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Catherine Ferrier, Stephane Konik, Marie Ballade, Camille Bourdier, Rémy Chapoulie, et al.. Cussac Cave (Dordogne, France): The role of the rock support in the parietal art distribution, technical choices, and intentional and unintentional marks on the cave walls. *Quaternary International*, 2017, 430, pp.30-41. 10.1016/j.quaint.2016.04.002 . hal-02140140

HAL Id: hal-02140140

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Submitted on 22 Jun 2020

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Cussac Cave (Dordogne, France): The role of the rock support in the parietal art distribution, technical choices, and intentional and unintentional marks on the cave walls

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Abstract

In this article, we present the relationships observed between the properties of the rock support in Cussac Cave and the choices made by the Paleolithic artists: the lithology of the limestone and the speleogenesis of the cave resulted in the creation of the vast rock surfaces on which the artists realized monumental engravings. The cartography of the formation processes in the cave and the petrographic analysis of samples collected from the ground show that following a superficial dissolution of the limestone, the rock became softer, thus facilitating engraving, even with a soft tool. The analyses (X-ray Diffraction, X-ray Fluorescence, Raman Spectrometry) indicate a relative concentration of goethite, responsible for the orangish patina visible on the wall surfaces. When engraved, the lighter material under this patina is exposed in the bottom of the incised lines, creating contrasting colors that contribute to the visibility of the depictions. Finally, the alteration of the limestone created a surface that also facilitated the realization of more tenuous marks, such as finger-tracings, as well as involuntary marks made by resting hands

Keywords: Geoarchaeology ; Taphonomy ; Parietal art ; Engraving ; Gravettian

1. Introduction

In the early 20th century, researchers began to recognize the phenomena responsible for wall surface alterations in decorated caves, largely thanks to the work of Henri Breuil in Font de Gaume Cave, Dordogne (Capitan et al., 1910). Later, in Pech-Merle (Lot), Amed ee Lemozi was also interested in the morphology of the rock support and its relationship to the parietal art works (Lemozi, 1929). But Michel Lorblanchet would be the first to consider the karstic environment and its evolution as fundamental to understanding parietal art, believing that their study was a necessary first step that could provide insights on the distribution of the depictions and the unfinished nature of some of them (Lorblanchet et al., 1973). Lorblanchet (1993, p.70) also considered the support and its alterations to be a determining factor in the technical choices of the artists (he observed this in his work in Australia as well). For him “the techniques used to realize the parietal depictions were adapted to the alterations of the support. The most perfect example of such an adaptation is the finger-tracing technique, which we find in decorated caves containing both Paleolithic decorations and easily accessible surfaces covered with mondmilch (in 17 decorated caves in Europe) (Lorblanchet, 1992)”. Philippe Renault, enlisted by Lorblanchet to study the karstology and micromorphology of cave walls, defined the fundamental questions and interpretive reasoning on this subject (Renault, 1987, 1989), which he applied in his study of the caves of Sainte-Eulalie at Espagnac, Pech-Merle both in Quercy (Lorblanchet et al., 1973, 1979), and Niaux, Pyrenees. More recently, in Lascaux Cave, monitoring of the walls through stereo-photography, macrophotography and cartography revealed the complexity

of the calcite alteration processes in some of the decorated sectors (Brunet and Vouve, 1996). Finally, we cannot recount the history of this research without mentioning the work of Norbert Aujoulat, especially in Lascaux Cave, who believed that parietal art must be studied through a global approach including the geomorphological context and its evolution (Aujoulat, 2004). This research approach has been developed most recently and most completely in the study of Chauvet-Pont d'Arc Cave, where analyses of the evolution of the support characteristics sheds light on the artists' choices of decorated sectors and artistic techniques, as well as on the taphonomic processes that have modified the parietal depictions (Kervazo et al., 2010; Ferrier et al., 2012).

From the beginning of the archaeological study of Cussac Cave (Dordogne), we have also considered that the relationships between the parietal art works and their rock supports is fundamental; this particularly significant in Cussac Cave since it is formed within limestone beds with petrographic features and contrasting surface characteristics that offered supports with varying properties to the Paleolithic artists. Our study is therefore based on an interdisciplinary approach involving parietal art specialists, geoarchaeologists and archaeometric specialists. In this article, we present the questions raised by the interactions between the rock supports and the parietal art in Cussac Cave, our methodology, and the advances made based on a confrontation of the first results obtained.

2. Cussac Cave

2.1. Location and geological context

Cussac Cave is located in the southern Perigord region in France, near the town of Le Buisson-de-Cadouin (Fig. 1). It opens at 118 m altitude on the right bank of the Belingou, a tributary stream of the Dordogne River. It is formed within Upper Campanian limestones in the Couze formation (Karnay et al., 1999) composed of variably sandy limestones deposited in an open platform characteristic of a proximal facies (Platel, 1989, 1996).

The cavity is composed of a single, meandering, sub-horizontal gallery at least 1.6 km long that splits into two branches starting from the location of the current entrance. The tunnel is 10-15 m wide and an average of 12 m high (Aujoulat et al., 2001a and b, 2002).

