The Use of Spatial Taphonomy for Interpreting Pleistocene Palimpsests: An Interdisciplinary Approach to the Châtelperronian and Carnivore Occupations at Cassenade (Dordogne, France)

EMMANUEL DISCAMPS
CNRS UMR5608 TRACES, University of Toulouse Jean Jaures, Toulouse 31058, FRANCE; ediscamps@gmail.com

FRANÇOIS BACHELLERIE
Archéologie Alsace, 11 Rue Jean-François Champollion, 67600 Sélestat; and, UMR5199 PACEA, B8, Allée Geoffrey Saint Hillaire, CS 50023, 33615 Pessac, FRANCE; bachellerie.francois@gmail.com

MICKAËL BAILLET
UMR5199 PACEA, B8, Allée Geoffrey Saint Hillaire, CS 50023, 33615 Pessac, FRANCE; micka.baillet@gmail.com

LUCA SITZIA
Universidad de Tarapacá, Facultad de Ciencias Sociales y Jurídicas, Arica, CHILE; lcsitzia@gmail.com

submitted: 1 November 2018; accepted 22 April 2019

ABSTRACT

One of the challenges commonly faced by Paleolithic archaeologists is disentangling archaeological layers in caves and rockshelters that often reflect complex palimpsests. Layers defined in the field are primarily used to distinguish occupations, yet their actual nature and integrity are rarely tested or justified after excavation. Distinct occupations may become mixed together in a single field layer either following depositional and post-depositional processes (taphonomic admixture) or difficulties in reliably separating assemblages in the field (analytical lumping). Here we explore how three-dimensional spatial analyses combined with geoarchaeological and taphonomical data can be used to interpret Pleistocene palimpsests using the example of the Châtelperronian and carnivore occupations of Cassenade, a recently excavated site in Dordogne (France). We combine field observations with extensive post-excavation analysis (using spatial, geoarchaeological, lithic and faunal data, lithic particle-size distributions, fabrics, refits, and Bayesian modelling of radiocarbon dates) in order to (re)define assemblage boundaries and test their integrity. This approach resulted in a more comprehensive understanding of Cassenade sequence, including 1) increased stratigraphic resolution compared to initial field layer attributions; 2) evidence of how carnivore and human activity could be mixed by natural processes; 3) more reliable interpretations weighed against data from site formation processes; and, 4) a clearer understanding of the nature of the Châtelperronian occupations at Cassenade (short stop-overs with a distinct site function?) and related mobility systems. Cassenade provides yet another example of the necessity of critically revising field layers after excavation through three-dimensional spatial and taphonomic analyses.

INTRODUCTION

Pleistocene deposits in caves and other karstic systems often yield lithic and faunal remains reflecting complex 'cumulative palimpsests' (sensu Bailey 2007). One of the primary challenges commonly faced by Paleolithic archaeologists is deciphering such palimpsests, distinguishing the different hominid occupations, and identifying the input of additional accumulation agents (e.g., carnivore activity). These issues are of key importance for the archaeological record of the Châtelperronian, a techno-complex dated to around 43–40 ka cal. BP that marks the onset of the Upper Paleolithic in France and northern Spain, and roughly coincides with the extinction of Neanderthals (Bachellerie 2011; Bordes and Teyssandier 2011; Connet 2002; Pelegrin 1995; Roussel 2011; Roussel et al. 2016; Soressi and Roussel 2014).

Recent work highlighted frequent mixing of Châtelperronian and Middle Palaeolithic material in several caves (e.g., Bachellerie 2011; Bar-Yosef and Bordes 2010; Bordes 2003; Gravina et al. 2018; Rigaud 1996; Roussel 2011; Zilhao and d'Errico 1999), potentially linked to important climatic changes that induced frequent post-depositional disturbances (Bertran et al. 2010; Laville 1969; Mallol et al. 2012). Moreover, this period is also characterized by an abundance of large carnivores, and Châtelperronian

  ISSN 1545-0031
doi:10.4207/PA.2019.ART136

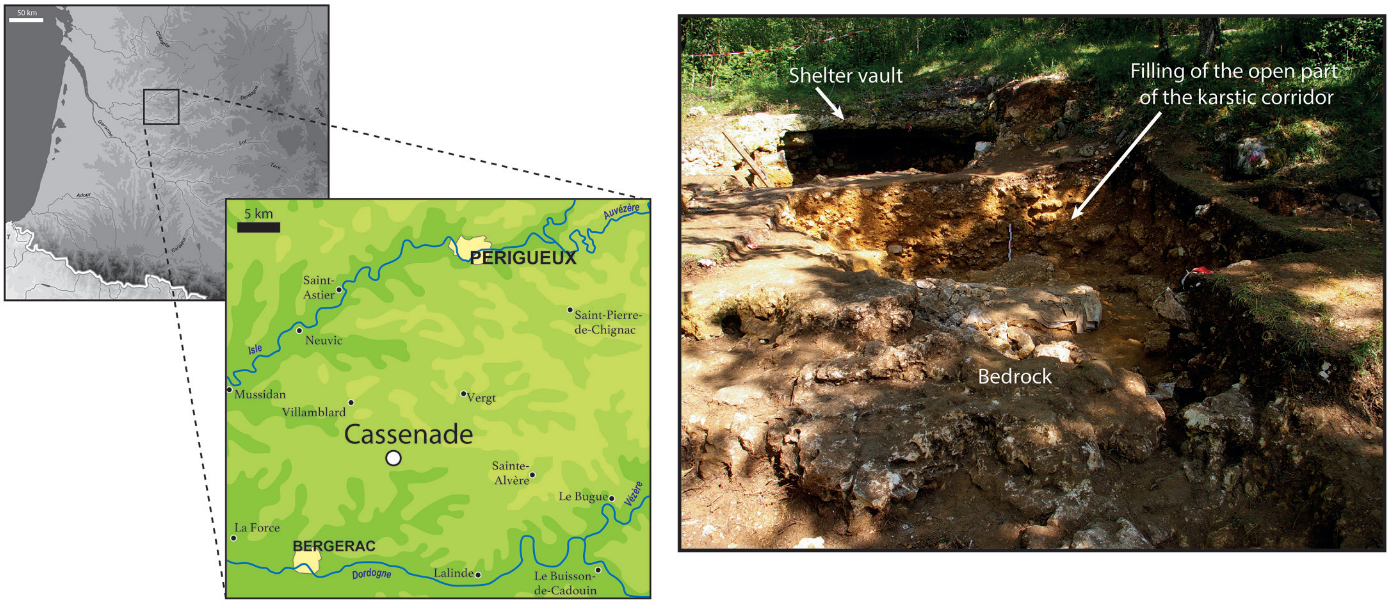


Figure 1. Site location (left) and general view from the north during excavations (right).

occupations are often found mixed with cave hyena occupations (Beauval and Morin 2010; Discamps 2011, 2014; Rios-Garaizar et al. 2012). Châtelperronian sites therefore present multiple challenges to Paleolithic archaeologists, added to the fact that they remain rare. Here we report on our work at the recently excavated Châtelperronian site of Cassenade, in the Dordogne area of southwestern France.

At Cassenade, Châtelperronian and carnivore occupations were found mixed within a single lithostratigraphic field layer. In this contribution, we explore how an interdisciplinary taphonomic approach that includes 3D spatial data can provide important insights for our understanding of palimpsests. We combine data from geoarchaeological, lithic, faunal, and spatial analyses as well as radiocarbon dates in order to:

1. explore variability in the archaeological and paleontological content of the field layer and identify the contribution of the different agents to the assemblage;
2. analyze this variability spatially, criteria by criteria, both horizontally and vertically in order to test if distinctive spatial patterns or clusters exist and evaluate possible effects of analytical lumping; and,
3. integrate data concerning site formation processes (depositional and post-depositional) using common but rarely combined analytical tools (stratigraphy, lithic and faunal refits, artifact surface alterations, lithic particle-size, and fabric analyses) to explore the potential taphonomic admixture of different occupations.

Finally, we reflect on the use of field layers and spatial data in Paleolithic archaeology, concluding that integrating multiple analytical tools, although time consuming and hence not routinely attempted for Paleolithic sites, can be extremely informative and crucially impact the interpretation of palimpsests. At Cassenade, the combination of field observations with extensive post-excavation analyses in an interdisciplinary taphonomic approach produces a better understanding of the site taphonomy and the occupational history of the site by humans and carnivores.

MATERIAL AND METHODS

SITE CONTEXT AND HISTORY

Cassenade is located in the municipality of Saint-Martin-des-Combes (Dordogne, France, Figure 1), on the left flank of an east-west oriented valley cut by the small Saint-Martin brook (a tributary of the Caudeau stream). The south-facing site is located about 70 meters above the valley floor, halfway up a Campanian limestone hillside. It corresponds to a karstic corridor whose distal part (closest to the slope) functions as an open karstic system following the collapse of the shelter vault (see Figure 1).

The site was discovered in the early 1970s by Michel Besse during speleological surveys. He subsequently explored part of the site (about 6m^2) over a depth of approximately 3 meters (Figure 2), recovering numerous faunal remains representing both human and carnivore occupations, as well as lithic artifacts attributable to the Mousterian and Châtelperronian. Despite some field observations and section drawings, most of the data and material collected by M. Besse are difficult to interpret, as the exact stratigraphic provenience of artifacts is often unreliable.

Recent excavations in 2012 and 2013 directed by one of us (ED) were aimed at better documenting the Châtelperronian occupations through a 16m^2 excavation of the uppermost part of the deposits located to the south of the previously excavated area (see Figure 2). Excavation was carried out using ¼m^2 squares and spits of typically 2cm to 5cm.

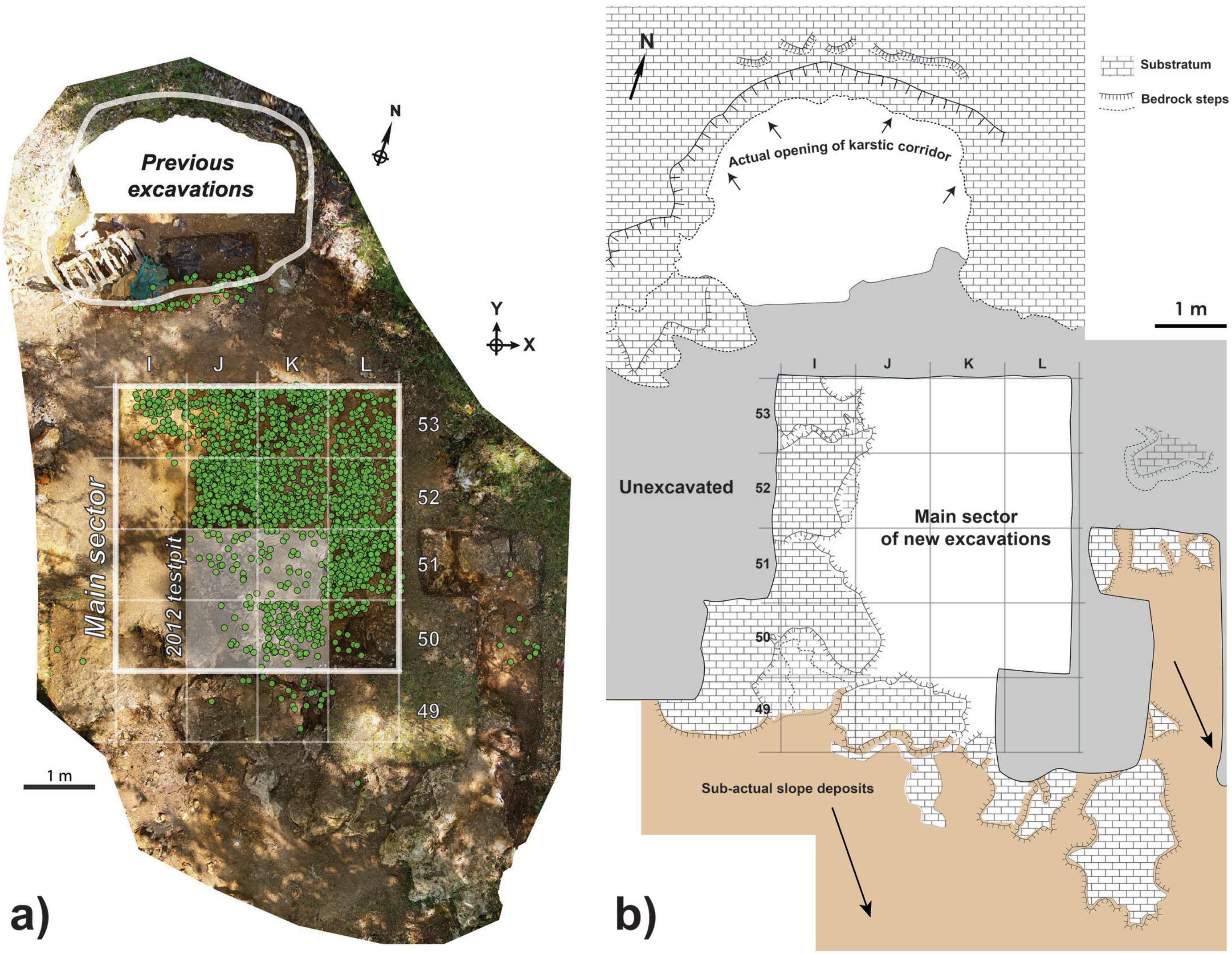


Figure 2. Top views of Cassenade with a) the extension of previous and new excavations (green circles: artifacts plotted in 2012 and 2013, background: orthophotography produced by photogrammetry, white rectangle: main sector, shaded grey: 2012 testpit); and, b) synthetic geomorphological map (opening of the karstic corridor, exposed bedrock, and slope deposits).

All lithic artifacts and faunal fragments larger than 3cm (in 2012) or 1cm (in 2013) were plotted in three dimensions using a total station. The size cut-off for plotted artifacts was reduced in 2013 in order to allow even the smallest remains (e.g., digested bones) to be integrated in the spatial analysis. The database of piece-plotted material (coordinates for each artifact) is provided in the Supplementary Information 2. Artifact orientation and dip (i.e., fabric measurements) were recorded for objects (n=173) that were twice as long as they were wide using a compass and an inclinometer (see Supplementary Information 2). Sediments were water-sieved with 2mm and 4mm meshes. Extensive photographic coverage combined with ground-control points (plotted with the total station) allowed for photogrammetric reconstructions of the excavated surfaces.

Here we focus on the main sector of the site (see Figure 2), where only one lithostratigraphic layer (Layer 2) could be identified during excavations (the overlying layer 1 was only preserved in another sector of the site). This layer corresponds to the upper-part of a collapsed and infilled karstic corridor whose walls were exposed during excavation (see Figures 1 and 2). Despite considerable effort, no evident changes in sediment texture, color, characteristics, or content were identifiable in the field, meaning that only one layer was defined throughout excavations in the main sector. In total, 2,003 faunal remains, 212 lithic artifacts, 125 coprolite fragments, and 9 charcoal fragments from Layer 2 were piece-plotted.

GEOLOGICAL CONTEXT

Field observations of the main landforms allowed a site-scale geomorphological map to be built. Stratigraphic sections left by the previous and new excavations were described in order to identify sedimentary processes. Sediments were sampled (n=6) for grain-size analysis using a Horiba LA-950 laser particle size analyzer at the PACEA laboratory of the University of Bordeaux. Three large thin sections from Layer 2 were prepared from undisturbed blocks of sediment vacuum-impregnated with a polyester resin following the protocol described by Guilloré (1980). The description of thin sections follows Stoops (2003).

LITHIC ANALYSIS

In total, 227 lithic elements were analyzed for this study (surface alterations, techno-typology, raw material provenience, and use wear). Lithic surface states and fractures were observed macroscopically and, when necessary, using a stereomicroscope. The overall preservation of the collection was assessed prior to use-wear analysis in order to identify mechanical damage typically caused by post-depositional processes (e.g., Chu 2016; Claud and Bertran 2010; Plisson 1985; Prost 1989; Vallin et al. 2013). Use-wear visible at low magnifications differs from post-depositional edge modifications and varies depending on the hardness of the material in contact and the motion employed (e.g., Odell 1981; Odell and Odell-Vereecken 1980; Plisson 1985; Tringham et al. 1974). Microscopic use-wear traces identified with a metallographic microscope provide more precise information concerning their exact nature (e.g., Plisson 1985; Semenov 1964). Patina, surface alterations, and edge damage were coded in a database for each artifact alongside length, width, and thickness.

