Universitat Autònoma de Barcelona

ESTUDIO DE LAS ACTIVIDADES DE PERCUSIÓN DE LOS GRUPOS CAZADORES RECOLECTORES DEL NORESTE PENINSULAR A INICIOS DEL HOLOCENO. EL ASENTAMIENTO AL AIRE LIBRE DE FONT DEL ROS (BERGA, BARCELONA)

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DOCTORADO EN ARQUEOLOGÍA PREHISTORICA

ESTUDIO DE LAS ACTIVIDADES DE PERCUSIÓN DE LOS GRUPOS CAZADORES RECOLECTORES DEL NORESTE PENINSULAR A INICIOS DEL HOLOCENO

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1. Introducción

El instrumental relacionado con las actividades domésticas de los cazadores-recolectores es un aspecto al que tradicionalmente se le ha prestado escasa atención. Este exiguo conocimiento me motivó a analizar cantos y fragmentos, un componente habitual pero poco descrito en la mayoría de contextos arqueológicos.

Los materiales líticos no tallados, también denominados instrumental macrolítico, *ground stone tools* (*sensu* Adams, 2002) o actividades de percusión (*sensu* Mora y de la Torre, 2004), han ocupado un lugar marginal en la investigación de los tecno-complejos de las sociedades del pasado. A lo largo de la última década, el panorama ha cambiado y los estudios centrados en estos artefactos han empezado a sistematizarse, evidenciando que las actividades con las que se los relaciona, -arqueológicamente poco visibles- son esenciales en la organización del entramado social de sus comunidades. Sobre este grupo de instrumentos centramos la atención de nuestro trabajo.

A lo largo de las siguientes páginas se evidencia que este utillaje está relacionado con la gestión de recursos ligados a la expansión forestal de inicios del Boreal (Gamble *et al.*, 2004; Burjachs, 2009; Jalut y Turu-Michels, 2009; Allué *et al.*, 2012). A su vez, se identifican otras actividades, como el tratamiento de carcasas animales, el procesado de pigmentos minerales y el trabajo de las pieles; a los que añadimos la molienda de frutos secos y carnosos, que abre nuevas perspectivas con las que evaluar el rol de la recolección en la subsistencia de los cazadores-recolectores. Este mosaico de tareas genéricamente calificadas como "domésticas", remiten a comportamientos y actividades básicas en el sostenimiento de estos grupos humanos, pero poco conocidas en el ámbito temporal de los cazadores-recolectores.

La abundancia de este instrumental en el yacimiento al aire libre de Font del Ros (Berga, Berguedà) se ha considerado tradicionalmente como un indicador de regresión cultural que ha servido para definir un vago mesolítico "atípico"

(Fullola-Pericot *et al.*, 1995; García-Arguelles *et al.*, 2005).El conjunto recuperado, compuesto por centenares de artefactos contextualizados, permite abordar la noción de regresión cultural asociada a estos tecno-complejos (Vallespi, 1961; Barbaza *et al.*, 1984; Utrilla, 2002). Este hecho lo convierte en un enclave privilegiado para analizar las transformaciones dentro de la organización socioeconómica de las sociedades cazadoras-recolectoras y las sociedades productoras del noreste de la Península (Pallarés *et al*., 1997; Pallarés y Mora, 1999; Martínez-Moreno *et al.*, 2006a, 2006b; Martínez-Moreno y Mora, 2011)*.* Paralelamente, hemos señalado que en la unidad arqueológica SG de Font del Ros atribuida al Mesolítico, se identifica un proceso de simplificación técnica del instrumental lítico. Este conjunto se elabora sobre materias primas de origen local y habitualmente de mala calidad, en el que se reconoce un proceso de miniaturización para obtener piezas de pequeñas dimensiones y poco estereotipadas, que se asocian a un instrumental elaborado a partir de cantos y fragmentos.

En esta tesis se presenta un compendio de aportaciones científicas publicadas en revistas y congresos internacionales que han sido sometidas a una revisión editorial por pares. La relevancia de esta línea de investigación ha permitido la aceptación de estos resultados en revistas indizadas en los principales repositorios de publicaciones científicas, como *Scopus* y *Thompson International Science Index*.

Cada uno de los artículos incluidos en esta monografía constituye una etapa en la gestación del proyecto de tesis que defendemos, y ha servido para tomar contacto con la obtención de resultados relevantes en la investigación de la arqueología prehistórica.

Las cuatro publicaciones incluidas abordan un mismo objeto de estudio desde diferentes perspectivas: el análisis e interpretación del instrumental no tallado y las actividades de percusión. Los resultados que presentamos evidencian el potencial de estos artefactos y manifiestan la necesidad de incorporar este segmento tecnológico dentro de la interpretación arqueológica. A continuación, se expone una síntesis de los objetivos y resultados de los artículos junto con la recapitulación de los datos bibliométricos de cada uno de ellos.

- Xavier Roda Gilabert, Jorge Martínez-Moreno, Rafael Mora Torcal.Pitted stone cobbles in the Mesolithic site of Font del Ros (Southeastern Pre-Pyrenees, Spain): some experimental remarks around a controversial tool type.

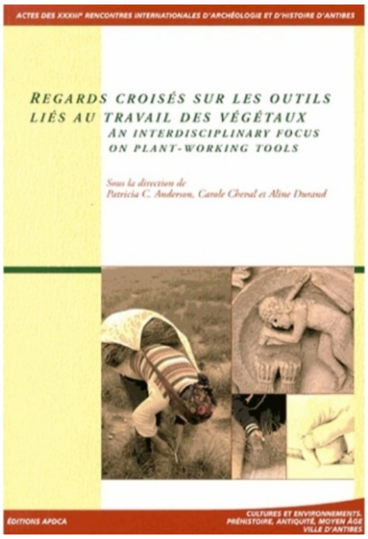
- Journal Archaeological Science, Volume 39, Issue 5, May 2012, Pages 1587-1598.

DOI: 10.1016/j.jas.2011.12.017

- *Cite Score*: 3.02
- Impact Factor: 2.602
- *5-Year Impact Factor*: 2.656

Scopus 19 Google Scholar 25 MENDELEY 49

En este artículo se exponen los resultados más relevantes del programa experimental desarrollado, centrado en el análisis de un tipo de útil especifico, los cantos con cúpulas, en el que se discuten las implicaciones derivadas en contextos arqueológicos y etológicos (Roda Gilabert *et al.*, 2012). Los experimentos incluyen la reproducción de actividades que pudieron estar vinculadas al desarrollo de estigmas centralizados, también denominados cazoletas, presentes en la unidad arqueológica SG de Font del Ros. Se evalúan los procesos que generan estos instrumentos incluyendo la talla de cuarzos, y la apertura y la molienda de avellanas; describiendo las huellas de uso vinculadas a cada una de estas actividades. Los resultados obtenidos indican que la formación de cantos con cúpulas se vincula claramente con la talla bipolar, mientras que el procesado de avellanas no genera patrones diagnósticos, al menos con la intensidad aplicada en el programa experimental.



- ❖ Xavier Roda Gilabert, Jorge Martínez-Moreno et Rafael Mora Torcal, La gestion des végétaux dans les Pyrénées: la consommation des noisettes sur le site mésolithique de Font del Ros.
- ❖ P. C. Anderson, C. Cheval et A. Durand (eds)Regards croisés sur les outils liés au travail des végétaux. An interdisciplinary focus on plant-working tools. XXXIIIe rencontres internationales d'archéologie et d'histoire d'Antibes Éditions APDCA, Antibes, 2013, 175-188.

ISBN : 978-2-904110-53-5
EAN : 9782904110535

Google Scholar 3

Las evidencias del consumo de vegetales centra el segundo de los trabajos, que deriva de la invitación a participar en el *workshop Regards croisés sur les outils liés au travail des végétaux*, coloquio adscrito a los prestigiosos Encuentros Internacionales de Arqueología e Historia de Antibes (Roda Gilabert *et al.*, 2013). El objetivo era presentar artefactos con huellas de uso ligadas con el procesado de vegetales. Los patrones de uso y la posición contextual de los restos de avellana recuperados permiten proponer que el procesado y el consumo de frutos secos jugaron un rol importante. La aplicación de análisis geoestadísticos, basados en la distribución por densidades *kernel*, identifica al menos cuatro áreas discretas vinculadas con el procesado de avellanas. Estas zonas se definen a partir de la posición espacial de cantos con trazas de procesado y molienda de frutos grasos, concentraciones de macro restos de avellana y la disposición de hogares. La combinación de estos elementos sugiere el torrefacto u otro tipo de transformación vinculada al consumo de frutos secos.

❖ Xavier Roda Gilabert, Rafael Mora; Jorge Martínez-Moreno. Identifying bipolar knapping in the Mesolithic site of Font del Ros (northeast Iberia).

❖ Philos Trans R Soc Lond B Biol Sci 2015 Nov 19; 370(1682): 20140354.

DOI: 10.1098/rstb.2014.0354

- Impact factor: 5.846
- Rank: 6/84 in Biology
- 5-Year Impact Factor: 6.9207
- 2016 SJR: 2137
- 20016 SNIP: 1137

Scopus 3 Google Scholar 3 MENDELEY 18

El análisis de los materiales tallados y la identificación del peso de la talla bipolar dentro de los esquemas técnicos aplicados en las ocupaciones mesolíticas de Font del Ros (Roda Gilabert *et al.*, 2015), configura el tercero de los artículos. Los resultados obtenidos en el programa experimental desarrollado al inicio de esta tesis evidencian que la talla bipolar jugaba un papel importante en el yacimiento. Esta técnica había pasado desapercibida en el análisis de la unidad SG, en gran medida por ser un método de talla poco conocido. La revisión sistemática de los cantos con cúpula, núcleos y desechos de talla, permite establecer los estigmas diagnósticos de la técnica bipolar, e indica que este método jugó un papel destacado en la gestión de materias primas de baja calidad que caracterizan el conjunto. Los resultados alertan sobre la importancia de esta sistemática de talla en la obtención del instrumental en yacimientos del noreste de la Península ibérica de cronologías similares.

- Xavier Roda Gilabert; Jorge Martínez-Moreno; Rafael Mora Torcal. Ground stone tools and spatial organization at the Mesolithic site of Font del Ros (southeastern Pre-Pyrenees, Spain)

- Journal of Archaeological Science: Reports. Volume 5, February 2016, Pages 209-224

  DOI: 10.1016/j.jasrep.2015.11.023

  - Cite Score:0.95
  - Source Normalized Impact per Paper (SNIP): 0.541
  - SCImago Journal Rank (SJR):0.570

Scopus 6 Google Scholar 10 Mendeley 23

La organización de las actividades relacionadas con los cantos recuperados en el sector central de la ocupación SG es el objetivo de este artículo (Roda Gilabert *et al.*, 2016). Se presenta un análisis multienfoque que combina los resultados obtenidos en el estudio de las huellas de uso de los cantos y el análisis espacial *intra site* mediante métodos geoestadísticos. Esta metodología identifica áreas de actividad discretas vinculadas con tareas concretas y aporta información sobre el modo de vida cazador-recolector. Al mismo tiempo permite profundizar en las dinámicas de ocupación reflejadas en el complejo entramado de acumulaciones que conforman este sector de la unidad SG.

2. Contexto de investigación. Font del Ros, un *asentamiento del Pre Pirineo oriental*

Font del Ros (Berga, Berguedà) se sitúa en la cuenca del río Llobregat, a 670 m. de altura en el contacto entre la Depresión Central Catalana y las primeras estribaciones del Pre Pirineo (X=404,478, Y= 4,660,989, Zona 31, ETRS89). Esta zona biogeográfica señala fuertes contrastes altimétricos, entre el gran valle abierto de la cuenca del Llobregat y los primeros relieves abruptos de la Serra de Queralt.

El asentamiento se localizó a finales de los años 80, a raíz de la expansión urbana del municipio de Berga, cuando D. Josep Carreras informó al *Servei d'Arqueologia* de la *Generalitat de Catalunya* de la existencia de un yacimiento arqueológico afectado por un solar en construcción, situado en la zona conocida como Pla de l'Alemany.

La excavación de Font del Ros marca un hito en la gestión y organización de excavaciones de urgencia afectadas por grandes obras. Realizada hace más de 25 años, la intervención permitió generar una documentación excepcional de elementos patrimoniales. La incorporación de elementos metodológicos como la georreferenciación espacial, la excavación en extensión, la aplicación de ordenadores en la gestión del trabajo de campo, o el tamizado sistemático con agua, permiten actualmente recuperar la información contextual de los restos. En la actualidad se dispone de un inventario riguroso y sistemático, clave en los estudios presentados en esta tesis.

A partir de los sondeos realizados en 1988, el *Servei d'Arqueologia* autorizó la excavación del solar con carácter de urgencia durante 1989, 1990 y 1991, una intervención arqueológica coordinada por Rafael Mora de la *Universitat Autònoma de Barcelona*. La excavación fue realizada en paralelo a las obras de construcción que destruyeron la parte norte del yacimiento, y se extendió por la manzana afectada limitada al este, al sur y al oeste por el entramado urbano. A su vez, la instalación en 1989 de una grúa en el sector este de la excavación, destruyó más de 150 m^2 en los que continuaba el yacimiento. A pesar de estos condicionantes, el asentamiento se excavó en una superficie que se extiende a lo largo de más de 1400 m^2, y continúa más allá de los límites de la zona excavada.

A nivel litoestratigráfico se identificaron seis unidades sedimentarias (F-A) con una potencia de 5,5 m. En el interior de la secuencia estratigráfica se documentan varias unidades arqueológicas: SGN correspondiente al Paleolítico superior (unidad D), SG y SGA adscritas al mesolítico (unidad C), y finalmente N vinculada con el neolítico antiguo (unidad B) (Jordà *et al.*, 1992) (Fig. 1). La secuencia corresponde a una sedimentación fluvial detrítica fina con carbonataciones oncolíticas ligadas a un arroyo próximo. En el tramo superior, la secuencia señala una surgencia kárstica situada al norte del yacimiento, configurando formaciones travertínicas que se adosan a una ladera con una suave inclinación. Esta estructura es responsable del rápido cubrimiento del paleosuelo y la acreción vertical de los sedimentos (Jordá *et al.*, 1992). El surtidor parece no haber afectado a la distribución espacial de los restos de las acumulaciones que conforman el nivel SG (Pallarés, 1999).

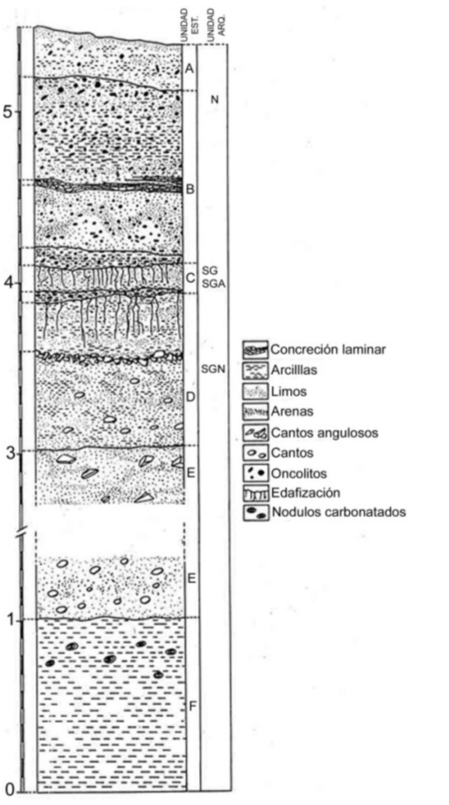


Figura 1. Columna litoestratigráfica del yacimiento de Font del Ros (Jordà et al. 1992 modificado).

Las unidades arqueológicas más relevantes son SG y N, sepaaradas por un paquete estéril de más de 50 cm de espesor. En SG los materiales arqueológicos se documentan de manera discontinua por una superficie de más de 1200 m^2. Por otra parte, en la unidad N se identificaron 43 estructuras de almacenamiento – fosas - a lo largo de 1300 m^2 y los restos de un suelo de ocupación de 100 m^2 muy afectado por los trabajos constructivos (Bordas *et al.*, 1996; Pallarés *et al.*, 1997).

La superposición de ambas unidades se contrasta por una serie de 16 dataciones radiométricas. En la actualidad disponemos de cinco muestras de carbón para SG y una para N, que fueron datadas por ^{14}C convencional en el laboratorio de UBAR. A su vez, cinco muestras de carbón procedentes de la unidad N fueron datadas en Tucson-Arizona, a las que podemos añadir cinco más para la unidad SG. El conjunto indica una ocupación del asentamiento entre 8300-4800 *cal BC.*, una horquilla cronológica que corresponde a más de 2500 años (tabla 1).

Pese a ello, la información parece segmentada por las desviaciones que presentan algunas de las dataciones. Si eliminamos las dataciones con más de $\sigma > 300$ correspondientes a la serie UBAR, se perfila una distribución que deriva inferencias sobre el tempo/modo de las ocupaciones. La representación gráfica de los nuevos resultados indica dos grandes bloques de ocupación (ver Fig. 2). El primero corresponde al mesolítico y está integrado por diez dataciones que posicionan la unidad SG entre 8300-6500 *cal BC.* Interpretamos la distribución escalonada de las mismas como resultado de eventos reiterados de ocupación a lo largo de más de 1800 años. El segundo bloque lo integran cinco dataciones del conjunto N, procedentes de 4 fosas y una del “suelo neolítico”, que ubican temporalmente este contexto entre 5550-4800 *cal BC*, y por lo tanto dentro del Neolítico antiguo. En estas fases crono-culturales de Font del Ros separadas por más de medio metro de sedimentos estériles, se detecta un hiato radiométrico de casi 900 años, que se observa en otros yacimientos del noreste de la Península Ibérica (Martínez-Moreno *et al.*, 2007).

UA	Contexto	# Laboratorio	Muestra	^{14}C	BP	σ	Cal BC p (95%)		Referencia
SG		Beta-231728	Carbón	AMS	9000	50	8297	7980	Roda et al. 2016
SG	Hogar VIII	Beta-231727	*Corylus*	AMS	8820	50	8206	7737	Roda et al. 2016
SG		Beta-231720	*Corylus*	AMS	8810	50	8206	7722	Roda et al. 2016
SG		UBAR 345	Carbón	CONV	8800	360	9119	7063	Roda et al. 2016
SG	Hogar VII	Beta-210732	*Corylus*	AMS	8690	60	7938	7590	Roda et al. 2016
SG		UBAR-397	Carbón	CONV	8400	180	7957	6858	Roda et al. 2016
SG	Hogar IX	UBAR-329	Carbón	CONV	8270	200	7676	6683	Roda et al. 2016
SG	Hogar V	UBAR-165	Carbón	CONV	8150	590	8756	5905	Roda et al. 2016
SG	Hogar IV	UBAR-185	Carbón	CONV	8050	150	7453	6613	Roda et al. 2016
SG	Hogar IV	Beta-210733	*Corylus*	AMS	7800	50	6767	6496	Roda et al. 2016
N	Suelo Neo.	UBAR-186	Carbón	CONV	6980	390	6699	5062	Bordas et al. 1996
N	Suelo Neo.	AA-16498	Carbón	AMS	6561	56	5624	5385	Bordas et al. 1996
N	E 33	AA-16501	Carbón	AMS	6307	68	5468	5075	Bordas et al. 1996
N	E 36	AA-16502	Carbón	AMS	6370	57	5474	5227	Bordas et al. 1996
N	E 15	AA-16499	Carbón	AMS	6243	56	5324	5047	Bordas et al. 1996
N	E 21	AA-16500	Carbón	AMS	6058	79	5211	4790	Bordas et al. 1996

Tabla 1. Dataciones radiométricas disponibles para las unidades arqueológicas SG y N de Font del Ros.

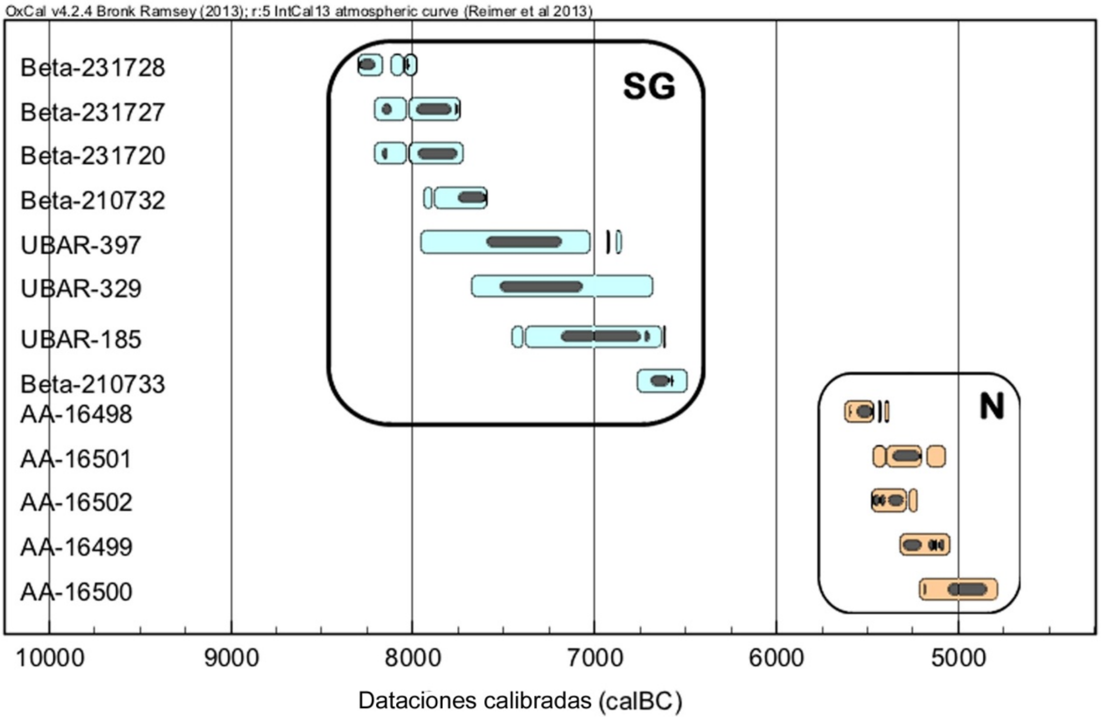


Figura 2. Horquilla cronológica de las dataciones radiométricas calibradas disponibles para Font del Ros.

2.1. La unidad SG

Las características fundamentales del nivel SG han sido estado expuestas en diferentes artículos a lo largo de los últimos años (Martínez-Moreno *et al.,* 2006a, 2006b; Martínez-Moreno y Mora, 2011*);* y son descritas en los artículos que forman parte de esta disertación (Roda Gilabert *et al*., 2012, 2013, 2015, 2016). En este apartado sintetizamos algunos rasgos fundamentales para la interpretación global del conjunto, incluyendo aspectos que han quedado fuera de las publicaciones, debido al limitado espacio disponible.

Integrado por 29349 restos líticos, óseos y vegetales, el nivel SG se inscribe dentro de la crono-zona Boreal. El nivel paleo-vegetal se caracteriza por el desarrollo de la asociación roble *(Quercus),* avellano *(Corylus avellana)* y boj *(Buxus semperirens)* que remiten a un bosque supra-mediterráneo caducifolio de elevada biodiversidad. Los datos antracológicos confirman esta impresión al señalar el uso de 14 taxones como combustible (Jordà *et al., 1992),* entre los que se encuentran el sauce *(Salix sp.)* y el olmo *(Ulmus sp.),* que denotan una alta humedad edáfica. Pese a la mala conservación de los restos óseos se identifican ciervo (*Cervus elaphus),* jabalí (*Sus scrofa)*, toro salvaje (*Bos sp.),* cabra (*Capra pirenaica*) o conejo *(Oryctolagus cuniculus),* asociación de fauna coherente con el entorno del yacimiento.

La distribución de materiales arqueológicos evidencia que a nivel horizontal los restos se acumulan de forma discreta y con una baja dispersión vertical a lo largo de 1200 m^2, alrededor de nueve hogares y dos fosas. Hemos sostenido que este patrón espacial, más que representar una ocupación generada por un gran campamento, corresponde a un número indeterminado de eventos de corta duración que confirma la serie radiométrica escalonada anteriormente referida (Martínez-Moreno y Mora, 2011; Roda Gilabert *et al.*, 2016).

El conjunto se integra dentro de un ciclo de ocupaciones estacionales que se sitúan entre verano e inicios del otoño. A lo largo de éstas, grupos de cazadores-recolectores realizan actividades de subsistencia, como la caza de animales de talla pequeña y mediana. Otra actividad es la recolección y procesado de frutos secos y carnosos. El registro antracológico advierte que en este bosque biodiverso se identifican diez taxones con frutos potencialmente comestibles o con usos medicinales conocidos. Paralelamente, la recuperación de macro-restos vegetales, entre los que destacan abundantes fragmentos de pericarpio de avellana, indica que la recolección fue una actividad relevante en estas ocupaciones (Pallarés y Mora, 1999), observación que compartimos (Roda Gilabert *et al.*, 2013).

El instrumental lítico permite elaborar varias hipótesis. Desde un punto de vista tecno-tipológico, la unidad SG se ha atribuido a un estadio crrono-cultural en cuya definición se incorporó Font del Ros, y que se articula en el espacio comprendido por el valle del Ebro y la vertiente sur de los Pirineos, denominado mesolítico de muescas y denticulados (ver artículos en Alday (*ed*.), 2006). El atributo central de este horizonte crono-cultural, es una incipiente simplificación técnica de los procesos de talla, que la unidad SG ejemplifica a partir de dos opciones técnicas: la aplicación generalizada de la talla bipolar y el uso de cantos y plaquetas vinculados con distintas actividades de subsistencia. Estos parámetros permiten gestionar una gran cantidad de rocas locales poco adecuadas para la talla (Martínez-Moreno *et al.*, 2006a; Roda Gilabert *et al*, 2015, 2016).

Font del Ros tiene acceso a la sierra del Cadí y al Pedraforca, facilitando la obtención de litologías del Pirineo axial, como calcarías, margas, arcillas, areniscas y graníticas del margen lateral de la cuenca del Ebro. Sin embargo, los recursos líticos silicios son escasos y de baja calidad, lo que explicaría la elección de la talla bipolar como método de talla. Estudios petrológicos previos han divido estos recursos en varios grupos que describimos brevemente (Terradas, 1995):

Cretácico: materiales sil²ceos incorporados a las calizas bioclásticas del manto del Pedraforca. Presenta una talla muy irregular por la gran presencia de impurezas y planos de debilidad de la roca. Esta roca sedimentaria tenaz está formada en gran parte por cuarzo, que le confiere una gran dureza. Los afloramientos están a poco más de una hora de camino desde el yacimiento, en el curso del torrente de la Golfa, situado en sus inmediaciones.

Eoceno inferior: pequeños núcleos sil²ceos recubiertos de caja contenedora en el interior de rocas calcarías. Se encuentran más lejos que los anteriores, y en los productos de talla se identifican impurezas calcáreas.

Eocénico medio y superior: rocas silíceas que se encuentran en el interior de conglomerados, especialmente en la formación Berga. El transporte fluvial separa liditas, cuarzos y rocas férricas de la matriz del conglomerado. Aparecen en posición secundaria en la zona circundante al yacimiento.

El resto de recursos líticos son principalmente cantos y fragmentos procedentes de las terrazas adyacentes al asentamiento, representado por una gran variedad de rocas metamórficas y sedimentarias, como la caliza, las cuarcitas y las areniscas. En este espectro litológico se detectan más de 350 cantos y fragmentos con trazas de uso (percusión y fricción), que se sitúan en el centro del estudio que presentamos en esta tesis. Como veremos, estos instrumentos dan respuesta a múltiples actividades, siendo su alta flexibilidad funcional la que los sitúa en la esfera de la subsistencia diaria.

2.2. Contextualización de Font del Ros dentro del marco del Mesolítico regional y europeo

Font del Ros es un reflejo de los cambios de paradigma que se han producido en la investigación arqueológica vinculada al Mesolítico de la península ibérica. El exiguo marco de referencia comparativo en el momento que fue excavado, sin duda fue un hándicap a la hora de evaluar la identidad del yacimiento. Las dificultades iniciales en su adscripción se ceñían a un corpus limitado de yacimientos. Entre ellos destaca Sota Palou (CPRES, 1985), en el que tras la apariencia tosca y “arcaica” de los artefactos, se esconden comportamientos técnicos singulares que reflejan la respuesta de los cazadores-recolectores ante nuevos retos propiciados por un escenario ecológico cambiante.

La atributos tecnológicos de las ocupaciones mesolíticas de Font del Ros hicieron que el yacimiento se viera envuelto en un debate sobre su adscripción crono-cultural, considerándolo como atípico (Fullola Pericot *et al.*, 1995; García-Argüelles *et al.*, 2005), ajeno a las propuestas tipológicas tradicionales (Fortea, 1973).
A lo largo de las dos últimas décadas se ha discutido el papel que juegan estos yacimientos y su posición dentro del epipaleolítico, caracterizado por la dualidad microlaminar/geométrico. Estos conjuntos anómalos, ajenos a las adscripciones, fueron referidos con connotaciones peyorativas que atribuían estas características a comportamientos no normativos, que se explicaban como una pobre respuesta ante constricciones ambientales o a la escasez de materias primas que advertían de un proceso de degradación cultural (entre otros Vallespi, 1961; Barbaza *et al.*, 1984; Utrilla, 2002; Fullola-Pericot *et al.*, 2005). La reunión celebrada en el año 2006, planteó que estos yacimientos configuran una nueva unidad: muescas y denticulados (Alday (*ed.*), 2006).

Pese a ello, no compartimos la denominación unidad de muescas y denticulados como una fase crono-cultural, y propugnamos como alternativa la noción de mesolítico sin armaduras (Roda Gilabert *et al.*, 2015).

Sin duda, es la ausencia de este tipo de artefactos, que funcionan como fósiles directores paneuropeos durante el mesolítico, lo que caracteriza el conjunto de más de treinta yacimientos situados a ambas vertientes del río Ebro y en la vertiente francesa de los Pirineos (ver referencias en Roda Gilabert *et al.*, 2013 y Soto *et al.*, 2016). Estos sitios comparten las características descritas en la unidad SG, entre las que destaca la presencia de utillaje sobre canto, que en la mayor parte de los casos no ha sido objeto de estudios sistemáticos y posiblemente en las excavaciones antiguas ni siquiera recogidos (Fig. 3).

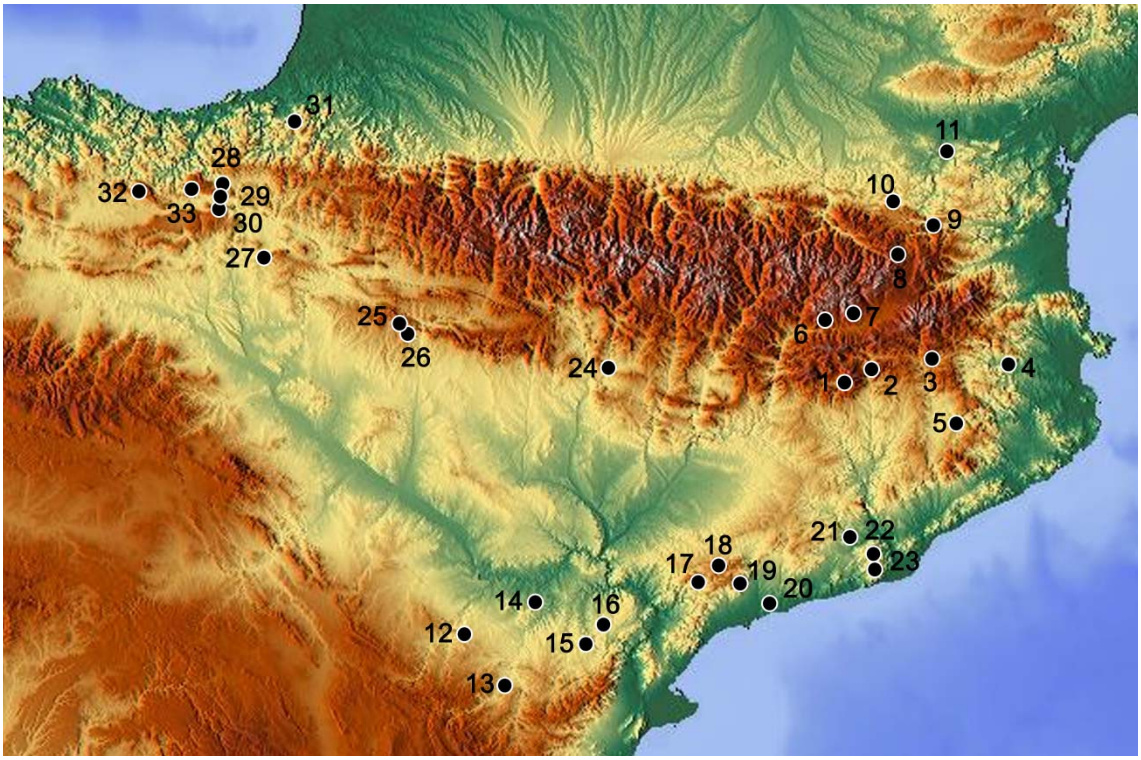


Figura 3. Mapa con la ubicación de los yacimientos arqueológicos con características tecnológicas similares a Font del Ros.

Listado de yacimientos referidos en la Figura 3:

1. Font del Ros (Pallarés *et al.*, 1997; Martínez-Moreno *et al.*, 2006a, 2006b; Roda Gilabert *et al.*, 2016).

2. Balma Guilanyà (Terradas *et al.*, 1992; Casanova y Pizarro, 2004; Martínez-Moreno *et al.*, 2006a; Martínez-Moreno *et al.*, 2006b; Casanova *et al.*, 2008; Martzlouf *et al.*, 2012).

3. Sota Palou (CPRES, 1985; Pallarés, 1995; Martínez-Moreno *et al.*, 2006b)

4. Bauma del Serrat del Pont (Alcalde y Saña, 2008).

5. Roc del Migdia (Rodriguez y Yll, 1992; Holden *et al.*, 1995).

6. Dougne (Guilaine *et al.,* 1993).

7. Balma Margineda (Guilaine y Martzlouf, 1995; Martínez-Moreno *et al.,* 2006a, 2006b; Martzlouf *et al.*, 2012).

8. Caune d'Arques (Sacchi, 1973).

9. Roc d'en Bertran (Barbaza, 1987-1988).

10. Adoutx (Barbaza, 1987-1988).

11. Balma de l'Abeurador (Vaquer *et al.*, 1986).

12. Los Baños (Montes *et al.*, 2006).

13. Plano del Pulido (Montes *et al.*, 2006).

14. Ángel 1 y 2 (Utrilla *et al.*, 2009).

15. Pontet (Mazo y Montes, 1992).

16. Costalena (Barandarian *et al.*, 2006).

17. Abric del Filador (García-Argüelles *et al.*, 2005, 2006).

18. Molí del Salt (Vaquero *et al.*, 2005; Vaquero, 2006; Vaquero *et al.*, 2009).

19. Picamoixons (García-Catalan *et al.*, 2009).

20. La Cativera (Morales *et al.*, 2013).

21. Abric Agut (Vaquero *et al.*, 2005; Vaquero *et al.*, 2006).

22. Can Sadurní (Fullola *et al.*, 2011).

23. Marge del Moro (Fullola *et al.*, 2011).

24. Forcas I y II (Utrilla y Mazo, 2014).

25. Peña 14 (Montes *et al.*, 2006).

26. Legunova (Montes, 2004).

27. Artusia (Garcia Martínez de Lagrán *et al.*, 2016).

28. Berroberia (Barandiaran, 1993-1994).

29. Atxoste (Alday, 2014).

30. Kanpanoste (Cava, 2004).

31. Kanpanoste Goikoa (Alday, 2002a; Alday, 2002b; Alday y Cava, 2006).

32. Fuente de Hoz (Baldeon *et al.*, 1983).

33. Mendandia (Alday, 2005; Alday y Cava, 2006).

Balma Margineda y Balma Guilanyà (Martínez-Moreno *et al.*, 2006b; Martzlouf *et al.*, 2012), bien conocidos por nuestro equipo de investigación, presentan un mayor número de similitudes en lo que respecta al utillaje. Pese a ello, es evidente que gran parte de estas ocupaciones se localizan en pequeñas cuevas o abrigos de zonas montañosas, una forma de instalarse en el paisaje distinta a la de Font del Ros, que se localiza en el contacto entre varios ecosistemas. Este yacimiento, ocupado durante un importante intervalo temporal, sugiere que quizás sea más adecuado compararlo con yacimientos al aire libre del norte de Europa, con los que sin embargo no comparte rasgos tecnológicos, pero que presentan analogías en cuanto a los patrones de asentamiento centrados en la explotación estacional de recursos forestales (Fig. 4).

Figura 4. Mapa con la distribución de los yacimientos europeos con patrones de asentamiento equiparables a los detectados en la unidad SG de Font del Ros.

Listado de yacimientos referidos en la Figura 4:

1. Wohnplatz 6 and 8 of Duvensee (Holst, 2010, 2011).
2. Staosnaig (Mithen *at al.*, 2001).
3. Lough Boora (Mc Comb y Simpson, 1999).
4. Ertebolle (Robinson y Harild, 2002).
5. Verrebroe Dok 1 (Sergant *et al.*, 2006).

Más allá de disquisiciones estrictamente culturales, o si se prefiere taxonómicas, esta tesis nos ha permitido reflexionar sobre los procesos técnicos de la talla bipolar, inadvertidos en análisis previos de este mismo yacimiento. Bajo nuestro punto de vista, esta técnica está presente, aunque no señalada en algunos conjuntos adscritos al horizonte muescas y denticulados. La talla sobre yunque es un método destacado en la elaboración de instrumental lítico sometido a un intenso proceso de miniaturización, y que se ha documentado en diversas regiones europeas, especialmente en el norte de Europa, como Escandinavia (Callahan, 1987; Ballin, 1999; Bjerck, 2008), Escocia (Mercer, 1980; Bjarke Ballin, 2008) o Irlanda (Driscoll, 2010).

La variada explotación de recursos señalada en estos yacimientos, refleja la versatilidad del instrumental elaborado y, como se discutirá, es un indicador de las capacidades técnicas de los grupos humanos sometidos a una situación de estrés derivado de la ausencia o mala calidad de la materia prima. Las posibilidades que abren las dataciones radiométricas más precisas, permiten interpretaciones cada vez más detalladas de las dinámicas propias de cada región, y es uno de los ejes que deberá abordarse en el futuro para corroborar la existencia de entramados sociales entre las diferentes comunidades mesolíticas.

3. Objetivos

El conjunto de instrumentos arqueológicos estudiados permite incidir en una serie de problemáticas que informan sobre la esfera funcional de artefactos concretos. El análisis de la distribución espacial y de los contextos en los que fueron recuperados facilita interpretaciones de orden organizativo. Los artículos que presento se sustentan en dos objetivos generales de los cuales derivan los siguientes resultados:

Objetivos generales

Estas características señalan cadenas operativas (*sensu* Pelegrin *et al.*, 1988) en las que participaron estos objetos.

- En paralelo con el punto anterior, caracterizar parte del registro material que dentro del marco cronológico y regional abordado no ha sido objeto de un estudio sistematizado previamente.

Objetivos concretos

- Analizar los suelos de ocupación para evaluar correspondencias entre los estigmas de los artefactos y los modelos de actividades indicados por el conjunto de restos arqueológicos. Esta propuesta considera estos instrumentos como marcadores de actividades domésticas (de Beaune, 2000a, 2000b). Esta perspectiva pretende contrastar las dinámicas de ocupación previamente señaladas en otros trabajos (Pallares, 1999).

- Revalorización de la esfera de las actividades domésticas en los sistemas de organización cazador-recolector, incidiendo especialmente en los artefactos relacionados con las técnicas de procesado y consumo de vegetales y en otras actividades vinculadas con este tipo de instrumental.

- Enfatizar las relaciones entre percusión y métodos de talla. Dentro de este apartado se caracterizan los soportes obtenidos al aplicar el método de talla bipolar, técnica con una amplía diacronía a lo largo de la Prehistoria, y actualmente centro de intensos debates en el ámbito de la tecnología.

4. Marco teórico y metodológico

Mi posicionamiento teórico-metodológico se asienta sobre un análisis multienfoque dirigido a abordar el estudio del registro arqueológico, teniendo en cuenta diversos niveles de observación:

- el estudio de las huellas de uso
- el análisis tecno-morfológico de la industria lítica tallada
- el desarrollo de un programa experimental
- el análisis contextual/espacial por medio de test geoestadísticos

La combinación de estos elementos permite acercarnos a los objetivos señalados en el epígrafe anterior.

4.1. Una cuestión nominal

Antes de recapitular estas directrices metodológicas, es necesario esclarecer varios puntos relativos a la propia definición, identificación y clasificación de los artefactos en los que centramos la investigación.

Los estudios tradicionales han estado ligados a la tipología y estadística (Bordes, 1979; Laplace, 1972), a los caracteres tecnológicos (Pelegrin *et al.*, 1988; Böeda *et al.*, 1990; Inizan *et al.*, 1995) o funcionales (Semenov, *1964;* Hayden, *1987*; Anderson*,* 1980*),* centrados principalmente sobre el instrumental lítico tallado. Sin embargo, en los yacimientos prehistóricos son habituales fragmentos, cantos, plaquetas o bloques con trazas de impacto, estrías y esquirlados sobre sus superficies, y flancos o extremidades generados por diversas actividades (de Beaune, 2000a, 2004; Procopiou y Treuil (eds.), 2002; Adams, 2002).

Desde un punto de vista motriz, estos artefactos se relacionan con lo que algunos autores definen como actividades de percusión (*sensu* Leroi-Gourhan, 1971; Chavaillon, 1979). Dentro de esta categoría tienen cabida un variado grupo de actividades para los que se emplean percutores, yunques o elementos de triturado y molienda.

Esta definición amplia y no restrictiva del instrumental lítico ha sido escogida para dar título a este trabajo, y deriva del concepto empleado en un estudio pionero por el director de esta tesis, el cual despertó mi interés por este tipo de utillaje (Mora y de la Torre, 2004).

Una búsqueda bibliográfica sobre estos artefactos evidencia que el análisis sistemático de los objetos se encuentra en un estadio inicial. Habitualmente, en la mayor parte de las publicaciones esta parte del registro material se ha relegado a anexos o meras notas descriptivas. Esta falta de interés posiblemente tiene su origen en la definición del concepto de tecnología lítica, tradicionalmente circunscrito a los elementos tallados, y configurados por acción antrópica a fin de una transformación preconcebida de la morfología del soporte (Boëda, 1991). Sólo algunos autores procesualistas (Clarke, 1984) o de la escuela francesa (Leroi-Gourhan, 1988), consideran este instrumental como parte del utillaje de las sociedades del pasado.

Este tratamiento marginal deriva en problemas como el de la variedad de vocabulario y clasificaciones referidas para denominar este utillaje de percusión (Kraybill, 1977); polisemia que provoca confusiones al referir un mismo tipo de instrumentos bajo denominaciones distintas (de Beaune, 2000a; Hamon, 2008).

De esta forma, vemos cómo los materiales han sido clasificados bajo nomenclaturas como macro-utillaje, utillaje de percusión o ground stone tools, siendo esta ultima la que se ha impuesto en las revistas anglosajonas (ver referencias en Dubreuil y Savage, 2014). Sin embargo, estos apelativos coinciden al integrar instrumentos que no han sido sometidos a procesos de acondicionamiento, y con superficies que registran huellas vinculadas a su uso. A lo largo del texto, estos conceptos se utilizaran indistintamente considerándolos equivalentes.

4.2. Análisis del utillaje de percusión

Como punto de partida tomamos la necesidad de demostrar que esos artefactos han sufrido algún tipo de actividad antrópica. Dada la naturaleza de los soportes, muy cercanos a las características de los cantos naturales, es

necesario identificar los estigmas de utilización o las transformaciones que experimenta un soporte natural como consecuencia del trabajo realizado y que afectan a su peso, materia o volumen, modificando así su morfología original.
Desde un punto de vista metodológico, estos materiales sólo en raras ocasiones han superado una fase inicial o descriptiva, limitada a catálogos y corpus descriptivos o clasificaciones tipológicas (Gallay, 2004).

El análisis de las huellas de uso sobre utillaje de percusión se inserta dentro de la corriente de análisis traceológico, desarrollada a partir de mediados del siglo XX, con la que comparte objetivos y problemáticas. Sin embargo, un factor que condiciona este enfoque es que no es hasta la década de los 90 cuando se inician estudios sistemáticos, una vez superados los debates metodológicos relacionados con los estudios de huellas de uso (ver referencias en Ibáñez y González, 2003; Longo y Skakun (ed.), 2008).

