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1 **Choosing rock art locations: geological parameters and social behaviours. The example**
2 **of Cussac Cave (Dordogne, France)**

3

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20

21 **Abstract:**

22 Cussac Cave, discovered in 2000 in the Dordogne department of France, is one of the major
23 decorated and sepulchral sites of the Gravettian period of the Upper Palaeolithic. It contains
24 spectacular engravings, human remains—some of which were deposited in bear hibernation
25 nests—and other well-preserved artefacts and traces of human and animal activity, such as
26 human and cave bear footprints. The exceptional preservation of this cave is due to its recent
27 discovery (followed by an extensive preservation program) and the apparent absence of
28 human frequentation since the Gravettian period. As part of the multidisciplinary research
29 program developed since 2008 (PCR Cussac, dir. J. Jaubert), this study aims to contribute to a
30 better understanding of the factors—natural and/or cultural—that influenced the Gravettian
31 people in their selection and general distribution of rock art panels in the cave. We investigate
32 the nature of the rock support, location, surroundings, accessibility, and visibility of 31
33 panels. For this purpose, we developed an innovative methodology combining the data
34 recorded in a dedicated database and on topographic documents with data processing using
35 complex statistics (Factor Analysis for Mixed Data - FAMD). Through this work, we
36 identified three groups of panels that reveal three ways of using the cave, two of which appear
37 homogenous. Group 1 is characterized by small panels located in narrow passageways of the
38 Palaeolithic path in the Downstream Branch of the cave. These panels share a strong potential
39 for visual relationships whereas it is impossible for more than four people to see a given panel
40 at the same time. In contrast, Group 3, also mainly located in the Downstream Branch, is
41 composed of large panels with numerous graphic entities. These panels are always located in
42 wide corridors and distant from the natural path, and their field of visibility is thus large

43 enough to accommodate a small group of individuals. They also share visual relationships
44 with other panels. Finally, Group 2 contains fewer intrinsic criteria, though all the panels are
45 situated between the beginning of the Downstream Branch and the Upstream Branch, and
46 they are visually isolated from each other. This study yields evidence of a strong interaction
47 between geological and cultural factors in the selection of the rock art panels in Cussac Cave.
48 The Gravettian people that frequented Cussac Cave linked their cultural goals to what the
49 cave had to offer in terms of geology, geomorphology and available space. They adapted to—
50 and even optimized—both the opportunities and constraints of the cave, thus demonstrating a
51 strong interaction between geological and cultural parameters.

52

53 Keywords: Cussac Cave; Rock Art; Accessibility; Lighting; Geomorphology; Topography;
54 Gravettian

55

56 **1. Introduction**

57

58 The location and distribution of rock art panels within sites has become a prominent scientific
59 issue in rock art studies over the past fifteen years (Chippindale and Nash, 2004). Are these
60 locations random or intentional? In the latter case, which factors dictated the choices made by
61 the makers and/or their communities? Many studies have investigated the relationships
62 between rock art and landscapes at the macro and micro-scales, i.e., between the environment,
63 topography and rock properties (Gjerde, 2006). They have yielded evidence of culturally
64 driven choices that influence rock art locations, usually interpreted as being embedded in the
65 symbolic features attributed to the landscapes. In this case, the location would be an active
66 element, meaningful in terms of its symbolism (e.g. Lewis-Williams and Dowson, 1990;
67 Bradley, 1997; Keyser and Poetschat, 2004).

68

69 These choices may also have been influenced by the human factor, however, with the image-
70 makers themselves making individual decisions and acting as primary agents, and/or viewers
71 acting as a potential secondary agent. As a visual production, rock art plays a major role in the
72 communication systems of human groups and in the construction of social strategies
73 (McDonald and Veth, 2013). Not all rock art motifs are meant to be viewed by an audience,
74 however; the intention behind their creation can also be linked solely to the act of creating
75 itself, of leaving a mark without any intended subsequent viewing, such as when rock art
76 images are associated with a non-human spiritual being. Therefore, in addition to the motifs
77 and their stylistic features (techniques, shapes, composition), the location and strategies of
78 perception that they induce depend partly on the intended audience of the images (Bourdier et
79 al., 2017).

80 In this paper, we use the example of Cussac Cave (Le Buisson-de-Cadouin, France) to explore
81 the interplay between the natural setting, the art makers and the potential viewers in the
82 choices of rock art locations made by prehistoric artists and communities. This decorated
83 sepulchral cave is considered as one of the major European Palaeolithic “sanctuaries”

84 discovered thus far. The association between intentionally placed human skeletons and an
85 almost entirely engraved art, the huge size of the cave (approximately 1,600 m long), the
86 numerous motifs (642 currently recorded) and the monumentality of some of the figures (up
87 to 3.5 m long), make this site exceptional. At first sight, two coexisting panel types are
88 apparent: small panels with one or only a few motifs, and large panels with many motifs,
89 which can sometimes be categorized as palimpsests (e.g. the Grand Panel – Feruglio et al.,
90 2015a). This opposition between two panel types and their variable distribution throughout
91 the cave raises numerous questions:

- 92 - How are these panels distributed within the cave?
- 93 - Are the two types of panels associated with different geological or geomorphological
94 features?
- 95 - Are they associated with the same image-making conditions (access, posture,
96 lighting)?
- 97 - Who was the intended viewers: only the image-makers, a secondary audience as a
98 group of people (and of which size?) or a non-human spiritual entity?
- 99 - Are they associated with the same behaviours?
- 100 - Did they play the same role in the appropriation and use of the cave by the Gravettian
101 people?

102 Our goal is to better understand the interplay between the natural and cultural factors that
103 influenced the Gravettian people in their selection of locations for the creation of rock art
104 panels in Cussac Cave. Beyond this specific context, our aim is to provide new insights into
105 the social uses of decorated caves by Palaeolithic hunter-gatherer societies, and on the
106 motivation(s) and meaning(s) of rock art.

107

108 **2. Contextual setting**

109

110 1.1. Different views on an old question

111

112 Researchers began to address questions concerning cave art locations and distributions in the
113 second half of the 20th century with the development of the structuralist approach and the
114 new attention paid to the rock art support, i.e., the rock art site and rock support itself
115 (Laming-Emperaire, 1962; Leroi-Gourhan, 1964; Raphaël, 1986). In his pioneering work, A.
116 Leroi-Gourhan claimed to identify distribution rules that dictated the locations of motifs
117 within caves. Even if the monolithic structuring model that he designed has since been
118 debated (Vialou, 1986), it highlights the concept of a “participating cave”, i.e., the active role
119 played by the physical space, seen as symbolically embodied, in the making of rock art. Like
120 the associations of motifs within the compositions, the distribution of the compositions at the
121 scale of the site were thus considered as part of the symbolic message delivered by the
122 images, interpreted by Leroi-Gourhan as cosmogonic myths based on the complementarity of
123 male-female principles. Many other studies have since yielded evidence of the planned
124 distribution of rock art motifs within cave art sites (Vialou, 1986; González García, 2002). In
125 addition to a general layout defined by the topography of the cave, some studies have
126 highlighted the role played by the natural features of rock volumes, shapes and surfaces and

127 their interplay with the motifs (Lejeune, 2004), as has been observed in many other rock art
128 traditions (Lewis-Williams & Dowson, 1990; Keyser & Poetschat, 2004; Gjerde, 2006).

129
130 The question of the motif-support relationship changed in the 1980s when researchers shifted
131 their focus to the anthropological aspects of the social functions and uses of rock art. In the
132 framework of multiscale contextual approaches, the selection of rock art panels is currently
133 considered via three main agents. First, geological determinism has become central in the
134 technological analysis of rock art and is considered as a prerequisite to the act of making the
135 art. In the dialogue between the hand and the material, the nature and morphology of the rock
136 are not neutral, but can alternately stimulate, facilitate and force adaptations, or constrain the
137 techniques and the making processes (Aujoulat, 2002; Ferrier *et al.*, 2017; Feruglio *et al.*,
138 2015b).

139
140 At a different scale, the relationship that humans develop with the support is also linked to
141 their global perception of the physical space (Lorblanchet, 1982). A few paleo-speleological
142 studies that sought to recreate the behaviours of Palaeolithic people in the subterranean
143 environment examined the dynamics of moving about inside the caves and the postures taken
144 by the authors. They showed evidence for very different access conditions to the decorated
145 walls between the sites and sometimes even within the same site (Rouzaud, 1978; 1997; Le
146 Guillou, 2005). Some simple geometric motifs (lines, dots) isolated on panels that are difficult
147 to reach have been interpreted as appropriation markings in the subterranean environment,
148 while others located on topographic nodes have been defined as beaconing elements (Delluc
149 and Delluc, 1974; Robert, 2017). Other studies have looked for connections between the motif
150 locations and the acoustics of the underground space (Reznikoff and Dauvois, 1988;
151 Reznikoff, 2012).