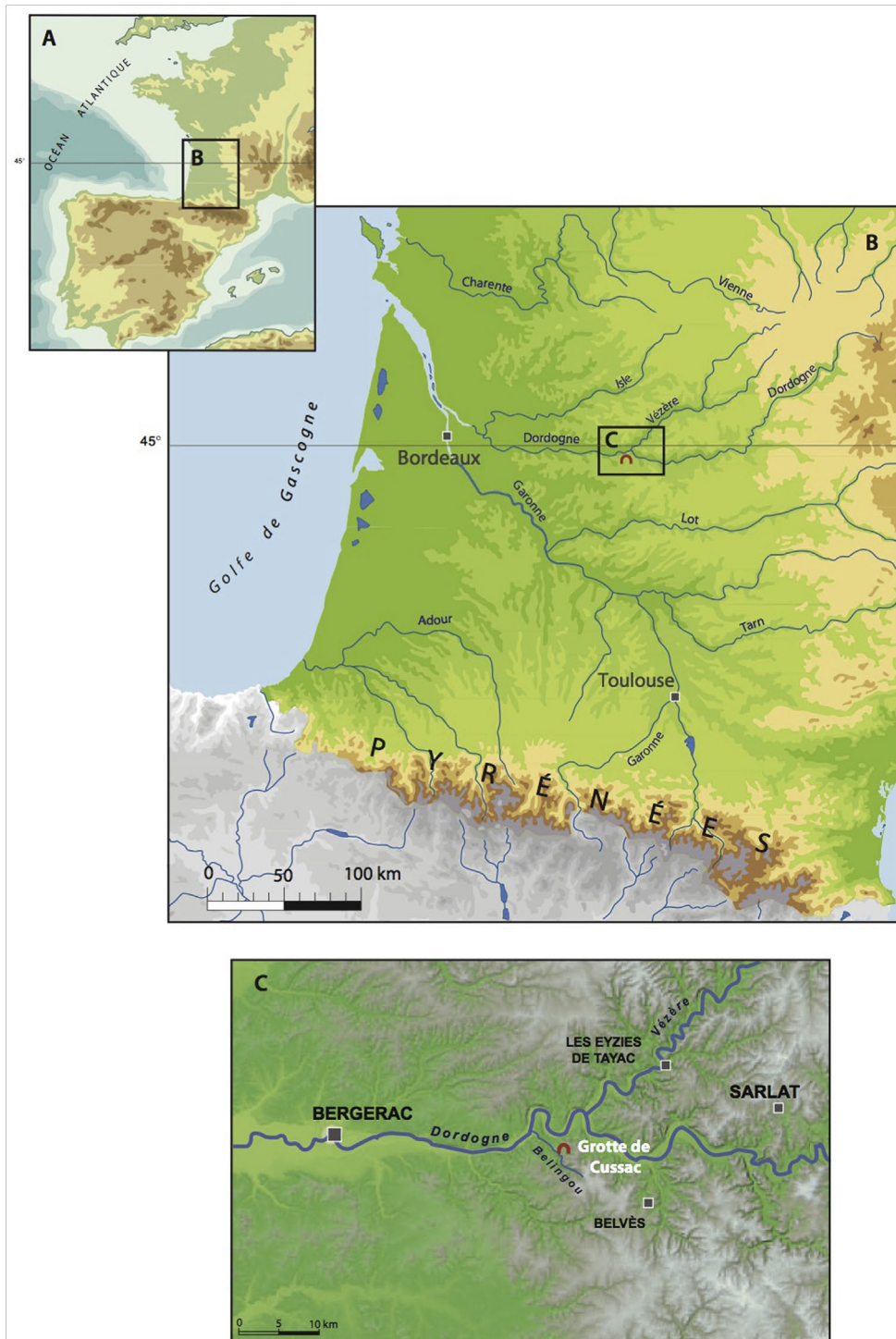


Fig. 1. Location of Cussac cave.

2.2. Archaeological context

The cave was discovered in September 2000 during a survey by Marc Delluc and members of the Speleo-Club de Périgueux (Delluc, 2000). It is both a decorated and sepulchral cave (Aujoulat et al., 2000; Henry-Gambier et al., 2013). The parietal art consists almost entirely of engravings that are most often grouped together on panels. In addition to numerous motifs, the engravings depict, in descending order, bison, mammoths, horses and aurochs (Aujoulat et al., 2013). Other species, goose, ibex, rhinoceros, bear and feline, are less numerous. Female silhouettes and male and female sexual genitalia are also represented.

The Gravettian attribution of the art in Cussac Cave is based on comparisons with other caves. Its themes and associations, such as female and mammoth figures, recall those at Pech-Merle, while it shares formal conventions with Gargas and Roucadour, and compositional ones with Pech-Merle (Aujoulat et al., 2001a, 2001b, 2002, 2004 and 2005).

Human remains have been found in three sectors (Loci 1, 2 and 3). They are associated with, and sometimes deposited inside, bear hibernation hollows (Henry-Gambier et al., 2013). A human bone in Locus 1 has yielded a ^{14}C date contemporary with the Gravettian period ($25,120 \pm 120$ BP Beta 156643 or 29,500-28,835 calBP, IntCal13) (Aujoulat et al., 2001a).

The cave also contains abundant evidence of animal and human presence, consisting of tracks, claw marks, polish, broken concretions and torch smears. A date obtained from a torch smear is coherent with that of the dated human bone (Jaubert et al., 2016).

3. Aims of the study

This study explores the links between the properties of the rock support and various aspects of the parietal art in Cussac Cave. This relationship was already discussed in the first publications of this cavity (Aujoulat et al., 2001a, 2002), in which the authors observed that most of the graphic depictions were realized on the middle segment of the wall, often on a protruding or overhanging area with a soft, fine-grained surface and no marked relief. They also noted the remarkable adaptation of the graphic techniques to the mechanical and optical properties of the wall: “the hardness of the wall permits an excellent preservation of the art, while being sufficiently soft to enable its realization with a stone, bone, or even hard wood tool. The continuous incisions are wide and deep, contrasting with the background due to both the chromatic variations created by the removal of the ochre colored calcin and the width of the line.” At the beginning of the study of the cave, the softness of the wall surface was linked to a disaggregation of the limestone, resulting in small accumulations of sand at the foot of the wall or irregularities on its surface.

Proceeding from these observations, we defined the following aims for our study:

- to verify the relationships between the lithology and the locations of the parietal depictions; to determine the nature of the rock surface alterations at the microscopic scale through the study of thin sections with a polarized light microscope, and to confirm the genetic link between the limestone and the sand accumulations through a petrographic analysis
- to understand the reasons for the color difference between the rock surface and the engraved lines;
- to consider the influence of the rock surface properties on the artists' technical choices and the visual appearance of the engraved lines.

4. Methods

This study is part of a broader interdisciplinary program developed with the aim of understanding the age and nature of the human incursions into this decorated and sepulchral cave (Jaubert et al., 2012). As with most recently discovered or currently studied decorated caves, we must adhere to strict regulations concerning access and circulation within the cave, requiring very limited invasive operations in order to protect this original and truly exceptional site (Fourment et al., 2012; Jaubert et al., 2012; Jaubert, 2015).

4.1. Field recording

4.1.1. Sand accumulations

The sand accumulations present on the cave floor, created by the disaggregation of the walls and ceiling, were recorded on the topographic map of the cave. These recordings were made in the Downstream Branch, from the entry zone to the Grand Panel (5G2). A color gradation was used to represent the quantity of sand grains and the degree of continuity of the accumulations (Fig. 2). Symbols are used to indicate the type of rock on which the

sand grains are deposited: limestone, calcite or clay. This recording enabled us to obtain a global perception of the variability and intensity of this phenomenon.

