3	7.31					8	9.69	0	14	13.84	7	6.97	7	17.45			28	38.26
0-25	2	2.16	1	0.73					3	2.89	0-25	8	12.13	6	9.85	1	1.45	1	0.47	16	23.9
25-50									0		25-50	3	11.88	2	3.13			1	8.31	6	23.32
50-75	1	0.35							1	0.35	50-75	3	3.9	1	17.2					4	21.1
75-100											75-100			3	6.95					3	6.95
100	1	2.61							1	2.61	100	3	8.35							3	8.35
Total	9	7.5	4	8.04					13	15.54	Total	31	50.1	19	44.1	8	18.9	2	8.78	60	121.88

Table S32. Type of product distribution from the concentrations and dispersed materials in Xb2in unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Flakes	89	76.07	163.35	48.25	Flakes	46	71.88	54.69	49.42	Flakes	250	71.63	525.91	50.66
Cores	2	1.71	75.64	22.34	Cores	1	1.56	19.98	18.05	Cores	10	2.87	290.79	28.01
Fragments	20	17.09	11.63	3.43	Fragments	16	25.00	30.36	27.43	Fragments	78	22.35	99.19	9.55
Retouched products	6	5.13	87.96	25.98	Retouched products	1	1.56	5.64	5.10	Retouched products	11	3.15	122.24	11.78
Total	117	100.00	338.58	100.00	Total	64	100.00	110.67	100.00	Total	349	100.00	1038.13	100.00

Table S33. Size-class distribution from the concentrations and dispersed materials in Xb2in unit.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
VS	86	73.50	66.65	19.69	VS	53	82.81	36.81	33.26	VS	251	71.92	191.42	18.44
S	22	18.80	81.89	24.19	S	8	12.50	35.21	31.82	S	64	18.34	280.56	27.03
M	4	3.42	39.75	11.74	M	3	4.69	38.65	34.92	M	25	7.16	275.95	26.58
L	5	4.27	150.29	44.39	L				0.00	L	5	1.43	170.85	16.46
VL					VL				0.00	VL	4	1.15	119.35	11.50
Total	117	100.00	338.58	100.00	Total	64	100.00	110.67	100.00	Total	349	100.00	1038.13	100.00

Table S34. Type of flint distribution from the concentrations and dispersed materials in Xb2in unit. Sums and percentages are not considering indeterminate materials.

C1	<i>n</i>	%	Weight (g)	%	C2	<i>n</i>	%	Weight (g)	%	Dispersed	<i>n</i>	%	Weight (g)	%
Serreta	44	42.31	67.09	20.24	Serreta	30	53.57	25.14	26.29	Serreta	156	53.24	407.37	41.73
Mariola	27	25.96	117.16	35.35	Mariola	14	25.00	24.56	25.69	Mariola	88	30.03	191.15	19.58
Beniaia	17	16.35	109.07	32.91	Beniaia	11	19.64	36.42	38.09	Beniaia	42	14.33	332.92	34.11
Font Roja	14	13.46	29.7	8.96	Font Roja					Font Roja	3	1.02	29.53	3.03
Catamarruc	2	1.92	8.41	2.54	Catamarruc	1	1.79	9.5	9.94	Catamarruc	4	1.37	15.13	1.55
Indeterminate	13		7.15		Indeterminate	8		15.05		Indeterminate	56		62.03	
Total	104	100.00	331.43	100.00	Total	56	100.00	95.62	100.00	Total	293	100.00	976.1	100.00

Table S35. Cortex on flakes distribution from the concentrations and dispersed materials in Xb2in unit.

C1	<i>n</i>	%	C2	<i>n</i>	%	Dispersed	<i>n</i>	%
0	44	49.44	0	29	63.04	0	144	57.60
0-25	19	21.35	0-25	10	21.74	0-25	55	22.00
25-50	5	5.62	25-50	4	8.70	25-50	20	8.00
50-75	4	4.49	50-75	1	2.17	50-75	9	3.60
75-100	10	11.24	75-100	1	2.17	75-100	13	5.20
100	7	7.87	100	1	2.17	100	9	3.60
Total	89	100.00	Total	46	100.00	Total	250	100.00

Table S36. Thermoaltered material distribution from the concentrations and dispersed materials in Xb2in unit.

C1	<i>n</i>	%	C2	<i>n</i>	%	Dispersed	<i>n</i>	%
Thermoaltered	16	13.68	Thermoaltered	10	15.63	Thermoaltered	96	27.51
No thermoaltered	101	86.32	No thermoaltered	54	84.38	No thermoaltered	253	72.49
Total	117	100.00	Total	64	100.00	Total	349	100.00

Table S37. Elongation (EI) and carination (CI) indexes from the concentrations and dispersed materials in Xb2in unit.