Los primeros intentos de clasificación tecno-tipológica rigurosos (Kraybill, 1977; de Beaune, 1989, 1993b; 2000a; Wright, 1992), son complementados con los primeros estudios funcionales a partir de la identificación de huellas de uso en este tipo de instrumental (Adams, 2002). Los primeros estudios surgen del interés por estos artefactos en contextos pre-agrícolas Natufienses del Creciente Fértil, y que se hacen evidentes durante el proceso de neolitización (ver referencias en Adams, 2002; de Beaune, 2000a). En esta discusión, la definición propuesta por Adams (2002) señala que los *ground stone tools* son artefactos de tamaño y peso elevado, usados en tareas de percusión, abrasión, pulido o molienda.

El análisis de este instrumental se centra en establecer el modo en que se utilizan, prestando atención al tipo de contacto con la materia prima, el tipo de percusión y la dirección del trabajo realizado. Varios factores condicionan los resultados obtenidos, especialmente los factores tafonómicos que dificultan la identificación de las zonas activas. Igualmente, las características propias de los materiales con frecuentes fases de reutilización que encadenan distintos usos, dificultan establecer una tipología y derivan en problemas de equifinalidad (Dubreuil, 2002).

Estos atributos hacen necesario que los estudios se planteen desde una perspectiva tecno funcional para analizar las dimensiones tecnológicas, económicas y sociales de los grupos del pasado (de Beaune, 2002). De este modo, los estudios se han orientado hacia dos enfoques complementarios, por una parte los centrados en el análisis morfo-técnico de los conjuntos (p. e. de Beaune 1989; 2000a; Adams 1988, 1989), y por otra en la identificación y descripción de las huellas de uso (p. e. Dubreuil, 2002; 2004; Hamon, 2008; Adams *et al.*, 2009).

La observación de estos artefactos implica diversos niveles de análisis, desde la inspección previa de las superficies hasta su observación mediante la lupa binocular. Su combinación permite posicionar las marcas de uso y la naturaleza del soporte (materia prima, peso, volumen, etc.), básicas en la adscripción funcional de estos útiles. El análisis mediante lupa binocular permite reconocer la topografía de las superficies (*sensu* Adams, 2002) y determinar zonas activas, así como el tipo de superficie de contacto de los materiales trabajados (Adams *et al.*, 2009). El uso de aparatos ópticos que magnifican las superficies, facilita detectar deformaciones no visibles macroscópicamente, siendo muy útiles en la identificación de tipos de materiales trabajados. En nuestro estudio se han empleado los instrumentos del servicio de microscopia de la *Universitat Autònoma de Barcelona*.

4.3. Huellas de uso consideradas

Trazas lineales, extracciones, fracturas, redondeamiento de los granos, pulido o lustre y arrasamiento son los estigmas considerados en la identificación de desgastes, que en gran medida están condicionados por sucesivas etapas de uso a las que se han visto sometidos los objetos. Para la descripción de estos parámetros nos remitimos especialmente a Adams *et al.* (2009) y Dubreuil (*et al.* 2015). Para la ubicación de los desgastes seguimos las Normas *DIN* que definen seis superficies que configuran su volumen a partir de los ejes X, Y, Z (ver Risch, 1995). Se define como anverso aquella superficie con mayor incidencia de huellas de uso, que jerarquiza el resto del volumen tomando como reverso la superficie opuesta. A continuación describimos brevemente las características de las huellas de uso consideradas:

Trazas lineales o estrías

Son deformaciones plásticas que encajan con las trazas lineales (Semenov, 1964), formadas por el contacto entre materiales, originadas por el contacto de superficies con diferente textura y dureza. En función de su amplitud se han diferenciado entre estrías (>0,5 mm) o rascadas (<0,5 mm) (Clemente *et al.*, 2002).

Extracción de granos

Pequeñas depresiones en la topografía y con morfologías variables que se forman por el levantamiento de granos originados en las superficies de trabajo, y que en gran medida dependen de las características petrológicas de la roca. La comparación entre zonas activas y zonas sin uso es clave para identificar estos desgastes. Así, la distinción entre desgaste y arrasamiento permite diferenciar entre útiles activos y pasivos de molienda (Procopiou, 2004).

Fracturas

Son alteraciones observables sobre las superficies, tanto en los agregados de granos como en los minerales individuales. Las fracturas escalonadas (*step fractures*) son habituales en el utillaje de percusión; mientras que las fracturas concoideas son poco frecuentes debido a las propias características de los soportes empleados como útiles macrolíticos.

Redondeamiento de los granos

La presencia/ ausencia de desgaste mecánico en los bordes y superficie de los granos. Depende en gran parte de la materia prima y de su dureza.

Pulido o lustre

Alteraciones brillantes producidas por el incremento de la luz reflejada por la superficie (Semenov, 1964). Su desarrollo depende de la composición mineralógica de la roca y de los materiales trabajados. Este proceso está ligado a procesos de desgaste como el arrasamiento (*leveling*) (Adams, 2002).

Arrasamiento

Este tipo de desgaste se reconoce sobre las superficies activas a diferentes escalas de magnificación. El proceso consiste en la regularización de la topografía, hasta llegar a la matriz del instrumento creando zonas homogéneas (*leveling*) (Adams, 1988, 1989, 2002; Dubreuil, 2002, 2004). Se documentan de manera más clara los soportes de grano grueso, siendo común en instrumentos abrasivos como los destinados a la molienda (*plateau d'usure)* (Dubreuil, 2002).

4.4. Tribología

Esta disciplina desarrollada dentro del ámbito industrial y las ciencias materiales, estudia el papel que juegan sustancias intermedias en los procesos de desgaste mecánicos de las superficies (Kato, 2002). Esta propuesta se ha trasladado al estudio del utillaje de percusión, a fin de definir un modo técnico referido a los mecanismos de desgaste de diferentes trabajos en la formación de marcas, que dominan fracturas y deformaciones. En prehistoria, estas sustancias intermedias corresponden a cereales, frutos o tubérculos, y otros elementos como resinas, pigmentos o madera (Adams, 2002). Se pueden distinguir cuatro mecanismos de desgaste en las superficies, resultado de la interacción mecánica y química (Tabla 2).

Tipo de desgaste	Atributos de desgaste
Desgaste adhesivo	Asociado a la presencia de residuos
Desgaste abrasivo	Vinculado al arrasamiento, redondeado de los granos, trazas lineales y fenómenos como el *frosting*
Desgaste por fatiga	Ligado a trazas de uso como fracturas, extracción de granos o fracturas escalonadas
Desgaste triboquímico	Disolución de la superficie de contacto por interacción mecanicoquímica. Se asocia a brillos y pulido (*glooshy sheen*)

Tabla 2. Mecanismos de desgaste tribológico vinculados al uso del utillaje de percusión.

4.5. Arqueología experimental y etnoarqueología

De Beaune (1997, 2000a, 2004) señala que la arqueología experimental es una disciplina que permite determinar la funcionalidad del utillaje de percusión, favoreciendo la caracterización de los estigmas causados sobre distintas materias primas, y contribuyendo a la contrastación de diferentes hipótesis sobre las actividades realizadas.

El objetivo principal del programa experimental es documentar patrones y estigmas asociados a actividades realizadas, controlando variables concretas. En nuestro caso, la primera fase se centró en la elaboración de un programa experimental que permitiera contar con un referencial para el estudio de los materiales arqueológicos. Diferentes sesiones desarrolladas entre 2009 y 2012 se centraron en diferenciar entre: talla bipolar/ talla a mano alzada, el retoque de instrumental lítico, el procesado y molienda de frutos grasos, y la fracturación de huesos (Tabla 3). Los resultados más remarcables aparecen reseñados en Roda Gilabert *et al.* (2012). Queremos señalar en este punto que los útiles experimentales fueron sumergidos durante 24 horas en agua destilada con jabón neutro *Derquim M02* de *Panreac* al 5%, y posteriormente aclarados con agua destilada a presión y secados a temperatura ambiente. Este proceso no está descrito en la publicación.

De forma paralela a los análisis experimentales, las observaciones etnográficas derivan información pertinente. En textos clásicos de mediados y finales del siglo XX, se recogen descripciones de utillaje de percusión e instrumental macrolitico (Boshier, 1965; Roux, 1985; O'Conell, 1983; Cane, 1989; Mc Carthy, 1976; Yellen*, 1977;* Hayden, 1987; Moura y Prous*, 1989*). La descripción de las actividades diarias de grupos cazadores recolectores sub actuales permite trazar analogías con los materiales recuperados en los yacimientos. Estas observaciones, junto con los datos obtenidos a lo largo del programa experimental, posibilitan la formulación de hipótesis sobre los esquemas técnicos vinculados a estos artefactos (*sensu* Balfet, 1991).

4.6. Análisis tecno-tipológico de elementos líticos tallados

La revisión de los materiales líticos de la ocupación mesolítica SG de Font del Ros, surge a raíz de los resultados obtenidos en las experimentaciones y las reflexiones sobre el origen propuesto para los cantos con cúpula. La vinculación de estos objetos con la talla bipolar evidenció que era necesario evaluar su papel en la unidad SG. De este modo se planteó una revisión del

ACTIVIDAD	SOPORTE ACTIVO	SOPORTE PASIVO	MATERIAL TRABAJADO	DURACIÓN	TIPO DE PERCUSIÓN	FUENTE
Apertura avellanas	caliza	caliza	2 kg avellanas tostadas (c. 800)	135 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Apertura de avellanas	caliza	caliza	1 kg. Avellanas tostadas (c. 400)	60 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Apertura de avellanas	granito	arenisca	1 kg. avellanas tostadas (c. 400)	70 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Apertura de avellanas	caliza	arenisca	2 kg. avellanas frescas (c. 800)	125 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Apertura de avellanas	caliza	arenisca	1 kg. avellanas frescas (c. 400)	40 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Apertura de avellanas	granito	arenisca	1 kg avellanas frescas (c. 400)	65 min.	Percusión lanzada difusa	Roda Gilabert *et al.*, 2012
Talla bipolar	caliza	arenisca	1 nódulo de cuarzo	25 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	caliza	arenisca	4 nódulos cuarzo	25 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	caliza	caliza	2 nódulos cuarzo	25 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	caliza	caliza	3 nódulos de cuarzo	5 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	cuarcita	arenisca	4 nódulos cuarzo	15 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	gneis	caliza	2 nódulo cuarzo	12 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	gneis	arenisca	1 nódulo cuarzo	4 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Talla bipolar	arenisca	caliza	1 nódulo cuarzo	6 min.	Percusión lanzada indirecta	Roda Gilabert *et al.*, 2012
Apertura y molienda de avellanas	caliza	arenisca	2 kg. avellanas tostadas (c. 800)	145 min.	Percusión lanzada indirecta y percusión apoyada difusa	Roda Gilabert *et al.*, 2012
Apertura y molienda de avellanas	caliza	arenisca	2 kg. avellanas tostadas (c. 800)	180 min.	Percusión lanzada indirecta y percusión apoyada difusa	Roda Gilabert *et al.*, 2012
Apertura y molienda de avellanas	caliza	granito	2 kg. avellanas tostadas (c. 800)	175 min.	Percusión lanzada indirecta y percusión apoyada difusa	Roda Gilabert *et al.*, 2012

Apertura y molienda de avellanas	caliza	granito	2 kg avellanas frescas (c. 800)	200 min.	Percusión lanzada indirecta y percusión apoyada difusa	Burguet Coca, 2012
Apertura y molienda de avellanas	caliza	granito	2 kg avellanas frescas (c. 800)	175 min.	Percusión lanzada indirecta y percusión apoyada difusa	Burguet Coca, 2012
Apertura y molienda de avellanas	cuarcita	cuarcita	2 kg avellanas frescas (c. 800)	180 min.	Percusión lanzada indirecta y percusión apoyada difusa	Burguet Coca, 2012
Machacado de huesos	caliza	arenisca	3 fémur caballo	35 min.	Percusión lanzada amortiguada	Burguet Coca, 2012
Machacado de huesos	arenisca	arenisca	1 fémur, 2 radios caballo	30 min.	Percusión lanzada amortiguada	Burguet Coca, 2012
Talla bipolar	caliza	caliza	4 nódulos cuarzo	360 min. (escaneados)	Percusión lanzada indirecta	en preparación
Talla sílex mano alzada	granito		Reducción nódulo sílex	10 min.	Percusión lanzada directa	Roda Gilabert, 2009
Talla y retoque sílex mano alzada	caliza		Talla soporte sílex y retoque	10 min.	Percusión lanzada directa	Roda Gilabert, 2009
Retoque sílex mano alzada	cuarcita		Retoque soporte de sílex	12 min.	Percusión lanzada directa	Roda Gilabert, 2009
Talla sílex mano alzada	caliza		Reducción sílex	8 min.	Percusión lanzada directa	Roda Gilabert, 2009
Talla y retoque sílex mano alzada	granito		Reducción soportes y retoque	40 min.	Percusión lanzada directa	Roda Gilabert, 2009
Retoque sílex mano alzada	caliza		Retoque sílex iniciación talla	5 min.	Percusión lanzada directa	Roda Gilabert, 2009
Retoque sílex mano alzada	cuarcita		Retoque sílex	12 min.	Percusión lanzada directa	Roda Gilabert, 2009

Tabla 3. Síntesis de las actividades desarrolladas a lo largo del programa experimental

conjunto de artefactos, a fin de determinar la incidencia de las técnicas de talla a mano alzada y sobre yunque (bipolar) (Roda Gilabert *et al.*, 2015). Para analizar los resultados desde un punto de vista tipo métrico y estadístico, se aplicó software específico (p. e. PAST, χLSTAT). Los criterios metodológicos utilizados son descritos en Roda Gilabert *et al.* (2015).

4.7. Análisis contextual

El análisis contextual del conjunto es indispensable para la interpretación de las diferentes acumulaciones de materiales. Esta aproximación se centra en primer lugar en el análisis de la dispersión horizontal y vertical de los objetos arqueológicos, prestando atención a categorías concretas que informen sobre actividades singulares desarrolladas en el yacimiento. *ArcGis es* un *software* que permite elaborar plantas y secciones verticales de las concentraciones de materiales, al mismo tiempo que permite aplicar test geoestadísticos y de densidades *Kernel* para visualizar agrupaciones significativas de materiales.

Por su parte, en el análisis de datos cuantitativos se aplicaron test disponibles en paquetes estadísticos como PAST o χLSTAT, que permiten contrastar una valoración cualitativa de la información obtenida; entre ellos se incluyen diversas modalidades del χ^2, el test de Lien (Volle, 1988; Lagarde, 1983).

4.8. Analíticas físico-químicas y uso de microscopia de grandes aumentos

A pesar de no ser un eje fundamental, durante una estancia en el *Institute of Archaeology del University College London (UCL)* pude analizar algunas piezas arqueológicas con *Enviromental Scanning Electron Microscope* (ESEM), que permite el análisis de puntos concretos de las superficies activas mediante *X-Ray energy dispersive Analysis* (EDAX). Esta técnica no destructiva identifica de forma semicuantitativa elementos traza sobre las superficies, contribuyendo a identificar la función de algunos artefactos estudiados. Los resultados no fueron satisfactorios debido al estado de conservación de los materiales estudiados, pero se detectaron elementos como el hierro *(Fe)* en piezas con huellas de uso relacionadas con el trabajo de ocres y pieles (Fig. 5). Sin embargo, una limitación de este tipo de microscopia es el tamaño de las piezas, lo cual dificulta su análisis. A esto podemos añadir que en muchos casos los útiles han sufrido los efectos de almacenamiento y manipulación desde su extracción, lo que ha afectado el estado de conservación de las superficies. Los avances que se realicen en los próximos años serán clave para profundizar en la naturaleza polifuncional de este instrumental. Otro problema de este tipo de aplicaciones se centra en la contaminación de las piezas, siendo necesario garantizar la fiabilidad de la toma de muestras.

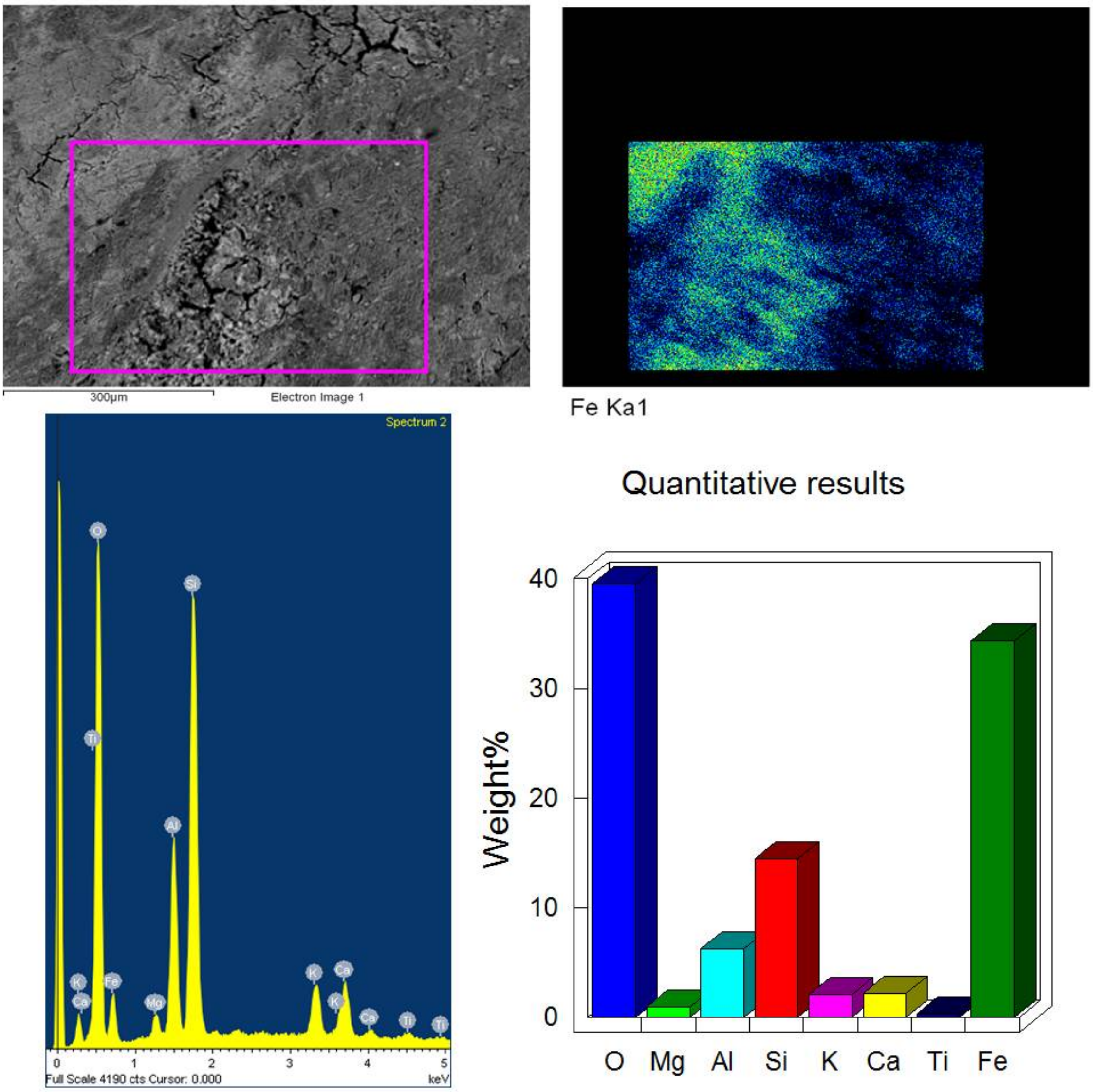


Figura 5. Resultados obtenidos en el ESEM que confirman la presencia de restos de ocre en la pieza FR 21-14-11.

Una línea de trabajo sería la identificación microscópica de residuos sobre las superficies activas, que se ha aplicado con éxito en materiales experimentales y arqueológicos *(entre otros* Vandiver *et al., 1994;* Christensen y Valla*, 1999;* Domínguez-Rodrigo *et al., 2001; Byrne et al., 2006). L*a elaboración de un referencial experimental adecuado, supone una alternativa al análisis físico-químico, que requiere unos recursos técnicos y una inversión económica más elevada. Pese a ello, la aplicación de estas analíticas exige unas condiciones de conservación y almacenaje que garanticen la preservación de los mismos. Algunos artefactos de materiales de la unidad SG no cumplen estos requisitos y condiciones, lo que ha forzado su exclusión de la tesis.

El uso de la microscopia de grandes aumentos permite la observación detallada de las deformaciones plásticas o la cuantificación de patrones mediante el uso de técnicas específicas. Entre éstos, podemos citar el microscopio electrónico de barrido (SEM) (Vergés y Ollé, 2011; Ollé y Vergés, 2014) o los microscopios confocales, que generan modelos tridimensionales de las superficies observadas (Stemp *et al.*, 2008; Stemp y Chung, 2011; Evans y Donahue, 2008; Stemp *et al.*, 2013). En lo referente a la cuantificación, encontramos en los últimos años aplicaciones novedosas, como los estudios de rugosidad de zonas activas de utillaje de molienda (Bofill *et al.*, 2013), o la aplicación del GIS para monitorizar los patrones de alteración y las huellas de uso en instrumentos de percusión (de la Torre *et al.*, 2013; Caruana *et al.*, 2014; Benito-Calvo *et al.*, 2015).

Siguiendo esta línea, estamos trabajando en la monitorización secuencial de la talla bipolar mediante *Laser Scanning Confocal Microscope* (LSCM), (manuscrito en fase de redacción). Este estudio ha permitido que obtengamos datos cuantitativos sobre la formación de depresiones centralizadas sobre los cantos. Documentar las deformaciones plásticas de las superficies ligadas a esta actividad y registrar las diferentes fases de modificación fue un objetivo del bloque experimental. El escaneo de las superficies después de cada una de las fases permite obtener modelos 3D de los útiles experimentales. Estos datos están siendo analizados mediante métodos estadísticos (*ArcGIS*) y aportarán información cuantitativa de los procesos de formación, indicadores que se pueden comparar con artefactos arqueológicos (Roda Gilabert *et al.*, 2012). Los microescaneados muestran las deformaciones plásticas y permiten cuantificar los patrones de desgaste mediante el análisis de variables, como la pendiente y rugosidad. Estos parámetros expresan la variabilidad topográfica al caracterizar las superficies activas. Paralelamente, su comparación con los artefactos arqueológicos revela diferencias significativas entre los diferentes tipos de uso. Los resultados obtenidos indican que la metrología de los cantos con cúpula está estrechamente relacionada con la percusión lanzada sobre materiales duros, y señala que el *Scanning Laser Confocal Microscope* (*SLCM*) es una técnica fiable para analizar a nivel cuantitativo los desgastes en los útiles macrolíticos.

4.9. Materiales técnicos y software utilizados

A lo largo del desarrollo de la tesis se han utilizado diferentes instrumentos para la toma de datos, el registro de las huellas de uso y la elaboración de los soportes gráficos presentados en los artículos. La siguiente tabla recapitula y describe brevemente cada uno de ellos (Tabla 4).

ArqueoUAB	Registro y gestión de los datos utilizados. Extracción de inventarios de los materiales.
Past **XLSStat**	Tratamiento estadístico de los datos obtenidos en la fase de análisis de materiales
Photoshop Elements **CorelDraw X4**	Edición y montaje de material gráfico incluido en las publicaciones.
ArcGis 10	Elaboración de planimetrías y aplicación de herramientas de análisis geoestadístico.
Olympia SZ-11	A lo largo del análisis de materiales se ha trabajado con un rango de magnificación situado entre 5x y 100x. Las imágenes de detalle presentadas se han realizado en el centro de microscopia de la *Universitat Autònoma de Barcelona* mediante cámaras digitales integradas en el dispositivo.
Helicon Ficus **Helicon Remoto**	Fotografías de detalle de las piezas. Creación de montajes de alta calidad de las fotografías donde todos los puntos de las mismas aparecen enfocados.
Nixon D300	Toma de fotografías a lo largo del programa experimental. Detalles generales de materiales arqueológicos.
Endnote	Gestión de las referencias bibliográficas

Tabla 4. Relación de *software* utilizado a lo largo del proceso de investigación.

5. Publicaciones

5.1. Roda Gilabert, X.; Martínez-Moreno, J.; Mora Torcal, R., 2012. Pitted stone cobbles in the Mesolithic site of Font del Ros (Southeastern Pre-Pyrenees, Spain): some experimental remarks around a controversial tool type. *Journal of Archaeological Science* 39, 1587-1598.

5.2. Roda Gilabert, X.; Martínez-Moreno, J.; Mora Torcal, R., 2013. La gestion des végétaux dans les Pyrénées: la consummation des noisettes sur le site mésolithique de Font del Ros. In Anderson, P. C.; Cheval, C.; Durand, A. (Eds.), *Regards croises sur les outils lies au travail des végétaux. An interdisciplinary focus on plant-working tools*. XXXIII Rencontres Internacionales d'Archéologie et d'Histoire d'Antibes, pp. 237-250. Éditions APDCA, Antibes.

5.3. Roda Gilabert, X.; Mora, R.; Martínez-Moreno, J., 2015. Identifying bipolar knapping in the Mesolithic site of Font del Ros. *Philos. Trans. R. Soc. B* 370, 20140354.

5.4. Roda Gilabert X.; Martínez-Moreno, J.; Mora Torcal, R., 2016. Ground stone tools and spatial organization at the Mesolithic site of Font del Ros (southeastern Pre-Pyrenees, Spain) *Journal of Archaeological Science: Reports* 5, 209-224.

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Pitted stone cobbles in the Mesolithic site of Font del Ros (Southeastern Pre-Pyrenees, Spain): some experimental remarks around a controversial tool type

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ABSTRACT

The presence of cobbles with activity-related marks in the Mesolithic site of Font del Ros (Berga, Spain), and in particular one group of artefacts – pitted stones – raises problematic issues associated with the characterization of percussion activities. Although these artefacts have generated an extensive bibliography on ethological, ethnographic, ethnoarchaeological and archaeological levels, various questions persist in relation to their possible contextual function. In this paper we present the results of an experimental programme in which three types of activities that could create pitted stones are reproduced: bipolar knapping of vein quartz, hazelnut cracking, and hazelnut grinding. The aim of this experimental programme is to describe marks and use-wear traces related to such activities.

Results indicate that pit formation is associated with bipolar knapping activity. However, the description of pitted stones related to hazelnut processing presents problems when it comes to define diagnostic attributes.

1. Introduction

In recent years descriptions of activities undertaken using pebbles and unworked lithic blanks have been stimulated by in-depth studies on the identification of use marks on these artefacts (de Beaune, 2000; Procopiou and Treuil, 2002; Adams, 2002 and references therein). However, the systematic study of percussion and ground stone tools is still at an initial stage, as sometimes it is difficult to go beyond classifications that are exclusively typological. Likewise, the range of vocabulary used in classifications to describe this tool type causes confusion (Kraybill, 1977), so that at times the same type of artefact is referred to in different ways (de Beaune, 2000; Hamon, 2008).

Experimental study has provided an alternative perspective to typological description, as it aims to describe use-wear marks on different types of raw material in order to identify the functional context of such objects. Recent studies have made significant progress in this direction, enabling identification of activities undertaken using these artefacts (among others Dubreuil, 2004; Hamon, 2008). The development of an experimental programme can contribute elements for discussion on two questions: the type of activities in which they were involved and a description of the resulting wear marks on them.

In this study, we will describe the possible functional contexts in which a particular type of percussion tool was used: pitted stones or *percuteurs à cupule.* These artefacts have been recognized in the Mesolithic site of Font del Ros (Berga, Spain), and we maintain that their analysis may indicate activities undertaken at this site, and provide a key towards understanding the spatial patterning of the settlement (Martínez-Moreno et al., 2006a; Martínez-Moreno and Mora, in press; Roda Gilabert et al., submitted for publication).

2. Pitted stones: a controversial tool type

Usually, *pitted stones* are described as flat spherical pebbles with a central zone on which wear traces of battering are visible (Chavaillon, 1979; Leakey, 1971; Leakey and Roe, 1994; Le Brun-Ricalens, 1989; de Beaune, 1989, 1993, 2000; Adams, 2002). Such artefacts have a wide diachronic and geographic distribution which suggests that they may have served multi-functional purposes throughout time (de Beaune, 1989, 1993, 2000).

Although their functional context has been discussed on various occasions, currently there is no broad consensus as to their significance. As such, we find objects that technologically correspond to

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different activities, grouped under the same nomenclature. Typologically, pitted stones share attributes with *pierres à cupules* described in various sites at Melká Kunturé (Chavaillon, 1979; Chavaillon and Piperno, 2004) and Olduvai Gorge (Leakey, 1971; Leakey and Roe, 1994; Jones, 1994), as well as at Gesher Benot-Yaqov (Goren-Inbar et al., 2002). Because of their morphological similarity, they have often been compared as analogous with pebbles used to smash fleshy fruits by *Pan troglodytes* (McGrew, 1992; Joulian, 1996; Mercader et al., 2002, 2007) or *Cebus libidinosus* (Fragaszy et al., 2004; Visalberghi et al., 2007).

Similarly, cobbles with pits are mentioned in numerous Upper Palaeolithic and Mesolithic sites in Western Europe (among others Simonnet, 1976; Champagne and Spitalié, 1981; Gob and Pirnay, 1980; Becker et al., 1994; de Beaune, 1989, 1997, 2000 and references therein). The presence of such artefacts is very common in Mesolithic sites on the slopes of the Pyrenees in the Iberian Peninsula: Mendandia (Alday Ruiz, 2006), Aizpea (Barandiaran and Cava, 2001), Balma Marguineda (Guilaine and Martzluff, 1995), Sota Palou, Font del Ros and Balma Guilanyà (Martínez-Moreno et al., 2006a, 2006b; Martínez-Moreno and Mora, in press; Roda Gilabert et al., submitted for publication; personal observations).

Several hypotheses have been proposed regarding the contextual function of *pitted stones.* Ethnographically, it has been noted that the processing of nuts and fleshy fruits creates artefacts with small, irregular pits, as seen in those called *kebra cocô* (Moura and Prous, 1989). Nut cracking stones are used by the *!Kung* (Yellen, 1977) and by recent hunter-gatherers of the Transvaal (Boshier, 1965; Maguire, 1965). They also form part of the toolkit of some Australian hunter-gatherers who use *kulki*, artefacts with a central depression caused by battering (McCarthy, 1976).

Alternatively, pebbles with pits have been associated with bipolar knapping (Leakey, 1971; Leakey and Roe, 1994), and experimental battering activities have demonstrated that this type of knapping produces pebbles with marks in the form of small depressions (Le Brun-Ricalens, 1989; Jones, 1994; Donnart et al., 2009; de la Peña, 2011). Similarly, it has been suggested that these artefacts are related to fire setting, used as fire-drill hearths or objects subjected to rotary actions (Gob and Pirnay, 1980; Rowe, 1995), a hypothesis that has been queried (Collina-Girard, 1998; de Beaune, 2000; Adams, 2002).

Such interpretations indicate that at present there is no broad consensus on the significance and function of these artefacts. As an alternative, we suggest that a detailed analysis of the marks visible on these cobbles and their archaeological context allow us to establish the significance of pitted stones. In the present case, our interest is in the analysis of their potential integration within tasks undertaken in the Mesolithic site of Font del Ros.

3. Archaeological setting

Font del Ros ($X = 404{,}478$, $Y = 4{,}660{,}989$, Zone 31, ETRS89 and 670 masl) is located on a shelf formed of quaternary colluvial deposits in the contact zone between the Central Catalan Depression and lower foothills of the Eastern Pre-Pyrenees of Barcelona

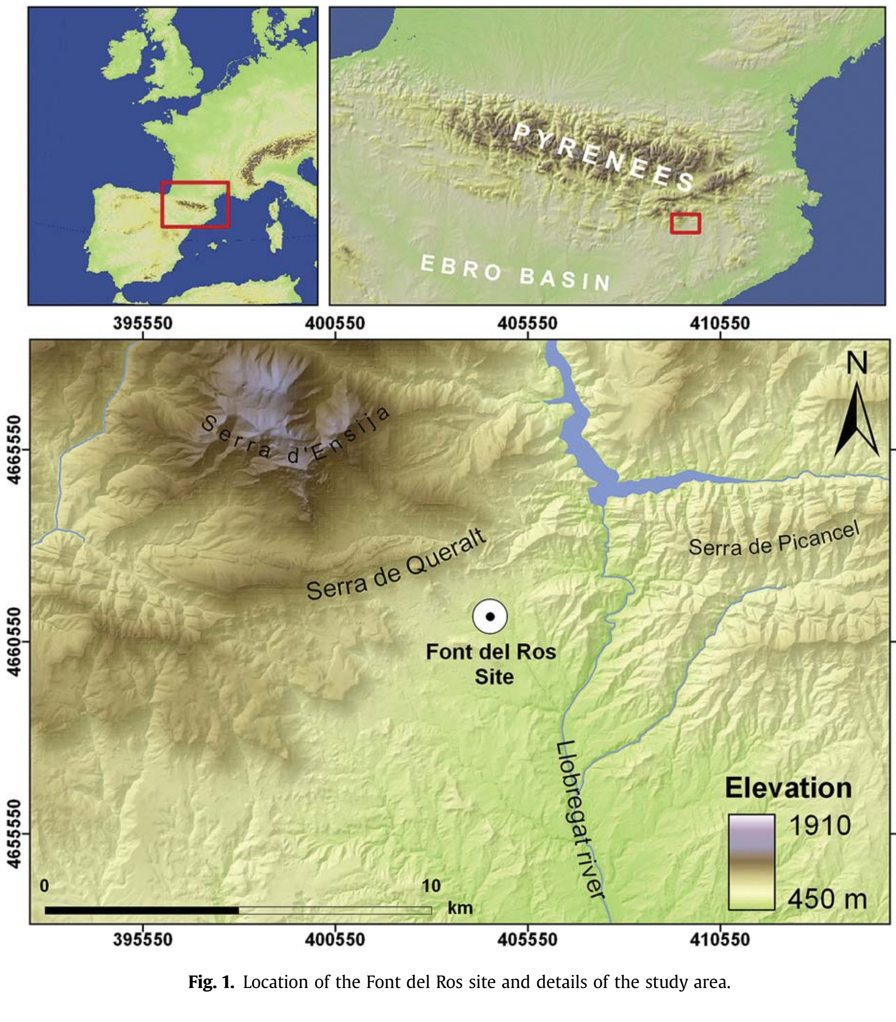

Fig. 1. Location of the Font del Ros site and details of the study area.

(Serra de Queralt) (Pallares, 1999; Pallares and Mora, 1999; Martínez-Moreno and Mora, in press). The Llobregat River that flows in the vicinity connects the Central Catalan Depression and interior of the Pyrenean Massif (Fig. 1).

Building construction in the municipality of Berga (Barcelona, Spain) exposed the existence of the site. Excavation has revealed two Mesolithic occupations (SGA and SG) in stratigraphic context, and a further occupation attributed to the early Neolithic (N).

Excavation of the Mesolithic occupation SG extended over an area of approximately 1200 m^2, from which around 27,800 lithic artefacts, bones and plants (charcoal and seeds) were recovered. Plant bio-indicators provide evidence of temperate taxa (*Quercus, Buxus sempervirens* and *Corylus avellana*, *Ulmus* sp., *Salix* sp., *Sambucus* sp.), all species associated with wet conditions and suggestive of dense deciduous woodland. Nine ^{14}C dates obtained in this level suggest an indefinite number of occupations between 10,400 and 8450 cal BP (calibrated at 2σ), which place the site firmly in the Boreal climatic period, an attribution additionally supported by charcoal analysis (Pallares, 1999; Martínez-Moreno and Mora, in press).

The lithic techno-complex included an abundant toolkit related to percussion activities; percussion tools from the central occupation zone -extending over an area of about 510 m^2- were the

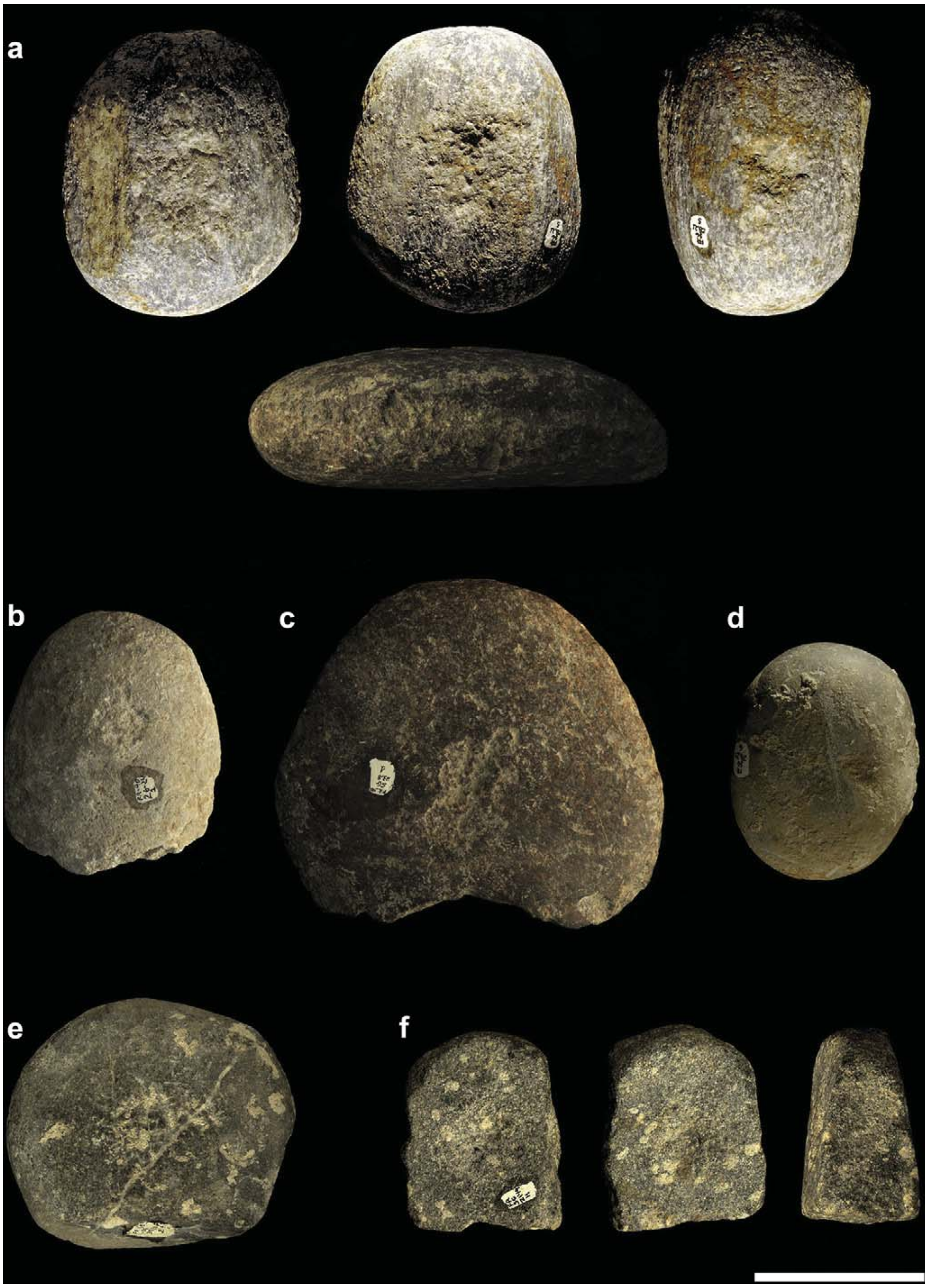

Fig. 2. Pitted stones recovered from the central zone of Font del Ros level SG (graphic scale 5 cm): a) pits with irregular section (quartzite, 77 × 63 × 52 mm); b) cobble with incipient pit (limestone, 78 × 65 × 43 mm); c) pits with irregular section (quartzite, 110 × 97 × 36 mm); d) cobble with incipient pit (limestone, 70 × 55 × 38 mm); f) pits with irregular section (limestone, 83 × 70 × 28 mm); e) pits with regular section (gneiss, 57 × 46 × 30 mm).

subject of systematic study (Roda Gilabert, 2009; Roda Gilabert et al., submitted for publication).

Six pitted stones with superimposed impact points indicating thrusting percussion that causes fractures and depressions were recovered from this sector of the site. This pattern may be associated with several activities implying bipolar battering. Nevertheless, several artefacts also have friction marks on their surfaces that suggest a combination of different activities so that they may be defined as multi-purpose implements (Martínez-Moreno et al., 2006b; Roda Gilabert et al., submitted for publication).

These items can be grouped into three morphological types: pits with a regular section, pits that are irregular in section and incipient pits. Two quartzite cobbles and one limestone cobble have pits with an irregular section (Fig. 2a, c, e). A gneiss fragment has two pits with a regular section (Fig. 2f) having characteristics similar to those resulting from experimental *piquetage* (*sensu* de Beaune, 1993b). Finally, two limestone cobbles have marks on one surface shaping incipient pits (Fig. 2b, d). This description brings to mind a classic methodological problem: we cannot discount the fact that different processes or activities can generate similar wear marks. In other words, these modifications indicate problems of equifinality that affect the identification of wear marks when determining functional correlations.

Based on information from the Font del Ros Mesolithic occupations, several hypotheses have been designed regarding the possible use of pitted stones. In particular, attributes of flint and quartz artefacts and cores indicate bipolar knapping (Le Brun-Ricalens, 1989, 2006; Mourre, 1996; Donnart et al., 2009; de la Peña 2011; Mourre and Jarry, 2011 and references therein). Furthermore, the remains of burnt *C. avellana* shells are regularly found around hearths, where pitted stones have also been recovered, suggesting the use of cobbles to break and pound nuts (Pallares, 1999), something that has been suggested in other Mesolithic sites of a similar chronological age.

As a result of these diverse functional contexts, we have developed an experimental programme to identify possible wear marks that will allow us to establish potential contexts in which these cobbles were used. The determination of diagnostic criteria should provide indicators that are essential for the analysis of activities in which these tools were involved on the site (Roda Gilabert et al., submitted for publication).

4. Materials and methods

We will identify modifications produced by these activities describing the location of marks on the surface of materials, relating them to their kinematics and the work-related modifications (Table 1 and Fig. 3). The experimental programme involves three types of anvil-related behaviour: a) bipolar knapping of poor quality vein quartz nodules, b) hazelnut cracking, c) hazelnut cracking and grinding. Following the conceptual framework proposed by de Beaune (2000, 2004) these activities involve three types of percussive technical gestures: thrusting percussion, diffuse thrusting percussion and diffuse resting percussion. In this sense, it is interesting to determine alterations produced by hazelnut cracking and grinding, due to the fact that these actions combine diffuse thrusting and diffuse resting percussion, which presumable may generate wear through abrasion.

Selection of the cobbles used in the experimental programme was based on the lithology and measurements of the cobbles recovered from Font el Ros; these range between 60 and 80 mm. Cobbles were collected from the Llobregat river ravines which are on the Berga and Vidrà (Middle/Upper Eocene) conglomerate formations. These spots provide access to a great variety of rocks in cobble form, and were used as primary sources of raw materials along with secondary sources located in the immediate vicinity of the site (Terradas, 1995).

Cobble surfaces were studied using a 5×–80× binocular microscope (Olympus SZ-11), and a 50×–100× metallographic microscope (Olympus BH-2). A digital camera was used to photograph some details of marks as the depth of field of the binocular microscope made it impossible to focus on the area to be analyzed.

5. Development and results of the experimental programme

5.1. Bipolar knapping of quartz

The bipolar experiments undertaken do not differ methodologically from those described in other experiences (Barham, 1987; Courtoni, 1996; Vergés and Olle, 2011) (see Table 1 and Fig. 3a). On a technological level, axial and non-axial knapping methods on anvil (*sensu* Mourre, 1996) were used. Application of these systems facilitates a more efficient transmission of energy which physically aids the knapping of poor quality nodules that may be difficult to knap by hand-held percussion (Barham, 1987; Breuil and Lantier, 1951; Prous and Alonso, 1990; Andrefsky, 1994).

Seventeen small to medium- (30–100 mm) sized cobbles of poor quality vein quartz were reduced with hammerstones and anvils of various lithologies (Table 2).

Anvil knapping sequences generated marks that rapidly formed pits as has been indicated by Le Brun-Ricalens (1989);

Table 1
Synthesis of the experimental database.