152
153 Between conspicuous compositions and hidden assemblages, the viewers is a third factor that
154 potentially influenced the location and distribution of rock art panels. As a complement to the
155 indispensable analysis of the archaeological context, several studies have considered the
156 visibility and legibility of the motifs to tackle the issue of the intended viewers. Distinct
157 parameters, criteria and analytical tools have been chosen and tested: the physical space, from
158 the setting of the site in the landscape to the rock art panel topography; the visibility
159 conditions; the lighting technique; the technical and formal characteristics, and; the agency of
160 the motifs (Fortea Pérez, 1994; Lorblanchet, 1995, 2010; Bahn, 2003; Villeneuve, 2008;
161 Pastoors & Weninger, 2011; Bourdier, 2013; Bourdier *et al.*, 2017; Hoffmeister, 2017).

162
163

164 1.2. Interdisciplinary research at Cussac Cave

165
166 Cussac Cave is located in southwestern France on the left bank of the Dordogne River, or
167 more precisely, on the right side of one of its tributaries, the Bélingou (44°82'94"N,
168 0°87'31"E; Fig. 1).

169 The cave was discovered in 2000 by Marc Delluc after he cleared the entrance porch that had
170 been blocked by fallen rock. After passing through the narrow opening, he continued 130
171 meters into the cave before he discovered an engraved panel and human remains placed in
172 bear hibernation nests. He saw that the cave was in an excellent state of preservation and had
173 the foresight to walk only on a narrow path. This same path is now marked or equipped with
174 walkways and is the only path that people are allowed to follow; not even the researchers are
175 allowed to venture beyond this past, thus significantly restricting the study conditions. The
176 Ministry of Culture now owns the site and has classified it as a “Cultural Heritage site.” A
177 large buffer zone in the surrounding exterior environment has also been delimited and is now
178 protected (Fourment *et al.*, 2012).

179 Preliminary studies of the cave attributed both the human remains and the parietal art to the
180 Gravettian period. A few archaeological remains were identified on the cave floor and
181 evidence for an abundant presence of bears was identified (Aujoulat *et al.*, 2001a, 2001b,
182 2002, 2004).

183 In 2008, a research team was formed to conduct an ambitious, multi- and inter-disciplinary
184 research project (Jaubert *et al.*, 2012, Jaubert, 2015). This project has three main objectives:

185 1) to study and understand the human corpse deposits, to specify their mortuary features, their
186 biological status, the minimum number of individuals, and to confirm their contemporaneity;

187 2) to systematically survey the cave with the aim of identifying and qualifying all the indices
188 of animal and human movement or stasis within the cave, and their respective diachrony;

189 3) to list and record the engraved panels and the rare painted marks, to conduct a techno-
190 stylistic analysis of them, to establish the chronology and modalities of the composition of the
191 panels, and to reconstruct the organization of parietal art inside the cave.

192 On a broad scale, our aim is to contextualize the site within its natural and cultural
193 environment and attempt to identify the reasons for which this site was chosen, and the
194 manner in which it was visited. For this purpose, we have developed several shared recording
195 and analysis tools: a detailed topography, 3D laser scanning, photogrammetry of sectors with
196 significant anthropogenic features, GIS, and cloud storage of research documents. We decided
197 from the outset that the parietal art surveys would be exclusively made on a 3D support
198 (Feruglio *et al.*, 2015a).

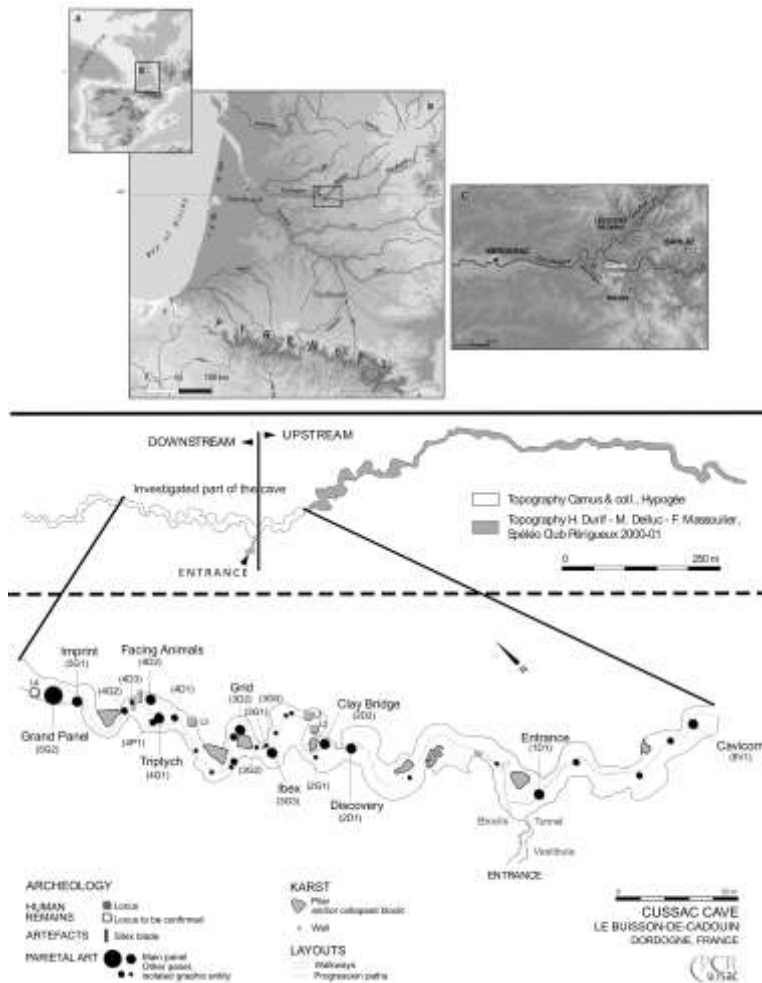
199 The cave is 1.6 km long and is subdivided, starting from the entrance, into a Downstream
200 Branch and an Upstream Branch (Fig. 1). The parietal art is composed of at least 630 motifs
201 distributed among fifteen main panels (such as the Grand Panel with at least 130 motifs:
202 Feruglio *et al.*, 2015b), and some less prominent and isolated motifs. Apart from a few ochre
203 or manganese dots, all the graphic elements are engraved, using tools or fingers. Among the
204 figurative representations, bison is dominant, followed by mammoths and horses. There are
205 also at least five female figures, female and male sexual representations and remarkable
206 rhinoceros and goose depictions. The figurative themes, patterns, formal conventions and

207 thematic associations in Cussac Cave are typical of the Middle Gravettian period and are
208 known in other caves as well, such as Gargas and Pech-Merle (Aujoulat *et al.*, 2004;
209 Lorblanchet, 2010; Jaubert, 2008; Feruglio *et al.*, 2011; Jaubert and Feruglio, 2013;
210 Petrognani, 2013).

211 The human remains (Henry-Gambier *et al.*, 2013) are distributed among three loci (L1, L2
212 and L3) and all of them are associated with bear hibernation nests. L1 is composed of two
213 main depressions and the very fragmented and unequally preserved remains of at least two
214 individuals (adult and adolescent). L2 contains only one nearly complete individual: a young
215 adult male with anatomical particularities compared to his assumed contemporaries, deposited
216 in the ventral decubitus position (Villotte *et al.*, 2015; Guyomarc'h *et al.*, 2017). Like in L1,
217 the bones in L3 are fragmentary, suggesting that the corpses could have been deposited in a
218 bear nest positioned on top of a mound. Post-deposition, some of them would have slid down
219 the slope. L1 and L3 are associated with ochre, confirming that the human remains were
220 intentionally deposited (Henry-Gambier *et al.*, 2013). Paleogenetic analyses have thus far
221 yielded only small sequence portions, thus prohibiting their interpretation (Deguilloux *et al.*,
222 2011).

223 The other artefacts and evidence of human presence consist of 1 laminar flake, 2 flint blades
224 (Klaric *in* Jaubert *et al.* 2012 and *in* Ledoux *et al.*, 2017), 1 reindeer stag antler beam (Goutas
225 *in* Jaubert *et al.* 2012 and *in* Ledoux *et al.*, 2017), 2 lamps, portions of broken, fragmented,
226 tipped and displaced speleothems, torch smears, foot and other body prints, and ochre and
227 manganese marks (Ledoux *et al.*, 2017).

228 At present, both the direct dates obtained from human bone and charcoal and relative
229 chronological elements (lithic and bone technology, parietal art), identify a single generation
230 of human groups that would have visited Cussac Cave during the Middle Gravettian period,
231 approximately 29-28 ka cal BP. The bears always preceded the humans in the cave (Jaubert *et*
232 *al.*, 2017).



233

234 Fig. 1: The location of Cussac Cave (Dordogne, France) and the locations of the 31 studied panels.

235

236 2. Methods

237

238 2.1. Field study

239

240 In this study, we recorded parameters focused on the supports of the panels and their
 241 environment to address the following questions: how are the panels distributed within the
 242 cave, which criteria influenced the locations of the supports, which paths did the Palaeolithic
 243 people follow, and where are the visibility areas for each panel? We compiled a database,
 244 performed statistical analyses of the data, and then completed this work with the study of
 245 topographic maps (H. Camus and collaborators). We collected most of the information
 246 included in the database and the topographic maps in the field through the direct study of the
 247 panels, as well as through discussions with researchers in the different fields of study applied
 248 at Cussac: parietal art, archaeological artefacts, parietal marks, ichnology (TrAcs for *Traces*
 249 *d'Activités* – Aujoulat *et al.* 2013, Activity Marks, Ledoux *et al.*, 2017), speleology, geology,

250 geomorphology, and geoarchaeology (Ferrier *et al.*, 2017). We added photographs and
251 sections of the cave to enhance the study.