Lithic artifacts were analyzed following a techno-typological approach aimed at describing the different *chaînes opératoires* present at the site and identifying the main intended endproducts in terms of both blank morphology and retouched tools (Inizan et al. 1995; Pelegrin 1995; Pelegrin et al. 1988; Tixier 1978). Refits were used to test the coherence of the identified *chaînes opératoires*. The chrono-cultural attribution of the Layer 2 material was based on comparisons with typo-technological data from other sites (Bachellerie 2011; Connet 2002; Pelegrin 1995; Roussel 2011).

Raw material type (petrographic characterization) and origin (location of currently-known outcrops in the region) was also identified for each lithic artifact in order to explore the acquisition, transport, and use of mineral resources within a specific geographical area (Perlès 1991) and utimately discuss mobility strategies.

Most of the lithic artifacts (92%, n=208) were observed for use wear traces. Low magnification observations with a binocular stereomicroscope to infer tool function from edge damage (e.g., Odell 1981; Odell and Odell-Vereeken 1980; Tringham et al. 1974) was combined with the use of a metallographic microscope for a little more than half of the artifacts (n= 114) to explore the surface state preservation and identify microscopic evidence of use (e.g., Keeley 1980; Plisson 1985; Semenov 1964).

FAUNAL ANALYSIS

Both the piece-plotted faunal material (n=1,973) and remains from the sieves (n=362) were analyzed. Pieces were identified as precisely as possible to species, anatomical part, and portion. Unidentified specimens were classified by mammal size classes following Discamps (2011: 95). Anthropic and carnivore modifications, as well as several other taphonomic alterations (root etching, concretions, abrasion, dissolution, weathering, manganese deposits), were recorded for all plotted remains as well as for a subset of sieve remains (total n=2,058). Cortical surfaces were observed under low-angled light using a 20x hand lens and a stereomicroscope when necessary. The preservation, or "readability," of cortical surfaces also was recorded (i.e., percentage of well-preserved cortical surface according to four classes; 0–25%, 25–50%, 50–75% and 75–100%), as well as the general macroscopic aspect of bones (i.e., hue/patina).

SPATIAL PROJECTIONS AND REFITTING

Data acquired throughout this study was systematically explored using QGIS, ArcGIS, and DataDesk software packages. Spatial projections of material in all three planes (X, Y, and Z) were carried out using transects of variable "width/thickness" to detect spatial variability across the site. The distribution and orientation of refits also was explored for both lithic and faunal elements in order to test the integrity of the analyzed assemblages. This process included systematic testing for conjoins among all piece-plotted flint artifacts and all faunal remains identified to species, complemented by the (unsystematic) inclusion of un-plotted and unidentifiable fragments.

The base geometry of assemblages was inferred using the methodology described by Lenoble (2005): 1) the excavated surface was divided in 25cm x 25cm squares; 2) the altitude of the lowest plotted artifact was recorded for each square; and, 3) contour lines were interpolated using these values. Once the difference between the lowest and highest object in each 25cm side-length square was calculated, a similar procedure was used to evaluate the thickness of the assemblages. The value obtained for each square was then used to construct an interpolation map using the ArcGis 9.3 software. Ordinary kriging was employed as the interpolation method.

FABRIC ANALYSIS

Fabric analysis was carried out according to the methodology of Lenoble and Bertran (2004). In the main sector, the orientation of 114 bones and 27 lithics were measured with a compass and an inclinometer during excavation (see Supplementary Information 2). Eigenvalues were calculated with the Stereonet software (Allmendinger et al. 2012), with the isotropy (SI=E3/E1) and elongation indexes (EL=1–(E2/E1)) calculated following Benn (1994). The intensity of the preferred orientation (Vector Magnitude L) and the p-value of the Rayleigh test, which test whether the preferred orientation is significant, were calculated using the method proposed by Curray (1956). Confidence intervals were computed on ternary diagrams using the code provided by McPherron on GitHub (https://github.com/surf3s/Orientations). However, considering the relatively small sample of measurements available from Cassenade, the analytical protocol proposed by McPherron (2018) to investigate spatial variability in artifact orientations could not be used.

LITHIC PARTICLE-SIZE ANALYSIS

Particle-size analysis of lithic artifacts follows the methodology outlined by Bertran et al. (2012) and concerned all squares for the coarse fraction (plotted finds and sieve mesh of 4mm) and only two squares (K52 and L53) for the fine fraction (sieve mesh of 2mm). All lithic artifacts were manually passed through a sieve column comprising 2mm, 4mm, 5mm, 10mm, 20mm, 31.5mm, and 50 mm meshes. A total of 679 lithics were measured for the fraction above 4mm (plotted pieces and 4mm sieve residues), in addition to 102 from the 2mm sieve residues (Squares K52 and L53). Particle-size distributions were compared to experimental results available in Lenoble (2005) and Bertran et al. (2012), and plotted on ternary diagrams to test for size sorting due to site formation processes (Bertran et al. 2012; Lenoble 2005). Confidence intervals were computed on ternary diagrams using the Triangle program (Weaver et al. 2011).

RADIOCARBON DATING

Ten samples were selected for radiocarbon dating. Specific elements were targeted in order to date either hominid (bones with cut-marks, charcoal fragments) or carnivore (bear and hyena teeth) occupations. Nine samples come from Layer 2 of the new excavations, and one from previous excavations that was found below Layer 2 (associated with Mousterian artifacts). All measurements obtained on faunal remains are ultrafiltrated dates. Dates were calibrated using IntCal13 atmospheric curve (Reimer et al. 2013) and OxCal 4.3.2 software (Bronk Ramsey 2009). Bayesian modelling was performed with OxCal to test the chronological ordering of Cassenade occupations by hominids and carnivores (using the Sequence, Phase, and Order functions, and applying a general outlier detection method, cf. Bronk Ramsey 2009b). The code for these models is provided in the Supplementary Data 3.

RESULTS

LITHOSTRATIGRAPHY

The lithostratigraphic layer excavated in the main sector (Layer 2) is a matrix-supported diamicton with a crude stratification. Matrix is clayey-sandy silt with limestone granules (Figure 3b), and fine to medium roots are common. The crude stratification observed in the frontal section (Figure 3a) corresponds to discontinuous wavy nonparallel strata of subrounded limestone pebbles, possibly delimiting lenticular bodies of clayey-sandy silt. This bedding also was observed in the frontal profile of the previously excavated area. The lower part of Layer 2 consists of pluridecimetric limestone slabs (see Figure 3a) that dip slightly toward the N-NE (dip angle: 10°). Thin sections show a channel to granular microstructure which is related to bioturbation by the activity of mesofauna and roots (Kooistra and Pulleman 2010).

The diamictic facies of Layer 2 is typically observed in slope deposits and can result from several sedimentary processes such as solifluction, debris flow, or surface runoff (Bertran 2004). The general organization of the deposits combined with the absence of sedimentary structures typically observed in solifluction deposits or debris flows argue in favor of surface runoff and debris fall from the walls of the shelter as the primary sedimentary processes. We interpret the observed pebble strata as erosion pavements resulting from sheet and rill erosion due to surface runoff (Ruhe 1959; Shaw 1929). Similar examples of erosion pavements have been described in other regional Paleolithic rock-shelters (Lenoble 2005).

LITHIC INDUSTRY

Lithic Taphonomy

The Cassenade lithic assemblage is, for the most part, heavily patinated and desilicified ("chalky white patina" as described by Hurst and Kelly [1961]). Although ridges appear fresh to the naked eye and touch, microscopic observations highlight slight smoothing and, in some extreme cases, localized corrosion and erosion, which likely removed any microscopic use-wear traces (micro-flaking, micro-polishes, micro-striations). This is particularly the case for softer, less well-developed polishes such as those linked to cutting meat. On the other hand, edges are generally fresh and only occasionally exhibit localized damage, meaning that macroscopic traces of use (fractures, scarring, and rounding) are preserved.

A little more than a third of the lithics (34%) are complete, and refits are frequent (about 20% of the lithics, see Refits in Spatial and Refitting Analyses below). Most fractures occurred during knapping, and there is no evidence of any major natural mechanical damage (e.g., argiliturbation or cryoturbation) or breaks resulting from rockfall or post-depositional processes (e.g., gelifraction).

Lithic Techno-Typolology

Technological analysis highlights a predominance of blade production, with 53% of the assemblage attributable to blade reduction sequences (blades, crested blades, core tablets, cf. Table 1). The majority of the remaining flakes retain some cortex (57%) and probably reflect the first phases of shaping-out blocks. There is no evidence of an independent flake production. The blade c*haîne opératoire* is geared towards the production of relatively short (35mm to 95mm), wide (15mm to 35mm) and thin (4mm to 9mm) blades with straight or slightly arched profiles (Figure 4: 4 to 6). These blades are produced from the wide surface of blocks or from the ventral surface of large flakes (Figure 4: 1, 3; Figure 5: 3). The presence of opposed scars on the dorsal surface on 30% (n=19) of laminar products demonstrate the recurrent use of a second, opposed striking platform (Figure 4: 1, 2; Figure 5: 1, 2, 7). Centered and non-cortical blades from the production phase were detached by direct percussion with a soft-stone hammer and a tangential blow, while elements linked to shaping and maintenance phases were detached by hard-hammer percussion (Roussel et al. 2009; Pelegrin 2000).

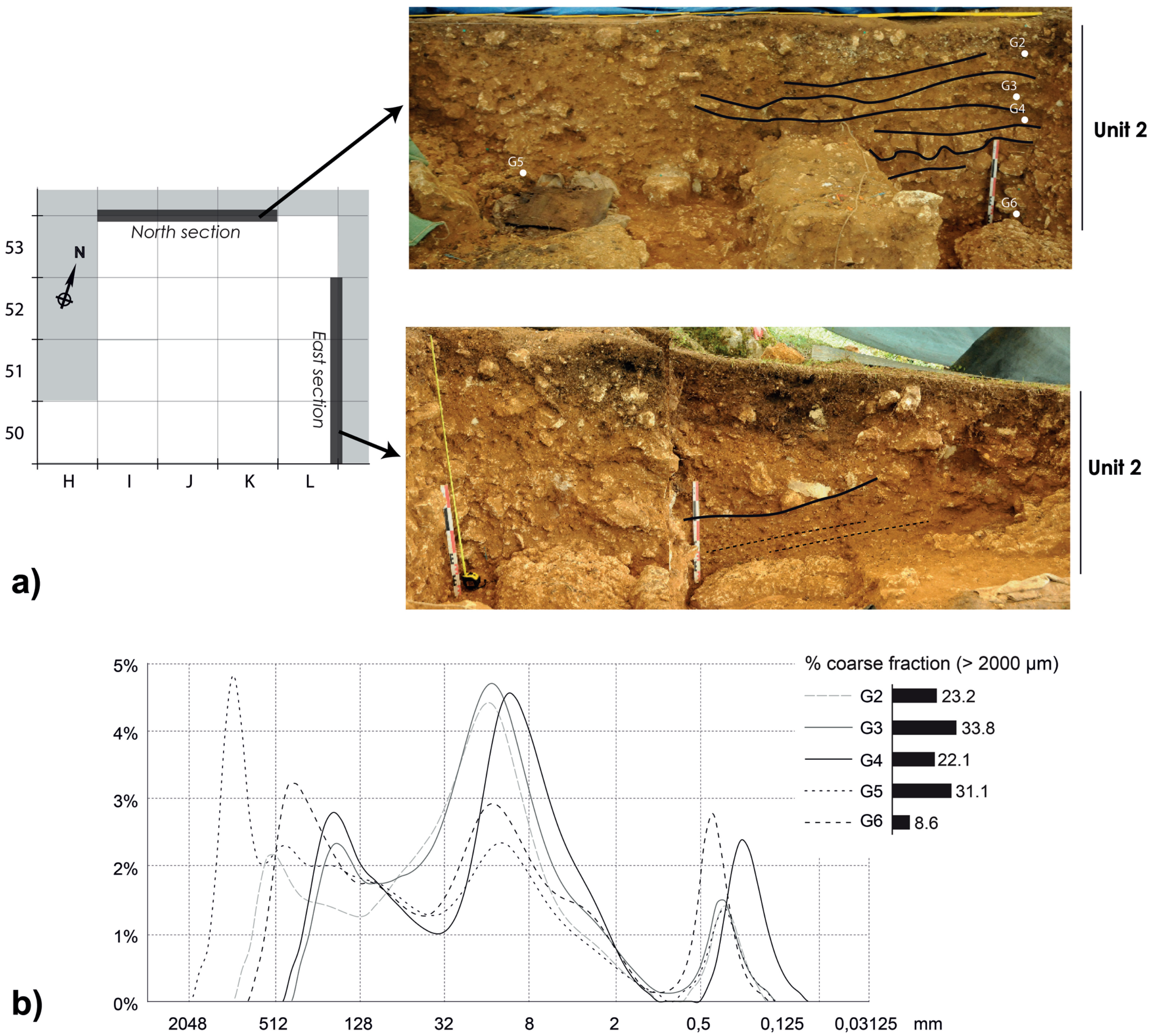


Figure 3. a) Stratigraphic sections showing Layer 2 (an A horizon developed on top of this layer). Black lines highlight the crude stratification; and, b) Particle-size distribution and abundance of coarse fraction (upper right) of samples from Layer 2 (see upper photo in a) for sample location).

Almost all of the 18 retouched tools are made on blades (n=17, 94%, see Table 1). Châtelperronian points dominate (n=6, 33% of tools, see Figure 5: 1 to 5), followed by blades with continuous retouch (22%), backed blades (11%, see Figure 5: 8) and truncated blades (11%, see Figure 5: 6, 7). Châtelperronian points are made on small, straight to slightly arched, blade blanks that are also the most regular and technically invested blanks. The remaining retouched tools are all made on what appear to be more irregular 'second-choice' blanks of variable size and profiles. This techno-typological data is perfectly consistent with what has been documented from other Châtelperronian sites (Bachellerie 2011; Connet 2002; Pelegrin 1995; Roussel 2011).

Raw Material Economy

Almost all of the identified raw materials (see Table 1, Figure 6) can be found in the immediate surroundings of the site or within a radius of 5km (e.g., Bergeracois outcrops in the Forêt de Monclard, cf. Fernandez et al. 2012). Only one piece (a Châtelperronian point) can be securely tied to a more distant source of Santonian flint known as "Grain de Mil," which outcrops in the Jonzac region (Caux 2015; see Figure 6: 4) about 100km northwest of Cassenade. The near exclusive use of local flint associated with the transport of retouched tools and/or preformed cores over longer distances has been documented at numerous other Châtelperronian sites (Bachellerie 2011).

TABLE 1. TECHNOLOGICAL, TYPOLOGICAL, AND RAW MATERIAL DETERMINATIONS FOR THE CASSENADE LAYER 2 LITHIC ASSEMBLAGE.*

		Raw material							Total	%
		Bergeracois	Senonian	Tertiairy	Grain de Mil	Jasper-like Materials	"Porcelained"?	Undetermined		
Technological Determination	**Non-cortical flake**									
	complete	8	15	-	-	-	-	2	25	**12.5**
	fragment	13	28	-	-	-	-	13	54	**27.0**
	Cortical flake									
	complete	4	5	-	-	-	-	2	11	**5.5**
	fragment	-	3	-	-	-	-	1	4	**2.0**
	Laminar flake									
	complete	8	4	-	-	-	-	-	12	**6.0**
	fragment	4	1	-	-	-	-	2	7	**3.5**
	Retouched flake									
	complete	1	-	-	-	-	-	-	1	**0.5**
	Blade									
	complete	5	5	1	-	-	-	-	11	**5.5**
	fragment	42	14	1			1		58	**29.0**
	Bladelet									
	fragment	2	1	1	-	-	-	-	4	**2.0**
	Crested blade									
	complete	1	-	-	-	-	-	-	1	**0.5**
	Core tablet	4	1	-	-	-	-	-	5	**2.5**
	Core	1	-	-	-	-	-	-	1	**0.5**
	Tested block	1	-	-	-	-	-	-	1	**0.5**
	Shatter	3	5	-	-	1	-	5	14	**7.0**
Retouched Tools	**Châtelperronian point**									
	on blade	5	-	-	1	-	-	-	6	**3.0**
	Backed blade									
	on blade	1	1	-	-	-	-	-	2	**1.0**
	on laminar flake	-	1	-	-	-	-	-	1	**0.5**
	Continuous retouch on									
	on blade	2	2	-	-	-	-	-	4	**2.0**
	on bladelet	-	1	-	-	-	-	-	1	**0.5**
	Truncation									
	on blade	3	-	-	-	-	-	-	3	**1.5**
	Partially retouched									
	on blade	1	-	-	-	-	-	-	1	**0.5**
Total		**109**	**87**	**3**	**1**	**1**	**1**	**25**	**227**	

* Raw material could not be identified for 25 fragments due to their poor preservation.

