J Archaeol Res
DOI 10.1007/s10814-011-9050-5

Cave Art in Context: Methods for the Analysis of the Spatial Organization of Cave Sites

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Abstract Investigations of prehistoric cave art have long neglected the surrounding context: space, archaeological objects, and imprints. As a result, an integrative structural approach that analyzes cave art as part of an anthropomorphized landscape has not been available. This article draws on urban planning and the physiology of the human eye to provide an innovative archaeospatial analysis of cave sites. A set of relevant features from the caves of Bédeilhac, Fontanet, and Le Portel was selected and defined (light zone, chamber type, path network, mode of movement, and available space). An analysis of the prehistoric remains in the caves allows the reconstruction of different concentrations of human activities (cave art, archaeological objects, and imprints). The projection of these concentrations onto the structured map of the caves results in four types of locations: drawing location, supply location, drawing location with substantial activities, and drawing location with consumption activities. This approach opens new avenues for the archaeological perception of caves and their inhabitants: Upper Paleolithic humans were very familiar with caves and probably followed a master plan during their stay in the dark.

Keywords Prehistoric cave art · Spatial organization · Landscape archaeology · Use of caves

Introduction

Caves are "[…] natural cavities in the earth's crust that are to a large extent enclosed by compact masses of stone and rock; they are filled with either air, sediment, or water […] and are large enough to permit entry by humans"

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(Wrede 1996, translation from the German by K. Schneider). Nevertheless, the world of the deepest caves is a foreign environment for humans; the solar cycle, which is such a structuring feature of life above ground, is completely absent; there is no night and day. Furthermore, in contrast to the outside world, the world of caves is constant. Slight changes in daily temperature and air humidity are barely perceptible, and constant darkness persists in the aphotic parts of the cave. Indeed, regardless of the time spent in this blackness, the human eye never adjusts. In spite of this hostile environment, and possibly exactly for that reason, humans have always been attracted by caves. In the past, caves have provided, and still provide, a place of concealment, accommodation, burial, shelter, and a place for ceremonial gatherings and initiations; they have been used as workshops, sports facilities, and more (Bonsall and Tolan-Smith 1997; Pasda 2004).

This article explores the relationship between humans and caves during the Upper Paleolithic by using an integrative approach. The aim is to reveal how humans adapted to the alien environment of deep caves and how, via intersite comparison, isolated phenomena and repetitive patterns of behavior can be identified. Three cave sites in the French Pyrenees—Bédeilhac, Fontanet, and Le Portel, all of which have yielded cultural remains from the Magdalenian—form the archaeological basis for the study.

Art, as part of cultural expression, is first visible in archaeological records in the Aurignacian. Even today, in spite of the long-standing research tradition in this field, the meaning of these representations and the interpretation of the surrounding context are still extremely speculative and influenced by the intuition of the researcher. This deficit is due not least to the prevalent approaches, whereby individual figures are first described in great detail and subsequently interpreted on the basis of highly personal levels of experience. To date, research still focuses on meticulous recording of figures and their modes of execution. Major enhancements in technology have even led to the atomization of the figures into their smallest graphical units (e.g., Fritz and Tosello 2007). The implementation of these graphical expressions into a wider frame of human behavior in caves is still pending, although the significance of caves as spaces with frequent human activities and cave art has been stressed by several Paleolithic researchers (e.g., Bahn 2003; Lorblanchet 1995). Research needs an integrative approach, linking art and other forms of human activities embedded in the natural space of the entire cave.

Since the compilation of the *apports mobiliers* from the Volp caves by Bégouën and Clottes (1981), we have been aware that a multitude of different prehistoric remains can occur in the context of cave art, even though they are rarely preserved. This is also due to the fact that, in many cases, researchers have rated the value of the artwork itself considerably higher than objects and traces of daily life (Bégouën 1926). Indeed, in the past this very approach has served as justification for blowing scientific caution to the wind and accepting the destruction of an apparently inferior source of information in favor of investigating marvelous artistic expressions. Unfortunately, this behavior can still be observed at times. Grotte Chauvet (Clottes 2001; Geneste 2005), Tuc d'Audoubert (Bégouën et al. 2007, 2009), Les Trois-Frères (Bégouën and Clottes 1981), Bédeilhac (Malvesin-Fabre et al. 1953; Sauvet 2007), Fontanet (Delteil et al. 1972; Vialou 1986), Le Portel (Beltrán et al. 1967;

Vézian 1955), La Garma (Arias Cabal 1999; Arias Cabal et al. 2003), and Cussac (Aujoulat 2002) all show that the quantity and quality of anthropogenic traces can be quite exceptional. It is quite possible that some of these traces can provide much greater contributions to the interpretation of cave art than the figures themselves.

A closer look at the caves of Bédeilhac, Fontanet, and Le Portel provides good examples. The descriptions of the caves themselves are intuitive and vague, and the same chamber is often described differently by different authors. The Galerie principale in Bédeilhac, for example, is described as *vaste* (Ministère de la Culture 1984), *proportions gigantesques* (Sauvet 2007), or large, *haute* (Vialou 1986). In Bédeilhac, the lateral galleries are described as *dimensions parfois fort exiguës* (Ministère de la Culture 1984), *réduits et étroits* (Vialou 1986), or *d'accès difficile* or *défendue par un long passage rampant* (Sauvet 2007). Other information concerning the cave morphology is given as a kind of circuit promenade through the cave. The information is more literal than structured. Except for cave art, the prehistoric remains are reported on the same level. There is no systematic differentiation between the activities. Classifications such as *aires des séjours*, *simple frequentation*, *séjours prolongés* (Bégouën et al. 2009; Sauvet 2007), and *Il fallait bien nourrir les artistes* (Bégouën et al. 2009) are terms that are used intuitively.

Fundamental studies that focused on the structuring of cave sites based on the distribution of prehistoric cave art were published by Leroi-Gourhan (1965) and Rouzaud (1977, 1996, 1997). Leroi-Gourhan (1965) suggested that a classification system could be achieved by systematic data acquisition. In doing so, he adhered to the basic principle that the application of figures provides a cave with a structure. Thus, in the eyes of Leroi-Gourhan, the cave is an ensemble of chambers comprising entrance zone, in-between areas, central and side areas, passages, and end zone. On the other hand, Rouzaud (1996, 1997) analyzed the traces of prehistoric humans in caves from the perspective of paleospeleology. This led him to his definition of chamber types based on lighting and modes of orientation. His integral feature is chamber size, which combines accessibility and illumination using an artificial light source.