252 2.1.1. Site preservation

253 Since the Gravettian people left the cave around 30,000 years ago, natural phenomena (calcite
254 deposits, flooding, etc.) have modified the floors and the walls of the cave (Ferrier *et al.*,
255 2017). The Entrance Panel appears to be the most altered, displaying large eroded or calcified
256 areas. Except for a few cases, the art in Cussac Cave is very well-preserved (Aujoulat *et al.*,
257 2004). Other than mainly Holocene accretions in some limited areas of the cave, the general
258 morphology of the galleries has changed only slightly since the Gravettian period. The
259 concretions have not grown significantly and have not altered the paths or the visibility range,
260 for example. In the Upstream sector, a few boulders may have collapsed after the Gravettian
261 period (Camus, pers. comm.). Some of these may have been engraved.

262 2.1.2. Investigated sectors

263 The cave is accessible only in winter when the CO₂ levels are at their lowest. Due to time
264 limitations, this study does not include all the panels discovered thus far. When selecting
265 panels for this study, we gave priority to the first two-thirds of the Downstream Branch
266 because it is accessible from the built walkways, has the greatest quantity of art, a variety of
267 panel types, and is currently the most thoroughly studied zone, thus enabling us to include
268 data from multiple disciplines. Because it is easily accessible and contains various panel
269 types, we also examined the entrance of the Upstream Branch. We will enlarge our selection
270 of study zones once the entire cave is secured, marked and equipped with walkways. We did
271 not include panels with ambiguous marks that could be related to art or other activities (e.g.
272 the diffuse red marks) in this study. In this current study zone, we have analysed a total of 31
273 panels: 27 from the Downstream Branch and four from the Upstream Branch.

274 2.1.3. Access and paths inside the cave

275 One aim in this study was to analyse the Palaeolithic accesses and paths to the parietal art
276 panels, and the visibility of the panel supports from different vantage points. The current path
277 (the combined authorized path and built walkway) inside the cave is limited, however; it is
278 linear and about 50 cm wide. One must, therefore, keep in mind that our viewpoints are
279 limited. We should also note that if the 3D model were available for the entire cave, this study
280 would have been much more precise. The bear and human paths are known through the
281 contribution of the TrAcs team and the recorded topography from the Entry to the Triptych
282 Panel.

283

284 2.2. The database

285

286 2.2.1. The database design

287 In the database analysis, our main aim was to determine if the prehistoric people chose the
288 panels because of their location in the cave, the appearance and texture of the walls, their

289 immediate environment, the visibility or accessibility of the surfaces, a combination of these
290 factors, or none of them, which would suggest more haphazard choices. To record a large
291 range of parameters on the decorated surfaces and in their environment, we constructed, tested
292 and completed the database on-site before statistically analysing it.

293 2.2.2. Description

294 The database contains 49 variables, five of which are continuous and 44 of which are
295 categorical (for a total of 104 levels). These variables can be divided into 5 subsets. The main
296 variables of each subset are as follows (for more details, see Table S1 and the Detailed
297 Database):

298 - Panel composition:

- 299 ○ Number of motifs
- 300 ○ Degree to which the figures overlap
- 301 ○ Distribution of the engravings (frieze, face-to-face, oriented motifs)

302 - Wall characteristics:

- 303 ○ Geology
- 304 ○ Morphology
- 305 ○ Alterations prior to the engravings
- 306 ○ Presence of bear claw marks on or near the panel

307 - Environment and physical context of the panel:

- 308 ○ Location (inclination, height, distance from the Palaeolithic path)
- 309 ○ Description of the cave floor (morphology and nature)
- 310 ○ Characteristics of the gallery (dimensions and morphology)
- 311 ○ Links to other panels (distance between panels, co-visibility)
- 312 ○ Panel delimitations (e.g. cracks in the walls, reliefs on the walls, height
313 between the cave floor and the wall surface)

314 - Accessibility and visibility of the surface for the engraver:

- 315 ○ Is the decorated surface accessible from the Palaeolithic path?
- 316 ○ Conditions of access to the panel (standing, leaning or crouching, with or
317 without the use of hands)
- 318 ○ Conditions of remaining in place at the panel (standing, leaning or crouching,
319 with or without the use of hands)

- 320 ○ The need for the engraver to move one or several times during the creation of a
321 motif
- 322 - Accessibility and visibility of the panel surface for potential viewers:
- 323 ○ Can the panel be observed without a prior indication of its location?
- 324 ○ Maximum distance from which the panel is visible
- 325 ○ Panel orientation (visibility from upstream or downstream)
- 326 ○ Conditions of remaining in place at the observation point (standing, leaning or
327 crouching, with or without the use of hands)
- 328 ○ The number of people the available space can accommodate
- 329 ○ Minimum number of lighting sources (was one Palaeolithic lighting source
330 sufficient to light the entire panel?)
- 331 ○ Was direct lighting sufficient to observe the panel or was it necessary for a
332 person to stand next to the panel with a light source?

333 2.2.3. Statistical methods

334 We recorded the data with FileMaker and processed it with R statistical software (R Core
335 Team, 2018). Because the database contains many variables, mainly qualitative but also
336 numerical, a Factor Analysis for Mixed Data (FAMD) was used to combine the information
337 of both types of variables. Factor analysis of this type of mixed data is usually done by
338 dividing the range of the quantitative variables into intervals to recode them as factors, and
339 then using a Multiple Correspondence Analysis. Using FAMD instead allows computation of
340 the principal axes deriving directly from both numeric and nominal data, which is preferable
341 when working with a relatively small sample (Pages, 2004).

342 Agglomerative hierarchical clustering with Ward's method was performed using the factorial
343 coordinates of the individuals to identify homogeneous clusters of panels.

344 These multivariate analyses were conducted using the R package FactoMineR (Le *et al.*,
345 2008). Before applying FAMD, the missing values were imputed using a regularized iterative
346 algorithm (Audigier *et al.*, 2016) implemented in the R package missMDA (Josse and Jussion,
347 2016).

348 To run R, the variables and modalities in the database were indicated with underscores and
349 abbreviations. To make them easier to understand, all the figures below, derived from the R
350 statistical analysis, were reworked with clearer sentences. The full database can be consulted
351 in the Supplementary Data (Table S1), with notes explaining each variable (Detailed
352 Database), as well as the unmodified graphs (Code).

353

354 2.3. Other documents and considerations

355

356 Because the field of visibility, the accessibility, the lighting, and the available space are
357 spatial information, they could not be entirely recorded into a database. We thus completed
358 the study using topographic maps, photographs, and sections.

359 2.3.1. Completion

360 The topographic maps used were produced by Hypogée (H. Camus and coll.) in 2010 and
361 2011. They were created in two steps. The first consisted of establishing a polygonal chain
362 route using a robotic Total station and the installation of stations with nails as survey points.
363 Using this topographic canvas, the second step was to accurately survey the topographic
364 details of the cave: concretions, blocks, clay floors, wall and ceiling shapes, flow traces. The
365 resulting map of the features of the underground landscape and a detailed legend, was
366 replicated on maps in A3 format and at a 1/100 scale. These maps served as the support for
367 our *in situ* observations. Because we are not allowed to leave the designated walkway inside
368 the cave, we could not always check, or even less often, measure, some of the paths and
369 visibility areas. When possible, precise measurements were taken using a laser telemeter.
370 When this was not possible, the measurements were extrapolated from the topographic maps.
371 The different indications were then recorded using image processing software (Inkscape).

372 Photographs and sections were used to complete the maps. The aim here was to highlight the
373 position of the motifs, the nature of their surroundings, and their accesses. The matching of
374 photographs, sections, and topographic maps enabled us to reconstitute the space within
375 which the graphical manifestations are placed despite our restricted walkway and lack of a 3D
376 model (ex. Fig. 2).