C1	<i>n</i>	EI	CI	C2	<i>n</i>	EI	CI	Dispersed	<i>n</i>	EI	CI
Flakes	89	1.12	3.62	Flakes	46	1.2	3.72	Flakes	250	1.18	3.95
Retouched products	6	1.23	2.73	Retouched products	1	1.94	2.25	Retouched products	11	1.3	2.99

Table S38. Comparison of flint types and type of products from the concentrations and dispersed materials in Xb2in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	32	36.79	22	65.02	14	19.21	14	29.7	2	8.41	84	159.13
Cores			1	34.13	1	41.51					2	75.64
Fragments	9	4.97	3	3.73							12	8.7
Retouched products	3	25.33	1	14.28	2	48.35					6	87.96
Total	44	67.09	27	117.16	17	109.07	14	29.7	2	8.41	104	331.43
C2	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	24	18.47	10	22.77	7	4.91					41	46.15
Cores					1	19.98					1	19.98
Fragments	6	6.67	4	1.79	3	11.53			1	9.5	14	29.49
Retouched products												
Total	30	25.14	14	24.56	11	36.42			1	9.5	56	95.62
Dispersed	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
Flakes	122	228.1	71	111.92	34	123.33	3	29.53	3	14.32	233	507.2
Cores	5	89.79	2	45.13	3	155.87					10	290.79
Fragments	24	46.81	12	13.87	3	2.44			1	0.81	40	63.93
Retouched products	5	42.67	3	20.23	2	51.28					10	114.18
Total	156	407.37	88	191.15	42	332.92	3	29.53	4	15.13	293	976.1

Table S39. Comparison of flint types and size-classes from the concentrations and dispersed materials in Xb2in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	35	21.18	18	15.01	11	7.61	9	18.21	1	0.64	74	62.65
S	7	33.29	5	14.59	3	11.6	5	11.49	1	7.77	21	78.74
M	2	12.62	1	14.28	1	12.85					4	39.75
L			3	73.28	2	77.01					5	150.29
VL												
Total	44	67.09	27	117.16	17	109.07	14	29.7	2	8.41	104	331.43
C2	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	27	13.96	11	6.11	9	10.66					47	30.73
S	3	11.18	2	9.28	1	5.78					6	26.24
M			1	9.17	1	19.98			1	9.5	3	38.65
L												
VL												
Total	30	25.14	14	24.56	11	36.42	0	0	1	9.5	56	95.62
Dispersed	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
VS	116	92.52	60	44.07	23	19.3	1	0.36	2	2.97	202	159.22
S	26	129.17	24	88.04	7	33.22			1	5.08	58	255.51
M	12	132.34	3	48.8	6	53.78	2	29.17	1	7.08	24	271.17
L	1	6.34	1	10.24	3	154.27					5	170.85
VL	1	47			3	72.35					4	119.35
Total	156	407.37	88	191.15	42	332.92	3	29.53	4	15.13	293	976.1

Table S40. Comparison of flint types by type of products (F: flakes; R: retouched products; C: cores) and size-classes from the concentrations and dispersed materials in Xb2in unit.

C1	Serreta			Mariola			Beniaia			Font Roja			Catamarruc		
	F	R	C	F	R	C	F	R	C	F	R	C	F	R	C
VS	26			16			11			9			1		
S	5	2		4			3			5			1		
M	1	1			1			1							
L				2		1		1	1						
VL															
Total	32	3		22	1	1	14	2	1	14			2		
C2	Serreta			Mariola			Beniaia			Font Roja			Catamarruc		
	F	R	C	F	R	C	F	R	C	F	R	C	F	R	C
VS	22			7			7								
S	2			2											
M				1					1						
L															
VL															
Total	24			10			7		1						
Dispersed	Serreta			Mariola			Beniaia			Font Roja			Catamarruc		
	F	R	C	F	R	C	F	R	C	F	R	C	F	R	C
VS	95	1		49			20			1			1		
S	19	1	2	20	3		7						1		
M	6	3	3	1		2	5		1	2			1		
L	1			1			1	1	1						
VL	1						1	1	1						
Total	122	5	5	71	3	2	34	2	3	3			3		

Table S41. Comparison of flint types and cortical groups from the concentrations and dispersed materials in Xb2in unit.

C1	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	17	14.23	13	10.82	9	9.3	1	1.61			40	35.96
0-25	3	2.33	3	9.31	2	0.61	10	20.19	1	0.64	19	33.08
25-50	2	0.37	1	1.21	2	9.13					5	10.71
50-75	1	0.71	1	0.36			2	4.7			4	5.77
75-100	5	9.26	2	23.3	1	0.17	1	3.2	1	7.77	10	43.7
100	4	9.89	2	20.02							6	29.91
Total	32	36.79	22	65.02	14	19.21	14	29.7	2	8.41	84	159.13
C2	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	16	9.22	5	1.84	4	2.96					25	14.02
0-25	4	2.51	3	15.21	3	1.95					10	19.67
25-50	3	5.24	1	0.39							4	5.63
50-75												
75-100	1	1.5									1	1.5
100			1	5.33							1	5.33
Total	24	18.47	10	22.77	7	4.91					41	46.15
Dispersed	Serreta		Mariola		Beniaia		Font Roja		Catamarruc		Total	
	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)	<i>n</i>	Weight (g)
0	70	77.71	42	47.96	17	21.78	1	0.36			130	147.81
0-25	30	45.3	13	24.16	8	34.47	1	15.49	1	5.08	53	124.5
25-50	9	18.97	9	10.86	1	2.34			1	2.16	20	34.33
50-75	4	14.17	2	18.99	2	16.17					8	49.33
75-100	8	71.6	1	0.44	3	30.43			1	7.08	13	109.55
100	1	0.35	4	9.51	3	18.14	1	13.68			9	41.68
Total	122	228.1	71	111.92	34	123.33	3	29.53	3	14.32	233	507.2

Table S42. Distance ranges of refitting lines by AUs and flint types.