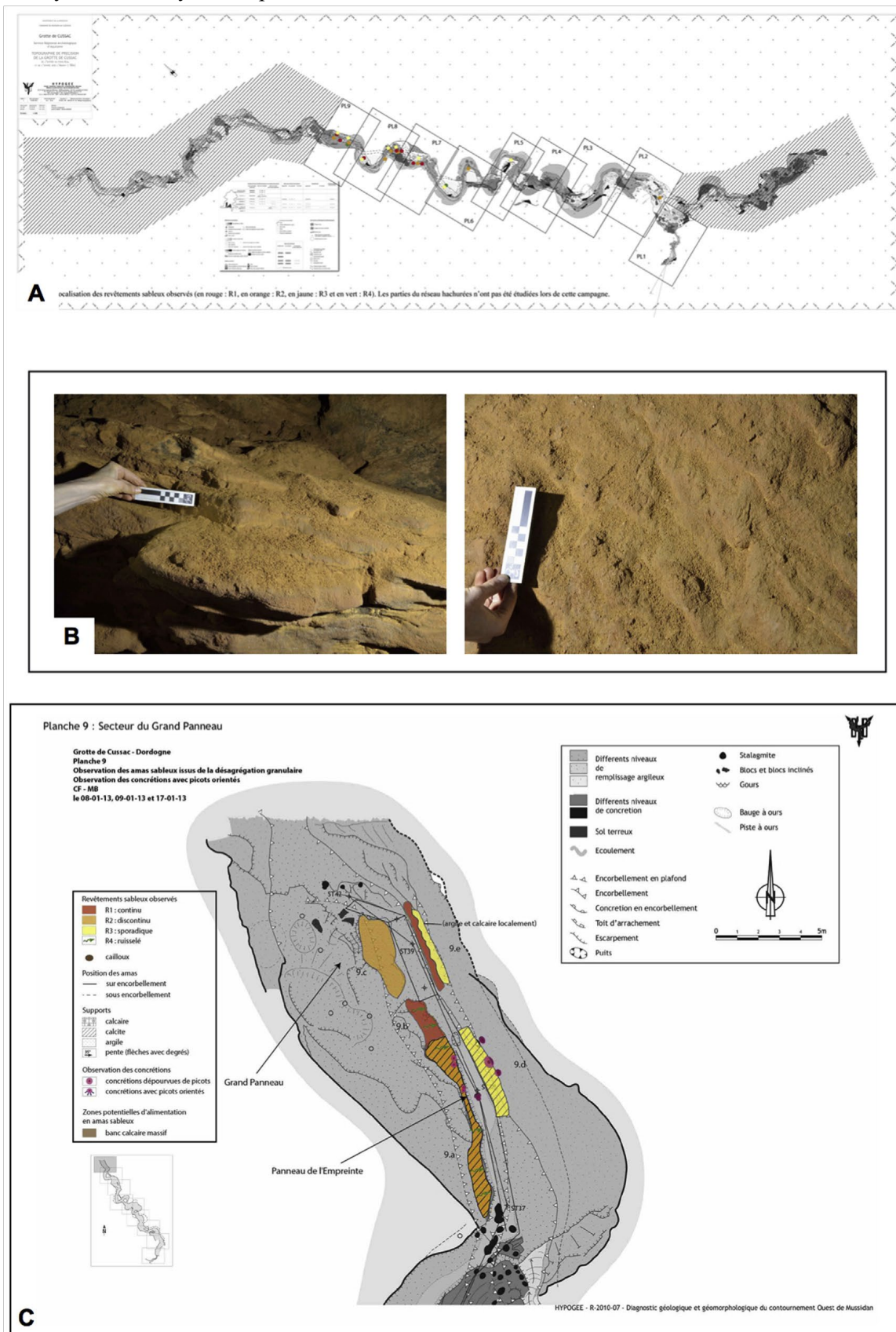


Fig. 2. Map of the sand accumulations resulting from the disaggregation of the cave walls (recording, M. Ballade, C. Ferrier, S. Konik; topographic background, Hypogée). A e Location of the sector studied (topographic background, Hypogée). B and C e continuous sand accumulations on the left, and discontinuous ones on the right (photos S. Konik, PCR Cussac). D: Example of mapped sand accumulations in the Grand Panel sector.

4.1.2. Taphonomic recording of the Triptych Panel (4G1)

The Triptych Panel (Fig. 3) is located in the Downstream Branch, after locus 3, between the Panel of the Mammoths (4D1) and the Panel of Facing Animals (4D2), approximately 250e255 m from the current entrance. It is located at eye-level, near the most accessible path and is composed of three groups of engravings: in the right group there are two “serpentine” forms composed of sinuous lines (4G1-1 and 2); in the center group, an engraved animal associates the hindquarters and neck of a bison with a horse head (4G1-4), with a sinuous line crossing the figure (4G1-3). The right group is more complex, composed of an animal head with large ears or horns turned toward the left (4G1-8), an undetermined motif (4G1-6) resembling the goose in the Upstream Branch, fingertracings (4G1-7) and deeply engraved, undetermined motifs (4G1-9 and 10).

The taphonomic recording of this panel includes:

- the support: micro-topography (ridges and concave zones, fissures, cupules, rugosity), clay infill in fissures, calcitic coating, observed by naked eye and reported on photographs.
- the anthropogenic transformations: engravings, finger-tracings, involuntary leaning and rubbing;

This recording thus represents the different states of the wall and their chronology relative to the anthropogenic lines and marks.

