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

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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 hominin 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; Zilhão 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...
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-excitation 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 6m²) 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 16m² 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 ¼m² squares and spits of typically 2cm to 5cm.

![Figure 1. Site location (left) and general view from the north during excavations (right).](image-url)
All lithic artifacts and faunal fragments larger than 3 cm (in 2012) or 1 cm (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 2 mm and 4 mm 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.

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 test pit); and, b) synthetic geomorphological map (opening of the karstic corridor, exposed bedrock, and slope deposits).
The description of thin sections follows Stoops (2003). 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=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 Curran (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 spa-
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 hominin (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 modeling 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 non-parallel 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 pluri-decimetric 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 Pullleman 2010).

The diamicton 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 typical 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 desilificated (“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., argiliturberation or cryoturbation) or breaks resulting from rockfall or post-depositional processes (e.g., gelifraction).

Lithic Techno-Typology

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 chaîne 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).
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).

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).

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

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<td>on blade</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>87</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>25</td>
<td>227</td>
<td></td>
</tr>
</tbody>
</table>

* 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).
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 unmodified 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 (scrapping). 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-
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 slimmer edges, cf. d’Errico and Villa 1997). Three piece-plotted bones...
**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:

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).

---

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

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

*The total includes 21 pieces from the coarse fraction (i.e., >4mm) that could not be reliably attributed to a given assemblage.
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.
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 to 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.
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 bladedebitage (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-PIELED 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).
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 2 upper Hominids” phase, and dates on hyena teeth from Layer 2 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 2 upper Hominids” phase, and dates on hyena teeth from Layer 2 in a “Layer2 upper Hyenas” phase. These two phases were...
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 2 upper Hominids” and “Layer 2 upper Hyenas” phases. This allowed for the calculation of Start and End boundaries of occupations of Layer 2 upper 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 charcoal dates, one model was run for “Layer 2 upper Hominids” phase including this measurement, and another one excluding it (see Figure 14c). Considering doubts concerning the reliability of the Square K52 charcoal dates, one model was run for “Layer 2 upper 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 2 upper 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 is 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 2 upper 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.

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

<table>
<thead>
<tr>
<th>Assemblages</th>
<th>Occupation</th>
<th>Field ID</th>
<th>Description</th>
<th>Lab Code</th>
<th>d$^{13}$C</th>
<th>Radiocarbon Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Layer 2</td>
<td>Hyenas</td>
<td>I13-336$^1$</td>
<td>Hyena, tooth</td>
<td>Lyon-10013(SacA 32378)</td>
<td>NA</td>
<td>41500±1600</td>
</tr>
<tr>
<td>Layer 2, lower</td>
<td>Bears</td>
<td>K50-71</td>
<td>Bear, tooth</td>
<td>Lyon-10016(SacA 32381)</td>
<td>NA</td>
<td>37380±980</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K50-9</td>
<td>Horse, tibia</td>
<td>Lyon-10014(SacA 32379)</td>
<td>NA</td>
<td>35800±810</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K51-24</td>
<td>Horse, tooth</td>
<td>Lyon-10015(SacA 32380)</td>
<td>NA</td>
<td>39100±1200</td>
</tr>
<tr>
<td>Layer 2, upper</td>
<td>Hyenas</td>
<td>K52-235</td>
<td>Hyena, tooth</td>
<td>Lyon-15854(SacA 55571)</td>
<td>NA</td>
<td>37800±1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K53-3</td>
<td>Hyena, tooth</td>
<td>Lyon-15855(SacA 55572)</td>
<td>NA</td>
<td>33020±600</td>
</tr>
<tr>
<td>part</td>
<td></td>
<td>K52-125,</td>
<td>Charcoal fragments</td>
<td>OxA-30956</td>
<td>-25.32</td>
<td>32950±450$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>126, 127 &amp; 138</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hominids</td>
<td>J52-487</td>
<td>Horse, metatarsal with cut-marks</td>
<td>OxA-31475</td>
<td>-20.30</td>
<td>38400±900</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OxA-31476</td>
<td>-20.34</td>
<td>39300±1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K52-30</td>
<td>Bovinae, metatarsal with cut-marks</td>
<td>OxA-31477</td>
<td>-19.79</td>
<td>36600±750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K53-88</td>
<td>Mammal size 3/4, long bone with cut-marks</td>
<td>OxA-31478</td>
<td>-20.31</td>
<td>35850±700</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OxA-31479</td>
<td>-20.27</td>
<td>34950±650</td>
</tr>
</tbody>
</table>

$^1$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.
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 hyenas, 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 palaeotopography 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 addressed 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 occurrences (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-depositional 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 Tambourrets), 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; Scanduzio 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; Machado and Pérez 2016; Machado et al. 2013; Malinsky-Buller et al. 2011; Mallory 2007, 2011; Martinez-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 contained within a single layer, spatial data often remains underused. Generally, spatial analyses are restricted to questions of intra-layer horizontal patterning (XY artifact...
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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].
