Technologies for the Control of Heat and Light in the Vézère Valley Aurignacian

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Online enhancements: supplemental figures

We can trace the beginnings of our knowledge of early Upper Paleolithic (Aurignacian) use of fire to the pioneering 1910–1911 excavations at Abri Blanchard undertaken by Louis Didon and Marcel Castanet. At Blanchard, the excavators recognized and described fire structures that correspond in many ways to features excavated more recently in Western and Central Europe. Here, we address the issue of heat and light management in the early Upper Paleolithic, demonstrating a pattern that builds on these early excavations but that is refined through our recent field operations. Topics to be discussed include (1) recently excavated fire structures that suggest complex fire management and use, (2) the seemingly massive use of bone as fuel in most early Aurignacian sites, and (3) the anchoring of skin structures for purposes of heat retention with fireplaces behind animal-skin walls. Furthermore, new data on activities around fireplaces make it possible to infer social and organizational aspects of fire structures within Aurignacian living spaces. The vast majority of early Aurignacian occupations, most of them now dated to between 33,000 and 32,000 BP (uncalibrated), occurred on a previously unoccupied bedrock platform into which the occupants dug their fire features.

The use of fire has long been recognized as a key innovation in human evolution as a source of light and heat, a mechanism for cooking (Chazan 2017; Villa, Bon, and Castel 2002; Wrangham 2017), and a focal point for fireside activities and social bonding (Alperson-Afil 2008; Fernández Peris et al. 2012; Karkanas et al. 2007; Roebroeks and Villa 2011; Stahlschmidt et al. 2015; Wiessner 2014; Wrangham and Caromed 2010). Often, however, we are overly preoccupied with the earliest occurrences of fire rather than its use in cultures where we have long known controlled fire to be present.

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Our research on classic sites in the Aurignacian shows that not only was fire an essential part of life for human groups during this time but that it was manipulated and used in a standardized and consistent manner within an overarching system of heat and light capture and control. This includes altering the limestone bedrock to create concavities in which the fires sat and the creation of adjacent structures for the control and manipulation of different types of heat (e.g., the removal of hot coals from the primary fire feature to an adjacent location for a special use) and light (portable lamps).

In this paper, we will first present a series of early Aurignacian sites from the Vézère Valley, combining our recent interventions as well as observations from early excavations. A clear pattern will emerge: at site after site, the earliest Aurignacian occupation sits directly on the bedrock, dates to between 32,000 and 33,000 years BP (uncalibrated), and exhibits complex fire structures within human-made depressions in the bedrock. The quality of information for each of these fire structures depends on when they were excavated, but a clear pattern can nevertheless be established. We do have a particularly clear window on this pattern, however, that derives from our recent excavations at Abri Castanet. Between 2005 and 2010 we excavated an interconnected set of fire structures that is testament to the sophisticated management of fire in the Aurignacian. Finally, we will discuss a few key topics relevant to the management of fire, heat, and light in the early Aurignacian. These include the organization of activities around fire structures, use of bone or wood as fuel, and the production of *pierres à anneaux*, rings carved in the limestone to enclose the rock-shelter with skins and retain heat. Many of our inferences surrounding these topics make use of an abundance of experimental research over the past 20 years that has sought to investigate cultural and natural formation processes of combustion-related features (see, e.g., Aldeias 2017; Costamagno et al. 2010; Lejay et al. 2016; Miller et al. 2010; Théry-Parisot et al. 2002).

Classic Aurignacian Sites of the Vézère Valley and Associated Fire Structures

Abri Castanet and Abri Blanchard

When Marcel Castanet discovered a complex of fire features at Abri Blanchard in May 1910, he and his employer, Louis Didon, were ill equipped to understand the importance of this find, and given the state of knowledge before World War I, they had few points of comparison. Castanet drew a rough sketch in plan view (fig. 1), and after having recovered many spectacular artifacts associated with these fire features, he simply backfilled the entire area containing the fire pits. Nearly 6 months later, in October 1910, Didon asked Castanet to reexpose the fire structures so that he could observe them himself. While there are allusions to photographs taken by Didon, these appear not to have survived. The only record is that plan view sketched by Castanet on May 21, 1910 (fig. 1), which shows one large elongate feature and three smaller satellite features all dug into the friable limestone bedrock.

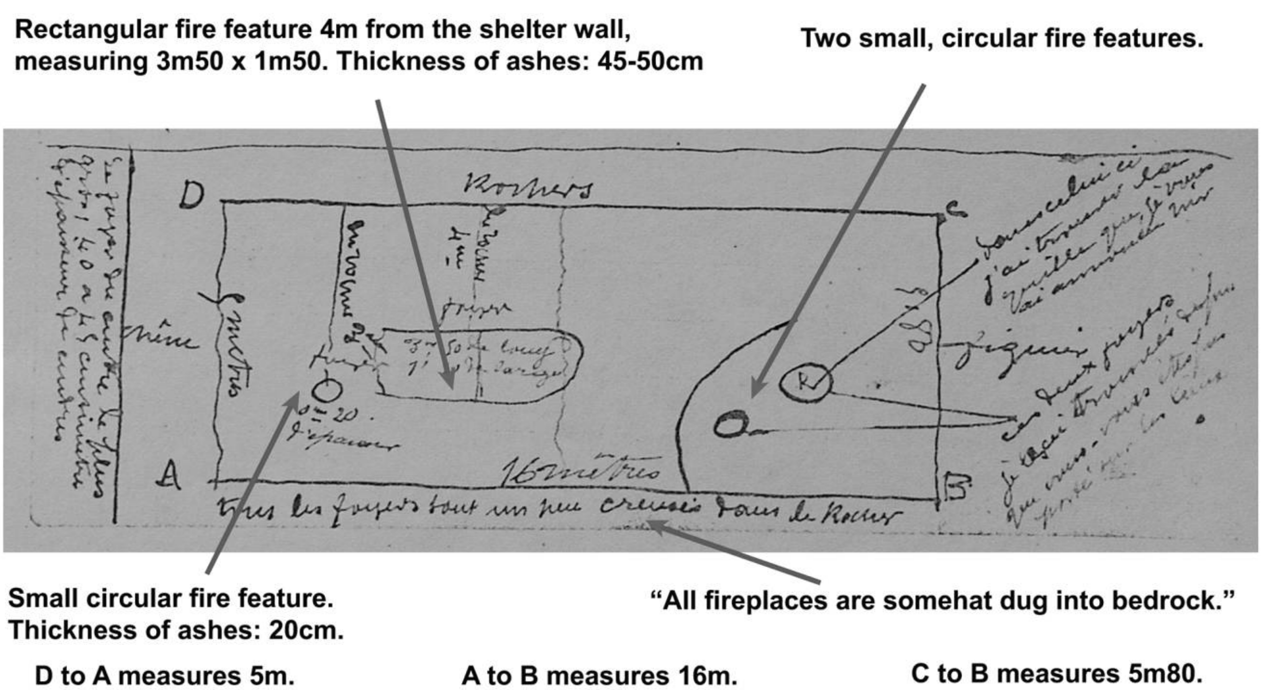

Figure 1. Castanet’s May 21, 1910, plan view of the fire features at Abri Blanchard, annotated and translated. L. Didon archive (cf. Delluc and Delluc 1978). A color version of this figure is available online.

In the Blanchard publication, Didon (1911) described the fire features as follows.

> The four hearths were constituted of shallow pits dug into the bedrock terrace. Three of the pits were circular, with an approximate diameter of 0.5 m and a depth of 0.2 m. The fourth, rectangular with semicircular extremities, measured 3.5 m long by 1.5 m wide, with a depth of ca. 0.4 m. They were infilled with ash and calcined bone. Because of the thickness of this layer, the ashes seemed to date to the previous day, and certain blocks of the material, a sort of breccia composed of ashes and conglomerated bones, were really impressive. I kept one of these blocks, and it was as if one needed simply to blow on it to revive the fire that had been extinguished so many centuries ago.

Didon describes these remarkable breccia-like blocks with greater detail in a letter to Breuil in February 1911, 4 months after the pits had been reexposed by Castanet.

> Yesterday, I retrieved from a case some hearth fragments. I use the term "hearth" in the usual sense of the word because these are far from being simple chunks of breccia. One block, 30 × 12 cm, was composed of large fragments of carbonized bone and reindeer antler with ashes adhering to them. It seemed as if one simply needed to blow on them to reignite the fire; it is very impressive. I retrieved them from the depressions dug into bedrock (by the Aurignacians).[1]

Beginning in 1911, Denis Peyrony employed Marcel Castanet to excavate the Abri Castanet, situated on the same bedrock platform just 50 m to the south of Abri Blanchard. At Abri Castanet, as at Abri Blanchard, the Aurignacian I layer (Peyrony's layer A) sat directly on bedrock. Following the excavation of this layer, Peyrony (1935) described and illustrated precisely the same kinds of fire features dug into the bedrock as those found at Abri Blanchard (see fig. S1; figs. S1–S15 available online). He observed four features, one of them 1.3 m long. He noted, as had Didon before him, that the most spectacular artifacts were concentrated around these fire features. At Blanchard, this Aurignacian I layer has now yielded to our team two hydrozyproline dates on mammal bone of 33,420 ± 350 and 33,960 ± 360 BP (uncalibrated; Bourrillon et al., forthcoming), and at Castanet, 15 ultrafiltration dates on bone give an average age of 32,400 BP for the same layer (White et al. 2012). We will return to Castanet later in this paper to describe our recent excavation of four such fire features within the previously unexcavated southern portion of the site.