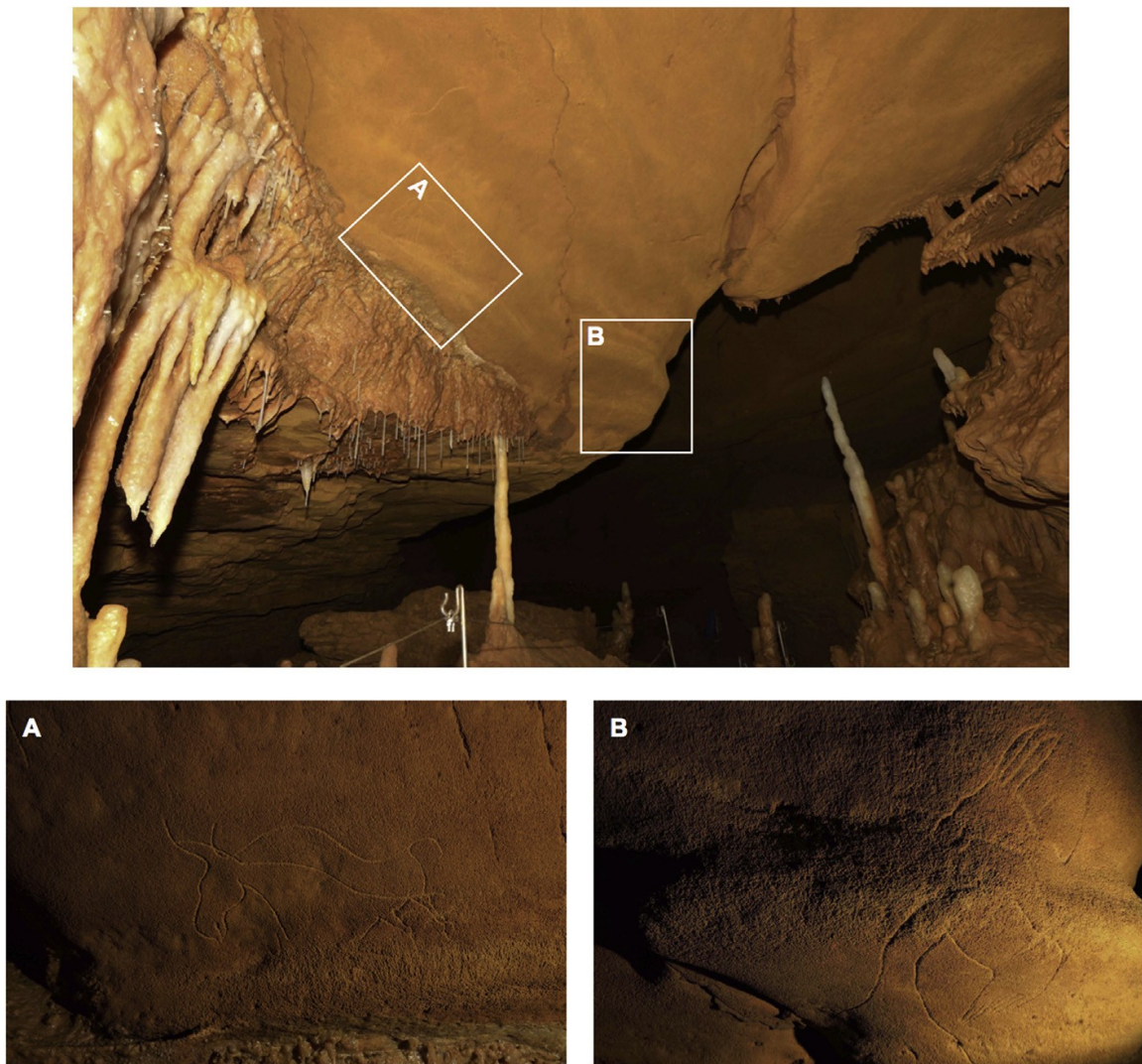


Fig. 3. Triptych Panel. The wall is delimited at the bottom by a flat surface corresponding to a stratification joint separating the thick limestone beds from the thinner ones. The engravings were realized above the joint, which is emphasized by stalactites. A: horsebison in the central group; B: an animal head and motif resembling a goose in the right group (photos S. Konik, PCR Cussac).

4.2. Laboratory analyses

The regulations stipulated to preserve the site forbid any damaging removal of material from the site and thus limit the samples that can be taken. A few rock fragments that were naturally detached from the walls or ceiling and fell on the floor near the authorized path, as well as sandy, non-calcitic coverings, could therefore be collected.

Five samples were made in the laboratory (Fig. 4):

- Three limestone samples. The first one was collected from a pile of rocks created by the collapse of bedded layers on the right wall near the entrance rockfall. The two others are clasts fallen from the thick beds. One comes from the Upstream Branch and the other from the foot of the Grand Panel. These two samples, though distant from each other, are representative of the degree of alteration of the walls, visible in both sectors.
- Two sand samples collected at the foot of the walls: one under the left group of the Triptych Panel, the other opposite the Grand Panel.

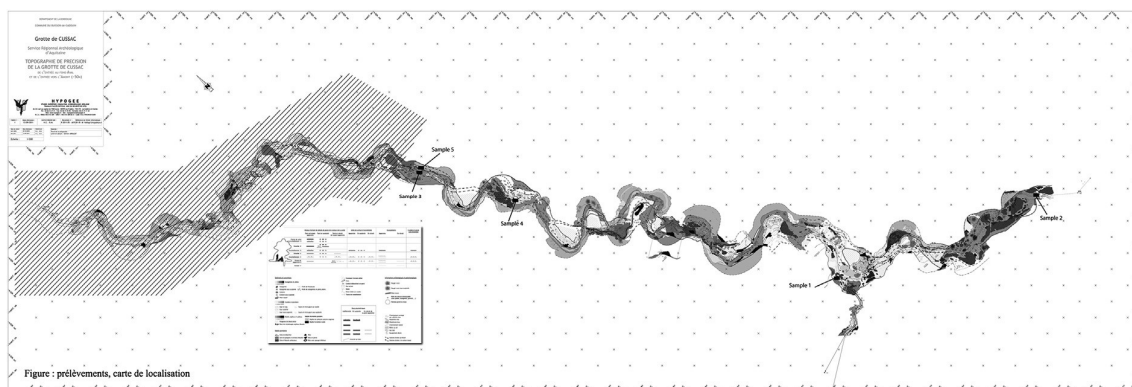


Fig. 4. Location of the samples studied. 1: limestone block collected from the bedded layer rockfall. 2: clast fallen from a thick bed. 3: clast fallen from a thick bed the foot of the Grand Panel. 4: sand collected from the wall under the left group of the Triptych Panel. 5: sand collected on the right wall, opposite the Grand Panel.

4.2.1 X-ray diffraction

The residue after hydrochloric acid digestion of the massive limestone sample was analyzed by X-ray diffraction using a silicon calibrated Panalytical diffractometer with a Bragg-Brentano (theta-theta) configuration. Data acquisition times of 30 min allowed an angle range of 8-80 with a resolution of 0.02. The diffraction spectra were analyzed using EVA application software coupled with the JCPDS-ICDD database. The mineral species were identified by their respective combinations of two or three characteristic peaks.

4.2.2 X-ray Fluorescence in energy dispersive spectrometry

Thin sections were prepared to register EDS-XRF spectra and mapping, using a SEIKO SEA 6000VX system working from 15 to 50 kV (Rhodium source). The detector is SDD with a 50 mm² active surface and 155 eV resolution. The scanned areas were 25 16.65 mm² (thin section) and 22.4 11.4 mm² (sediment 11 inf), with 50 microns/pixel and a collimator of 200 microns.

Light elements were detected with 15 kV accelerating voltage with no filter, and 50 kV was used with a Pb Map filter for heavy elements. Acquisition time was 100 ms/pixel. Spectra were extracted from the maps to quantify and provide the Ca/Fe ratio.

4.2.3 Raman Spectrometry

One aggregate from a sand sample and the residue of the hydrochloritic digestion of a limestone fragment sample were analyzed with a confocal Raman microspectrometer SENTERRA (Bruker Optics, Ettlingen, Germany) equipped with both 532 nm and 785 nm exciting lines. Spectra were automatically compared with RRUFF database (Lafuente et al., 2015)

5. The properties of the rock support

5.1. Lithology

Two lithologies can be distinguished in the cave:

- The base of walls is composed of beds with a decimetric thickness forming an irregular, stepped profile. Three sub-facies have been distinguished: the lowest beds are highly bioturbated, the next overlying ones are organized in large oblique folds several meters long, and the highest ones correspond to tempestite formations (Fig. 5). Erosion caused large rock volumes to collapse from these beds, creating obstructions in the path (Fig. 6). Outside the cave, these limestones are covered with slope colluviums.
- The beds composing the higher parts of the walls and the ceiling have a metric thickness. The speleogenesis of the cave carved out wide and regular, sub-vertical or overhanging surfaces, which most often correspond to the interface between two beds (Fig. 6). On the valley slope, the outcropping of these levels forms a rock bar with a maximum height of 3 m (Fig. 7), into which the cave porch opens.