377 On these documents, for each panel, we recorded:

- 378 - The extent of the panel,
- 379 - The different probable paths (numerous Palaeolithic anthropic traces allow us to
380 determine which paths were used or were the most likely used), especially those
381 leading to panels.
- 382 - The field of verified visibility (precise measures were taken)
- 383 - The field of potential visibility (no precise measurement could be taken from these
384 locations because of their distance from the current walkway, but they seem suitable
385 for the observation of the panel)
- 386 - The ideal observation area when relevant and possible (the area from which the
387 figurative engravings can be seen when standing upright)
- 388 - The major topographic obstacles that cannot be traversed (some ledges, for example)
- 389 - Significant topographic obstacles that can be traversed, but require substantial effort

390

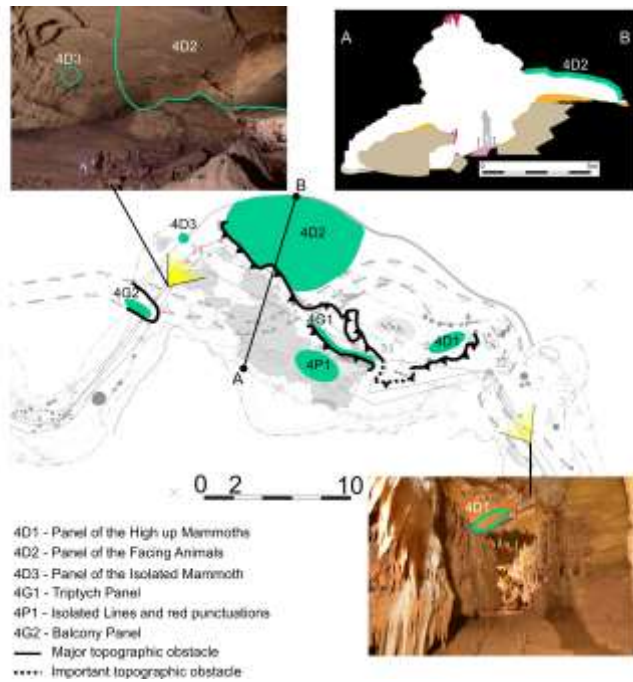
391 2.3.2. Palaeolithic lighting

392 The visibility of cave art depends both on the overall physical abilities of the observer and
393 his/her previous experience and knowledge of the cave. This notion of visibility is nonetheless
394 essential to understand the role of potential viewers. We therefore analysed only the area of
395 visibility of the panels (where the panel surface is illuminated and within the field of
396 visibility) and not the legibility of the lines, which implies recognition of the motifs, and is
397 therefore dependent to an even greater degree on cultural and experiential factors.

398 Our lack of knowledge concerning the power of Palaeolithic lighting induces a bias into the
399 study. We assumed that most of the engravings were located in an area of complete darkness
400 with no natural light. With scarce available information on torch lighting in the literature, this
401 study focused on oil lamp lighting. Experiments (Delluc and Delluc, 1979; de Beaune, 1987)
402 demonstrated that regardless of the operating mode or raw material used, oil lamps produce a
403 luminance of about 5-15 lumens with a naked flame. Therefore, the lighting of oil lamps is
404 similar to the lighting of modern candles. With this type of lighting, it is impossible to
405 determine the distance from which an engraving can be observed since it depends on the size
406 of the lines and their contrast with the walls (Pastoors and Weniger, 2011).

407 Human eyes can detect the lighting produced by a candle up to a distance between 22.36 m
408 and 38.73 m (Pastoors and Weniger, 2011). Therefore, if someone lights a panel, it can be
409 seen from such distances, even if the question of the detection of the engravings is still
410 unresolved. Due to topographic obstacles, the visibility distances measured in Cussac Cave
411 never exceed 38.73 m and exceptionally 22.36 m. We therefore assumed that with oil lamps,
412 the Palaeolithic people had the same potential indirect visibility of their panels that we do.

413 In this study, we recorded the visibility with an indirect lighting source, the panels being
414 illuminated by an outsider standing next to the wall. The purpose of this was to estimate the
415 maximum distance of visibility and the potential observation points when the wall is
416 illuminated. We also used direct lighting to examine the co-visibility between two panels.
417 Because our modern lamps are much more powerful than Palaeolithic ones, we considered the
418 direct measures as a maximum. The halo-type lighting of the oil lamp is another limitation in
419 our *in situ* observations made using the directional-type lighting of modern electric lamps.



420

421 *Fig. 2: Topographic map of the Facing Animals chamber, completed with photographs (V. Feruglio, C. Bourdier, A.*
 422 *Jouteau/MCC) and one section (H. Camus, Hypogée). This association of different documents helps to show to the position of*
 423 *the graphic entities and their accessibility.*

424

425 3. Results

426

427 3.1. Statistical analysis

428

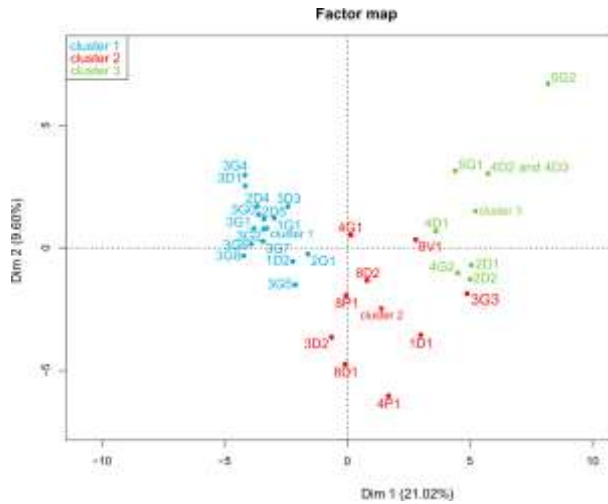
429 Thirty-one panels were recorded in the database. To highlight the main variables implicated in
 430 the choice of the panel supports, a FAMD was performed on the database (see Methodology).

431

432 3.1.1. Identification of panel groups

433 A hierarchical clustering performed on FAMD coordinates enabled us to distinguish three
 434 groups of panels (Fig. 3). The modalities related to the first axis oppose Groups 1 and 3, while
 435 the second cluster is homogeneous according to the variables related to the vertical axis. In
 436 the following figures, the panels are referenced by their number. To facilitate the reading of
 437 the text, which sometimes indicates the panels by name, a table summarizes the corresponding
 438 numbers, names and groups of all analysed panels (Table 1).

439



440

441

Fig. 3: Factor map of the studied panels. Modified with Inkscape (see Code for the original graph).

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443

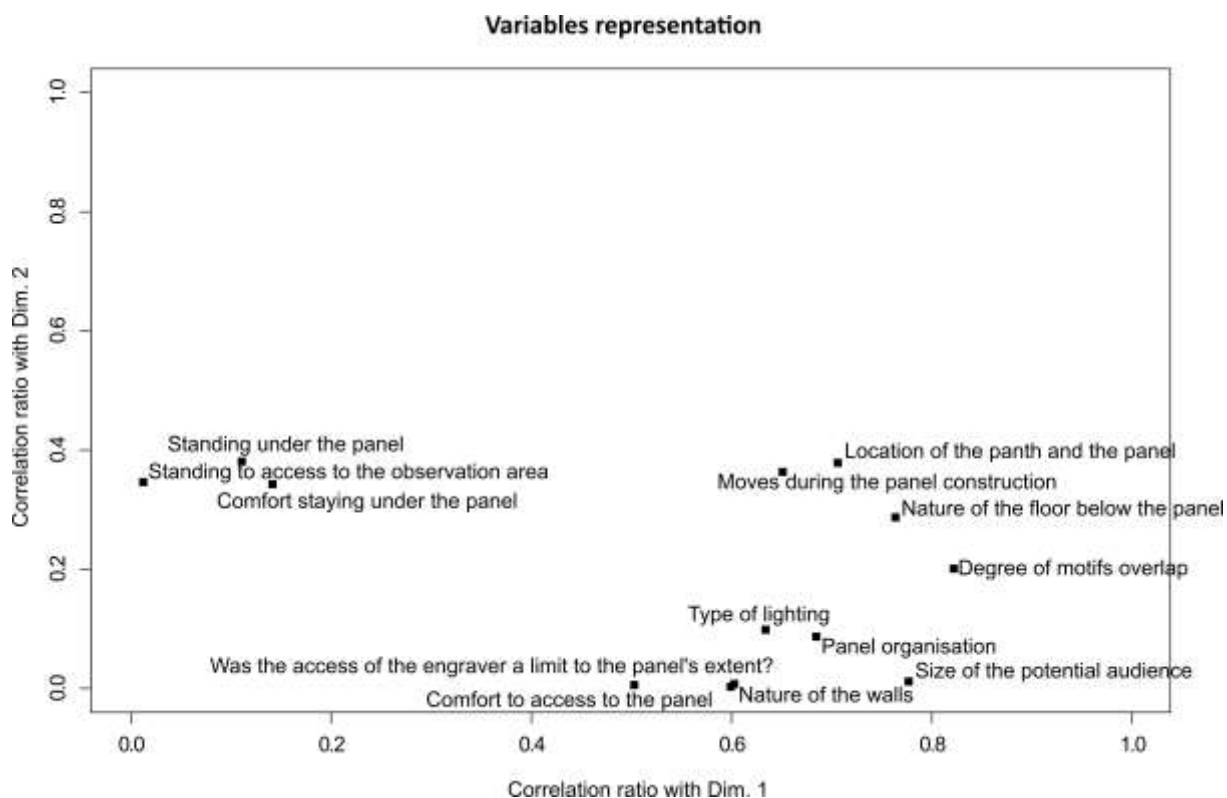
Table 1: Panel numbers, names, and groups.