Since the beginning of cave art research, the close relationship between figure and rock surface has been outlined (e.g., Bahn 2003; Lorblanchet 1995); Leroi-Gourhan (1971) created the term of *la caverne participante* to describe this phenomenon. This also applies to the positioning of the figure in the immediate surrounding space. A very sophisticated methodology was recently published by Villeneuve and Hayden (2007). They propose that the visibility of single figures should be analyzed in detail to draw conclusions concerning their social function, thus differentiating between intimate and public presentation (e.g., Bahn 2003). A quantitative approach was developed by Lorblanchet (2001). He analyzed the distribution of figures in the Pergouset cave and, in this same context, calculated the absolute volume (in cubic meters) of single chamber units. This resulted in the identification of a unit of measurement (number of graphical units per cubic meter) that makes it possible to describe varying densities of cave art. The need for well-defined features to structure cave sites with cave art can be noted in all of the cited

authors. Indeed, this ever-growing demand has been confirmed recently by investigations at the Grotte Chauvet (Le Guillou 2005).

Basic principles of a spatial organization analysis of cave sites

The review of research history clearly shows the need for an integrative spatial approach for the study of caves and associated prehistoric remains. In addition, there is a general consensus that the distribution of cave art is influenced by the prevailing cave topography (Sieveking 1997). Nevertheless, the possibility of formally investigating this influence is at the same time regarded as slight, not least because of the high natural variability of the caves themselves (Sieveking 1997). That said, the identification of structural similarities should merely be a question of the correct angle of vision and viewing distance. Indeed, various disciplines such as architecture, ethnology, speleology, religious studies, social science, and urban planning are all engaged in the study of space. At a workshop dedicated to this topic in 2002, representatives from various disciplines came together (Pastoors and Weniger 2003). There was consensus among participants that space used by humans serves two main purposes: passage and stopover. This duality is a basic principle of the use of space and also pertains to caves. In analyzing caves, three different aspects are of particular significance: the natural structure of the cave, the ability of the human eye to react to darkness and artificial light, and the classification of detectable prehistoric remains.

Currently, cave research does not have recognized standards for classifying cave structure that are oriented toward human needs. The situation is quite different in the case of urban planning, where plans are developed and decisions are made on how available areas can best be put to use for humans (e.g., Streich 2005). For this particular task, there is an array of methodological instruments, comprising maps, plans, and appropriate terminology. Some components of these instruments are applicable to the spatial organization analysis of caves. Of particular significance in urban planning are lines of communication, e.g., pedestrian and cycle paths, railways, and roads, that is, elements of a superordinate transit infrastructure that only in their totality make transportation possible. This system includes features such as links and connection points (crossroads), modes of regulation and control (traffic signs, signals), signposts, and parking and meeting points. In short, communication plays a very special role in all aspects of urban planning. Therefore, although the entire repertoire of instruments cannot be directly transferred to the spatial analysis of caves, it serves to highlight interesting perspectives that may assist in organizing the path network in caves according to lines of communication and connection points.

Humans are among those beings that must leave the cave on a frequent basis both to gather food and for temporal orientation, i.e., to ascertain whether it is morning or afternoon, day or night, summer or winter. In the course of human evolution, humans have never adapted to the conditions that prevail in those parts of a cave without any source of light. For temporal and spatial orientation, the eye is the most important human organ; between 80 and 90% of information about the environment

is taken in visually (Griefahn 1996). This also applies to stopovers in a cave, although here all sense organs react with hyper-receptivity to the exceptional conditions: darkness and silence.

The retina of the eye is covered by some 6 to 7 million cones that serve daytime and color vision, and by some 130 million rods that function in dim light. Through adjustment, the human eye can adapt to various states of illuminance, ranging from 0.01 lx (starlit night) to 100,000 lx (full sunlight) (lx = lux/illuminance). Whereas adjusting to high intensities of light occurs more or less immediately (between 1 and 1.5 seconds), adapting to darkness takes considerably longer. Although adaptation begins quite rapidly, between 20 and 40 minutes are required to complete the entire process. Impaired vision, for example, due to insufficient lighting, can lead to premature tiredness and consequently to a reduction in the ability to react and concentrate. Because of dilation (relaxation) of the pupil in twilight conditions, focus depth is reduced, resulting in relative shortsightedness to about 0.5-1.5 diopters (Bartenbach and Witting 2009; Griefahn 1996). The fact that all cats at night are gray is certainly not due to the cats, but rather to the retina of the human eye. In poor light, only the rods that function in those conditions react to their sensors, and they can only register gray tones. The cones responsible for color vision remain inactive. For the very same reason, color vision is considerably impaired in caves. Further important factors that influence the perception of color are the color and brightness of the surroundings.

Visible light comprises electromagnetic waves in the region of 380 N·m for blue (short waves) to 780 N·m for red (long waves) (N·m = Newton meter). With increasing darkness, first the short waves (blue) disappear until finally the long waves (red) are no longer distinguishable. For this reason, red is the color most visible in poor light (Harten 1997). The threshold of color visibility is given as 3 lx. Blue-gray and brown tones are the natural fundamental colors of limestone in a dripstone cave, with calcareous sinter and mineral deposits adding to the repertoire of observable colors. In this environment, attention can best be aroused by the color red. In parts of a cave void of natural light, visual perception is triggered less by color than by the sharp contrast between illuminated and nonilluminated areas, i.e., light and shade. For human sight, the cognition of secondary light sources is of particular significance (Harten 1997). In the cave, the wall and ceiling become reflectors. During the Paleolithic, the primary source of light could only have been the naked flame; torches, tallow lamps, and fireplaces have all been confirmed from archaeological investigations (de Beaune 1987; Harten 1997). The luminous flux emitted by the naked flame of a candle lies in the region of 5-15 lm (lm = lumen) (Harten 1997), and experiments have shown that Paleolithic tallow lamps would have reached similar values (de Beaune 1987). Therefore, adhering to the aforementioned threshold of color perception (3 lx) and the known luminous flux of a candle (5-15 lm), it can be deduced at what distance the color red becomes visible to the human eye. This is given by the definition of illuminance (lux, lx): $lx = lm/m^2$. Lux is the illuminance that is generated in an area of one square meter when illuminated by one luminous flux (1 lm). Illuminance is subject to distance and decreases quadratically with increasing distance from the light source. Accordingly, in the light of a single candle in an aphotic environment, the color

red first becomes visible at a distance of 2.24 m [= $\sqrt{}$(15 lm/3 lx)] and at the latest at a distance of 1.29 m [= $\sqrt{}$ (5 lm/3 lx)]. The distance at which black (coloring) or engravings are visible cannot be measured. Here, the contrast with surroundings and the size of the figure are both key factors. Nevertheless, it is remarkable that a naked flame of 5-15 lm is sufficient to generate an illuminance of 0.01 lx that is observable at a distance of between 38.73 m [= $\sqrt{}$(15 lm/0.01 lx)] and 22.36 m [= $\sqrt{}$5 lm/0.01 lx)]. This value corresponds to the darkness of a night illuminated solely by starlight (Griefahn 1996) and is adequate for simple orientation purposes. However, considering the often-difficult conditions encountered in a cave, it is unlikely that this illuminance would be sufficient to allow for controlled movement.