La Souquette

Blanchard and Castanet are situated at the base of the cliffs on the eastern slope of the small Castel-Merle valley. The opposing western side of the valley has also yielded a rich early Aurignacian site, the Abri de la Souquette, just 50 m across the valley from Abri Blanchard. Unfortunately, because of late medieval quarrying and massive pillaging at the beginning of the twentieth century, only a small fragment of the site was available for modern excavations by Roussot (1982) in the 1980s.[2] Roussot observed and excavated a few square meters of the Aurignacian I level, situated directly on bedrock (see fig. S2).

We have been able to analyze and date this early Aurignacian assemblage, which is virtually identical in its contents (typologically, technologically, artistically) to Blanchard (lower level) and Castanet (lower level in the northern and southern sectors). Although no preserved fire features were discovered in the small area of Roussot's excavations, reindeer bone fragments from this level yielded molecular filtration dates of 32,400 ± 500 BP and 32,150 ± 450 BP (dates uncalibrated; O'Hara et al. 2015). This information from La Souquette reinforces the pattern that in the Vézère Valley, the first Aurignacian I occupation occurred directly on bedrock and dates to around 32,000 BP uncalibrated.

Abri Cellier

In the summer of 1927, George Collie from Beloit College, Wisconsin, undertook excavations at Abri Cellier (Collie 1928; White and Knecht 1992) near Le Moustier in the Vézère Valley. Although there is some stratigraphic confusion (White 1992; White and Knecht 1992), our return to the site in 2014 did much to clarify the situation (figs. 2, S3; White et al., forthcoming). As at Abri Castanet and Abri Blanchard, the initial occupation of the site by early Aurignacian groups was on an exposed bedrock platform. It was only late in the excavation that Collie recognized bedrock at the site and thus did not clearly observe related fire features. In cleaning the bedrock surface in 2014, we were nonetheless able to observe fire-reddened depressions (*cuvettes*) on the surface of the bedrock and were even able to excavate highly calcined deposits within a residual fire pit feature preserved in a deep hollow in the bedrock (fig. 3). Bone from this structure yielded an ultrafiltration date of 33,600 ± 550 BP (White et al., forthcoming). We were struck by the similarity of the Cellier features to those described at Blanchard and especially to those described by Peyrony (1946) and excavated by us at Abri Castanet.

Abri Pataud

In his excavations at Abri Pataud, Movius (1966) paid particular attention to fire features. Those in layer 14, situated directly on bedrock, are indistinguishable from those described above in having been excavated into the bedrock platform (fig. 4).

Other sites in the Vézère have yielded the same pattern of occupation by Aurignacians directly on bedrock with instal-

1. Périgueux, February 2, 1911, Louis Didon to H. Breuil, Breuil Archive, Muséum National d'Histoire Naturelle, Paris.

2. Also, A. Roussot, unpublished administrative report, "Abri de la Souquette, Commune de Sergeac Dordogne. Rapport de Fouilles. Récapitulatif, 1980–1982."

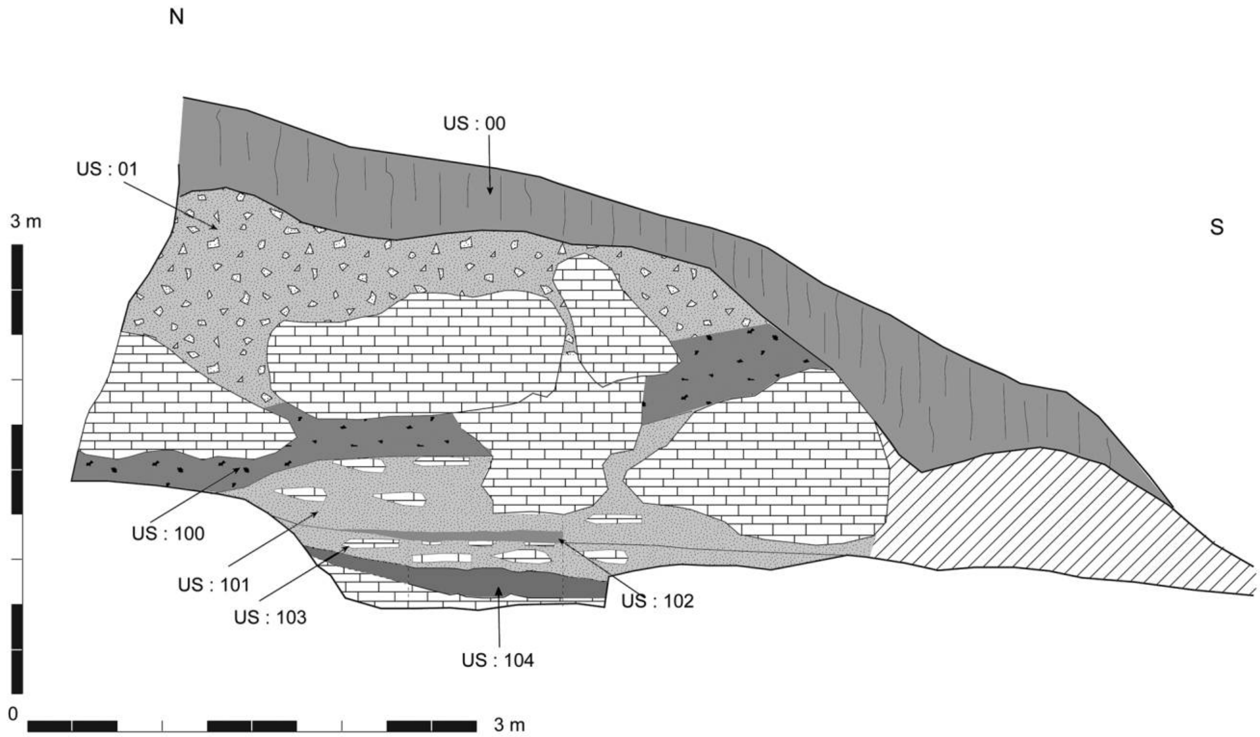

Figure 2. Stratigraphic section on the eastern extremity of the Abri Cellier (from White et al., forthcoming). Layer 104 at the base of the sequence is an early Aurignacian level directly on bedrock. A color version of this figure is available online.

lation of fire features directly on or in the fractured and spalled limestone surface (Delporte 1968). However, we have restricted our discussion here to those with which we have personal experience. It is worth noting, however, that where the early Aurignacian is followed by later Aurignacian levels within the same stratigraphic sequence, such as at Abri Pataud and Abri du Facteur, there is significant change through time in hearth structure (e.g., cobble lining) and arrangement (Delporte 1968; Movius 1966).

Returning to Castanet

Our own excavations at Abri Castanet between 2005 and 2010 focused on what appeared at first to be a massive and diffuse fire feature (stratigraphic unit 109) that resolved into three separate features as we descended through the layer (the equivalent of Peyrony's layer A; fig. 5). All three of these features were excavated by the Aurignacians into the bedrock platform by removing a number of plaquettes of which the bedrock is constituted. These three features are named Structures 216, 217, and 218 (see fig. S4).

Excavation Strategy and Techniques

The meticulous, but routine excavation of the overlying, undifferentiated black stratum (our US 214), allowed us to identify a spatially extensive (ca. 2.6 m^2) feature, which seemed at first encounter to be either (1) several adjacent fire structures, (2) a single combustion feature having been subjected to postdepositional alteration, (3) an ash dump, or (4) all of these at the same time.

In order to evaluate the relative merits of these different hypotheses, we moved from excavation in .25 m^2 units to a .0625 m^2 grid. We sought to sample and provenience all the fine-fraction bulk sediment in order to record, quantify, and situate in three-dimensional space all of the products and residues of combustion. Our objective was to treat raw sediment samples in the laboratory in order to detect, recover, and study microvestiges of combustion such as charcoal, burned bone, and phytoliths.

In complement to the recovery of bulk sediments, we undertook the extraction, embedding, and micromorphological study of oriented blocks of in situ sediment. Micromorphology sought an understanding of the microstratigraphic context of each sample and a characterization of the taphonomic processes underlying the nature and distribution of macromicrovestiges recovered from the raw sediments.

As we descended through the fire feature, it became apparent that the diffuse black deposit (our stratigraphic unit 214) resolved into three observable structures, which we labeled 216, 217, and 218. We continued to employ the same fine-grained procedures but now carefully separated the bulk samples from adjacent structures 217 and 218.

Structure 216 posed special problems because it contained little sediment, and its heavily calcined bone infilling did not