Panel location	Panel number	Panel name	Panel cluster
Downstream Branch	1D1	Entrance	2
	1D2	First Shaft	1
	1G1	Three black Dots	1
	2D1	Discovery	3
	2D2	Clay Bridge	3
	2G1	Toupillon	1
	2D4	Sinuuous Line	1
	2D5	Wavy Line	1
	3D1	Fusifforms	1
	3G0	Domino Circles	1
	3G1	Converging Lines	1
	3G2	Head with Oval Eye	1
	3G3	Ibex	2
	3G4	Aligned Circles	1
	3D2	Grid	2
	3D3	Finger flutings	1
	3G5	Thin engravings	1
	3G6	Head with ears	1

	3G7	Headless Cervid	1
	3G8	Two carmine Spots	1
	4D1	Mammoths	3
	4P1	Isolated Lines and Red Dots	2
	4G1	Triptych	2
	4D2-4D3	Facing Animals and Isolated Mammoth	3
	4G2	Balcony	3
	5G1	Imprint	3
	5G2	Grand Panel	3
Upstream Branch	8P1	Macaroni	2
	8D1	Scratching	2
	8D2	Bunk	2
	8V2	Cavicorn	2

444

445 Due to the large number of qualitative variables, the standard graphic representations of the
446 FAMD (cloud of all modalities, cloud of all variables) would not be understandable here.
447 Figure 4 is a reduced version of these standard graphs, with only the variables that contribute
448 most significantly to the construction of the first two axes. For the cloud of variables, in order
449 to identify which information carries each axis, we represented the ten variables with the
450 highest correlation ratio (Saporta, 2006) with axis 1, and the five variables with the highest
451 correlation ratio with axis 2.



452
453 *Fig. 4: Variables that contribute most to the identification of the first two axes of the FAMD. Modified with Inkscape (see*
454 *Code for the original graph).*

455
456 To further clarify which modalities contribute most to the identification of the three clusters,
457 Figure 4 has been enhanced with the corresponding modalities in a tabular form (Table 2).

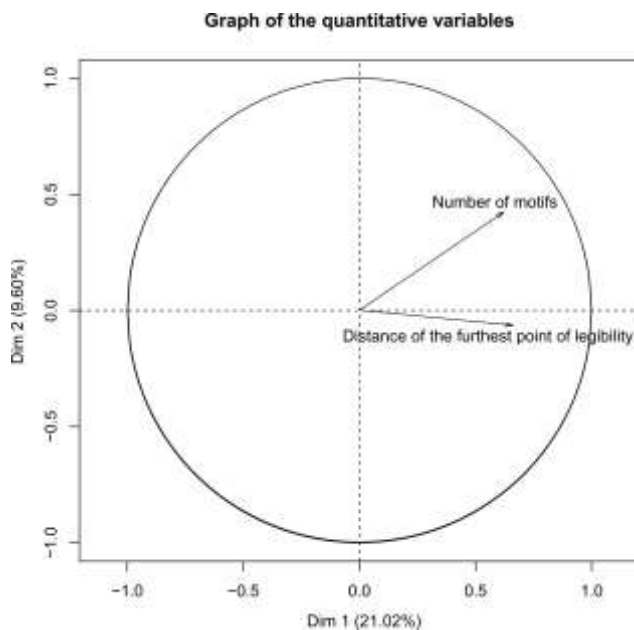
458
459 *Table 2: List of the modalities associated with each panel group.*

Variable	Cluster 1	Cluster 2	Cluster 3
Panel organization	Single motif	Mixed	Oriented motifs
Degree of motif overlap	Isolated figures	Juxtaposition	Juxtaposition, overlap, palimpsest
Moves during the panel construction	No need to move	Need to move between the motifs	Need to move between and within the motifs
Did the engraver's access to the panel limit its size?	No	Mixed	Yes
Type of lighting	Direct	Direct	Indirect
Nature of the floor below the panel	Cave floor (clays and gravels)	Cave floor (clays)	Blocks and promontory
Nature of the walls	Layered bed limestone	Layered and massive limestone	Massive limestone
Distance between the path and the panel	Contiguous	Combined	Far from each other
Size of the potential audience	Small	Mixed	Large
Comfort during access to the panel	Easy	Easy	Difficult
Comfort staying under the panel	Easy	Difficult	Easy
Position under the panel	Standing	Standing, leaning, crouching	Standing

Position to access to the observation area	Standing	Crouching	Standing
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Regarding the quantitative variables, only two appear to be decisive in the identification of the clusters: the “Number of motifs” and the “Distance of the furthest point of legibility.” They are represented on a correlation circle to visualize their relationship with the factorial axes (Fig. 5), and it appears that they are linked with the first axis, and thus with the clusters 1 and 3.



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Fig. 5: Correlation circle of the quantitative variables that contribute most to the characterization of the first two axes of the FAMD. Modified with Inkscape (see Code for the original graph).

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3.1.2 Summary

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The Group 1 panels are most often composed of one, or sometimes a few, motifs engraved on layered limestone beds. The motifs are small enough to enable the author to create them without moving and they are not limited by the engraver’s access to the wall. They are located near the path, directly above the cave floor, and with no need for high ground. Direct lighting is sufficient for a small group of people to observe them in their entirety, but only a restricted group (between two and five people, according to Bourdier *et al.*, 2017) can observe one of these panels at the same time and their maximum distance of legibility is relatively short (mean of 6.8 m). There is no apparent difficulty of access to the panel or observation area.

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It is easy to distinguish the panels of Group 3 from those of Group 1 because they are their opposites in several ways: they are composed of several figures (usually more than 10 and up to 130 for the Grand Panel), and they sometimes juxtapose each other on a single panel or even overlap one or several times. The figurative motifs are always oriented in one direction, and their large size often required the engraver to move to create a single motif and the entire panel. The artist had to limit the panel’s width according to the size of the blocks or

488 promontories below, and the height under the ceiling. The support is always massive, non-
489 layered limestone, often located far from the natural path. It is the only group for which the
490 access to the panel is also difficult, which means that the maker may have needed to support
491 him/herself with one hand. On the other hand, it was easy to remain under the panel and to
492 reach the observation area. A group of at least six people could observe the panel at the same
493 time (“plural”) with indirect lighting. This can probably be linked with their long maximum
494 distance of legibility (mean of 13.6 m).

495
496 The Group 2 panels are more difficult to distinguish from the others (especially from Group
497 1). Of the 13 discriminatory factors, 6¹ have intermediate or mixed characteristics and
498 characteristics identical to those of Group 1 (3 cases²). There are never isolated figures,
499 however, but most often a few that are juxtaposed to each other. While the figurative motifs
500 are never large enough to have required the engraver to move during the engraving of a single
501 motif, it was necessary to move between them to construct the panel. The path is often melded
502 with these panels, and it is thus necessary to walk under them to move through the cave.
503 Furthermore, this is the only group for which remaining under the panel can be difficult,
504 requiring leaning or crouching, and for which it is often necessary to move in a crouched
505 posture to access to the observation area.

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507

508 3.2. Further analysis of the panel groups

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510 The criteria studied above are those constituting the database. In this complementary study,
511 the three groups are studied from different viewpoints, enabling us to confirm, nuance or
512 invalidate their homogeneity.

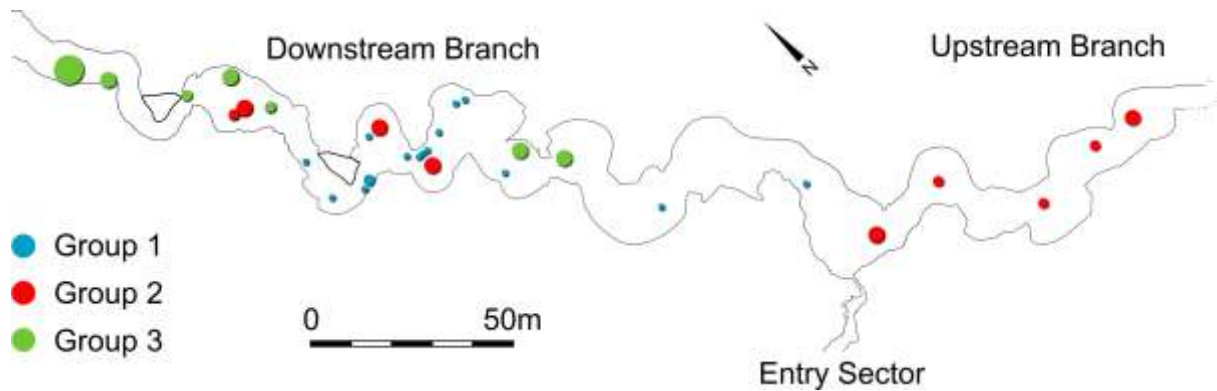
513

514 3.2.1. Panel distribution

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¹ Medium number of figures, medium distance of the furthest point of legibility, the panel organisation is variable, the access to the surface for the engraver was sometimes a limit to the panel extent, and sometimes not, both layered and massive limestone supports were used, the size of the group could be small as well as large

² Direct lighting is sufficient to observe them, the panels are located above the cave floor, and the access to the panel was easy



516
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Fig. 6: Distribution of panels inside the cave, according to their group (topographic background, Hypogée).