Distance (m)	Serreta	Mariola	Beniaia	Font Roja	Catamarruc
Xb1out					
<0.5					
0.5-1					
1-2	1				
2-3	1				
Xb2out					
<0.5	1				
0.5-1					
1-2					
2-3					
Xb1in					
<0.5					
0.5-1					
1-2					
2-3					
Xb2in					
<0.5	5	3		6	
0.5-1		1			1
1-2				2	
2-3					

Comprehensive description of lithic assemblages within AUs

AU Xb1out

C1 comprises 43 lithic products weighing 147g. This cluster is characterised by the prevalence of Serreta flint type (53%), followed by Mariola (33%) and Beniaia (14%). These three groups mainly consist of very small and small flakes within their assemblages. Only one core and one retouched product, both made from Serreta flint type, are recorded. Approximately, 26% of the materials within this cluster exhibit signs of thermal alteration. The majority of the flakes within the three flint types display low to medium cortical percentages, falling into the groups of 0%, 0-25%, and 25-50%. C2 encompasses 15 lithic remains with a total weight of 17g. This cluster is defined by the predominance of Serreta flint type (71%), trailed by Mariola (21%) and Beniaia (7%). These assemblages are once again composed of very small and small flakes. No cores and retouched products have been noted. Roughly 7% of the materials within this cluster show signs of thermal alteration. The majority of the flakes, regardless of the flint type, exhibit minimal cortical percentages, with 85% categorised as 0%.

C3 contains 12 lithic products weighing 87g. This cluster is defined by the prevalence of very small and small flakes and fragments, primarily crafted from Mariola (50%), followed by Serreta (38%) and Beniaia (12%) flint types. Notably, one large core and one very large retouched product (both from Mariola flint type) are present, both collectively accounting for around 74% of the total weight. Around 34% of the materials within this cluster exhibit signs of thermal alteration. All the flakes display low cortical percentages, falling into the categories of 0% and 0-25%. C4 comprises 10 lithic remains (18g). This cluster is exclusively composed of very small and small flakes (n9) and one fragment. Within this short assemblage, the three principal flint types are represented, with Serreta being the predominant type (50%), followed by Beniaia (30%) and Mariola (20%). Two thermoaltered products, accounting for 20% of the assemblage, are identified. Regarding the flakes, nearly all cortical categories are present: 3 in 0%, 2 in 0-25%, 2 in 25-50% and 2 in 100%, the latter from Serreta and Mariola flint types. C5 contains 13 lithic products, with a total weight of 29g. This cluster is defined by containing flakes of very small and small size, primarily of the Serreta flint type (70%) and a mix of very small, medium and very large flakes in the case of Beniaia (30%). Mariola flint type is notably absent. Interestingly, these percentages shift when the weight is considered: Serreta (36%) and Beniaia (64%). No cores and retouched products have been identified. In this assemblage, 31% of the remains present signs of thermoalteration. Lastly, among the flakes, there is a predominance of low cortical categories (ranging from 0% to 50%) within the two flint types.

Dispersed materials represent the majority of this AU assemblage, encompassing 211 lithic products with a combined weight of 1,479g. This group is predominantly composed of Serreta (64%), followed by Mariola (19%) and Beniaia (17%) flint types. However, the weight distribution tells a different story. In this case, Beniaia is the most prominent (591g), followed by Serreta (452g) and Mariola (336g). This variance can be attributed to the weight of Beniaia cores. These three flint types share a similar distribution of product types and sizes: a major part of each 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, unless the Mariola flint type that lacks retouched

elements. On the other hand, 26% of the products exhibit signs of thermoalteration. Considering cortical representation on flakes, Serreta and Mariola predominantly feature low cortical percentages (0% to 25%), while also containing several products in higher categories (>50%). In contrast, these higher categories are absent in the Beniaia flint type.

AU Xb2out

C1 contains 55 lithic remains, totaling a weight of 262g. This cluster is dominated by the Serreta flint type (70%), followed by Mariola (14%) and Beniaia (16%), with a fairly even weight distribution among them. Very small and small flakes are present across all three flint types, while cores are specific to the Serreta (medium-sized) and Beniaia (large-sized) types, and retouched products appear in both the Serreta (medium-sized) and Mariola (medium-sized) types. Around 24% of the materials within this cluster display signs of thermoalteration. The majority of the flakes in the three flint types display low to medium cortical percentages, primarily falling within the groups of 0% and 0-25%. Notably, the Serreta flint type is the only one with representation in all the cortical categories.

C2 consists of 48 lithic products, weighing a total of 1,084g. This assemblage is predominantly composed of Serreta (53%), followed by Mariola (27%) and Beniaia (20%) flint types. Nevertheless, the distribution of weights takes a different trajectory. In this cluster, Beniaia holds the highest weight (701g), followed by Mariola (185g) and Serreta (160g). This variation can be attributed once again to the weight of Beniaia cores (large and very large), as well as flakes (mostly very small in Serreta and small to very large in Beniaia). The Mariola flint type, on the other hand, presents larger products compared to Serreta, closer in size to Beniaia, but they are not as weighty. Fig. 8 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. Another notable difference is that, while all types of products are represented in Serreta and Mariola flint types, Beniaia lacks fragments and retouched elements. On the other hand, about 10% of the products exhibit signs of thermal alteration. Regarding cortical representation on flakes, Serreta stands as the sole type with representation across all cortical categories. Mariola is primarily characterised by low cortical percentages (0% to 25%), while Beniaia lacks representation in the medium categories.