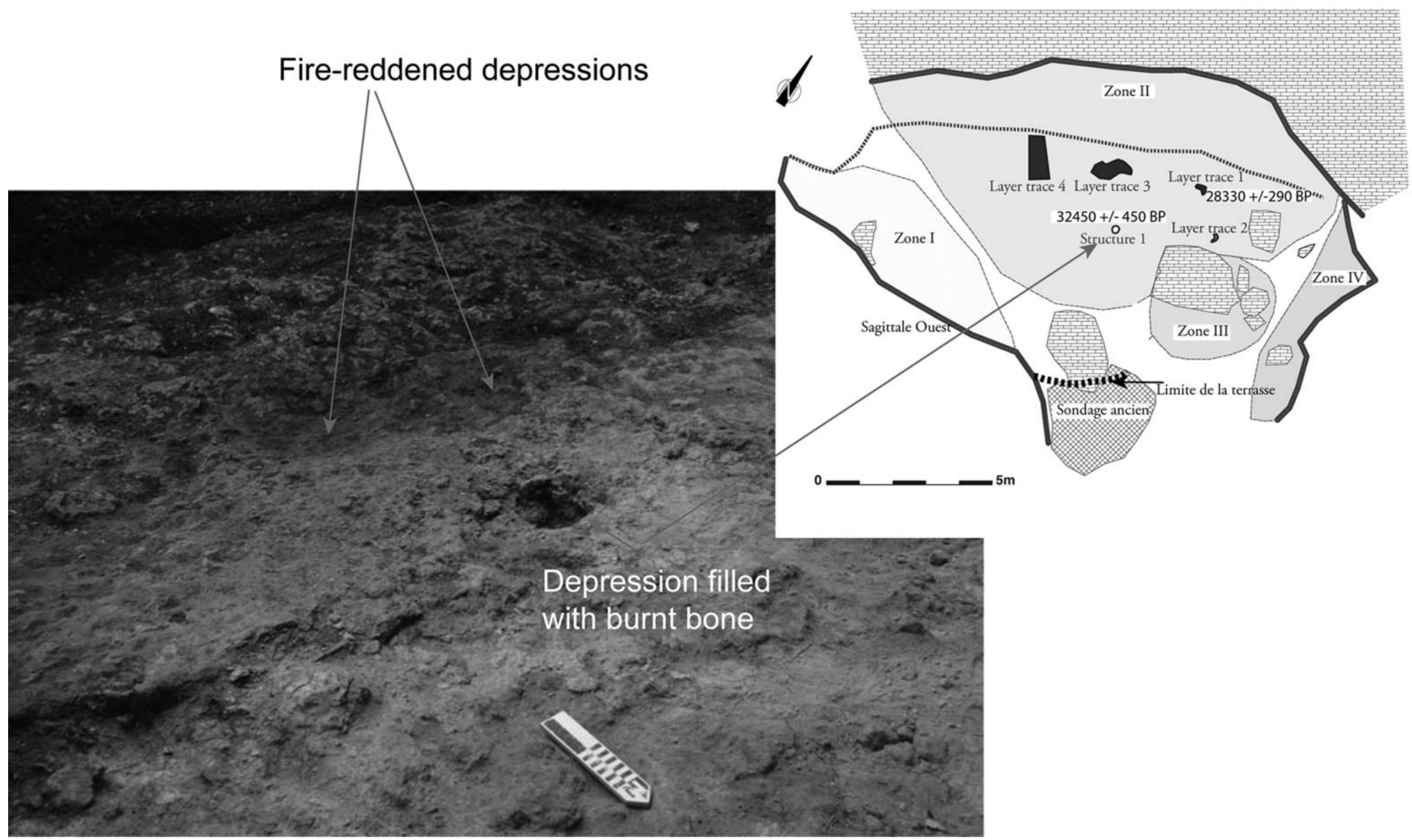

Figure 3. Abri Cellier, cleaned bedrock with small fire pit adjacent to two large fire-reddened depressions excavated by the Aurignacians into the underlying bedrock. A color version of this figure is available online.

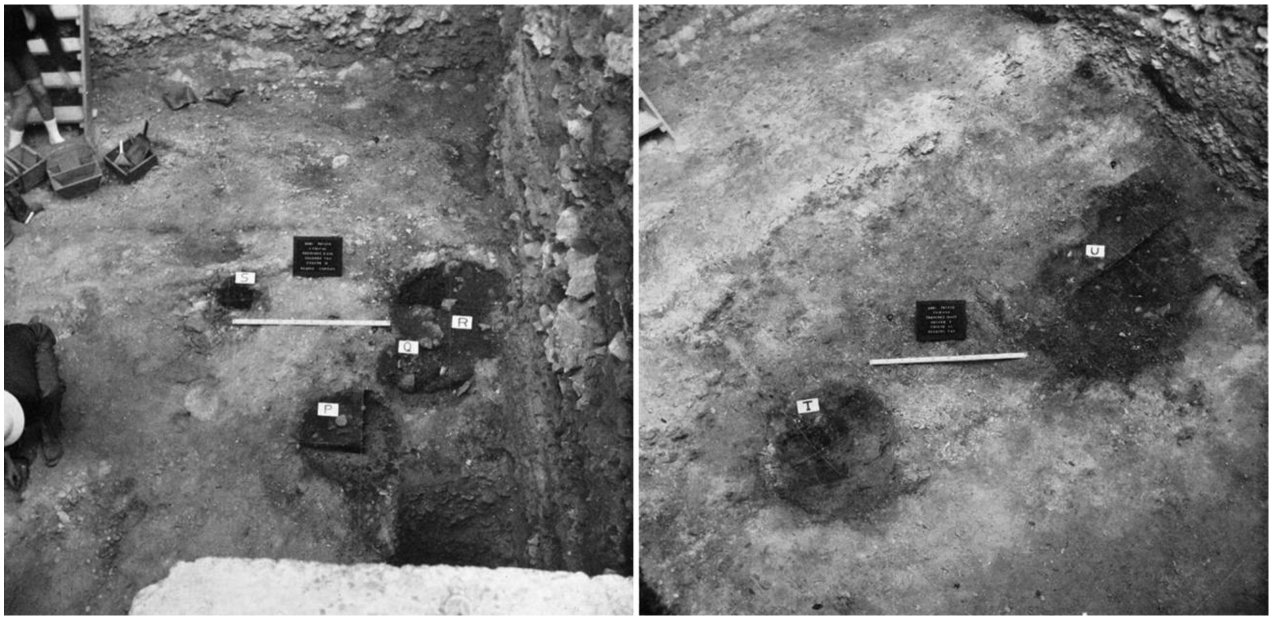

Figure 4. *Left*, Abri Pataud, early Aurignacian layer 14, hearths T and U in square B of trenches 3 and 4. Hearth T is completely excavated, leaving only a depression in the bedrock (from Movius 1966). *Right*, Abri Pataud, early Aurignacian layer 12, fire pits of differing dimensions, including a small feature filled with burned bone as at Castanet and Cellier (from Movius 1966).

permit normal excavation because osseous tissue simply fell to dust under the slightest tool contact. The decision was made to remove the entire contents in bulk, again controlling the microstratigraphy with micromorphological samples.

Magnetic Susceptibility

In 2010, we performed magnetic susceptibility analysis (Brodard et al. 2016; Lecoanet, Léveque, and Ambrosi 2003; Lecoanet, Léveque, and Segura 1999) of the excavated area, including the observed combustion features. One of the objectives of mapping the magnetism of the substratum and immediately overlying deposits is to distinguish between zones where combustion occurred in situ and those of secondary deposition. Because the underlying Coniacian bedrock showed virtually no magnetic signal, the surprisingly intense magnetic signal observed at Castanet had to emanate from the structures' infilling. Our microvestige analysis of the fire features' contents enabled us to demonstrate that each of the three structures contained high frequencies of iron oxides and kaolinite at both microscopic and macroscopic scales. During combustion these were transformed to magnetite and took on the prevailing planetary magnetic field. The three structures appear to be contemporaneous and to have functioned more or less independently. Some of the conclusions of the magnetic analysis will be presented below.

Structure 216

This small fire feature, dug into the bedrock platform, was roughly 30 cm in diameter with a maximum depth of 20 cm. It contained a dense deposit of burned and calcined bone with no interstitial sediment except some heat disaggregated limestone bedrock.

Structure 216 contained only 29 lithic pieces, two of which refit with a piece from Structure 218. All three are fire exploded. Another piece refits with six others from outside the fire features per se. All seven pieces are products of the creation of a carinate scraper/core blank (Chiotti and Cretin 2011). The constituents of both of the above refits are from the same block of flint.

The infilling is identical to that of Structure 217 with respect to oxidized residues, but the magnetic signal is less intense, leading to the suspicion that the contents of Structure 216 were extracted from Structure 217 while still hot. At its summit, this fire feature had a large portion of a burned bovid horn core (visible in fig. S5). Observations at all scales converge to suggest that the nature and function of this feature are radically different from Structures 217 and 218. In its absence of sediment and dominance of burned/calcined bone, Structure 216 resembles very closely the small fire features with "breccia" described by Didon at Abri Blanchard, and it is very similar to residual structure 1 from Abri Cellier.

Structures 217 and 218

Structure 217 is a roughly circular structure with a diameter of ca. 0.6 m, bordered on the west by six vertically arranged *plaquettes* that close off the northwest side of the structure the margins of which are otherwise formed by the contours of the depression dug into bedrock by the Aurignacians. Two profiles excavated into structure 217 show its infilling and topography (see fig. S7). It contained 64 lithic pieces, none