Experiment	Goal	Development of activity
Bipolar knapping of vein quartz (Fig. 3a)	To determine marks linked with this knapping method	The active blank is grasped in the palm of the hand, preferably using the flat surfaces of the cobble. The other hand then can anchor the quartz blank to be knapped on the anvil. The experimental knappers were in a kneeling position, and aimed blows perpendicular or at an angle to the plane of percussion. Usually several blows were needed to remove blanks.
Hazelnut cracking (Fig. 3b)	To determine possible marks associated with hazelnut cracking	Half of the hazelnut sample (3 kg) was roasted for approximately 5 min in an open-air fire with a temperature that ranged between 170 and 200 °C. Throughout the experiment, the cobble was held in the palm of the hand using flat areas to crack the nuts. The experimenters maintained either a kneeling position or sat with legs crossed. Many blows were often required to break the exocarp, but it was notably much easier to achieve once the nuts had been roasted.
Hazelnut cracking and grinding (Fig. 3c)	To analyze marks associated with hazelnut cracking and grinding	In order to achieve a homogeneous roasting of nuts, a refractive oven was used for 15 min at approximately 200 °C. Gestures used during the nut cracking process were identical to those described above. In the grinding phase, blanks were hand-held and perpendicular blows directed at the passive element, while the crushing phase involved a rocking or rotary movement. Both flat and lateral surfaces of the cobble were used. The combination of movements caused the nuts to reduce in size and the crushed paste to spread towards the edges of the grinding slab.

Fig. 3. Development of the experiments presented: a) bipolar knapping of vein quartz; b) hazelnut cracking; c) hazelnut cracking and grinding (see Table 1 for details).

Jones (1994); Donnart et al. (2009) and de la Peña (2011). From the patterns observed, and similarly to those indicated elsewhere (Le Brun-Ricalens, 1989), formation of these depressions can be divided into three phases (Table 3).

Several morphological indicators relating to pit formation are apparent under a binocular microscope (Fig. 4). Initially, a fracture forms in the cortical surface of the cobble and spreads from the perimeter to the centre of the blank. As the fracture advances towards the centre, the pit increases in depth, exhibiting a stepped appearance with impact cracks, ripping and crushing of grains (Fig. 4a). In some cases, microscopic removals are visible, produced by subsidence of the surface due to repeated compression on some zones (Fig. 4b). Finally, the interior of the pit displays intense percussion marks and a frosted appearance (*sensu* Adams, 1989, 2002) affecting most of its surface (Fig. 4c).

These results suggest that variability in marks arise from the combination of different types of material. The most clearly defined marks occurred when using limestone hammerstones and anvils, decreasing when other rock types were used. It is possible that the greater capacity of sandstone anvils to absorb impact resulted in marks of lesser intensity than those evidenced on other blanks. This variability ensures that in some cases we can define marks created as incipient pits (Fig. 5a and b). That is, the development and depth of pits is related to the mechanical quality of the raw material (Donnart et al., 2009). Similarly, the intensity of marks depends on the number and force of blows on the blank rather than length of time used.

Some experimental studies have shown that after a similar period of use, anvils employed in bipolar knapping develop marks that spread forming an extended section (Moura and Prous, 1989).

Table 2
Bipolar knapping experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion.

Active element	Passive element	Quantity & nature	Time	Percussion
Limestone	Sandstone	1 vein quartz nodule	25 min	Indirect thrusting
Limestone	Sandstone	4 vein quartz nodules	25 min	Indirect thrusting
Limestone	Limestone	2 vein quartz nodules	25 min	Indirect thrusting
Limestone	Limestone	3 vein quartz nodules	5 min	Indirect thrusting
Quartzite	Sandstone	4 vein quartz nodules	15 min	Indirect thrusting
Gneiss	Limestone	2 vein quartz nodules	12 min	Indirect thrusting
Granite	Limestone	1 vein quartz nodule	4 min	Indirect thrusting
Sandstone	Limestone	1 vein quartz nodule	6 min	Indirect thrusting

Table 3
The process of pit formation during bipolar knapping.

Stages of formation	Description
Stage 1	The first punctiform marks appeared after 10/15 blows. These were small chips and compression points that could be seen on the cobble surface. The superposition of these modifications on a specific zone formed a pattern that we term 'incipient pit' (Fig. 5).
Stage 2	As work continued (c.10–15 min), the original form of the blank was altered. The superposition of marks on the same zone led to identification of active zones as pit-shaped (Fig. 4).
Stage 3	Finally, due to the compression and fatigue of the active surface the cobble is fractured. In some cases it is possible to detect the impact point from which the fracture originated. Association between fracture and pit development is involved more with the internal structure of the rock than time or intensity of cobble use.

This morphology originates, often imperceptibly, from the sliding movement of the blanks knapped on the anvil that abrades earlier marks (Donnart et al., 2009). Nevertheless, distinction between active and passive blanks on the basis of wear marks is not conclusive, and attempts to associate depth of marks with blank function remain inconsistent. The anvils used in our experimental programme display an extensive active zone, elongated in section and with marks similar to those evident on active cobbles, combining compression marks with grain crushing and fatigue wear.

As Donnart and his colleagues suggested (Donnart et al., 2009) we accept that there is certain versatility in the part played by active elements (hammerstones) and passive elements (anvils) whose roles may interchange during their use-life. This hypothesis applies to most of the Font del Ros percussion blanks provided that the only determining factor is object size, since weight is the attribute that differentiates between hammerstones and anvils (de Beaune, 1993a).

5.2. Hazelnut cracking

The aim of the second experimental programme was to distinguish the possible modifications generated in hazelnut cracking (Table 1 and Fig. 3b). The experiment began by cooking half the hazelnuts that were to be used. Roasting dry fruits eliminates tannins and lessens toxicity which contributes to a better processing of digestive enzymes and greater absorption of the nutritive value of the fruit (Stahl, 1989; Wandsnider, 1997). Equally, this process has been widely documented on an ethnographic level (Stahl, 1989) and is a practice suggested in various Mesolithic sites in Western Europe (Mithen et al., 2001; Holst, 2010). Indeed, all the *Corylus* remains recovered at Font del Ros were charred which might indicate roasting as a process associated with the consumption and/or storage of dry fruits (Martínez-Moreno and Mora, in press).

Roasting probably affects the type of marks visible on cobbles used to break dried fruits, as it generates use-wear traces that are not very clear, at least from the intensity of the work undertaken

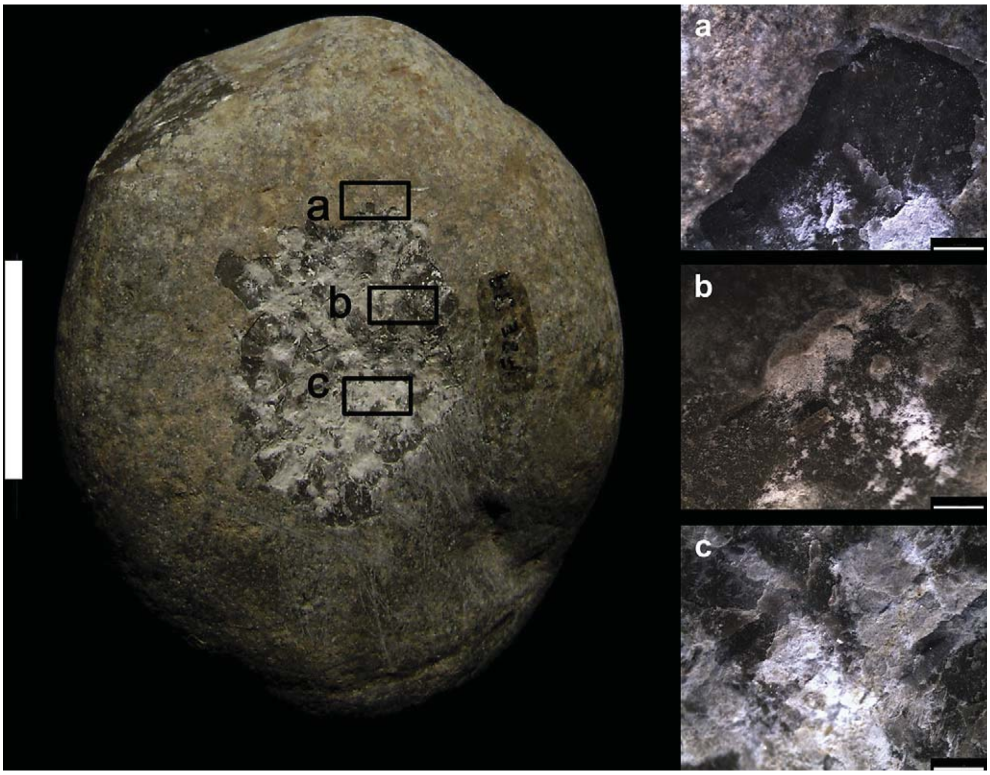

Fig. 4. Experimental pitted stone associated with bipolar knapping (limestone, 84 × 65 × 45 mm) (graphic scale 3 cm): a) detail of the external zone showing rupture of the cortical surface by impact cracks; b) micro removals associated with surface deterioration through compression; c) frosted appearance and compression points located in the centre of the pit. (a, b, c, graphic scale 1 mm).

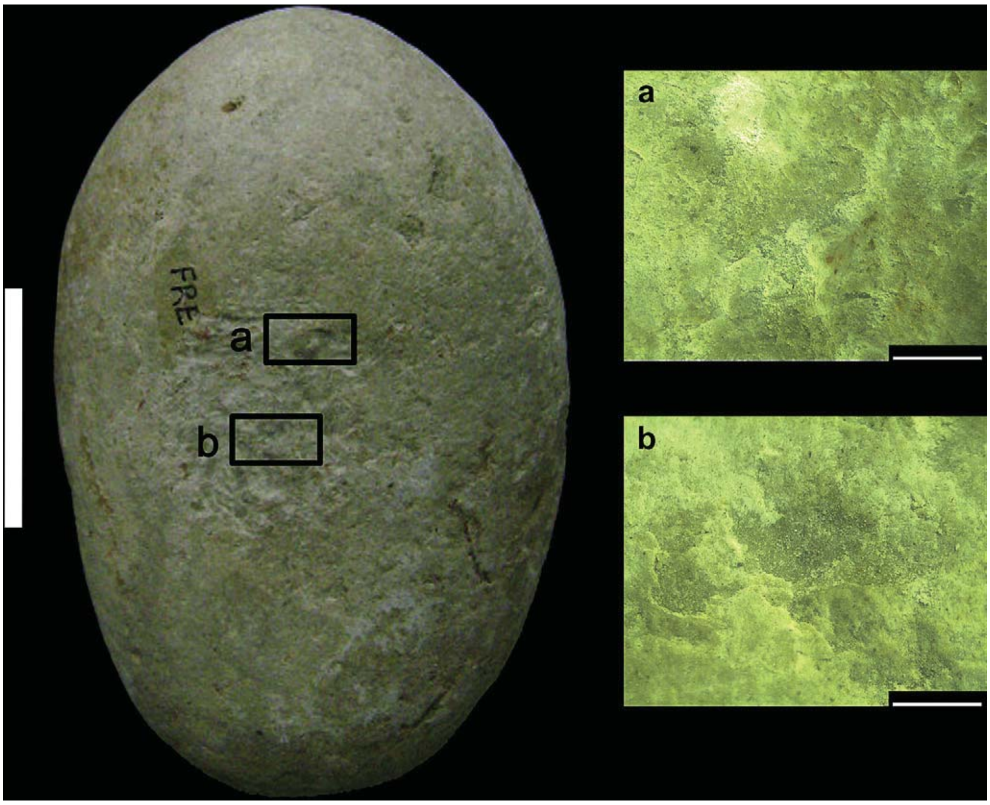

Fig. 5. Experimental incipient pit associated with bipolar knapping (limestone, 79 × 50 × 42 mm) (graphic scale 3 cm): a) external zone where impact points initiate pit depression; b) detail of the central zone with cracks, ripping and crushing of the surface (a and b graphic scale 1 mm).

in our experimental programme (Table 4). The binocular and metallographic microscopes revealed no specific marks; modifications observed could be intrinsic to the cobble, or confused with taphonomic modifications (Fig. 6). On a macroscopic level it is not easy to recognize use marks if they are not associated with residues adhering to the cobble surface (Fig. 6b and Fig. 7). Likewise, these residues are more abundant when fruits have been roasted (Fig. 7a and b). In sum, it is difficult to detect roasting without microscopic analysis or physicochemical description of residues preserved on these cobbles (Roda Gilabert, 2009).

In recent years, many analytical studies undertaken to identify plant residues on ground stone tools have yielded positive results (Fullagar et al., 2008; Piperno et al., 2009; Revedin et al., 2010). Likewise, some experimental studies have demonstrated that it is possible to identify the nature of the material of the hammerstone or anvil used in knapping activities (Byrne et al., 2006; Vergés and Ollé, 2011). Similar studies of the Font del Ros percussion tools are scheduled for the future.

5.3. Hazelnut cracking and grinding

We have noted that a pattern of modifications identified on some of the Font del Ros pitted stones indicates a repeated combination of diffuse thrusting percussion and diffuse resting percussion. Such modifications affect the horizontal plane and perimeter of the cobble creating morphologies that have been classified as *edge-ground cobbles* (Rodríguez Ramos, 2005). Our third experiment focused on replicating sequences of actions related to hazelnut cracking and grinding (see Table 1 and Fig. 3c), to assess whether these marks were associated with these percussion modalities. Six kilograms of roasted hazelnuts were processed during this experiment (Table 5).

The initial cracking open of nuts confirmed an absence of conspicuous marks that enabled precise identification of this activity. However, crushing and grinding generated diagnostic wear traces such as the formation of use facets, striations and slight glossy sheen (Fig. 8). Repeated use of the cobble surface in crushing and grinding created longitudinal striations (Fig. 8a) as well as tribochemical dissolution that particularly affected the central area of the artefact (Adams, 1989) (Fig. 8b). These striations are linked to friction action on the surface resulting from longitudinal movements used when cleaning off the product resulting from grinding. On the other hand, degradation of the cobble surface could be due to the lubricating action of *Corylus* dough which in the zone of greatest friction causes wear that is identified by glossy sheen, and which is associated with many oily residues

Table 4
Hazelnut cracking experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion.

Active element	Passive element	Quantity & nature	State	Time	Percussion
Limestone	Limestone	2 kg (c. 800 nuts)	Roasted	135 min	Diffuse thrusting
Limestone	Limestone	1 kg (c. 400 nuts)	Roasted	60 min	Diffuse thrusting
Granite	Sandstone	1 kg (c. 400 nuts)	Roasted	70 min	Diffuse thrusting
Limestone	Sandstone	2 kg (c. 800 nuts)	Fresh	125 min	Diffuse thrusting
Limestone	Sandstone	1 kg (c. 400 nuts)	Fresh	40 min	Diffuse thrusting
Granite	Sandstone	1 kg (c. 400 nuts)	Fresh	65 min	Diffuse thrusting

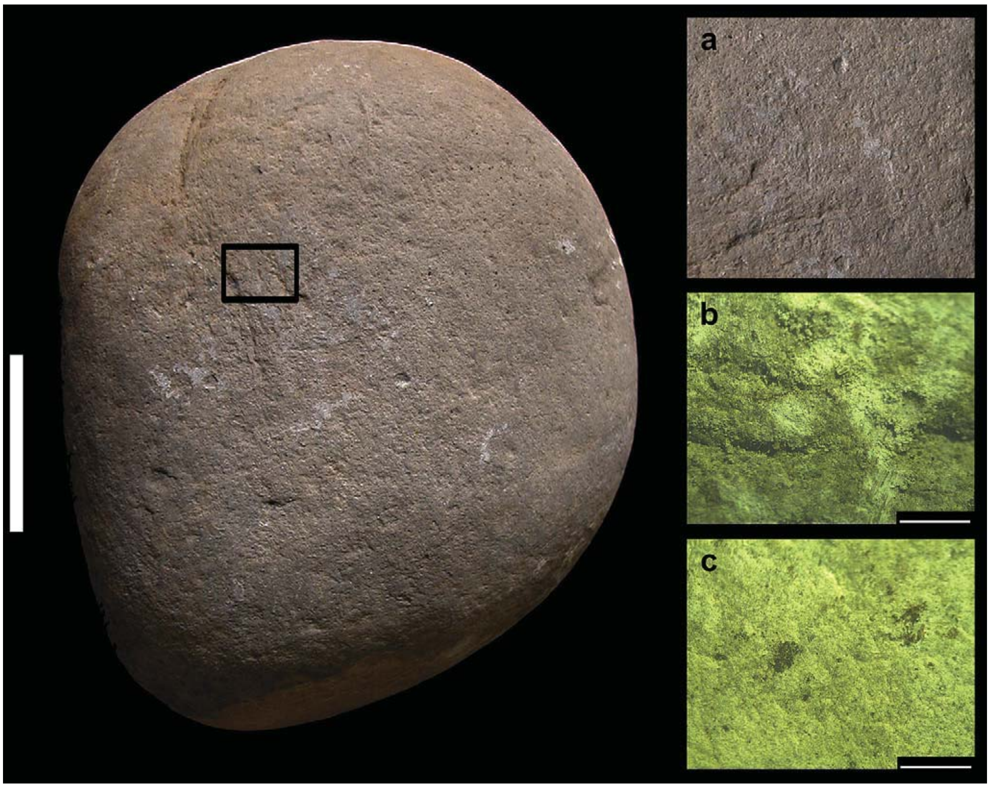

Fig. 6. Experimental cobble used to crack fresh hazelnuts (limestone, 80 × 67 × 51 mm) (graphic scale 3 cm): a) macro view of an unused zone sowing surface alterations previous to the experimentation; b) residues and traces of use-wear polish associated with hazelnut cracking; c) use-zone after cleaning in ultrasonic bath showing slightly evident of use (b and c graphic scale 1 mm).

produced during crushing and grinding activities (Adams, 1989; Dubreuil, 2004).

6. Discussion

Despite the limited number of blanks included in this study, some observations can still be made. The results presented here indicate a strong association between bipolar reduction and the formation of depressions and pits in percussion tools. Similar marks, documented since the earliest experiments on anvil percussion (Breuil and Lantier, 1951), have also been identified in experimental programs (Moura and Prous, 1989; Jones, 1994; Donnart et al., 2009).

In this sense, similar pounding activities using intermediate tools such as stone chisels or wedges can also be associated with

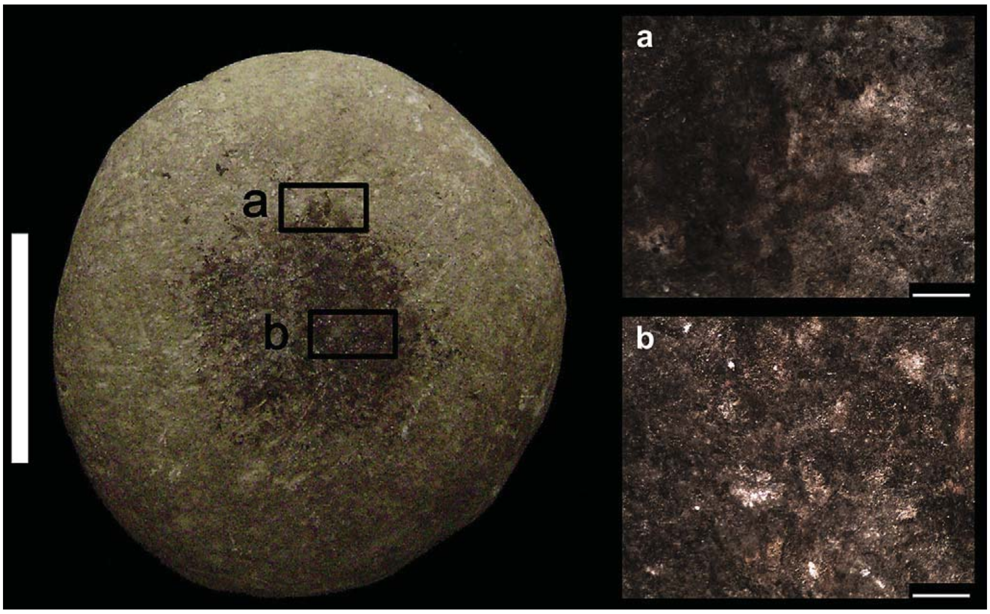

Fig. 7. Experimental cobble used to crack roasted hazelnuts (limestone, 63 × 60 × 33 m) (graphic scale 3 cm): a) contact zone between the cobble surface and location of residues; c) detail of *Corylus* associated residues (b and c graphic scale 1 mm).

Table 5
Hazelnut cracking and grinding experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion and gestures involved.

Active element	Passive element	Quantity & nature	State	Time	Percussion type and main gestures
Limestone	Sandstone	2 kg (c. 800 nuts)	Roasted	145 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction movements
Limestone	Sandstone	2 kg (c. 800 nuts)	Roasted	180 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction and rotary movements
Limestone	Granite	2 kg (c. 800 nuts)	Roasted	175 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction and rotary movements

pitted stones (Hayden, 1980; Mazière, 1984; Chauchat et al., 1985; Le Brun-Ricalens, 1989; Jones, 1994; Gibaja et al., 2007; de la Peña, 2011). Among the different functional hypothesis proposed for this pair of artefacts is remarkable their use for cracking organic materials such as wood or bones. This later assumption seems to be confirmed regarding recent archaeological evidences (Bicho and Stiner, 2005; Gibaja and Bicho, 2006; Gibaja et al., 2007). Although these behaviours have not been included in our experimental program these functional inferences cannot be ruled out in the interpretation of the Font del Ros pitted cobbles.

The presence of pitted stones with irregular pits -disorganized impact points- have been identified on several of the cobbles from level SG, allowing us to associate pitted stones and splintered pieces/*outils écailles* (Roda Gilabert et al., submitted for publication). On the other hand, at Font del Ros this observation exists side by side with other bipolar by-products associated with axial percussion on an anvil (Pallares, 1999). Indeed, a bipolar knapping system is commonly used to remove blanks from tough, poor quality rocks, as has been noted in Mesolithic levels of several sites on the southern slopes of the Pyrenees (Martínez-Moreno et al., 2006b). Future research will contribute new data to the ongoing discussion on whether splintered pieces identification as tools or cores (Hayden, 1980; Chauchat et al., 1985; Shott, 1989, 1999; Le Brun-Ricalens, 1989, 2006; Lucas and Hays, 2004).

In parallel, we note that scanty hardness of the *Corylus* exocarp does not cause a pattern of marks on cobble surfaces that can be positively identified macroscopically and/or mesoscopically. We think that association of these tools with fleshy fruit processing stems from the transfer by analogy of archaeological and ethnographic models onto different contexts. Processing of different types of nuts by *P. troglodytes* (Joulian, 1996; Mercader et al., 2002, 2007; Carvalho et al., 2008) and *C. libidinosus* (Fragaszy et al., 2004) produces cobbles and fragments with centralized pits and depressions. It should be noted that such of these nuts requires a very powerful force to get at the kernel (Joulian, 1996; Mercader et al., 2002). These small depressions, then, result from the compression of materials of poor elasticity which deform under repeated powerful blows (Visalberghi et al., 2007). The cited examples remark the possibility that processing hard-shelled nuts could explain the evident modifications indicated in descriptions of artefacts at Olduvai or Gesher Benot-Yaqov (Leakey, 1971; Leakey and Roe, 1994; Goren-Inbar et al., 2002; Mora and de la Torre Sainz, 2005).

It has been suggested that during the European Mesolithic cobbles with pits and friction facets are associated with hazelnut processing (Holst, 2010). However, if we consider the results presented in this paper this interpretation cannot be supported. The physical characteristics of dried fruits consumed in temperate zones do not match those described in the above cases (Mason and Hather, 2002), implying that pitted stones documented in these contexts are associated with other bipolar activities on hard materials. At present, we do not rule out the fact that hazelnut processing causes the formation of clear deep pits. Alternatively, we propose that the combination of use-wear patterns associated with grinding causes friction wear that regularises the cobble

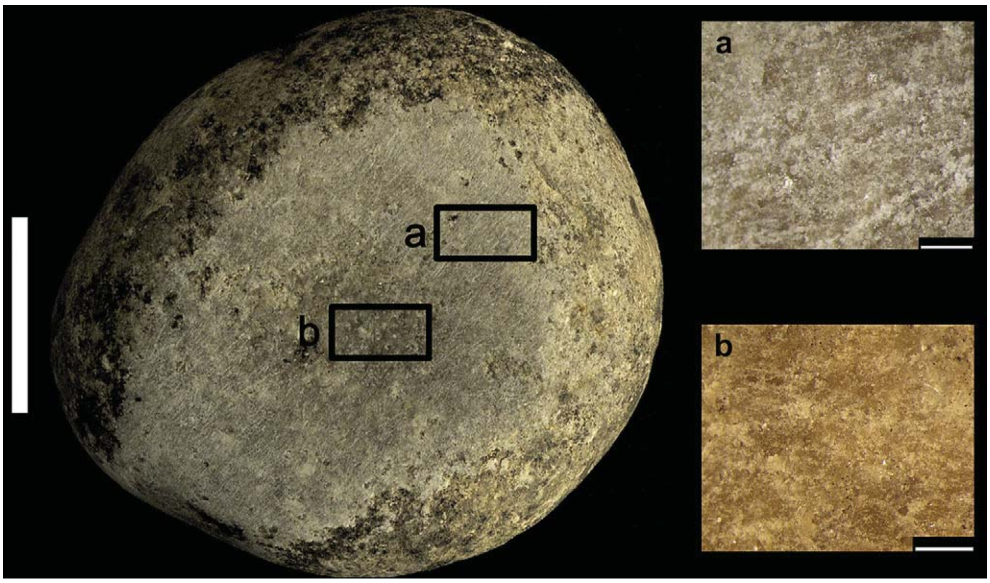

Fig. 8. Experimental cobble used to crack and grind hazelnuts (limestone, 84 × 73 × 46 mm) (graphic scale 3 cm): a) longitudinal striations and glossy sheen; c) detail of the tribochemical dissolution (a and b graphic scale 1 mm).

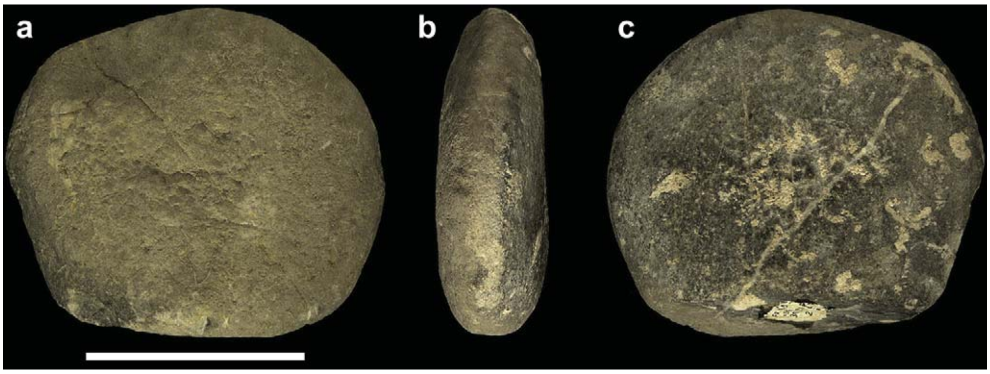

Fig. 9. Archaeological pitted stone from Font del Ros level SG (limestone, 83 × 70 × 28 mm): a) central pitting associated with bipolar knapping; b) edge use-wear facet caused by friction movements; c) central pitting associated with bipolar activity surrounded by tribochemical dissolution (graphic scale 5 cm).

surface causing striations and tribochemical dissolution of the surfaces noted in some artefacts (Fig. 2e). In fact, kinematically such alterations are opposed with the mechanical alterations related with the pit formation (Roda Gilabert, 2009).

Similarly, such use-wear patterns showing the superposition of several activities indicate the multifunctionality of these tools, understood as their use for different, overlapping activities. The overlapping of diffuse resting percussion and friction on the cobble edge creates use-wear pattern facets that are similar to those described for *edge-ground cobbles* (Rodríguez-Ramos, 2005) (Fig. 9b). Added to these features is the presence of light modification in the central zone produced by thrusting percussion (Fig. 9a), and tribochemical changes evident in the presence of polish on the tool surface (Fig. 9c). The combination of the above attributes may be macroscopic indicators of the use of this artefact, among other tasks, as tools for crushing and grinding of dried fruits. Interestingly, preliminary studies of some of the Font del Ros cobbles revealed starch from *Corylus* and *Quercus* on a pitted stone which displayed wear traces resulting from friction activities along the perimeter (Juan, 1997).

Finally, a gneiss cobble showed intentional shaping of two central pits, regular in section, displaying in this case well delimited pecking patterns on opposite surfaces of the artefact (Fig. 10b and c). On the other hand, friction traces associated with pounding and grinding activities, were present on all surfaces of the same cobble as well as on the lateral and transversal edges. Some

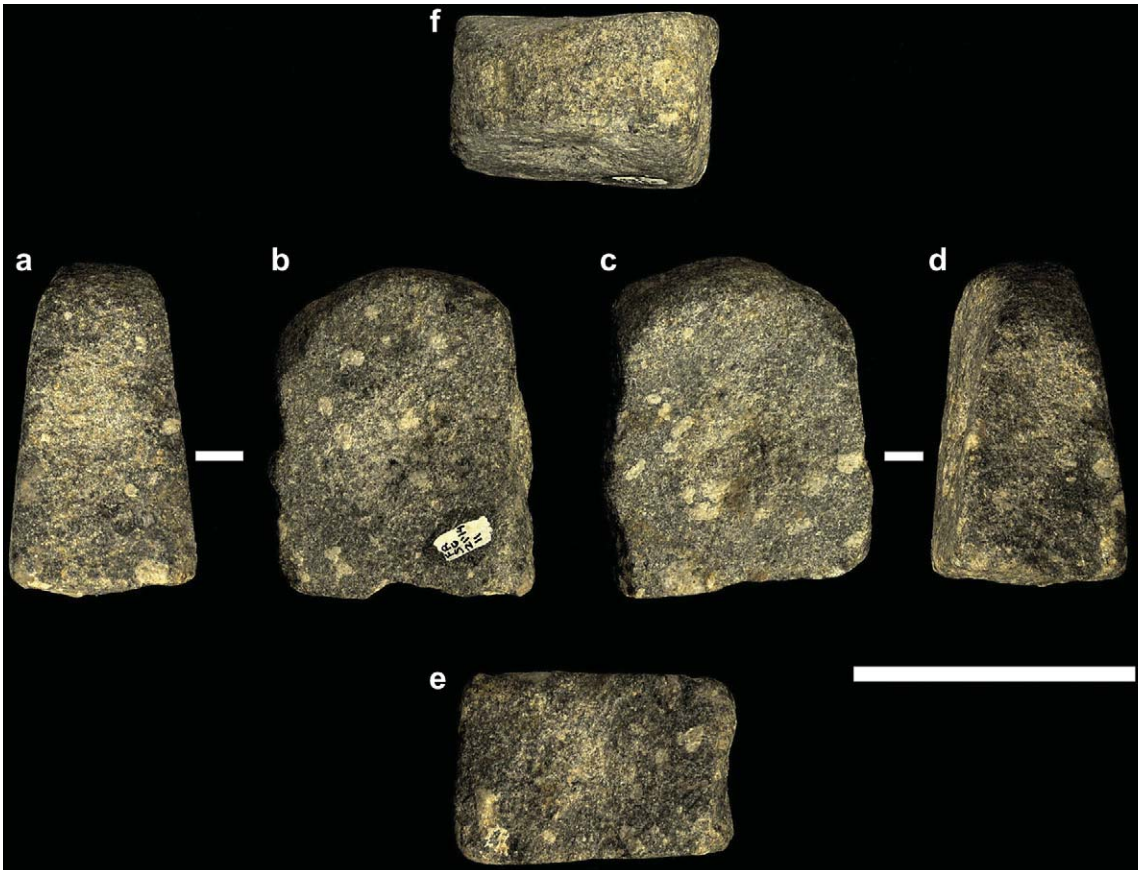

Fig. 10. Archaeological pitted stone fragment showing multi-functional use-wear marks from Font del Ros level SG (gneiss, 57 × 46 × 30 mm): a, d, f) thrusting percussion marks; b, c) pits with regular section suggesting intentional pecking; e) convex use-wear facet produced by friction (graphic scale 5 cm).

ethnographic observations stress the utility of central, regular depressions as *finger grips* (de Beaune, 2000; Adams, 2002) to hold worked materials. In this sense, we agree that it is not always easy to differentiate between manufacture and use-wear scars (de Beaune, 1993b). It is not the remit of this paper to analyze potential context of this type of artefact.

7. Conclusions

The results of the experimental programme presented here contribute towards a greater understanding of percussion activities. We have shown that most of the Font del Ros pitted cobbles included in this study, have modifications associating them with bipolar knapping, an observation that complements results indicated by other studies (Le Brun-Ricalens, 1989; Donnart et al., 2009; de la Peña, 2011).

Nevertheless, we emphasize the fact that in other cases these modifications may signify different activities. We have indicated that the association of marks on the same active surface, in which the combination of thrusting and resting percussion linked with tribochemical changes, may be related to nut cracking (Fig. 9). This activity is difficult to verify without concomitant analysis to identify the presence of residues (Piperno et al., 2009), as it is necessary to establish protocols regarding the recuperation of residues from these artefacts. It would be interesting if this hypothesis were analyzed in other sites where similar artefacts have been identified, in order to determine whether or not they are related with food processing.

In summary, the marks identified on pitted stones show a certain degree of variability, and in principle pose a problem of equifinality in the exact determination of the function of these tools. However, we should not forget that such variability is an important attribute given the multi-functional nature of these artefacts that are relatively simple and easy to make, but at the same time are used effectively for a wide range of activities (de Beaune, 2000). Likewise, because of their use in essential domestic activities, we emphasize their diagnostic potential for the analysis of spatial activity patterns.

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Appendix. Supplementary material

Supplementary data related to this article can be found online at doi:10.1016/j.jas.2011.12.017.

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Regards croisés sur les outils liés au travail des végétaux.
An interdisciplinary focus on plant-working tools.
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La gestion des végétaux dans les Pyrénées : la consommation des noisettes sur le site mésolithique de Font del Ros

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Résumé
Pendant le Mésolithique de l'Europe occidentale, les galets, plaquettes et autres supports lithiques non taillés faisaient partie de la panoplie d'outils liés à la gestion des végétaux. Sur le site de Font del Ros (Pré-Pyrénées, Espagne) certains des galets présentent des traces de mouture et de broyage qui peuvent être liées à la transformation et à la consommation de végétaux, parmi lesquels les noisettes constituent un élément remarquable. L'objectif de ce travail est de présenter l'étude des traces d'usure sur ces galets ainsi que l'analyse des macrorestes végétaux, développée notamment en termes statistiques et spatiaux. Ce cadre méthodologique conduit à documenter le rôle que la cueillette a joué dans les activités développées sur le site.
Mots clés : Mésolithique, macro-outillage, traces d'usure, cueillette, Font del Ros.

Abstract
It has been suggested that during The Western Europe Mesolithic period cobbles, fragments and other not-knapped lithic artifacts were integrated within the tool-kit related to plant resources management. At the Font del Ros site some cobbles yielded use-wear traces related to pounding and grinding. These artifacts can be linked to the processing and consumption of plants, hazelnuts being a key element. The purpose of this paper is to present the use-wear analysis conducted on these cobbles combined with geo-statistical analysis. This methodological framework permits to analyze the role of gathering within the activities developed on the site.
Keywords : Mesolithic, macrolithic, use-wear, gathering, Font del Ros.

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Consommation des végétaux au Mésolithique : à l'encontre des normes et des clichés

Bien que les végétaux constituent une ressource nutritionnelle importante, il est difficile de démontrer leur consommation par l'archéologie (Mason, Heather [éd.], 2002). À partir du Mésolithique, une augmentation et une diversification dans l'exploitation des plantes est mise en évidence (Clark, 1976). Ce phénomène est associé à l'apparition des *broad spectrum economies* (Flanery, 1969). L'expansion forestière du postglaciaire a permis à la cueillette de devenir une activité centrale, avec une généralisation de la consommation des fruits, racines et tubercules (Zvelebil, 1994). Cependant, des problèmes de conservation et de déficiences inhérentes aux techniques d'échantillonnage ont entravé leur documentation sur les sites de chasseurs-cueilleurs (Mason, Heather [éd.], 2002).

Des techniques telles que la flottation (Mason, Heather [éd.], 2002 ; et références à l'intérieur) ou l'analyse de résidus sur des artefacts (Revedin *et alii*, 2010) permettent d'identifier la présence de végétaux. Un autre indicateur provient de l'outillage utilisé dans la préparation et la consommation d'aliments (de Beaune, 2000 ; Procopiou, Treuil [éd.], 2002). La panoplie instrumentale de broyage et de concassage est connue au Proche-Orient à partir du Natoufien (Dubreuil, 2004) et, en général, en Europe occidentale, à partir du Néolithique (Hamon, 2008). Cependant, les études sur les artefacts utilisés par les chasseurs-cueilleurs sont rares (de Beaune, 2000). L'identification de l'utilisation de galets combinée aux données des analyses botaniques ouvre de nouvelles voies pour caractériser la gestion de végétaux au Mésolithique.

Dans ce travail, le rôle de la cueillette chez les chasseurs-cueilleurs mésolithiques du côté sud des Pyrénées sera documenté à partir de l'analyse bioarchéologique de semences. Des évidences telles que la présence de noisettes ainsi que les informations apportées par les artefacts présentant des marques de concassage et de broyage récupérés sur le site de Font del Ros nous permettent de mieux approcher cette activité.

Le Mésolithique dans les Pyrénées et les preuves d'une consommation de fruits

On trouve de part et d'autres des Pyrénées une série de gisements mésolithiques généralement situés au contact des premiers contreforts montagneux et aux abords des vallées fluviales (Pallarés, Mora, 1999) (fig. 1). Cette situation suggère une biodiversité de ressources élevée, et les restes animaux et végétaux récupérés définissent une saisonnalité marquée sur ces sites. Ces gisements partagent des attributs techno-culturels initialement identifiés comme « faciès de fortune » (Barbaza *et alii*, 1984). Ce faciès chrono-culturel a reçu différentes appellations telles que « Épipaléolithique macrolithique » ou « Mésolithique d'encoches et denticulés » (Alday (éd.), 2006). Parmi ces ensembles, on trouve fréquemment des outils macrolithiques qui peuvent être associés, entre autres activités, au traitement et à la consommation de végétaux (Martínez-Moreno *et alii*, 2006a).

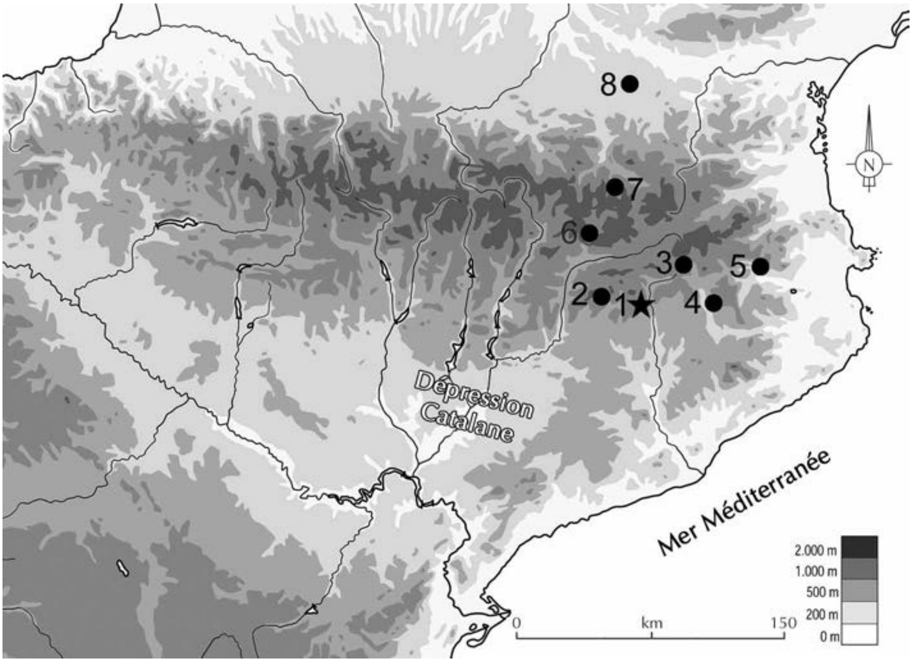

Fig. 1. *Carte de la zone d'étude : gisements mésolithiques où sont documentés des restes de noisettes :* ***1.*** *Font del Ros ;* ***2.*** *Balma Guilanyà ;* ***3.*** *Sota Palou ;* ***4.*** *Roc del Migdia ;* ***5.*** *Bauma del Serrat del Pont ;* ***6.*** *Balma de la Margineda ;* ***7.*** *Dourgne :* ***8.*** *Abeurador.*

Des restes carbonisés de noisettes se retrouvent dans la majorité d'entre eux (fig. 1). Cette dynamique est cohérente avec l'expansion de la forêt feuillue mésophile holocène. L'utilisation de noisettes en tant que ressource alimentaire présente divers avantages : les récoltes sont faciles à organiser, à cueillir et à stocker (Zapata, 2000). Par ailleurs, c'est une denrée avantageuse car abondante, et ce fruit sec est d'une valeur énergétique élevée (Marinval, 1988). Selon Wandsnider (1997), la torréfaction allonge sa conservation et élimine les tanins et les micro-organismes, en même temps qu'elle facilite sa préservation archéologique. Toutefois, l'importance du rôle de ces fruits dans l'alimentation des chasseurs-cueilleurs est difficile à évaluer, et Font del Ros ne fait pas exception à la règle.

Le site mésolithique de Font del Ros

Ce gisement en plein air est situé dans la zone urbaine de la ville de Berga (Barcelone), en contact avec la Dépression catalane et les premiers contreforts des Pré-Pyrénées, à 670 mètres d'altitude (x = 404478, y = 4660989, UTM H31, ETRS89).

Lors de la fouille, deux niveaux mésolithiques et un troisième daté du Néolithique ancien ont été identifiés (Pallarés *et alii*, 1997). Ce travail est centré sur l'unité archéologique SG, qui s'étend sur un niveau de 1 200 m^2 et où ont été identifiés plus de 27 800 vestiges lithiques, de restes osseux et végétaux. Dans

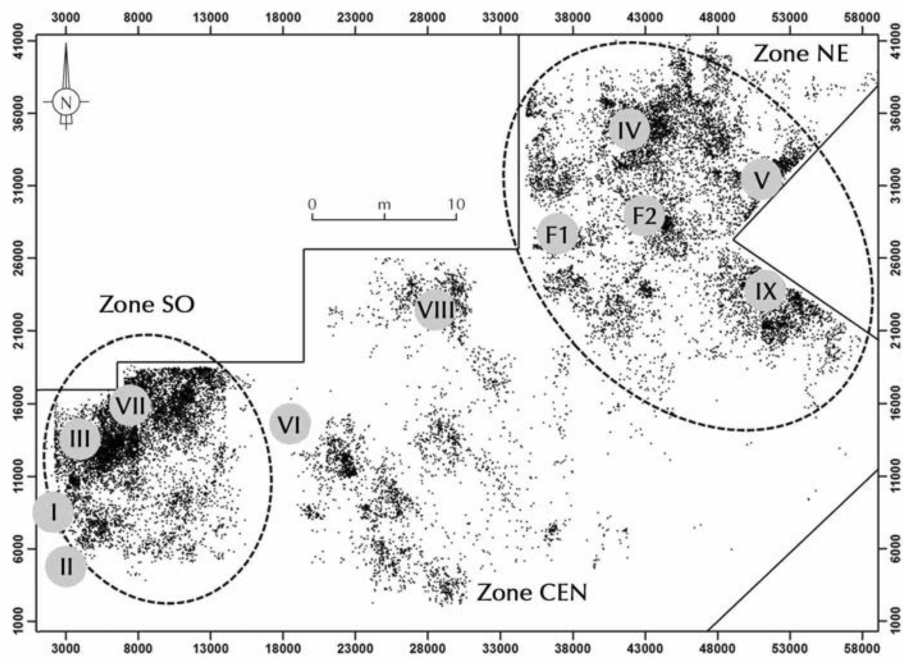

Fig. 2. *Plan de l'unité archéologique SG de Font del Ros avec la délimitation des trois zones différenciées et les structures associées (cercles numérotés).*

l'ensemble lithique, plus de 350 galets et fragments ont été comptabilisés. Certains présentent des traces d'usure macroscopiques sur leurs surfaces. Ces traces sont apparentées à des activités de découpe ou de travail des matières organiques, végétaux et peaux (Pallarés, 1999; Roda Gilabert *et alii*, 2012).

Lors de la fouille, trois accumulations ont été distinguées autour de neuf structures de combustion et deux fosses (fig. 2). Les remontages lithiques et les analyses *intrasite* suggèrent diverses zones d'occupation qui fonctionnent de manière indépendante (Martínez-Moreno, Mora, 2011). La série de radiocarbone fournit un argument décisif pour étayer cette diachronie interne. Cette série, calibrée à 2σ, situe le niveau SG entre 10,250-8,450 cal. B.P., dans la chronozone boréale. Les trois zones identifiées présentent des caractéristiques contextuelles différenciées (Pallarés, 1999; Martínez-Moreno, Mora, 2011) (fig. 2):

— zone sud-ouest (Zone SO): elle s'étend sur 100 m^2 et l'on y trouve les foyers I, II, III, VII;

— zone centrale (Zone CEN): elle s'étend sur 510 m^2. Elle présente une moindre densité de matériaux qui peut être associée au foyer VIII;

— zone nord-est (Zone NE): elle s'étend sur 350 m^2 et l'on y trouve les foyers IV, V et IX, ainsi que les deux fosses (F1 et F2).