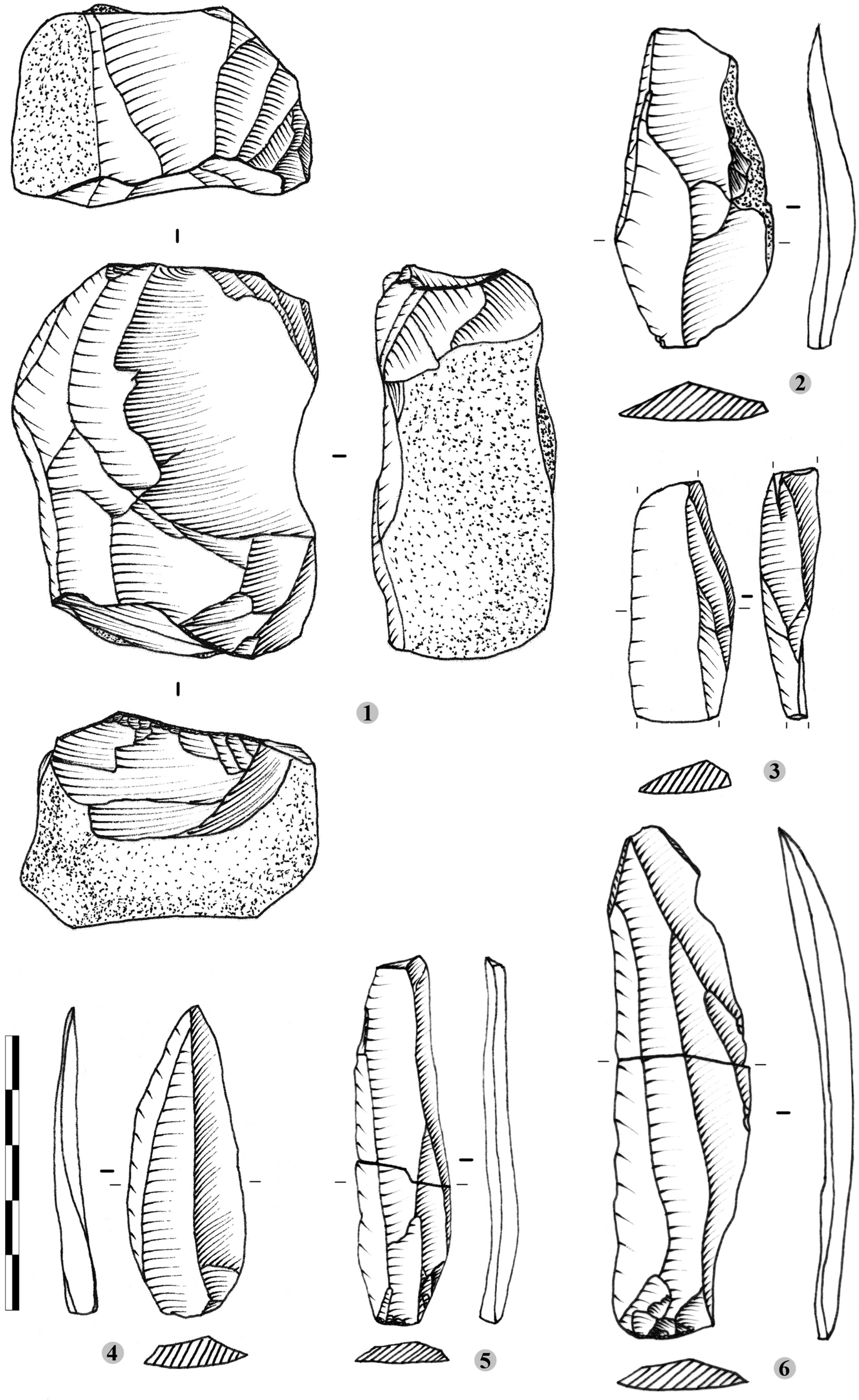


Figure 4. Blade component from Cassenade Layer 2 (1: blade core, 2: laminar flake, 3 to 6: blades). All are made on Bergeracois flint (drawings by FB).

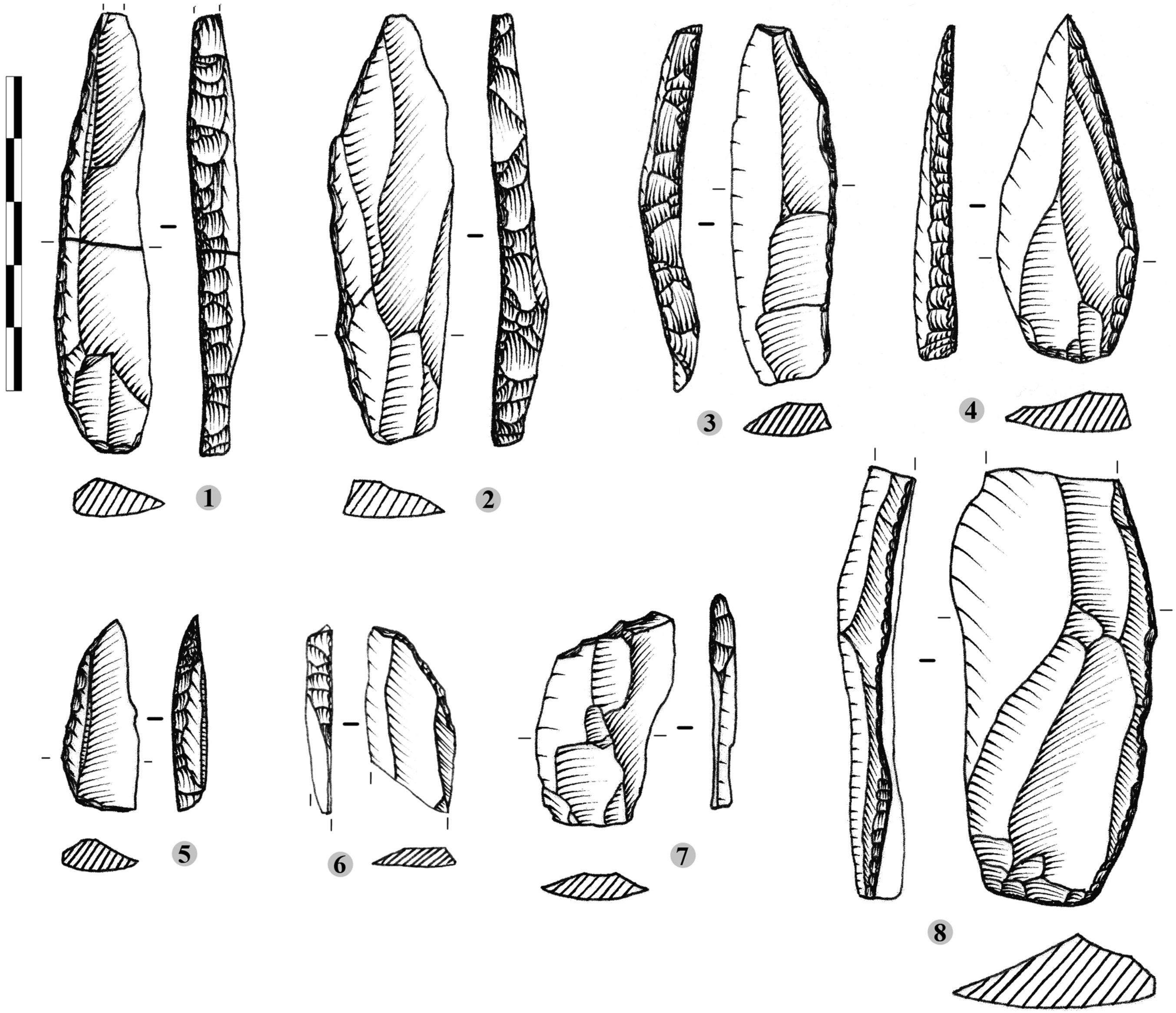


Figure 5. Retouched tools from Cassenade Layer 2 (1 to 5: Châtelperronian points, 6 and 7: truncated blades, 8: backed laminar flake). All but #3 (Grain de Mil flint) and #8 (Senonian flint) are made on Bergeracois flint (drawings by FB).

Cortical pieces are abundant (31% of the flakes have cortex on more than half of their dorsal surface), and local raw materials were apparently introduced in the form of "tested" blocks or large flakes that were knapped on-site. Conversely, there is a marked deficit in cores, even for the most common raw materials (only one in Bergeracois, none in Senonian while the entire *chaîne opératoire* is present for this raw material), pointing to a potential export of cores shaped on-site. Similarly, only a few blade fragments and one core maintenance blade were found in Tertiary flint, leaving open the possibility that this raw material was introduced in the form of preshaped cores, before being exported from the site.

Lithic Use-Wear Analysis

The sample analyzed for use-wear comprised 6 Châtelperronian points, 2 backed blades, 1 bladelet with direct retouch, 2 truncated blades, 4 retouched blades, 1 retouched flake, 70 unmodifed blades, 4 modified bladelets, 1 core, and 118 flakes. Only five pieces displayed macrotraces of use and none bore microtraces (cf. Lithic Taphonomy above). One blade exhibited traces on its distal edge consistent with a transverse action on a semi-hard material (scraping). One Châtelperronian point displayed a single distal fracture (Figure 7); two backed blades and one retouched blade exhibited the same traces both in the mesial and distal parts. These fractures are always complex with a bending or cone initiation, located on either the dorsal or ventral surfaces, and associated with multiple termination types (i.e., spin-off, feather, hinge, step). These fractures are diagnostic of projectile use, indicating these pieces to have potentially been abandoned after hunting and replaced on-

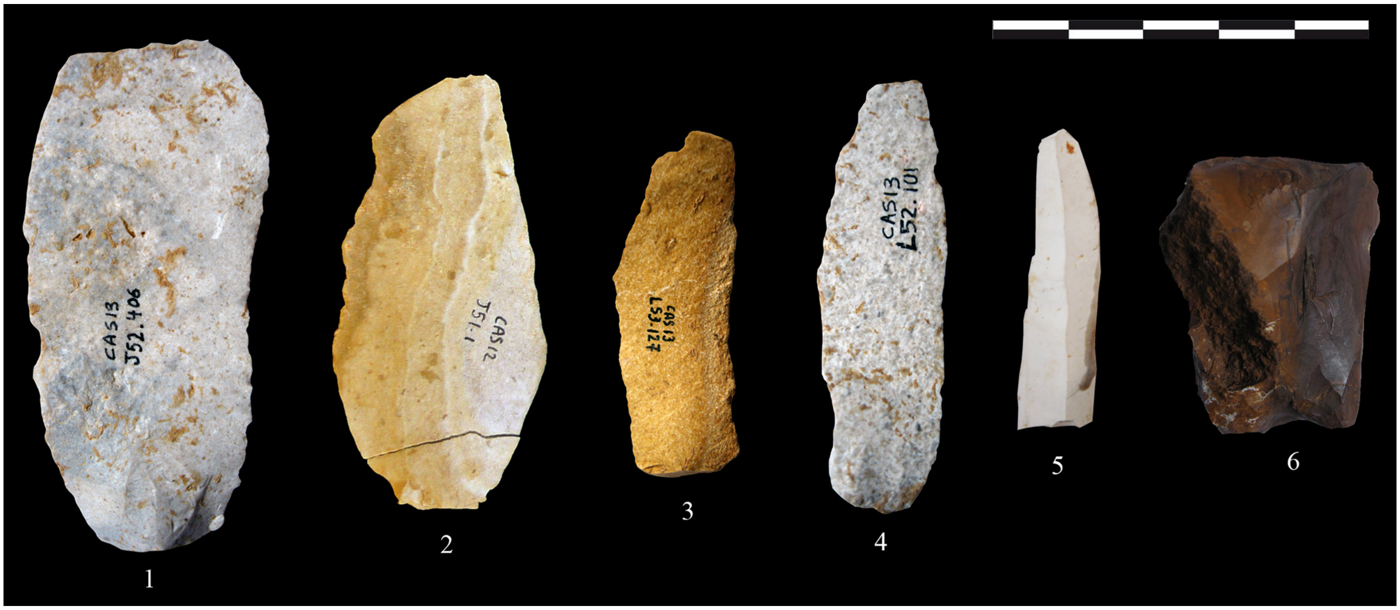


Figure 6. Raw materials from Cassenade (1: Maastrichtian Senonian flint, 2: Maastrichtian Bergeracois flint, 3: Tertiary flint, 4: Santonian "Grain de Mil" flint, 5: "Porcelained" flint, 6: argilite).

site.

FAUNAL REMAINS

Identified Species

More than 2,300 faunal remains from the main sector were collected and analyzed, of which 698 could be identified as large mammals (Table 2). About half of these remains belong to large herbivores, among which wild horse and large bovids are the most abundant (respectively 47% and 36% of the identified ungulates). This diverse faunal spectrum (10 herbivore species, including the extinct giant deer, woolly mammoth, and woolly rhinoceros) is typical of regional MIS 3 assemblages (Discamps and Royer 2017; Discamps et al. 2011). The other half of the macrofauna comprises carnivores, among which bear (68%) and cave hyena (25%) are the most prominent, with juvenile individuals being particularly abundant (68% of bear teeth are deciduous, 42% for cave hyena). All the bear remains that could be identified to species (based on criteria provided and summarized by Quiles 2003) correspond to the cave bear *Ursus spelaeus*.

In addition to bones, antler, and teeth, numerous coprolites were recovered from Cassenade Layer 2. More than a hundred (n=125) were sufficiently large to be plotted during excavations, and thousands of smaller millimetric to centimetric fragments were recovered during sieving. The best-preserved specimens all display the same morphology, typical of cave hyena coprolites (Chame 2003; Diedrich 2012; Larkin et al. 2000)—large, rounded, heavily mineralized pellets, sometimes containing small fragments of digested bone, with circular depression at their base.

Fragmentation

The faunal assemblage is heavily fragmented; excluding teeth, only 2% of the remains are complete and consist of phalanges and short bones attributable primarily to bear (64%). Of all diagnostic long bone fractures, 88% correspond to green-bone breaks. About 5% of bones present notches, whose origin (carnivore or anthropic) could not be identified, except for one case of an impact notch associated with percussion marks (anthropic).