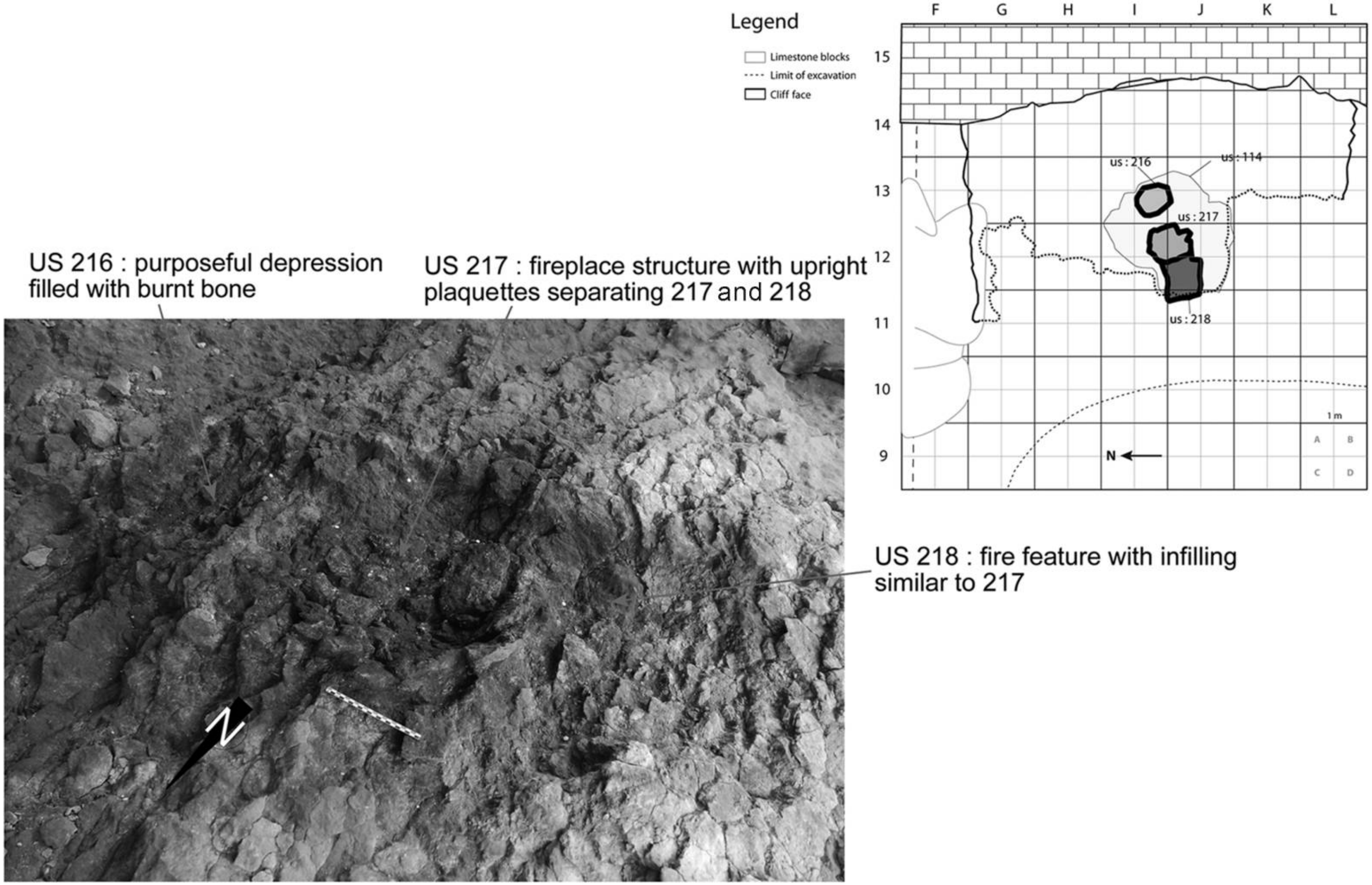

Figure 5. Castanet southern sector with "footprints" of three distinct fire features after excavation. Grid in square meters divided into one-quarter square meters. A color version of this figure is available online.

refitting with the other fire structures. All other refits were internal to one of the fire structures.

Magnetic susceptibility and micromorphology (see figs. S8–S10) indicate that Structure 217 is relatively well preserved and that combustion took place there. In contrast, Structure 218 is magnetically heterogeneous, suggesting that the contents are not at the site of original combustion. Possibilities include an ash dump or an overflow of ashes and combusted material from Structure 217 that were subsequently subjected to trampling (see Schiegl et al. 2003). Curiously, 217 and 218 each had an unburned cervid mandible on their upper surfaces. Structure 218 yielded 73 lithic pieces with a single, heavily burned piece refitting with two pieces from Structure 216 also heavily burned.

Although we refer to 216, 217, and 218 as "structures" in the plural, these features appear to have been components of one large, simultaneously utilized fire complex. From the evidence presented above, we can infer that Structure 217 was used as the primary fire location, and its contents were moved to Structures 216 and 218 for different purposes. Hot bone embers seem to have been moved to Structure 216, probably as a way to control heat and flame for special tasks as yet undetermined. Structure 218 was, at the very least, a dumping location for the contents of Structure 217, but it may have served more diverse purposes as well. The abundance of fire-altered iron oxides within these features raises the possibility of heat processing of this material for coloring and/or abrasive functions, an idea supported by thick deposits of paint (or at least ochre paste) on the bedrock adjacent to Structure 217 (fig. S11). In sum, this fire complex indicates a highly specialized and systematic use of fire that is spatially distinctive. An additional feature was found at Abri Castanet southern sector, residual structure 1, situated approximately 3 m from the 216, 217, and 218 complex (see fig. S6).

The spatial orientation of these three fire structures was found replicated at Abri Cellier when we uncovered the bedrock (described above). Not only did we find a feature that appeared to be a direct analogue to Structure 216, but adjacent to this structure were two fire-reddened concavities in the bedrock (fig. 6) that were the same size and orientation as Structures 217 and 218.

Similar fire complexes were probably excavated by Didon and Peyrony (or more accurately, Castanet) but were not observed as such. In particular, the large rectangular fire structure found at Blanchard and described by Didon and Castanet (fig. 1) is suspiciously similar to our perception (in descending) of a single spatially extensive feature before careful excavation revealed that it was made up of three interconnected but distinct structures.

Activities Concentrated around the Fire Features: Examples of Osseous Industry and Ornaments

The surface excavated by us at Castanet amounts to about 30 m^2. A single level is present. This layer is dense with faunal remains, debris from the final stages of production of lithic and osseous tools, fragments of colorants such as ochre and hematite, and debris from the production of personal ornaments. Much of this constitutes the refuse from a diversity of activities that took place around the fire features. As is the case for many Paleolithic and ethnographic sites (Binford 1998; Gamble 1991; Hahn 1988; Miller et al 2010; Rigaud and Simek 1991; Stapert 1989; Surovell and Waguespack 2007; Vaquero and Pastó 2001), the fire features at Castanet served as a focal point or "tether" for activities within the site.

It is noteworthy that carinate scrapers/bladelet cores were produced around these fire features (Chiotti and Cretin 2011), and resulting microbladelets are abundant. However, the blades and flakes that served as blanks for these and other retouched lithic tools were produced somewhere outside of the excavated area. Not a single flint blade or flake core has been recovered from the 30 m^2 excavated area of the southern sector of Abri Castanet. The act of blade/flake production, resulting in messy and dangerous by-products, seems to have been excluded from the living space immediately surrounding the Castanet fire features.

Two activities exemplify this pattern: osseous tool/weapon manufacture and use, and personal ornament manufacture and use. It is particularly interesting to contrast the spatial location of formal finished artifacts and their production debris.

Osseous Tool/Weapon Manufacture and Use

Observed patterns in the distribution of different formal categories of osseous tools, weapons, and debitage and the distribution of burned and unburned osseous pieces almost certainly reflect functional differences among fire features and the spatial organization of different activities associated with them. Fine-grained proveniencing permits a number of specific observations.

Almost all formal osseous artifacts are situated outside the perimeter of the three combustion features 216, 217, and 218 (fig. 6), and none are burned. Split-based antler points and the tongued pieces related to their production (Tartar and White 2013) are concentrated to the south of these features. Smoothers (*lissoirs*) are concentrated at the northeastern margins.

Bone retouchers, intermediate tools such as wedges and chisels, as well as bone and antler waste and debitage products bearing technical stigmata show no special distribution (apart from four retouchers found adjacent to the 1995–1998 fire feature 1). Some of these objects are found outside of the fire structures per se but within the perimeter (near its eastern limit) of the diffuse cloud of black sediment (US 109) encountered in descending through the layer (dotted outline on fig. 6) before the three fire features revealed themselves.

Small burned pieces of antler ($N = 55$) showing no technical traces are abundant in both Structures 217 and 218 as well as in the area just to their north, but they are entirely