L'étude anthracologique de 1254 restes (tab. 1) restitue une forêt présentant une biodiversité élevée où l'on trouve en abondance des taxons à feuilles caduques tels que le chêne (*Quercus sp.* : 38 %), le noisetier (*Corylus avellana*: 21 %), le poirier sauvage (*Pyrus pyraster*: 6 %), les *pomo*ïdées (*Pomoidea sp.* : 5 %), et la présence sporadique de l'orme (*Ulmus sp.),* de saules (*Salix sp.),* du sureau (*Sambucus sp.)* et d'arbustes comme le buis (*Buxus sempervirens*: 17 %). Cette flore est de tonalité supraméditerranéenne à mésophile (Jordá *et alii,* 1992). Par ailleurs, cette analyse montre que le noisetier est un combustible habituellement employé.

Taxons	Nombre de fragments	Pourcentage
Quercus sp.	480	38,27 %
Corylus avellana	260	20,73 %
Buxus semperivens	214	17,06 %
Cf. Pirus	72	5,74 %
Pomoidea	58	4,62 %
Prunus avium	24	1,91 %
Sorbus sp.	22	1,75 %
Acer sp.	12	0,95 %
Prunus spinosa	11	0,87 %
Rhamnus cathartica	10	0,79 %
Pinus sylvestris	8	0,63 %
Salix sp.	6	0,47 %
Ulmus sp.	6	0,47 %
Pinus halepensis	3	0,23 %
Prunus sp.	2	0,15 %
Sambucus sp.	2	0,15 %
Leguminosa	1	0,07 %
No déterminable	63	5,02 %
Total	**1254**	**100 %**

Tab. 1. *Données brutes des charbons de bois récupérés sur l'unité SG de Font del Ros (étude réalisée par R Piqué, voir Jordá et alii, 1992).*

Les macrorestes végétaux ont été collectés lors de tamisages par flottation manuelle. L'analyse carpologique a mis en évidence une présence significative de noisetier (*Corylus avellana*: 220), mais aussi du pommier sauvage (*Malus silvestris*: 9), du poirier sauvage (*Pyrus pyraster*: 2) et du prunellier (*Prunus spinosa*: 1) (Pallarés, 1999). Elle n'a caractérisé ni gland ni pignon, deux fruits potentiels, pourtant bien identifiés par l'étude anthracologique (Jordá *et alii,* 1992).

D'autres indices suggèrent que la consommation de végétaux, plus particulièrement de la noisette, est une activité réalisée sur le site. Ils viennent renforcer l'idée selon laquelle la cueillette de végétaux se généralise pendant le Mésolithique, comme cela a été évoqué sur des sites proches tels que Margineda (Marinval, 1988), Guilanyà ou Sota Palou (Pallarés, Mora, 1999 ; Allué *et alii,* 2012), ou encore dans le nord de la péninsule Ibérique (Zapata, 2000).

Méthodologie

Afin de reconnaître les instruments associés au traitement du noisetier, nous avons examiné les traces d'utilisation sur l'outillage macrolithique. Parallèlement, l'analyse spatiale d'éléments contextuels a été conduite pour tenter d'obtenir des informations sur les zones de traitement ou de consommation de noisettes sur le site. Ces deux approches conjuguées ouvrent la voie pour reconnaître les activités de subsistance développées sur le site.

Analyse du matériel macrolithique

Les observations menées sur les galets ou des fragments de galet utilisés suivent la méthodologie proposée par Adams *et alii* (2009). Celle-ci a été enrichie par l'application des résultats de notre propre programme expérimental publié récemment (Roda Gilabert *et alii*, 2012). Les schémas identifiés expérimentalement caractérisent les marques associées à l'ouverture et au concassage/ broyage de noisettes (tab. 2). Ces traces se reconnaissent sur le matériel archéologique au moyen de l'utilisation de la loupe binoculaire (Olympus SZ-11) au grossissement variant de 3 × à 60 ×.

Analyse spatiale et géostatistique

L'analyse de la distribution spatiale de galets présentant des traces de concassage/ broyage, des macrorestes végétaux et la situation contextuelle de structures d'habitat (foyers et fosses) permettra de détecter des zones spatiales associées à la préparation et à la consommation d'aliments. Pour leur visualisation, deux types de représentations ont été élaborées au moyen d'un logiciel GIS (ESRI ArcMap v.10) :

Activité	Description de l'activité	Traces identifiées
Ouverture de noisettes	Les galets ont été tenus dans la paume de la main, on a utilisé les surfaces plates pour l'ouverture des noisettes. Simultanément, les fruits étaient tenus avec l'autre main sur une enclume. Dans la majorité des cas, plusieurs coups ont été nécessaires pour l'ouverture des fruits. La torréfaction des noisettes facilite la fragmentation de l'exocarpe.	— Absence de traces diagnostiquées — Au niveau macroscopique et à faibles augmentations il est difficile d'identifier des zones actives. — La torréfaction de fruit génère une abondance de résidus. — La relation entre le traitement de noisettes et la formation de pierres à cupules est écartée.
Concassage broyage de noisettes	L'ouverture des fruits a été réalisée de manière identique à celle qui a été décrite pour l'expérimentation précédente. Le concassage se réalise par une percussion avec des coups perpendiculaires à l'enclume. Pendant le broyage, on utilise les galets au moyen d'un va-et-vient ou de mouvements de rotation, en employant aussi bien les surfaces plates que les surfaces latérales des galets.	— Modification de la délinéation originale des surfaces actives. — Formation de facettes d'usure (plage), de stries et de lustres brillants. — Nivellement des grains. — Stries verticales, résultat du contact pierre contre pierre.

Tab. 2. *Traces d'usures identifiées expérimentalement, associées à l'ouverture et au concassage/ broyage de noisettes (voir Roda* et al. *2012).*

a. le dénombrement par mètre carré de restes de noisettes, qui visualise la distribution spatiale des restes ;
b. les cartes de densité Kernel élaborées à partir de nuages de points ; ce processus permet l'analyse non paramétrique d'estimation de la densité d'une variable aléatoire.

Cette méthodologie a déjà été utilisée sur d'autres gisements, où elle a mis en évidence des zones d'activité non immédiatement visibles (Alperson-Alfil *et alii*, 2009 ; Mhamdi, Davtian, 2011).

Présentation des données

Ensemble macrolithique associé au traitement de végétaux

Trente-neuf galets ou fragments présentent des traces d'utilisation qui peuvent être associées au traitement de végétaux. Les roches les plus représentés sont le grès (18), le quartzite (8) et le calcaire (5), dont l'approvisionnement provient des terrasses adjacentes au gisement.

Les morphologies prédominantes sont des artefacts ovales ou semi-ovales aux profils convexes de dimensions inférieures à 100 mm. Ces caractéristiques facilitent leur prise en main et leur utilisation pour différents modes de percussion. Le format de certains fragments laisse voir qu'une partie de l'ensemble correspond à des pièces de grand format, certaines employées comme enclumes s'étant brisées suite à l'usage.

Les traces d'utilisation détectées proviennent de gestes associés à la percussion posée (de Beaune, 2000). On détecte des modifications telles que des facettes (plages) d'utilisation polies au profil plat (fig. 3a, d) ou convexe (fig. 3b, c), et du point de vue topographique, on observe l'émoussement des grains et l'arasement du relief (Adams *et alii*, 2009). Dans certains cas, des stries ou des lustres apparaissent (fig. 3a).

On peut remarquer divers outils présentant des traces périmétrales d'utilisation, dénommés *edge ground cobbles* (Rodríguez-Ramos, 2005) (fig. 3b, c, d). Sur ces pièces, les traces d'abrasion et de polissage modifient la forme de la pièce et définissent une section transversale à la délinéation convexe. Sur certaines, les zones actives laissent voir aussi des marques de percussion lancée (de Beaune, 2000) qui mettent en évidence une large diversité de gestes réalisés avec ces outils. Nous associons ces traces au traitement de noisettes, car leur description est similaire à celles obtenues expérimentalement sur des galets utilisés pour écraser des tubercules (Rodríguez Ramos, 2005).

La coexistence de divers types de traces sur différentes surfaces d'un même artefact signale que certains outils sont polyfonctionnels (Roda Gilabert *et alii*, 2012). Bien qu'il s'agisse d'artefacts simples, qu'ils présentent une préparation faible ou nulle, ces galets s'intègrent dans des chaînes opératoires différenciées qui laissent entrevoir le développement de tâches essentielles dans le mode de vie des chasseurs-cueilleurs (de Beaune, 2000).

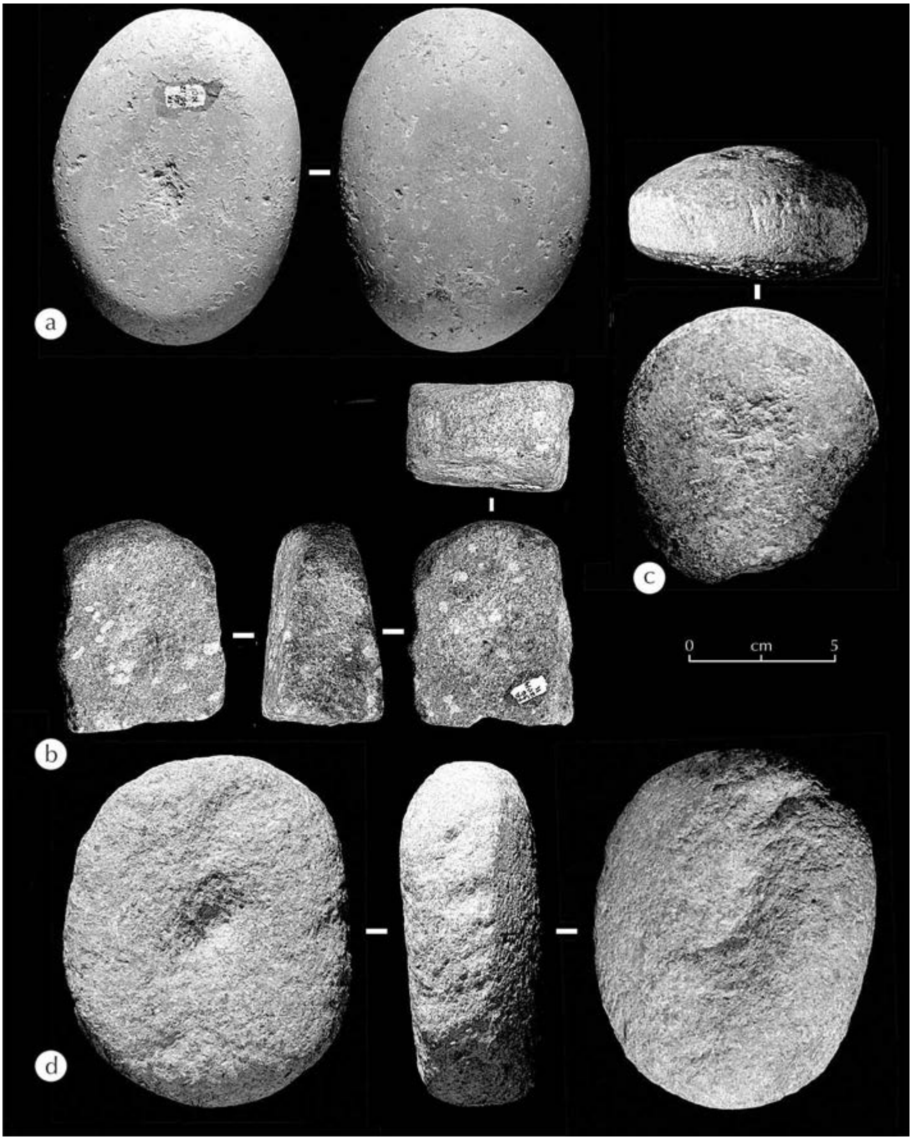

Fig. 3. *Galets et fragments présentant des traces d'utilisation associées au traitement de végétaux.*

Zones d'activité

La visualisation des relations entre la position spatiale de coques de noisettes (*Corylus*) et les artefacts macrolithiques constitue une approche pour analyser la validité de ces propositions fonctionnelles. Le poids et les dimensions des galets suggèrent que ces artefacts ne sont pas, en principe, déplacés lors des processus de remaniement; leur position spatiale constitue ainsi une donnée importante.

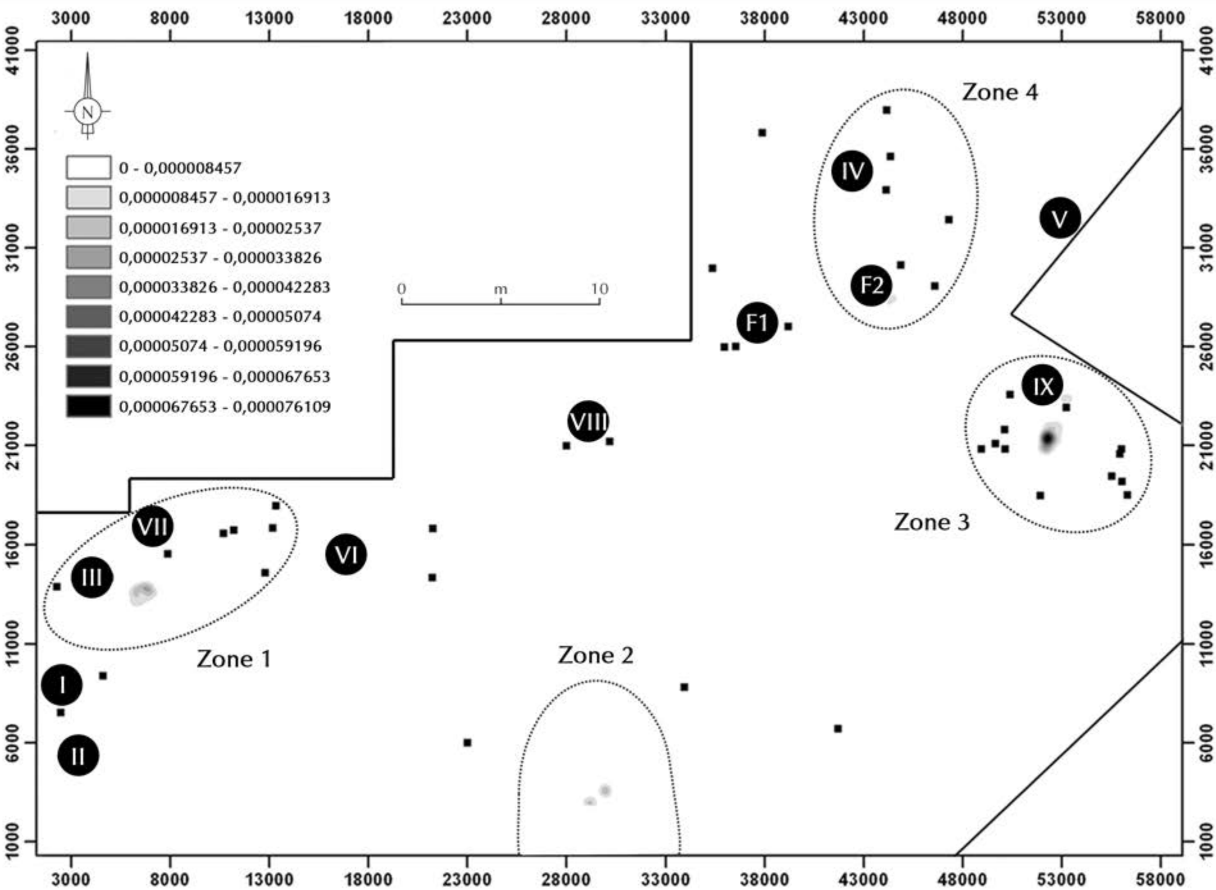

Fig. 4. *Plan de densité kernel des restes de noisettes avec la délimitation des 4 zones liées à la consommation des végétaux (ellipses). La représentation comprend les foyers et les fosses (cercles numérotés) ainsi que les galets et les fragments présentant des marques de concassage et broyage (carrés).*

D'autres données archéologiques fournissant des informations sont constitués par les foyers, d'autant plus si l'on considère la torréfaction de la noisette avant son concassage comme une technique probable pour faciliter sa consommation ou sa conservation (Wandsnider, 1997 ; Cunningham, 2011) (tab. 2).

La combinaison de ces différents indices permet de chercher s'il existe des zones d'activité où l'on puisse détecter le traitement de noisettes. Les résultats obtenus par l'analyse de densité *Kernel* des macrorestes de noisettes distinguent quatre concentrations. Dans toutes les zones de concentration, les galets se situent à proximité de foyers, et c'est en même temps autour de ces derniers que la majorité des restes de noisettes ont été trouvés. Cependant, chaque zone présente des attributs différents (fig. 4) :

— Dans la zone 1 les restes de noisettes sont associés aux foyers VI et VII, où l'on identifie des outils macrolithiques avec des traces de concassage et de broyage. Cette association suggère une zone de traitement de végétaux.

— Dans la zone 2, même si l'on trouve nombre de restes de noisettes, les galets portant des marques de traitement de végétaux et les foyers sont absents. Il faut remarquer que cette accumulation présente une continuité latérale vers la limite sud du gisement, qui n'a pas pu être fouillée.

— La zone 3 présente un plus grand nombre de restes de *Corylus*. Elle est associée au foyer III avec un dallage circulaire de petites dimensions (30 cm × 30 cm) (Pallarés, 1999). Des études préliminaires de chimie organique réalisées sur les sédiments de cette structure ont permis de détecter des résidus de fruits (Juan, 1997). Autour du foyer, la fouille a livré des restes végétaux et des galets présentant des traces liées au traitement de végétaux.

— La zone 4 est située à côté d'une fosse où des fragments de noisettes ont été collectés. Des galets présentant des traces de friction et des macrorestes végétaux sont positionnés à proximité. Ces indices suggèrent la possibilité qu'il s'agisse d'une zone de traitement de végétaux qui a postérieurement été démantelée pour d'autres activités ou pour la réutilisation de cet espace par des occupations postérieures.

Ces résultats montrent que le traitement des coques de noisettes – et peut-être d'autres fruits – est une activité réalisée sur le gisement. Cette tâche peut être circonscrite à des zones spatiales discrètes où d'autres tâches domestiques sont réalisées, comme l'obtention de supports lithiques, le traitement et la consommation de faune ou le travail de peaux (Martínez-Moreno, Mora, 2011).

Discussion

Le croisement des données fournies par l'étude du macro-outillage et celles des macrorestes de noisettes localise des zones concrètes d'occupation directement liées au traitement et à la consommation de fruits. Ce scénario indique que la cueillette peut constituer une activité centrale des groupes qui sont passés par Font del Ros.

Divers indicateurs, confirmés par la série radiométrique, signalent que le niveau SG n'est pas un campement de grande dimension formé à l'occasion d'un unique événement. Le site est stratifié à partir d'un nombre indéterminé de visites qui se sont échelonnées sur 2 000 ans, entre 10 250 et 8 450 cal. B.P. La diachronie entre les différents espaces d'occupation a été récemment discutée (Martínez-Moreno, Mora, 2011).

Les galets présentant des modifications en relation avec le traitement de végétaux se retrouvent autour des foyers. De la même manière, les fragments brûlés de noisettes laissent voir que ces activités sont réalisées à proximité immédiate, ce qui suggère que la torréfaction est une technique employée pour l'ouverture, la conservation et la consommation de fruits (Wandsnider, 1997). Les galets ont activement été utilisés dans toutes ces tâches (Roda Gilabert *et alii*, 2012).

La noisette serait une ressource stratégique expliquant la réoccupation du site au cours d'une large période de temps. Sa prédictibilité, son abondance et la facilité à l'obtenir convertiraient ce paysage en un lieu attractif pour les chasseurs-cueilleurs du Boréal. Dans ce sens, on a signalé qu'elle constitue une ressource exploitée de manière intensive sur les sites mésolithiques de Duvensee (Holst, 2010) ou de Staosnaig (Mithen *et alii*, 2001).

Des constatations similaires ont été formulées à Font del Ros. Elles sont probablement transposables à l'instrumental macrolithique de Balma Guilanyà, Sota Palou (Pallarés, Mora, 1999 ; Martínez-Moreno *et alii*, 2006b), Balma Margineda (Guilaine, Martzluff, 1995), ou aux gisements du cours supérieur de la vallée de l'Ebre comme Aizpea ou Mendandia (Alday [éd.], 2006). Ainsi, à Bauma del Serrat del Pont, il est suggéré que certains galets soient en relation avec le traitement d'éléments de faible dureté, comme des végétaux ou des os (Alcalde, Saña [éd.], 2008).

Diverses questions mériteront d'être explorées dans le futur, par exemple la surreprésentation de ces fruits par rapport aux tubercules et aux racines, difficiles à identifier archéologiquement et qui peuvent être associés à des facteurs taphonomiques (Heather, Mason [éd.], 2002). Une autre question relève du stockage destiné à une consommation différée de *Corylus* et d'autres fruits secs et charnus, possibilité difficile à documenter ou évaluer (Marinval, 1988 ; Cunningham, 2011). On a suggéré que cette activité explique la présence de noisettes dans des fosses sur les gisements mésolithiques de Staosnaig (Mithen *et alii*, 2001), Lough Boora (Mc Comb, Simpson, 1999) ou Ertbolle (Robinson, Harild, 2002). À Font del Ros, la fonction de ces structures n'a pas pu être précisée : elles pouvaient fonctionner comme décharges ou être employées alternativement comme lieu de stockage.

Des études en cours permettront d'avancer dans ces hypothèses, en apportant une meilleure connaissance sur le rôle de la cueillette au Mésolithique dans les Pyrénées.

Conclusions

Les témoignages archéologiques livrés par la fouille de Font del Ros associent les restes de noisettes à l'outillage macrolithique utilisé pour leur transformation. Les galets et les fragments présentent des surfaces d'usure de délinéation plate et convexe ainsi que les traces périmétrales associées à des traces d'usure, à l'émoussement des grains, à l'arasement du relief, présentent des stries ou des lustres expérimentalement associés au processus de transformation de ces fruits secs : ils se trouvent en abondance dans l'unité SG de la Font del Ros.

La contextualisation spatiale de ces macrorestes de noisettes conjugués à la présence de l'outillage macrolithique plaide en faveur de l'existence de zones de travail associées à des structures de combustion, permettant de mieux comprendre l'usage de ces galets. Ces artefacts apportent des informations sur des aspects déterminants de l'organisation des activités de subsistance des chasseurs-cueilleurs qui ont occupé Font del Ros pendant le Mésolithique.

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Identifying bipolar knapping in the Mesolithic site of Font del Ros (northeast Iberia)

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Despite recent advances in the identification of bipolar knapping, its role in many sites is not well known. We propose to assess the significance of this technique in the context of changes that occur in the Mesolithic. A lithic assemblage was recovered from unit SG at Font del Ros (Catalunya, Spain) in which pitted stones, cores and products arising from bipolar reduction (flakes, fragments and splintered pieces) were identified. This study indicates that the bipolar technique is fundamental in the settlement. These results are key to defining the organization of Holocene hunter-gatherer subsistence in northeast Iberia.

1. Introduction

Bipolar knapping, originally defined by Breuil & Lantier [1], is a method which involves the interaction of anvils, hammerstones and the raw material exploited. However, bipolar artefacts and the functional contexts in which they are used are not well known. In recent years, there has been increased interest in investigating the technological, cognitive and evolutionary implications of a technique closely linked with the origin of percussive technology [2–4], and which is ubiquitous in its far-reaching geographical and chronological dispersion [5–18].

This method is structured on effortless technical principles and knapping actions [14], but which enable the production and/or shaping of artefacts. The expedient nature of bipolar knapping has caused it to be considered a 'solution of last resort' [14] which, as such, has not motivated much interest in undertaking a more in depth technical diagnosis of the method.

Bipolar knapping is identified through knapping sequences with minimum core management limited to maintenance of the edge from which the volume of stone is exploited recurrently. The method generates a wide variety of blanks, often difficult to distinguish due to low morphological standardization [7,12]. In the past decade, some variability in actions has been identified which allows several methods of bipolar flaking to be described. Depending on the placement of the blank on the anvil and orientation of percussion, it is possible to differentiate between axial and non-axial percussion, internal oblique percussion and vertical splintering percussion. These methods are recognized by the way the knapping surface is split in two, and whether the exploitation area of the core is affected on one or several edges of its periphery. Based on these characteristics, it has been suggested that bipolar knapping generates diagnostic marks which differ from those of freehand percussion [14].

However, these criteria are not easy to identify, and methodological and terminological problems, indicated by Hayden [19] when referring to 'confusion in the bipolar world', persist. In particular, this 'confusion' affects artefacts with similar formal attributes which are described ambiguously as scaled piece, splintered core piece or *pièce esquillé* [20,21]. Likewise, the functional inferences of splintered pieces are an issue of discussion [22–29]. Finally, it should be noted that the bipolar method is commonly used with quartz, which hinders recognition of knapping indicators [10,30].

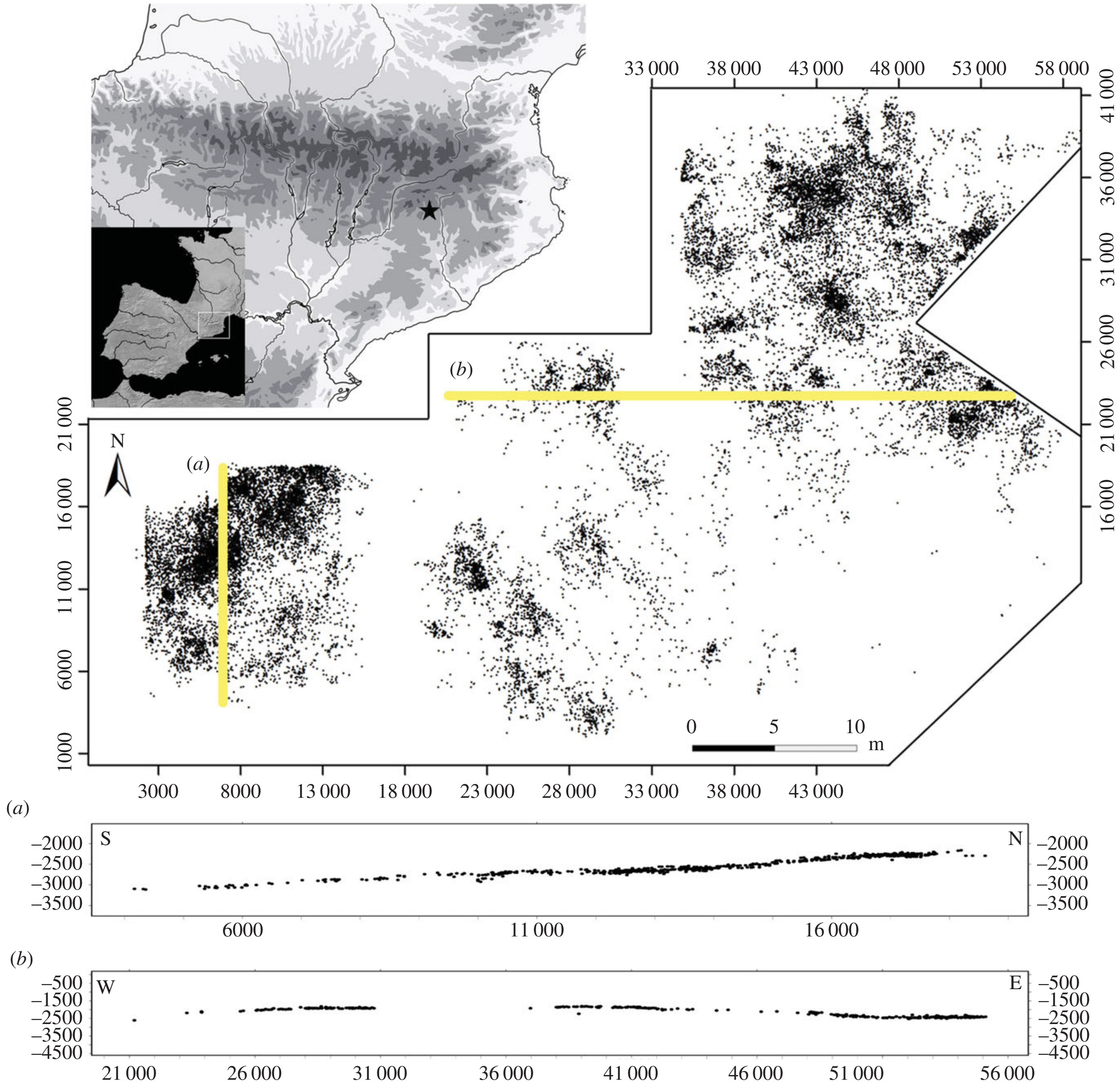

Figure 1. Site location and distribution of materials in unit SG. Top left: location of the Font del Ros site in the southeast Pyrenees ($X = 404\,572$ $Y = 4\,661\,194$ UTM H31N ED509, 670 a.s.l.). Top right: plan of materials recovered from unit SG showing several clusters across a 1200 m^2 area. Vertical plot showing the sparse dispersion of materials in the level. (*a*) Vertical plot (N-S) on the *x*-axis, $x = 7000$–7500 and (*b*) vertical plot (E-W) on the *y*-axis, $y = 22\,500$–$23\,000$. (Online version in colour.)

In recent years, we have shown the bipolar technique to be very common in the Mesolithic of the southern slopes of the Pyrenees. In this chronocultural context, we have noted the absence of microlithic armatures and the incidence of a significant amount of unspecialized artefacts typologically defined as the 'fond commun' in which indicators of bipolar knapping abound [31–36]. These techno-typological features allow us to assess the role of the bipolar technique in the lithic assemblage of unit SG at Font del Ros.

(a) The Mesolithic level of SG at Font del Ros

Font del Ros is located at the contact zone between the Catalan Depression and the lower foothills of the Pyrenees (figure 1). This open-air site, located in the town of Berga (Barcelona, Spain) and excavated in the early 1990s, revealed a stratigraphic sequence with two Mesolithic units (SGA and SG) and another attributed to the Early Neolithic (N) [31,34,37] (M. Pallares 1999, unpublished data).

Unit SG extends over more than 1200 m^2 in which nine hearths and two pits were recorded, and from which more than 27 800 remains were recovered. A series of ^{14}C dates indicate several occupation events during the early Holocene between 10 250 and 8450 cal BP (electronic supplementary material, figure S1). The interpretation of an indeterminate number of recurring visits over 1800 years corresponds well with the spatial distribution of the archaeological record, consisting of patches with little vertical dispersion (5 cm thick) as indicated in E–W and N–S vertical plots (figure 1*a*,*b*). These horizontal and vertical spatially discrete clusters suggest brief occupation events during which lithic artefacts, bones and plants (seeds and charcoal) were abandoned, providing information on the organization of subsistence activities [34] (M. Pallares 1999, unpublished data).

Table 1. Technical indicators and attributes for identification of bipolar cores and products.

	cores	products
flint	— striking platform and contact zone on anvil with blunt scars	— broken and linear butts
	— step and hinge terminations of scars produced by percussion	— butt fissuration
	— blunting and splintering of the striking platform on recurrent knapping	— incidence of parasite chipping
	— overlap of removals and possible opposition of extractions	— deep ripples on ventral side
		— hinge bulb
		— rectilinear profile and sometimes twisting around knapping axis
		— possible splintering of distal and proximal areas
quartz	— absence of conchoidal negatives	— absence of impact points
	— step scars related to low elasticity of the rock	— linear butts
	— bluntness and fissuration of striking platforms	— absence of bulb
	— edge battering on recurrent knapping	— rectilinear profile
	— presence of overhang extractions	— hammering scars on proximal and distal surfaces
		— crushing and radial fissures on butt
		— siret and tranversal fractures

Site formation processes have spatially affected bone conservation, hindering taxonomic identification, although *Cervus elaphus*, *Capra pyrenaica*, *Sus scrofa*, *Bos* sp. and *Oryctolagus cuniculus* have been identified, all of which indicate temperate environmental conditions within a mosaic landscape. Charcoal analysis reveals a community composed of *Quercus* sp., *Buxus sempervirens*, *Corylus avellana*, *Ulmus* sp., *Salix* sp. and *Sambucus* sp., typical of dense deciduous forest requiring high humidity [38]. Shells of *Corylus*, *Quercus* sp. were recovered along with seeds from *Pirus* sp., *Malus* sp., *Prunus avium* and *Prunus spinosa*, implying the regular processing and consumption of plants collected in the vicinity [36]. Such an ecological characterization indicating post-glacial expansion of forests is consistent with the available radiometric framework.

More than 15 different rock types were identified in the SG lithic assemblage, among them flint, quartz, limestone and other rocks. The raw materials most commonly associated with knapping are flint (46%), quartz (36%) and limestone (9%), and to a lesser extent other rocks. Cryptocrystalline and vein quartz are present in the form of irregular cobbles with fissures, flaws and internal planes of weakness, and are found in terraces near the site. Flint appears as small tabular nodules (less than 10 cm) veined with limestone and with internal weaknesses coming from mountains about 10 km away from the site [39]. This management of poor quality raw materials which are abundant in the surrounding area and which are worked using expedient methods is a technical feature defining this assemblage [31,32,34] (M. Pallares 1999, unpublished data), and whose characteristics are presented below.

From a typological perspective, the absence of backed points/bladelets or microliths and bone tools at Font del Ros, along with the poor preservation of fauna, make it difficult to assess the role of hunting in subsistence practices [40,41]. Faced with the absence of lithic armatures, a key element in the cultural identity of the Mesolithic [42], in SG we stress the importance of the 'fond commun' consisting of scrapers, notches, denticulates and splintered pieces, usually associated with domestic activities. Such a composition ascribes this assemblage to a Mesolithic 'without armatures' as identified in the Ebro Basin and the Pyrenean slopes of the Iberian Peninsula [43].

2. Material and methods

In our study of the SG lithic assemblage, we pay particular attention to technical elements and attributes recorded on cores, flakes and knapping debris which define bipolar knapping, as well as other diagnostic artefacts: pitted stones and splintered pieces.

Analysis of volumetric structure and pattern of removals allows us to differentiate blanks originating from freehand knapping [44], while parameters set by Driscoll [10], Prous *et al.* [45] and de la Peña & Wadley [15] are followed for bipolar cores. Products are identified through technical indicators, macroscopic traces and fractures [46–50], and we follow criteria proposed by Donnart *et al.* [12], Prous *et al.* [45] and de la Peña & Vega Toscano [51] to recognize bipolar blanks (table 1). This distinction is not without its problems due to the absence of core preparation and the high fragmentation generated by bipolar knapping [20,21,45]. Typometric and statistical analyses were performed using XLSTAT Statistical Software.

Active areas on percussion tools were identified using a binocular microscope (Olympus SZ-11) ($10\times - 80\times$). Functional studies follow criteria and interpretation proposed by Adams *et al.* [52].

Artefacts analysed in this study include cores, flakes, fragments, macrolithic tools and splintered pieces (table 2).

(a) Bipolar knapping in Font del Ros SG

The characterization of bipolar knapping in Font del Ros is complicated due to the great variability in products and the poor quality of the raw material, so that many pieces apparently linked to the bipolar method do not have diagnostic attributes. Given that these problems hinder identification, bipolar must be under-represented in our counts. Nevertheless, attributes and technical traces [13] on cores, cobbles, products and splintered pieces indicate the relevance of this method in the assemblage.

(i) Macrolithic tools: pitted stones

Level SG at Font del Ros yielded more than 350 cobbles or fragments of limestone, quartzite and sandstone with use-wear on

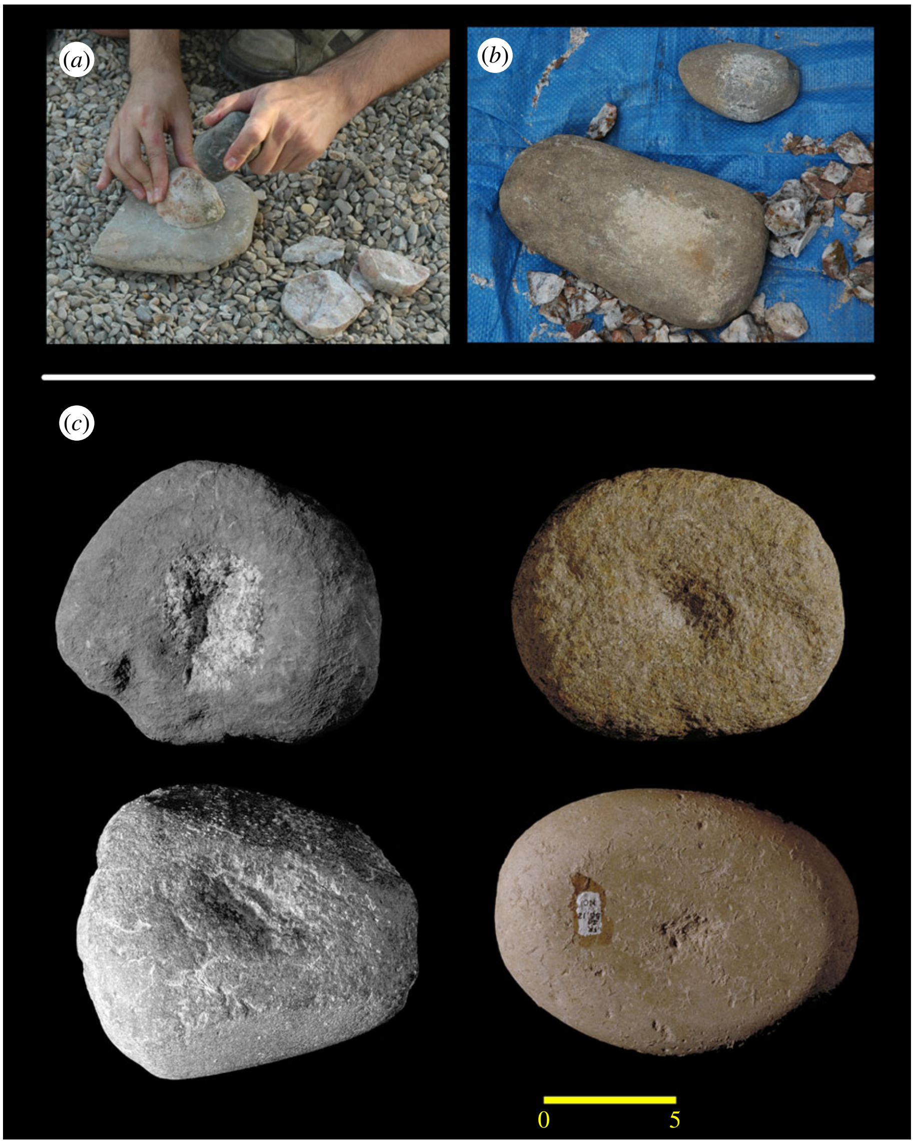

Figure 2. Macrolithic artefacts related to bipolar knapping. (*a*) Elements linked to experimental bipolar knapping (hammerstone, anvil, knapped nodule) and technical actions characteristic of anvil stone working; (*b*) example of a pitted stone obtained during the experimental knapping of quartz [35]; and (*c*) pitted stones from level SG at Font del Ros with central pits caused by use as hammerstones or anvils. (Online version in colour.)

Table 2. Frequency, percentages and weight of the SG lithic assemblage.

categories	pieces	%	weight (kg)
cores	369	1.67	19.99
splintered	192	0.87	0.5
flakes	1599	7.26	8.08
macrolithic	387	1.75	19.99
retouched	385	1.75	4.2
manuports	2873	13.05	203.86
blade/bladelet	239	1.08	0.48
debris	7543	34.28	0.3
fragments	4722	21.46	16.54
chunks	3693	16.78	55.52
Σ	22 002	100	329.46

their surfaces. These oval cobbles, averaging 10 cm and 400 g, provide essential information for the recognition of knapping and the processing of bones, plants, ochre or skin, and are key for the analysis of daily activities at Font del Ros [34–36] (M. Pallares 1999, unpublished data).

We focus here on pitted stones, cobbles showing battering marks in their central area [2,25,35,53–57]. Usually, description of these tools has focused on their morphological traits evident at a macroscopic level. Following an experimental programme and use-wear analysis, we were able to link the SG pitted stones to bipolar knapping [35], similar to that indicated by other studies [12,29,45] (figure 2*a*,*b*).

The most diagnostic tools are 24 pitted stones with use-wear generated by battering (figure 2*c*). Their active surfaces have a frosted appearance, show grain crushing and use-wear linked to compression of the active surface. Step fractures and micro-flaking are observed when the intensity of the task modifies the topography of the contact surface. From a technical perspective, distinct morphotypes are related to different degrees of intensity of use such as pits of irregular section (16), or incipient pits (four). Pits which are regular in section (four) could correspond to intentionally shaped depressions. In some cases, tools are multi-functional, bearing knapping traces which are associated with or superimposed on wear traces related to the crushing and grinding of plants [36] (table 3).

One question on which there is no consensus is whether artefacts linked with bipolar knapping are active or passive elements.

Table 3. Typology of pitted stones and corresponding rock types.

	quartzite	gneiss	limestone	sandstone	Σ
irregular pit	6	5	4	1	16
incipient pit	2		2		4
regular pit	1	2		1	4
Σ	9	7	6	2	24

Table 4. Relative and absolute frequencies of cores in Unit SG.

	quartz	%	flint	%	other	%	Σ	%
bipolar	26	30.95	154	43.63	2	5.56	182	38.48
blade/bladelet	1	1.19	15	4.25	2	5.56	18	3.81
unifacial	31	36.90	10	2.83	27	75	68	14.38
bifacial	2	2.38	2	0.57	1	2.78	5	1.06
multifacial	3	3.57	4	1.13	1	2.78	8	1.69
splintered	21	25	168	47.59	3	8.33	192	40.59
Σ	84	100	353	100	36	100	473	100

We agree with the idea that hammerstones and anvils can be interchanged during the reduction process, passing from active to passive elements and vice versa [12]. In Font del Ros, only the heavier pieces (more than 2 kg) function as resting anvils [2].

(ii) Cores: freehand knapping versus bipolar technique

One hundred and eighty-two of the analysed cores were positively identified as resulting from bipolar reduction, indicating a high incidence of the technique as opposed to other modes such as freehand, unifacial knapping and other methods (table 4).

Bipolar knapping is systematically used with flint (44%) and to a lesser degree quartz (31%). This dynamic is accentuated when splintered pieces, which should be considered as exhausted bipolar cores, are included in the bipolar assemblage as we show in §2*a*(iv). In this case, almost all the flint (91%) and 56% of the quartz assemblages are connected to anvil work.

These cores show little preparation of platforms and knapping surfaces but take advantage of flat cortical areas and natural fractures (figure 3*a*). Surfaces are generally cortical and can be parallel or have diverging morphologies forming quadrangular or rectangular volumes. Superimposed removals around striking platforms and blows from orthogonal axes are common (figure 3*b*). On occasion, striking and counterstrike surfaces are blunt and fissured from prolonged contact between the anvil surface and hammerstone before detachment of the flake [13] (figure 3*c*). There are dihedral scars on the knapping platform and contact surface of cores which are symmetrical in profile; however, scars are unifacial on asymmetric cores (particularly quartz cobbles) (figure 3*d*). Likewise, cores with polygonal section present secant planes on the knapping platform and are the result of core fracture or several sequences of extractions [45].

The most striking feature of both flint and quartz bipolar cores is their small size (electronic supplementary material, tables S1–S4). A metrical comparison of bipolar cores and those produced by freehand knapping shows a bimodal distribution. Attributes such as length, width, thickness and mass, indicate a similar pattern, grouping bipolar cores in lower ranges, while those resulting from freehand percussion show greater dispersion, especially in the quartz group. This difference is due to exploitation of cobbles in the case of quartz and small tabular fragments for flint. The dual distribution is conclusive when mass is considered, with 75% of bipolar cores falling within the less than 10 g range, as opposed to 17% of freehand cores (figure 4). Differences are statistically significant; a normality test shows that only length, width and thickness of bipolar quartz cores have a normal distribution (table 5). Likewise, comparison using the Mann–Whitney *U*-test reveals significant differences in these metrical attributes (table 6).

Interesting technical inferences stem from these results. On the one hand, they suggest that freehand knapping is undertaken on blanks of all sizes associated with core reduction; by contrast, bipolar knapping is used systematically on small-sized blanks, possibly to extend exploitation of the core and get pieces of smaller dimensions. On an organizational level, these techniques of core management are not mutually exclusive, but rather the contrary; metrical data define two segregated but complementary populations found at each end of blank size distribution (figure 4). This suggests rotation or succession of reduction techniques, a pattern similar to the recycling window [16], whereby bipolar reduction allows exploitation of cores for which freehand percussion is not viable.