Dispersed materials comprise 268 lithic products, with a collective weight of 1,657g. This group exhibits a prevailing presence of Serreta flint type (58%), followed by 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 (692g), Serreta (543g) and Mariola (330g). Within products, all three flint types present flakes, retouched products, fragments and cores. The two latter are specially weighty and very large products in the case of Beniaia, which could account for the observed reordering of flint proportions. Approximately, 23% of the assemblage displays indications of thermoalteration. In terms of cortical representation, the preponderance of minor percentages (0% to 50%) is evident across the three flint types. However, it is noteworthy that the Serreta type once again encompasses all cortical categories, whereas the Mariola and Beniaia types lack medium cortical categories.

AU Xb1in

C1 contains 31 lithic remains, with a collective weight of 63g. This cluster showcases a dominance of Serreta (47%), followed by Mariola (39%) and Beniaia (13%). These three flint types primarily consist of flakes, with some retouched products in both Serreta and Mariola types. Interestingly, no cores have been identified in this cluster. A preponderance of very small and small products is noted in the three flint types, including the retouched elements. The 29% of the assemblage exhibits indicators of thermal alteration. Notably, within the flakes, a complete range of cortical categories is present, with the dominance in the minor groups in the three flint types (0% to 25%).

C2 comprises 38 lithic products, weighing a total of 56g. 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. Around 32% of the elements show signs of thermal alteration. Lastly, the flake assemblage predominantly displays low corticality (0% to 25%), although a few examples of full corticality are discernible in Serreta and Beniaia flint types. C3 encompasses 16 lithic products, weighing 19g. This cluster is exclusively composed of Serreta (69%) and Mariola (31%) flint types, with a notable prevalence of very small and small flakes, particularly evident in the Serreta type. We identified a retouched product crafted from Mariola flint type, while no cores have been recognised. The 22% of the assemblage demonstrates indications of thermoalteration. Notably, while the Serreta flint type is represented across nearly all cortical categories, the representation of Mariola type is confined to the minor groups (0% to 25%).

Dispersed materials comprise 93 lithic products, collectively weighing 290g. In this instance, we once again identified the four flint types, ranked as follows: Serreta (51%), Mariola (36%), Beniaia (10%), and Font Roja (3%). 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. Roughly 19% of this cluster shows signs of thermoalteration. In terms of flake assemblages, the entire spectrum of cortical categories is present in Serreta and Mariola flint types, while Beniaia and Font Roja exclusively exhibit products falling within the minor groups (0% to 50%).

AU Xb2in

C1 encompasses 117 lithic products, with a total weight of 339g. 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 (117g) at the forefront, followed by Beniaia (109g) and Serreta (67g). 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. The 14% of the

assemblage presents evidence of thermal alteration. In terms of cortical representation, Serreta and Mariola offer a full representation of cortical categories, with a prevalence of minor groups. Meanwhile, Beniaia, Font Roja and Catamarruc predominantly present elements within the minor categories, but also feature items in higher groups, exceeding the 50%. C2 consists of 64 lithic products, weighing 111g. 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 (36g), followed by Serreta (25g), Mariola (24g) and Catamarruc (10g). 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, with the exception of a medium-sized core within the Beniaia assemblage. The 16% of this cluster exhibits signs of thermoalteration. In terms of cortical representation, flakes mainly fall within the lower cortical categories (0% to 50%) across the three flint types.

Dispersed materials comprise 349 lithic remains, with a combined weight totaling 1,038g. This group exhibits a prevailing presence of Serreta flint type (53%), followed by Mariola (30%), Beniaia (14%), Catamarruc (1%) and Font Roja (1%). Interestingly, the weight distribution in this group has little impact on the order: Serreta maintains its position (407g), followed in this case by Beniaia (333g), Mariola (191g), Font Roja (30g) and Catamarruc (15g). 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 size. In the case of Font Roja and Catamarruc flint types, they are restricted to very small and small flakes. Approximately, 28% of the assemblage displays signs of thermal alteration. The representation of cortical surfaces indicates a preponderance of minor percentages (0% to 50%) across the three principal flint types, although they also feature elements in other categories. In the case of Font Roja and Catamarruc, their flakes are distributed across several groups, but they lack some of them.

Appendix III

Supplementary material for:

**Knapping... sleeping and consuming? Spatial
variability in the high-resolution Neanderthal context of
Abric del Pastor (Alcoi, eastern Iberia)**

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Carolina Mallol, Laura Sánchez-Romero, Manuel Vaquero, Cristo M. Hernández