Due to the often-difficult topography of a cave, it is by no means easy to pinpoint exactly the amount of illuminance essential for controlled movement. It is assumed that a night illuminated by a full moon with a value of 0.25 lx (Griefahn 1996) is sufficient for this purpose. Candlelight offers an illuminance of that value up to a distance of between 4.47 and 7.75 m. These calculated distances assume that the area upon which the light falls provides optimal reflection (100% reflectivity); this is certainly not the case for the gray-brown walls of caves. For that reason, we suggest that this distance be brought down to 4 m.

Cave sites not only contain rock art but, in favorable conditions, also have yielded other types of remains left behind by their prehistoric visitors (e.g., Arias Cabal 1999; Arias Cabal et al. 2003; Bégouën and Clottes 1981; Bégouën et al. 2009). These could be used as a frame of reference for artwork. In addition to cave art, two groups of prehistoric remains can be distinguished: archaeological objects and imprints. The former are part of the material culture (physical residue) (e.g., Eggert 2001, p. 52), though Bégouën and Clottes extend this term to include *apports mobiliers*, by which they refer to intentionally and unintentionally left marks (Bégouën and Clottes 1981, p. 157). These include imprints of the people themselves. An imprint is generated by the accidental or deliberate pressure of an object or body part against a plastic surface. The imprints of both objects and humans are of considerable significance for archaeological research. One of the best known places to have yielded this type of evidence is the upper gallery at Tuc d'Audoubert, where a very diverse spectrum of imprints is preserved, including removed or moved bones and stalagmites, projectiles, feet, heels, toes, fingers (including a fingernail), and knees (Bégouën et al. 2009). With due respect to the very particular circumstances contributing to preservation of this type of evidence, in the following, imprints are designated as an independent group of prehistoric remains.

Ideally, all three categories—cave art, archaeological objects, and imprints—can contribute to an analysis of the spatial organization of a cave. These different categories can vary in frequency. The fine-grained breakdown into quantitative classes based on statistical calculations proposed by Lenssen-Erz (2001) in his analysis of the prehistoric artwork at the Brandberg in Namibia seems to be the most suitable method for a sensible arrangement of rock art into quantitative groups. Unfortunately, this was not possible for the caves at Bédeilhac, Fontanet, and Le Portel, where we have to make do with coarse-grained descriptions from earlier publications.

Concentrations of cave art, archaeological objects, and imprints can be analyzed both quantitatively and qualitatively. A concentration is defined by the presence of more than one prehistoric remain per unit area. The dimension of the unit area has to be determined with respect to the individual situation. As such, activities at each concentration can be reconstructed by the analysis of operational processes. For open-air sites, Binford (1983) proposed differentiating between concentrations with substantial activities and those with qualified activities. Whereas complete reduction sequences of lithic blank production, the production of retouched tools, and the occurrence of predominantly complete skeletons of prey are characteristic features of concentrations with substantial activities, isolated skeletal elements and fragmentary reduction sequences of lithic production are classified as qualified activities. In addition to these substantial activities, two classes of qualified activities (consumption and drawing) have been identified in the caves under study here. Whereas consumption activity involves the utilization of provisions brought into the caves without important blank production, the term "drawing activity" subsumes the creation of figures or other artistic representations on the walls or floors of the caves. Due to the large repertoire of methods used in their completion, as well as the vast array of diverse motifs found, these features provide further means for patterning according to visibility and dimensions of motif (Bahn 2003; Villeneuve and Hayden 2007).

A tool kit for the analysis of spatial organization in cave sites

Rouzaud (1997) proposed applicable criteria for the analysis of human use of caves. His approach is based on the criteria of illumination and orientation. As such, Rouzaud's work is incorporated into the concept of spatial organization presented in this article. The aforementioned condition of the human eye in the darkness provides a tangible basis for the calculation of different light zones and chamber types. Different chambers can be connected to one another via a path network comprising different lines of communication and connection points. In some caves, e.g., Fontanet, figures are situated within clambering passages inside the cave (Delteil et al. 1972), which provides evidence that the mode of movement and the placement of figures are probably linked. Therefore, the mode of movement should be included as an important feature of this analysis. By measuring the available space at locations used by humans, the maximum number of people that could have stayed for the same time in the same place should be estimated.

In summary, a tool kit for the analysis of spatial organization in cave sites comprises five tools: light zone, chamber type, path network, mode of movement, and available space.

Trimmel (1965) has referred to the light-dark boundary as the final point to be reached by sunlight. Rouzaud (1997) refers to this same point as the beginning of the dark zone. Following Rouzaud, there is a further sphere between daylight and the dark zone—the so-called half-shade zone (Fig. 1). The boundaries between the different zones can be ascertained, when possible, on the basis of illuminance measurements. An illuminance of under 0.01 lx no longer permits any form of

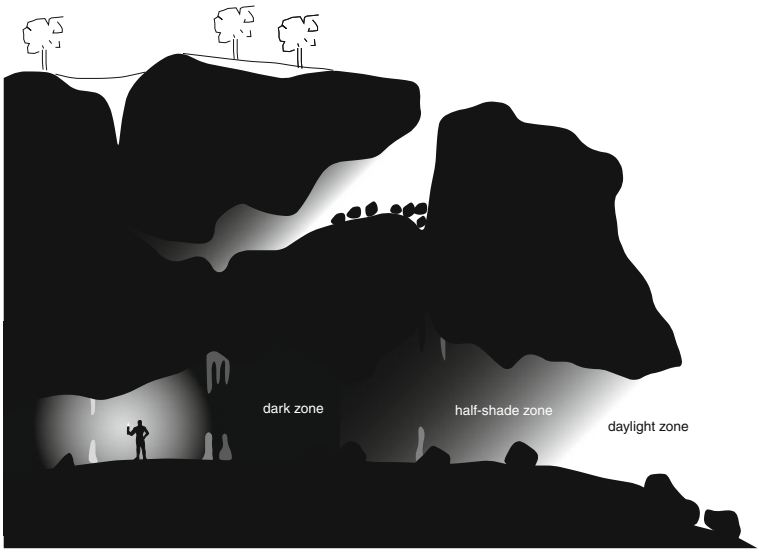

Fig. 1 Light zones (after Rouzaud 1997): Daylight zone, half-shade zone, and dark zone

orientation or movement. Thus, it would appear reasonable to place the transition from half-shade zone to dark zone at this particular point. Open-air illuminance fluctuates between 2,000 lx (overcast sky) and 100,000 lx (clear sky) (Griefahn 1996). Since these values are directly influenced by the position of the sun as well as by climatic factors, the maximum illuminance during adverse conditions, i.e., overcast sky, is taken as the boundary between daylight and the aforementioned half-shade zone; this is around 2,000 lx. Due to many variables, however, the general transitional zone between these two units must retain a certain flexibility. The aforementioned zones can serve only as approximations of potential conditions.