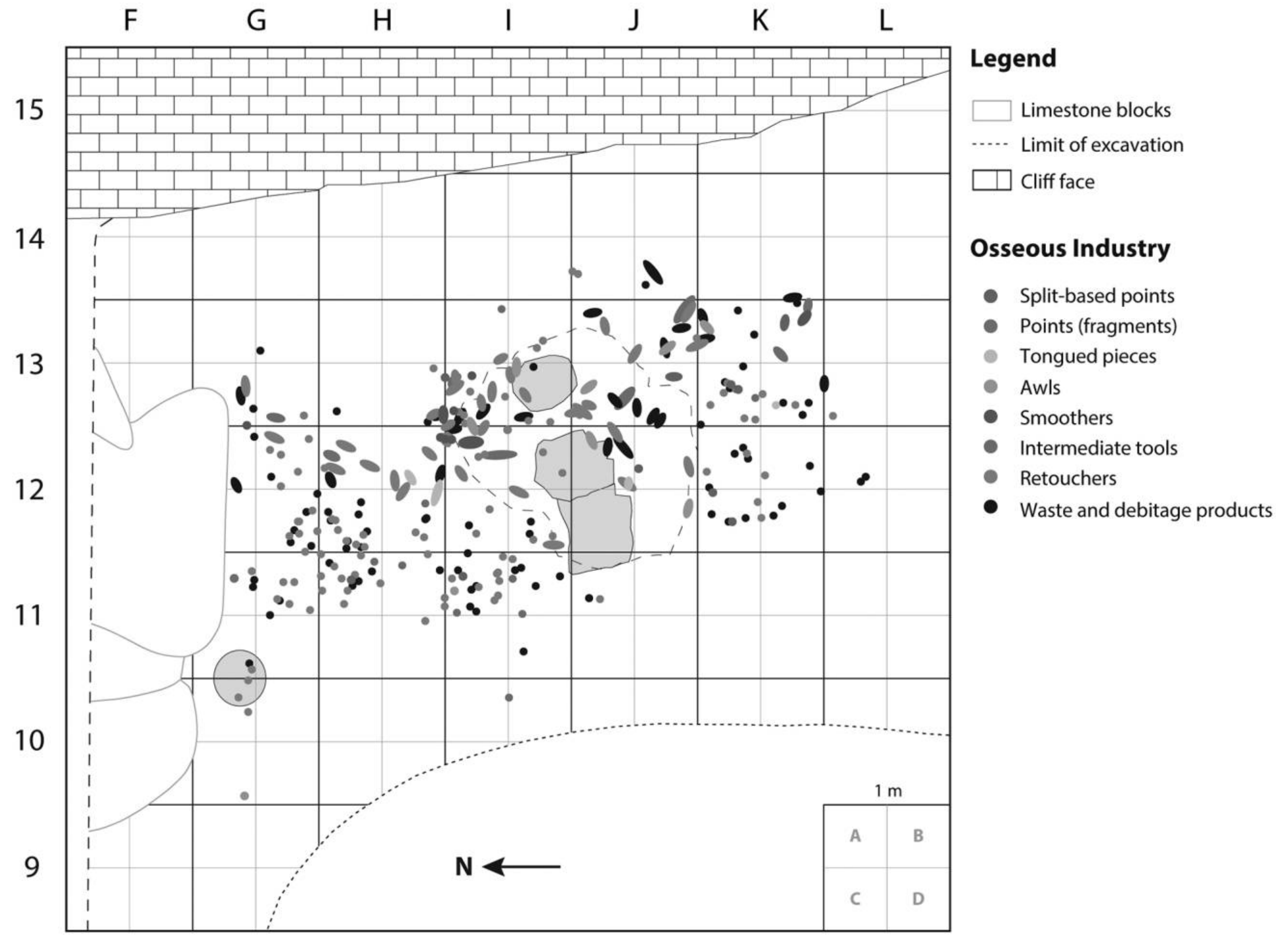

Figure 6. Spatial distribution of principal categories of osseous objects that make up the bone and antler industry in the southern sector of Abri Castanet. Grid in square meters divided into subsquares of one-quarter square meter. A color version of this figure is available online.

absent from Structure 216. The abundance of these nondietary faunal remains in Structures 217 and 218 might result from the first steps of antler exploitation that were somehow linked to these structures. If so, Structure 216 was not involved in such activities.

Personal Ornament Manufacture and Use

The distribution of objects linked to personal ornaments and their production is equally suggestive. Raw ivory fragments imply the on-site reduction of large chunks of subfossil mammoth tusks. The creation of usable blanks by direct percussion and torsion of fragments of old tusks seems to have been the objective. The morphology of the by-products of this percussion varies from small flakes and splinters from the external tusk layers to angular fragments of complex morphology emanating from direct percussion of the interior parts of already desiccated tusks. Fresh tusks cannot be worked in this way. The spatial distribution across the entire excavated area (fig. 7) is consistent with fragments being projected during high-impact direct percussion (Heckel and Wolf 2014).

Farther along the bead production chain, unfinished bead stages have a different distribution, with important concentrations to the north and west of the Structure 216, 217, 218 perimeters. Both raw ivory fragments and unfinished production stages show concentrations in square H12, while that square does not contain a single finished bead (fig. 7).

Finished, unbroken beads show two hot spots, one to the north of 217–218 and the other toward the southeastern extremity of the excavated area (fig. 7). Broken, finished beads (not shown) have a broader distribution, suggesting loss due to breakage during use.

The spatial organization of the two examples presented here, osseous technology and personal ornaments, indicate that some spatial patterning between production debris and finished products can be observed around the fire features at Abri Castanet. The presence of both production debris and finished products indicates that the fire features were a focal

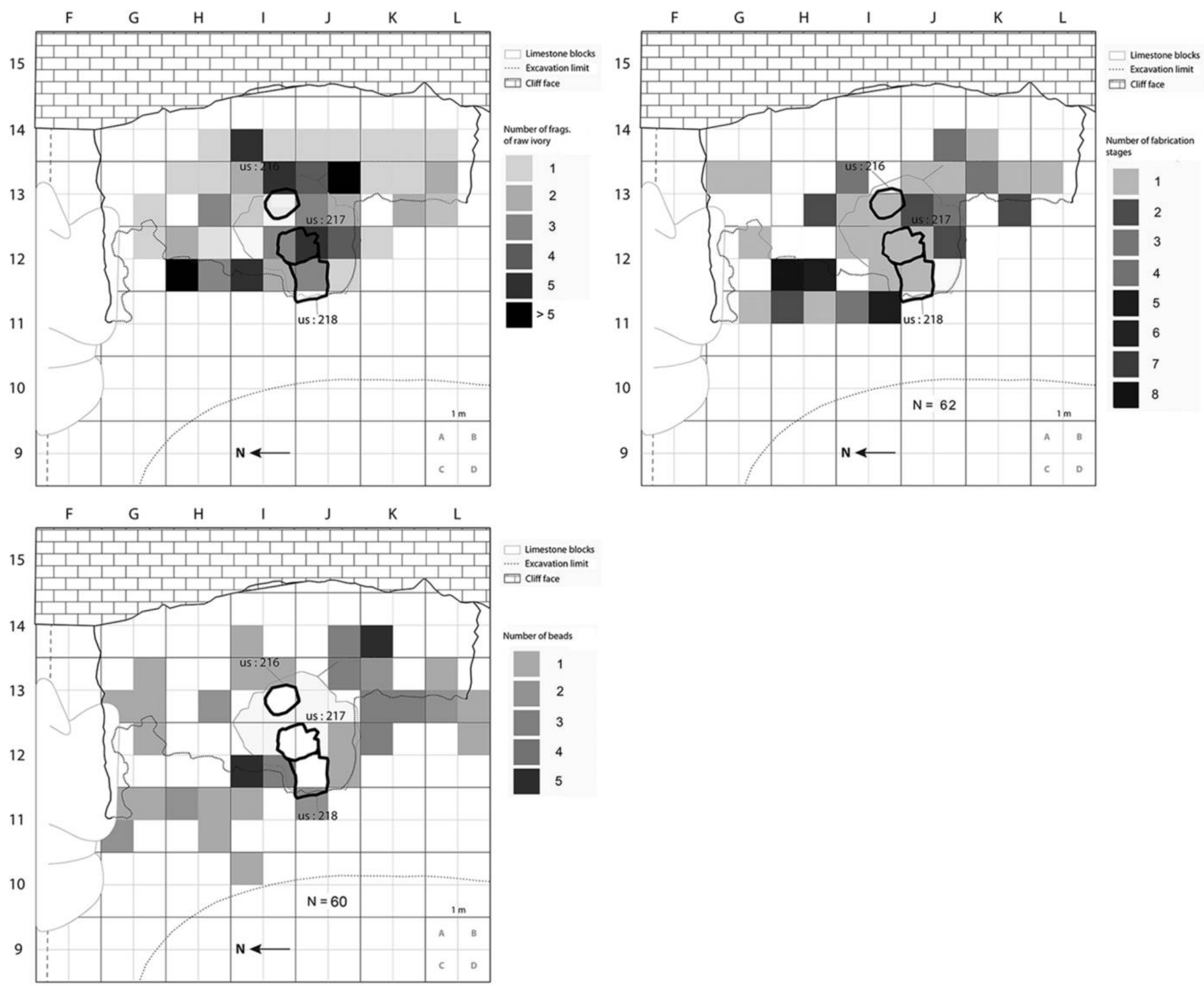

Figure 7. In all cases the grid is in square meters divided into subsquares of one-quarter square meter. *Top left*, Abri Castanet, southern sector, 1995–2010. Shading indicates frequency per one-quarter square meter of raw ivory fragments. *Top right*, Abri Castanet, southern sector, 1995–2010. Distribution of stages 1–4 of the basket-shaped bead production chain. Shading indicates frequency per one-quarter square meter of unfinished objects. *Bottom*, Abri Castanet, southern sector, 1995–2010. Spatial distribution of finished ivory basket-shaped beads including fragments. Shading indicates frequency per one-quarter square meter of finished beads. A color version of this figure is available online.

point for a diversity of activities that were concentrated around its borders.

Use of Bone as Fuel

Early Aurignacian sites in southwest France are famous for yielding very high frequencies of burned and calcined bone with relatively little wood charcoal being present (Costamagno et al. 2005; Marquer et al. 2010; Théry-Parisot 2001, 2002; Théry-Parisot et al. 2002). While this has often been interpreted as reflecting an emphasis on bone as fuel in Pleistocene landscapes where tree cover is minimal, the link to low tree-cover environments is not always agreed on.

Microcharcoal analysis (Marquer 2010; Marquer et al. 2010, 2015) of the Castanet fire feature contents provides new insights into the observed predominance of bone and scarcity of wood charcoal there. In fact, controlled sieving of the fire feature contents yielded an abundance of microscopic wood charcoal (microscopic charcoal results from combustion processes and secondary fragmentation of macroscopic charcoal), almost all of -it with a particle size of less than 63 μm (fig. 8). Therefore, while bone was certainly used as a fuel at Castanet, the abundance of wood charcoal at smaller particle sizes indicates that wood played a much more important role than was previously assumed. In sum, wood charcoal appears to be invisible to the usual array of recovery techniques because of taphonomic or cultural processes that remain to be determined (Marquer et al. 2010, 2012).

The pattern found at Castanet does not necessarily extend to all early Aurignacian sites; although Marquer et al. (2010) found an abundance of microscopic charcoal at Abri Pataud, burned bone still dominated all size fractions (Marquer et al. 2010). Bone, however, is less susceptible to taphonomic processes than is charcoal (Marquer et al. 2010), and based on rates of bone combustion established by experiments performed by Théry-Parisot (2002), an overly high dependence on bone as fuel would result in the improbable situation of humans hunting to feed the fire. It cannot be assumed that bone was more plentiful than wood in the environment; indeed, neither were plentiful, and Aurignacians likely exploited any and all fuel sources available to them. It is therefore most likely that both wood and bone were utilized as fuel in ratios that varied by availability but that, in general, the use of wood in early Aurignacian sites is underestimated.