Extended site background

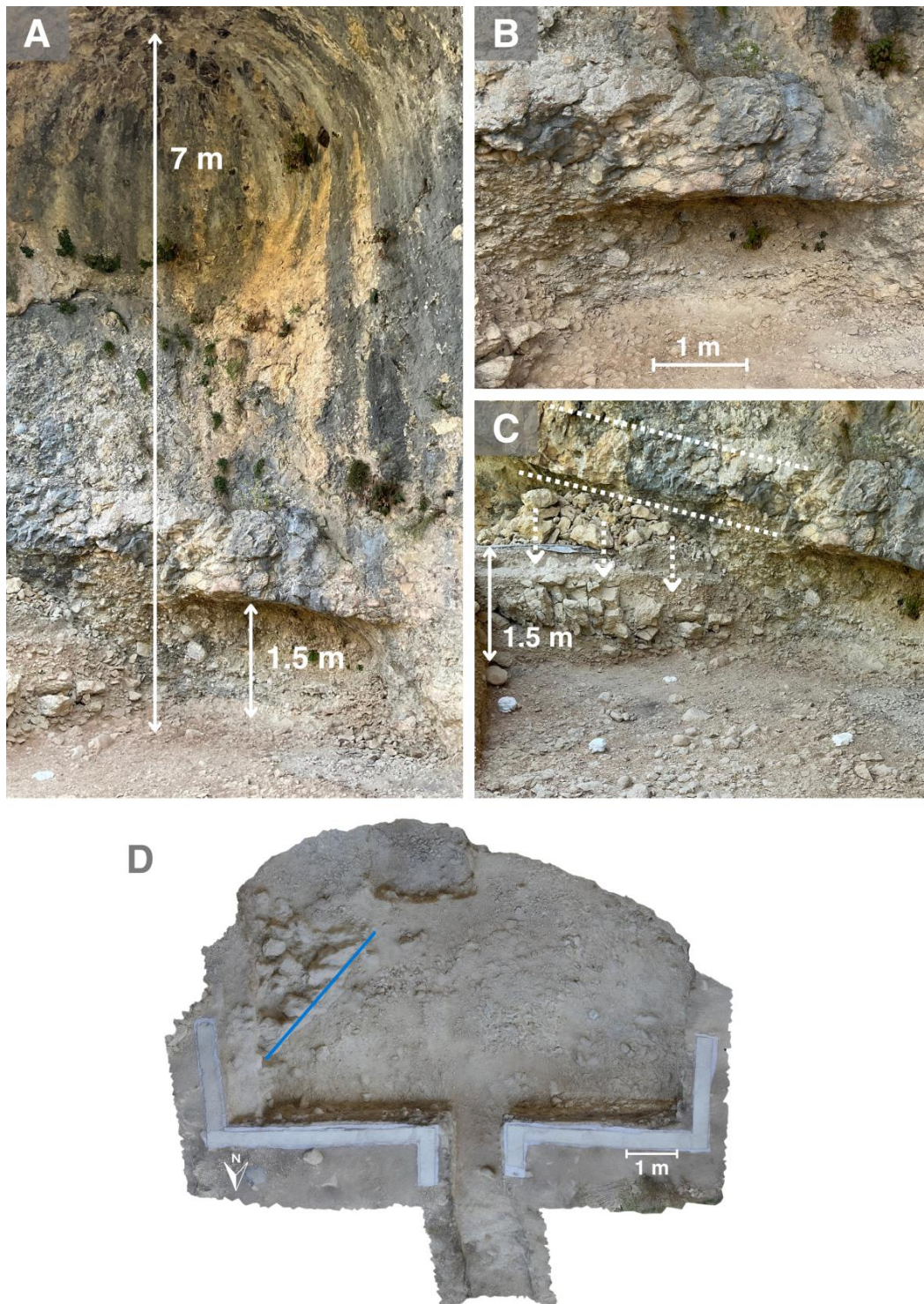


Fig. S1. Picture of the roof representing the Drip Line (A), the remaining limestone Ledge in the southeast (B), the other part of the ledge, which collapsed during SU IV (C), and a top view picture showing the fallen blocks from the ledge during the excavation of SU IV (D).

Extended methods

n-Alkane analysis

Gas chromatography-mass spectrometry (GC-MS)

n-Alkane extracts were analysed using a gas chromatography (GC) system coupled to a single quadrupole (Q) mass spectrometer (MS) (GC-Agilent 7890B, MSD Agilent 5977A), equipped with a multimode injector (MMI) and an HP-5MS capillary column ((5%-phenyl)-methylpolysiloxane phase, 30 m length x 0.25 mm i.d., 0.25 mm film thickness). The MMI temperature was initially programmed at 70 °C for 0.85 min and then ramped to 300 °C at a rate of 720 °C/min. Injections were performed in split mode at a ratio of 5:1. The GC was initially set at 70 °C for 2 min, followed by a ramp to 140 °C at a rate of 12 °C/min, and finally to 320 °C at a rate of 6 °C/min, with a hold time of 16 min. Helium flow was maintained at 1.0 mL/min, and the total run time was 53.83 min. The MS operated in full-scan mode (m/z 40-580), with an electron ionization energy of -70 eV. The transfer line temperature was set to 280 °C, with the ion source at 230 °C and the quadrupole at 150 °C.

n-Alkanes were identified by comparison of their retention times and mass spectra with those of reference compounds (mix *n*-alkanes C₈-C₄₀, 500 mg/L in DCM) and using the NIST mass spectra library (v. 2.2). *n*-Alkane concentrations were estimated by comparing the areas of the analytes of interest to those of known quantities of the internal standard. Concentrations were normalized to the sample weight and expressed in ng/g sample.

Carbon Preference Index (CPI) calculation

Even/odd numbered *n*-alkanes distribution was evaluated by calculating the Carbon Preference Index (CPI₁₉₋₃₃) using the revised formula proposed by Marzi et al. (1993):

$$\text{CPI}_{19-33} = \frac{(C_{19} + C_{21} + C_{23} + C_{25} + C_{27} + C_{29} + C_{31}) + (C_{21} + C_{23} + C_{25} + C_{27} + C_{29} + C_{31} + C_{33})}{2 (C_{20} + C_{22} + C_{24} + C_{26} + C_{28} + C_{30} + C_{32})}$$

where C₁₉ to C₃₃ are the estimated concentrations of the compounds.