The classification of chamber types is based on the level of illumination by a single tallow lamp (Fig. 2). Approximately 130 tallow lamps were found in the cave of Lascaux (Delluc and Delluc 1979), and one can imagine other scenarios of illumination. We based our calculation on minimum lighting by a single person. Gray-brown walls of caves do not expose the optimum reflectivity. In that environment, the illuminance of 0.25 lx of a tallow lamp can light an average distance of 4 m. We define this distance as the radius within which controlled movement would have been possible under Paleolithic conditions by one single tallow lamp. Narrow chambers stand out in particular because they are smaller than 4 m wide, so that both walls are adequately illuminated at the same time. Accordingly, we define medium-sized chambers as measuring between 4 and 8 m wide; in these chambers at least one wall is reached by light at any one time. In wide chambers just one wall can be illuminated. In low chambers the ceiling can serve as a reflector and, irrelevant of chamber width, can provide quite sufficient light. It follows that there are only two chamber types for which illumination and orientation can be problematic: in medium-high and wide-high chambers. These chambers

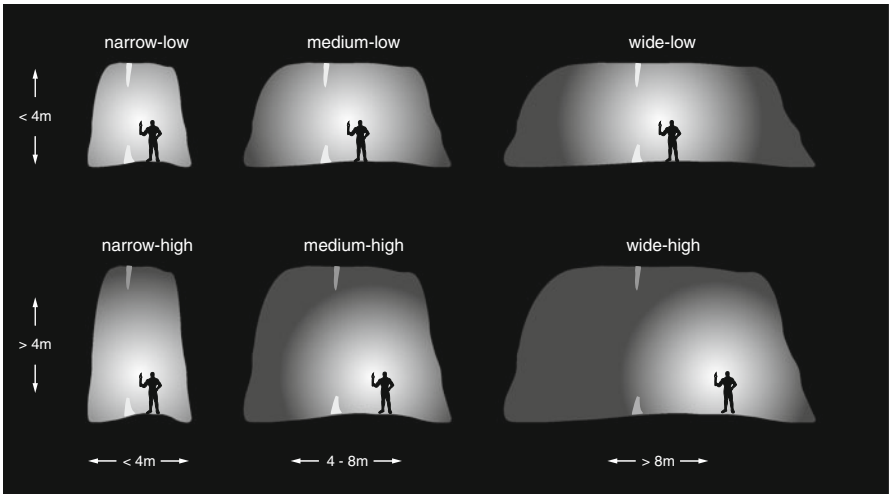

Fig. 2 Chamber types based on the level of illumination by a single tallow lamp

compel the visitor to be near one of the two walls in order to use its surface to reflect light.

The different chambers within a cave are connected to one another via a path network that is made up of different lines of communication and connection points. With respect to the lines of communication, we differentiate between side passages and passageways. Whereas a side passage has an explorative character, at the same time it is also the only way out. With a passageway, there is always at least one alternative way back. Different lines of communication intersect and are connected via connection points, crossings, junctions, dead ends, and entrances. A crossing connects at least four different lines of communication, a junction at least three. For us, a dead end is a special type of connection point; such a path stops with an end piece instead of being connected to the path network.

Decisive for the exploitation of caves is the mode of movement. Trimmel (1965) also considered this aspect. Accordingly, differences can be ascertained in the way paths and constricted paths can be navigated. Whereas paths can be comfortably negotiated, constricted paths can be passed only in a crawling position. This differentiation is taken up and incorporated into the systematics of our analysis of spatial organization. In addition to walking and crawling, climbing is another alternative mode of movement that we consider.

The space available in a cave is of particular significance for its anthropogenic usage. According to the architect Neufert (1951), a human requires a surface space of 0.77 m^2 when walking, and 1.75 m^2 when lying down. If we add to this a value to reflect a certain degree of free moving space, then we arrive at a figure of around 2 m^2 of space that is required by each human (e.g., Pager 1989). With this value in mind, we calculate the maximum number of people that could have stayed in the same place at the same time. We stress, however, that this value should not be understood as a precise unit of measure, as cave size can never be measured

accurately owing to individual chamber structures. Therefore, we propose the application of a scale by which the available space is divided in steps of five people (10 m^2 = 5 people, 20 m^2 = 10 people, 30 m^2 = 15 people, and so on).

Cave art in its context: A first application of a spatial organization analysis in the cave sites of Bédeilhac, Fontanet, and Le Portel (Ariège)

In this first application of spatial organization analysis, caves were chosen that fulfilled certain criteria. First, they featured not only cave art but also published data on concentrations of other prehistoric remains. In addition, the concentrations of finds from each cave were culturally and chronologically coherent. Furthermore, the caves are in geographical proximity to one another so that their geographical and cultural uniformity is ensured. Three cave sites in Ariège in the southwest of France—Bédeilhac, Fontanet, and Le Portel—met these conditions (Fig. 3). We have used only published data and are aware of the deficits and problems that arise from such an approach. One major problem is the sloppy documentation of the sites in publications. Many discoveries and details from each site remain unpublished. There is a great need for a precise and detailed standard of publication for such important sites. Otherwise, a serious scientific usage of published data by the scientific community is impossible.

Bédeilhac

Investigations at Bédeilhac (Fig. 4) were begun in the mid-19th century, first by Garrigou from 1861 to 1864, followed by Robert from 1941 to 1953 (Malvesin-Fabre et al. 1953), and since 1990 by Sauvet (2007) and Barbaza, from whom only preliminary reports are currently available (Barbaza et al. 1996).

The cave art from Bédeilhac is described as exceptionally homogeneous and, on the basis of its stylistic traits, is attributed to the middle Magdalenian (Vialou 1986). According to Vialou, there are 76 figures at Bédeilhac; most are in color (73.7%) and are found throughout the entire cave. Engravings are featured in just three concentrations: in the Salle terminale, the Galerie des modelages, and in the Galerie Vidal. The frequent use of black and red suggests that the figures were intended to be seen; this does not apply to the 18 engravings. Among the 76 figures are 25 animal representations, 7 are indeterminate elements, and 44 are abstract signs. Animal representations are dominated by bison ($n = 18$) but also include horse ($n = 4$), ibex ($n = 2$), and deer ($n = 1$). In addition to some solitary figures, Bédeilhac boasts four concentrations with drawing activities in the Galerie Vidal ($n = 37$), in the Galerie des modelages ($n = 16$), in the Salle terminale ($n = 12$), and the Diverticule aux bisons ($n = 3$). The Galerie principale and the Diverticule aux bisons are the only localities in which figures solely of bison and abstract signs are found. The Galerie principale is significant not just for this reason; it is the only gallery in which cave art appears scattered, i.e., there is no concentration fixed on one particular point.