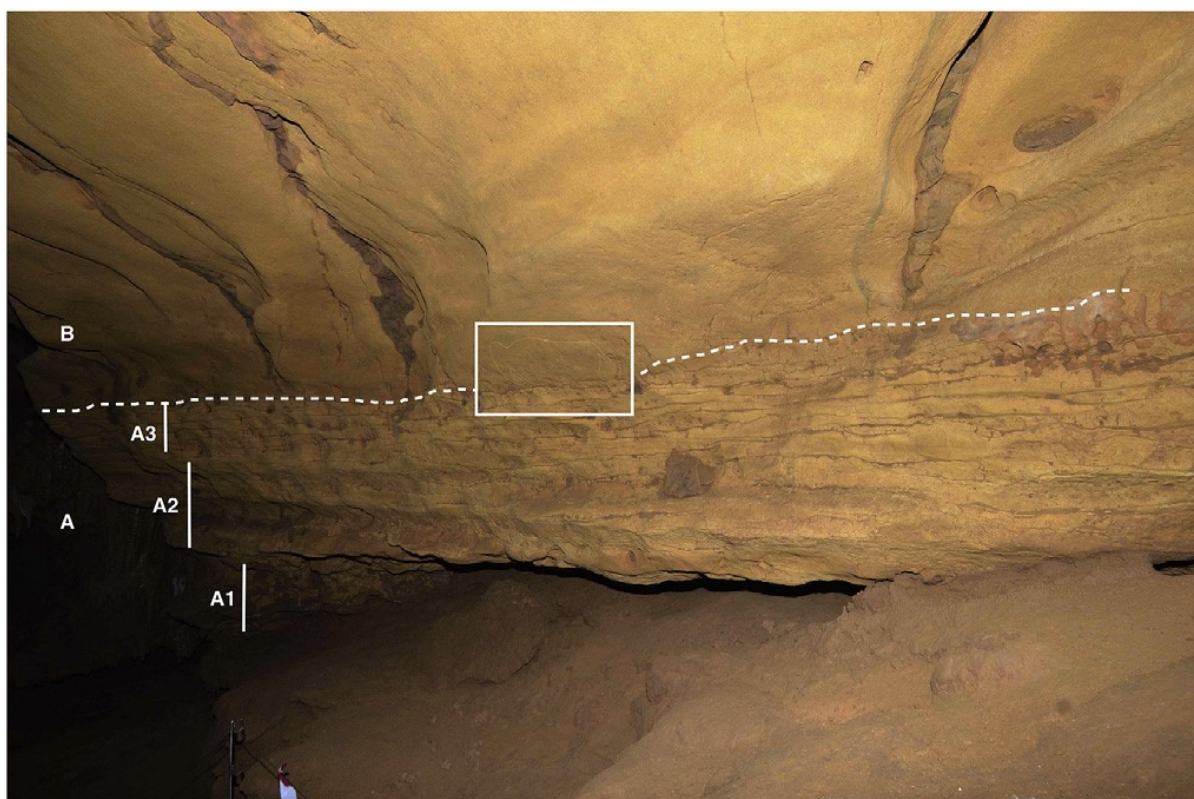


Fig. 5. Upper Campanian limestone facies visible on the cave walls. A: beds with decimetric thickness; A1: highly bioturbated beds; A2: large oblique folds; A3: tempestite formations. B: beds with metric thickness. In the square, the Isolated Mammoth (4D2-23) on the left-hand side of the Panel of the Facing Animals (photo S. Konik, PCR Cussac).



Fig. 6. Cussac Cave, Downstream Branch (photo O. Got, Université de Bordeaux). The high part of the walls and the ceiling are composed of thick beds, resulting in large overhanging areas (a: Panel of the Discovery) or sub-horizontal surfaces. The lower part of the walls is composed of thinner beds, resulting in an irregular profile and the collapse of large rock volumes, such as this one which enabled Paleolithic people to reach the engraved surface (b).



Fig. 7. Overhang composed of Upper Campanian limestone beds of metric thicknesses (photo B. Kervazo, PCR Cussac). In Cussac Cave, these beds form the upper part of the walls and ceilings.

5.2. Wall alterations

The rock is composed of a sandy, yellow to red limestone with a grainstone texture. Its constituent elements - allochems (pellets, lamellibranchiata, echinoderms, bryozoan, foraminifera) and detrital grains (gravels, quartz and feldspar) - are cemented by sparite and microsparite. In the thick beds, these elements are a bit larger (coarse sands) and the porosity is qualitatively greater than in the smaller, layered beds (Fig. 8). Goethite, identified by XRD and Raman spectroscopy (Fig. 9), impregnates some micritic grains and sparitic cement in both facies (Fig. 8C and D). The proportion of residual materials after HCl digestion is around 8%.