(iii) Bipolar flakes, fragments and knapping waste

From a mechanical perspective, products resulting from bipolar knapping are the consequence of interaction between anvil and hammerstone. It is not easy to recognize this technique on flakes and fragments due to the great quantity of non-diagnostic pieces generated throughout the knapping process. A classic attribute such as the presence of bulbs at both extremes of the product—counterstrike—[1,7,58–60] is rare in the Font del Ros assemblage. The absence of platforms and distinct bulbs on quartz flakes makes it difficult to identify bipolar knapping on quartz [10,61].

There are 393 bipolar products in flint (80%) and quartz (20%), 226 flakes and 167 fragments with technical indicators similar to those described in other assemblages [10,15,27,62].

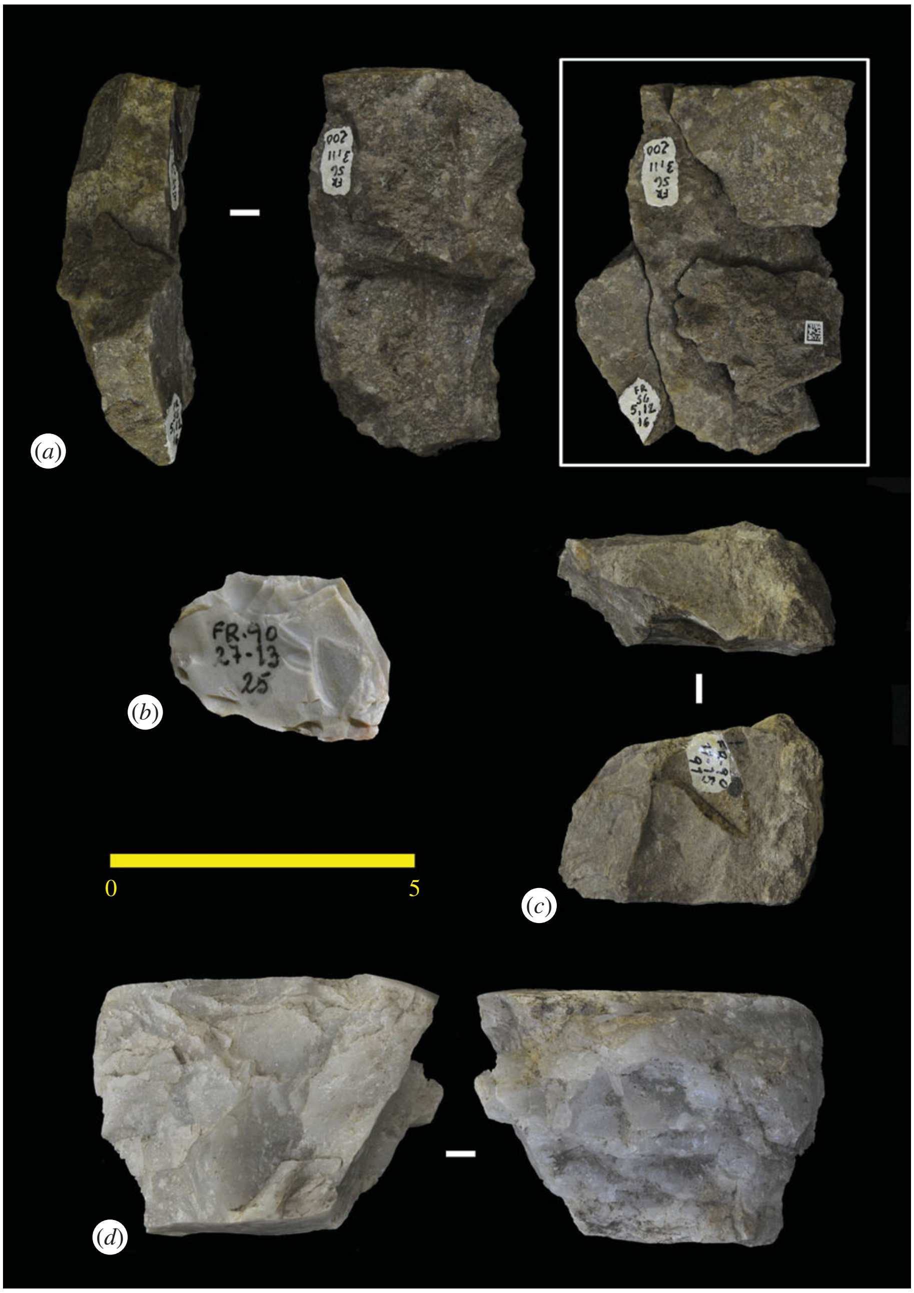

Figure 3. Bipolar cores from unit SG. (*a*) Bipolar quartz core with cortical platforms, and refit series with an example of opposed extractions; (*b*) bipolar flint core with superimposed removals around striking platforms; (*c*) flint core with cortical platform and splintering; and (*d*) bipolar quartz core on cobble with step extractions and striking platform fissures. Scale bars, 5 cm. (Online version in colour.)

Although previously we have indicated the limited preparation of cores, products share some features in common. The repeated impact on poorly prepared cores produces pieces which are rectilinear in profile and with parallel or subparallel edges.

Relevant attributes indicating bipolar origin are recorded when documenting striking platforms. Platforms are often cortical and the intensity of percussion produces crushing of the edges. Evident on the dorsal face in particular are removals opposed to the direction of the knapping axis. Striking platforms on flint flakes tend to be lineal, and usually have micro fissures. Ventral faces show marked percussion ripples, bulbar fractures and cracked bulbs (figure 5). On quartz pieces, the absence of bulbs and ripples hinders recognition of the bipolar method.

Bipolar percussion causes much fragmentation in the form of chunks (fragments and knapping waste), which are very common in SG (table 2) and associated with a high frequency of pieces with longitudinal fractures (Siret burins) and transversal breaks. Indications of bipolar knapping among knapping debris include features such as crushing of the bulb due to impact damage, platform surface morphologies which are punctiform or trihedral, twisting around the knapping axis (figure 5*a*) or flakes with very highly defined ripples known as 'eclats vibres' [62]. Other very characteristic by-products include 'batonets' (spalls), non-cortical flakes with a longitudinal fracture and triangular or quadrangular section [63,64] (figure 5*a*), or 'aiguilles', long segments obtained from fissures in the blank [45].

(iv) Splintered pieces: cores or tools?

Splintered pieces form another category usually associated with the anvil technique [34,35]. Generally, they are rectangular pieces which show splintering on the sides and ends of both faces and have well-defined impact points [63,65]. These are common tools in Upper Palaeolithic and Mesolithic assemblages of Western Europe [66–68]. However, recently there has been debate on whether they could be cores [20,21,27] or, alternatively, wedges or chisels for the working of wood or bone [69–71]. Due to this dispute, an in depth identification of attributes to assess such distinct functional implications should be undertaken. Given the lack of use-wear analysis on archaeological pieces,

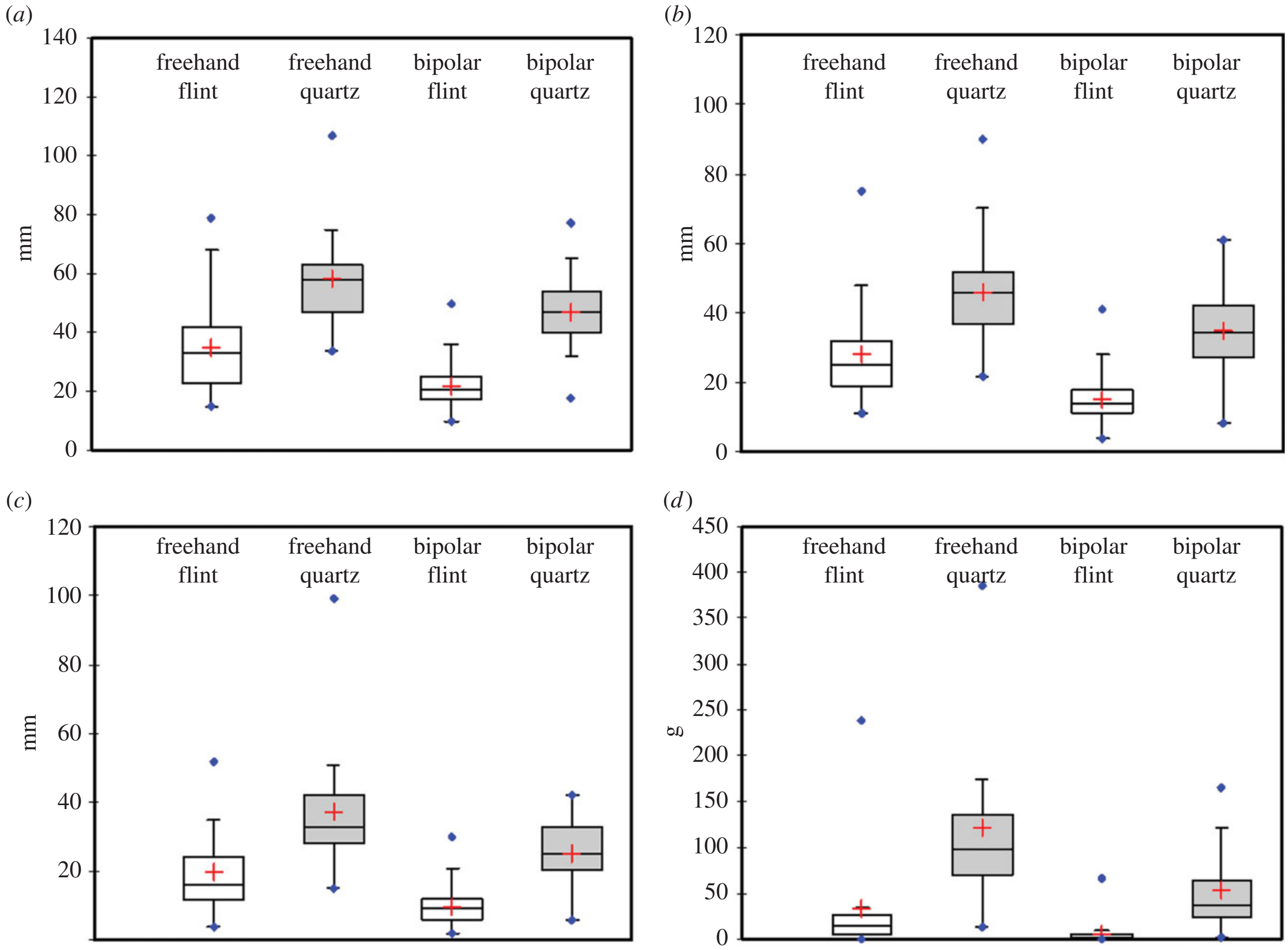

Figure 4. Box plots of (*a*) length, (*b*) width, (*c*) thickness and (*d*) mass comparing freehand and bipolar cores. (Online version in colour.)

Table 5 Shapiro–Wilk test for normal distribution.

	freehand		bipolar	
	flint	quartz	flint	quartz
W (length)	0.9071	0.8868	0.9157	0.9794
P (normal)	0.0109	0.0013	<0.0001	0.8608
W (width)	0.8543	0.9334	0.9181	0.9523
P (normal)	0.0006	0.0285	<0.0001	0.9187
W (thickness)	0.874	0.7828	0.9217	0.9725
P (normal)	0.0017	<0.0001	<0.0001	0.6894
W (mass)	0.6123	0.8394	0.5501	0.8566
P (normal)	<0.0001	<0.0001	<0.0001	0.0019

Table 6. Mann–Whitney *U*-test comparing freehand and bipolar cores.

	flint		quartz	
	U	*p*(same)	*U*	*p*(same)
length	3733.5	<0.0001	670.5	<0.0001
width	3951	<0.0001	718	<0.0001
thickness	3831.5	<0.0001	721.5	<0.0001
mass	3930	<0.0001	740	<0.0001

several experimental studies show that bipolar knapping produces marks similar to those on scaled pieces [26,29,72].

According to typological classification, splintered pieces ($n = 192$) are the most abundant type in level SG, forming 30% of the retouched assemblage. Laplace [68] differentiated between scraper splintered pieces (E1) which account for 78% of retouched pieces, and 'burin' splintered pieces (E2). Nonetheless, we think that classification of these pieces as a specific tool type derives from a problem of morphological convergence in which pieces classified as splintered pieces are exhausted bipolar cores. Likewise, it has been shown that use of splintered pieces as wedges does not produce scalariform traces [29], which is a principle attribute of the Font del Ros pieces.

The average dimensions of splintered pieces are lower than bipolar cores (figure 6) (electronic supplementary material, tables S4–S8), which suggest that these products originated from bipolar knapping, and could correspond to a final phase of exploitation, which is confirmed at a statistical level where significant differences are seen between bipolar core and splintered piece dimensions (table 7).

It seems to be more appropriate to consider most splintered pieces in SG as nucleliform [45] (figure 5*b*), on which superposition of removals indicates that they are exhausted or heavily exploited bipolar cores which produced small, elongated blanks similar to bladelets, but morphologically irregular (figure 5*c*).

3. Discussion

The points presented in §2 show the use of bipolar knapping to be common in the SG lithic assemblage. This technical system coexists with freehand flaking and is used with flint

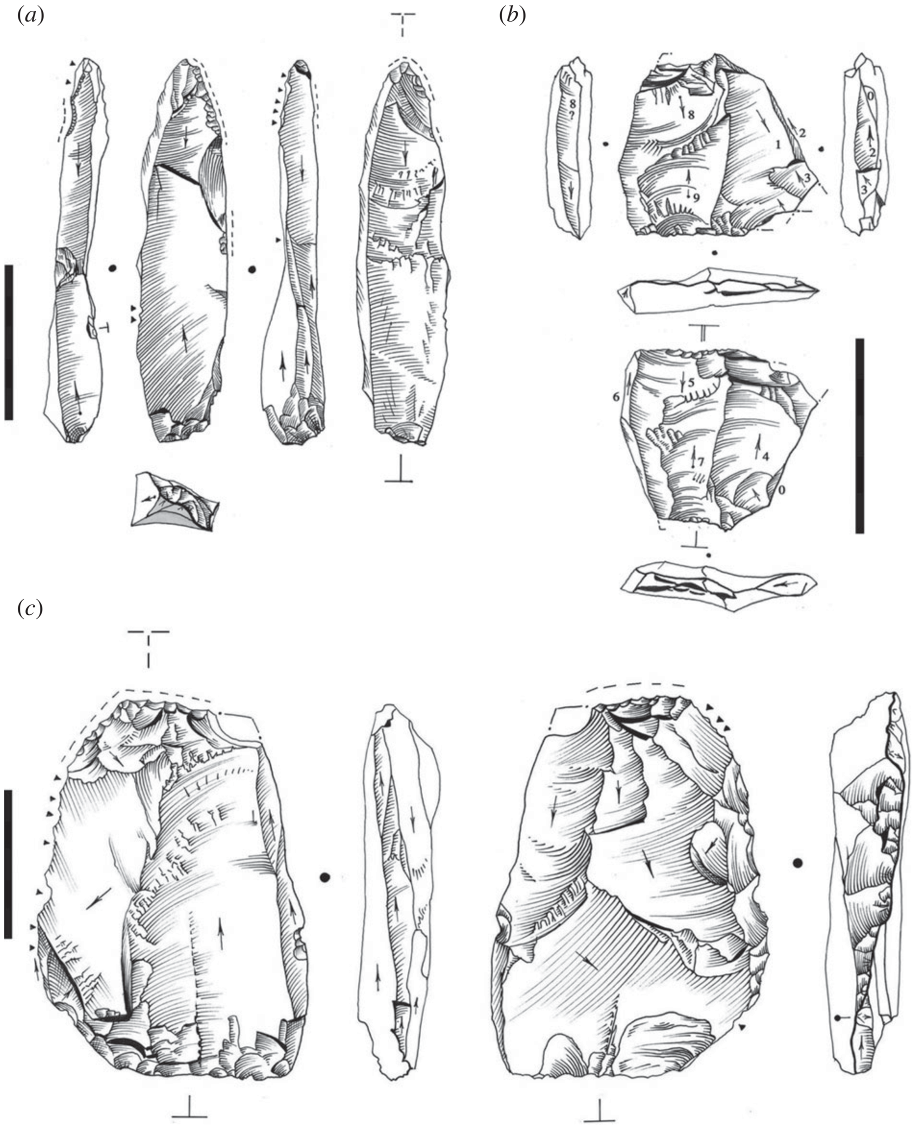

Figure 5. Flint pieces from level SG with diagnostic marks from bipolar knapping. Note the direction of removals on the faces and edges of the pieces indicating previous removals produced by rotating the knapping axis. (*a*) Bipolar by-product «bâtonnet» (spall) which shows curving around the axis and micro retouch on the point suggesting rotational movement of this active area. Due to its size, this piece must have been hafted or formed part of a composite tool. (*b*) Blank shaped by multiple opposing removals indicating rotation of bipolar knapping which generated a miniscule core-like blank (nucleiform). (*c*) Splintered piece showing crushing of the edges, and in particular microdenticulation on one side. Scale bar, 1 cm. (Drawings by Michel M. Martzluff).

and quartz. It is a knapping method which overcomes constraints derived from poor quality raw materials and produces small, short, but relatively standardized products [15,32] (M. Pallares 1999, unpublished data).

The use of bipolar knapping in the Mesolithic has generated a great diversity of interpretations, from techno-economic aspects to socio-organizational factors of Holocene hunter-gatherers [73]. Usually it is considered as an immediate response to contexts where raw material is limited or of poor quality. This reflects 'expediency' in design, manufacture and raw material procurement, and has been linked to an immediate use in special-purpose sites [74], or it may be related to a task undertaken by a determinate age/sex group. On this assumption, were women and children more actively involved than men in on-site activities, then bipolar debitage increases because generally they were less skilled knappers than men [75].

We believe that environmental, functional and cultural arguments only partially explain use of the bipolar technique at Font del Ros. The technique enabled the production of non-specialized tools from raw materials which were locally abundant. Such simple artefacts made it possible for groups to acquire, process and consume animal and plant nutrients essential for their livelihood and their socio-organizational continuity. We consider that the process of technical simplification affecting knapping strategies and tool shape is a characteristic attribute of the technical organization of Mesolithic hunter-gatherers and is not an isolated occurrence. Similar behaviour has been described at the end of the Pleistocene in Mesolithic contexts in Scandinavia [76–78], Ireland [10], Scotland [79,80], and has been identified in numerous sites in Italy, Spain and Greece [43].

Due to the similarity of technical parameters of Font del Ros, it is relevant to recall discussion on the significance of the regional group of sites located in the eastern Pyrenees and western Languedoc. Here, many assemblages are made on locally available poor quality materials and thus appear atypical in classic typological terms; many sites, mainly rock shelters, seem to show expedient use of raw materials collected during fairly specialized activities [81]. However,

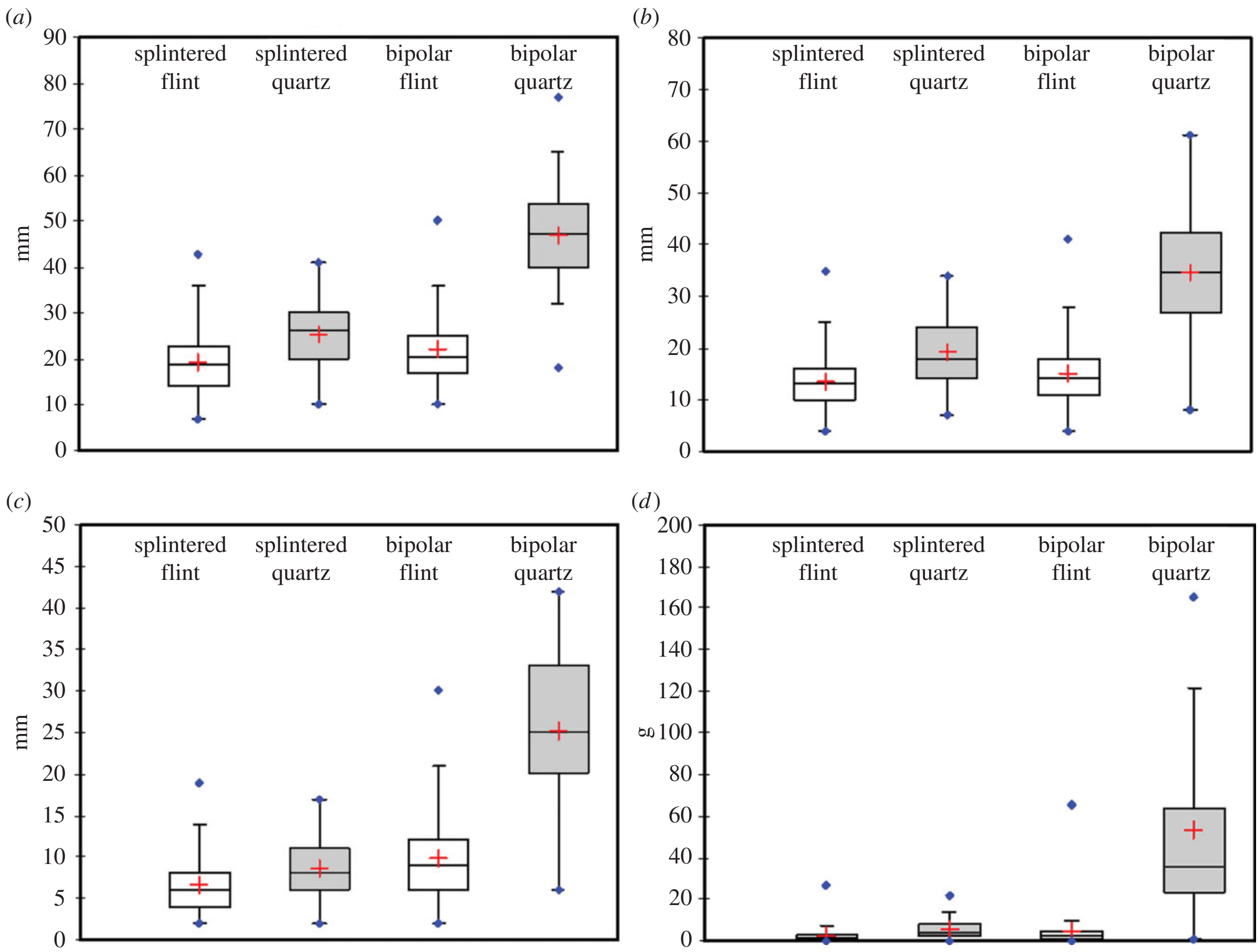

Figure 6. Box plots of (*a*) length, (*b*) width, (*c*) thickness and (*d*) mass comparing splintered pieces and bipolar cores. (Online version in colour.)

Table 7. Mann–Whitney *U*-test comparing physical data of splintered pieces and bipolar cores.

	flint		quartz	
	U	*p*(same)	*U*	*p*(same)
length	10 024	<0.0001	48.5	<0.0001
width	11 450	0.0746	72.5	<0.0001
thickness	7766	<0.0001	37	<0.0001
mass	9086.5	<0.0001	35	<0.0001

such a link between an expedient technical option and special-purpose sites or specialized activities has been questioned by some researchers who suggest that use of low quality, local material is an attribute of technical regression signalling a widespread crisis affecting post-glacial hunter-gatherer subsistence and social organization [82–84].

Faced with these processual and cultural-historical scenarios, we propose that bipolar technique is a key attribute in the simplification of technical systems attested in the early Holocene. This knapping method enables management of ecosystems with raw material constraints but in which predictable and highly nutritional resources are accessible [36,85].

Possibly, an opportunistic approach to the use of bipolar knapping would help overcome constrictions related to limited/poor quality raw material [33], and so could not strictly be considered as adaptive behaviour to environmental conditions [86]. These options are integrated within a technical knowledge which was used repeatedly from the Late Upper Palaeolithic onwards, but such approaches have been identified in earlier periods as will be discussed below.

The aim of knapping at Font del Ros was to get products smaller than 2 cm. This pattern of miniaturization aimed at obtaining standardized products is a technical option clearly rooted in the early Upper Palaeolithic in Western Europe, present since the emergence of backed points/bladelets, basic components throughout the Upper Palaeolithic [51,87]. It should be emphasized that in the earlier Howiesons Poort of the South African MSA, microlithic artefacts were made using the bipolar technique [15]. Similarly, in the Iberian Peninsula, it has been shown that this process of tool reduction intensified during the late Upper Palaeolithic (Magdalenian), and particularly in the Mesolithic [88–90]. Furthermore, the bipolar technical tradition has been recognized throughout late prehistory in some areas of Western Europe [62,86,91].

We do not rule out that current understanding of the use of bipolar is under-represented because systematic studies of lithic assemblages in which it was used are limited. Nevertheless, the bipolar method has interesting properties such as its versatility. The reduction system can be used directly on cores to get functional blanks, but also allows continued knapping of cores produced by freehand percussion which are too small for further freehand knapping. The bimodal distribution of blank size in level SG suggests a continuity of reduction of freehand cores which were subsequently exploited on an anvil for the production of some small, albeit poorly standardized, products equivalent to bladelets. Such a system is not novel; bladelets were regularly obtained from burins and/or end scrapers throughout the Upper Palaeolithic [92,93]. In some late Glacial and early Holocene lithic assemblages from sites in the Pyrenees and Alps, it has been proposed that micro-backed points and geometrics were made from scaled pieces and/or bipolar cores [33,84,94]. Based on metrical criteria, it is relevant to name pieces resulting from bipolar knapping as 'microliths', although they are not retouched [95].

Although many spalls and fragments can be considered as residuals derived from bipolar knapping, some of them have been used for the manufacture of specialized tools such as Gravettian and Azilian backed points [51]. Other small artefacts may be equally functional; in fact, recognition of evident macroscopic wear on some pieces indicates they formed part of composite or hafted tools [33] (figure 5*c*), and it is possible that some pieces may be identified through microwear analysis [94,96,97].

Finally, we emphasize the importance of the study of macrolithic tools. Pitted stones are diagnostic artefacts of the bipolar knapping system and are accurate markers of activity on a functional and spatial level [35]. As these tools were very common in the northern Iberian Peninsula from the beginning of the Holocene [43], we cannot dismiss the possibility that the importance of bipolar knapping at Font del Ros had its roots in this regional context.

Many questions remain to be explored, among them examination of the spatial and temporal dimension of the bipolar knapping system in Font del Ros, a site of more than 1500 m^2 and which, according to ^{14}C dating, was intermittently occupied over 1800 years (10 250–8 450 cal BP). Within this wide spatial/temporal scale, future studies will try to identify possible variations in reasons for using this knapping system.

4. Conclusion

At present, there is much literature on the recognition of bipolar percussion, with experimental studies and macroscopic analyses forming the basis for its identification [5,9–18,29]. Previously, we have emphasized the temporal and spatial ubiquity of the method, present from the earliest evidence of stone tools [98] and lasting until late prehistory [8–18]. Although there is no doubt that a large part of its success is due to its simplicity, nevertheless there is a need to define patterns in which the same knapping system is apparently applied. Its persistence indicates it to be an effective technique for various technical and functional contexts, and as such, studies should be undertaken to determine whether there are differences in the employ of this practice.

Bipolar knapping is an important technique used in the production of the Font del Ros lithic assemblage. Cores, pitted stone and products with diagnostic attributes unequivocally identify this reduction system, and form a benchmark for the technical diagnosis of the method. In a context in which the corpus of experimental data is increasing, the results presented here constitute an archaeological example in which signs and attributes of the bipolar method have been identified systematically in a precise temporal context related to changes developed by post-glacial hunter-gatherers [99].

The explanation of bipolar knapping as an adaptive response to restrictions imposed by poor quality raw material is a reductionist interpretation. It is worth bearing in mind that Mesolithic artefacts and subsistence patterns are not incompetent attempts of Neolithic behaviour or degenerated Upper Paleolithic products. Mesolithic toolkits were well designed and well adapted to achieve an adequate food supply from the environment [100,101]. This alternative scenario suggests that the versatility of the bipolar method enabled expansion into new environments based on the management of local, poor quality raw materials. Use of the bipolar technique enabled hunter-gatherers to deal resolutely with daily subsistence activities and is essential in the characterization of Holocene hunter-gatherer lifestyles. In this sense, we think that Font del Ros provides important perspectives which characterize organizational changes occurring in the Mesolithic of the northern Iberian Peninsula.

Data accessibility. The datasets supporting this article have been uploaded as part of the electronic supplementary material.

Authors' contributions. X.R.G., R.M. and J.M.-M. designed the research programme. X.R.G. and R.M. performed the analysis of datasets. X.R.G., R.M. and J.M.-M. interpreted the resulting data and wrote the manuscript.

Competing interests. We declare we have no competing interests.

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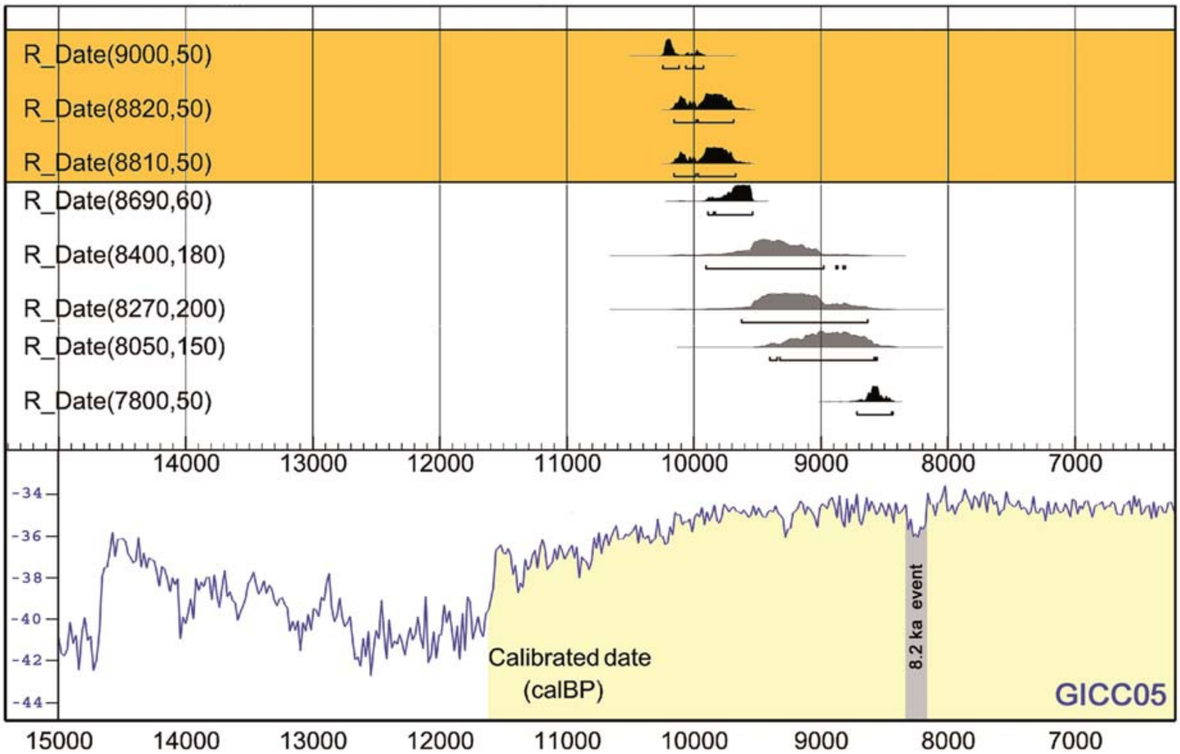
Supplementary material

Supplementary Figure 1: Radiocarbon dates from Font del Ros.

Two sigma calibrations follow the IntCal09 model [1]. Results have been processed and graphically expressed by Oxcal v4.17 [2]. Dates with σ>200 years have been excluded because of their poor temporal resolution. Shaded areas correspond to samples from central area of SG unit.



#	Context	# laboratory	Sample	Method	^{14}C	δ	$^{13}C_{‰}$	Cal BP p (95%)
1	Isolated charcoal	Beta-231728	Charcoal	AMS	9000	50	-23,3	10246-9925
2	Hearth VIII	Beta-231727	*Corylus*	AMS	8820	50	-23,2	10156-9687
3	Isolated charcoal	Beta-231720	*Corylus*	AMS	8810	50	-22,2	10155-9671
4	Isolated charcoal	UBAR 345	Charcoal	CON	8800	360	-26,3	11068-9012
5	Hearth VII	Beta-210732	*Corylus*	AMS	8690	60	-24,2	9888-9539
6	Isolated charcoal	UBAR-397	Charcoal	CON	8400	180	-26,2	9906-8808
8	Hearth IX	UBAR-329	Charcoal	CON	8270	200	-23,4	9626-8633
7	Hearth V	UBAR-165	Charcoal	CON	8150	590	-	10707-7582
6	Hearth IV	UBAR-185	Charcoal	CON	8050	150	-	9402-8559
10	Hearth IV	Beta-210733	*Corylus*	AMS	7800	50	-24,6	8717-8434

Supplementary Table 1: Univariate statistic of physical attributes length of freehand and bipolar cores of flint and quartz from unit SG.

	LENGHT			
	Freehand flint	Freehand quartz	Bipolar flint	Bipolar quartz
N. Observations	31	37	154	26
Minimum	15,0000	34,0000	10,0000	18,0000
Maximum	79,0000	107,0000	50,0000	77,0000
Sum	1088,0000	2154,0000	3384,0000	1214,0000
Mean	35,0968	58,2162	21,9740	46,6923
Varian (n-1)	256,9570	270,3408	53,0712	188,5415
Standard deviation (n-1)	16,0299	16,4420	7,2850	13,7310

Supplementary Table 2: Univariate statistic of physical attributes width of freehand and bipolar cores of flint and quartz from unit SG.

	WIDTH			
	Freehand flint	Freehand quartz	Bipolar flint	Bipolar quartz
N. Observations	31	37	154	26
Minimum	11,0000	22,0000	4,0000	8,0000
Maximum	75,0000	90,0000	41,0000	61,0000
Sum	866,0000	1709,0000	2331,0000	901,0000
Mean	27,9355	46,1892	15,1364	34,6538
Varian (n-1)	200,2624	171,8243	50,3277	145,9954
Standard deviation (n-1)	14,1514	13,1082	7,0942	12,0829

Supplementary Table 3: Univariate statistic of physical attributes thickness of freehand and bipolar cores of flint and quartz from unit SG.

	THICKNESS			
	Freehand flint	Freehand quartz	Bipolar flint	Bipolar quartz
N. Observations	31	37	154	26
Minimum	4,0000	15,0000	2,0000	6,0000
Maximum	52,0000	99,0000	30,0000	42,0000
Sum	614,0000	1373,0000	1514,0000	653,0000
Mean	19,8065	37,1081	9,8312	25,1154
Varian (n-1)	143,5613	278,0435	24,4811	87,5462
Standard deviation (n-1)	11,9817	16,6746	4,9478	9,3566

Supplementary Table 4: Univariate statistic of physical attributes weight of freehand and bipolar cores of flint and quartz from unit SG.

	LENGHT			
	Freehand flint	Freehand quartz	Bipolar flint	Bipolar quartz
N. Observations	31	37	154	26
Minimum	0,9000	12,7000	0,1000	1,1100
Maximum	238,4200	385,9000	65,8500	165,2500
Sum	1011,5300	4492,5000	778,2600	1398,7800
Mean	32,6300	121,4189	5,0536	53,7992
Varian (n-1)	2710,7677	8335,6954	62,9413	2121,3058
Standard deviation (n-1)	52,0650	91,3000	7,9336	46,0576

Supplementary Table 5: Univariate statistic of length of splintered pieces and bipolar cores from unit SG.

	LENGHT			
	Splintered flint	Splintered quartz	Bipolar flint	Bipolar quartz
N. Observations	168	21	154	26
Minimum	7,0000	10,0000	10,0000	18,0000
Maximum	43,0000	41,0000	50,0000	77,0000
Sum	3230,0000	531,0000	3384,0000	1214,0000
Mean	19,2262	25,2857	21,9740	46,6923
Varian (n-1)	45,2779	71,8143	53,0712	188,5415
Standard deviation (n-1)	6,7289	8,4743	7,2850	13,7310

Supplementary Table 6: Univariate statistic of width of splintered pieces and bipolar cores from unit SG.

	WIDTH			
	Splintered flint	Splintered quartz	Bipolar flint	Bipolar quartz
N. Observations	168	21	154	26
Minimum	4,0000	7,0000	4,0000	8,0000
Maximum	35,0000	34,0000	41,0000	61,0000
Sum	2253,0000	400,0000	2331,0000	901,0000
Mean	13,4107	19,0476	15,1364	34,6538
Varian (n-1)	26,6626	56,7476	50,3277	145,9954
Standard deviation (n-1)	5,1636	7,5331	7,0942	12,0829

Supplementary Table 7: Univariate statistic of thickness of splintered pieces and bipolar cores from unit SG.

	THICKNESS			
	Splintered flint	Splintered quartz	Bipolar flint	Bipolar quartz
N. Observations	168	21	154	26
Minimum	2,0000	2,0000	2,0000	6,0000
Maximum	19,0000	17,0000	30,0000	42,0000
Sum	1131,0000	182,0000	1514,0000	653,0000
Mean	6,7321	8,6667	9,8312	25,1154
Varian (n-1)	10,0057	12,6333	24,4811	87,5462
Standard deviation (n-1)	3,1632	3,5543	4,9478	9,3566

Supplementary Table 8: Univariate statistic of weight of splintered pieces and bipolar cores from unit SG.

	WEIGHT			
	Splintered flint	Splintered quartz	Bipolar flint	Bipolar quartz
N. Observations	168	21	154	26
Minimum	0,1000	0,3000	0,1000	1,1100
Maximum	26,3200	22,0600	65,8500	165,2500
Sum	384,9800	125,0800	778,2600	1398,7800
Mean	2,2915	5,9562	5,0536	53,7992
Varian (n-1)	8,1380	30,4675	62,9413	2121,3058
Standard deviation (n-1)	2,8527	5,5197	7,9336	46,0576

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Ground stone tools and spatial organization at the Mesolithic site of font del Ros (southeastern Pre-Pyrenees, Spain)

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Iberian Pre-Pyrenees

ABSTRACT

Used cobbles (ground stone tools) help identify a range of tasks related to basic domestic activities associated with subsistence. Here, we combine techno-morphological analysis and the study of use-wear patterns with intra-site spatial analysis of tool distribution at the Font del Ros SG unit (southeastern Pre-Pyrenees, Spain). Successive occupations during the Boreal climatic phase characterize this site. We have identified areas that may correlate with specific activities that could represent internal diachronic events on surfaces with little vertical dispersion. In this approach, ground stone tools are key artifacts that define domestic activities usually considered as having little archeological visibility, and help identify activities undertaken across different parts of the site. Intra-site spatial patterns help us define the domestic aspect of Mesolithic hunter-gatherer lifestyle in the northeastern Iberian Peninsula.

1. Introduction

Ground stone tools form an assemblage of artifacts associated with activities of human groups in the past. Various techno-typological, experimental, and ethnographic studies (e.g. Leroi-Gourhan, 1971; Yellen, 1977; Chavaillon, 1979; Hayden, 1987; Adams, 1989; Wright, 1991; de Beaune, 1989) have highlighted their use in making and retouching lithics, as well as in pounding, grinding, and milling organic and inorganic materials. In recent years, studies of ground stone tools (also called percussion tools) have enabled us to define the functional nature of these tools that were essential to a hunter-gatherer lifestyle (de Beaune, 2000a, 2004; Procopiou and Treuil, 2002; Adams, 2002; Adams et al., 2009; Revedin et al., 2010; Cristiani et al., 2012; de la Torre et al., 2013; Dubreuil and Savage, 2014; Dubreuil et al., 2015).

Traces on these cobbles and fragments allow us to connect them with the type of percussion used and the materials worked, thus making them diagnostic elements in identifying subsistence tasks (Adams, 1988, 1989; de Beaune, 2002). Tools associated with percussion activities on hard materials are often mentioned in the literature (e.g., de Beaune, 1997; Goren-Inbar et al., 2002; Chavaillon and Piperno, 2004; Mora and de la Torre, 2005; Donnart et al., 2009; de la Torre et al., 2013; Harmand et al., 2015). There have been advances in the characterization of ground stone tools related to plant-processing and other abrasive activities (Hayden, 1987; Adams, 1988, 1989; Dubreuil, 2002, 2004; Hamon, 2003, 2008; Dubreuil and Nadel, 2015). Nonetheless, there remains a substantial lack of information about these artifacts for the Paleolithic and Mesolithic periods. Usually studies of ground stone tools have concentrated on description of their technical attributes. Although spatial analyses have increased in recent years (Wright, 2000; Hamon, 2004; Weiss et al., 2008; Cristiani et al., 2012; Nadel et al., 2012; Wright, 2014), those that also include statistical analyses are less common.

Discussion of living floors and palimpsests (e.g. Leroi-Gourhan and Brezillon, 1973; Bordes, 1975; Villa, 2004; Bailey, 2007; Malinsky-Buller et al., 2011) has hindered consideration of the technical and functional significance of ground stone tools in certain contexts. Such interpretative constraints focus on the difficulty of identifying occupational time spans and defining activity areas. We argue that spatial associations provide information about activity areas and functional differences (Binford, 1978), and the social organization of activities (Leroi-Gourhan and Brezillon, 1973; Yellen, 1977).

Our aim here is to present the results of a multidisciplinary study that combines techno-morphological analysis and use-wear patterns with intra-site spatial analysis of tool distribution at the site of Font del Ros (Berga, Spain). In sector SG, 43 ground stone tools have wear traces that suggest different activities; we believe that these artifacts indicate spatial patterning of activities performed at the

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site (de Beaune, 2000a, 2000b). Our study has enabled us to reconstruct Holocene hunter-gatherer subsistence activities and, in addition, to determine general trends in spatial organization during the Mesolithic.

2. Archeological context

Font del Ros is located on a shelf of Quaternary colluvial deposits in the contact zone between the Catalan Central Depression and the lower foothills of the Pre-Pyrenees of Barcelona (Serra de Queralt). The Llobregat River facilitates communication between the Catalan Central Depression and the interior of the Pyrenees (Fig. 1a, b). Construction work in the municipality of Berga (Barcelona, Spain) exposed materials in stratigraphic position. Excavation revealed two Mesolithic levels (SGA and SG) and more recent occupation attributed to the early Neolithic (N) (Pallarés et al., 1997; Pallarés, 1999; Pallarés and Mora, 1999; Martínez-Moreno and Mora, 2011).

The Mesolithic unit SG (Fig. 1c) covered an area of approximately 1200 m^2 from which 27,800 lithics, bones, and burned plant remains (charcoal and seeds) were recovered (Pallarés, 1999; Martínez-Moreno and Mora, 2011). In this paper, we concentrate on the central zone that extends over an area of approximately 510^2 m in which the discrete distribution of the low density of materials aids in determining patterns of spatial organization. The more than 3200 coordinated pieces taken from the area included bones, plants and lithic tools. Among the lithic artifacts were chipped stones indicating use of both freehand and bipolar knapping (Roda Gilabert et al., 2015), and ground stone tools (43) with use-wear traces related to function (Fig. 2). A single feature has been identified in this area, a flat hearth (hearth VIII) with a significant accumulation of charcoal, burned bones, and thermo-altered fragments of sedimentary rocks (Pallarés, 1999).

Currently, there are 10 radiocarbon dates (calibrated at 2σ) based on the IntCal09 model (Reimer et al., 2009). Although some dates are very imprecise (Table 1), the series places the settlement in the Boreal chrono-climatic phase of the Early Holocene (Martínez-Moreno and Mora, 2011) and indicates an indeterminate number of occupation phases between 10,250 and 8450 cal BP (Fig. 3).

There are three direct AMS dates for this area: one on charcoal, two on burned hazelnut shells, one of which has recovered directly from hearth VIII. The dates seem to represent the first phases of settlement and could correspond to a single occupation event between 10,150 and 9925 cal BP (Fig. 2). However, we suspect that at least two different occupational phases cannot be discounted; one is suggested by radiocarbon sample #1 (Beta 231,728), and a second by samples #2 (Beta 231,727) and #3 (Beta 231,720) which are practically identical (Fig. 3, Table 1). New radiometric dating should help determine whether or not the area was formed by different overlapping occupations separated by a limited time span.

Level SG is embedded in a soil formed of silt and sand and showing features indicating bioturbation. Occupation occurred at the time of soil formation following a period of low energy deposition. The relative abundance of organic matter is a result of the juxtaposition of edaphic and anthropogenic processes (Jordá et al., 1992).

Sedimentary conditions have affected the faunal material; bones are poorly preserved and almost all the assemblage consists of fragments of <2 cm, which are difficult to identify. Nevertheless, *Cervus elaphus*, *Capra pyrenaica*, *Sus scrofa*, *Bos* sp., and *Oryctolagus cuniculus* have been determined, which may correspond to a mosaic landscape in the immediate vicinity of the site (Martínez-Moreno and Mora, 2011) (Fig. 1a), as indicated by macrovegetal proxis.