References

Marzi, R., Torkelson, B.E., Olson, R.K., 1993. A revised carbon preference index. *Organic Geochemistry* 20, 1303–1306. [https://doi.org/10.1016/0146-6380\(93\)90016-5](https://doi.org/10.1016/0146-6380(93)90016-5)

Extended results

Table S1. Average Nearest Neighbour results for lithic assemblages.

	Lithics (all)	Serreta	Mariola	Beniaia
Ratio	0.6736	0.6837	0.5969	0.8520
Z-score	-7.5700	-4.6861	-5.8718	-1.2005
p-value	0.0000	0.0000	0.0000	0.2299
Expected mean distance	0.2608	0.4082	0.4152	0.7453
Observed mean distance	0.1756	0.2791	0.2478	0.6351

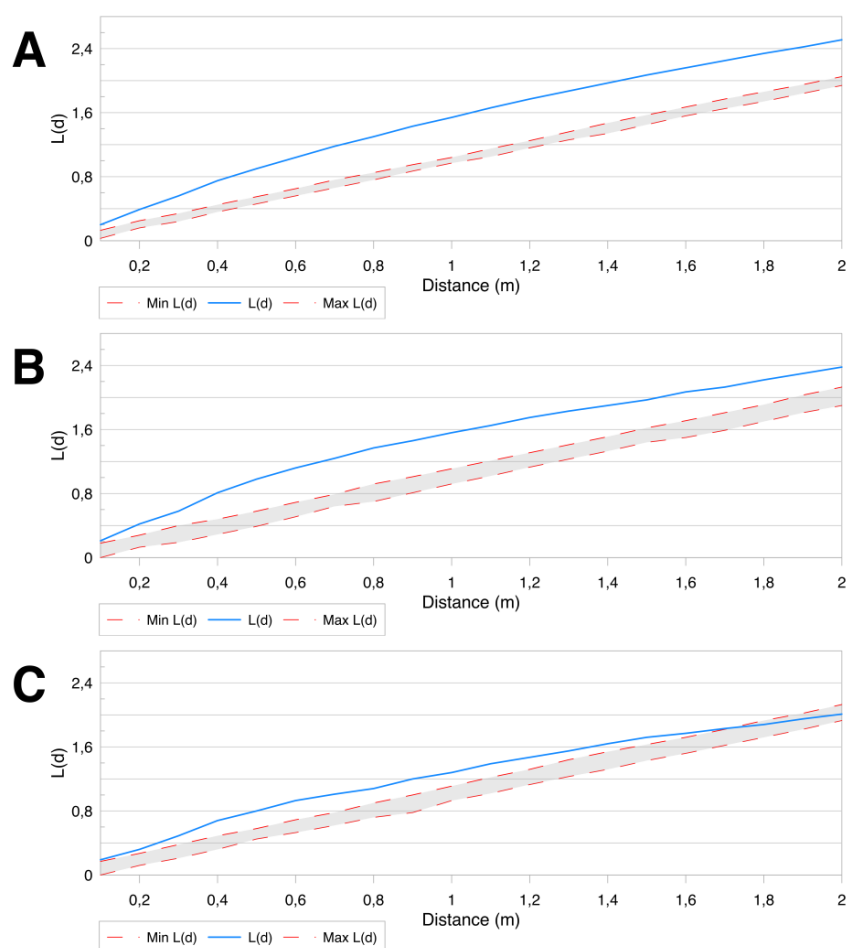


Fig. S2. Homogeneous Ripley L -function results for **A)** the entire lithic assemblage **B)** Serreta flint type and **C)** Mariola flint type.