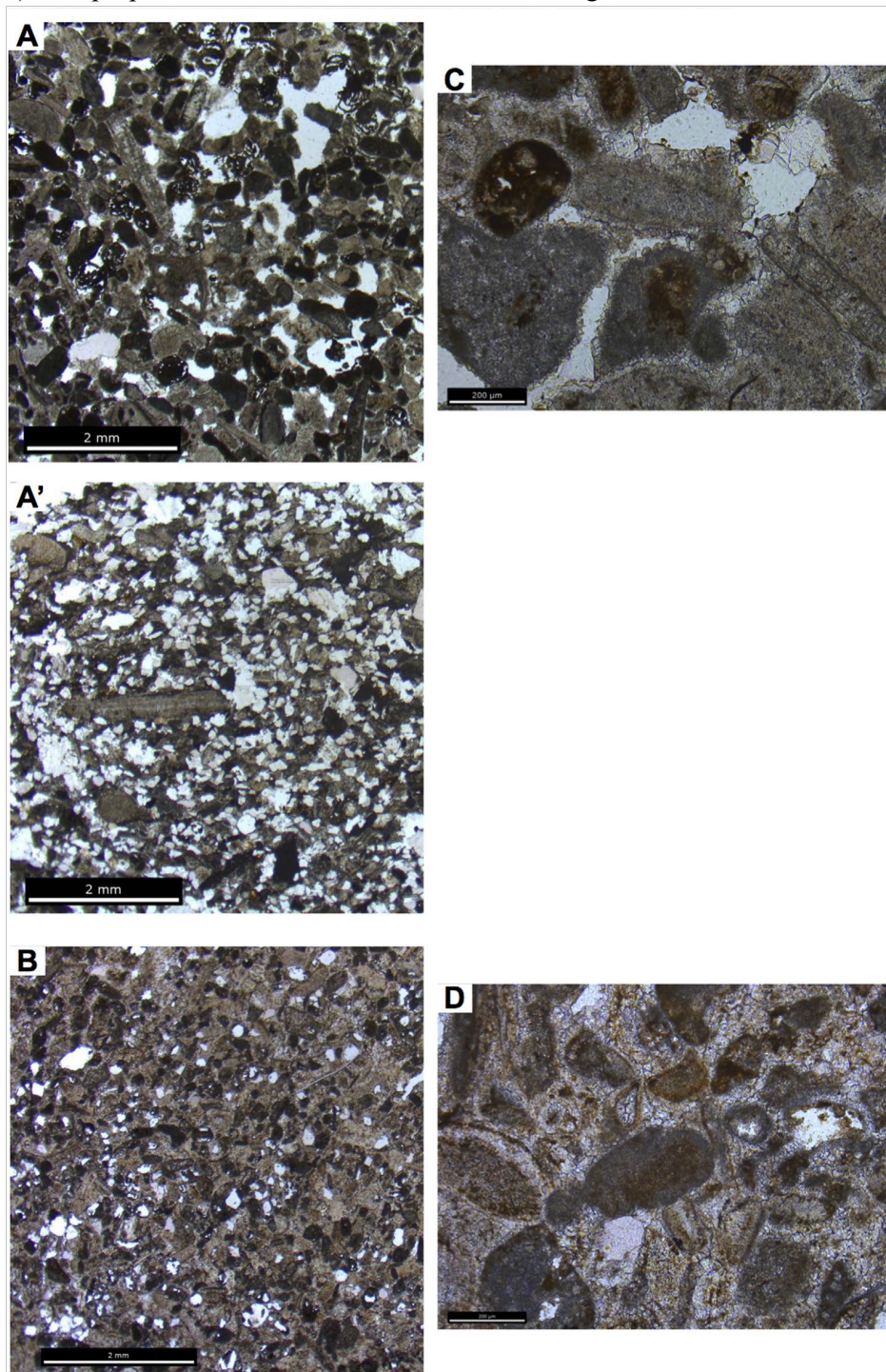


Fig. 8. Petrography of the karstified Upper Campanian levels (photos M. Ballade). A and A': limestone constituting the thick beds (upper part of the walls and ceiling of the cave) - PPL. It is composed of calcitic and quartzose sands cemented by sparite and microsparite crystals. It includes thin layers with coarser sands, rich in quartz (A0). B: limestone constituting the lower part of the walls. It is less coarse (silts) and has a lower porosity - PPL. C et D: Goethite impregnates micritic grains in both facies - PPL.

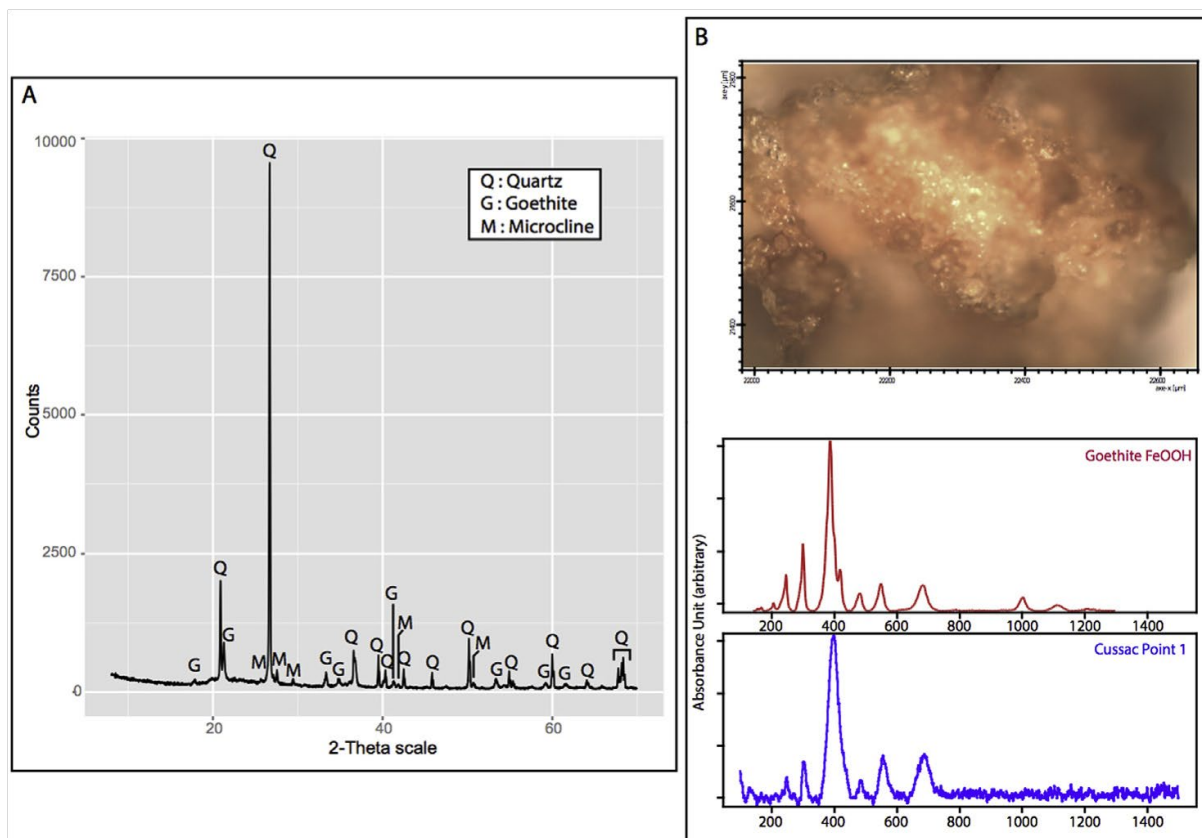


Fig. 9. Mineralogical analysis of the insoluble limestone residue forming the thick beds of the cave: presence of quartz, goethite and feldspars. A: X-ray diffraction. B. Raman spectroscopy.

Thin section analysis of rock clast detached from the thick beds shows that the face corresponding to the wall surface was subject to a partial dissolution, two to 3 mm thick (Fig. 10). This mainly affects the cement, as well as some of the allochems.

An XRF analysis of the variation in iron proportion between the altered superficial surface and the non-altered rock shows a relative enrichment linked to the calcite dissolution and the goethite concentration (Fig. 11). This alteration contributes to an increased porosity, making the rock softer in the affected zone and is probably responsible for the orange-ochre coloration of the wall surfaces.

This dissolution process is also responsible for the release of calcitic grains and the insoluble minerals (quartz, feldspars and goethite) (Fig. 12) that accumulate by gravity on the ground or on wall protrusions (Fig. 13). This phenomenon was observed in twenty sectors in the Downstream Branch. The first tenuous signs of disaggregation were found at 11 m from the current cave entrance and become increasingly numerous toward the end of the cavity. The process was particularly active in the deep part: the number of sand accumulations increases in the 75 m preceding the Grand Panel, where they become denser and more continuous (Fig. 2).