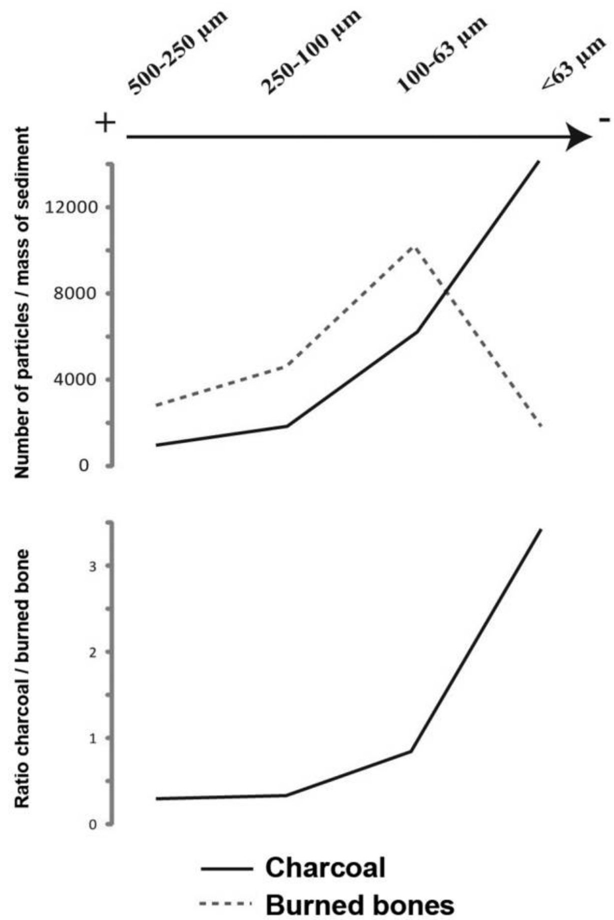

Figure 8. Numbers of fragments and particles of charcoal and burned bones and their ratios relative to size classes of the recovered samples.

Heat and Light Capture and Retention

Maximization of heat and light would have been beneficial to Upper Paleolithic hunter-gatherers in the late Pleistocene lower midlatitudes of late Pleistocene Europe. It has long been recognized that in the Vézère Valley, the very placement of their occupations (see fig. S12) was an accommodation to these concerns (White 1983, 1985). While the advantage of solar energy capture on south-facing cliff faces is significant (Bouvier 1967; Legge 1972), it should not be forgotten that at the latitude of the Dordogne, winter days are short (8 hours, 47 minutes of daylight at the winter solstice compared to 15 hours, 35 minutes at the summer solstice[3]), and south orientation would have provided maximum daily light.

A common occurrence in Vézère Valley early Aurignacian sites is that of so-called *pierres à anneaux*, limestone blocks and slabs with a distinctive form of a carved ring. Castanet, Blanchard, La Souquette, Cellier (fig. 9), and Pataud have all produced these. At Blanchard and Castanet, these were observed to be concentrated along the supposed original drip line of the shelter (Didon 1911; Peyrony 1935). In the last year of excavations at Castanet, we too found *anneaux* in the rubble of the collapsed drip line of the shelter.

We have been able to demonstrate as well that these labor-intensive features were also placed on freestanding blocks on the living surface of the site. Our experiments show that these rings withstand very little force, strain, and stress, and we also know from our analysis of site formation that the ceiling of the shelter was approximately 2 m above the occupational surface.

3. https://www.timeanddate.com/sun/france/bordeaux?month=12.

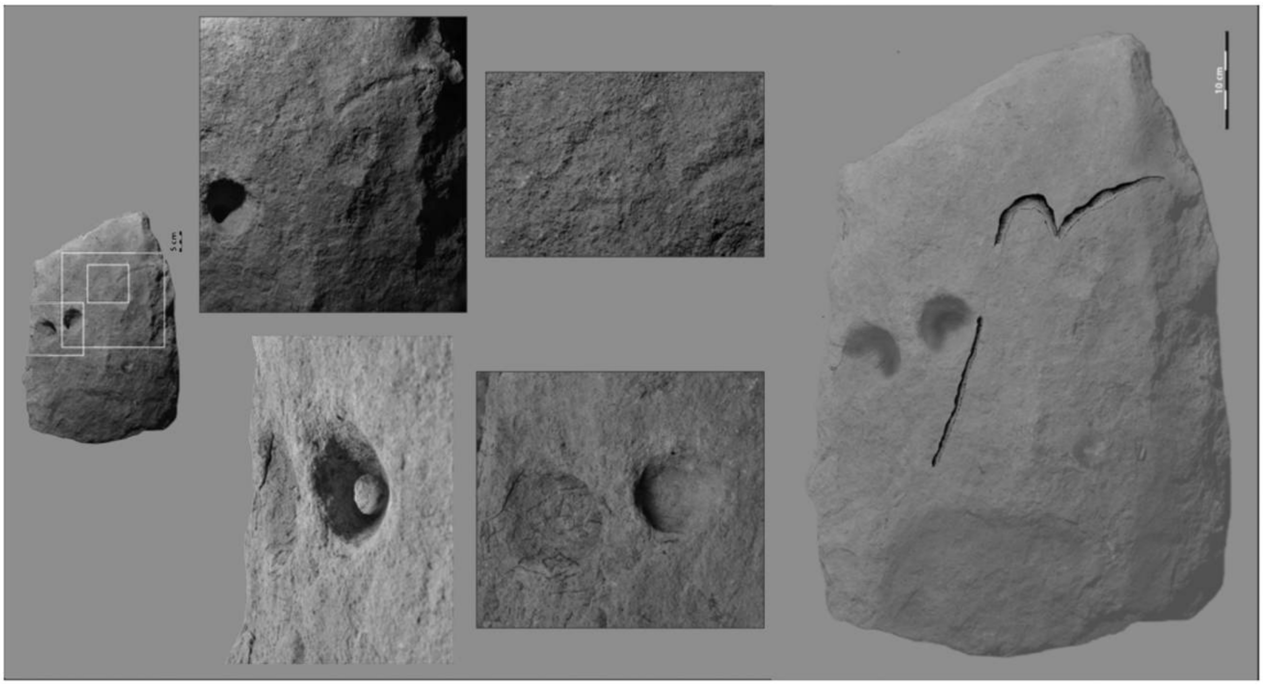

Figure 9. Abri Cellier, roof collapse block with *anneau* and engraved profile of mammoth. A color version of this figure is available online.

These data and observations incline us to support Denis Peyrony's old hypothesis (Peyrony 1935) that the *anneaux* served to guide and suspend animal skins from the drip line of the shelter in order to retain heat, to reflect heat and light back into the shelter, and to serve as a windbreak vis-à-vis westerly and northwesterly winds entering from the front of the shelter. Moreover, new seasonal data, based on cementum annuli analysis (Naji, Gourichon, and Rendu 2015; Rendu 2007, 2010) of reindeer and horse teeth, are categorical;[4] Castanet was an exclusively cold season occupation (figs. 10, S13).

The southern sector of Abri Castanet has also yielded a fat-burning lamp, associated with Structure 218, which would have complemented and rendered portable the light provided by the fires (see fig. S14). Such portable light technology (de Beaune and White 1993) would have allowed the Aurignacian occupants of Castanet to better adapt to long winter nights and to the darkness of the enclosed living space and the outside surroundings.

Régismont-le-Haut, a Point of Comparison for the Vézère Valley Sites

Régismont-le-Haut (Poilhes, Hérault) is one of the rare open-air Aurignacian sites to have yielded well-preserved evidence of the organization and arrangement of living space separated into distinguishable activity areas (Bon and Mensan 2007).

The site has been the object of long-term, programmed excavations by one of us (RM) since 2000.[5] In the course of this research, 28 combustion features have been excavated, concentrated in two paleochannels that served to shelter the Aurignacian occupants. Around these fire features are dense concentrations of archaeological material reflecting functionally complementary poles of activity.

Two primary zones have been identified, one in each of the perpendicularly oriented paleochannels. The first contains several vast multifunctional structures that we interpret as belonging to a "domestic area." The second is constituted of several structures of a more specialized nature that we interpret as a "workshop area."

The principal domestic area is organized around a concentration of three fire structures. These are three pits, two of which are characterized by intense traces of combustion (12 and 16) and the third showing brownish impregnations and an infilling of burned bones (see fig. S15). This organization is strikingly similar to that of the southern sector of Abri Castanet. The archaeological material associated reveals a range of activities such as bladelet production, tool re-

4. For example, A. Pike-Tay's unpublished manuscript, 2000, "Dental growth mark analysis of *Rangifer tarandus* and *Equus* of Abri Castanet."

5. The lithic industry is rather original compared with other assemblages available for comparison, making chronological attribution difficult. Attempts to date the site radiometrically (Bon 2002) do not allow attribution to a particular Aurignacian phase. It could be a regional facies of the early Aurignacian or a previously unobserved variant of a later Aurignacian.

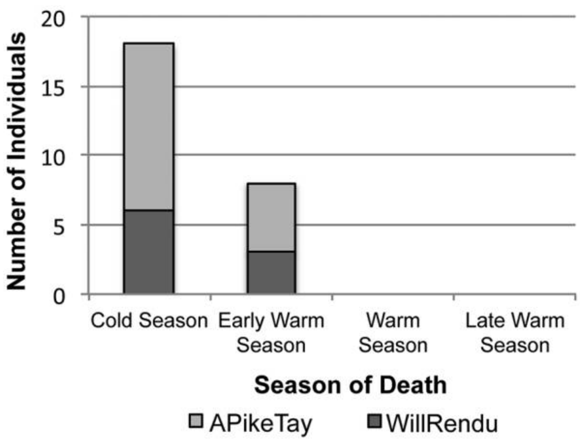

Figure 10. Cementum annuli analysis of season of death for 25 reindeer teeth and one horse tooth from the southern sector of Abri Castanet based on a large comparative collection of known age at death (Burke and Castanet 1995; Pike-Tay 1995, 1998).

sharpening, and the processing of mineral pigments as at Castanet.