Surface Modifications

Taphonomic alterations of bone cortical surfaces are abundant at Cassenade—chemical alteration (72% of the analyzed remains), manganese deposits (60.5%), and root marks (59%) are particularly frequent. As a consequence, cortical surfaces are relatively poorly preserved—67% of the observed bones have less than a quarter of their cortical surface well preserved. This percentage is comparable when only bones longer than 3cm are considered (58%), highlighting the overall poor preservation of cortical surfaces at Cassenade. Only 17% (n=116) of the bones have cortical surfaces that can be considered relatively well preserved (more than three-quarters of well-preserved cortical surface). This generally poor preservation, combined with relatively frequent linear marks that can clearly be attributed to trampling (19% of the remains), makes the identification of human activities in the form of cut or percussion marks particularly challenging. Consequently, cut-marks could be securely identified on only 3% of bones longer than 3cm (n=22), which probably underestimates the actual number of cut-marked bones prior to burial. In comparison, evidence of carnivore activities is more abundant, in the form of gnawed bones (7%) and heavily chemically altered bones (38%) resembling digested bones (i.e., bones with corroded surfaces, perforations, and/or slimmed edges, cf. d'Errico and Villa 1997). Three piece-plotted bones

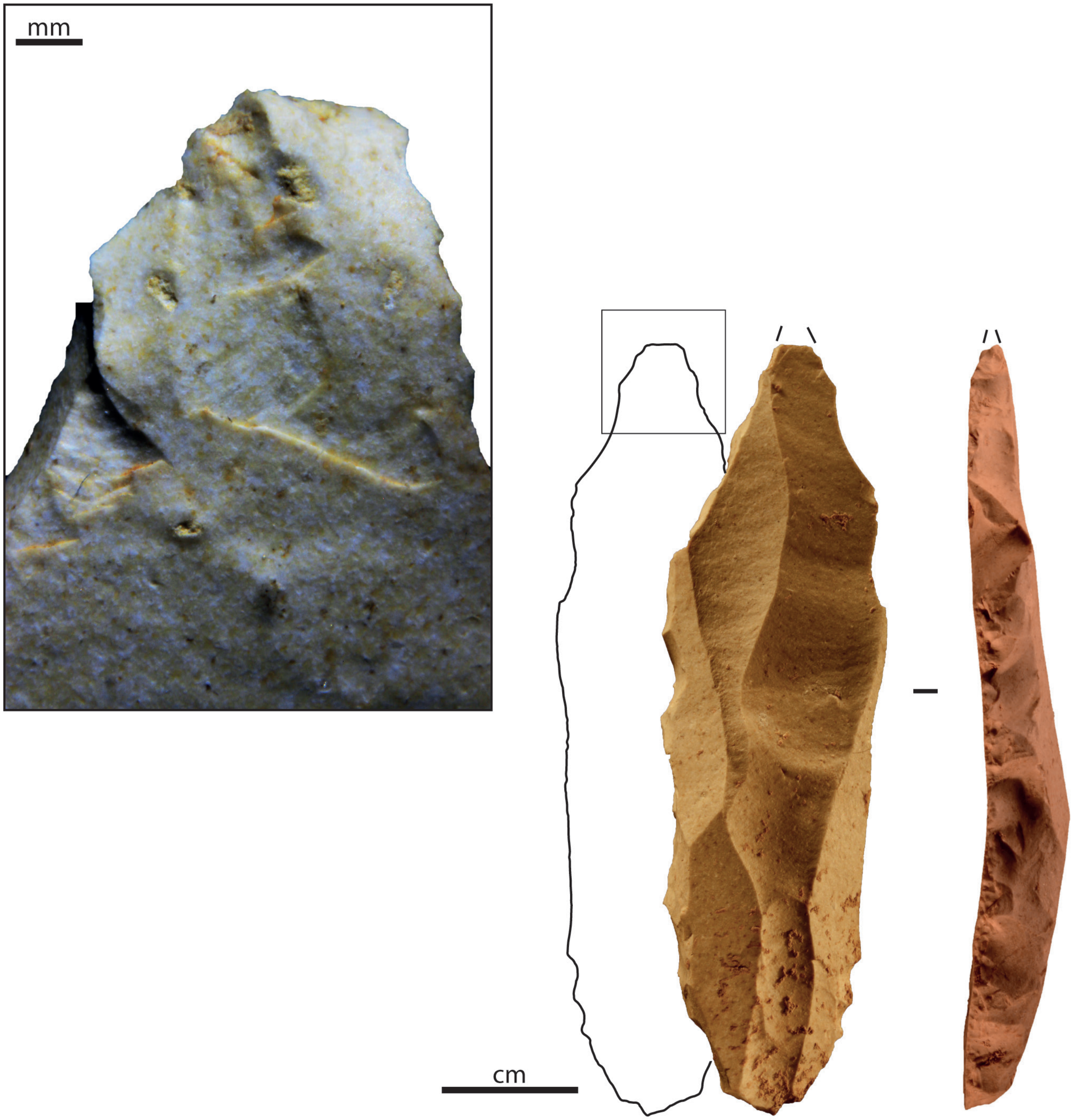


Figure 7. Example of a Châtelperronian point from Cassenade with a diagnostic distal impact fracture.

show evidence of combustion, and some burnt bone fragments were also found in sieve residues.

Two bones have both carnivore and anthropic marks on their surfaces, however, these traces do not overlap, making it impossible to discern the chronology of the access to bones by the two agents. Human action was identified on remains of horse, large bovids, and reindeer, while carnivore damage was evident on a larger suite of species (red deer, horse, large bovids, cave hyena, reindeer, rhinoceros, and fox).

SPATIAL AND REFITTING ANALYSES

Projections

If the spatial distribution of occupation indices show no particular horizontal clustering, distinct features are observable vertically. Detailed frontal (XZ) and sagittal (YZ) projections in 50cm slices are provided in Supplement 1, while only overall projections of material recovered from the entire excavated surface are provided in Figure 8. The most important observations are the following:

TABLE 2. CASSENADE FAUNAL ASSOCIATIONS FOR THE OVERALL LAYER 2 ASSEMBLAGE AND THOSE IDENTIFIED FOLLOWING THE SPATIAL ANALYSIS (lower and upper part, cf. Spatial and Refitting Analyses section).

Taxon	Scientific Name	Main Sector (all*)	Lower Part	Upper Part
Large bovid	Bovinae	117	32	82
Red deer	*Cervus elaphus*	8	2	6
Wild horse	*Equus ferus*	150	31	119
Roe deer	*Capreolus capreolus*	1	-	1
Wild ass	*Equus hydruntinus*	5	-	5
Woolly mammoth	*Mammuthus primigenius*	2	-	2
Giant deer	*Megaloceros giganteus*	3	1	2
Reindeer	*Rangifer tarandus*	17	6	11
Woolly rhinoceros	*Coelodonta antiquitatis*	14	5	9
Wild boar	*Sus scrofa*	3	3	-
Total Ungulates	**-**	**320**	**80**	**237**
Wolf	*Canis lupus*	1	-	1
Cave hyena	*Crocuta crocuta*	94	31	58
Cave bear	*Ursus spelaeus*	256	221	22
Fox	Vulpinae	27	6	21
Total Carnivores	**-**	**378**	**258**	**102**
Total ID Macrofauna	**-**	**698**	**338**	**339**
Birds	Aves	1	-	1
Leporids	Leporidae	5	-	5
Unidentified Mammals	Unknown size	1391	257	1134
	Size 1/2	40	11	29
	Size 3/4	193	62	131
	Size 4/5	5	2	3
Total Unidentified	**-**	**1629**	**332**	**1297**
Grand Total	**-**	**2335**	**670**	**1644**

*The total includes 21 pieces from the coarse fraction (i.e., >4mm) that could not be reliably attributed to a given assemblage.

- lithic artifacts and charcoal are much more abundant in the upper part of the deposits, while faunal remains are found throughout the stratigraphy (see Figure 8a);
- plotted coprolites (i.e., the larger and better preserved ones) are more abundant in the lower part of the stratigraphy, in bands J and K but not band L (cf. Supplement 1). Numerous coprolite fragments were found in the sieve residues from all squares;
- the concentration of lithic artifacts visible in the upper part of Layer 2 depicts a strong slope towards the cave entrance in the north (see Figure 8a);
- cave bear remains are much more abundant in the lower part of Layer 2 (65% of identifiable macrofaunal remains, compared to 6.5% in the top part), while the other most abundant species (horse, large bovids, and cave hyena) are found throughout (see Figure 8b, see Table 2);
- cut-marks, percussion marks, and burnt bones are more abundant in the upper part (see Figure 8c), while carnivore marks and digested bones are found throughout the stratigraphy (see Figure 8d);
- lithic surface states and taphonomic alterations of bone cortical surfaces show very little differences in spatial distribution. However, bones with a "brown" hue/patina are concentrated in the lower

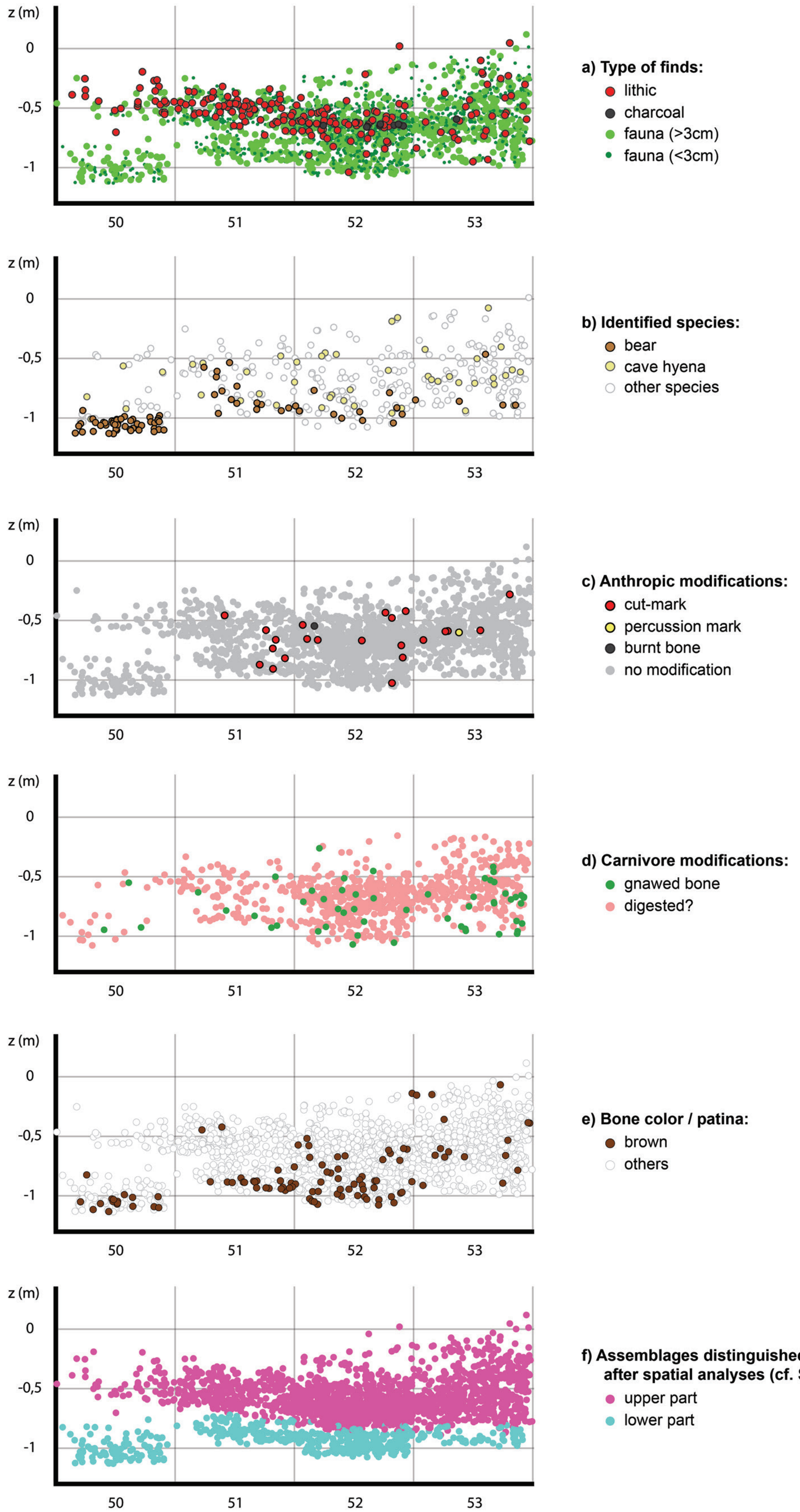


Figure 8. Spatial distribution of key artifact types (sagittal YZ projections). The total width of projection varies across the profile (cf. Figure 2) but is around 3 meters for most of it. More detailed projections, with a constant 50cm width of projection, are available in Supplement 1. Note that the lower part of the deposits (below Z= -1m) was not excavated in lines 51 and 53.

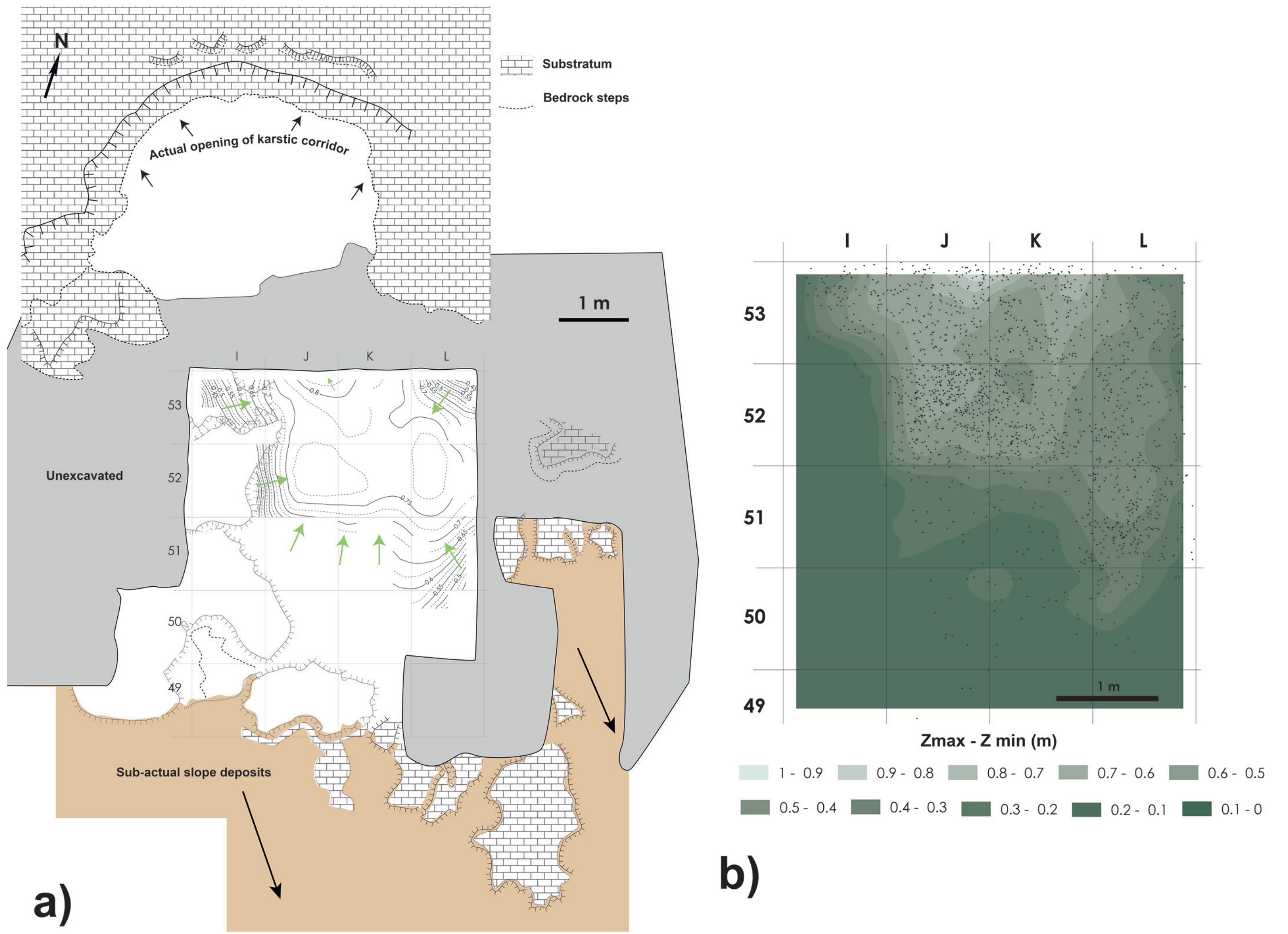


Figure 9. a) Geomorphological map of Cassenade (cf. Figure 2) with superposition of the paleotopography corresponding to the surface aspect before the formation of the "upper" assemblage (see method sections for details on how the contour lines were established). Squares lacking contour lines correspond to areas with less than 5 artifacts per 25cm square. b) Thickness map of the "upper" assemblage (see method sections for details on map construction).

part of the deposit (see Figure 8e);

- in several squares, a nearly sterile band is present between the upper and lower assemblages highlighted above (cf. Supplements 1 and 2), making their distinction much more easier in bands J and K compared to band L.

Two distinct assemblages can be identified based on the above observations and the detailed examinations of projections with varying "widths" (see Figure 8f).

Paleotopography

Considering that the base of the lower assemblage was not reached during our excavations, only the paleotopography of the upper assemblage could be reconstructed. The base geometry of the upper assemblage, which includes most of the Châtelperronian lithics, is provided in Figure 9. Contour lines show a "depression" (Squares J52, J53, K52, K53, L52), possibly the head of a north-west oriented channel (i.e., towards the cave entrance). This lower area is surrounded by higher zones (Squares I51-I53, K51, L51) that follow the topography of the bedrock exposed during excavation (see Figure 9a), which slopes abruptly towards the karstic corridor. Additionally, the upper assemblage is thicker in the "depression" zone than in the higher bordering areas (see Figure 9b).

Refits

In total, 23 refitting groups were found for lithic elements (46 plotted and 6 unplotted pieces), and 14 groups for faunal remains (28 plotted, 1 unplotted). Lithic conjoins mostly concern ancient breaks (n=9, Figure 10: 2) and debitage (n=14, Figure 10: 1, 3, 4, 5). Debitage refits among smaller elements (<2cm) were also found (Figure 10: 4). When conjoins on recent breaks are excluded and only plotted pieces considered, around 20% of the lithic elements could be refitted. Overall, the vertical distribution of the 37 refit groups is in good agreement with the proposed distinction of upper and lower assemblages in field Layer 2 (Figure 11).