A study of the lithological context indicates that this process operated mainly on the thick limestone beds, on which the majority of the engraved figures are located.

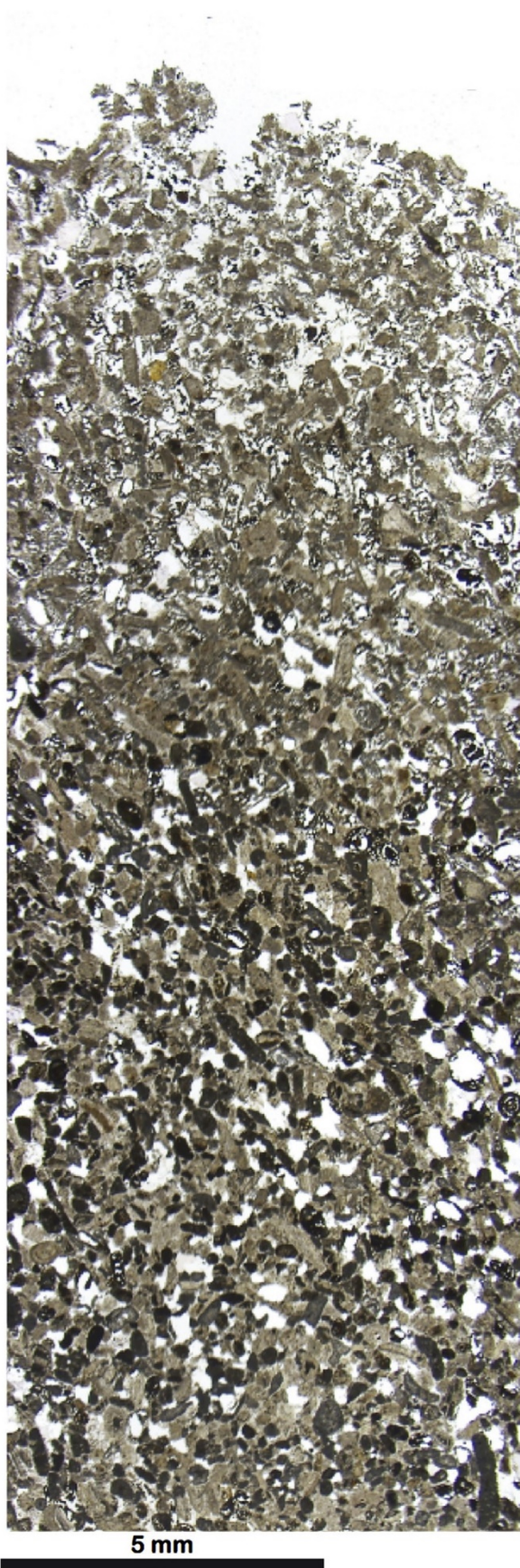


Fig. 10. Microphotography of a rock clast fallen from the thick bed at the foot of the Grand Panel. The face corresponding to the wall surface is at the top. The porosity, linked to the dissolution of the calcitic cement, is higher in this zone, through a few millimeters of thickness (PPL, photo M. Ballade).



	% Fe	% Ca	Fe / Ca
Zone 1	3.81	47.22	0.08
Zone 2	2.91	56.88	0.05

Fig. 11. XRF analysis of the fallen rock clast at foot of the Grand Panel (thick polished section). Zone 1 is located in the altered rock or patina. Zone 2 is from the non-altered rock. Mean values (out of 4 acquisitions) of chemical composition for Fe and Ca, are given in relative percentage.

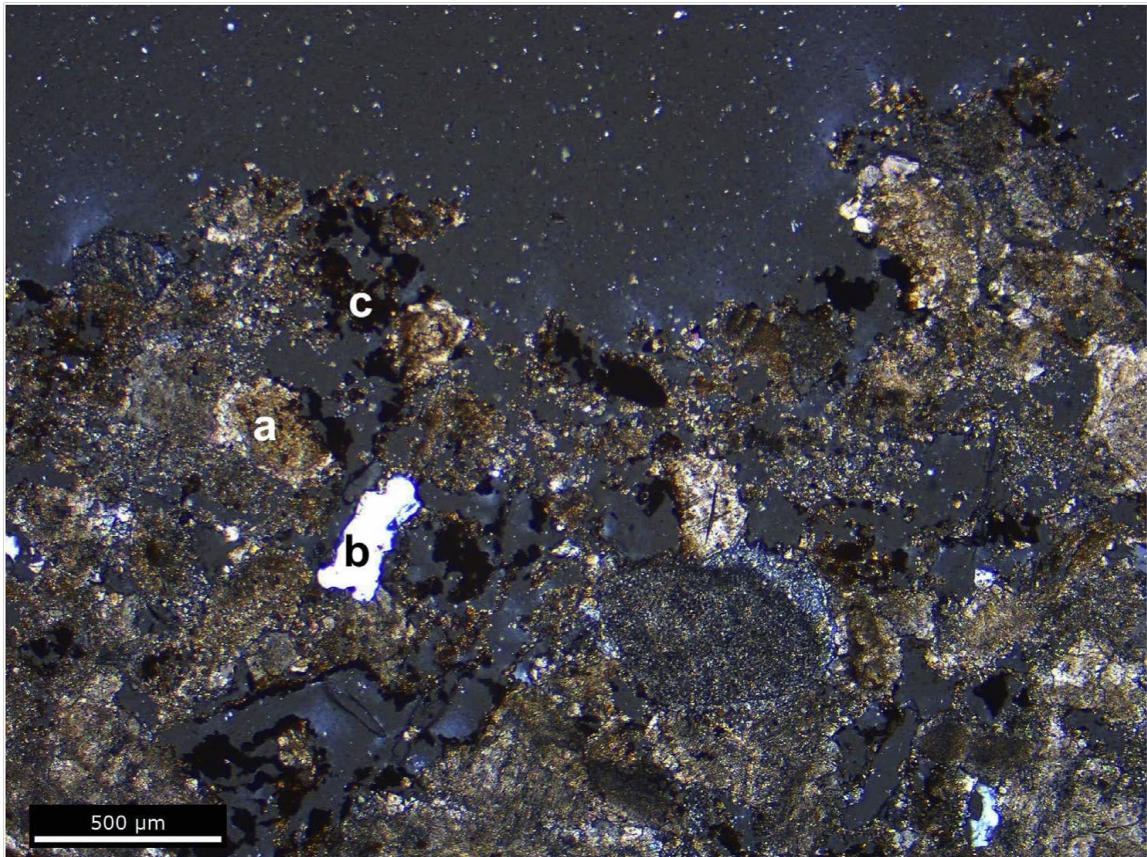


Fig. 12. Disaggregation due to the dissolution of the sparitic cement. The micritic grains (a), quartz (b), and goethite (c) are released and then accumulate on the cave floor (XPL, photo M. Ballade).