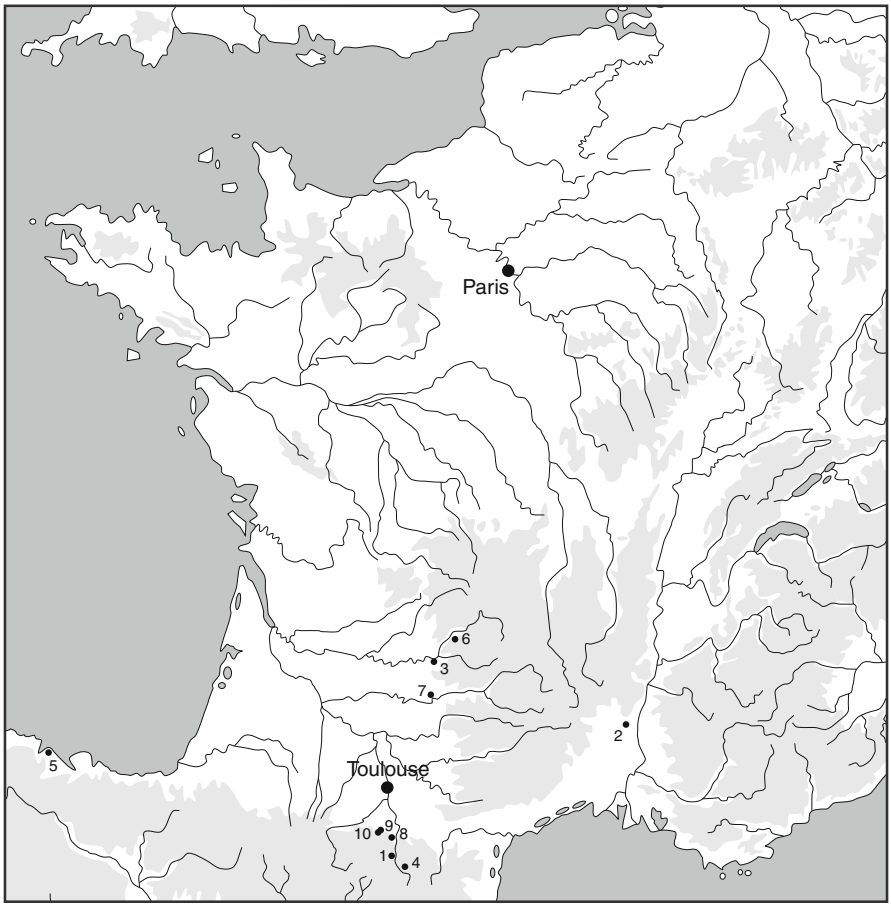

Fig. 3 Franco-Cantabrian Europe showing the cave sites mentioned: Bédeilhac (1), Chauvet (2), Cussac (3), Fontanet (4), La Garma (5), Lascaux (6), Pérgouset (7), Le Portel (8), Les Trois-Frères (9), and Tuc d'Audoubert (10)

At least 11 concentrations of archaeological objects and two single occurrences are known in Bédeilhac (Barbaza et al. 1996; Malvesin-Fabre et al. 1953). Unfortunately, the level of information known about each concentration varies, and they can be compared only with restrictions. The information ranges from simple, superficial, jotted down notes to modern excavations. Concentrations 1-11 follow the numbering by Malvesin-Fabre et al. (1953). The list was supplemented with the concentration of archaeological objects in the Galerie Vidal (12), which was excavated by Barbaza in the middle 1990s (Barbaza et al. 1996). The following can be derived from the artifact inventories that have been published for Bédeilhac (Barbaza et al. 1996; Malvesin-Fabre et al. 1953): five concentrations (1, 4, 10, 11, and 12) have evidence of substantial activities with blank production, formal tools, and the remains of hunting preparation. Five other concentrations (3, 5, 6, 7, and 9) have primarily formal tools without corresponding reduction sequences; the

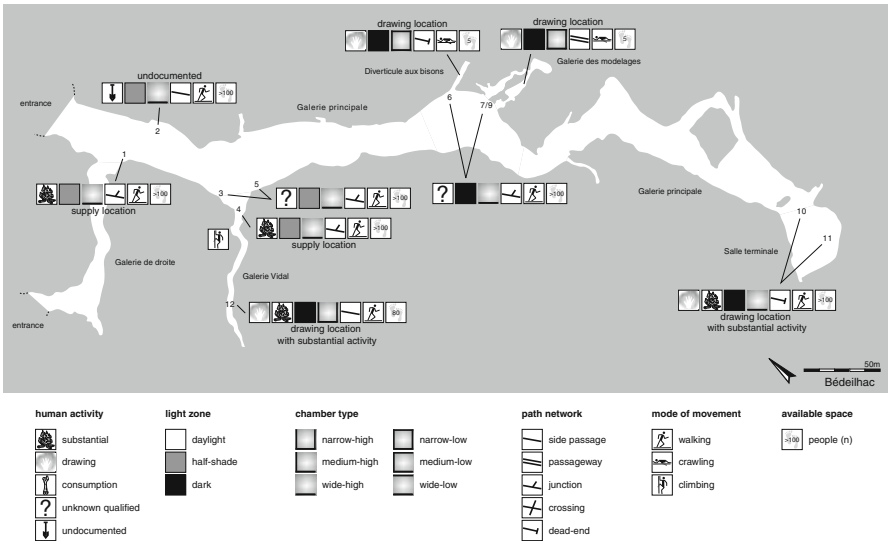

Fig. 4 Distribution of human activities with structured notes about their spatial organization in Bédeilhac (numbers refer to concentrations)

activities carried out are unknown qualified activities. Concentration 2 lacks sufficient documentation. Projectiles are found in 10 of the 11 concentrations (Barbaza et al. 1996; Malvesin-Fabre et al. 1953). Even the very small inventory with unknown qualified activities is characterized by projectiles. Except for concentration 12, in addition to projectiles, mobiliary art is a defining characteristic of the concentrations with substantial activities. In the smaller concentrations with unknown qualified activities, cave art is found irregularly.

Due to the extremely large dimensions of the entrance area and the straight course of the first 150 m, the boundary between the daylight and half-shade zone is not distinct. The half-shade zone extends approximately to the junction to the Galerie Vidal. All other chambers and galleries in Bédeilhac are in the dark zone. The illumination available for orientation in the cave is uncomplicated. In the Galerie principale, one must be near one of the two walls because the ceiling is too high to reflect the light of the tallow lamps. This also holds true for the Galerie de droite, the second entrance to the cave. The other two galleries and diverticula, which branch off to the side, are so narrow and low that orientation is simple. It is possible to stand and walk comfortably in all parts of the Bédeilhac cave. The only exceptions are the Diverticule aux bisons and the Galerie des modelages, both of which are passages in which one has to crawl. The only hindrance is a climbing passageway in the first part of the Galerie Vidal that formed when the ceiling collapsed and the remaining rock debris blocks the access.