518

519 It appears (Fig. 6) that the panel distribution within the cave is heterogeneous. There is a low
520 concentration of panels in the Upstream Branch and the Entrance, while they are numerous in
521 the Downstream Branch, particularly after the first third of the branch length. The distribution
522 per group is also uneven. The Upstream Branch and the Entrance contain only Group 2
523 panels, while they are the least represented panel type in the rest of the cave. Group 3 panels
524 dominate the last third of the studied portion the Downstream Branch (plus two in the middle
525 of the Downstream Branch), while the Group 1 panels are all located in the first two-thirds of
526 the Downstream Branch. The panels of the second group present in the Downstream Branch
527 are located in its centre portion.

528

529 This distribution adds support to the division of the cave between the Upstream and
530 Downstream Branches. The Upstream Branch seems to contain fewer panels, which are
531 attributed to only one group, whereas the Downstream Branch contains numerous panels
532 attributed to different groups, with a gradual increase of Group 3 panels, until the last one, the
533 Grand Panel, which is the largest panel in the cave.

534

535 3.2.2. Visibility areas

536

537 The fields of visibility of the panel supports were documented on topographic maps and then
538 compiled according to the panel group (Figs. 7, 8, 9).

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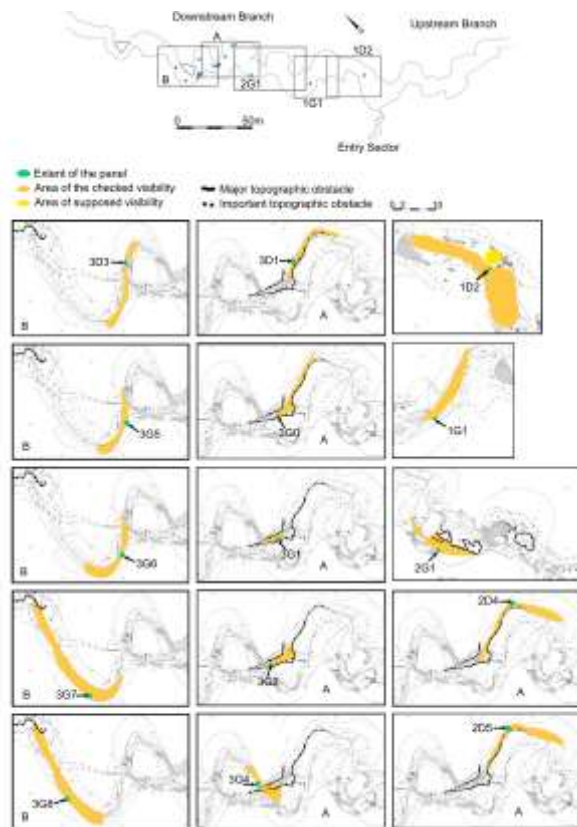
540 We can see (Fig. 7) that the Group 1 panels are located in narrow passages and that their
541 fields of visibility are thus very elongated. It is thus impossible for more than three people to
542 observe these panels simultaneously. The only exception is panel 1D2 (First Shaft), whose
543 field of visibility is quite large. Nevertheless, due to its disposition, this panel cannot be
544 observed by a large group of people.

545 Most of the panels are visible regardless of the direction of movement, except for signs 1G1
546 (Three black Dots), 3G0 (Domino Circles) and 3G2 (Head with Oval Eye), which can be
547 viewed only from upstream, and sign 3G1 (Converging Lines), which is visible from
548 downstream.

549 These narrow visibility fields, along with the small dimensions of these figures (up to a few
550 decimeters) and their position adjacent to the walkways, indicate that it was possible to
551 observe them with a minimal light source, such as a single oil lamp.

552 These panels were therefore always observed from a location very close to them and on the
553 path.

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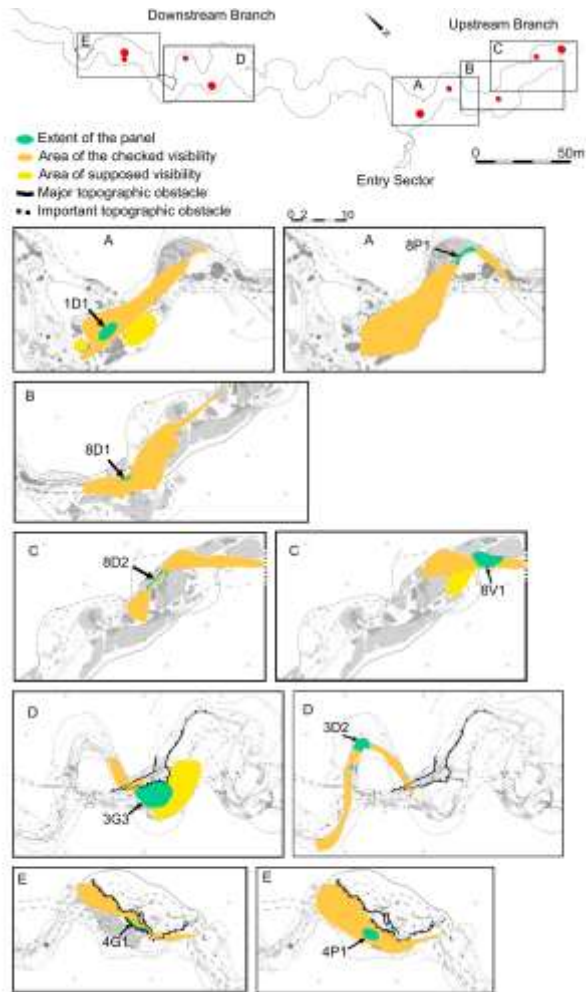
556

557 *Fig. 7: Representation of the visibility areas of all the Group 1 panels on topographic maps (modified from the topographic*
558 *background, Hypogée).*

559

560 Even if the sizes of the fields of visibility of the Group 2 panels (Fig. 8) are variable, they are
561 always quite large and extend in both the upstream and downstream directions. One
562 interesting thing we have observed is that the figurative motifs of these panels are never
563 oriented in the direction of the furthest point of visibility of the panel. It was therefore
564 impossible for a large group of people to observe the panel in the right direction at the same
565 time. Furthermore, we have observed no preferential orientation of the panels.

566



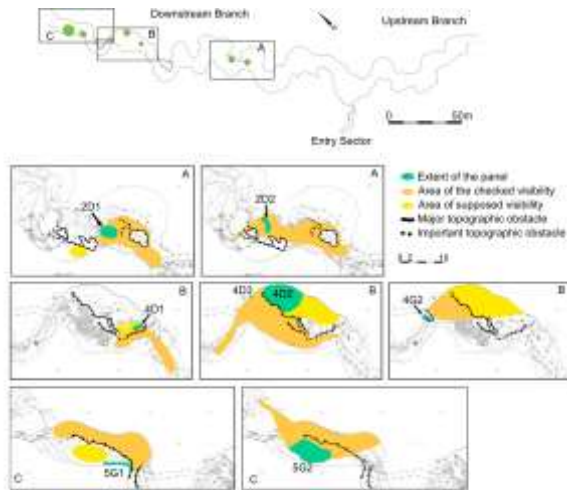
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Fig. 8: Representation of the visibility areas of all the Group 2 panels (topographic background, Hypogée).

569

570 The Group 3 panels (Fig. 9) always have large fields of visibility, and their main difference
571 from the Group 2 panels is their orientation: they are always oriented in a preferred direction
572 that also corresponds to the area from which the figurative engravings are legible. We have
573 identified two direction types: one (2D2, 4D1, 4G2) is towards the path in an upstream-
574 downstream direction, while the other (for the remaining panels) is oriented toward a large
575 area that coincides with the ideal observation point of the panel (space from which the
576 figurative entities can be seen in the right direction). All these panels can be observed by a
577 group of people at the same time. These areas are always located below the panel, and the
578 most suitable observation area is always too far from the surface of the panel to be observed
579 with direct lighting from an oil lamp. To observe these panels, it was thus necessary for at
580 least one person to be located near the surface to illuminate it, in addition to the observers.
581 The size of these panels, which is always large, requires either the presence of several light
582 sources or a moving light source.

583

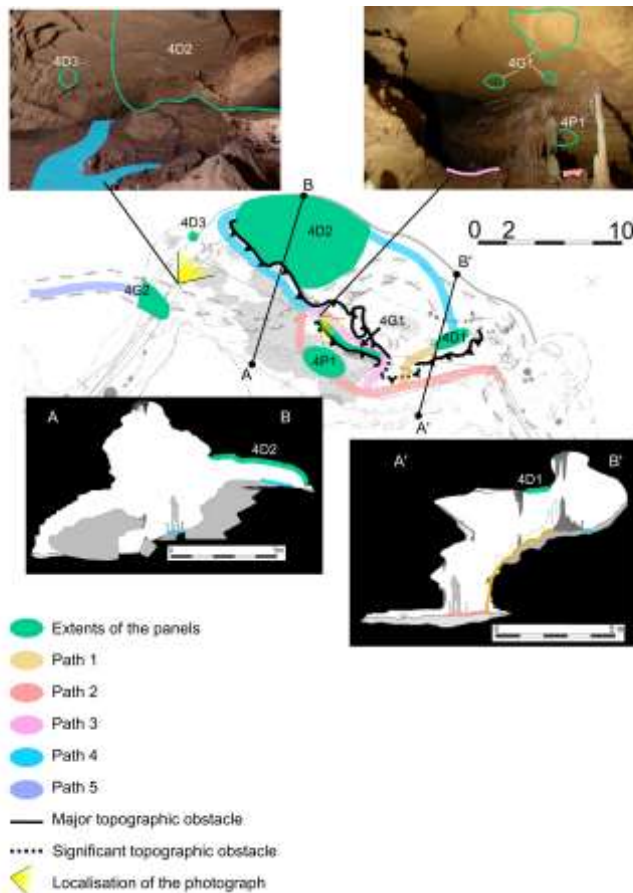


584
585 *Fig. 9: Representation of the visibility areas of all the Group 3 panels (topographic background, Hypogée).*

586
587 The study of the fields of visibility also tends to confirm the presence of three groups, which
588 correspond to three types of behaviour.