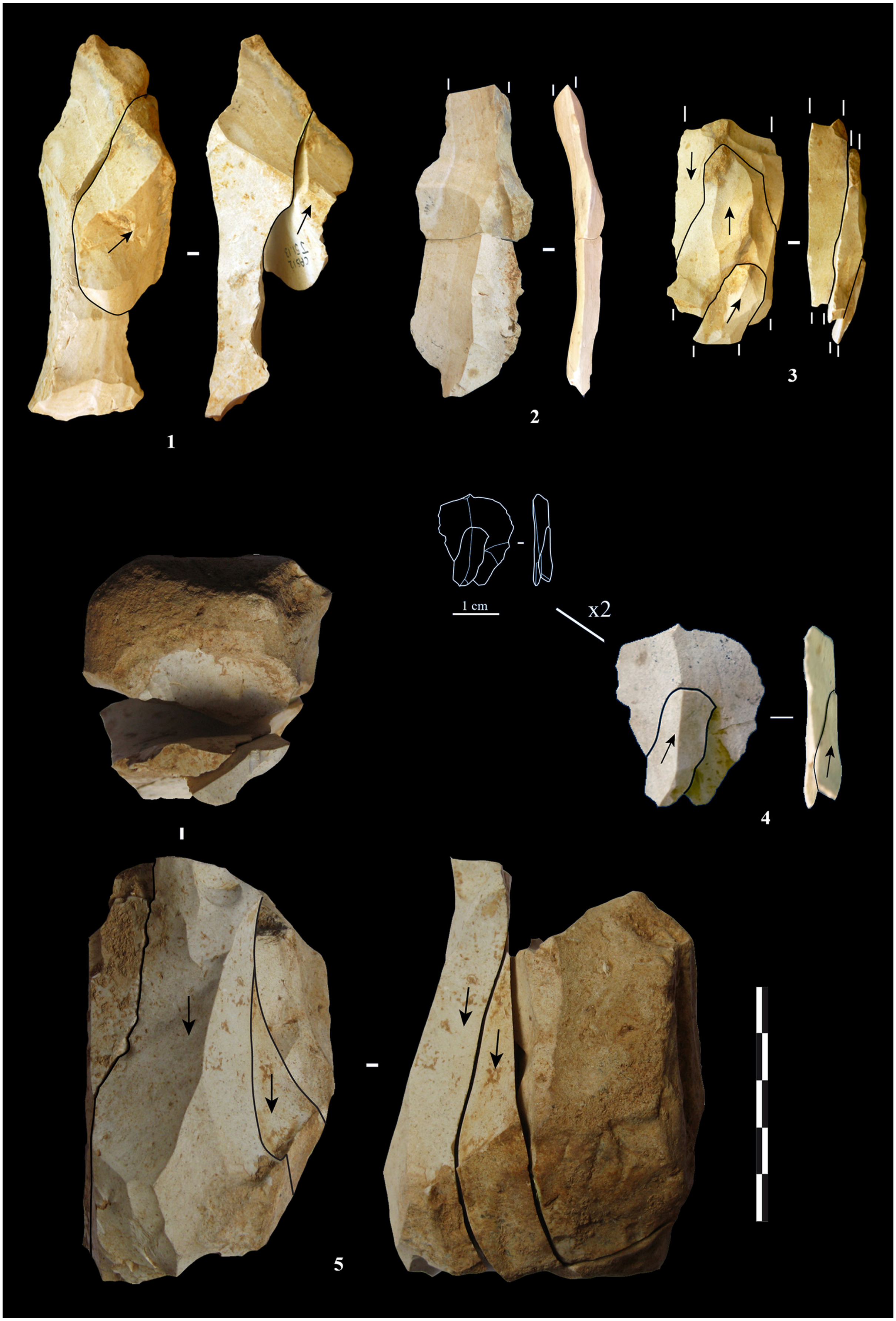


Figure 10: Examples of debitage (1, 3, 4, 5) and ancient break (2) refits.

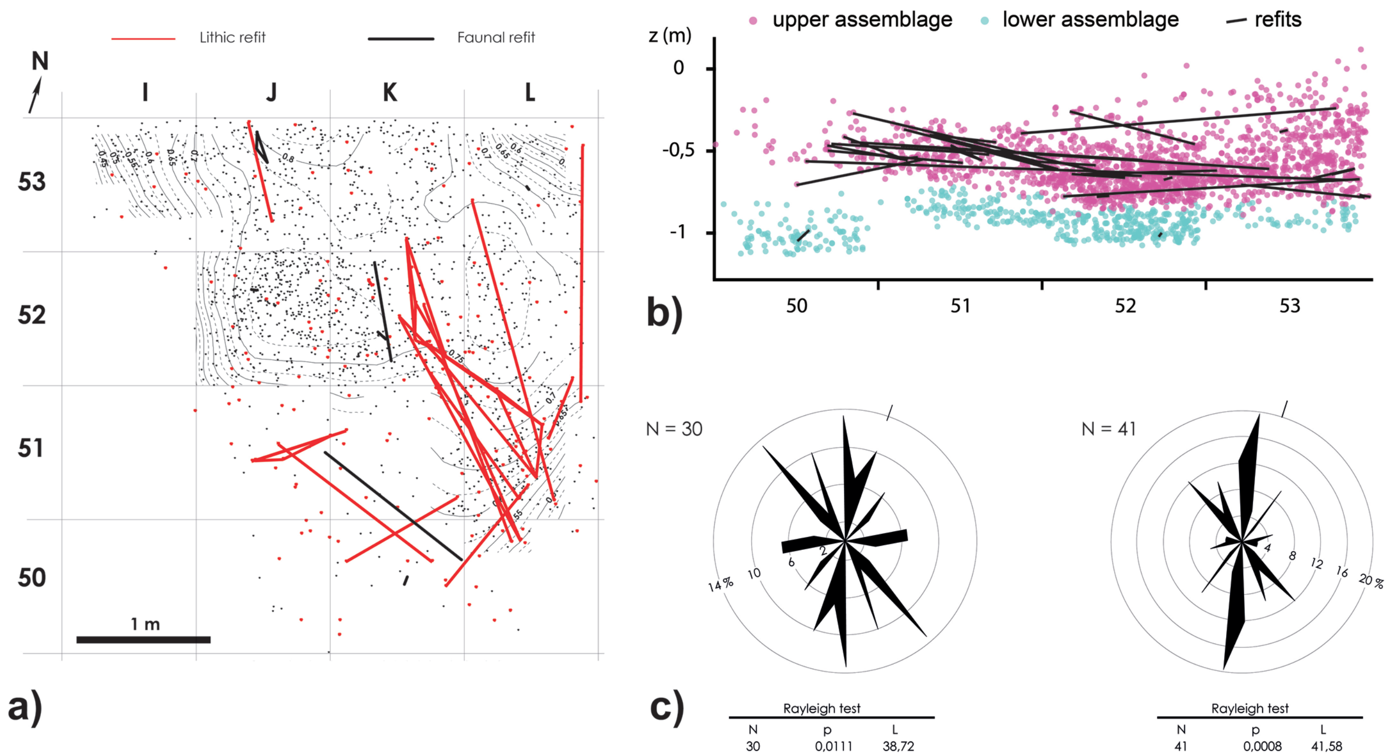


Figure 11. a) Top projection (XY) of refit links for lithic (red) and faunal (black) remains; b) Sagittal projection (YZ) of refits links; c) Rose diagram and statistical parameters of refit orientations (left: lithic refits only, right: faunal and lithic refits).

The spatial distribution of refitted artifacts shows a strongly orientated pattern (see Figure 11), confirmed by the L-magnitude vector values and the Rayleigh test, the latter rejecting the hypothesis of a random orientation of refits. The results are nearly identical whether only lithic or both lithic and faunal refits are taken into account (see Figure 11c). Overall, the rose diagrams suggest a preferential NW-SE orientation of the connections, which is in agreement with the direction of the slope in the area where most of the connections were identified. The plunge of these connections and the geometry of the deposits demonstrate a N-W oriented slope beginning from Square L51.

FABRIC ANALYSIS

The rose diagrams for Squares J52, J53, K52+L52, and K53 are shown in Figure 12a. Although the distribution of object orientations appears polymodal, this should be considered with caution, as the number of measures per square is less than 30. The distribution is also polymodal when the measurements from all squares are considered together (Figure 12b), with a vector magnitude value of 6.5% and a p-value of Rayleigh test >0.05. The p-value rejects the hypothesis of a preferential orientation for the entire assemblage.

The projection of IS and EL values on the ternary diagram developed by Lenoble and Bertran (2004) places the upper assemblage in the area of sites affected by surface runoff (Figure 12c and d). Projecting IS and EL values for measurements taken only on faunal or lithic remains produce comparable results (Figure 12c and e).

LITHIC PARTICLE-SIZE ANALYSIS

Particle-size distribution of the lithics wider than 5.66mm (i.e., sieve mesh diameter=4mm) shows a bell-shaped distribution, with a slight under-representation of the smallest artifacts (width: w=5.66mm to 7.07mm, sieve mesh diameter=4mm to 5mm) compared to experimental blade debitage (Figure 13a). Inclusion of smaller artifacts (mesh of 2mm) in the analysis for Squares K52 and L53 confirms the Cassenade lithic assemblage to be weakly sorted (Figure 13c), reflecting what Lenoble (2005) and Bertran et al. (2012) have described as the "first stages of residualisation". In surfaces affected by water runoff, this first stage of sorting seems to be associated with the formation of lag deposits and residual concentrations.

Tests carried out for artifacts wider than 5.66mm (mesh of 4mm) identified no differences between squares in terms of artifact size sorting. Confidence ellipses generated by the Triangle software almost certainly overlap due to low sample sizes. Similarly, no significant differences are evident between Squares K52 and L53 when the 2–4mm fraction is included (see Figure 13c). Mapping the distribution of piece-plotted artifacts according to size identifies no specific horizontal distribution and only a weak vertical concentration of the largest artifacts at the center of the upper assemblage (Figure 13b).

DATING OF CASSENADE OCCUPATIONS

The twelve radiocarbon dates obtained are reported in Table 3. Most samples (all but one) come from Layer 2 and

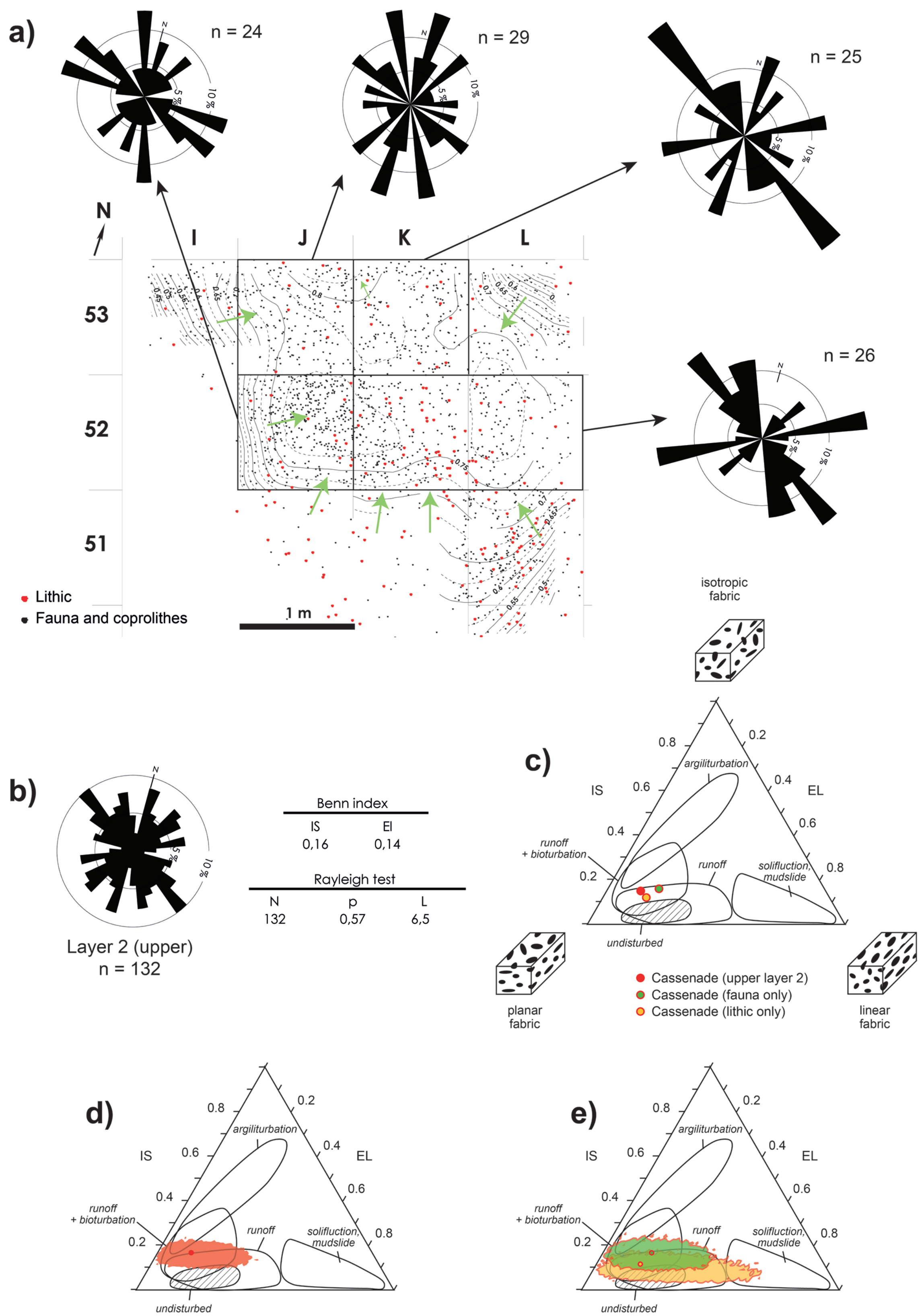


Figure 12. a) Spatial distribution (XY) of artifacts plotted against paleotopography, and rose diagram of the orientation of elongated lithics and faunal remains by square (measurements from L52 and K52 are combined to reach a sufficient sample size). b) Rose diagram and statistical parameters for all orientation measurements from the upper assemblage. c) Benn diagram according to sedimentary context (after Lenoble and Bertran 2004). d) and e) Benn diagrams with confidence intervals computed using the code provided by McPherron on GitHub (cf. main text for details), for all measurements (d, ellipse in red), for faunal remains (e, ellipse in green) and lithic artifacts (e, ellipse in yellow).