The path network in Bédeilhac consists mainly of side passages that terminate as dead ends and junctions. Only the Galerie des modelages offers the possibility of a passageway. When entering the Galerie principale, it is possible to orient yourself along one wall and on the way out you can orient yourself along another wall

(Simonnet 1976). These dead ends all branch off the central side passage. There are no crossings in Bédeilhac.

People began using the cave in the middle Magdalenian, based on stylistic, typological, and absolute-chronological arguments (Vialou 1986). At that time, all areas of the cave were explored and used. In addition to the concentrations with substantial activities and the others with unknown qualified activities, there are another five concentrations with drawing activities [Galerie Vidal, Diverticule des modelages, Salle terminale (two concentrations), and Diverticule aux bisons] (Sauvet 2007), for a total of 16 concentrations. A definite synchrony of these concentrations cannot be assured due to the lack of chronological resolution. However, their cultural-chronological unity is very clear (Vialou 1986). Most of the concentrations (74.3%) are in the unlit area of Bédeilhac, which underscores the interest of staying in the deeper parts of the cave. Darkness was obviously not a hindrance. Exceptions are two concentrations with substantial activities (1 and 4) and two with unknown qualified activities (3 and 5); these are still in the half-shade zone.

The concentrations are differently distributed in the path network of the cave. Whereas concentrations with substantial activities are at junctions (1 and 4), in dead ends (10 and 11), and in a side passage (12), those with unknown qualified activities occur only at junctions. In contrast, concentrations with drawing activities occur in dead ends (Diverticule aux bisons and Salle terminale), in side passages (Galerie Vidal), and in passageways (Diverticule des modelages); junctions were avoided for drawing activities. The placement of the concentrations with substantial activities was oriented toward different factors: sufficient light, good access, and supervision of the entrance (1 and 4); yet proximity to cave art also was desired (Galerie Vidal [12] and Salle terminale [10/11]). Furthermore, the concentrations with unknown qualified activities in the cave system are oriented toward the central side passage, the Galerie principale, yet also toward the junctions to galleries with drawing activities. Perhaps the function of some of these concentrations in Bédeilhac can be better defined due to their location in the path network and the projectiles found there. Concentrations 6, 7, and 9 are found at the junction of the central pathway axis going to a concentration with only drawing activities. In some of their inventories there are several projectiles. Their function as a hunting weapon cannot initially explain their presence in a cave. Perhaps they belong to the basic technical equipment, require extra maintenance, have a high value, or simply another unknown function. In comparison with the other tools, the projectiles are found frequently in the listed concentrations and perhaps have special importance. The concentrations with substantial activities are found in locations that have room for more than 100 people; this is also true for the concentration that has both substantial and drawing activities in the Salle terminale. A location with comparable activities in the Galerie Vidal (12) has room for 80 people, as does the concentration (6) with unknown qualified activity; others (7 and 9) need less space. The concentrations with only drawing activities (Diverticule aux bisons and Diverticule des modelages) are in much smaller

chambers that have space for only five people. The concentrations with only substantial activities tend to be near the entrances, i.e., closer to daylight; the locations with drawing activities are farther away from daylight.

Fontanet

In February 1972 the Galerie Wahl was discovered in the Fontanet cave (Fig. 5), a few kilometers south of Tarascon-sur-Ariège (Delteil et al. 1972). For the first time since the early discoveries at the beginning of the 20th century and the catastrophic handling of the Lascaux cave, which was discovered in 1940, an intact, completely preserved concentration of prehistoric cave art, archaeological objects, and imprints was found; it was an exceptional find.

The cave art in Fontanet is extremely homogeneous and, on the basis of its stylistic features, belongs to the middle Magdalenian (Ministère de la Culture 1984; Vialou 1986). According to Vialou (1986) there are 224 figures, of which 77 are engravings and 147 are color drawings. The fact that two-thirds of the figures are colored supports the assumption that they were made to be looked at. Of the 224 figures, 142 are undefined and miscellaneous figures, 45 are abstract figures, 31 are animals, and 6 are anthropomorphs. Among the animal figures, bison ($n = 6$) are the most frequent. There also are horses ($n = 4$), ibex ($n = 4$), and deer ($n = 2$). Within the first 50 m of the Galerie ornée, the cave art forms a clear concentration

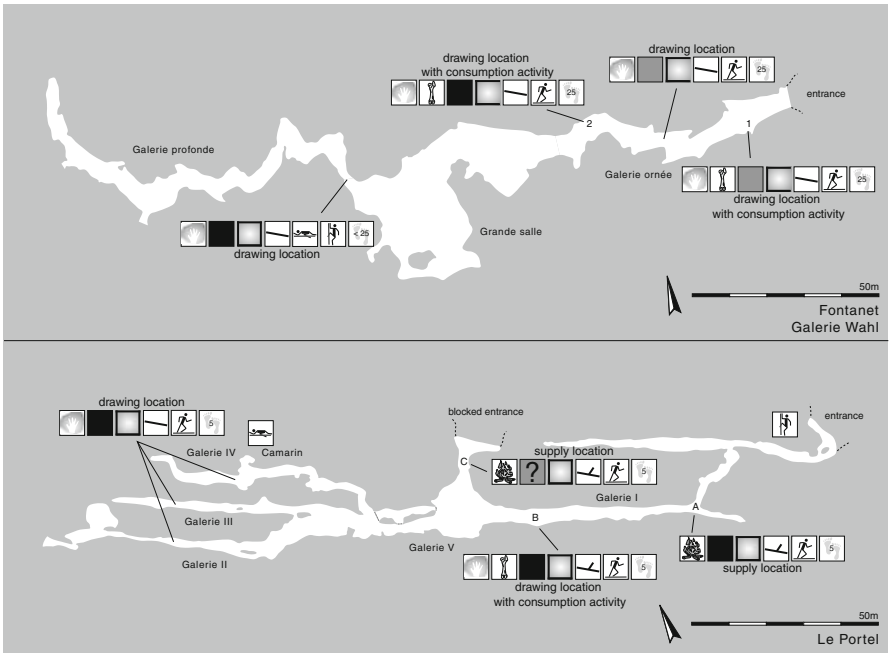

Fig. 5 Distribution of human activities with structured notes about their spatial organization in Fontanet and Le Portel (numbers and letters refer to concentrations)

of drawing activities. Elsewhere, in addition to isolated, sporadic figures, there is a concentration of cave art in the Galerie profonde.