589
590 3.2.3. Access to panels

591 Cussac Cave is composed (in most of its length) of a single, narrow gallery, often with only
592 one possible access. The most logical path is therefore often located near the graphic entities.
593 Some of the more complex areas should be further considered, however, to better understand
594 the speleological behaviour of the prehistoric people. The room containing the Panel of the
595 Facing Animals is for this purpose particularly complete, and we will now focus on this space
596 (Fig. 10).



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Fig. 10: Representation of the access and path in the "chamber" of the Facing Animals on the topographic map (topographic background, Hypogée), sections (H. Camus, Hypogée), and photographs (V. Feruglio, C. Bourdier, A. Jouteau/MCC).

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The Mammoths Panel (4D1) is the first to be seen in the upstream-to-downstream direction. Located very high, however, it can only be seen with Palaeolithic lighting if someone near the support illuminates the panel. There are two ways to reach it. The first one is to climb an almost vertical slope, several meters high with a few horizontal steps (Fig. 10, path 1). The second consists of taking a detour through the 4D2 Facing Animals Panel in a downstream-to-upstream direction, which is done with no particular difficulty (Fig. 10, path 4). No evidence of the first route was detected, even if such climbing, followed by passing under a low roof, would have left some traces. It thus seems probable that the Palaeolithic people preferred the solution of the detour. It is interesting to note that the surface on which this panel is engraved is not observable from the logical path; it was thus discovered during an exploration phase of the cave or during the creation of the Panel of the Facing Animals.

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Farther into the room, two paths are possible. The first one (Fig. 10, path 2) consists of a low passage above collapsed blocks with some lines engraved on the ceiling, known as the Panel of the Isolated Lines and Red Dots (4P1). The second (Fig. 10, path 3) is a narrow but approximately 2 m high passage along which the Triptych Panel (4G1) is engraved. Regardless of the chosen path, the visitor finds him/herself in the room of the Panel of the Facing Animals. This panel (4D2) and the associated figure of the Isolated Mammoth (4D3)

620 are visible from the entire room. The 4D2 Panel is reachable only by walking along the wall,
621 passing close to the Isolated Mammoth (Fig. 10, path 4), because a high and steep ledge
622 (about 2 m) prevents the passage.

623
624 Leaving the room, always in the upstream-to-downstream direction, one must pass under the
625 4G2 Balcony Panel. This one is very high, like the Mammoths Panel. Furthermore, the
626 surface of the latter is indistinguishable from the path using Palaeolithic lighting, and the
627 engraver had to make a detour by an access under the vault channel, located much farther
628 downstream, to reach the surface. Here the detour consists of climbing a steep slope located in
629 the Grand Panel gallery (Fig. 10, path 5).

630
631 These different behaviours are found in the other parts of the cave as well, with some
632 consistencies within the groups. As for the Triptych, the Group 2 panels are located on a
633 ceiling or a wall next to the logical path; to move inside the cave, the visitor thus had to walk
634 under or near all these panels. These are rarely easy and comfortable paths, however, and it is
635 often necessary to crouch or lean above an inclined or tiered floor, as is the case for the panel
636 of the Isolated Lines and Red Dots (4P1). The Group 3 panels, on the other hand, are often
637 located some distance from the natural path (except for the 2D1 and 2D2 panels), far above it,
638 sometimes requiring the artist to climb up boulders or promontories to access to the wall
639 surface. The observer, therefore, was always on a path below the panel. The 4D1 and 4G2
640 panels even required an intensive search for their support, illustrating a very accomplished
641 speleological behaviour in an environment considered far from challenging. The Group 1
642 panels are not included in this example because they are all located in single-corridors which
643 thus constitute the only available path. These panels are all located on the natural path through
644 the cave, above a regular floor and at the same height as the observer, with no additional
645 access difficulty.

646
647

648 **4. Discussion**

649
650 These combined analyses yield evidence for three groups of rock art panels in Cussac Cave.
651 Each group has distinctive characteristics even if all the panels of a given group do not strictly
652 share the same features. The groups therefore attest to clear choices underlying the locations
653 of the motifs within this huge cave. These choices were motivated by a combination of the
654 nature of the cave wall, the physical access to the wall for the maker(s), and the potential
655 visual access to the motifs for the observer(s). It seems that the selected criteria varied
656 between the three groups. Several features of two of the groups are opposed to each (clusters
657 1 and 3), while the third group has its own intrinsic features.

658
659 Group 1 is characterized by panels engraved on chaotic supports located in narrow corridors
660 that are contiguous to the path. Due to the narrowness of the corridors, only a small number of
661 people could have observed the motifs at the same time, using a direct lighting source. It is
662 possible to access and stay near the panels in an upright position and without difficulty via a

663 path directly above the cave floor. Today, these small panels, often composed of a single
664 motif, are difficult to read because the engraved lines are not always easy to decipher among
665 the irregularities of the limestone. Four panels are clearly oriented in the direction of the path,
666 and most of them are located at eye level, meaning they could probably be seen by visitors.
667 The main unknown factors are how the engraved lines would have appeared in their freshly
668 engraved state, and the nature of their visibility with Palaeolithic lighting. Regardless of these
669 factors, their location in low and narrow spaces along the paths would have made them
670 unsuitable for contemplation and for viewing by large groups.

671
672 Group 2 includes more diverse geological supports and geomorphological environments
673 (presence on both layered and massive limestone). These panels do not seem to be randomly
674 located, however, because it is necessary to pass under or near them to move forward into the
675 cave. They are often located above junctions or crossings (3G3, 3D2, 4G1, 4P1) and direct
676 lighting is adequate to observe them. The panels are composed of between 3 and 15 motifs,
677 always in juxtaposition. Some panels are large enough to have required the engraver(s) to
678 move during their creation, in some cases limiting the extent of the panel to the accessibility
679 of the surface. The figurative motifs of these panels are never oriented in the direction of its
680 furthest point of visibility and the accesses to the ideal observation area are among the most
681 uncomfortable, often requiring one to crouch. These two elements appear to prohibit large
682 groups and even contemplation of the motifs by viewers other than the image-maker(s).
683 Although the panels are engraved above the cave floor, they are in places where it is difficult
684 to stand, and where leaning and crouching are often necessary. The discomfort of the
685 engraver's position also makes it clear that he/she did not place the motifs randomly or
686 according to his/her own preferences but instead had to follow a code that remains to
687 identified.

688
689 The geological supports of the Group 3 panels, on the other hand, are very homogeneous.
690 They consist of large, flat and regular surfaces on the massive limestone and are located on
691 ceilings or high enough on walls to be observed from below. Often far from the path, these
692 supports clearly represent a deliberate and intensive search for locations fulfilling these
693 precise criteria. In addition, they are all situated in large spaces that offer the greatest visibility
694 distances. The figurative motifs of these panels are oriented towards the widest, most
695 comfortable and easily accessible areas, suggesting that they were deliberately staged,
696 probably for an audience other than the image-maker(s). The large size and number of the
697 motifs would have often required the engraver(s) to move during their creation, and the
698 decorated surfaces were limited by the image-maker(s) access to them. Even if the panels and
699 the observation area can be reached in an upright position, the engraver(s) access to the panel
700 was often difficult, requiring them to climb to the top of blocks and promontories.

701 Despite these homogeneous features, this group of panels can be subdivided into two
702 subgroups:

703 - Subgroup 3a: panels with only a few motifs (2-12), which are located very high up, far from
704 the Palaeolithic path and clearly oriented towards it. These panels could therefore have been

705 hidden from potential visitors and would have required lighting by someone who knew their
706 location for them to be contemplated by an audience.

707 - Subgroup 3b: panels with many engravings (15-130), usually located away from the natural
708 path but not as far away as the Subgroup 3a panels. These panels also required an indirect
709 lighting source. In this group, however, the figurative motifs are not oriented in the direction
710 of the path but towards the location with the largest available space, which may have required
711 the audience to leave the natural path to observe them. These panels have many superimposed
712 motifs, sometimes forming palimpsests that make the figures difficult to decipher despite
713 clearly visible engraved lines.

714

715 Despite these results, we still have reservations concerning the inclusion of some panels
716 within a given group. This is the case for the Triptych, for example. When seen as three
717 distinct panels, it matches all the significant criteria of Group 1, but when it is considered as a
718 single set, numerous and significant criteria link it to Group 2. This is also true for the Panel
719 of the First Shaft, which displays features of Group 1 (e.g. single motif, small dimensions and
720 easy access and staying conditions), while its visibility and access characteristics—located on
721 a ceiling with the path underneath, a wide field of visibility but with motifs that are not
722 oriented towards the most distant observation point—fit better with Group 2.