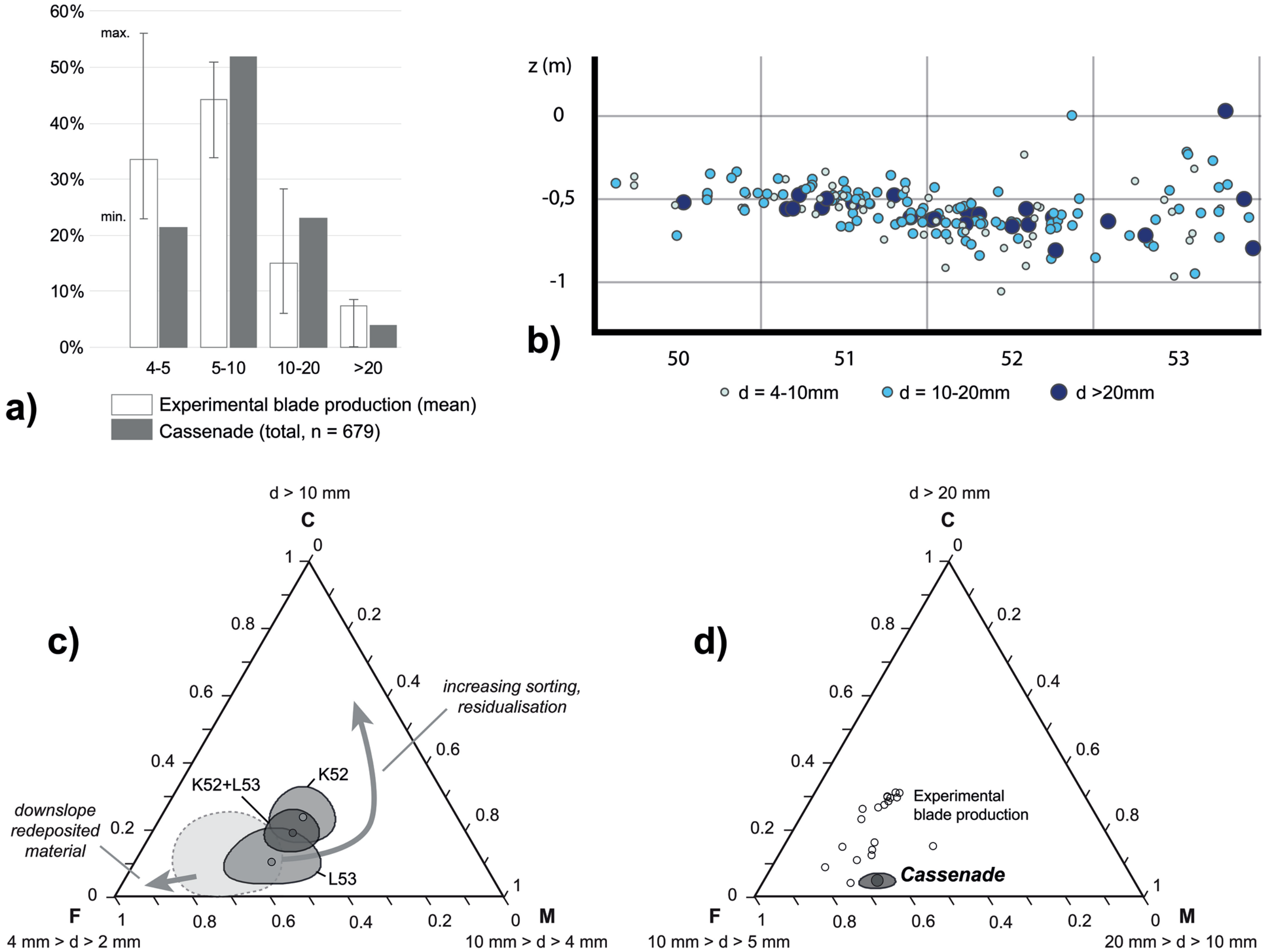


Figure 13. Particle-size distribution of Cassenade lithics. a) Histogram of artifacts wider than 5.66mm (sieve mesh diameter=4mm). b) Sagittal projection (YZ) of plotted artifacts by size (expressed in corresponding sieve mesh). c) Ternary diagram of lithic material for the artifacts wider than 2.83mm (Squares K52 and L53 only). d) Ternary diagram of lithic material for the artifacts wider than 7.07mm (all squares). Confidence intervals (ellipses with solid outlines) were computed on ternary diagrams (c and d) using the Triangle software (Weaver et al. 2011). In addition, expected compositional changes according to hydraulic sorting are represented in c) (adapted from Bertran et al. 2012 and Lenoble 2005), and the open circles in d) correspond to experimental blade production (Bertran et al. 2012; Lenoble 2005).

correspond to four teeth, four bones, and one set of charcoal fragments found in close spatial association (Figure 14). For samples K53-88 and J52-487, two measurements were obtained from the same bone, and thus dates were combined in OxCal.

Roughly speaking, three sets of age measurements can be distinguished (see Figure 14):

- The date obtained on a sample from previous excavations, found in association with Mousterian artifacts, is slightly older than the others;
- Most measurements from Layer 2 place the occupations (both hominids and carnivores) to around 39 to 44 kyr cal. BP, consistent with other recently-obtained dates for the Châtelperronian (cf. Soressi and Roussel 2014);
- Two measurements are younger, the K52 charcoals and the K53-3 hyena tooth. The younger age measurement obtained from the charcoal fragments is probably due to contamination from humic acids, considering that the best pretreatment protocols (ABOX-SC) failed. The case of K53-3 is harder to explain, as its position near the top of the stratigraphy (see Figure 14b) could support either a younger age or imply a higher chance of contamination.

We used Bayesian modelling to test the ordering of occupations in the upper assemblage by hyenas and hominids. Measurements obtained on cut-marked bones and charcoal fragments were grouped in a "Layer 2upper Hominids" phase, and dates on hyena teeth from Layer 2 in a "Layer2upper Hyenas" phase. These two phases were

TABLE 3. LIST OF RADIOCARBON DATES OBTAINED FOR CASSENADE (all but OxA-30956 are ultrafiltrated dates on bone collagen).

Assemblages	Occupation	Field ID	Description	Lab Code	d¹³C	Radiocarbon Date
Below Layer 2	Hyenas	I13-336[1]	Hyena, tooth	Lyon-10013(SacA 32378)	NA	41500±1600
Layer 2, lower part	Bears	K50-71	Bear, tooth	Lyon-10016(SacA 32381)	NA	37380±980
Layer 2, upper part	?	K50-9	Horse, tibia	Lyon-10014(SacA 32379)	NA	35800±810
		K51-24	Horse, tooth	Lyon-10015(SacA 32380)	NA	39100±1200
	Hyenas	K52-235	Hyena, tooth	Lyon-15854(SacA 55571)	NA	37800±1100
		K53-3	Hyena, tooth	Lyon-15855(SacA 55572)	NA	33020±600
	Hominids	K52-125, 126, 127 & 138	Charcoal fragments	OxA-30956	-25.32	32950±450[2]
		J52-487	Horse, metatarsal with cut-marks	OxA-31475	-20.30	38400±900
				OxA-31476	-20.34	39300±1100
		K52-30	Bovinae, metatarsal with cut-marks	OxA-31477	-19.79	36600±750
		K53-88	Mammal size 3/4, long bone with cut-marks	OxA-31478	-20.31	35850±700
				OxA-31479	-20.27	34950±650

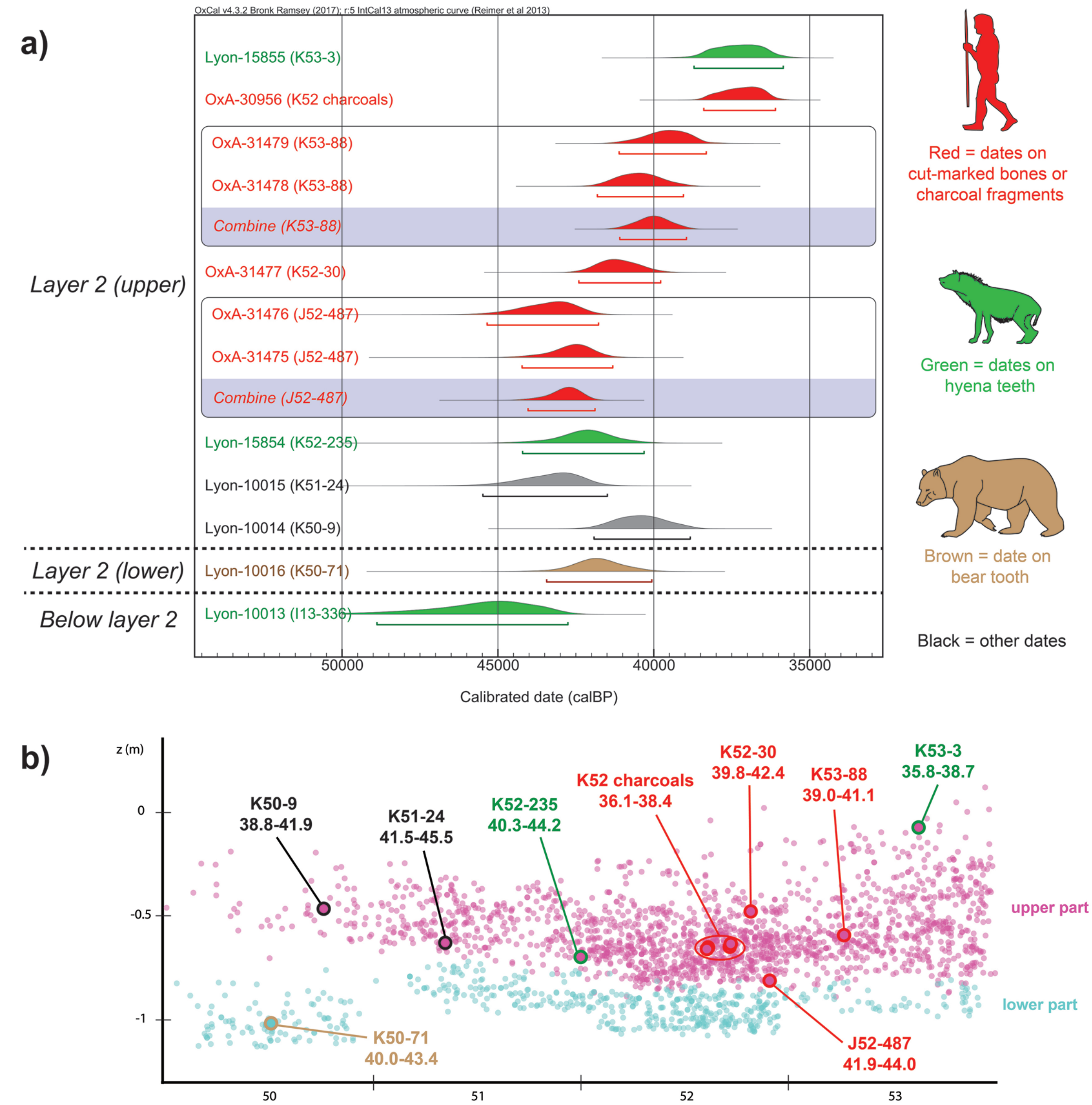
[1]This sample comes from previous excavations (all other come from the new fieldwork).
[2]This age measurement was obtained on a A-B-A treated sample (ABOX-SC methods failed), and should be considered as a minimum age.

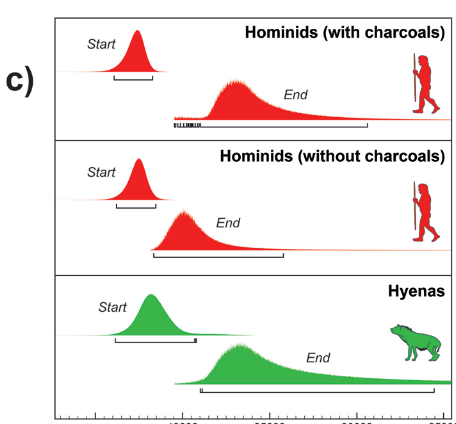
each separately constrained by the two measurements obtained from the underlying deposits (samples I13-336 and K50-71) using the Sequence function. No stratigraphic constraint was applied between "Layer 2upper Hominids" and "Layer 2upper Hyenas" phases. This allowed for the calculation of Start and End boundaries of occupations of Layer 2upper by hominids and hyenas, without the insertion of any prior information on their chronological ordering (see Figure 14c). Considering doubts concerning the reliability of the Square K52 charcoals date, one model was run for "Layer 2upper Hominids" phase including this measurement, and another one excluding it (see Figure 14c).

The Order command from OxCal returned results consistent with visual inspection of the dates (see Figure 14d). The chronological ordering of the occupations by hominids and hyenas in Layer 2upper is extremely difficult, if not impossible, to determine:

- When the charcoal date is included, a complete overlap between occupations is statistically supported—the hyena occupation starts before the end of the hominid occupation (p=0.99), and the hominid occupation starts before the end of the hyena occupation (p=1); and,
- When the charcoal date is excluded, the overlap is less apparent—the hominid occupation starts before the end of the hyena one (p=1), but it impossible to demonstrate the hyena occupation to start before the end of the hominid one (p=0.93), meaning that hyena occupation might (or might not) post-date the hominid occupation.

Bayesian modelling thus does not offer a clear answer to the issue at hand. Considering that the number of radiocarbon dates considered is low, combined with the unsatisfactory stratigraphic constraints (only two dates come from below Layer 2upper and none above it), and the demonstrated sensitivity of such models to priors and parameters for this time period (Discamps et al. 2015), these results should be regarded with considerable caution, if not disregarded.





d)

Order (Layer 2upper): probability $t_1 < t_2$		WITH CHARCOALS		
t_1 \ t_2	Start Hyenas	End Hyenas	Start Hominids	End Hominids
Start Hyenas	0	1	0.13964	**0.9926**
End Hyenas	0	0	**0**	0.3645
Start Hominids	0.8604	**1**	0	1
End Hominids	**0.007443**	0.6355	0	0

Order (Layer 2upper): probability $t_1 < t_2$		WITHOUT CHARCOALS		
t_1 \ t_2	Start Hyenas	End Hyenas	Start Hominids	End Hominids
Start Hyenas	0	1	0.17434	**0.9314**
End Hyenas	0	0	**0**	0.07406
Start Hominids	0.8257	**1**	0	1
End Hominids	**0.0686**	0.9259	0	0

Figure 14. a) Radiocarbon dates for Cassenade, calibrated using IntCal13 atmospheric curve (Reimer et al. 2013) and OxCal 4.3.2 software (Bronk Ramsey 2009a). OxA-31475 and OxA-31476 were obtained on the same bone, as OxA-31478 and OxA-31479, and were thus combined in OxCal. The color codes identify samples related to hominid, hyena, or bear occupations (silhouettes in the legend modified after M. Coutureau and J.-B. Mallye); b) Sagittal projection (YZ) of the dated samples; c) Results of the Bayesian modelling (start and end boundaries of each phase); and, d) results of the Order command (cf. text for more details). Probabilities of interest (discussed in the text) are in bold characters.

DISCUSSION

WHO OCCUPIED CASSENADE?

Techno-typological analysis of the Cassenade lithic artifacts identifies a single techno-cultural component, the Châtelperronian. On the contrary, zooarchaeological and taphonomical analyses identify at least three major agents responsible for accumulating the mammal remains—humans, cave hyena,s and cave bears. More specifically, the abundance of gnaw marks, digested bones, coprolites, and juvenile hyena remains indicates a large portion of the Cassenade faunal assemblage to have been accumulated by cave hyenas. Spatial analyses of the faunal data shows the human and bear contributions to be concentrated, respectively, in the upper and lower parts of the stratigraphy. Although some remains exhibit clear evidence of anthropic modification (cut and percussion marks, burnt bones), the precise role of humans in the accumulation of faunal remains in the upper part of the assemblage is difficult to estimate due to the poorly preserved cortical surfaces. Concentrations of cave bear remains, notably juveniles, in the lower part of Layer 2 show Cassenade to have initially functioned as a den for both cave hyenas and bears before the Châtelperronian occupation, a frequently observed pattern for MIS 3 in southwestern France (e.g., Armand et al. 2003; Beauval and Morin 2010; Discamps 2011, 2014; Discamps et al. 2012a, 2012b).

Artifact distributions clearly show Cassenade field Layer 2 to reflect two distinct phases of occupation; denning cave hyenas and bears with only limited evidence of human activity, followed by cave hyenas and Châtelperronian groups whose occupations are spatially indistinguishable. Only five lithics were recovered from the lower part of Layer 2; three are undiagnostic, while two (a distal fragment of a backed blade and a small Châtelperron point) can be attributed to the Châtelperronian. Their patinas are similar to the lithics found in the upper assemblage, and all five pieces are small (<4cm). Their presence at the base of Layer 2 is likely connected to a limited post-depositional incorporation of material from the upper assemblage.

HOW DID OCCUPATIONS BECOME INTERMINGLED?

Data from sedimentology, local topography, lithic particle-size, fabric analysis, and refits shed light on how markers of carnivore and human activities became mixed in the upper part of Cassenade field Layer 2.

When the upper assemblage of Layer 2 was deposited, Cassenade was an exposed but nearly completely infilled karstic corridor. Sedimentological analyses point to the important role played by surface water run-off in site formation processes. Data from the reconstructed paleotopography shows that the local geomorphology induced pronounced slopes, with higher areas surrounding a depression. In a scenario where surface runoff was a key post-depositional process, deposits in the higher areas, lying directly on top of corridor walls, would have been eroded, before being re-deposited in the depression zone. This is supported by the increased thickness of the deposits in the depression zone (see Figure 9) and is consistent with the observations of Lenoble (2005) for active systems.

Such a site formation scenario is also supported by the refit data and fabric analyses. Spatial analysis of the refits shows a preferential orientation, with conjoined pieces connecting the higher areas and the depression zone. Fabric analysis places Cassenade in the zone of sites affected by surface runoff, despite slightly lower vector magnitude (L) values compared to active systems (Lenoble 2005). These lower values could be explained by the effects of bioturbation identified in the micromorphological thin-sections, which would have induced the minor displacement of the artifacts, thus increasing the isotropy. They could equally be explained by the fact that the assemblage was analyzed as one layer while it probably includes several sub-layers formed by surface run-off (the low sample size precludes fabric analysis by sub-square or spit).

Particle-size distribution of lithic artifacts supports a scenario where the Cassenade assemblage reflects the first stages of residualization. While this would be expected for Square L53 (in the higher area), it is inconsistent with the idea that Square K52 (close to the depression zone) functioned as a redeposition area. Therefore, material was probably redeposited further along the slope, closer to the cave entrance. Residualization is, however, quite limited, which would account for how surface runoff mixed the hyena and human occupations while only remobilizing material over short distances, and thus preserving the general homogeneity of the lithic assemblage and a high refitting ratio.