Two concentrations of archaeological objects from Fontanet were mentioned (Vialou 1986), and another was listed by Clottes (Ministère de la Culture 1984), but no details were published. The following, however, can be summarized from the listed publications: There are traces of fire and a diverse faunal spectrum (Vialou 1986) but only a few lithic artifacts. Blanks were not produced. Thus, no substantial activities took place in Fontanet; rather, supplies were consumed there (consumption activities). In the back area of the cave, two lithic artifacts were found on the surface of the floor of the cave (Delteil et al. 1972), indicating that there were not only the two concentrations in Fontanet but other isolated occurrences of lithic artifacts.

According to the information from Vialou (1986), daylight reaches up to the first small bend in the 300-m-long gallery. The bend is located 40 m from the original entrance. It can be assumed that light conditions did not change abruptly from the half-shade zone to the dark zone. The rest of the cave is in the dark zone. Notwithstanding the actual range of the half-shade zone, the illumination for orientation in Réseau Wahl is uncomplicated. Only when cutting across the Grande salle does one have to stay close to one of the walls. Otherwise, the path width of 3-5 m requires only a tallow lamp to light at least one of the cave walls. In all parts of the Réseau Wahl, it is possible to walk upright and comfortably. The only exceptions are the climbing passage and the crawling passage between the Grande salle and the back part of the gallery. The path network here consists of only a single side passage that terminates in a dead end. Since there is no passageway and no junction, there are no alternatives for a different way out. In spite of the high standard deviations of the absolute dating, the prehistoric remains from Fontanet form a cultural unit and are classified as middle Magdalenian (Ministère de la Culture 1984; Vialou 1986). This corresponds to the results of the spatial organization analysis of the cave. There is a clear center of prehistoric activities that is located within the first 50 m of the cave. Over 90% of the cave art is within this area, which is partially in the half-shade zone and partially in the bordering dark zone. Due to the simple structure of the Galerie Wahl in Fontanet, there is only one central side passage, which terminates in a dead end. The climbing passage and the single crawling passage were not especially marked. The dead end was not of special interest. However, isolated figures, traces on the cave floor, and the discovery of two isolated lithic artifacts are evidence that people were also in the back part of the cave. Both concentrations with consumption activities form the closure of the concentration with drawing activities. There is room for approximately 25 people in front of the different figures. Proximity to the cave entrance was important for all activities. In sum, Fontanet has a simple pattern. The space between daylight and the Grande salle was used as an activity center. The Grande salle was avoided, and the back part of the cave was only reconnoitered.

Le Portel

Amid the Plantaurel limestone massif is the fossil cave system of Le Portel (Fig. 5). Approximately 30 m below this cave section is the system that is active today.

Le Portel has hardly been investigated since its discovery in 1908; there are only the excavations by Noulet, Vézian (Vézian 1955), and recording of the cave art by Beltrán et al. (1967) and Dauvois.

Vialou (1986) counted 138 figures in Le Portel, including 64 animals, 41 abstract and 28 miscellaneous figures, and 5 anthropomorphs. Among the animals, horse ($n = 26$) and bison ($n = 23$) are dominant. Deer ($n = 4$), ibex ($n = 1$), fish ($n = 1$), and 8 undefined animals also are represented. The stylistic features as well as the continuous completion of the monochromatic drawings in either red or black argue for their homogeneity. They are classified as middle Magdalenian (Vialou 1986). The cave art is fairly uniformly distributed in all parts of the cave; there is no distinct center. Differences between the individual galleries can be seen among the dominant motifs. In Galerie III (Galerie Régnault), horse is dominant. In contrast, bison is dominant in Galerie IV (Galerie Breuil) (Ministère de la Culture 1984).

At the beginning of the 20th century, four concentrations of archaeological objects of the middle Magdalenian were found in Le Portel during prospection work (Vézian 1955). The first concentration at the entrance to the Galerie de droite received no further attention in the literature; due to lack of data, it could not be included here. The available material on the artifact finds in the other three concentrations is similar and is classified as middle Magdalenian (Vézian 1955). The presence of blanks, formal tools, and the remains of hunting preparation in two of the artifact inventories indicate substantial activities (concentrations A and C). The formal tools and faunal remains in concentration B indicate consumption activities.

Today, all of the galleries and chambers are in the dark zone. Artificial light is needed for orientation and movement everywhere in the cave, yet it is easy to illuminate the entire cave. Except for parts of Galerie V (Grande salle), the paths are so narrow or low that illumination poses no problem. In contrast, movement in Le Portel is hindered by various small climbing passages. These are found repeatedly in Galerie III and Galerie IV. Upright movement is possible everywhere else. Especially notable is the Camarin in Galerie IV, a small chamber that can be entered only by crawling. In the path network, the Galerie I (Galerie Jeannel), Galerie V, and Galerie II (Galerie Jammes) form the central axis, and both Galerie III and Galerie IV junction off from there. There is no crossing in Le Portel. All of the side passages terminate in dead ends. None of the chambers can serve as a passageway.

There are different opinions on the uniformity and distribution of cave art within the cave. Whereas the cave art is subclassified by Breuil and Leroi-Gourhan into early to middle Upper Paleolithic and Magdalenian ensembles (Ministère de la Culture 1984), Vialou (1986) stresses the uniformity of the prehistoric remains. According to the published artifact spectra of the different concentrations of archaeological objects (Vézian 1955), concentrations A and C have traces of substantial activities; there are no drawing activities. The topographic location near the possible original entrance ensures that concentration C had natural light, controlled access, and quick entrance to the cave system, all basic necessities that are ensured through positioning in Le Portel. The function of concentration A is not easily deduced. Entry into the cave via the steep and narrow northeast entrance is difficult. Although there is a lack of natural light, concentration A may have been

placed so that the basic necessities could be achieved in a comfortable place. According to the artifact spectrum, the activities carried out in concentration B can be classified as consumption activities. Drawing activities also were carried out at the same location. In the path network of Le Portel, this spot is located directly at a junction in the second quarter of the cave system. Except for individual spots in Galerie II and Galerie V, the available space in Le Portel is limited basically to five people. The listed exceptions clearly have more space (c. 50 people). Through the distribution of the concentrations with exclusively substantial activities, it is possible to control access to the entire cave system. This also holds true if both entrances to the cave were open at the same time. The cave art is relatively uniformly distributed in the three galleries, each of which terminates in a dead end and is as far away from the entrance as possible. There is no distinct center. Due to limited available space, the cave art is not intended to be viewed by larger groups at the same time. Thus, the intensive use of color does not correspond to a larger audience.