At Régismont, all of the combustion features and surrounding concentrations of material culture are attributed to a single, spatially continuous occupational surface. The redundancy in the spatial organization and association of different groups of structures such as the one described above sustains the hypothesis of a single episode of occupation that took the form of a vast seasonal residential camp. The careful observation and documentation of the internal organization of the site around combustion features makes Regismont-le-Haut a key point of comparison for the Aurignacian record of the Vézère Valley (Anderson et al., forthcoming). That comparison leads us to propose that the redundant fire feature organization that we observe in the Vézere was the expression of a geographically widespread characteristic of Aurignacian culture.

Conclusions

Using both old archives and the new methods and data available to us, we are beginning to be able to address important questions of heat and light management in the early Upper Paleolithic. In one region, the classic Vézère Valley of southwest France, we have seen the existence of complex and diverse fire features that require excavation and analysis with forensic precision. The kinds of fire features and their arrangement across living surfaces repeat from one site to the next and may well be part of a broader European pattern. We maintain that fire was manipulated and used in a standardized and consistent manner within an overarching system of heat and light capture and control.

A remarkable aspect of the early Aurignacian record in the Vézère Valley is that we can follow particular fire features across a time horizon marked by the availability for occupation of bare bedrock terraces in the period between 33,000 and 32,000 BP (uncalibrated). Early Aurignacians, moving directly onto the previously unoccupied bedrock, dug their fire pits directly into the substrate. This seems to have been a characteristic of the early Aurignacian only; cobble-lined or bordered fireplaces show up and become dominant in later stages of the Aurignacian.

The fire features themselves also display a very consistent pattern. The fire complex that we excavated at Abri Castanet (consisting of Structures 216, 217, and 218) demonstrates a fire use that was intensive and easily adaptable to many specialized functions. Given that Castanet was a winter occupied site, the fire in Structure 217 could have burned more or less continuously, with its contents subsequently moved to Structures 216 and 218 for cleaning or for tasks that required the control of heat and flame. A nearly identical arrangement of fire features found at Abri Cellier reinforces the view of a highly systematic management of fire in the early Aurignacian.

Evidence from Abri Castanet suggests that while these fires were fueled to a certain extent by bone, wood played a very important role, one that is probably significantly underrepresented because of taphonomic processes. Provisioning the site with enough fuel to feed these intensive fire complexes would have come at a significant economic cost.

The hypothesis of the anchoring of skin structures within rock-shelters for purposes of heat retention, with fireplaces behind animal-skin walls, was made first in 1935 by Peyrony (1935). Our recent research supports this hypothesis. It is worth asking whether this is a seasonal phenomenon, as it is now clear that Abri Castanet was an entirely cold season occupation.

New robust data on activities around fireplaces at sites like Castanet make it possible to infer social and organizational aspects of fire structures within Aurignacian living spaces. The spaces created within these Aurignacian sites, combining complex fire structures, *anneaux* for enclosing the rock-shelters with hides, and engraved and painted artwork on the walls and ceilings (White et al. 2012) would have been extremely important sanctuaries for the protection from the cold and the extension of daylight hours.

During the cold winter evenings, when daylight departed early, Aurignacian groups would have been able to continue to make beads, produce and maintain their tools and weapons, process pigments, prepare meals, and strengthen social bonds through fireside talk (Dunbar 2014; Wiessner 2014). This warm and protected space would have given these groups a powerful advantage and may explain why Aurignacian peoples seem to have thrived in the glacial conditions of late Pleistocene France.

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References Cited

Aldeias, Vera. 2017. Experimental approaches to archaeological fire features and their behavioral relevance. *Current Anthropology* 58(suppl. 16):S191–S205.

Alperson-Afil, N. 2008. Continual fire-making by hominins at Gesher Benot Ya'aqov, Israel. *Quaternary Science Reviews* 27:1733–1739.

Anderson, L., M. Lejay, J.-Ph. Brugal, S. Costamagno, C. Heckel, M. De Araujo Igreja, J.-V. Pradeau, et al. Forthcoming. Insights into Aurignacian daily life and camp organization: the open-air site of Régismont-le-Haut. *Quaternary International*.

Binford, Lewis R. 1998. Hearth and home: the spatial analysis of ethnographically documented rock shelter occupations as a template for distinguishing between human and hominid use of sheltered space. In *Middle Palaeolithic and Middle Stone Age settlement systems*. N. J. Conard and F. Wendorf, eds. Pp. 229–239. Forli, Italy: ABACO.

Bon, F. 2002. *L'Aurignacien entre mer et océan: réflexion sur l'unité des phases anciennes de l'Aurignacien dans le sud de la France*. Mémoire de la Société Préhistorique Française 29. Paris: Société préhistorique française.

Bon, F., and R. Mensan (with the collaboration of Marina de Araujo Igreja, Sandrine Costamagno, Philippe Gardère, Clément Ménard, Farid Sellami, Carolyn Szmidt, and Isabelle Théry-Parisot). 2007. Le site de plein air de Régismont-le-Haut: une halte Aurignacienne dans les Plaines du Languedoc. In *Qui est l'Aurignacien?* Pp. 53–71. Aurignac: Musée-Forum.

Bourrillon, R., R. White, E. Tartar, L. Chiotti, R. Mensan, A. Clark, J.-C. Castel, et al. Forthcoming. A new discovery of Aurignacian art at Abri Blanchard (Dordogne): implications for understanding Aurignacian graphic expression in Western and Central Europe. *Quaternary International*. doi: http://dx.doi.org/10.1016/j.quaint.2016.09.063.

Bouvier, J.-M. 1967. Topographie et climatologie des Abris Paléolithiques dans la Region des Eyzies. In *Comptes Rendus de la VIIe Congres National de Speleologie*, Bordeaux 28–30 mai 1966. Spelunca 4e séries. Mémoires no. 5:27–31.

Brodard, A., Delphine Lacanette-Puyo, Pierre Guibert, François Lévêque, Albane Burens, and Larent Carozza. 2016. A new process of reconstructing archaeological fires from their impact on sediment: a coupled experimental and numerical approach based on the case study of hearths from the Cave of Les Fraux (Dordogne, France). *Archaeological and Anthropological Sciences* 8(4):673–687.

Burke, A., and J. Castanet. 1995. Histological observations of cement growth in horse teeth and their applications to archaeology. *Journal of Archaeological Science* 22:479–493.

Chazan, Michael. 2017. Toward a long prehistory of fire. *Current Anthropology* 58(suppl. 16):S351–S359.

Chiotti, L., and C. Cretin. 2011. Les mises en forme de Grattoirs Carénés/Nucléus de l'Aurignacien Ancien de l'Abri Castanet (Sergeac, Dordogne). *Paléo* 22:69–84.

Collie, G. 1928. *The Aurignacians and their culture*. Beloit, WI: Logan Museum, Beloit College.

Costamagno, S., I. Théry-Parisot, J. P. Brugal, and R. Guibert. 2005. Taphonomic consequences of the use of bone as fuel: experimental data and archaeological applications. In *Biosphere to lithosphere: Proceedings of the 9th Conference of the International Council of Archaeozoology*, T. O'Conner, ed. Pp. 51–61. Oxford: Oxbow.

Costamagno S., I. Théry-Parisot, D. Kuntz, F. Bon, and R. Mensan. 2010. Taphonomic impact of prolonged combustion on bones used as fuel. In *The taphonomy of burned organic residues and combustion features in archaeological contexts*. I. Théry-Parisot, L. Chabal, and Costamagno S., eds. *Palethnologie* 2:169–183.

de Beaune, S., and R. White. 1993. Ice age lamps. *Scientific American* 268:108–114.

Delluc, B., and G. Delluc. 1978. Les manifestations graphiques Aurignaciennes sur support Rocheux des environs des Eyzies (Dordogne). *Gallia Préhistoire* 21(1/2):213–438.

Delporte, H. 1968. *L'abri du facteur à Tursac (Dordogne)*. Paris: Presse du CNRS.

Didon, L. 1911. L'Abri Blanchard des Roches. *Bulletin de la Société Historique et Archéologique du Périgord* 87:246–241, 321–345.

Dunbar, R. 2014. How conversations around campfires came to be. *Proceedings of the National Academy of Sciences of the USA* 111:14013–14014.

Fernández Peris, J., V. Barciela González, R. Blasco, F. Cuartero, H. Fluck, P. Sañudo, and C. Verdasco. 2012. The earliest evidence of hearths in southern Europe: the case of Bolomor Cave (Valencia, Spain). *Quaternary International* 247:267–277.

Gamble, C. 1991. An introduction to the living spaces of mobile peoples. In *Ethnoarchaeological approaches to mobile campsites: hunter-gatherer and pastoralist case studies*. C. Gamble and W. A. Boismier, eds. Pp. 1–23. Ann Arbor, MI: International Monographs in Prehistory.

Hahn, J. 1988. *Die Geissenklösterle-Höhle im Achtal bei Blaubeuren: Fundhorizontbildung und Besiedlung im Mittlelpaläolithikum und im Aurignacien*. Stuttgart: Theiss.

Heckel, C., and S. Wolf. 2014. Ivory debitage by fracture in the Aurignacian: experimental and archaeological examples. *Journal of Archaeological Science* 42:1–14.