The importance of surface runoff at Cassenade equally explains why distinct sub-levels related to human and carnivore occupations could not be identified in the field and why no particular horizontal spatial distribution of the artifacts is evident despite the general homogeneity of the preserved lithic assemblage. The displacement and mixture of artifacts precluded the analysis of any behaviorally linked spatial patterns. Furthermore, we might expect mixing in residualization zones (i.e., several sub-levels concentrated into a single layer), and stratigraphic inversions in deposition zones. However, the weakly-sorted pattern of lithic particle-size indicates that little material was lost, so that the analysis of the overall assemblage composition can still be adressed and used to discuss site function.

WHAT CAN WE LEARN FROM CASSENADE ABOUT THE CHATELPERRONIAN?

When combined, data from technological, raw material, and use-wear analyses provide an interesting perspective on the Châtelperronian occupations of Cassenade, despite their rather small and somewhat unimpressive character.

Several characteristics of the upper assemblage from Cassenade are noteworthy:

- local raw materials were apparently introduced in the form of “tested” blocks or large flakes that were knapped on-site;
- conversely, there is a marked deficit in cores, pointing to a potential export of cores shaped on-site;

- similarly, Tertiary flint seems to have been introduced in the form of preshaped cores, before being exported from the site;
- the sole artifact transported over a significant distance was introduced in the form of a retouched tool;
- Châtelperronian points are abundant. The analysis of use-wear traces support the hypothesis of projectile points that were abandoned after hunting and replaced on-site. This pattern is consistent with what has been observed at other Châtelperronian sites (Bachellerie et al. 2011; Baillet 2017; Rios-Garaizar et al. 2012), including open-air occurences (Baillet 2017; Grigoletto et al. 2008);
- despite some limits due to a poor preservation of bone surfaces, the human contribution to faunal accumulation seems minimal. It is still, however, possible that most of the cut-marks were erased by post-depositionnal processes;
- some bones bear traces of both carnivore and anthropic activity, supporting the hypothesis of a short interval between occupations by the different agents; and,
- there is very little evidence of fire on the site.

Taken together, these data suggest Châtelperronian groups only briefly visited the site, producing a handful of points and discarding broken ones, while processing some animal products and lighting a few small fires. This scenario is supported by taphonomic data, and it might be the brevity of the human occupations themselves which allowed carnivores to extensively occupy Cassenade. This pattern could potentially be extended to other late Mousterian and Châtelperronian occupations in southwestern France.

The Cassenade example equally reinforces previous models of Châtelperronian mobility strategies (Bachellerie et al. 2011; Baillet 2017; Rios-Garaizar et al. 2012). In fact, while many large sites with long and/or frequent occupations have been interpreted as base camps (e.g., Roc-de-Combe, la Grotte du Renne at Arcy-sur-Cure, Quinçay, Gatzarria, le Basté, les Tambourets), others seem to correspond to field camps with evidence of one or just a few short stopovers (e.g., Brassempouy, Labeko Koba, Font-de-Gaume, Ekain, Caminade-Est, etc.). Cassenade is a good example of the latter, and highlights a socio-economic organization of Châtelperronian groups that incorporates significant functional complementarity, and thus variation between sites with distinct functions (Baillet 2017; Bachellerie et al. 2011). In base camps, the range of activities is larger (including shaping bone tools and pigment use) and Châtelperronian points should be under-represented compared to cores and blanks, indicating their export to other sites (Bachellerie 2011; Grigoletto et al. 2008; Scandiuzzi 2008). Conversely, small sites such as Cassenade, where broken points are abandoned and a few more produced, might represent the only remaining evidence of logistically organized (hunting?) forays. Reliably assessing the site function at Cassenade is nevertheless difficult considering the poor preservation of faunal remains and use-wear traces, and that a large part of the site may have been destroyed by post-depositional processes or simply not excavated. Thus, exploring how exactly Cassenade was integrated within Châtelperronian mobility patterns is currently tentative.

CONCLUSION: BREAKING FREE FROM FIELD LAYERS

Excavating an archaeological sequence traditionally requires a significant time investment during fieldwork in order to define the most precise stratigraphic layers possible, based on criteria such as sediment color or texture, or changes in the density of archaeological material or clasts. These field layers are often thought to reflect distinct occupations and, as such, are often uncritically adopted as the analytical units by which diachronic changes are investigated (Romagnoli et al. 2018). The actual nature and integrity of these layers are, however, rarely tested or justified after excavation despite a growing body of work that has clearly shown the interest of such approaches (e.g., Aubry et al. 2012, 2014; Bachellerie 2011; Bargalló et al. 2016; Bordes 2002, 2003; Chacon et al. 2015; Deschamps and Zilhão 2018; Discamps and Henshilwood 2015; Discamps et al. 2012a; Gabucio et al. 2017; Geiling et al. 2018; Giusti et al. 2018; Goldberg et al. 2018; Gravina et al. 2018; Hovers et al. 2014; Machad and Pérez 2016; Machado et al. 2013; Malinsky-Buller et al. 2011; Mallye 2007, 2011; Martínez-Moreno et al. 2016; McPherron et al. 2005; Michel 2010; Morin et al. 2005; Villa 1982, 2004; Zilhão et al. 2006, 2008; this paper).

Field layers still shape many chronological analyses, potentially distorting interpretations and/or reducing analytical resolution. First, distinct occupations may become mixed together in a single "layer" either following depositional and post-depositional processes (*taphonomic admixture*, as for hominid and carnivore occupations in Cassenade upper assemblage) or difficulties in reliably separating assemblages based uniquely on criteria observed in the field (*analytical lumping*, as for Cassenade upper and lower assemblages of Layer 2). Furthermore, accurately recording changes in the occupation history of a cave or rockshelter directly from the site stratigraphy during excavation is highly unlikely. For example, there is no apparent reason why patterns in site occupation should be systematically correlated with sedimentary changes detectable during fieldwork. The nature of a given palimpsest equally depends on how, and for how long, the different accumulation agents used the site (e.g., site function, season of occupations). Two successive occupations of a cave by different human groups in a context of constant but relatively slow sedimentation will produce a palimpsest likely impossible to disentangle without a detailed taphonomic and 3D spatial analysis after excavation. Despite their common use, field layers are actually ill suited to disentangling the archaeological record of cave and rockshelters. Although archaeologists and paleontologists continue to improve methods for distinguishing different occupations cointained within a single layer, spatial data often remains underused. Generally, spatial analyses are restricted to questions of intra-layer horizontal patterning (XY artifact maps), while the vertical (i.e., temporal) dimension of space (Z) is often overlooked (McPherron et al. 2005).

Despite the generalization of systematic 3D piece-plotting in Paleolithic excavations, this extremely informative spatial data is still rarely considered when defining analytical units. Notably, assemblage boundaries are seldom (re)defined after excavation, and the integrity of field layers often remains untested. The Cassenade example shows the interest of combining spatial and taphonomical data to "break free" from field layers and achieve a better understanding of the site's occupational history. Furthermore, in the absence of such an approach, the site's Châtelperronian occupations would have, at best, been considered as "mixed" and excluded from regional syntheses. When such "small" sites are ignored, a large part of the mobility systems of past groups becomes undetectable, with a consideration of only the largest, better-preserved sites resulting in a biased view of prehistoric hunter-gather lifeways.

Taphonomic analysis that includes three-dimensional spatial projections, refitting studies, and fabric and lithic particle-size analyses remain rare despite such interdisciplinary approaches to spatial and taphonomic data being an excellent means of assessing the importance of taphonomic admixture and analytical lumping. The example of Cassenade shows evidence of both types of "mixing" in a single field layer. Our results highlight the benefits of such an approach to Paleolithic contexts, as it constitutes the necessary first step for reliably interpretating past human behavior.

ACKNOWLEDGEMENTS

ED received funding for the Cassenade project by the Service Régional d'Archéologie d'Aquitaine, the Conseil Général de la Dordogne, the UMR-5199 PACEA, the UMR-5608 TRACES and the Région Nouvelle-Aquitaine project NATCH. MB research was also funded by a Ph.D. grant from the IdEx (ANR No.–10–IDEX-03-02). The project received constant support from N. Fourment (DRAC Aquitaine), J.-P. Chadelle (CG Dordogne), C. Beauval and F. Lacrampe-Cuyaubère (Archéosphère), as well as numerous other colleagues. We are deeply indebted to M. Besse, C. Besse, D. Besse, H. Durst, and inhabitants of Saint-Martin des Combes for their trust and precious help. Thanks also go to J.-G. Bordes, S. Caux, B. Gravina, and J. Jaubert for help and discussions. The comments of three reviewers helped to improve the manuscript, most notably those of S. McPherron. Finally, and most importantly, our deepest thanks go to the people (and friends) that excavated Cassenade with us, among which the most devoted A. "Piou" Cassanis, S. Desguez, C. Fossé, M. Grenet, A. "MéliMélo" Huet, J. "Jojo" Marot, S. "Soso" Solanas, M.-C. Soulier, R. "Sauc'" Suso and A. "Bichette" Viero.

REFERENCES

Allmendinger, R.W., Cardozo, N., and Fisher, D. 2012. *Structural Geology Algorithms: Vectors and Tensors in Structural Geology*. New York, Cambridge University Press.

Armand, D., Plassard F., and Prat F. 2003. L'ours des cavernes de Font-de-Gaume III. *Paléo* 15, 241–244.

Aubry, T., Dimuccio, L.A., Almeida, M., Buylaert, J.-P., Fontana, L., Higham, T., Liard, M., Murray, A. S., Neves, M.J., Peyrouse, J.-B., and Walter, B. 2012. Stratigraphic and technological evidence from the Middle Palaeolithic-Châtelperronian-Aurignacian record at the Bordes-Fitte rockshelter (Roches d'Abilly site, Central France). *Journal of Human Evolution* 62(1), 116–137.

Aubry, T., Dimuccio, L.A., Buylaert, J.-P., Liard, M., Murray, A.S., Thomsen, K.J., and Walter, B. 2014. Middle-to-Upper Palaeolithic site formation processes at the Bordes-Fitte rockshelter (Central France). *Journal of Archaeological Science* 52, 436–457.

Bachellerie, F. 2011. *Quelle unité pour le Châtelperronien? Apport de l'analyse taphonomique et techno-économique des industries lithiques de trois gisements aquitains de plein air : le Basté, Bidart (Pyrénées-Atlantiques) et Canaule II (Dordogne)*. Ph.D. dissertation, Bordeaux, University of Bordeaux 1.

Bachellerie, F., Bon, F., Deschamps, M., Eizenberg, L., Henry-Gambier, D., Mourre, V., Normand, Ch., Pelegrin, J., Primault, J., Scandiuzzi, R., and Thiébaut, C. 2011. La signature archéologique de l'activité de chasse appliquée à la comparaison des industries moustériennes, châtelperroniennes et aurignaciennes des Pyrénées : nature des équipements et fonctions des sites. In *Haltes de chasse en Préhistoire. Quelles réalités archéologiques?*, Bon, Fr., Costamagno, S., and Valdeyron, N. (eds.), Actes du colloque international du 13 au 15 mai 2009, université Toulouse II - Le Mirail, P@lethnologie 3, pp. 131–168.

Bailey, G. 2007. Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology* 26, 198–223.

Baillet, M. 2017. *Éclairage de la tracéologie lithique sur le système techno-économique nomade châtelperronien*. Ph.D. dissertation, Bordeaux, University of Bordeaux.

Benn, D. 1994. Fabric shape and the interpretation of sedimentary fabric data. *Journal of Sedimentary Research* 64, 910–915.

Bargalló, A., Gabucio, M.J., and Rivals, F. 2016. Puzzling out a palimpsest: testing an interdisciplinary study in level O of Abric Romaní. *Quaternary International* 417, 51–65.

Bar-Yosef, O. and Bordes, J.-G. 2010. Who were the makers of the Châtelperronian culture? *Journal of Human Evolution* 59(5), 586–593.

Beauval, C. and Morin, E. 2010. Les repaires d'hyènes du Lussacois (Lussac-les-Châteaux, Vienne, France). Apport des sites des Plumettes et des Rochers de Villeneuve. In *Préhistoire Entre Vienne et Charente*, Buisson-Catil, J., and Primault, J. (eds.), Hommes et Sociétés Du Paléolithique. Association des Publications Chauvinoises, Chauvigny, pp. 175–190.

Bertran, P. 2004. *Dépots de pente continentaux: dynamiques et faciès*. Quaternaire Hors Série 1.

Bertran, P., Klaric, L., Lenoble, A., Masson, B., and Vallin,

L. 2010. The impact of periglacial processes on Palaeolithic sites: the case of sorted patterned grounds. *Quaternary International* 214, 17–29.

Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P.M., and Sørensen, M. 2012. Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites. *Journal of Archaeological Science* 39, 3148–3166.

Bordes, J. G. 2002. *Les interstratifications Châtelperronien / Aurignacien du Roc-de-Combe et du Piage (Lot, France). Analyse taphonomique des industries lithiques; implications archéologiques*. Préhistoire et Géologie du Quaternaire, Ph.D. dissertation, Bordeaux, Université Bordeaux 1.

Bordes, J.-G. 2003. Lithic taphonomy of the Châtelperronian/Aurignacian interstratifications in Roc de Combe and Le Piage (Lot, France). In *The Chronology of the Aurignacian and of the Transitional Technocomplexes, Dating, Stratigraphies, Cultural Implications*, Zilhão, J. and d'Errico, F. (eds.), Lisbonne, Trabalhos de Arqueologia 33, pp. 223–244.

Bordes, J.-G. and Teyssandier, N. 2011. The Upper Paleolithic nature of the Châtelperronian in South-Western France: archeostratigraphic and lithic evidence. *Quaternary International* 246(1–2), 382–388.

Bronk Ramsey, C. 2009a. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–360.

Bronk Ramsey, C. 2009b. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* 51, 1023–1045.

Caux, S. 2015. *Du territoire d'approvisionnement au territoire culturel : pétroarchéologie et techno-économie du silex Grain de mil durant l'Aurignacien dans le Sud-ouest de la France*. Ph.D. dissertation, Bordeaux, Université de Bordeaux.

Chacón, M.G., Bargalló, A., Gabucio, M.J., Rivals, F., and Vaquero, M. 2015. Neanderthal behaviors from a spatio-temporal perspective: an interdisciplinary approach to interpret archaeological assemblages. In Settlement Dynamics of the Middle Paleolithic and Middle Stone Age, Conard, N. and Delanges, A. (eds.), (Vol. 4), Tübingen, Kerns Verlag, pp. 253–294.

Chame, M. 2003. Terrestrial mammal feces: a morphometric summary and description. *Memórias do Instituto Oswaldo Cruz* 98, 71–94.

Chu, W. 2016. *Fluvial Processes in the Pleistocene of Northern Europe*. London, British Archaeological Reports International Series 2797.

Claud, E. and Bertran, P. 2010. Effet de la solifluxion sur les traces d'utilisation des outils lithiques : mise en place d'une expérimentation in vivo à gavarnie (Hautes-Pyrénées, France). In *Mise en commun des approches en taphonomie*, Thiébaut C., Coumont, M.-P., and Averbouh, A. (eds.), Actes du workshop n° 16 - XVe congrès international de l'UISPP, Lisbonne, septembre 2006. Paléo supplément n°3, pp. 31-42.

Connet, N. 2002. *Le Châtelperronien : Réflexions sur l'unité techno-économique de l'industrie lithique. L'apport de l'analyse diachronique des industries lithiques des couches châtelperroniennes de la grotte du Renne à Arcy-sur-Cure (Yonne)*. Ph.D. dissertation, Lille, University of Lille I.

Curray, J.R. 1956. The analysis of two-dimensional orientation data. *Journal of Geology* 64, 117–131.

d'Errico, F. and Villa, P. 1997. Holes and grooves: the contribution of microscopy and taphonomy to the problem of art origins. *Journal of Human Evolution* 33, 1–31.

Deschamps, M. and Zilhão, J. 2018. Assessing site formation and assemblage integrity through stone tool refitting at Gruta da Oliveira (Almonda karst system, Torres Novas, Portugal): a Middle Paleolithic case study. *PLoS One* 13, e0192423, doi:10.1371/journal.pone.0192423.

Diedrich, C.G. 2012. Typology of Ice Age spotted hyena *Crocuta crocuta spelaea* (Goldfuss, 1823) coprolite aggregate pellets from the European Late Pleistocene and their significance at dens and scavenging sites. In *Vertebrate Coprolites*, Hunt, A.P., Milàn, J., Lucas, S.G., and Spielman, J.A. (eds.), Albuquerque, New Mexicl Museum of Natural History and Science, pp. 369–378.