Charcoal analysis provides evidence of temperate taxa, such as *Quercus* sp., *Buxus sempervirens*, *Corylus avellana*, *Ulmus* sp., *Salix* sp., and *Sambucus* sp., associated with wet conditions suggest dense, deciduous woodland (Jordá et al., 1992). Such plant associations are characteristic of forest expansion and concur with the radiocarbon dates for the site. A similar ecological pattern, present during the Boreal climatic phase, has been detected in other archeological sites in northeastern Iberia (Allué et al., 2012).

The Font del Ros SG unit revealed horizontal and vertical accumulations of lithic, bone and plant remains with distinct spatial boundaries. Transversal (E–W) and longitudinal (N–S) sections show a very limited vertical dispersion of coordinates, forming a layer 5 cm thick followed by a sterile layer (Fig. 2). The vertical dispersion

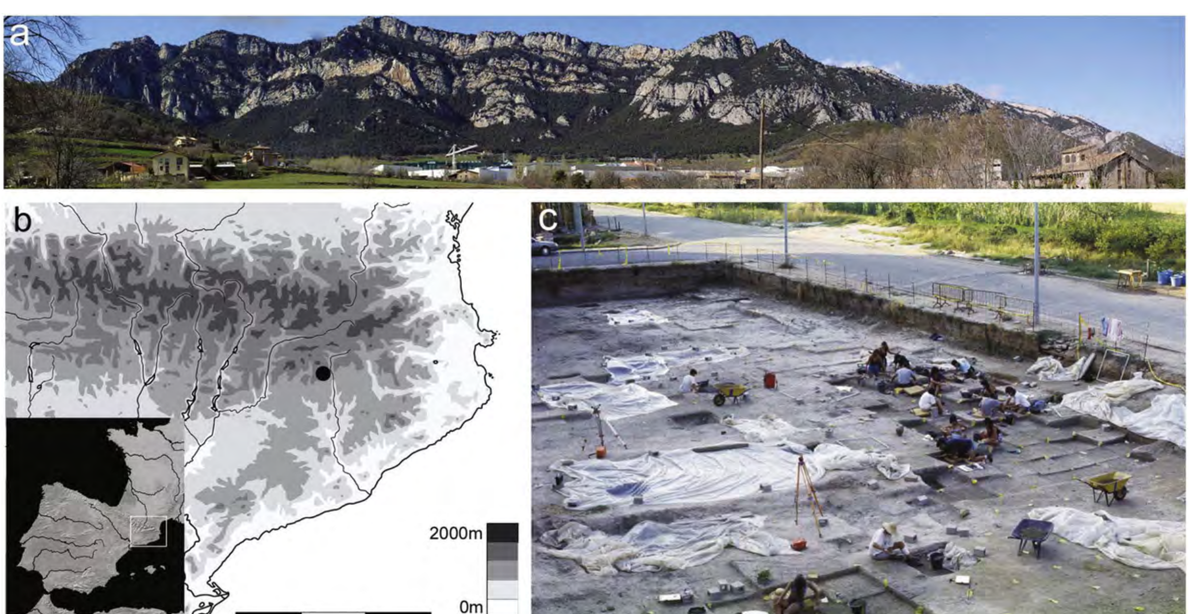

Fig. 1. Location of Font del Ros site. a) General view of the contact zone between the Catalan Central Depression and the western Pre-Pyrenees of Barcelona; b) Geographical location of the site; c) Level SG during excavation.

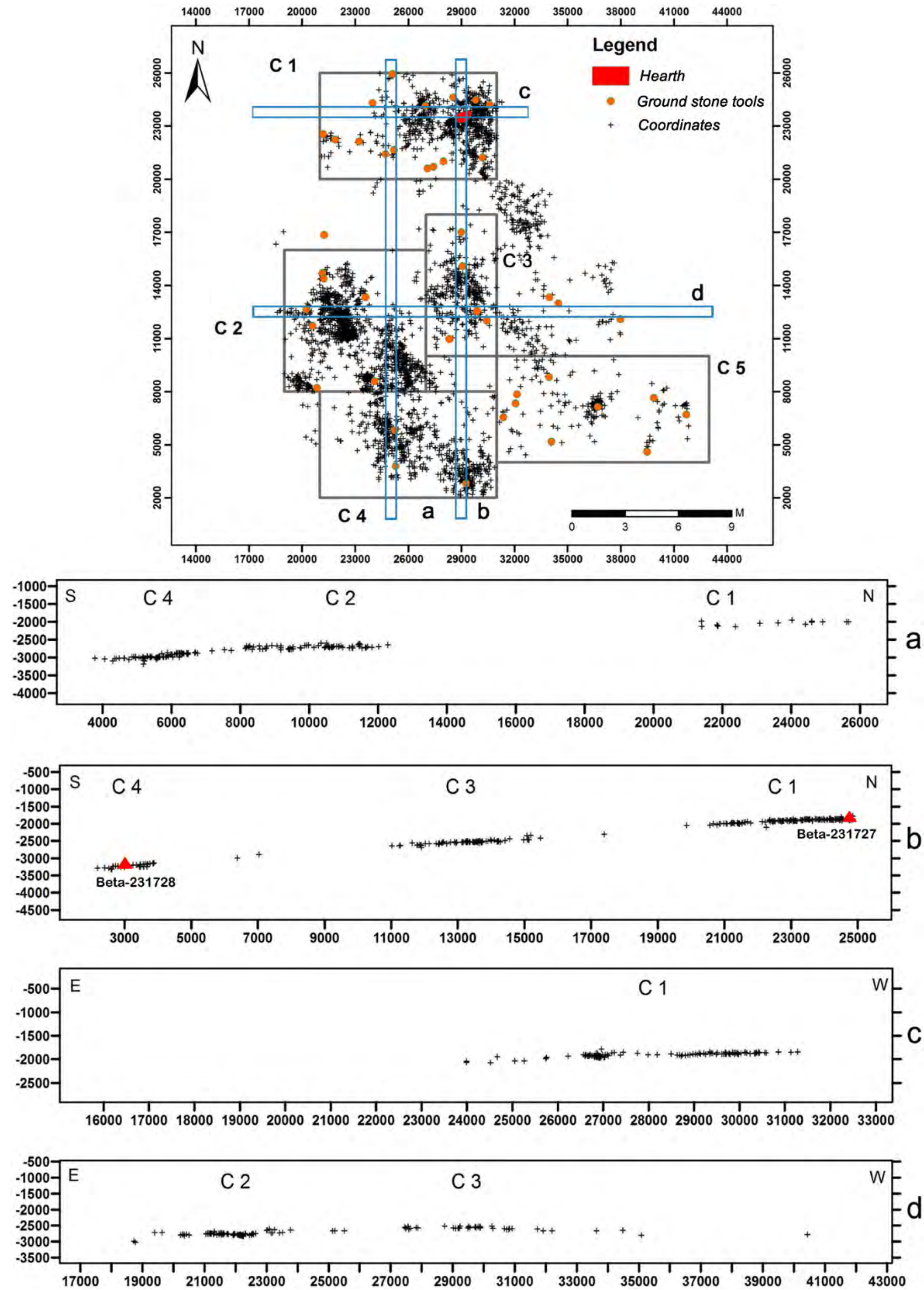

Fig. 2. Plan view of part of the Font del Ros site showing C1–C5 clusters (top). Circles indicate the ground stone tools analyzed in this study. Below, four sections (a, b, c, d) show the vertical dispersion of materials in clusters. The vertical plan b indicates the spatial location of the ^{14}C dates from C4 (Beta-231,728) and Hearth VIII on C1 (Beta-231,727).

of associated materials could correspond to a single event which, on an analytical level, allows us to consider them as living floors (sensu Villa, 2004; Malinsky-Buller et al., 2011). Nevertheless, we support the hypothesis that these coordinates may represent more than one event, which would correspond with the radiometric dates obtained for this sector (Fig. 3), as well as with the spatial separation of different clusters considered in the study (Fig. 2), that will be defined in the following section.

Table 1
Radiocarbon dates from Font del Ros. Shaded areas correspond to samples from the study area. Two sigma calibrations follow the IntCal09 model (Reimer et al., 2009).

#	context	# laboratory	Sample	method	BP	δ	^{13}C‰	Cal BP p (95%)
1	charred charcoal	Beta-231728	Charcoal	AMS	9000	50	-23,3	10246-9925
2	Hearth VIII	Beta-231727	*Corylus* shell	AMS	8820	50	-23,2	10156-9687
3	charred charcoal	Beta-231720	*Corylus* shell	AMS	8810	50	-22,2	10155-9671
4	charred charcoal	UBAR 345	Charcoal	CON	8800	360	-26,3	11068-9012
5	Hearth VII	Beta-210732	*Corylus*	AMS	8690	60	-24,2	9888-9539
6	charred charcoal	UBAR-397	Charcoal	CON	8400	180	-26,2	9906-8808
8	Hearth IX	UBAR-329	Charcoal	CON	8270	200	-23,4	9626-8633
7	Hearth V	UBAR-165	Charcoal	CON	8150	590	-	10707-7582
6	Hearth IV	UBAR-185	Charcoal	CON	8050	150	-	9402-8559
10	Hearth IV	Beta-210733	*Corylus* shell	AMS	7800	50	-24,6	8717-8434

3. Materials and methods

3.1. Intra-site spatial analysis

Due to the volume of remains, it was difficult to interpret the spatial distribution of materials and place them on thematic maps. An alternative way to determine spatial patterns and artifact associations was to apply geo-statistical and non-parametric statistical tests (d'Andrea et al., 2002; Alperson-Afil et al., 2009).

Five clusters (C1 to C5) or discrete artifact concentrations, separated by areas with few coordinated items, were identified (Fig. 2; Supplementary Information 1). The sedimentary context and materials recovered from unit SG do not appear to have been greatly affected by syn/post-depositional processes (Jordá et al., 1992). Similarly, a general reorganization of artifacts disturbed by depositional agents can be rejected according to the results of previous spatial analysis (Pallarés, 1999). Consequently, we assume that because of their weight, ground stone tools probably remained in primary position within the clusters. Differences in elevation seen in sections are due to surface topography within this large area of more than 1200 m^2.

There are striking differences in the composition of the archeological accumulations (Table 2). Given the incidence of taphonomic and anthropogenic processes, the causes of such differences are not obvious. Poor bone preservation, or the fact that different activities do not necessarily leave similar patterns in the archeological record, are factors that hinder characterization of clusters, creating a "fuzzy" image of tasks conducted in the settlement.

Analysis of the distribution of specific classes of material was undertaken using scatter plots and kernel density maps (Alperson-Afil et al., 2009; Supplementary Information 1, 2). In addition, inferential statistics were used to determine statistical significant differences in the composition of lithics and other archeological materials (bone, plant remains, and minerals). Once the different artifact categories in each of the defined clusters had been counted, we applied chi-squared (χ^2) and Lien non-parametric tests that can detect statistically significant differences in assemblage composition. The Lien test is a derivation of χ^2 that assesses category weight and on a statistical level provides more information in contingency tables (Laplace, 1980; Volle, 1981; Simek and Leslie, 1983; Supplementary Information 1). Significant statistical differences serve to test hypotheses about the function and activities of clusters.

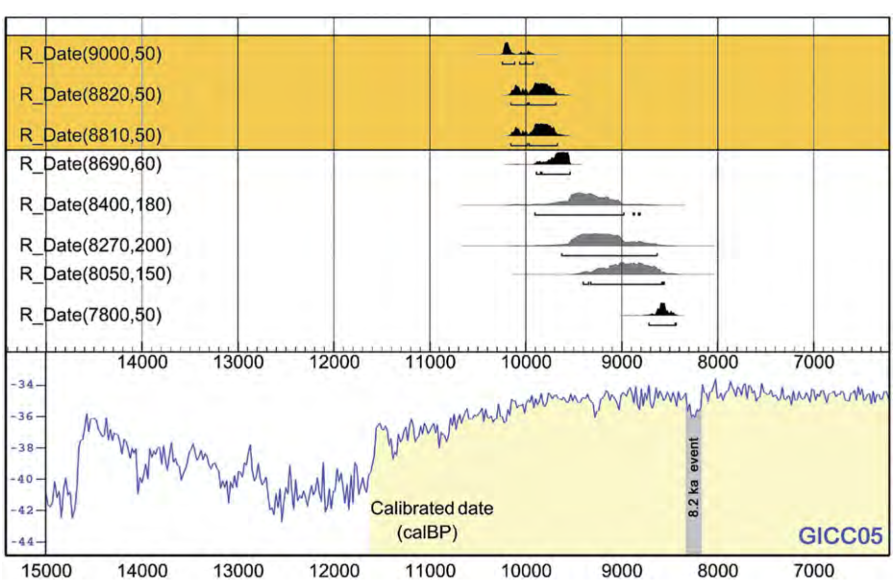

Fig. 3. Probability distributions of modeled radiocarbon dates from Font del Ros SG Unit. Shaded areas correspond to samples from the study area. Results have been processed and graphically expressed by Oxcal v4.17 (Bronk Ramsey, 2009). Dates with $\sigma > 200$ years have been excluded because of their poor temporal resolution.

Table 2
Artifact categories recovered from defined clusters.

	Ground stone tools	Flakes	Retouched pieces	Cores	Fragments	Chunks	Unused cobbles	Microdebitage	Bones	Mineral/pigments	Molluscs	Seeds	Σ
C 1	15 (1.97)	30 (3.98)	17 (2.23)	12 (1.57)	126 (16.54)	73 (9.58)	9 (1.18)	250 (32.81)	225 (29.53)	4 (0.52)	0 (0)	1 (0.13)	762 (25.18)
C 2	7 (0.57)	37 (3.01)	21 (1.71)	8 (0.65)	166 (13.51)	172 (13.20)	12 (0.98)	645 (52.48)	154 (12.53)	3 (0.24)	4 (0.33)	0 (0)	1229 (40.61)
C 3	5 (1.54)	24 (7.41)	9 (2.78)	3 (0.93)	74 (22.84)	48 (14.81)	6 (1.85)	136 (41.98)	14 (4.32)	4 (1.23)	1 (0.31)	0 (0)	324 (10.71)
C 4	3 (0.53)	30 (5.31)	11 (1.95)	6 (1.06)	101 (17.88)	100 (17.70)	4 (0.71)	244 (43.19)	39 (6.90)	10 (1.77)	0 (0)	17 (3.01)	565 (18.67)
C 5	9 (6.16)	6 (4.11)	4 (2.74)	1 (0.68)	24 (16.44)	24 (16.44)	8 (5.48)	58 (39.73)	5 (3.42)	2 (1.37)	0 (0)	5 (3.42)	146 (4.82)
Σ	39 (1.29)	127 (4.20)	62 (2.05)	30 (0.99)	491 (16.23)	417 (13.78)	39 (1.29)	1333 (44.05)	437 (14.44)	23 (0.76)	5 (0.17)	23 (0.76)	3026 (100)

Patterns detected (Table 3) allowed us to establish inferential hypotheses between qualitative information on ground stone and data derived from geo-statistical tests.

From an analytical perspective, these accumulations may be considered as events generated from unrelated temporal occupations despite the spatial proximity of their components. Alternatively, the abundance of activities or spatial isolation of some tasks can help clarify whether they form an interdependent network of activities at a structured campsite where different, but concurrent, domestic activities took place.

3.2. General analysis of ground stone tools

The development of wear on ground stone tools results from damage produced by the interaction of surfaces (Shizhu and Ping, 2012). The precise determination of use-wear relies on changes in texture or grain arrangement (fabric) of the mineralogical composition of the cobbles (Adams et al., 2009; Dubreuil et al., 2015). It is also important to consider tool kinematics in order to identify the active zones of the tool. In this sense we discuss "thrusting percussion" and "resting percussion" (*percussion lancée* and *percussion posée* respectively, sensu Leroi-Gourhan, 1971; de Beaune, 2000a, 2004) or simply "percussion" and "abrasion" (Stroulia, 2010). A stereoscopic microscope (Olympus SZ-11) was used to study use-wear traces identifiable on cobble surfaces (10×–80× magnifications), following protocols described in other studies (Adams, 1989; Dubreuil, 2002, 2004; Hamon, 2003, 2008; Adams, 2002; Adams et al., 2009; Dubreuil and Savage, 2014; Dubreuil et al., 2015).

Table 3
Relational hypotheses extracted from nonparametric tests.

		Proposed functional hypotheses arising from statistical tests
Cluster 1	χ^2	• Significant presence of bones • Significant differences in the layout of ground stone tools
	Lien	• Most important cluster on a statistical level • A priori, a range of activities are combined in this cluster • Overrepresentation of faunal remains in this area
Cluster 2	χ^2	• Significant presence of microdebitage: possibly a knapping area • A very heterogeneous zone
	Lien	• Important representation of knapping waste
Cluster 3	χ^2	• Significant difference in the presence of ground stone tools
	Lien	• Limited presence of bone remains • Important occurrence of knapping products • Significant presence of iron oxides
Cluster 4	χ^2	• Significant presence of plant macro-remains • Important presence of iron oxides
	Lien	• High representation of plant macro-remains • Limited presence of bone remains
Cluster 5	χ^2	• Significant presence of unused cobles and ground stone tools • Low informative weight of cores and retouched tools • Important presence of plant macro-remains
	Lien	• Elevated weight of information inside ground stone tools category • Prominent informative weight of plant macro-remains

Cobbles associated with thrusting percussion activities have battering traces on their surfaces; use-wear recorded on the active surfaces depends on the properties of the raw materials used. These tools are associated with knapping, bone-breaking, and the processing of hard materials, and function either as hammerstones or anvils (Dubreuil et al., 2015 and references therein). Low-power microscopic analysis of use-wear traces helps detect the pounding and pulverizing of cobble grains. Compression generated by impact produces alterations such as cracks, pits, splinters and a frosted appearance (Adams, 1989, 2002; Adams et al., 2009). Equally, bone-breaking causes scars with crushed ridges; such cobbles are known as pounding or *concassage* hammerstones (de Beaune, 1993a, 2000a), or hammerstones with fracture angles (Mora and de la Torre, 2005).

Cobbles associated with resting percussion are identified by abrasive wear traces that regularize the blank topography (sensu Adams, 2002). Linear traces, leveling and rounding of grain edges, and development of a glossy sheen (polish) are the main features related to this type of wear (Adams et al., 2009). Various experimental studies link these traces with hide-working, plant-processing activities, and the crushing and grinding of ochre (Adams, 1988, 1989, 1999; Dubreuil, 2002, 2004; Rodríguez Ramos, 2005; Hamon, 2003, 2008; Dubreuil and Grosman, 2009; Dubreuil and Savage, 2014; Dubreuil et al., 2015).

Previous experiments (Roda Gilabert et al., 2012) have enabled us to characterize use-wear traces on pitted stones and activities linked to this tool-type. Pit formation seems to be clearly associated with bipolar knapping or other bipolar pounding on hard materials. While hazelnut cracking presents problems when defining diagnostic attributes, pit formation linked to hazelnut cracking can be rejected. The pounding and grinding of hazelnuts can be associated with the appearance of flat and convex facets, a glossy sheen, and linear traces (see below). It should be noted that features identified on archeological pitted stones show a certain degree of variability that may relate to the multifunctional nature of these tools.

4. Ground stone tools and activities

4.1. Morphometric features

Forty-three ground stone tools were identified from the selected area: 13 complete cobbles and 30 fragments. The assemblage is dominated by limestone (33%, 14 pieces), quartzite (23%, 10 pieces), and sandstone (14%, 6 pieces); other raw materials such as granite (3), gneiss (2), ignimbrite (2) and andesite (1) are present in very small percentages. Quartz (3) and flint (chert) (2), used to produce blanks and retouched pieces, were occasionally used as ground stone tools. All the rocks are from local sources, coming from the terraces of the Llobregat River located about 10 km away from the site and from other nearby outcrops. The percentages of materials exploited at the site correspond with the composition of rocks at the source areas, suggesting little selection of materials (Terradas, 1995; Pallarés and Mora, 1999).

Cobbles are oval and semicircular in cross section with average dimensions of 75 mm in length, 55 mm in width and 37 mm in thickness, with a mean weight of around 400 g. (Fig. 4). They are generally convex (70%) and have wide, flat, active use surfaces (97%). Such characteristics imply a selection of cobbles that facilitated handling for various activities. The high percentage of broken cobbles (70%) does not match studies of the natural fracture of riverbed cobbles which is generally very low (Fallet, 1982). When added to the lack of taphonomic alteration observed in the lithic raw material, this fact indicates that breaks were made by humans. Indeed, angled side fractures, which are very common on percussion tools, are one attribute that could be connected with thrusting percussion (de Beaune, 1997, see below). Cobbles show use on several surfaces, and a third of the stones in the assemblage have use-wear traces over most of their surfaces. Such indicators imply the repeated use of cobbles.

Inferential and descriptive statistics show that ground stone tools form 29% of the total weight of all lithic materials, thus demonstrating their importance in the assemblage (Supplementary Information 3). The Lien test indicates that, although numerically few, cobbles are important in defining activities at the site (Supplementary Information 4). The morphometric characteristics and use-wear traces allow us to infer a group of identifiable tasks for ground stone tools. Confirmation is based on the results of our own experimental program (Roda Gilabert et al., 2012) and patterns established in other studies, summarized in Table 4. The association between different raw materials and activities identified on ground stone tools can be seen in Table 5.

4.2. Ground stone tools associated with thrusting percussion

Thirty-two of the 43 cobbles are associated with thrusting activities on stone (Table 5). Use-wear traces on their surfaces link this set to free-hand and bipolar stone knapping activities and the processing of bones. These cobbles are hammerstones that show impact fractures and modifications in areas of convexity (de Beaune, 2002; Mora and de la Torre, 2005; de la Torre et al., 2013; Dubreuil et al., 2015) (Fig. 5). Seven of the remaining cobbles are anvil fragments (Table 5).

Two ground stone tools have flake removals and step scars around their perimeters. We believe that this pattern of damage could have resulted from pounding to break bones. Marks observed on active dihedral angles are similar to those described on tools suggested as having been used to process animal carcasses (Thiébaut et al., 2010; Casanova et al., 2014). Such tools can be placed in the category of *concassage* hammerstones (de Beaune, 1993a, 2000a; Mora and de la Torre, 2005; Daulny and Dachary, 2009) (Table 4) (Fig. 6a).

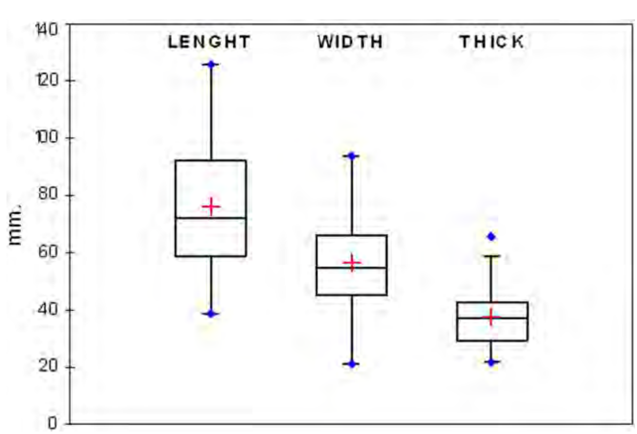

Fig. 4. Box plots of length, width and thickness of the ground stone assemblage.

Anvil fragments are mainly broken limestone blocks (Fig. 6b, c) (Table 5). The plasticity of limestone absorbs shock and prevents early breakage. Surface traces indicate that they may have been used to break bones – an activity associated with forceful percussion and identified by marks on the flat surface of the tool and on the perimeter (Alimen, 1963; Moura and Prous, 1989; Mora and de la Torre, 2005; de la Torre et al., 2013; Goren-Inbar et al., 2015). These fragments are from much larger, elongated, thick cobbles used as anvils (Fig. 6b). Several attempts were made to refit fragments but without success. It is possible that when they were no longer useful for their primary purposes, these fragments were transported to other places or used in other activities. The differences between hammerstones and anvils are subtle, and they may have been used interchangeably (Donnart et al., 2009).

Finally, use-wear depressions in the centre of six cobbles are characteristic of *pierres à cupules* or pitted stones (e.g. Chavaillon, 1979; de Beaune, 1989, 1993a, 2000a), and may be associated with bipolar battering (Le Brun-Ricalens, 1989; Jones, 1994; Donnart et al., 2009; Roda Gilabert et al., 2012) (Figs. 7, 8) (Table 5). Bipolar knapping has been identified on fragments and chunks, indicating that they are by-products of thrusting percussion. Furthermore, the assemblage includes scaled pieces in flint and quartz showing significant morphological variation, suggesting complex patterns of use. Together, these attributes highlight bipolar knapping as an important method of lithic reduction in the Pyrenean Mesolithic (Martínez-Moreno et al., 2006a; Roda Gilabert et al., 2015).

4.3. Ground stone tools associated with resting percussion activities

Ten cobbles have use-wear traces associated with resting percussion activities. All cobbles with traces of grinding also had marks characteristic of thrusting percussion, implying that they may have been used for several activities or were used at different stages of a task requiring a combination of different types of percussion. These artifacts are related to tasks such as mineral processing, hide-working, and the pounding of plant materials.

In addition to ochre fragments recovered during excavation, some complete and broken cobbles bearing mineral residues were found. Three pieces have use-wear traces and residues suggestive of the grinding and crushing of minerals (Dubreuil, 2002, 2004) (Table 5).

Three quartzite pieces show active working areas and polish with attributes suggesting hide-working (Adams, 1988; Dubreuil, 2002, 2004; Hamon, 2008; Dubreuil and Grosman, 2009) (Table 5). Of these, two flat quartzite cobbles are morphologically similar to ground stone tools on which hide-working has been identified (Roux, 1985; González Urquijo and Ibáñez, 2002) (Fig. 7c).

Four ground stone cobbles have convex facets on their flat surfaces and lateral edges that could be associated with pounding and grinding plants (Table 5). Such scars indicate a type of repeated resting percussion that produces polish on surfaces. Leveling of grains and parallel striations have been identified together with reflective sheen on these cobbles (see Roda Gilabert et al., 2013). Given that hazelnut (*Corylus avellana*) shells and seeds have been recovered from the level, we suggest that the traces on these cobbles may be related to nut-processing (Dubreuil, 2002, 2004; Rodríguez Ramos, 2005; Roda Gilabert et al., 2012, 2013) (Figs. 7b, 8).

It has been documented ethnographically that cobbles with centralized pitting are intentionally shaped to facilitate activities such as the opening of fleshy fruits (de Beaune, 2000a). One gneiss cobble has a regular surface with clearly defined pits similar to those experimentally produced by pecking (de Beaune, 1993b; see Roda Gilabert et al., 2012).

The identification of organic and inorganic residues is a further indicator of function. Some cobbles preserve oxide residues on their surfaces that can be observed with the naked eye (Fig. 7a). In addition, a preliminary study of several ground stone tools identified starch from edible plants and bone collagen residues, linking these cobbles with plant-processing and bone-breaking tasks (Pallarés, 1999).

Table 4
Functional assumptions of percussion tools.

Functional assumptions	Type of Percussion	Features	Use-wear traces	Main tribological mechanism
Hammerstones	Direct thrusting percussion on hard materials	Impact fractures, removals and modifications of convex areas, concentrated pitting derived from compression stress (Adams, 2002; de Beaune, 2002; Mora and de la Torre, 2005)	Fractures, cracks, pits, frosted appearance (Adams, 2002; de la Torre et al., 2013; Dubreuil et al., 2015)	Fatigue wear
Anvil/Anvil fragments	Indirect thrusting percussion on medium/hard materials	Battered edges, impact fractures in the contact between horizontal and transversal planes, plunging scars (Alimen, 1963; Moura and Prous, 1989; Mora and de la Torre, 2005; de la Torre et al., 2013; Goren-Inbar et al., 2015)	Cracks, pits, linear traces, frosted appearance (Moura and Prous, 1989; Adams, 2002; Donnart et al., 2009; de la Torre et al., 2013)	Fatigue wear, abrasive wear
Concassage cobble	Direct/Indirect thrusting percussion on medium/hard materials	Battering in active cortical/non cortical orthogonal planes, irregular edges with step and convex angles of detachment (de Beaune, 1993a, de Beaune, 2000a; Mora and de la Torre, 2005; de la Torre et al., 2013)	Fractures, frosted appearance, cracks, chipping of the ridges (Thiébaut et al., 2010; Casanova et al., 2014)	Fatigue wear
Bipolar knapping	Indirect thrusting percussion on hard materials	Developed pits with irregular section, step and impact fractures, breaking and crushing of grains (Donnart et al., 2009; de la Peña, 2011; Roda Gilabert et al., 2012)	Frosted appearance, crushing of grains, cracks, pits, fractures (Roda Gilabert et al., 2012)	Fatigue wear
Mineral pounding/grinding	Indirect thrusting percussion and resting percussion	Isolated impact fractures, surface regularization, visible, colored strias (Dubreuil, 2002, 2004; Hamon, 2008; Dubreuil and Savage, 2014; Dubreuil et al., 2015)	Grain extraction, striations, leveling, crushing of grains (Dubreuil, 2002, 2004; Hamon, 2008; Dubreuil and Savage, 2014)	Abrasive and fatigue wear
Plant pounding/grinding	Indirect thrusting percussion and resting percussion	Development of flat and convex facets, polish areas (Adams, 1989, 2002; Dubreuil, 2002; Hamon, 2008; Rodríguez Ramos, 2005; Roda Gilabert et al., 2012; Dubreuil and Savage, 2014; Dubreuil et al., 2015)	Highly reflective gloss, leveling, edge rounding, colored striations, (Adams, 1988; Dubreuil, 2002, 2004; Hamon, 2008; Dubreuil and Savage, 2014; Dubreuil et al., 2015)	Abrasive and fatigue wear, tribochemical wear
Hide-working	Resting percussion with possible intermediate elements	Development of convex facets, lustrous sheen, striations linked to addition of intermediate elements (Adams, 2002; Dubreuil, 2002; González Urquijo and Ibáñez, 2002; Hamon, 2008; Dubreuil and Savage, 2014; Dubreuil et al., 2015)	Leveling, dark reflective sheen, grain rounding, linear traces (Adams, 1988, 1989, 2002; Dubreuil, 2002, 2004; Hamon, 2008; Dubreuil and Grosman, 2009)	Adhesive and tribological wear, abrasive wear

4.4. Multipurpose nature of the assemblage

Cobbles are embedded in different parts of a knapping *chaine opératoire*, functioning as hammerstones, as cores for the production of blanks, and finally reused or recycled as ground stone tools. It is not unusual to see several active zones on a cobble and use-wear traces indicating prolonged reuse for the same task (Figs. 7b, 8). Of particular interest are traces that suggest different types of percussion on the same artifact, indicating a combination of different tasks (Fig. 8) (de Beaune, 1994). This mix of use-wear traces indicates the multipurpose nature of these tools (Martínez-Moreno et al., 2006a; Roda Gilabert et al., 2013).

5. From ground stone tools to identification of activity areas

The combination of functional inferences with the spatial position of ground stone tools can aid identification of patterns in the arrangement of the activities undertaken (de Beaune, 2000a, 2000b). Such inferences may confirm the spatial-functional pattern of the site (Pallarés, 1999; Martínez-Moreno and Mora, 2011).

We use the number of activities recorded as units of analysis. This differs from a count of cobbles as cobbles may be used for more than one activity (Fig. 9). Comparison of qualitative observations on cobbles along with hypotheses resulting from statistical tests allows us to establish functional inferences for the different clusters identified.

5.1. Stone knapping: a ubiquitous activity

The spatial distribution of ground stone tools identified as hammerstones which have traces associated with stone knapping, suggests that this activity was undertaken in all clusters – an observation that concurs with the abundance of microdebitage in all areas (Pallarés, 1999; Supplementary Information 2, 3). Microdebitage is not randomly distributed on the surface, and at least seven patches can be detected by geo-statistical analyses (Fig. 10). At the same time, there are numerous chunks and broken flakes associated with hammerstones in some patches; such a combination can be observed in clusters C1, C2, and C3. In C5, a concentration of microdebitage (debris) centered on a hammerstone was detected (Fig. 10). Spatial distributions suggest widespread knapping over the entire surface, but segregated in specific spots. Moreover, in some cases, we cannot ignore areas where lithic refuse from knapping activities was discarded.

Pitted cobbles associated with knapping by-products (broken flakes and chunks) support our interpretation of knapping activities (Roda

Table 5
Distribution of ground stone tools according to raw material and assumed functions.

	Andesite	Sandstone	Limestone	Quartzite	Quartz	Gneiss	Granite	Ignimbrite	Flint	Σ
Hammerstones	1	6	9	8	3	2	1	2		32
Anvil		5					2			7
Concassage coble			1	1						2
Bipolar Knapping			3	2		1				6
Mineral pounding/grinding			1	1				1		3
Plant pounding/grinding			1	2		1				4
Hide working				3						3
Indeterminate			5	2					1	8
Σ	1	11	20	19	3	4	3	3	1	65

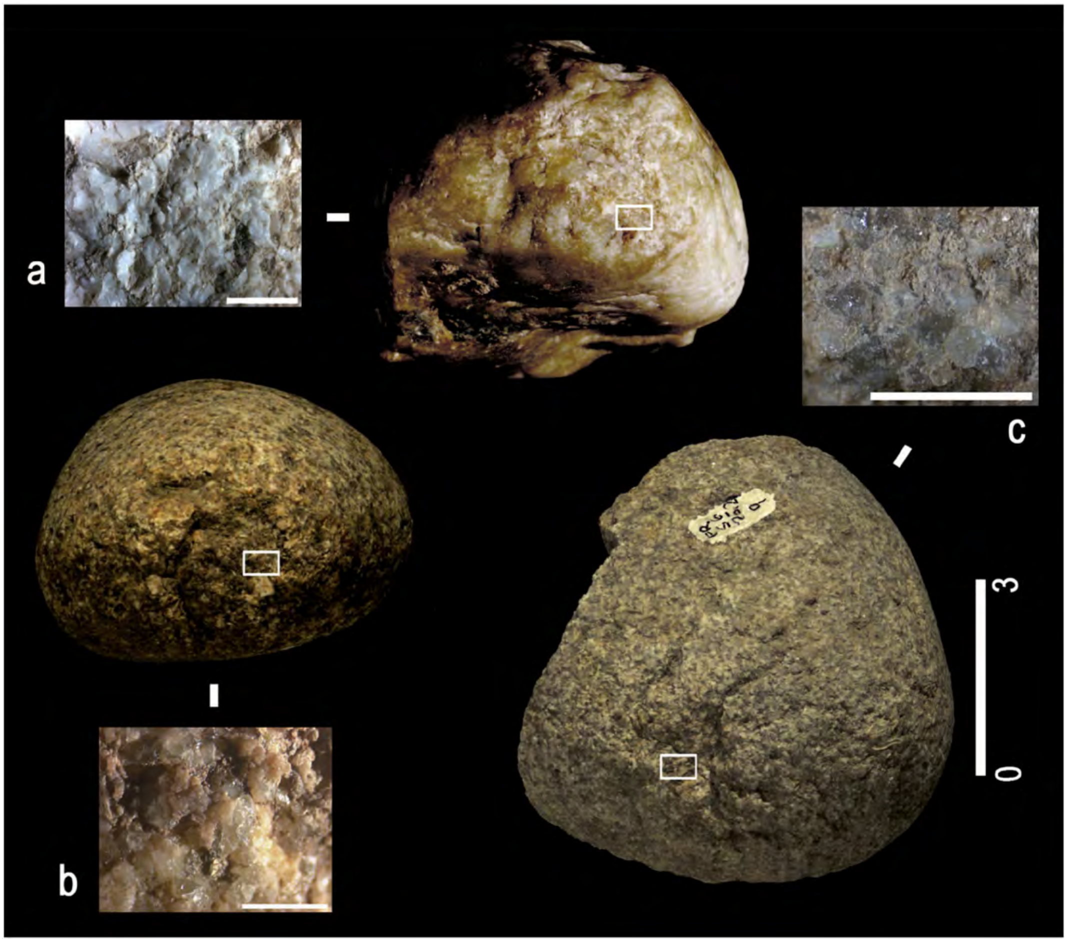

Fig. 5. Hammerstones. Areas of use were identified by impact cracks, micro-removals, and the crushing of grains. a) Quartz cobble fragment (49 × 48 × 37 mm) (graphic scale detail: 5 mm); b) Granite cobble (60 × 50 × 31 mm) (graphic scale detail: 2 mm); c) Granite cobble fragment (66 × 50 × 43 mm) (graphic scale detail: 3 mm).

Gilabert et al., 2012). Further support for bipolar knapping is found in C2 and C3, where hammerstones with punctiform traces (from thrusting percussion) and a blank with several pits were recovered. Additionally, scaled pieces and four cobbles bearing traces associated with bipolar knapping were found in C1.

Such associations emphasize the need for focused studies on the morpho-typological variability of scaled pieces (pieces esquillées). Results obtained in the Font del Ros SG unit indicate that scaled pieces should be considered exhausted bipolar cores and highlight the importance of this tool type in understanding bipolar knapping (Roda Gilabert et al., 2015).

5.2. Clusters and the identification of spatially segregated activities

Analysis of the five accumulations has allowed us to identify spatial distribution patterns that correspond with segregated activities in space, providing information about domestic activities during occupation of the site.

5.2.1. Cluster 1: a multipurpose domestic area

In C1, all activities suggested by ground stone tools indicate that they took place around hearth VIII (Fig. 2). Near this feature, we found three anvils and nine cobbles with scars associated with freehand knapping, and four cobbles used in bipolar knapping. Despite the general poor preservation of bones on the surface of the site, there were abundant small bone chips (mostly burned) around the hearth, suggesting activities associated with animal processing/consumption (Supplementary Information 3). In addition, two *concassage* hammerstones (sensu de Beaune, 1993a) were identified in the area. Given the importance of faunal remains in this cluster, these tools could be associated with bone-breaking and possibly with meat-pounding, the latter activity generating a pattern of modification with translucent gloss and striations recorded on one limestone cobble (Dubreuil, 2002, 2004). Although few plant remains were recorded, two cobbles with polished facets related to plant-processing were identified (Fig. 11; Supplementary Information 2).

The group of activities identified around the hearth in C1 corresponds with the Lien test results, indicating that this cluster has the highest level of information of the contingency tables (Supplementary Information 3). Multifunctional activities around hearths form a spatial pattern well documented in both ethno-archeological (Yellen, 1977; Kroll and Price, 1991; Kelly, 1995) and archeological studies (Leroi-Gourhan and Brezillon, 1973). Activities undertaken at C1 suggest tasks related to regular knapping, retouching of tools, bipolar production of blanks, and use of minerals that could be related to the preparation or production of composite tools (Audouin and Plisson, 1982) (Figs. 10, 11). All these activities are combined with tasks associated with subsistence, such as animal- and plant-processing (Fig. 11). C1 demonstrates the convergence of the main domestic activities around hearths (Pallarés, 1999; Roda Gilabert et al., 2013). Similarly, although no architectural elements have been identified at Font del Ros, the accumulation of tasks around this hearth could indicate the presence of a potential hut around which subsistence activities and other daily maintenance tasks were organized in this area of the site (Martínez-Moreno and Mora, 2011).

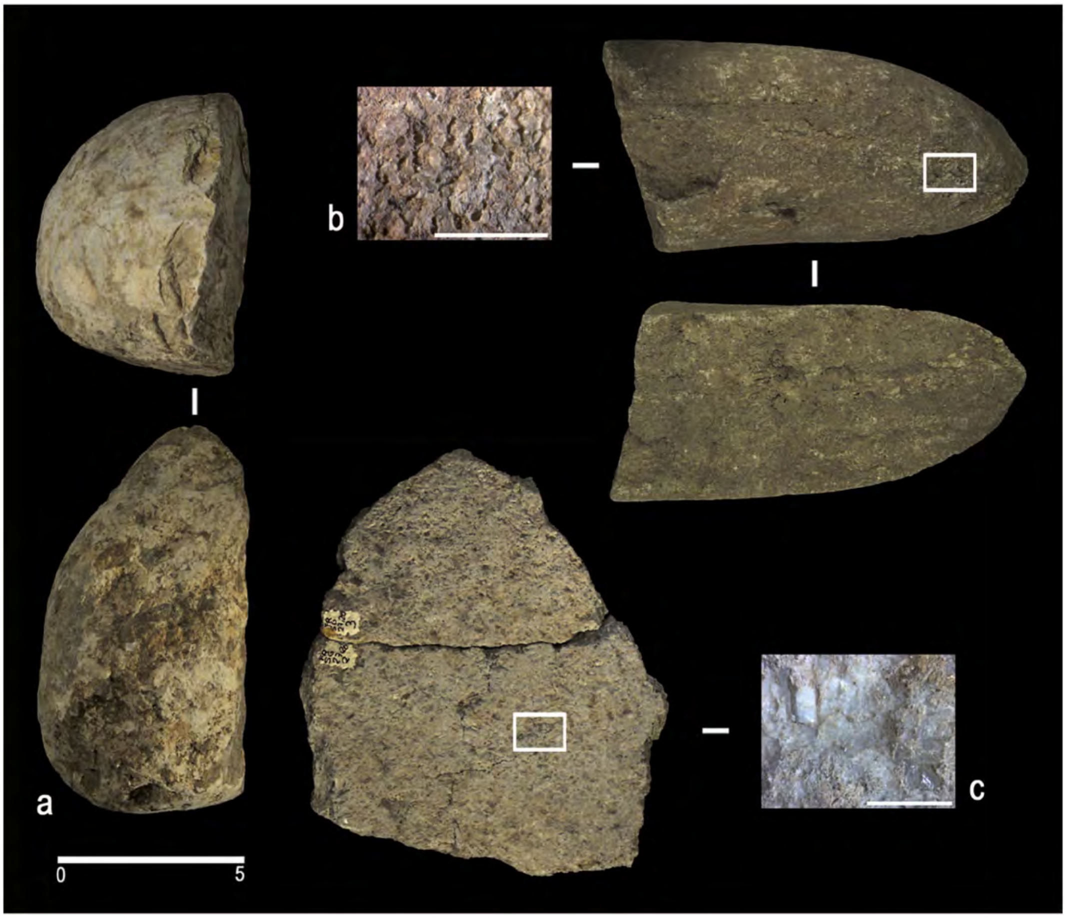

Fig. 6. a) C*oncassage* limestone hammerstone (126 × 86 × 65 mm) with conchoidal flake removals at one end produced by repeated percussion on this area of the tool, and numerous step scars on both sides of the ridge. The convex removals are not associated with knapping. The lateral zone shows intense percussion that has modified the original surface; b) Limestone anvil fragment (117 × 52 × 59 mm) and section of cobble indicating its possible origin from a large, thick cobble (graphic scale detail: 5 mm); c) Granite anvil fragment (177 × 79 × 54 mm) with the use surface modified by percussion (graphic scale detail: 3 mm).

5.2.2. Cluster 2: stone knapping and tool production

In contrast to the wide range of activities in C1, wear traces on ground stone tools from C2 suggest intensive production and modification of lithic artifacts. Our observation concurs with statistical inferences, indicating the importance of microdebitage in this group. In comparison with the general dynamic of the other clusters, the C2 attributes suggest bipolar knapping and retouching were the main activities in this area. Two separate locations identified in C2 correspond to two different knapping sequences which, while not linked by lithic refits, could be part of the same occupation (Table 2; Fig. 10).

5.2.3. Cluster 3: hide-working area

The scenario seen in C3 is different. Here, three ground stone tools in close spatial proximity are linked with an accumulation of iron oxide (Fig. 11). Statistically, the mineral distinguishes C3 from other areas (Table 3) (Pallarés, 1999; Supplementary Information 3), while the association of cobbles and iron oxide may indicate both a pigment-processing (Audouin and Plisson, 1982; Couraud, 1983, 1988, 1991) and a hide-preparation zone (Adams, 1988; González Urquijo and Ibáñez, 2002; Dubreuil and Grosman, 2009). It is possible that such tasks were undertaken in a larger area, including parts of C3 and C5, and an area extending along the perimeter of these clusters. Low artifact density in C3 indicates an empty space (or a space with few artifacts) that may correspond to a hide-working area (Fig. 11; Supplementary Informations 2, 3). Ethnoarchaeological studies suggest that from an archeological perspective, a characteristic attribute of hide-working is the presence of empty zones, that constrains positive identification of such tasks (Beyries et al., 2002).

5.2.4. Cluster 4: plant-processing area

Contextual data obtained during excavation indicates an abundance of plant macro-remains in C4 and C5 (Fig. 11; Pallarés, 1999; Supplementary Informations 2, 3). Nevertheless, it is important to stress that C4 is located at the edge of the excavated area, which makes it difficult to identify activities undertaken there. The presence of hazelnut shell residues associated with nut processing emphasizes the relevance of this activity on the site and is a significant indicator of spatial task patterns at Font del Ros (Pallarés, 1999; Martínez-Moreno and Mora, 2011; Roda Gilabert et al., 2013), However, use-wear traces identified on the pebbles in this area are not diagnostic of plant-processing.