723 Among the criteria that influenced the distribution of rock art in Cussac Cave, the geological
724 factor (i.e., the rock) is apparent in the highly dominant selection of massive, non-layered
725 limestone surfaces over layered limestone ones. The distribution of the rock art is
726 discontinuous, however, even if this type of rock can be found almost everywhere in the cave.
727 Therefore, while geology influenced the Gravettian engravers' selection of softer and more
728 regular surfaces, which allow a large range of techniques and gestures, other parameters also
729 played a role. Contrary to what is often observed in cave art, the motifs in Cussac Cave do not
730 seem to incorporate natural features in their lines. In any case, the extent to which the natural
731 shapes of the rock panels could have been evocative to the image-maker(s) is a tricky topic
732 since the identification of shapes is culturally constructed. Given this methodological
733 limitation, none of the general outlines of the panels have yet appeared suggestive to us.

734

735 From the perspective of the potential Palaeolithic viewers, the selection of the rock art panels
736 within the specific geomorphology of Cussac Cave shows two potential broad social uses of
737 the motifs: an individual use corresponding to images that can be seen only by the maker
738 and/or are not suitable for contemplation or for large audiences (Groups 1 and 2), and a
739 collective use with a visual and physical open display for other engraved panels (Groups 3a
740 and 3b). It is not clear whether the panels in Groups 1 and 2 were intended for subsequent
741 viewing or if the intention of the maker(s) was the process of making itself, meaning in the
742 performance of leaving a mark or a motif on the rock surface. In the latter case, the meaning,
743 purpose and use of these motifs would not require intended viewers. Another argument for
744 this possibility is the placement of some panels on layered limestone bed surfaces, meaning
745 that the technical advantages of the massive limestone surfaces were not seen as necessary or
746 particularly beneficial. An individual approach to image-making such as this can be linked to
747 the purpose(s) of the rock art for the maker(s), perhaps considered as creations by an

748 individual in the context of spiritual activities without intended viewing by subsequent
749 visitors, or as signposts or as motifs intended to be read individually. In this sense, being
750 mainly located at key points along the path (junctions, crossings), the Group 2 panels could
751 have served both as pragmatic signposts and as symbolic milestones/gates within a possible
752 spiritual journey experienced in the site.

753

754 Groups 3a and 3b, on the other hand, seem to have been dedicated to contemplation by
755 intended viewers other than the image-maker(s), and the Group 3b features suggest that this
756 audience was large. The question of the temporality of this audience remains unresolved,
757 however. Were these images made and viewed simultaneously, or were they intended for
758 viewing after they were made? Today, the rich panels of Group 3b appear as palimpsests in
759 their final stage. The analysis of the Grand Panel composition (Feruglio et al., 2015b) yielded
760 evidence of structuring rules in the distribution, associations and superimpositions of the
761 motifs, probably motivated by narrative processes that contradict the idea of a diachronic
762 assemblage made through an accumulation of single motifs. The entire Grand Panel could
763 have been made in a relatively short time span (or even a single event). If this is the case, it is
764 likely that the viewers were present when the engravings were made (and perhaps only
765 then)—when the movements and gestures of the engraver(s), and perhaps simultaneous story-
766 telling, made the motifs more perceptible and the narrative more intelligible. This would not
767 exclude later viewings, which would have required: 1) previous knowledge of the panel
768 locations by at least one individual in the group, and 2) special lighting from the bottom of
769 panels to make them visible from a distance. Regardless, this precise selection of supports
770 suggests an intimate knowledge of the cave with probable visits before the panels were
771 decorated. Assuming that groups 3a and 3b were both intended for contemplation by a
772 collective audience, whether during the image-making process and/or subsequently, these
773 panel groups may have been associated with the same behavioural motivation in Cussac Cave,
774 representing different aspects of a single message. Long versus short stops, together with the
775 contrast between numerous and few motifs, could reflect complementary contents within the
776 same semantic field.

777

778 The distribution of the panel groups at the scale of the cave shows a clear distinction between
779 the Downstream Branch—containing the panels of Groups 1 and 3—and the area from the
780 Entrance to the Cavicorn panel in the Upstream Branch, where only Group 2 panels are
781 present. The density of the panels also differs between these two branches: in the Downstream
782 Branch, the panels are numerous and close to each other while in the Upstream Branch there
783 are fewer panels with more space between them. However, the Entrance and the Upstream
784 Branch are the two sectors that have been most affected by taphonomic phenomena (calcite
785 deposits and rock falls, for example), which may bias the current panel distribution.
786 According to our hypotheses, the Group 3 panels are probably linked to the presence of an
787 audience, unlike the panels of Groups 1 and 2. Our results seem to show distinct behaviours
788 and distinct uses of the two branches: in the Upstream Branch there would have been only
789 individual actions, perhaps without subsequent viewing, while in the Downstream Branch,
790 both individual actions and simultaneous or subsequent collective contemplation seem to have

791 occurred. The presence of human remains exclusively in the Downstream Branch could also
792 indicate different uses of the spaces in the cave. These different behaviours, and perhaps uses,
793 are coherent with the distinct geomorphologies of the two branches. In the Upstream Branch,
794 where the meanders are wider and less pronounced, and the floors are more chaotic, with
795 slopes that make the journey difficult and require frequent crawling, the widest available
796 panels are located on the ceiling and there are no wide observation areas, as there are in the
797 Downstream Branch. At the same time, the stylistic and thematic links between the two
798 branches attest to their relative contemporaneity (e.g. the presence of rare motifs such as birds
799 and rhinoceros heads in both branches). The differences revealed in this study could therefore
800 reflect diachronic human behaviours in relationship to rock art, with a stage of exploration
801 and marking of the cave by one or a few individual(s), and a stage of rock art image-making
802 with or without subsequent viewing. Each stage could have occurred a single episode or
803 several successive episodes. It is also possible that separate groups of people synchronously
804 used different spaces in the cave in different ways.

805
806
807 As we have seen, this study reveals potentially varied behaviours towards rock art creation
808 and uses in Cussac Cave. It shows that a single cave may have hosted diverse intentions and
809 varied social and spiritual functions. Although it has been assumed that different rock art sites
810 could have played different roles based on their physical, iconographic and archaeological
811 features (Lorblanchet, 1982, 1995, 2010; Fortea Pérez, 1994; Bourdier, 2013), our research
812 indicates that the role of cave art sites in Palaeolithic societies was even more complex than
813 this. Nevertheless, the hypotheses we propose in this paper should be taken with caution as
814 the study of Cussac Cave is still in progress, and new elements may confirm or refute them in
815 the future. Uncertainties regarding the inclusion of some panels in the three defined groups
816 show we must refine and complete our database. Future phases of research should include
817 graphic criteria, such as the technical characteristics and formal traits of the representations.
818 We will use the 3D model of the cave to compensate for our limited walkway access to the
819 decorated panels and to increase our knowledge of the visibility of the engravings with
820 simulations of oil lamp and/or Palaeolithic torch lighting. We will also conduct an exhaustive
821 study of all the panels once the entire cave has been surveyed, following the necessary
822 installation of walkways throughout. In addition to the current data limitations we have
823 discussed, we must bear in mind that the physical and visual access to rock art may also be
824 determined by social rules, regardless of the topographic opportunities of a site (Domingo et
825 al., 2016; Zubieta, 2016). An open display of rock art, such as that associated with the main
826 panels in Cussac Cave, does not necessarily imply a large group of people. At present, this is
827 an assumption that must be further explored and verified by complementary analyses of the
828 archaeological context, especially the abundant human imprints and marks that are well
829 preserved in Cussac Cave (Ledoux et al., 2017).

830 Comparing the Cussac Cave data corpus to that of other cave art assemblages attributed to the
831 Middle Gravettian could contribute significantly to our understanding of the underlying
832 choices made by Gravettian people in the visitation and use of subterranean spaces. At the

833 regional and extra-regional scales, such comparisons could inform us on the extent to which
834 different underground behaviours, and the potentially multiple uses of subterranean spaces
835 they represent, could be linked to cultural patterns and/or local, or even individual, choices. In
836 this context, it would be particularly relevant to compare our data with other major regional
837 cave art sites, such as Gargas and Pech-Merle (Barrière, 1976; Lorblanchet, 2010). At the
838 local scale, investigating the unity or diversity in the strategies of rock art panel choices can
839 inform us on the homogeneity or plurality of the socio-cultural uses and functions of cave art
840 sites. This type of analysis also opens new perspectives on the symbolic content(s) of rock art
841 motifs and assemblages that are complementary to the structuralist approach. Finally, this
842 method could be applied to other periods and geographic zones to contribute to a broader
843 understanding of the phenomenon of decorated caves. Investigating the dialogue between the
844 natural sites and the primary and potential secondary agents of the rock art (i.e., the image-
845 makers and the viewers) will provide a more balanced and distinct image of their uses and
846 roles in prehistoric hunter-gatherer societies.

847

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849

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864

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