Discamps, E. 2011. *Hommes et hyènes face aux recompositions des communautés d'Ongulés (MIS 5-3) : Éléments pour un cadre paléoécologique des sociétés du Paléolithique moyen et supérieur ancien d'Europe de l'Ouest*. Ph.D. dissertation, Bordeaux, Université Bordeaux 1.

Discamps, E. 2014. Ungulate biomass fluctuations endured by Middle and Early Upper Paleolithic societies (SW France, MIS 5-3): the contributions of modern analogs and cave hyena paleodemography. *Quaternary International* 337, 64–79.

Discamps, E. and Henshilwood, C.S. 2015. Intra-site variability in the Still Bay fauna at Blombos Cave: implications for explanatory models of the Middle Stone Age cultural and technological evolution. *PLoS One* 10, 1–21. doi:10.1371/journal.pone.0144866

Discamps, E. and Royer, A. 2017. Reconstructing palaeoenvironmental conditions faced by Mousterian hunters during MIS 5 to 3 in southwestern France: a multi-scale approach using data from large and small mammal communities. *Quaternary International* 433, 64–87.

Discamps, E., Jaubert, J., and Bachellerie, F. 2011. Human choices and environmental constraints: deciphering the variability of large game procurement from Mousterian to Aurignacian times (MIS 5-3) in southwestern France. *Quaternary Science Reviews* 30, 2755–2775.

Discamps, E., Delagnes, A., Lenoir, M., and Tournepiche, J.-F. 2012a. Human and hyena co-occurrences in Pleistocene sites: insights from spatial, faunal and lithic analyses at Camiac and La Chauverie (SW France). *Journal of Taphonomy* 10, 291–316.

Discamps, E., Boudadi-Maligne, M., Chagneau, J., Armand, D., Guadelli, J.L., and Lenoir, M. 2012b. Ours, hommes, hyènes : qui a occupé la grotte de Bourdette (Sainte-Colombe-en-Bruilhois, Lot-et-Garonne, France) ? *Paléo* 117–136.

Discamps, E., Gravina, B., and Teyssandier, N. 2015. In the eye of the beholder: contextual issues for Bayesian modelling at the Middle-to-Upper Palaeolithic transition. *World Archaeology* 47, 601–621.

Fernandes, P., Morala, A., Schmidt, P., Seronie-Vivien, M.-R., and Turq, A. 2012. Le silex du Bergeracois : état de la question. In *Livret-guide de l'excursion AFEQ-ASF en*

Aquitaine du 30 mai au 1er juin 2012 «Quaternaire Continental d'Aquitaine : Un Point Sur Les Travaux Récents », Bertran, P. and Lenoble, A. (eds.), AFEQ-ASF, Bordeaux, pp. 22–33.

Gabucio, M.J., Fernández-Laso, M.C., and Rosell, J. 2017. Turning a rock shelter into a home. Neanderthal use of space in Abric Romaní levels M and O. *Historical Biology* 2963, 1–24.

Geiling, J.M., Marín-Arroyo, A.B., Straus, L.G., and González Morales, M.R. 2018. Deciphering archaeological palimpsests with bone micro-fragments from the Lower Magdalenian of El Mirón cave (Cantabria, Spain). *Historical Biology* 30, 730–742.

Giusti, D., Tourloukis, V., Konidaris, G., NicholasThompson, N., Karkanas, N., Panagopoulouc, E., and Harvati, K. 2018. Beyond maps: patterns of formation processes at the Middle Pleistocene open-air site of Marathousa 1, Megalopolis basin, Greece. *Quaternary International* 497, 137–153.

Goldberg, P., McPherron, S.P., Dibble, H.L., and Sangathe, D. 2018. Stratigraphy, deposits, and site formation. In *The Middle Paleolithic Site of Pech de l'Azé IV*, Dibble, H.L., McPherron, S.P., Goldberg, P., and Sandgathe, D. (eds.), Cave and Karst Systems of the World, New York, Springer, pp. 21–74.

Gravina, B., Bachellerie, B., Caux, S., Discamps, E., Faivre, J.-Ph., Galland, A., Michel, A., Teyssandier, N., and Bordes, J.-G. 2018. No reliable evidence for a Neanderthal-Châtelperronian association at La Roche-à-Pierrot, Saint-Césaire. *Scientific Reports* 8, 15134, doi:10.1038/s41598-018-33084-9.

Grigoletto, F., Ortega, I., and Rios, J. 2008. Le Châtelperronien des Vieux Coutets (Creysse, Dordogne). Premiers éléments de réfexion. *Bulletin de la Société Préhistorique Française* XLVII, 245-259.

Guilloré, P. 1980. *Méthode de fabrication mécanique et en série des lames minces*. Institut National d'Agronomie Paris-Grignon, Département des Sols.

Hovers, E., Ekshtain, R., Greenbaum, N., Malinsky-Buller, A., Nir, N., and Yeshurun, R. 2014. Islands in a stream? Reconstructing site formation processes in the late Middle Paleolithic site of 'Ein Qashish, northern Israel. *Quaternary International* 331, 216–233.

Hurst, V.J. and Kelly, A.R. 1961. Patination of cultural flints. *Science* 134, 251–256.

Inizan, M.-L., Reduron, M., Roche, H., and Tixier, J. 1995. *Technologie de la pierre taillée*. Meudon, CREP.

Keeley, L.H. 1980. *Experimental Determination of Stone Tool Uses*. Chicago, University of Chicago Press.

Kooistra, M.J. and Pulleman, M.M. 2010. *Features Related to Faunal Activity. In: Interpretation of Micromorphological Features of Soils and Regoliths*. Amsterdam, Elsevier, pp. 397–418.

Larkin, N.R., Alexander, J., and Lewis, M.D. 2000. Using experimental studies of recent faecal material to examine Hyaena coprolites from the west Runston freshwater bed Norfolk, U.K. *Journal of Archaeological Science* 27, 19–31.

Laville, H. 1969. L'interstade Wu̎rm II - Wu̎rm III et la position chronologique du Paléolithique supérieur ancien en Périgord. *Comptes Rendus de l'Académie des Sciences de Paris* 269, 10–12.

Lenoble, A. 2005. *Ruissellement et formation des sites préhistoriques: référentiel actualiste et exemples d'application au fossile*. British Archaeological Reports International Series 1363. J. and E. Hedges, Oxford, England.

Lenoble, A. and Bertran, P. 2004. Fabric of Palaeolithic levels: methods and implications for site formation processes. *Journal of Archaeological Science* 31, 457–469.

Machado, J. and Pérez, L. 2016. Temporal frameworks to approach human behavior concealed in Middle Palaeolithic palimpsests: a high-resolution example from El Salt Stratigraphic Unit X (Alicante, Spain). *Quaternary International* 417, 66–81.

Machado, J., Hernández, C.M., Mallol, C., and Galván, B. 2013. Lithic production, site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). *Journal of Archaeological Science* 40, 2254–2273.

Malinsky-Buller, A., Hovers, E., and Marder, O. 2011. Making time: 'living floors', 'palimpsests' and site formation processes - a perspective from the open-air Lower Paleolithic site of Revadim Quarry, Israel. *Journal of Anthropological Archaeology* 30, 89–101.

Mallol, C., Hernández, C.M., and Machado, J. 2012. The significance of stratigraphic discontinuities in Iberian Middle-to-Upper Palaeolithic transitional sites. *Quaternary International* 275, 4–13.

Mallye, J.-B. 2007. *Les restes de Blaireau en contexte archéologique : Taphonomie, archéozoologie et éléments de discussion des séquences préhistoriques*. Ph.D. dissertation, Bordeaux, Université Bordeaux 1.

Mallye, J.B. 2011. Badger (*Meles meles*) remains within caves as an analytical tool to test the integrity of stratified sites: the contribution of Unikoté Cave (Pyrénées-Atlantiques, France). *Journal of Taphonomy* 9, 15–22.

Martínez-Moreno, J., Mora Torcal, R., Roy Sunyer, M., and Benito-Calvo, A. 2016. From site formation processes to human behaviour: towards a constructive approach to depict palimpsests in Roca dels Bous. *Quaternary International* 417, 82–93.

Michel, A. 2010. *L'Aurignacien récent (post-ancien) dans le Sud-Ouest de la France : variabilité des productions lithiques. Révision taphonomique et techno-économique des sites de Caminade-Est, l'abri Pataud, Roc-de-Combe, Le Flageolet I, La Ferrassie et Combemenue*. Ph.D. dissertation, Bordeaux, Université Bordeaux 1.

McPherron, S.P. 2018. Additional statistical and graphical methods for analyzing site formation processes using artifact orientations. *PLoS ONE* 13(1): e0190195, doi.org/10.1371/journal.pone.0190195.

McPherron, S.P., Dibble, H.L., and Goldberg, P. 2005. Z. *Geoarchaeology* 20(3), 243–262.

Morin, E., Tsanova, T., Sirakov, N., Rendu, W., Mallye, J.-B., and Lévêque, F. 2005. Bone refits in stratified deposits:

testing the chronological grain at Saint-Césaire. *Journal of Archaeological Science* 32, 1083–1098.

Odell, G.H. 1981. The mechanics of use-breakage of stone tools : some testable hypothesis. *Journal of Field Archaeology* 8 (2), 197–209.

Odell, G.H. and Odell-Vereecken, F. 1980. Verifying the reliability of lithic use-wear assessments by "blind tests": the low power approach. *Journal of Field Archaeology* 7(1), 87–120.

Pelegrin, J. 1995. *Technologie lithique : le Châtelperronien de Roc-de-Combe (Lot) et de la Côte (Dordogne)*. Paris, Cahiers du Quaternaire 20, éditions du CNRS.

Pelegrin, J. 2000. Les techniques de débitage laminaire au Tardiglaciaire : critères de diagnose et quelques réflexions. In *L'Europe Centrale et Septentrionale au Tardiglaciaire : confrontation des modèles régionaux de peuplement*, Valentin, B., Bodu, P., and Cristensen, M. (eds.), Actes de la Table-ronde, Nemours 13-16 Mai 1997, Nemours, A.P.R.A.I.F. Mémoires du Musée de Préhistoire d'Ile-de-France, pp. 73–86.

Pelegrin, J., Karlin, C., and Bodu, P. 1988. « Chaînes opératoires » : un outil pour le préhistorien, In *Technologie préhistorique*, Texier, J. (ed.), Notes et Monographies Techniques n°25, Paris, Editions du CNRS, pp. 55–62.

Perlès, C. 1991. Économie des matières premières et économie du débitage : deux conceptions opposées ?, In *25 ans d'études technologiques en préhistoire : bilan et perspectives*, Juan-les-Pins: A.P.D.C.A. (Actes des XIe rencontres internationales d'Archéologie et d'Histoire d'Antibes), pp. 35–45.

Plisson, H. 1985. *Étude fonctionnelle d›outillages lithiques préhistoriques par l›analyse des micro-usures : recherche méthodologique et archéologique*. Ph.D. dissertation, Paris, University of Paris I.

Prost, D.-C. 1989. *Enlèvements accidentels, enlèvements d'utilisation et de retouche sur les outils de pierre taillée*. Ph.D. dissertation, Nanterre, Université Paris X Nanterre.

Quiles, J. 2003. *Les Ursidae du Pléistocène moyen et supérieur en Midi méditerranéen : apports paléontologiques, biochronologiques et archéozoologiques*. Ph.D. dissertation, Paris, Muséum National d'Histoire Naturelle.

Reimer, P.J., Baillie, M., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Burr, G., and Edwards, R.L. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon* 51, 1111–1150.

Rigaud, J.-P. 1996. L'émergence du Paléolitique supérieur en Europe occidentale. Le rôle du Castelperronien. In *The Lower and Middle Palaeolithic*. Bar Yosef, O. and Cavalli-Sforza, L., March, R., and Piperno, M. (eds.), Forli, ABACO, pp. 219–223.

Rios-Garaizar, J., Arrizabalaga, J., and Villaluenga, A. 2012. Haltes de chasse du Châtelperronien de la Péninsule Ibérique : Labeko Koba et Ekain (Pays Basque Péninsulaire). *L'Anthropologie* 116, 532–549

Romagnoli, F., Nishiaki, Y., Rivals, F., and Vaquero, M. 2018. Time uncertainty, site formation processes, and human behaviours: new insights on old issues in high-resolution archaeology. *Quaternary International* 474, 99–102.

Roussel, M. 2011. *Normes et variations de la production lithique durant le Châtelperronien. La séquence de la Grande- Roche-de-la-Plématrie à Quinçay (Vienne)*. Ph.D. dissertation, Nanterre, University Paris Ouest Nanterre-La Défense.

Roussel, M., Soressi, M., and Hublin, J.-J. 2016. The Châtelperronian conundrum: blade and bladelet lithic technologies from Quinçay, France. *Journal of Human Evolution* 95, 13–32.

Roussel, M., Bourguignon, L., and Soressi, M. 2009. Identification par l'expérimentation de la percussion au percuteur de calcaire au Paléolithique moyen : le cas du façonnage des racloirs bifaciaux Quina de Chez Pinaud (Jonzac, Charente-Maritime). *Bulletin de la Société Préhistorique Française* 106(2), 219–238.

Ruhe, R.V. 1959. Stone lines in soils. *Soil Science* 87, 223–231.

Scandiuzzi, R. 2008. *Les Tambourets (Couladère, Haute-Garonne) : un gisement châtelperronien de plein air, au seuil des Petites Pyrénées*. M.A. dissertation, Toulouse, University of Toulouse Le Mirail.

Semenov, S.-A. 1964. *Prehistoric Technology; An Experimental Study of the Oldest Tools and Artefacts from Traces of Manufacture and Wear*. London, Cory, Adams and Mackay.

Shaw, C.F. 1929. Erosion pavement. *Geographical Review* 19, 638–641.

Soressi, M. and Roussel, M. 2014. European Middle to Upper Paleolithic transitional industries: Châtelperronian. In *Encyclopedia of Global Archaeology*, Smith, C. (ed.), New York, Springer, pp. 2679–2693.

Stoops, G. 2003. *Guidelines for Analysis and Description of Soil and Regolith Thin Sections*. Madison, WI, Soil Science Society of America.

Tixier, J. 1978. *Méthode pour l'étude des outillages lithiques : notice sur les travaux scientifiques*. Ph.D. dissertation, Nanterre, Université Paris X Nanterre.

Tringham, R., Cooper, G., Odell, G.H., Voytek, B., and Whitman, A. 1974. Experimentation in the formation of edge damage. A new approach to lithic analysis. *Journal of Field Archaeology* 1(1–2), 171–196.

Vallin, L., Caspar, J.-P., Guillemet, G., Masson, B., and Ozouf, J.-C. 2013. Altérations des artefacts préhistoriques en silex par les processus périglaciaires: présentation des expériences conduites au Centre de Géomorphologie du CNRS de Caen. *Quaternaire* 24(3), 259–266.

Villa, P. 1982. Conjoinable pieces and site formation processes. *American Antiquity* 47, 276–290.

Villa, P. 2004. Taphonomy and stratigraphy in European prehistory. *Before Farming* 1, 1–20.

Weaver, T.D., Boyko, R.H., and Steele, T.E. 2011. Cross-platform program for likelihood-based statistical comparisons of mortality profiles on a triangular graph. *Journal of Archaeological Science* 38, 2420–2423.

Zilhão J. and d'Errico, F. 1999. The chronology and taphonomy of the earliest Aurignacian and its implications for the understanding of Neandertal extinction. *Journal of World Prehistory* 13, 1–68.

Zilhão, J., d'Errico, F., Bordes, J.-G., Lenoble, A., Texier, J.-P., and Rigaud, J.-Ph. 2006. Analysis of Aurignacian interstratification at the Châtelperronian-type site and implications for the behavioral modernity of Neandertals. *Proceedings of the National Academy of Sciences USA* 103, 12643–12648.

Zilhão, J., d'Errico, F., Bordes, J.-G., Lenoble, A., Texier, J.-P., and Rigaud, J.-Ph. 2008. Grotte des Fées (Châtelperron): history of research, stratigraphy, dating, and archaeology of the Châtelperronian type-site. *PaleoAnthropology* 2008, 1–42.

SUPPLEMENTARY DATA

Supplement 1. Detailed frontal and sagittal projections of some key artifact types (transects of 50cm "width/thickness") [pdf file].

Supplement 2. Field database with XYZ coordinates of plotted finds, assemblage attributed after spatial analysis, orientation and dip for Cassenade 2012 and 2013 excavations (including main sector and others) [Excel file].

Supplement 3. Code of the Bayesian models performed in OxCal to test the chronological ordering of occupations by hominids and hyenas in the upper part of Layer 2 [pdf file].