5.2.5. Cluster 5: a "fuzzy" pattern task area

In contrast to C2, C3, and C4, a range of activities can be identified in C5, but the spatial pattern is imprecise, and materials appear dispersed. Nevertheless, ground stone tools here indicate a combination of tasks, including freehand knapping, bipolar knapping, the processing of plants, and hide-working. Our observation matches the statistical importance of used cobbles in C5, and despite the lack of functional resolution, the combination of activities is interesting (Table 6).

Although only one ground stone tool in C5 has traces indicating plant-processing (Fig. 11), we suggest that some cobbles in this area, whose precise functions remain unclear, may be associated with short-term plant-processing. Similar use-wear patterns have been

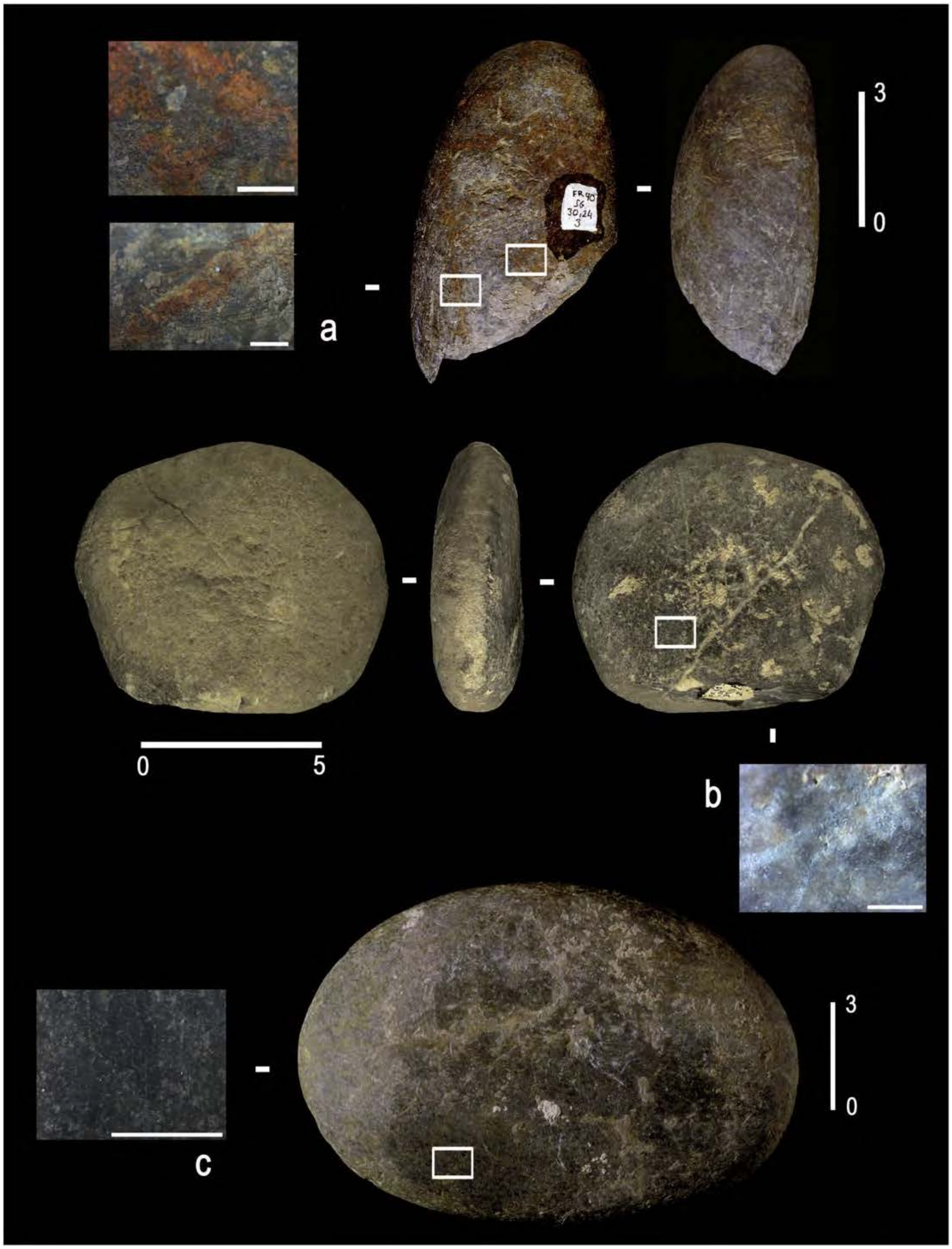

Fig. 7. Resting percussion. a) Ignimbrite fragment (80 × 48 × 37 mm) with pitting and striations impregnated with iron oxides (scale details of linear traces and residues: 2 mm); b) Limestone cobble (57 × 46 × 30 mm) with central pitting associated with bipolar knapping and a use-wear facet caused by friction on its edge (edge-ground cobble). Detail of the central pitting associated with linear traces (graphic scale detail: 1 mm).c) Flat quartzite pebble (126 × 88 × 32 mm) used in hide-working that shows a lustrous, dark gloss and light striations caused by abrasive activities (graphic scale detail: 5 mm).

observed on experimental cobbles used for cracking hazelnuts (Roda Gilabert et al., 2012).

C5 may be connected to adjacent concentrations, especially C4. Or, alternatively, it could represent an area where ground stone tools were preferentially used for specific activities, some of which were undertaken at the periphery of the central domestic unit, implying use of a large surface area. Such a possibility would be recorded by ^{14}C dates which suggest a greater radiometric age for C4 than C1 (Fig. 2).

6. Discussion

This study underlines the importance of ground stone tools as technical and spatial indicators of activities undertaken at Font del Ros (Pallarés and Mora, 1999; Martínez-Moreno and Mora, 2011; Roda Gilabert et al., 2013). Spatial analysis enabled the identification of five artifact segregated clusters in a part of level SG. This sector extends for about 500 m^2 and represents 30% of the excavated surface of this

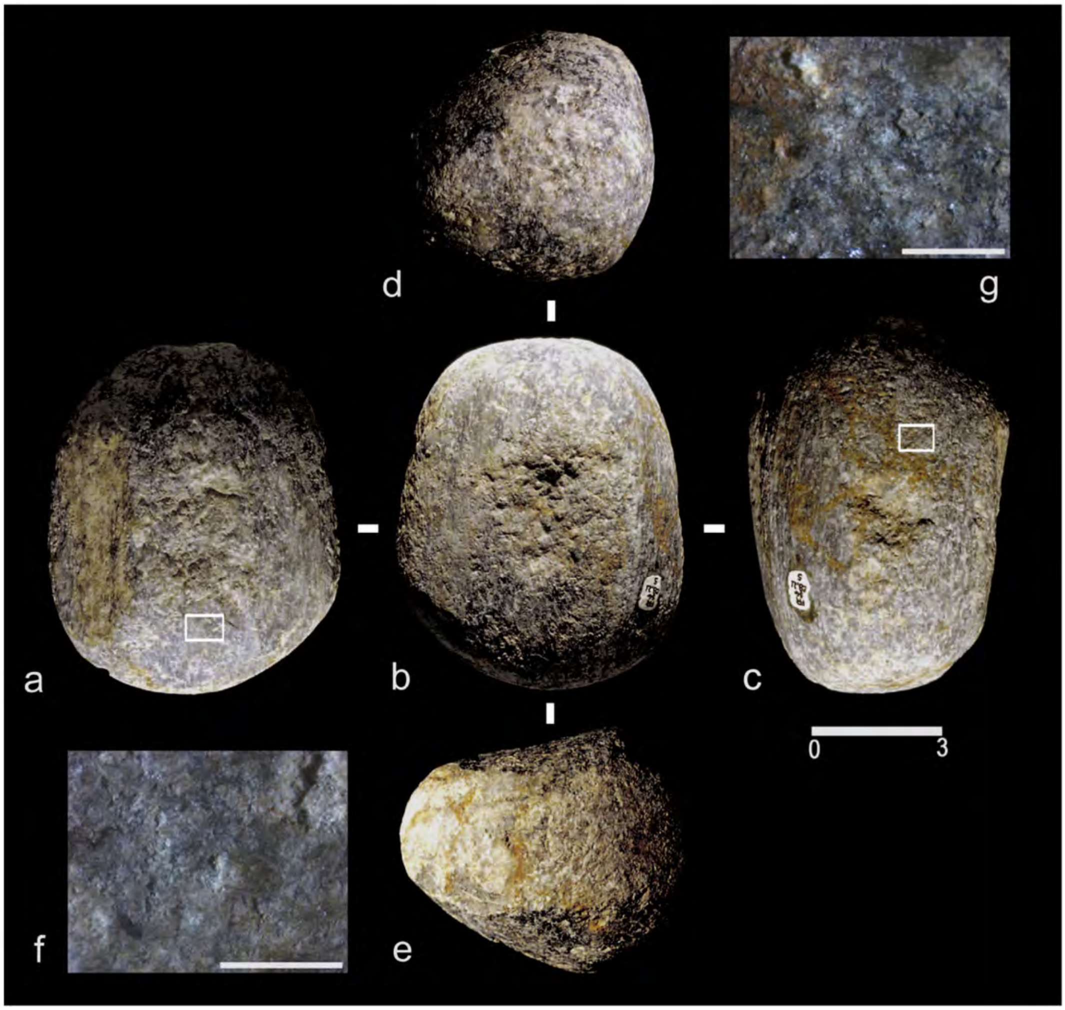

Fig. 8. Multipurpose quartzite cobble (74 × 63 × 38 mm) with several traces of thrusting and resting percussion. a, b, c) Depressions, irregular in section, with traces of polish on three surfaces; d) Pitting caused by thrusting percussion; e) Convex use-wear facet caused by friction; f) Detail of the area of polish (graphic scale detail: 2 mm); g) Center of the depression (b) showing frosting and compression points (graphic scale detail: 2 mm).

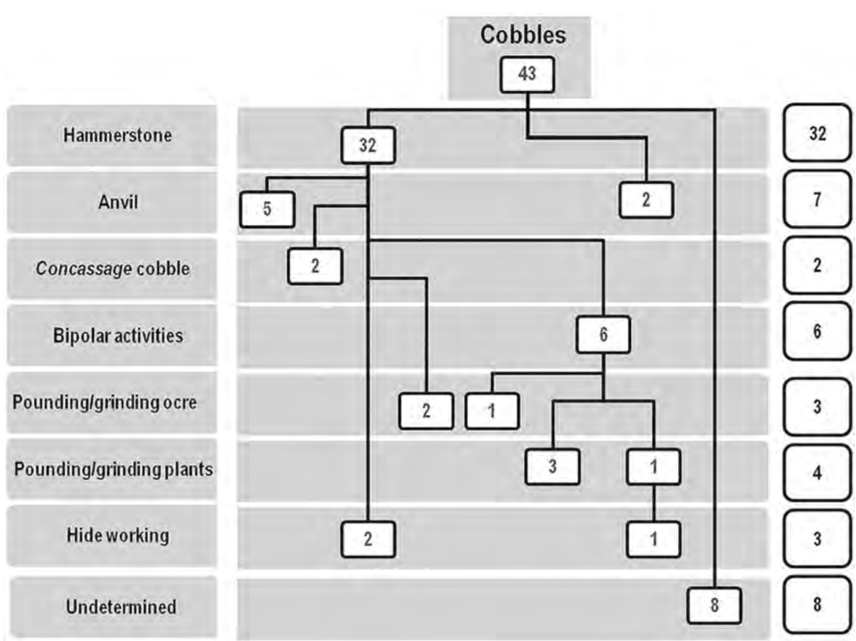

Fig. 9. Suggested distribution of ground stone tools according to their assumed functions (based on the model proposed by de Beaune, 1997: 81]). Numbers of artifacts are indicated.

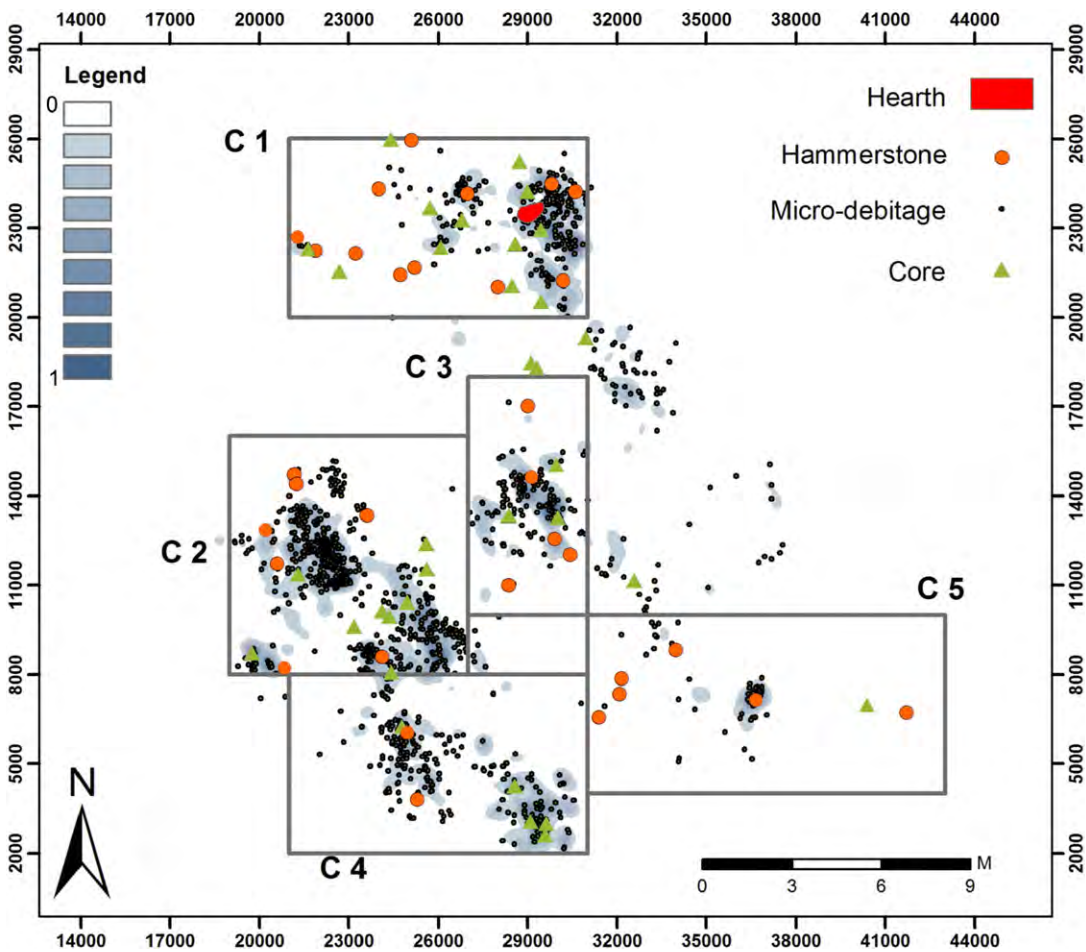

Fig. 10. Kernel density map of cores, microdebitage, and hammerstones from knapping activities. C1–C5 are clusters.

archeological level. Some indicators, such as radiometric dates and the spatial distribution of remains, suggest these accumulations were the result of successive and distinct occupation events, superimposed over a period of time which was not necessarily long.

The interrelationship between clusters allowed us to address functional and organizational questions. The tasks identified are domestic activities, including knapping and retouching of lithic artifacts, processing of fauna (bone-breaking and possibly meat-pounding), gathering and processing of nuts and fresh fruits, mineral-grinding and hide-working. These spheres of activity enable construction of the subsistence and social organization of Mesolithic hunter-gatherer lifestyle at Font del Ros during the Boreal crono-zone (Martínez-Moreno and Mora, 2011).

Our analysis of ground stone tools identified multiple use and recycling events (sensu de Beaune, 1994; Adams, 2002; Dubreuil et al., 2015), indicating a non-specialized tool assemblage in which raw material properties do not seem to be important (Table 5). Apart from sandstone, which is primarily associated with anvil fragments, and quartzite linked to hide-working, there does not seem to be a selection of raw materials according to the task to be undertaken. This characteristic is particularly interesting when one considers that tools used in activities involving resting percussion, such as pounding and grinding plants and minerals, are not those which have the greatest abrasive capability. It would seem, then, that concepts such as tool efficiency and productivity did not play an important role for the human groups at Font del Ros (Delgado-Raack et al., 2009).

These attributes agree with results from statistical tests and geostatistical analysis. Far from identifying specialized clusters or specific tasks zones, ground stone tools define a system that we call "multipurpose areas" (Pallarés, 1995; Martínez-Moreno and Mora, 2011). Cobbles may have use-wear traces connected with various technical processes applied to different subsistence activities.

One such activity is the cracking and pounding of hazelnuts (Roda Gilabert et al., 2012, 2013). The dense concentration of fresh fruit and nut trees in the Font del Ros area, suggested by charcoal analysis, could also have made it an attractive place on the regular foraging routes by post-glacial hunter-gatherers of the southern Pyrenees. Hazelnut shells and seeds of *Malus*, *Prunus spinosa*, and *Pyrus pyraster* have been identified at the site. These remains suggest that reliable and nutritious resources were available whose acquisition did not require significant investment of time and energy, thus promoting repeated visits leading to recurrent settlement (Pallarés and Mora, 1999; Roda Gilabert et al., 2013). Intensive plant-gathering has been proposed as a key attribute of Mesolithic subsistence in Western Europe (Clarke, 1976; Zvelebil, 1994; Mason and Hather, 2002). However, problems related to organic preservation and the scarcity of plant-processing tools have hindered assessment of the role of such resources (Marinval, 1988; Cane, 1989; Valdeyron, 2014).

Ground stone tools linked to food preparation tasks are known in Natufian contexts in the Near East (Dubreuil, 2004; Dubreuil et al., 2015), and particularly in the European Neolithic (Hamon, 2008; Stroulia, 2010). Nevertheless, there is little available information about such tools in Pleistocene hunter-gatherer contexts (Piperno et al., 2004; Aranguren et al., 2007; Revedin et al., 2010; Nadel et al., 2012). As such, the ground stone tools recovered from Font del Ros are clearly relevant because of their association with the processing of oily plants. Furthermore, throughout the entire excavated surface of Level SG, the spatial distribution of macro plant remains covaries with archeological

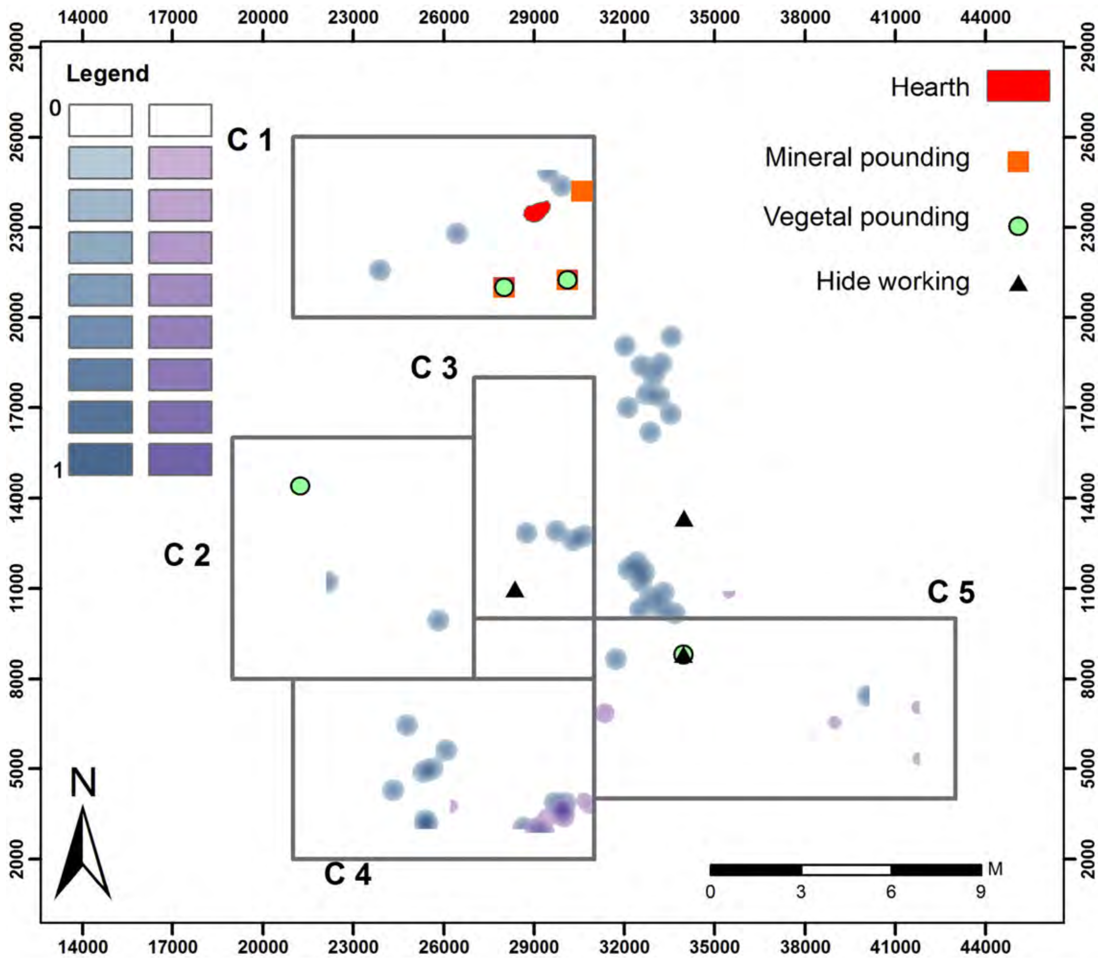

Fig. 11. Kernel density maps of mineral pigments (blue) and plant remains (purple) with superimposed spatial distribution of ground stone tools related to hide-working, mineral-pounding, and plant-processing. C1–C5 are clusters.

features and identifies plant food processing areas next to hearths (Roda Gilabert et al., 2013).

It has been shown that roasting and grinding/crushing of nuts aids absorption of nutrients and facilitates storage for later consumption (Stahl, 1989; Wandsnider, 1997; Score and Mithen, 2000). Such a scenario has been proposed for Staosnaig (Mithen et al., 2001), Verrebroek Dok 1 (Sergant et al., 2006), Wohnplatz 6 and 8 of Duvensee (Holst, 2011); Lough Boora (Mc Comb and Simpson, 1999) and Ertbølle (Robinson and Harild, 2002), where roasting and processing of hazelnuts would have been a strategic activity. In such cases, it is suggested that nuts form a substantial portion of nutritional requirements, providing a concentrated food source, easy to shelve, transport, or store throughout the year (Holst, 2010).

It is difficult to assess the importance of the consumption of nuts and plants in general for Font del Ros people because of factors associated with conservation of vegetal remains and in general the difficulties of identifying small scale storage systems which Upper Paleolithic and Mesolithic hunter-gatherers are assumed to have developed (Cunningham, 2011; Valdeyron, 2014). Nonetheless, it should be noted that there were concentrations of burned hazelnuts in all accumulations found at Font del Ros indicating periodic management of hazelnuts in the different clusters of this area over a long period (Roda Gilabert et al., 2013).

We emphasize the need to apply use-wear analysis along with protocols for the analysis of inorganic (phytoliths) and organic (starch) residues (Aranguren et al., 2007; Buonasera, 2007; Field et al., 2009; Revedin et al., 2010; Liu et al., 2010; Portillo et al., 2013). Such an approach enables a more precise characterization of the tasks for which artifacts were used that will provide information essential in establishing the organization of, and activities undertaken at the site.

The data presented here highlight the structure of an organizational system in which the gathering and processing of nuts and fresh fruits was a subsistence activity of increasing importance in the Mesolithic. These new behaviors are detected through seeds and husks, but also by the recovery, identification and study of ground stone tools linked to their processing.

Table 6
Functional assumptions detected on cobbles from each of the defined clusters.

	C1	C2	C3	C4	C5	Σ
Hammerstones	12	7	5	2	6	32
Anvil	2	2		1	2	7
Concassage cobble	2					2
Bipolar knapping	4	1			1	6
Mineral pounding/grinding	3					3
Plant pounding/grinding	2	1			1	4
Hide-working			1		1	3
Indeterminate		1	2	1	4	8
Total	25	12	8	4	15	65

7. Conclusions

In summary, concentrations of artifacts suggest a large range of tasks in the SG unit of Font del Ros. Usually these tasks cannot be detected through a straightforward reading of the archeological record. The present study has shown that ground stone tools are key to the identification of such activities (Dubreuil et al., 2015). The combination of qualitative information supplied by use-wear in cobbles, with intra-site spatial analysis and nonparametric statistical techniques, provided valuable information about the activities undertaken by past human groups (de Beaune, 2000a, 2000b).

The assignment of particular functions to ground stone tools in turn suggests certain domestic activities, among them the processing and consumption of plants, and other tasks such as lithic production, processing of fauna, hide-working and preparation of pigments, all of which are essential for the production and maintenance of subsistence and the social life of these hunter-gatherers. Cluster analysis identified the spatial dimension of tasks undertaken, and the results suggest a scenario that combines multipurpose activity areas with other activity areas segregated in space.

Likewise, artifacts with similar features have been described for sites of the same temporal and geographic range such as Balma Margineda (Guilaine and Martzluff, 1995), Balma Guilanya or Sota Palou (Martínez-Moreno et al., 2006b).

Ground stone tools have also been noted in several Mesolithic sites on the slopes of the Pyrenees, although it is not known what they were used for (Alday, 2006).Therefore, the presence of ground stone tools in the technical tool-kit is not an isolated phenomenon exclusive to Font del Ros. The study of these artifacts will enable us to characterize post-glacial hunter-gatherer adaptations on the south face of the Pyrenees and the Ebro basin. An extensive geographic environment with significant ecological contrasts and a wide biodiversity of plants, tubers and nuts (Zapata, 2000; Allué et al., 2012), easy to obtain, and providing high-energy returns, the processing of which was mediated by a ubiquitous tool such as a river cobble.

This conclusion indicates the need to recover and analyze such tools which often go by unnoticed, or are assigned to tasks related to knapping, and considered only as hammerstones. The cobble assemblage recovered at Font del Ros corroborates such activities, while also allowing us to tackle other tasks related to the maintenance of essential technological elements, among them hide-working, the preparation of mineral pigments and the processing of plants and animals that provide basic nutrients for the biological and social sustenance of prehistoric hunter-gatherers.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2015.11.023.

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Ground stone tools and settlement spatial organization in the Mesolithic site of Font del Ros (Iberian Southeastern Prepyrenees)

Supplementary information

Supplement 1: Methodology of statistical and geostatistical tests.

Supplement 2: Spatial distribution of archaeological categories considered in the statistical analyses. Kernel density maps (Fig. 1 to Fig 10).

Supplement 3: Results of non-parametric statistical tests: Table 1 to Table 4.

Supplement 4: Global weight (kg) of the different lithic categories in the studied area: Table 1.

Supplement 1: Methodology of statistical and geostatistical tests

Statistical tests

We used non parametric tests to analyze distribution of material within the five delimited clusters. This method complements spatial patterns detected through geostatistical methods (Kernel density maps), and can add supporting evidence for activity-related areas in combination with the functional hypotheses provided by the techno typological study of ground stone tools. Once a count of different artefact categories in each of the delimited clusters had been obtained using ArqueoUAB software (Mora et al., 2010), we applied *chi-square tests* (χ^2) and *Lien non-parametric tests* to detect significant differences in assemblage composition.

Chi square test (χ^2)

Chi square is useful for the analysis of potential differences among each of the accumulations by providing statistical parameters in order to detect significant differences in assemblage composition. The χ^2 value was calculated by the following equation:

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

where:

O_i = observed frequency;
E_i = expected theoretical frequency, asserted by the null hypothesis;
n = number of cells in the table.

Yates correction was used for cells in which numbers were small (observed results < 5) and was calculated using the following equation:

$$\chi^2_{\text{Yates}} = \sum_{i=1}^{N} \frac{(|O_i - E_i| - 0.5)^2}{E_i}$$

where:

O_i = observed frequency

E_i = expected theoretical frequency, asserted by the null hypothesis

N = number of distinct events

Lien non parametric test

The *Lien* test is a derivation of χ^2 that quantitatively evaluates weight which on a statistical level provides more information in contingency tables (Laplace, 1980; Volle, 1988). The Lien test value was calculated using the following equation:

$$Lien\ test = E_{ij}\ ((f_{ij} - f_i{*}f_j)^2)/\ f_i{*}f_j$$

where:

$B_{(i,j)}$=[N*Lien(I,J)- (Row-1)*(Col-1)]/SQR(ROw-1)*(Col-1)]

Row= number of rows

Col= number of columns

If $B_{(i,j)}$ >3 Error dependence hypothesis 5%

If $B_{(i,j)}$ >6 Error dependence hypothesis 1%

If $B_{(i,j)}$ <3 Data independence hypothesis (statistical analysis cannot be continued)

Spatial analysis

The spatial distribution of remains was analyzed using Kernel density maps. In these representations, point features were converted into smoothly curved surfaces around each output cell highlighting areas of high density. The cell size (0.01 m) and search radius (0.5 m) plotted using ESRI ArcGIS® spatial analysis tools.

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Supplement 2: Spatial distribution of archaeological categories considered in the statistical analyses. Kernel density maps.

Figure 1. Kernel density maps of flakes on which the spatial distribution of ground stone tools (orange circles) has been superimposed .

Figure 2. Kernel density maps of retouched pieces on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 3. Kernel density maps of cores on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 4. Kernel density maps of blank fragments on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 5. Kernel density maps of chunks on which the spatial distribution ground stone tools (orange circles) has been superimposed.

Figure 6. Kernel density maps of unused cobbles on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 7. Kernel density maps of *micro-debitage* spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 8. Kernel density maps of bones on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 9. Kernel density maps of minerals/pigments on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Figure 10. Kernel density maps of seeds on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

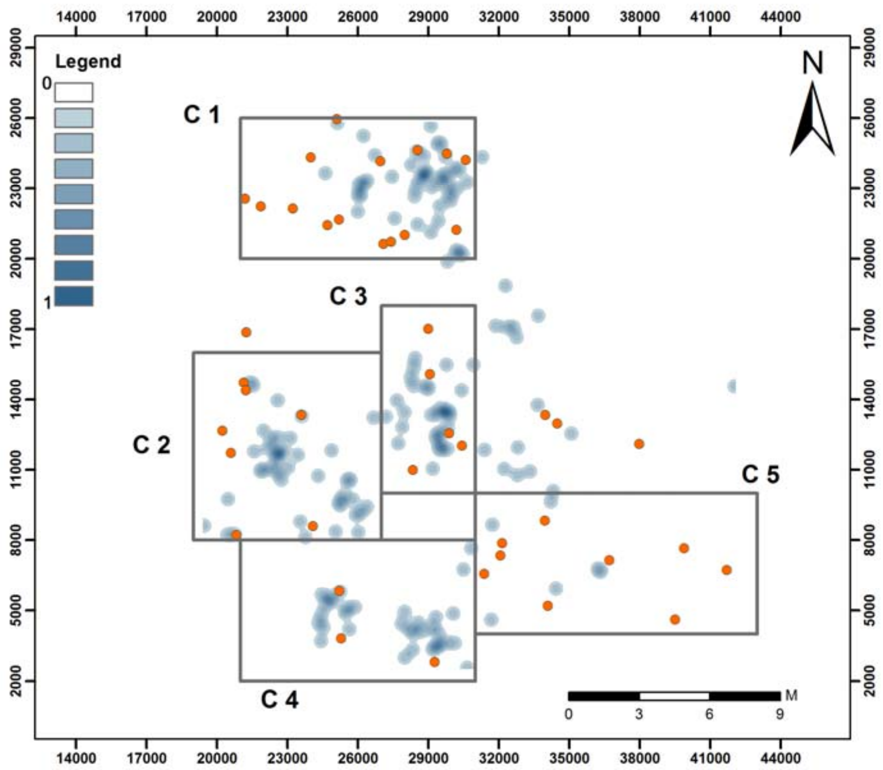

Figure 1. Kernel density maps of flakes on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

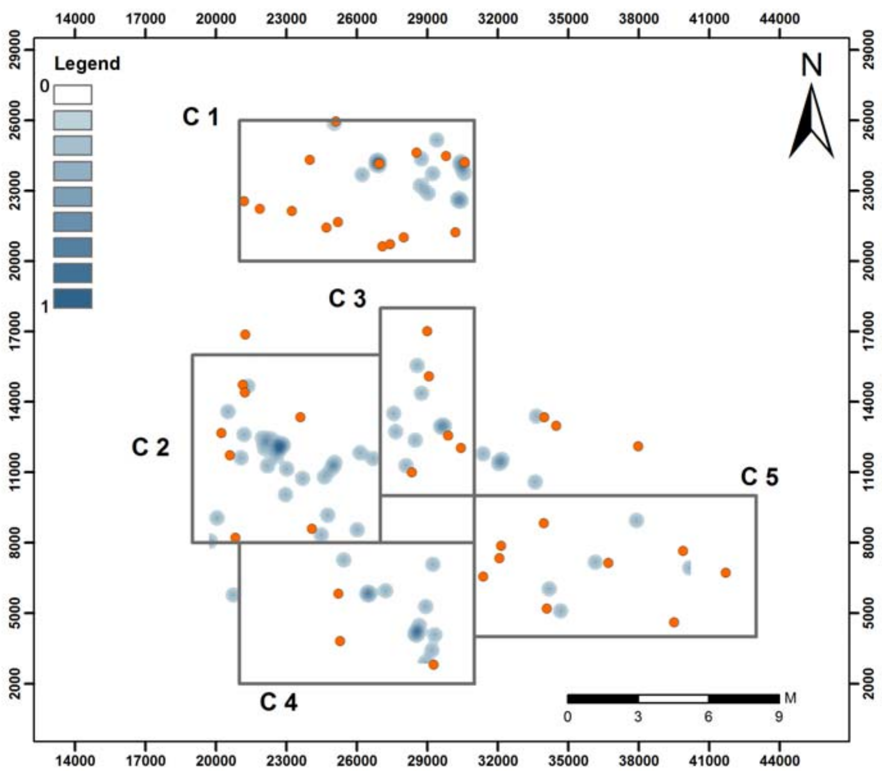

Figure 2. Kernel density maps of retouched pieces on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

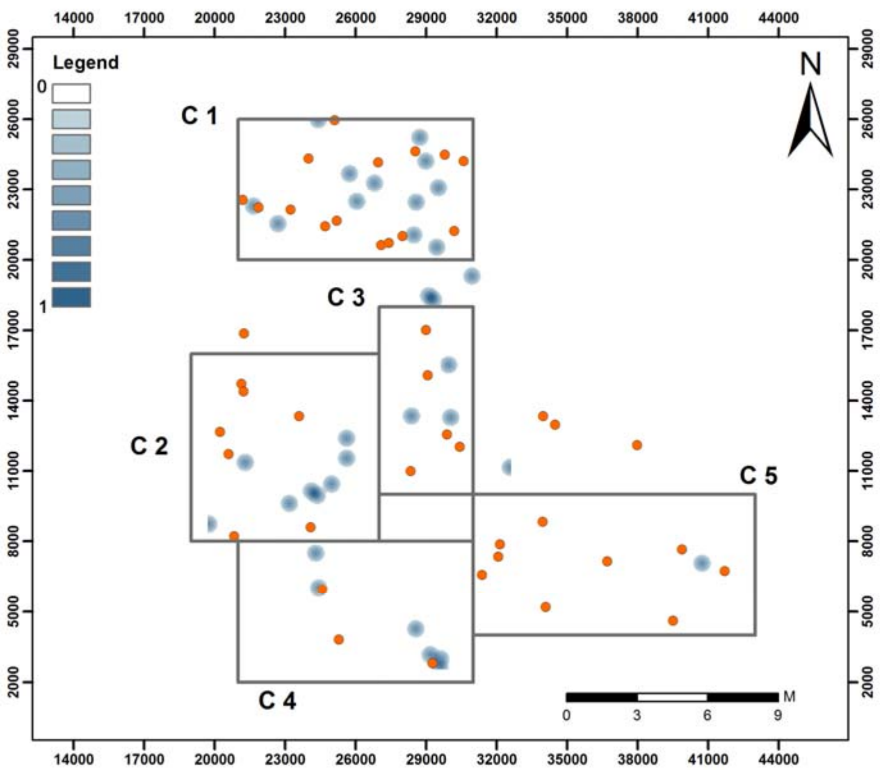

Figure 3. Kernel density maps of cores on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

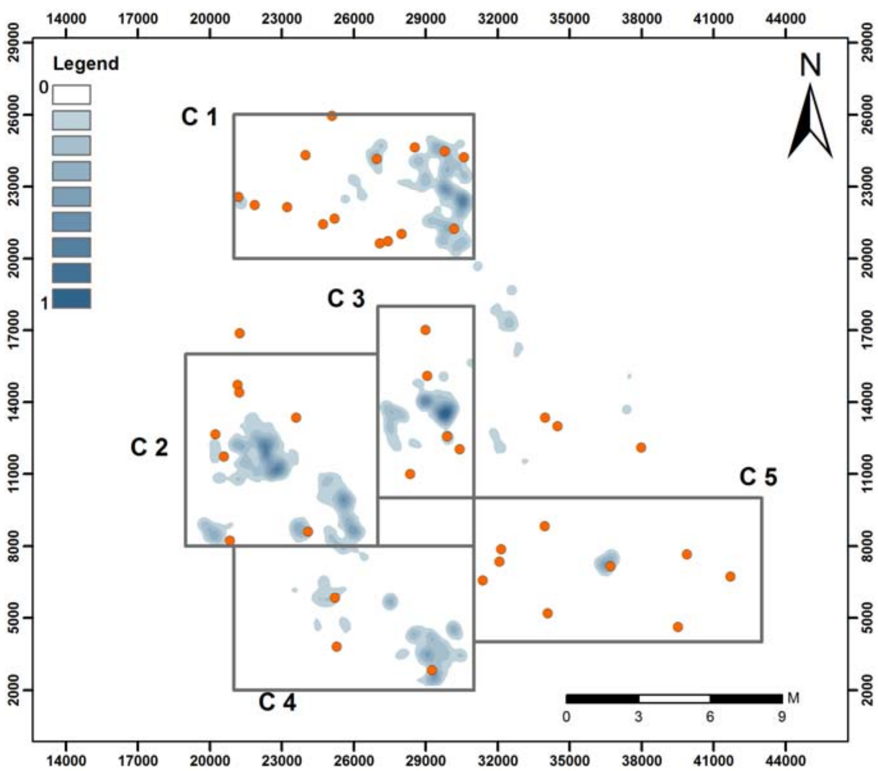

Figure 4. Kernel density maps of blank fragments on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

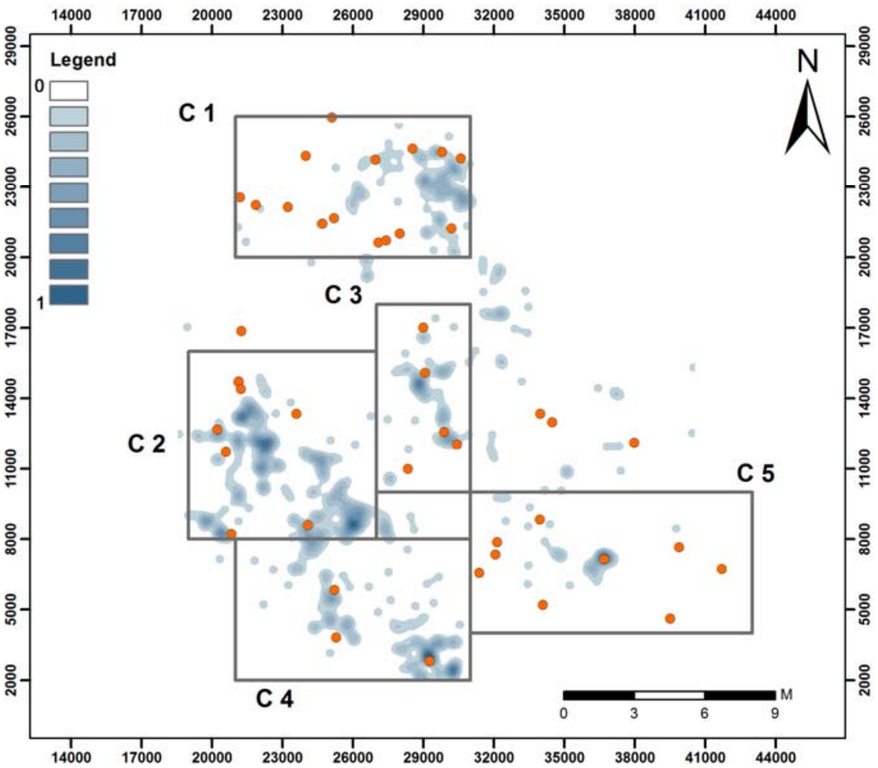

Figure 5. Kernel density maps of chunks on which the spatial distribution ground stone tools (orange circles) has been superimposed.

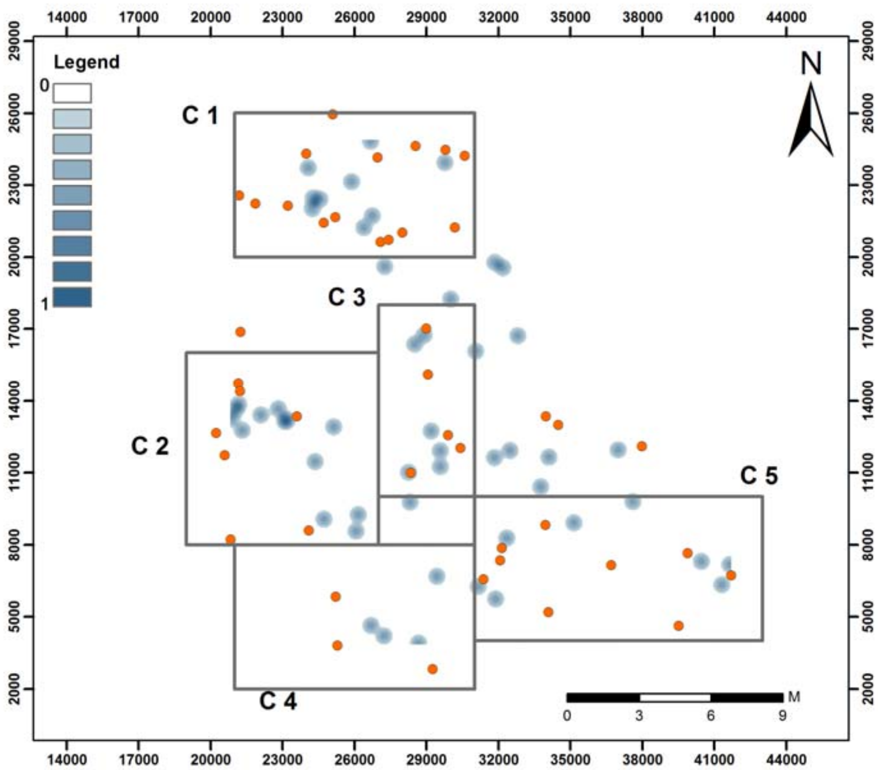

Figure 6. Kernel density maps of unused cobbles on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

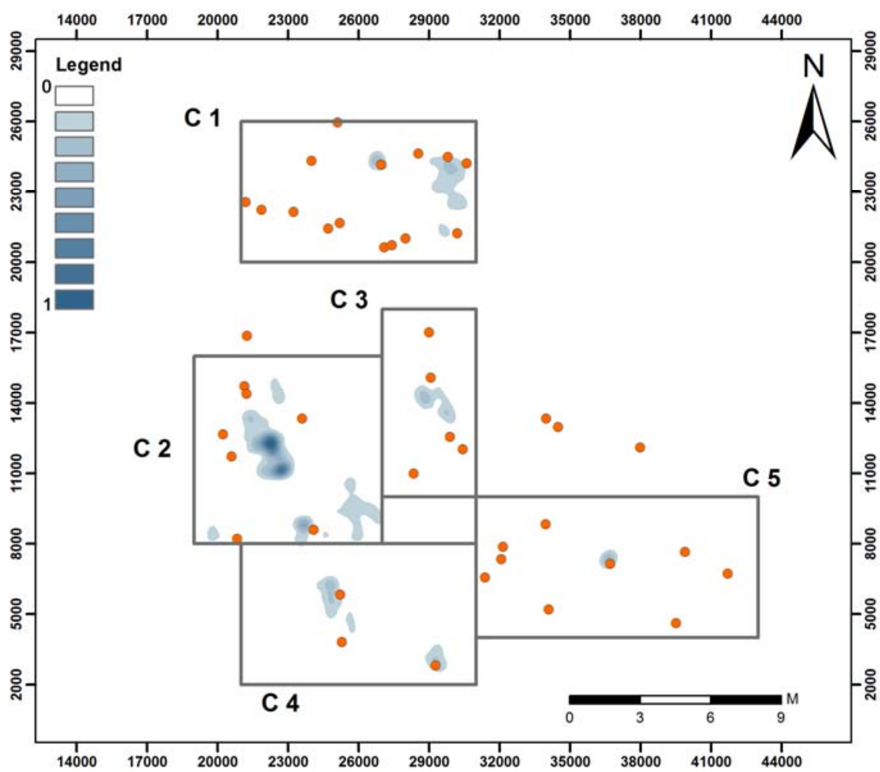

Figure 7. Kernel density maps of *micro-debitage* spatial distribution of ground stone tools (orange circles) has been superimposed.