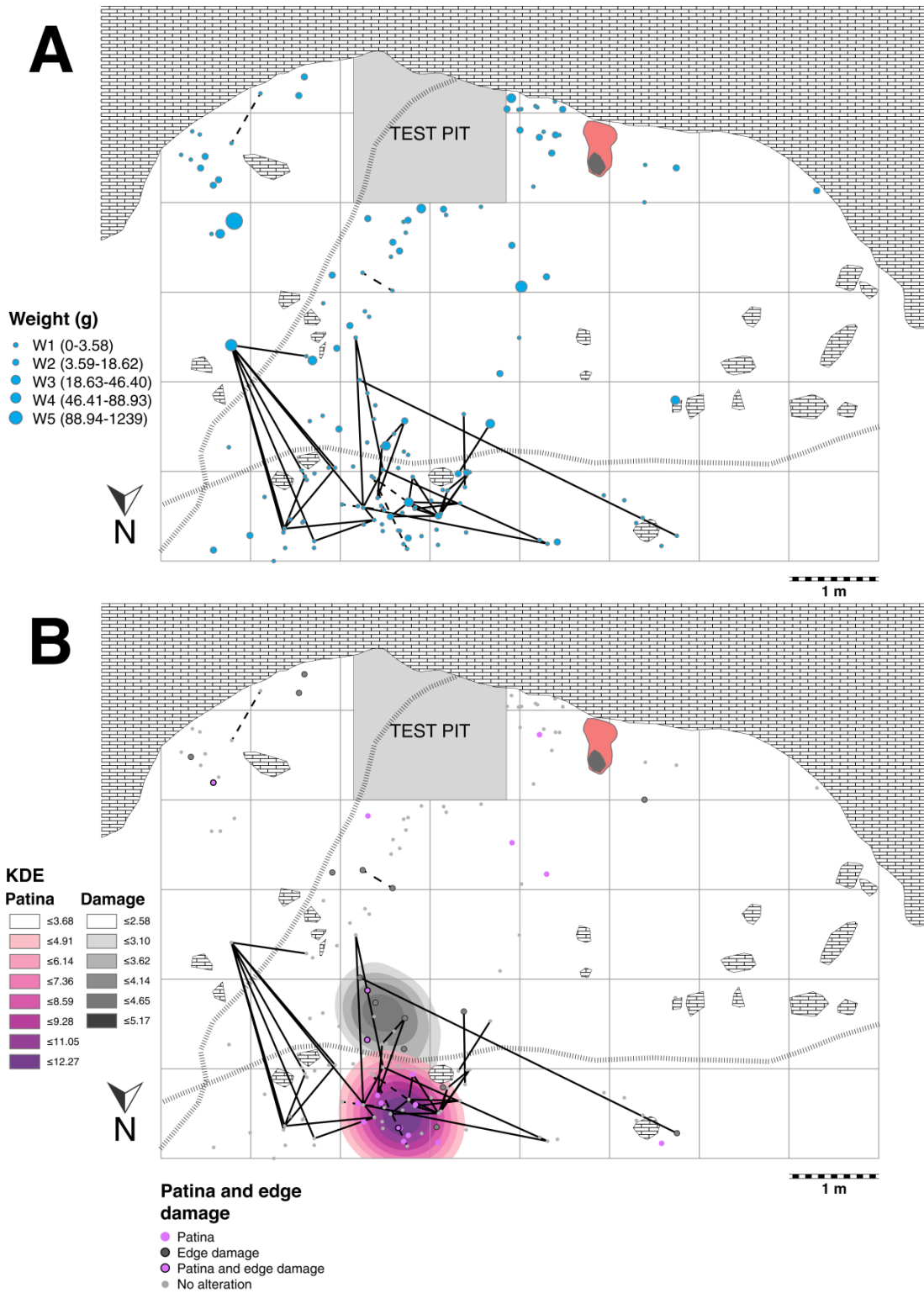


Fig. S3. Weight-class distribution (A), and KDE results for patina and edge damage (B).

Table S2. Results of statistical tests assessing the relationship between the inner part of the second drip line and the distribution of archaeological materials, including lithics and faunal remains.

Test		Value
Chi ²		87.67
	<i>p</i> -value	7.7325E-21
	Monte Carlo <i>p</i> -value	0.0001
Fisher's exact test		
	<i>p</i> -value	1.0177E-22
Cramer V		0.4423

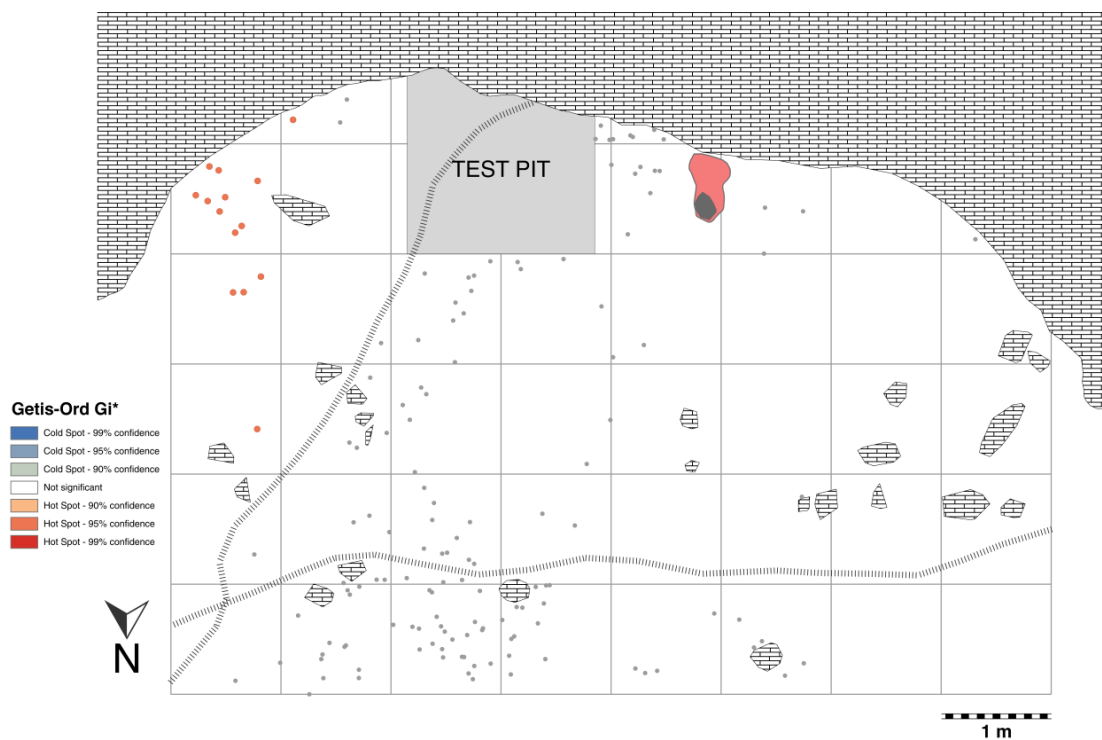


Fig. S4. Optimised Hot-Spot Analysis on lithics applied to the weight variable.