Conclusions and perspectives

Our concept for the analysis of spatial organization of cave sites follows an integrative approach. All items found in well-preserved caves are handled with the same care. Cave art, archaeological objects, and imprints are seen as equally ranked traces of human activities and are classified using standard archaeological methods. The spatial patterning of human activities in the cave is analyzed by a defined tool kit for space analysis as used today in urban planning. This structured approach opens a new field of investigation; a consistent nomenclature and definition of features as light zone, chamber type, path network, mode of movement, and available space complement intuitive and individualistic descriptions. The reconstructed human activities are then evaluated in their topographical and archaeological contexts. The proposed set of features is easy to handle, even when drawn only from published data. A direct comparative analysis of cave sites is possible. Although this broad approach bears the risk of ignoring individual, fine-grained details of each cave, it has the advantage of illuminating patterns in the human use of caves.

In the three caves investigated here, 29 individual concentrations were recognized and divided into two basic categories: substantial activity ($n = 7$) and qualified activity ($n = 21$). One concentration could not be classified. The qualified activities comprise 13 drawing, 3 consumption, and 5 unknown. The relative positions of these concentrations in the caves combine to produce 22 locations. Projecting them onto maps of the caves produces four broad groups of locations that are characterized first by kind of human activity and second by spatial feature (light zone, chamber type, path network, mode of movement, and available space) (Fig. 6).

(1) Supply locations, where substantial activities are carried out, are in the half-shade and dark zones. These locations can be reached easily because they are near the entrance. Access to the entire cave system can be controlled from these

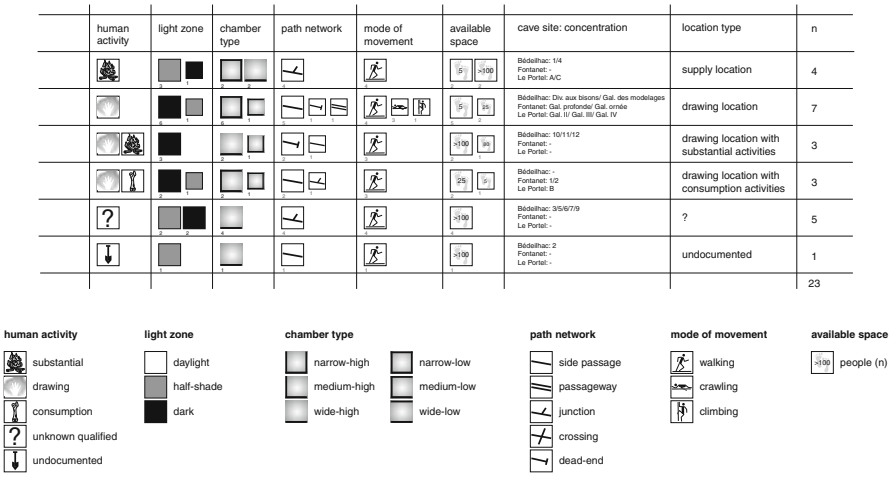

Fig. 6 Combination of human activities and the structured notes about their spatial organization in Bédeilhac, Fontanet, and Le Portel

locations. (2) Absolute darkness is important for drawing locations with substantial activities. Although substantial activities are recorded, they have little effect on the positioning within the cave. (3) Drawing locations with consumption activities are variably positioned in the caves. These locations, which show the lowest profile of definition, are recorded in the half-shade and dark zones. (4) Drawing locations are those areas where there is no evidence of any activities other than drawing and no archaeological objects are found. They are positioned in the dark zone, provide little space, and are found in passageways or side passages that terminate in dead ends.

That four cave-specific groups of locations were generated from the 22 different locations testifies to some kind of patterning in the human use of caves and their spatial arrangement in the cave landscape. What is particularly remarkable is the orientation of the locations along the respective path network of the caves (Figs. 4 and 5). Complete control (physical and symbolic) over all movements in the cave is achieved through the supply locations. Locations that exclusively display drawing activities are restricted to the dark zone. Very narrow spaces that accommodate only a few people at a time were selected for this. Locations in which drawing and substantial or consumption activities were carried out have too few data at present to allow the recognition of defined patterns of their positioning in the path network. Of particular importance is the observation that substantial activities were carried out in Bédeilhac and Le Portel. These substantial activities are macroscopic identical to those at open-air sites. They indicate the provisioning of basic needs. Due to a lack of data, it is not possible to carry out calculations on the length of stay or group size. However, this type of location in the cave makes sense only if people intended to stay inside the cave for a longer period of time. It would be helpful to know how long the supply of food would have lasted and to what extent the production and improvement of tools, which were used outside later, were carried out in the caves. These data could indicate how outside activities—carried out after the stay in the

cave—were included in the overall planning process. This additional information is necessary for a holistic interpretation of cave use and would provide indications for the interpretation of the cave art.

There are no supply locations at Fontanet. The support of the internal activities from a location within the cave was not necessary. Due to the small number of caves in our analysis, we do not have a counterpart for this pattern. A reasonable argument for the spatial setting at Fontanet would be the short distance from the locations to the exterior. A very preliminary look at a similar situation in Lascaux seems to support this assumption.

Up to now, only the figures themselves were used in the interpretation of cave art. Our integrative concept includes all prehistoric remains for a detailed analysis of human behavior in caves with rock art. The caves under study indicate a balanced relationship between drawing activities and substantial or consumption activities. Such a balanced relationship might indicate that the cave was surveyed completely by Paleolithic users to develop a mental map of the space and anthropomorphize it afterwards. The creation of various recurrent locations throws light on the extraordinary capabilities of Paleolithic users in spatial recognition of the caves. The patterning gives evidence that a kind of master plan for residence in caves was in operation.

Our results should be regarded as a first basic step to provide a spatial framework for the interpretation of cave art locations in their context. It would be a tremendous advance if researchers of cave art would agree to use the same nomenclature and would describe their sites in precise reports that allow further scientific applications. It is obvious that different concepts or master plans were followed by the Paleolithic users. A prolonged stay in a cave interior supported by supply locations as in Bédeilhac and Le Portel affords strategies other than the visits in Fontanet. The meaning of this varying behavior is still open to debate. We have to admit that in the present state of research, even the ritual character of this behavior is questionable (Arias Cabal 2009, p. 287). For more detailed research we need to include features other than space, as there are, e.g., the tangible and the intangible, visibility and views, sound, and public or private access (Bahn 2003). The art panels themselves are packed with detailed quantitative information that is waiting to be unpacked by researchers. Spatial statistical analysis of cave art provides access to this information (Classen and Zimmermann 2003). The combination of spatial organization of cave architecture as proposed here with spatial patterning and organization of art panels linked by GIS tools will provide an excellent database in the near future. This approach should allow an interpretation of Paleolithic rock art that abandons narrative flights of fancy and touches down on empirical terrain.

Acknowledgments The German Science Foundation (DFG) supported this research project from 2001 to 2004. P. G. Bahn, B. Hayden, T. Lenssen-Erz, K. Kindermann, H. Riemer, the anonymous reviewers, and the editors gave useful advice. K. Schneider and L. Clare translated the text into English.

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