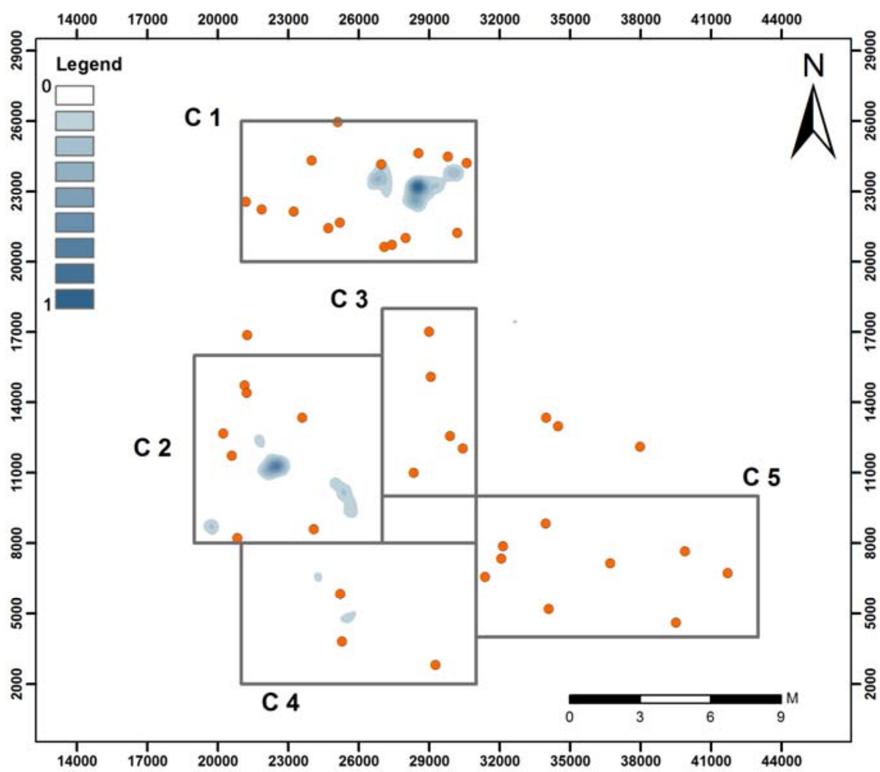

Figure 8. Kernel density maps of bones on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

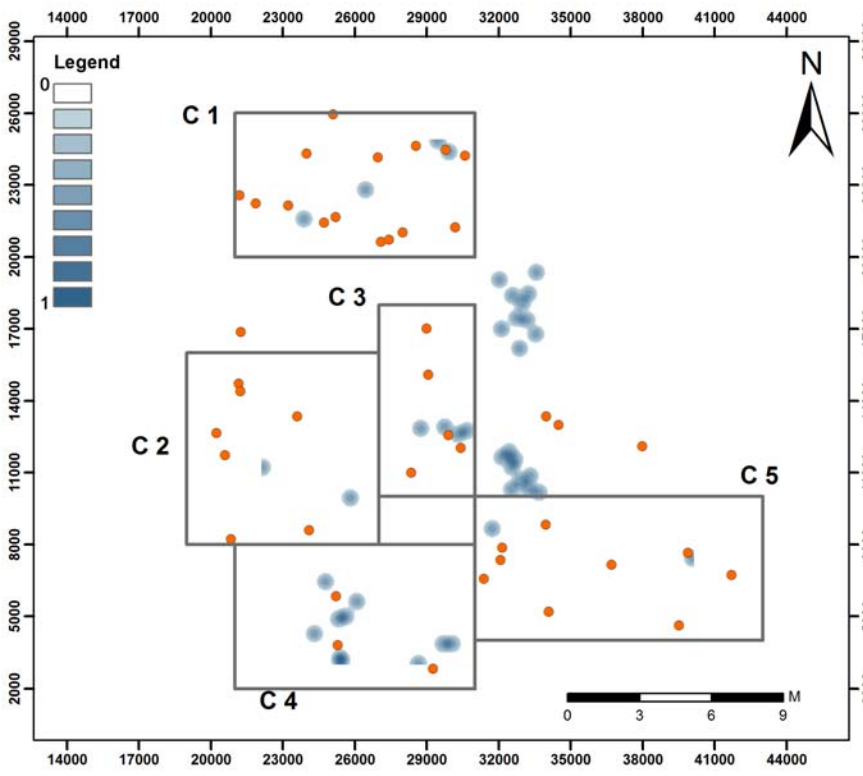

Figure 9. Kernel density maps of minerals/pigments on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

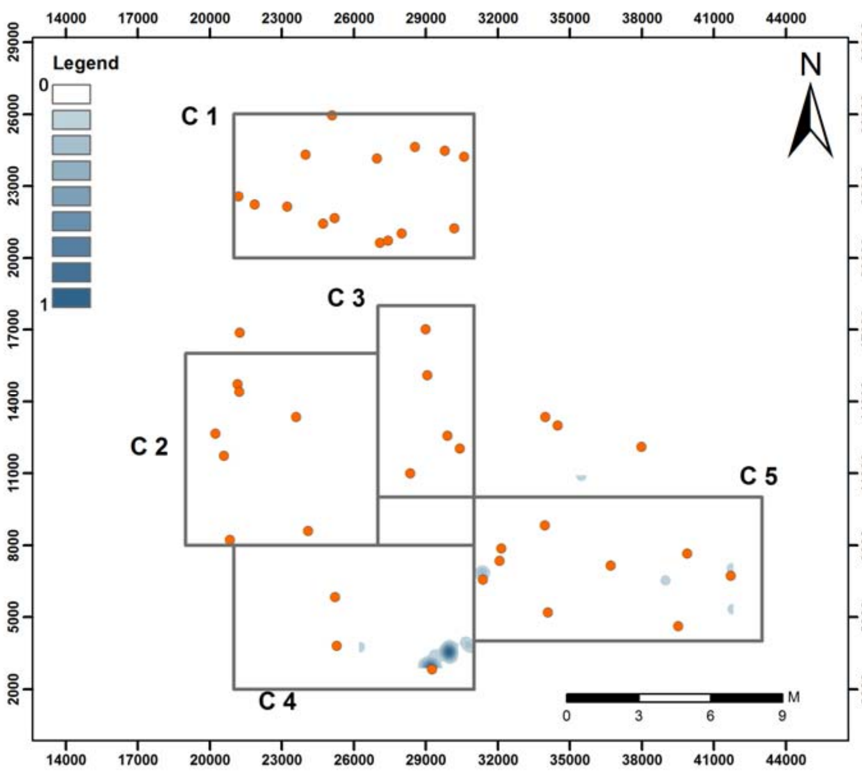

Figure 10. Kernel density maps of seeds on which the spatial distribution of ground stone tools (orange circles) has been superimposed.

Supplement 3: Results of non-parametric statistical tests

Table 1. Absolute frequency of materials within clusters in the area discussed in this article.

Table 2. Results of the χ^2 global table. $\chi^2_{(44,\ 0.05)}$= 442,26; Phi= 0,9916; χ^2 = 61,656, that reject the null hypothesis. In categories with effective theories of less than 5 the Yates correction has been applied. Colour sections indicate significant differences allowing rejection of the null hypothesis.

Table 3. Results of the χ^2 paired test on materials of the central area. Colored sections indicate significant differences allowing rejection of the null hypothesis.

Table 4. Results of the Lien Test (Volle 1988) applied to the contingency table of the inventory of the central area. Lien B $_{(i,\ j)}$= 57,025 supporting the hypothesis of a 1% dependency error. Colored cells refer to qualitative information for the category indicated.

Table 5. Conditional Lien frequencies (Volle 1988). The first column indicates relative frequency of information for each category; the second column indicates accumulated frequency.

Table 1. Absolute frequency of materials within clusters of the area discussed in this article.

	Ground stone tools	Flakes	Retouched pieces	Cores	Fragments	Chunks	Unused cobbles	Micro debitage	Bones	Minerals/ pigments	Molluscs	Seeds	Σ
C1	15	30	17	12	126	73	9	250	225	4	0	1	762
C2	7	37	21	8	166	172	12	645	154	3	4	0	1229
C3	5	24	9	3	74	48	6	136	14	4	1	0	324
C4	3	30	11	6	101	100	4	244	39	10	0	17	565
C5	9	6	4	1	24	24	8	58	5	2	0	5	146
Σ	39	127	62	30	491	417	39	1333	437	23	5	23	3026

Table 2. Results of the χ^2 global table. $\chi^2_{(44, 0.05)}$= 442,26; Phi= 0.9916; χ^2 = 61.656, that reject the null hypothesis. In categories with effective theories of less than 5, the Yates correction has been applied. Colored sections indicate significant differences allowing rejection of the null hypothesis.

χ^2	Ground stone tools	Flakes	Retouched pieces	Cores	Fragments	chunks	Unused cobbles	Micro-debitage	Bones	Minerals/ pigments	Molluscs	Seeds	Σ
C1	2.7312	0.123	0.123	2.6159	0.045	9.757	0.0686	21.866	120.09	0.554	1.2591	3.9645	163.19
C2	4.9332	4.122	0.694	1.437	5.6	0.041	0.9308	19.8271	3.1078	4.305	1.9097	9.3414	56.249
C 3	0.1627	7.957	0.84	0.014	8.734	0.252	0.7969	0.3171	22.979	0.96	0.4033	2.4627	45.878
C4	2.5178	1.667	0.029	0.0284	0.948	6.296	1.4791	0.0961	22.236	7.58	0.9336	37.591	81.401
C5	26.928	0.003	0.34	0.1383	0.004	0.748	19.894	0.6201	12.27	0.714	0.2412	13.638	75.539
Σ	37.273	13.87	2.026	4.2336	15.33	17.09	23.169	42.7264	180.68	14.11	4.7469	66.997	422.26

Table 3. Results of the χ^2 paired test on materials of the central area. In categories with effective theories less than 5, the Yates correction has been applied. Colored sections indicate significant differences allowing rejection of the null hypothesis.

		Ground stone tools	Flakes	Retouched pieces	Cores	Fragments	Chunks	Unused cobbles	Micro-debitage	Bones	Minerals/ pigments	Molluscs	Seeds
C1-C2	*x²*	8.424	1.241	0.685	4.037	3.447	8.497	0.189	73.57	88.17	P = 0.92	P = 1	P = 1
	Phi	0.065	0.025	0.019	0.045	0.042	0.065	0.01	0.192	0.21			
C1-C3	*x²*	0.227	5.794	0.291	P = 0.872	6.013	6.292	P = 0.272	8.339	84.154	P = 0.944	P = 1	P = 1
	Phi	0.014	0.073	0.016		0.074	0.076		0.088	0.278			
C1-C4	*x²*	5.011	1.416	0.127	0.638	0.411	18.864	0.749	14.951	104.21	4.817	P = 1	20.078
	Phi	0.061	0.033	0.01	0.022	0.018	0.119	0.024	0.106	0.28	0.06		0.123
C1-C5	*x²*	P = 0.008	0.01	P = 0.444	P = 0.899	0.001	6.04	P = 0.002	2.616	44.138	P = 0.249	P = 1	P = 1
	Phi		0.003			0.001	0.082		0.054	0.22			
C2-C3	*x²*	P = 0.084	13.136	1.547	P = 0.411	17.092	0.142	P = 0.154	11.322	17.912	P = 0.994	P = 0,69	P = 1
	Phi		0.092	0.032		0.105	0.01		0.085	0.107			
C2-C4	*x²*	P = 0.657	5.691	0.125	P = 0.258	5.833	4.128	0.316	13.38	12.769	P = 1	P = 1	37.333
	Phi		0.056	0.008		0.057	0.048	0.013	0.086	0.084			0.144
C2-C5	*x²*	P = 1	P = 0.302	P = 0.27	P = 0.637	0.942	0.637	P = 0.001	8.497	10.581	P = 0.09	P = 1	P = 1
	Phi					0.026	0.022		0.079	0.088			
C3-C4	*x²*	P = 0.969	1.588	0.646	P = 0.697	3.209	1.235	P = 0.968	0.123	2.448	0.381	P = 1	9.939
	Phi		0.042	0.027		0.06	0.037		0.012	0.052	0.021		0.106
C3–C5	*x²*	P = 0.998	1.832	P = 0.614	P = 0.775	2.499	0.205	P = 0.99	0.21	0.208	P = 0.604	P = 1	P = 1
	Phi		0.062			0.073	0.021		0.021	0.021			
C4-C5	*x²*	P = 1	0.348	P = 0.372	P = 0.801	0.166	0.128	P = 1	0.568	2.417	P = 0.742	P = 1	P = 0.483
	Phi		0.022			0.015	0.013		0.028	0.058			

Table 4. Results of the Lien Test (Volle, 1988) applied to the contingency table of the inventory of the central area. Lien $B_{(i, j)}$= 57.025 supports the hypothesis of a 1% dependency error. Colored cells refer to qualitative information for the category indicated.

	Ground stone tools	Flakes	Retouched pieces	Cores	Fragments	Chunks	Unused cobbles	Micro-debitage	Bones	Minerals/ pigments	Molluscs	Seeds	Σ
C1	90 (1.67)	-4 (0.07)	4 (0.07)	86 (1.62)	1 (0.02)	-322 (5.97)	-2 (0.04)	-722 (13.39)	3968 (73.58)	-18 (0.33)	-41 (0.76)	-131 (2.43)	5393 (38.65)
C2	-163 (8.77)	-136 (7,32)	-22 (1.18)	-47 (2.53)	-185 (9.96)	1 (0.05)	-30 (1.61)	655 (35.25)	-102 (5.49)	-142 (7.64)	63 (3.39)	-308 (16.58)	1858 (13.32)
C3	5 (0.33)	262 (17.28)	27 (1.78)	0 (0)	288 (19)	8 (0.53)	26 (1.72)	-10 (0.66)	-759 (50.07)	31 (2.04)	13 (0.86)	-81 (5.35)	1516 (10.86)
C4	-83 (3.09)	55 (2.04)	0 (0)	0 (0)	31 (1.15)	208 (7.73)	-48 (1.78)	-3 (0.11)	-734 (27.28)	250 (9.29)	-30 (1.11)	1242 (46.17)	2690 (19.28)
C5	889 (35.62)	0 (0)	11 (0.44)	-4 (0.16)	0 (0)	24 (0.96)	657 (26.32)	-20 (0.08)	-405 (16.23)	23 (0.92)	-7 (0.28)	450 (18.03)	2496 (18.36)
Σ	1231 (8.82)	458 (3.28)	66 (0.47)	139 (1)	506 (3.63)	564 (4.04)	765 (5.48)	1411 (10.11)	5970 (42.78)	466 (3.34)	156 (1.12)	2214 (15.87)	13954 (100)

Table 5. Conditional Lien frequencies (Volle 1988). The first column indicates relative frequency of information for each category; the second column indicates accumulated frequency.

Lien $B_{(i, j)}$	***R. f.***	***A. f.***
C1-BONE	28.44	28.44
C4-SEED	8.9	37.34
C5- GROUND STONE TOOLS	6.38	43.72
C3-BONE	-5.44	49.16
C4-BONE	-5.27	54.43
C1-MICRO DEBITAGE	-5.18	59.61
C5-UNUSED COBBLE	4.71	64.32
C2-MICRO DEBITAGE	4.7	69.02
C5-SEED	3.23	72.25
C5-BONE	-2.91	75.16
C1-CHUNK	-2.31	77.47
C2-SEED	-2.21	79.68
C3-FRAGMENT	2.07	81.75
C3-FLAKE	1.88	83.63
C4-MINERAL	1.8	85.43
C4-CHUNK	1.49	86.92
C2-FRAGMENT	-1.33	88.25
C2- GROUND STONE TOOLS	-1.17	89.42
C2-MINERAL	-1.02	90.44
C2-FLAKE	-0.98	91.42
C1-SEED	-0.94	92.36
C2-BONE	-0.74	93.1
C1- GROUND STONE TOOLS	0.65	93.75
C1-CORE	0.62	94.37
C4- GROUND STONE TOOLS	-0.6	94.97
C3-SEED	-0.58	95.55
C2-MOLLUSC	0.45	96
C4-FLAKE	0.39	96.39
C4- UNUSED COBBLE	-0.35	96.74
C2-CORE	-0.34	97.08
C1-MOLLUSC	-0.3	97.38
C3-MINERAL	0.23	97.61
C4-FRAGMENT	0.22	97.83
C4-MOLLUSC	-0.22	98.05
C2-UNUSED COBBLE	-0.22	98.27
C3-RETOUCH	0.2	98.47
C3-UNUSED COBBLE	0.19	98.66
C5-CHUNK	0.18	98.84
C5-MINERAL	0.17	99.01
C2-RETOUCH	-0.16	99.17
C5-MICRO DEBITAGE	-0.15	99.32
C1-MINERAL	-0.13	99.45
C3-MOLLUSCS	0.1	99.55
C5-RETOUCH	0.08	99.63
C3-MICRO DEBITAGE	-0.08	99.71
C3-CHUNK	0.06	99.77
C5-MOLLUSCS	-0.06	99.83
C3- GROUND STONE TOOLS	0.04	99.87
C5-CORE	-0.03	99.9
C1-RETOUCH	0.03	99.93
C1-FLAKE	0.03	99.96
C4-MICRO DEBITAGE	-0.02	99.98
C1-UNUSED COBBLE	-0.02	100
C1-FRAGMENT	0.01	100.01
C2-CHUNK	0.01	100.02
C4-RETOUCH	-0.01	100.03
C4-CORE	0.01	100.04
C3-CORE	0	100.04
C5-FRAGMENT	0	100.04

Supplement 4: Global weight (kg) of the different lithic categories in the study area.

Table 1. Global weight (kg) of lithic categories in the study area.

	N	Weight (kg)	%
Ground stone tools	43	11.29	29.15
Unused cobbles	44	9.36	26.17
Chunks	432	7.93	20.48
Cores	30	2.65	6.84
Fragments	482	2.03	5.24
Retouched pieces	62	0.42	1.08
Flakes	127	0.39	1.00
Other	1304	4.32	11.14
Σ	2524	38.73	100

6. Discusión

Los dos ejes en los que se centra esta tesis -las implicaciones funcionales del instrumental macrolítico y las implicaciones técnicas relacionadas con la talla bipolar- permiten caracterizar el conjunto material recuperado en Font del Ros. Las actividades productivas vinculadas con artefactos no relacionados directamente con la talla, subrayan el papel central que jugaron estos instrumentos en los esquemas organizativos de dichos grupos humanos. Los resultados invitan a reflexionar sobre el significado de conjuntos de cronologías similares en el noreste de la península ibérica.

Más allá de la descripción de las huellas de uso ligadas a actividades concretas, mi interés era caracterizar los procesos de deformaciones plásticas, identificar la panoplia de actividades relacionadas con este instrumental, y detectar a nivel espacial áreas de actividad en las que se integran.

En este apartado señalo los principales elementos de discusión implicados en esta línea de investigación, y que se han tratado en los artículos presentados en esta tesis.

6.1. Impacto climático/ecológico: de la resiliencia a la panarquía

El paradigma adaptacionista explica el éxito de la dispersión explosiva de *Homo sapiens* por una amplia biodiversidad de ecosistemas distintos, especialmente al final del Pleistoceno. Paradójicamente, la consolidación de las actuales condiciones climáticas holocenas supone un reto. Conceptos como *Post-pleistocene adaptations* o *broad spectrum economies*, son sinónimos de crisis en la organización de los cazadores-recolectores del Mesolítico, y se sitúan en el núcleo de la definición de este periodo. Sin embargo, sólo escasas excepciones propugnan una perspectiva más optimista (Clarke, 1976).

En los últimos años, se ha generalizado la aplicación del concepto resiliencia definido en Ecología (Holling, 1973). Este concepto propone analizar la capacidad de recuperación de un ecosistema ante cambios o perturbaciones, sean de origen natural o antrópico, generando respuestas en forma de ciclos adaptativos (Holling, 2001). La aplicación de la resiliencia ante cambios climáticos en los sistemas socio-ecológicos es una línea que se está integrando en el análisis arqueológico (Widlok *et al.*, 2012). Este concepto se ha aplicado para evaluar cambios climáticos, procesos migratorios o transformaciones socioeconómicas de los grupos prehistóricos (Zimmermann, 2012; Freeman *et al.*, 2015; Torrence, 2016; Bar-Yosef, 2017).

Bajo esta óptica, a partir del inicio del Holoceno, el sistema organizativo de los grupos de cazadores-recolectores está sometido a condiciones de *stress* relacionadas con eventos de cambio climático. Se ha considerado que algunos cambios tecno-económicos propios del Mesolítico serían fruto del impacto ambiental del Holoceno, por lo que se considera que es una etapa de degradación del modo de vida cazador-recolector.

Considerar degradación cultural como un indicativo de crisis ambiental, no deja de ser una posición reduccionista y errónea. El estudio del instrumental que he presentado permite avanzar en el conocimiento de las decisiones técnicas de grupos que pueden estar afectados por factores ambientales, pero en los que son claves las tradiciones socio-organizativas.

Relecturas recientes del concepto de resiliencia (Gunderson y Holling, 2002; Allen *et al.*, 2014) son más acordes con los planteamientos procesuales y sistémicos de nuestra disciplina. Alternativamente, estas propuestas plantean el concepto de panarquía, según el cual la interacción entre medio/grupo humano se descompone en distintos ciclos que interactúan de forma jerárquica, afectando al resto de subciclos, tanto en sentido ascendente como descendente. De esta manera, los ciclos adaptativos están interconectados entre sí, en diferentes escalas espacio-temporales.

Esta noción de interacción entre componentes orgánicamente jerarquizados es equiparable con las unidades taxonómicas arqueológicas sistematizadas por Clarke (1984) y aplicada posteriormente por varios autores (Gamble *et al.*, 2005). Nos centraremos en las unidades técnicas más próximas a nuestra investigación, como son atributos, tipos, conjuntos y tecno-complejos que informan genéricamente sobre categorías como artefacto, individuo, grupo doméstico y comunidad, lo que nos aproxima a la esfera socio-organizativa de esos grupos. Proponemos que estas unidades taxonómicas son análogas a un sistema panárquico, y configuran un sistema jerárquico de categorías que engloban las entidades arqueológicas en un orden ascendente y de creciente complejidad.

6. 2. Metodología multienfoque. Interpretación panárquica

Anteriormente hemos definido que aplicaríamos un enfoque *multiaproach* (Roda Gilabert *et al.*, 2016). Las diferentes escalas de observación e interpretación de los artefactos y del registro arqueológico, constituyen una aproximación equiparable al concepto de panárquico. Esta perspectiva considera las huellas de uso como punto de partida de observación, mientras que los cantos utilizados constituyen la unidad mínima de análisis que centraliza el diseño de la organización del sistema técnico. Por un lado, son materias primas fáciles de obtener y aparecen en terrazas adyacentes a Font del Ros. Por otro, se usan en contextos funcionales específicos: en áreas de trabajo, en la organización de estructuras de hábitat y en coberturas de hogares; lo que las convierte en indicadores funcionales y espaciales precisos. Al mismo tiempo, permiten analizar cómo esas decisiones afectan a varias escalas dentro de la organización del diseño técnico de las unidades taxonómicas, que concatena de forma creciente tipo-artefacto-conjunto-tecno complejo, equiparable a la escala referida con la organización social: individuo-grupo domestico-población.

La aplicación de este enfoque en el utillaje de percusión ha permitido avanzar en el estudio de la dinámica de ocupación de Font del Ros. La amplia superficie excavada, la identificación de *clusters* configurados a partir de hogares, y las manchas de ocres o fosas proporcionan indicadores sobre la acumulación de eventos de ocupación que se repiten durante una escala temporal imprecisa, pero que puede acotarse por el ^{14}C AMS. La serie de dataciones de la que se dispone proporciona una imagen dinámica compuesta por momentos de ocupación intercalados con fases de abandono, que se suceden por lo menos durante más de 1800 años solares. No puede descartarse que nuevas fechas amplíen el rango temporal, y paralelamente permitan determinar con mayor precisión los rangos temporales de algunas de las áreas.

A nivel metodológico, es esencial la definición concreta de los contextos arqueológicos. La actual estructura temporal de Font del Ros permite analizar conjuntos arqueológicos a partir de principios organizativos más precisos. La imbricación entre las dimensiones temporales que proporcionan la cronometría y el tiempo humano derivado de los artefactos permite evaluar la noción de continuidad o de posibles cambios.

En este sentido, la información aportada por el utillaje de percusión caracteriza las actividades realizadas dentro del ámbito domestico y de la esfera organizativa de los cazadores-recolectores. Los datos de los que disponemos indican una escasa interacción entre las diferentes acumulaciones identificadas en superficie, observación coherente con los patrones que deriva el remontaje de artefactos líticos y cantos. Esta observación afecta a la noción de tecno-complejo e indica que los artefactos recuperados en la unidad SG comparten una misma tradición técnica durante casi 2000 años (Roda Gilabert *et al.*, 2015).

6.3. Más que simples cantos

Cantos y fragmentos utilizados son la unidad mínima de análisis para abordar la interpretación de la unidad SG. Los artículos presentados indican que estos elementos participan en las principales cadenas operativas y su estudio ha facilitado la caracterización de las esferas técnicas representadas. A la vez, son marcadores espaciales de las actividades desarrolladas en las diferentes ocupaciones del yacimiento. La relevancia del utillaje macrolítico se afianza por la cantidad de información que contiene, que va desde las huellas de uso, que permiten inferir en su funcionalidad, hasta su ubicación espacial, lo que facilita elaborar una propuesta sobre las actividades registradas dentro de las acumulaciones. Desde el punto de vista informativo vemos que en la escala de análisis más pequeña (p. e. estigmas o deformaciones plásticas) son indicadores técnicos; mientras que a medida que ampliamos el enfoque permiten avanzar hacia categorías generales de tipo cultural (p. e. procesos técnicos, objetos tipo).

En los últimos años se ha señalado el interés creciente por caracterizar la panoplia de artefactos sobre cantos o fragmentos con trazas, derivados de actividades de percusión y/o abrasión (ver referencias en Dubreuil y Savage, 2014, Dubreuil *et al.*, 2015). A pesar de su simplicidad técnica, estos artefactos contienen información esencial para la identificación de tareas básicas en la organización de la subsistencia de los cazadores-recolectores. Sin embargo, el conocimiento del que disponemos sobre este tipo de instrumental es muy limitado, siendo fundamental reivindicar su normalización en los análisis tecnológicos.

Estos instrumentos *a posteriori* no presentan formas o volúmenes específicos ni han sido sometidos a procesos de manufactura. Estos útiles concebidos en términos de forma y uso como piedras flexibles (*flexible stones*) (Stroulia, 2010), es una definición que compartimos. .A pesar de su diversidad tecno-morfológica este grupo presenta atributos propios que podemos sintetizar en los siguientes puntos:

- Oportunista (*expediency*) no existe una selección de soportes (cantos o fragmentos utilizados) ni de materias primas.
- Ausencia de preparación de las superficies activas.
- Ausencia de mantenimiento (*curation*) o estandarización en los cantos utilizados.
- *Ground stone tools* como artefactos dinámicos: a lo largo de su vida pueden incluirse en varias categorías dentro de la cadena operativa.
- Polifuncionalidad documentada a través de las superposiciones de huellas de uso que corresponden con actividades diversas.
- Intercambiabilidad desde un punto de vista cinemático: alternancia entre rol activo y pasivo a lo largo de la vida útil del instrumento.
- Reutilizacion (re-use) de los soportes con nuevas funciones interconectándose diferentes usos.
- Reciclaje hacia otras actividades. Formando parte de estructuras de combustión, o mediante su transformación en núcleos.
- Eficiencia a la hora de realizar las actividades relacionadas con la subsistencia diaria.

El análisis de las trazas de uso sobre los objetos revela actividades difíciles de detectar en el registro recuperado, como el procesado de vegetales, la molienda de minerales o el trabajo de las pieles (Roda Gilabert *et al.*, 2012; 2013, 2016). A nivel de comportamiento aportan información de actividades singulares, que encadenan diferentes gestos técnicos que forman parte de una misma actividad (Balfet, 1991).Un ejemplo sería el caso se secuencias de talla a mano alzada o bipolar, secuencias homogéneas que repiten un mismo patrón/gesto pero responden a actividades distintas.

Más allá de estos comportamientos técnicos, igualmente relevantes son los cantos y fragmentos alterados térmicamente, que han quedado fuera de este estudio pero que merecen un análisis pormenorizado, ya que están estrechamente relacionados con actividades de mantenimiento, como la cocción culinaria. (Julien *et al.*, 1992; Pagoulatos, 1992; Petraglia, 2002; Thoms, 2008; Nakazawa *et al.*, 2009).

6.4. Útiles simples, conceptos complejos

En los artículos publicados surgen conceptos de forma recurrente a la hora de interpretar el utillaje de percusión, como, equifinalidad, oportunismo o polifuncionalidad; atributos que los señalan como instrumentos con una compleja "*toollife history*" (*sensu* Dubreuil *et al.*, 2015). Los estudios relacionados con estos artefactos deben enfrentarse a diversas problemáticas comunes a la traceología sobre instrumental tallado, como la necesidad de realizar programas experimentales para cada contexto o la variabilidad de respuestas de las materias primas en diferentes trabajos.

Reciclaje, reutilización y polifuncionalidad son conceptos que forman parte del análisis e interpretación de los patrones de uso sobre las superficies activas (Stroulia, 2010; Adams, 2002; Dubreuil *et al.*, 2015). Este es un atributo relevante en muchos cantos de Font del Ros, en los que en el mismo artefacto se usó de forma recurrente en varias tareas. Estas sinergias entre atributos técnicos y cognitivos, refuerzan la noción de que se trata de un instrumental fácil de obtener y que potencialmente puede emplearse en una amplia gama de actividades. Es decir estos indicadores no denotan un proceso de regresión técnica, y señalan artefactos eficientes.

Los datos obtenidos a partir del análisis de las huellas de uso son sugerentes al incidir en detalles como la cinética, los mopvimientos y la fuerza vinculada al funcionamiento de la herramienta (Adams, 2002). Sin embargo, integrarlos dentro de la esfera humana es difícil, tanto en su escala temporal obtenida a partir de dataciones radiométricas, como, sobre todo por la complejidad intraespacial de un conjunto de restos derivado de reiteradas ocupaciones. Un ejemplo de esta problemática es el escenario presentado en el sector central de la unidad SG. Este área muestra una densidad menor de restos, atributo que permite establecer relaciones categóricas que difícilmente son aplicables al resto de la ocupación, en el que el número de restos y las interacciones observadas a través de los remontajes, evidencian modelos de ocupación que indican posiblemente una mayor reiteración. Aunque la abundancia de *ground stone tools* indica la reocupación del sitio y remarca la importancia de actividades domésticas, el sesgo de información sobre actividades como la caza en estas ocupaciones, complica el análisis del patrón de asentamiento de estos espacios.

En este marco de trabajo, la distinción entre conceptos como multifuncional, reutilización o uso múltiple no es evidente. De ello se deriva la variedad de conceptos referidos, como desuso, descarte, pérdida, abandono, reciclaje o rediseño que, como veremos, se entroncan con la discusión del significado del concepto mantenimiento (*curation*). Un punto remarcable es el de ver cómo se inserta el utillaje macrolítico con actividades técnicas como la talla bipolar, dentro del modelo de ocupación intermitente que se observa en la unidad SG. A pesar que desde un punto de vista técnico se trate de materiales que no requieren de una gran inversión técnica, en su elaboración las dinámicas de uso descritas remiten al concepto de mantenimiento y las diferentes definiciones que se ha realizado del mismo.

Partiendo de acepciones sumarias del término mantenimiento, la amplitud de su definición se ha ido extendiendo, tal y como recientemente se ha advertido (Vaquero y Romagnoli, 2017). Empleado por primera vez para designar el transporte de útiles entre yacimientos (Binford, 1973), este concepto originalmente pretendía valorar factores relacionados con la productividad y la eficiencia de los útiles que incluyen manufactura previa al uso, multifuncionalidad del diseño, transporte entre yacimientos, acondicionamiento para su enmangue o reciclaje; comportamientos que no tienen por qué documentarse simultáneamente. Por lo tanto, desde su definición es un concepto polisémico y con múltiples connotaciones.

Siguiendo a Shoot (1996: 267), que considera mantenimiento la relación establecida entre los objetos, vemos cómo, más allá de sus particularidades técnicas, la unidad SG se inserta dentro de un marco comportamental especifico. .A pesar de las características técnicas oportunistas y la baja inversión en la talla, la obtención de artefactos se rige por comportamientos que responden a unas finalidades concretas. En este sentido, los conjuntos que en un principio se analizaron como disgregados, pensamos que se articulan entre ellos configurando una esfera cultural que define un tecno-complejo, con unas características propias que se extienden a lo largo de las ocupaciones y, en consecuencia, a lo largo del tiempo. La identificación de útiles polivalentes señala su reciclaje para adaptarlos a nuevas necesidades, pero también un comportamiento para prolongar su vida útil. A pesar de que no se documentan comportamientos de mantenimiento, la aplicación de las dinámicas descritas extiende su eficiencia.

6.5. La talla bipolar: analizando una nueva dimensión técnica

La talla bipolar es un método al cual se ha prestado escasa atención, a pesar de ser una técnica de talla recurrente desde el Olduvayense hasta época histórica (Jeske y Laurie, 1993; Pargeter y Duke, 2015; Hiscock, 2015).

El interés creciente por este método de explotación se refleja en artículos que han profundizado en la caracterización de atributos cualitativos(de la Peña, 2011; de la Peña y Vega Toscano 2013; de la Peña y Wadley 2014; Mourre y Jarry (ed.), 2011; Roda Gilabert *et al.*, 2015; de la Peña, 2015).La relativa simpleza operativa y la versatilidad resolviendo problemas logísticos como tiempo, escasez de materia prima, movilidad y materias primas de baja calidad, convierte la talla bipolar en un sistema ubicuo que en gran medida, es una respuesta ante retos estratégicos (Jeske y Lurie, 1993).Frente a visiones lineales propias de los análisis evolucionistas que definen esta técnica como simple e ineficiente, se ha señalado que es una técnica *multipurpose* y *skilldependent* (Pargeter y Duke, 2015).

Habitualmente, esta técnica ha sido interpretada como indicador de condicionantes tales como ausencia o baja calidad de las materias primas. En contextos más próximos a nuestro objeto de estudio, se ha indicado que denota un proceso de degeneración técnica ante situaciones de crisis y que expresa situaciones de “regresión cultural” (Barbaza *et al.*, 1984), una perspectiva que habitualmente se asocia a conceptos como “mesolítico atípico” o “facies de fortuna” (Martínez-Moreno *et al.*, 2006b).

Este método fue identificado en la unidad SG especialmente a partir de su vinculación con cantos con cúpula central. En la reciente revisión de los materiales líticos tallados se han reconocido estigmas diagnósticos de talla, facilitando la identificación de soportes bipolares (núcleos) y grupos de remontajes. Actualmente, la talla bipolar es el método de talla mayoritario dentro de las ocupaciones mesolíticas, hecho que deriva un nuevo marco interpretativo del conjunto lítico (Roda Gilabert *et al.*, 2016). Esta sistemática permite la gestión de materias primas de baja calidad para obtener soportes de tamaños inferiores a los 3 cm, proceso de miniaturización que afecta a la práctica totalidad del conjunto. Estas dimensiones hacen que los objetos sean funcionales únicamente enmangados o como parte de instrumentos compuestos. La ausencia de armaduras microlaminares y geométricas (triángulos, trapecios y segmentos) habituales en estas cronologías, nos llevan a proponer la caracterización del conjunto de Font del Ros como un mesolítico sin armaduras (Roda Gilabert *et al.*, 2012, 2015).

El problema radica en la dificultad de tipificar un método que se aplica en materias primas de baja calidad y en la de identificar atributos cualitativos, que se engloba dentro del concepto *“confusion in bipolar world”* (Hayden, 1980). En la mayoría de casos, es más sencillo en los núcleos que en los desechos de talla, lo que provoca que, cuantitativamente, los productos derivados de esta sistemática estén subrepresentados dentro de los conjuntos, como detectamos en la unidad SG, en la que los núcleos bipolares son más abundantes que en el resto de categorías líticas.

Otra característica es que muchos artefactos no son fáciles de asignar ni a categorías tecno-tipológicas ni a las principales categorías de talla bipolar. Núcleos, productos, fragmentos y nucleiformes/*écailles* se interrelacionan con la talla a mano alzada en diferentes fases de explotación, y se aplica indistintamente sobre sílex y cuarzo, materias primas mayoritarias de *débitage*. Esta movilidad entre categorías es común en piezas esquilladas métricamente microlíticas (<3 cm), evidenciando la dificultad de valorar la incidencia a nivel cuantitativo de la técnica bipolar dentro del conjunto.

La complementariedad entre talla a mano alzada y talla bipolar debe ser remarcada, al ser decisiones intencionales dirigidas a obtener productos deseados y que se encadenan en distintos momentos de la explotación. La extrema reducción de los núcleos mediante talla bipolar facilita la obtención de fragmentos de pequeño tamaño que podrían ser utilizados como sustitutorios de las armaduras, que prácticamente no se documentan en el yacimiento. Este comportamiento se detecta en los remontajes de cuarzo y sílex, en los que los fragmentos obtenidos mediante talla bipolar son reconvertidos posteriormente en núcleos.

En este esquema, la talla bipolar permite prolongar la reducción intensiva de los núcleos que no pueden ser tallados a mano alzada. A la vez facilita el mantenimiento y el reciclado de artefactos en momentos finales de la explotación, comportamiento que remite a la noción de *curated technology*. Esta conducta subraya la idea que hemos señalado, ya que desde un punto de vista formal son instrumentos aparentemente sencillos. Sin embargo, los comportamientos aplicados para maximizar su gestión son el resultado de las decisiones tomadas por el tallador para determinar cuál de los dos sistemas es más pertinente en cada momento.

6.6. Font del Ros y las facies de fortuna

Es relevante combinar dos esferas como son el tecno-complejo y nivel/ocupación (*assamblage*), para analizar las singularidades técnicas de estos conjuntos. Se ha sugerido que el impacto de unas nuevas condiciones ambientales explicaría el proceso de degradación cultural identificada en varios yacimientos post-glaciales del Rousillon/Languedoc y la vertiente surpirenaica (Barbaza *et al.*, 1984; Garcia-Argüelles *et al.*, 2005). El atípismo o atavismo atribuido a estos yacimientos, entre los cuales se incluye Font del Ros, se sustenta en un debate articulado en principios de orden taxonómico y tipológico sobre los que no se incide en este trabajo. Pese a ello, los datos que presentamos invitan a reflexionar sobre la interpretación de estos conjuntos, y advierten de la necesidad de ampliar las categorías de análisis para evaluar elementos como los *ground stone tools* o la talla bipolar.

La unidad SG es clave para visualizar la relevancia de la simplificación de los procesos técnicos, que permite la continuidad de una tradición social de forma discontinua durante no menos de 1800 años. Las gentes que se instalan en ese lugar convierten este asentamiento en un sitio privilegiado para analizar si el impacto ambiental afecta a la esfera socio-organizativa de estos grupos. Los cantos utilizados evidencian adaptaciones y transformaciones que se relacionan con el procesado de nuevos recursos generalizados durante el Holoceno. Al mismo tiempo, las referencias sobre el uso de la talla bipolar empiezan a ser mencionadas en el continente europeo a lo largo del Mesolítico (ver referencias en Roda Gilabert *et al.*, 2015). El escenario que describimos en Font del Ros puede constituir un modelo común para yacimientos de estas cronologías.

El escaso interés que han despertado estos materiales se puede relacionar con las dificultades de analizar los artefactos. Aunque la mención de instrumentos macrolíticos y cantos con huellas de uso es recurrente (ver referencias en Roda-Gilabert *et al.*, 2013), en pocas ocasiones se analizan de manera detallada. Sin embargo, los cantos con cúpula (*pittedstones*) son mencionados en los yacimientos postglaciares con cronologías similares a lo largo del valle del Ebro y Prepirineo. Un hecho que sugiere que este tipo de artefacto unido a la presencia de cantos utilizados, a nuestro entender es un rasgo distintivo de estos grupos culturales. Del mismo modo, la relevancia de la talla bipolar que señalamos en la unidad SG no es un atavismo derivado de condiciones locales. Apostamos que en futuras revisiones la identificación de este tipo de sistemática en otros yacimientos, indicará que este método forma parte del sistema organizativo y que permite la explotación recurrente de los ecosistemas del Holoceno.

6.7. Perspectivas de futuro

De cara a avanzar en el estudio de las implicaciones que señalamos en esta tesis doctoral, proponemos dos ejes: continuar con el estudio de los materiales de Font del Ros, y paralelamente ampliar este enfoque a otros sitios de este marco cronocultural.

Font del Ros es un sitio de gran extensión al aire libre en el cual se registran niveles de ocupación mesolíticos y neolíticos. Esta singularidad permite plantear hipótesis relacionadas con las esferas organizativas y sociales, asociadas a dos formas de organización socio-subsistencial que se asumen como antagónicas: cazadores-recolectores vs. agropastores.

Durante la fase final de la elaboración de esta tesis se identificó un suelo de ocupación en la unidad N, con importantes paralelismos técnicos en los métodos de talla. Esta similitud técnica entre Mesolítico y Neolítico antiguo señala la continuidad en aspectos claves, como la gestión de materias primas de origen local con parámetros similares de miniaturización del instrumental en el que dominan raederas y denticulados. La recuperación de un peque¶o grupo de microlitos o de una lámina de sílex alóctono, señalan que durante esta fase el yacimiento estuvo integrado dentro de las redes de intercambio de materiales que operaban en esta zona durante el Neolítico antiguo. Paralelamente, molinos y cereales cultivados, ausentes durante el Mesol²tico, est§n presentes en esta fase. Llaman la atenci· n cambios en las dimensiones y caracter²sticas del instrumental de molienda, que con su aumento de tama¶o denotan modificaciones en la organizaci· n de las actividades y en las formas de vida de los grupos del Neol²tico (Roda Gilabert et al., en prensa).

Analizar de forma detallada las implicaciones de estas divergencias, puede configurar una línea de investigación principal. Especialmente si consideramos la persistencia de elementos técnicos entre ambos periodos, hecho que nuestro equipo de investigación ya ha señalado (Pallares *et al.*, 1997).Visualizar cómo se incorporaron estas nuevas técnicas y tecnologías, transformando de manera irreversible el modo de vida de las gentes que poblaron este valle del Prepirineo Oriental, se presenta como un elemento clave a la hora de discutir el proceso de Neolitización.

La comparación de los resultados de que se disponen para las ocupaciones mesolíticas con las del Neolítico, permitirá discutir la extensión de esas singularidades que afectan a la caracterización del cambio predador/campesino en el norte de la península ibérica. Los datos de los que disponemos señalan que varias de las tendencias detectadas en el mesolítico continúan a lo largo del Neolítico antiguo. Es decir, este yacimiento juega un papel relevante en la discusión sobre las causas relacionadas con la desaparición del modo de vida predador y la irrupción del modelo productor.

La incorporación de datos de otros yacimientos próximos como Balma Guilanyà (Solsona, Lleida) (Martínez-Moreno *et al.*, 2006b; Casanova *et al.*, 2008) es relevante, ya que presentan similitudes con Font del Ros. La posibilidad de estudiar las actividades en las que está involucrado el instrumental macrolítico desde el final del Tardiglaciar hasta el Holoceno medio, es una fase crítica antes de la irrupción de las comunidades agrícolas.

Por otra parte, se planea revisar artefactos de otros yacimientos del Prepirineo y Valle del Ebro que, como hemos señalado, se mencionan en numerosas publicaciones. Esta catalogación permitirá realizar un tránsito temporal y espacial, desde el Paleolítico superior final al Neolítico antiguo en el tercio noroccidental de la Península Ibérica, y permitirá definir trayectorias técnicas, culturales y sociales con las que testar las hipótesis e interpretaciones que se han propuesto a lo largo de esta Tesis Doctoral.

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