Fig. 13. Sand accumulation resulting from the alteration of the thick beds forming the ceiling near the Triptych Panel (photo S. Konik, PCR Cussac).

6. Archaeological implications

6.1. Lithology and the parietal art distribution

The large, relatively flat and sub-horizontal surfaces formed by the collapse of thick beds along stratification joints (middle zone) were preferentially decorated by the Paleolithic artists. They permitted the realization of large figures and panels, such as the bison (over 3.5 m long) on the Grand Panel (5G2-38). The figures and the motifs located on the lower part of the walls are much smaller as they were constrained by the thinness of the limestone beds. Only two panels are entirely engraved on the thin-bedded facies, four are straddled between the thick bands and thinner bedded bands, and the 24 others are located only on the thick bands.

6.2. Rock surface properties and technical choices

Several properties of the wall surface resulting from its alteration can explain the artists' choice to engrave rather than paint, as well as the types of engravings realized:

- the low cohesion of the rock surface, due to the dissolution of the calcite that cements the limestone grains, enabled the easy realization of deep and wide incisions using hard or soft tools. It also permitted the creation of “Egyptian” relief by scraping one of the edges of the incision to soften the shadow and thus creates a modeled effect (Fig. 14). The softness and friability of the support also permitted the realization of finger-tracings, resembling the older, contemporary or more recent ones in other caves, such as Chauvet-Pont d’Arc (Clottes *dir.*, 2001), Cosquer (Clottes *et al.*, 2005), Gargas and Rouffignac (Plassard, 1999). In contrast to Cussac, however, the surfaces engraved by finger-tracing in these caves are composed of soft limestone or limestone covered with mondmilch.
- the color contrast between the superficial altered wall surface that corresponds to the patina and the lighter, underlying zone exposed in the bottom of the incisions, combined with the large size of the representations, contributes to the visibility of the figures and their spectacular appearance.

In Cussac Cave, the properties of the support surface thus offered technical opportunities that the engravers knew how to use, and they adapted their technical choices to the specific properties e especially texture e of the surface to be engraved.



Fig. 14. Panel of the Discovery, example of an “Egyptian” engraving of a bison hindquarter (photo V. Feruglio, PCR Cussac).

6.3. Rock surface properties the engraved line morphologies

The study of the Triptych Panel revealed that the depth, width and precision of the engraved lines are closely linked to the rock surface properties, determined by the intensity of the alteration undergone by the wall before it was decorated. This alteration is manifest in differences in the rugosity of the rock surface, which vary depending on the wall morphology:

- - the less protruding and convex parts have a low to medium rugosity that corresponds to the less altered zones. Here the engraved lines are narrow (in the millimeter range) and have clean edges;
- - on the more protruding parts, the alteration is greater and the rugosity is higher, caused by the detachment of limestone grains. These surfaces are visually distinct due to their lighter color. Here, the engraved lines are wider and less visible, such as those of the back legs of the bison (Fig. 14).

This relationship between the rugosity of the rock surface and the morphology of the walls is found throughout the Downstream Branch and could be related to the condensation/corrosion process (Dublyansky and Dublyansky, 2000), which is more active on convex surfaces than on concave ones. Its influence on the morphology of the engraved lines was also observed on the Panel of the Isolated Mammoth (4D3), whose lines are more incisive and narrower on the concave surfaces. By influencing the morphology of the engraved lines, whose variations can also result from changes in the pressure and/or inflexion of the engravers' movements, the properties of the rock surface contributed to the visual appearance of the engravings.

6.4. Rock surface properties and the presence of other intentional and unintentional marks

Due to the nature of the limestone at Cussac and its degree of alteration, rare in decorated caves, marks and lines that we would normally expect to see on plastic surfaces such as clay or mondmilch were realized by the artists and remain visible. These marks and lines are of two types: intentional, such as finger-tracings, or unintentional, such as the marks created by the resting hand of an engraver on the periphery of the figures of the Panel of the Discovery 2D1 (Aujoulat et al., 2013, Fig. 14). Curiously, we have not observed any rubbing of the surface, which could have created "colored" zones to fill-in the figures or to represent fur, shadowing or modeling. Though the Gravettian artists did not take advantage of this very specific support property, Magdalenian artists did in the caves of Les Trois-Freres (Ariège, France) (Begouën et al., 2014), Altxerri (Guipuzcoa, Spain) (Altuna and Apellaniz, 1976) and even Massat (Ariège, France) (Barrière, 1990).

7. Conclusions and perspectives

This study of the rock supports in Cussac Cave and their alterations have enabled us to better understand the conditions in which the parietal art works were realized, as well as the technical choices made by the Gravettian artists. The results show the influence of the lithological properties and surface conditions of the supports on different aspects of the graphic expressions. It appears that monumental engraving was facilitated by the large surfaces exposed by the karstogenesis and the specific nature of the thick limestone bed, whose friable surface results from the dissolution of the rock cement through a few millimeters in thickness. The choice to engrave in this manner on this surface contributes to the exceptional nature of the art in Cussac Cave.

Due to fragility of the patina on several decorated panels, the stigmata created by subtle differences in the movements of the artists can be observed, such as changes in tool pressure, along with diverse marks unintentionally made during the realization of the depictions (Panel of the Discovery), such as light rubbing across the wall or indentations made by resting hands.

The alterations responsible for the state of the wall when the engravings were made sometimes continued after the graphic depictions were realized. This is the case of the right part of the Triptych Panel near the depiction of a "goose" with a broken neck 4G1-6 and the base of the horns or ears of the animal head 4G1-8 (Fig. 3), where the falling of grains freed by the cement dissolution resulted in a loss of material and the erosion of the engraved

lines, which thus appear shallower. On the other decorated panels, it is sometimes difficult to untangle the chronological order of engravings and alterations. The potential influence of the engravings on the taphonomic evolution of the walls is also difficult to evaluate and will be further explored in future research.

Studies of the rock support are often integrated into research on parietal art, but never as a constituent element of the artistic procedure or as a contributing factor in its final rendering. Thanks to its very recent discovery, ensuring the preservation of multiple lines of evidence, Cussac Cave offers this possibility and enables us to more precisely interrogate the work of the artists. This art now appears much more complex and complete, integrating parameters far beyond the spontaneous artistic acts that we too often imagine.

Acknowledgments

We thank the French Ministry of Culture and Communication, MCC (DRAC-SRA Aquitaine), Bordeaux, the University of Bordeaux PACEA, Magen O'Farrell for editing and translation. We are grateful to Eric Lebraud (ICMCB e UPR9048 CNRS) who performed the XRD acquisition. This work is mainly supported by French MCC (DRAC-SRA Aquitaine) and in part by others laboratories and French institutions of the authors and by the LabEx LaScArBx (label of excellence Archaeological Sciences Bordeaux) according to the general program supported by the ANR (Agence Nationale de la Recherche) e n-ANR-10-LABX-52.

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