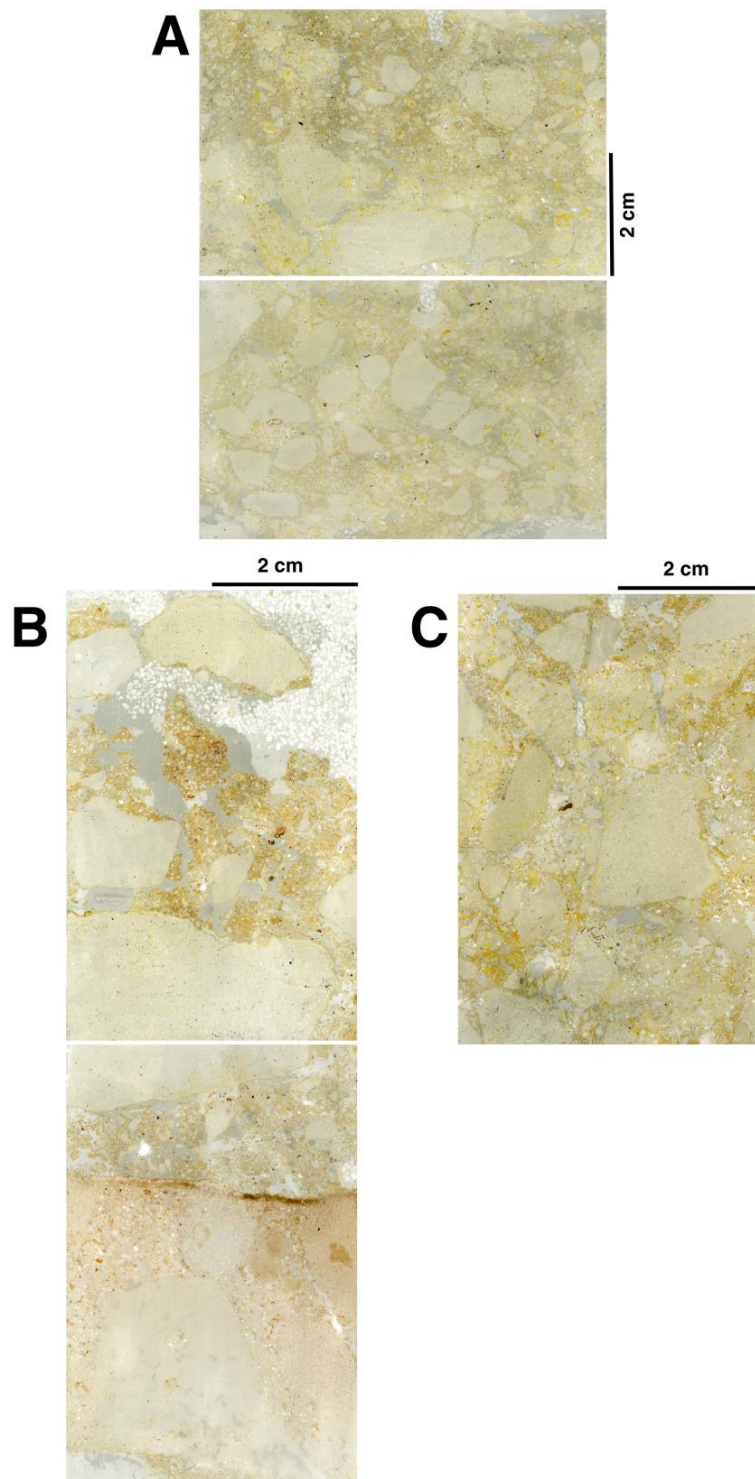


Fig. S5. Thin section scans from the western (**A**) (sample AP-23-2) and combustion (**B** and **C**) (samples AP-23-3 and AP-23-5) areas.

Table S3. *n*-Alkane abundances (ng/g sample) and CPI values for the samples. ND: not detected

	H19 BL	H19 RL	H19 CTRL	H20 BL	H20 RL	H20 CTRL
C₁₆	1.0	0.6	ND	1.0	1.1	0.9
C₁₇	1.5	0.8	ND	1.3	1.3	1.2
C₁₈	3.4	1.1	0.3	2.0	1.9	2.2
C₁₉	5.2	1.6	0.7	3.1	2.7	3.2
C₂₀	6.4	2.2	1.3	3.9	3.5	4.2
C₂₁	7.5	2.4	2.3	4.4	4.3	4.9
C₂₂	7.1	2.3	3.1	4.8	5.0	5.1
C₂₃	5.2	1.9	3.0	4.2	4.7	4.7
C₂₄	2.7	1.0	1.3	2.2	2.7	2.5
C₂₅	2.7	0.8	2.8	2.6	3.8	3.2
C₂₆	0.9	0.3	0.7	0.8	1.1	0.9
C₂₇	4.3	0.8	3.3	5.3	8.7	6.3
C₂₈	0.5	0.1	0.5	0.7	1.0	0.7
C₂₉	6.9	1.1	7.4	9.4	19.7	13.6
C₃₀	0.2	0.1	0.3	0.3	0.6	0.4
C₃₁	3.6	0.7	3.9	3.3	11.2	7.3
C₃₂	ND	ND	0.1	ND	0.2	ND
C₃₃	ND	0.1	0.3	0.5	1.3	0.6
Total	59.1	18.0	31.1	49.7	74.9	61.8
CPI	1.8	1.4	3.2	2.5	3.9	3.0