Karkanas, P., R. Shahack-Gross, A. Ayalon, M. Bar-Matthews, R. Barkai, A. Frumkin, A. Gopher, and M. C. Stiner. 2007. Evidence for habitual use of fire at the end of the Lower Paleolithic: site-formation processes at Qesem Cave, Israel. *Journal of Human Evolution* 53:197–212.

Lecoanet, H., F. Léveque, and J. P. Ambrosi. 2003. Combination of magnetic parameters: an efficient way to discriminate soil contamination sources (south France). *Environmental Pollution* 122:229–234.

Lecoanet, H., F. Léveque, and S. Segura. 1999. Magnetic susceptibility in environmental applications: comparison of field probes. *Physics of the Earth and Planetary Interior* 115:191–204.

Legge, A. J. 1972. Cave climates. In *Papers in economic prehistory*. E. Higgs, ed. Pp. 97–103. Cambridge: Cambridge University Press.

Lejay M., M. Alexis, K. Quénéa, F. Sellami, and F. Bon. 2016. Organic signatures of fireplaces: experimental references for archaeological interpretations. *Organic Geochemistry* 99:67–77.

Marquer, L. 2010. From microcharcoal to macrocharcoal: reconstruction of the "wood charcoal" signature in Paleolithic archaeological contexts. In *The taphonomy of burned organic residues and combustion features in archaeological contexts*. I. Théry-Parisot, L. Chabal, and Costamagno S., eds. *Palethnologie* 2:105–115.

Marquer, L., V. Lebreton, T. Otto, and E. Messager. 2015. Étude des macro- et des micro-charbons du Site Epigravettien de Mezhyrich (Ukraine): données taphonomiques et anthracologiques. *L'Anthropologie* 119:487–504.

Marquer, L., V. Lebreton, T. Otto, H. Valladas, P. Haesaerts, E. Messager, D. Nuzhnyi, and S. Péan. 2012. Charcoal scarcity in Epigravettian settlements with mammoth bone dwellings: the taphonomic evidence from Mezhyrich (Ukraine). *Journal of Archaeological Science* 39:109–120.

Marquer, L., T. Otto, R. Nespoulet, and L. Chiotti. 2010. A new approach to study the fuel used in hearths by hunter-gatherers at the Upper Palaeolithic site of Abri Pataud (Dordogne, France). *Journal of Archaeological Science* 37:2735–2746.

Miller, C., N. Conard, P. Goldberg, and F. Berna. 2010. Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modified combustion features. In *The taphonomy of burned organic residues and combustion features in archaeological contexts*. I. Théry-Parisot, L. Chabal, and Costamagno S., eds. *Palethnologie* 2:25–37.

Movius, H. L., Jr. 1966. The hearths of the Upper Perigordian and Aurignacian horizons at the Abri Pataud, Les Eyzies (Dordogne), and their possible significance. *American Anthropologist* 68(2):296–325.

Naji, S., L. Gourichon, and W. Rendu. 2015. La cémentochronologie. In *Messages d'os: archéométrie du squelette animal et humain*. M. Balasse, J.-P. Brugal, Y. Dauphin, E.-M. Geigl, C. Oberlin, and I. Reiche, eds. Pp. 217–240. Paris: Sciences Archéologiques, Edition des Archives Contemporaines.

O'Hara, J. F., R. White, Z. S. Garrett, T. Higham, and A. Roussot. 2015. The Aurignacian site of the Abri de la Souquette (Commune de Sergeac, Dordogne): a history of archaeology. In *Aurignacian genius: art, technology and society of the first modern humans in Europe*. R. White and R. Bourrillon, eds. *Palethnologie* 7:98–117.

Peyrony, D. 1935. Le Gisement de Castanet, Vallon de Castelmerle, Commune de Sergeac (Dordogne). *Bulletin de la Société préhistorique française* 32:418–443.

———. 1946. Le Gisement Préhistorique de l'Abri Cellier, au Ruth, Commune de Tursac (Dordogne). *Gallia* 4(1):294–301.

Pike-Tay, A. 1995. Variability and synchrony of seasonal indicators in dental cementum microstructure of the Kaminiriak caribou population. *Archaeofauna: International Journal of Archaeozoology* 4:273–284.

———. 1998. Dental growth mark analysis of a *Rangifer tarandus* sample from Abri Castanet. In *Rapport de Fouille Programmée Triannuelle 1995–1998*, sec. A5. Bordeaux: Service Régional de l'Archéologie.

Rendu, W. 2007. Planification des activités de subsistance au sein du territoire des derniers Moustériens cémentochronologie et approche archéozoologique de gisements du Paléolithique moyen (Pech-de-l'Azé I, La Quina, Mauran) et Paléolithique supérieur ancien (Isturitz). Doctoral dissertation, Université Bordeaux 1.

———. 2010. Hunting behavior and Neanderthal adaptability in the Late Pleistocene site of Pech-de-l'Azé I. *Journal of Archaeological Science* 37 (8):1798–1810.

Rigaud, J.-P., and J. F. Simek. 1991. Interpreting spatial patterns at the Grotte XV: a multiple-method approach. In *The interpretation of archaeological spatial patterning*. E. M. Kroll and T. D. Price, eds. Pp. 199–220. New York: Plenum.

Roebroeks, W., and P. Villa. 2011. On the earliest evidence for habitual use of fire in Europe. *Proceedings of the National Academy of Sciences of the USA* 108:5209–5214.

Roussot, A. 1982. Abri de la Souquette. *Gallia Préhistoire* 25:112–114.

Schiegl, S., P. Goldberg, H. U. Pfretzschner, and N. J. Conard. 2003. Paleolithic burnt bone horizons from the Swabian Jura: distinguishing between in situ fireplaces and dumping areas. *Geoarchaeology* 18:541–565.

Stahlschmidt, M. C., C. E. Miller, B. Ligouis, U. Hambach, P. Goldberg, F. Berna, D. Richter, B. Urban, J. Serangeli, and N. J. Conard. 2015. On the evidence for human use and control of fire at Schöningen. *Journal of Human Evolution* 89:1–21.

Stapert, Dick. 1989. The ring and sector method: intrasite spatial analysis of Stone Age sites, with special reference to Pincevent. *Palaeohistoria* 31:1–57.

Surovell, T. A., and N. Waguespack. 2007. Fulsome hearth-centered use of space at Larger Gulch, Locality B. In *Emerging frontiers in Colorado Paleoindian archaeology*. R. S. Brunswig, and B. Pitblado, eds. Pp. 219–259. Boulder: University of Colorado Press.

Tartar, E., and R. White. 2013. The manufacture of Aurignacian split-based points: an experimental challenge. *Journal of Archaeological Science* 40: 2723–2745.

Théry-Parisot I. 2001. *Economie des combustibles au Paléolithique: expérimentation, taphonomie, anthracologie*. Paris: CNRS Editions.

———. 2002. Fuel management (bone and wood) during the Lower Aurignacian in the Pataud Rock Shelter, Les Eyzies de Tayac, Dordogne, France: contribution of experimentation. *Journal of Archaeological Science* 29:1415–1421.

Théry-Parisot, I., S. Costamagno, J.-P. Brugal, P. Fosse, and R. Guilbert. 2002. The use of bone as fuel during the Palaeolithic: experimental study of bone combustible properties. In *The zooarchaeology of fats, oils, milk and dairying*. J. Mulville and A. K. Outram, eds. Pp. 50–59. Oxford: Oxbow.

Vaquero, M., and I. Pastó. 2001. The definition of spatial units in Middle Palaeolithic sites: the hearth-related assemblages. *Journal of Archaeological Science* 28:1209–1220.

Villa, P., F. Bon, and J.-C. Castel. 2002: Fuel, fire and fireplaces in the Palaeolithic of Western Europe. *Review of Archaeology* 23(1):33–42.

White, R. 1983. *Upper Paleolithic land use in the Périgord: a topographic approach to subsistence and settlement*. British Archaeological Reports, International Series 253. Oxford: BAR.

———. 1985. The influence of solar aspect on Upper Paleolithic site location. *New York University Journal of Anthropology* 1:1–7.

———. 1992. The history and research significance of the Logan Museum's French Paleolithic collections. In *French Paleolithic collections in the Logan Museum of Anthropology, Beloit College*. R. White and L. Breitborde, eds. *Bulletin of the Logan Museum of Anthropology*, n.s., 1(2):1–38.

White, R., R. Bourrillon, R. Mensan, A. Clark, L. Chiotti, T. Higham, S. Ranlett, E. Tartar, A. Morala, and M.-C. Soulier. Forthcoming. Newly discovered Aurignacian engraved blocks from Abri Cellier: history, context and dating. *Quaternary International*. doi: http://dx.doi.org/10.1016/j.quaint.2017.02.001.

White, R., and H. Knecht. 1992. Abri Cellier (or la Ruth), Commune de Tursac (Dordogne): results of the 1927 Beloit College excavations. In *French Paleolithic collections in the Logan Museum of Anthropology, Beloit College*. R. White and L. Breitborde, eds. *Bulletin of the Logan Museum of Anthropology*, n.s., 1(2):39–96.

White, R., R. Mensan, R. Bourrillon, C. Cretin, T. Higham, A. E. Clark, M. Sisk, et al. 2012. Context and dating of Aurignacian vulvar representations from Abri Castanet, France. *Proceedings of the National Academy of Sciences of the USA* 1089:8450–8455.

Wiessner, Polly W. 2014. Embers of society: firelight talk among the Ju/'hoansi Bushmen. *Proceedings of the National Academy of Sciences of the USA* 111:14027–14035.

Wrangham, R., and R. Caromed. 2010. Human adaptation to the control of fire. *Evolutionary Anthropology* 19(5):187–199.

Wrangham, Richard. 2017. Control of fire in the Paleolithic: evaluating the cooking hypothesis. *Current Anthropology* 58(suppl. 16):S303–S313.