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Émilie Lesvignes, Eric Robert, Boris Valentin

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Title: Using digital techniques to document prehistoric rock art: first approaches on the engraved panels of the Paris Basin shelters

Authors:

(Corresponding author) Emilie LESVIGNES, UMR 7041 ArScan – Ethnologie préhistorique; CEDARC. emilie.lesvignes@hotmail.fr

Eric ROBERT, MNHN; UMR 7194 HNHP – NOMADE. eric.robert@mnhn.fr

Boris VALENTIN, Université Paris 1; UMR 7041 ArScan – Ethnologie préhistorique. boris.valentin@univ-paris1.fr

In collaboration with the scientific team: Michèle BALLINGER, Alain BÉNARD, Fantine BELLANGER, Béatrice BOUET, François BOUGNÈRES, Alexandre CANTIN, Laurent COSTA, Cécile DARDIGNAC, Sophie DAVID, Patrick DUBREUCQ, Colas GUÉRET, Emmanuel GUY, Isabelle de MIRANDA, Vanesse ROMERO-GODOFREDO, Thomas SAGORY, Médard THIRY, Benoit TOUCHARD, Régis TOUQUET, Laurent VALOIS and Lydia ZOTKINA.

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Title: Using digital techniques to document prehistoric rock art: first approaches on the engraved panels of the Paris Basin shelters

Abstract:

In the sandstone boulder fields of the southern Paris Basin, over two thousand small engraved shelters have been identified. A new collective research programme aims to investigate on this broad subject and focus above all on Mesolithic contexts, which constitute a large proportion of the engravings in the shelters, among other earlier or later periods represented.

Since 2017, several field campaigns led to the documenting of rock shelters at various scales, their environment and a selection of their engraved panels, focusing on issues of relative chronology. Photographic techniques, digital technologies and recording processes are used to meet three objectives: preserving the sites by means of digital archiving, raising awareness of this heritage, and carrying out new studies.

The documenting methods, digitisation rationale, and use of the different media, along with their contributions and limits, is discussed below.

Keywords: preservation; prehistoric rock art; photographic techniques; 3D; *relevés*; Paris Basin.

Text:

1. Introduction

The group research programme, *Art rupestre préhistorique dans les chaos gréseux du Bassin parisien. Etude, archivage et valorisation*[1] (PCR ARBap) is funded by the French Ministry of Culture (DRAC Île-de-France). Launched in 2017 and directed by B. Valentin, it aims to investigate the decorated shelters in the sandstone boulder fields of the southern Paris Basin (Fig.1) (Valentin, 2018). Over two thousand engraved shelters have been identified to date, notably thanks to the *relevés* and inventories carried out by an Association called *GERSAR* (*Groupe d'Etudes, de Recherches et de Sauvegarde de l'Art Rupestre*[2]), founded in 1975. The shelters are distributed over a vast geographical area, visible in Fig.1, between Rambouillet and Fontainebleau, in which the density of engraved shelters varies greatly according to their location, from 1 shelter to more than 50 shelters for 10 km square area. These shelters may contain only few engraved features, but for the most part, dozens or even hundreds of engravings, which are generally quite deep and are often found over almost the entire inner surfaces of the small caves (Bénard, 2014). In general, geometric themes predominate, notably grid patterns (Fig.2 a.), with a few more or less schematic figurative depictions (Fig.2 b.).

Figure. 1 Location and repartition of the decorated shelters in the sandstone boulder fields of the southern Paris Basin. Doc. E. Lesvignes/PCR ARBap from A. Bénard/GERSAR.

Figure. 2 a. Engraved inner surfaces of a shelter, geometric themes (Abri Leuillet). b. Schematic figurative depictions, cervids (Mont-Rouget). Photos E. Lesvignes/PCR ARBap.

Current research tends to attribute most of these engraved shelters to Mesolithic contexts (Guéret, Bénard, 2017). However some rare but important engraved panels have been attributed to earlier periods such as the Upper Palaeolithic (Bénard, 2010), and to later periods such as Neolithic, Metal Ages, Middle-Age and Modern period, whose figurative motifs are easily recognizable.

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[1] *Prehistoric rock art in the sandstone boulder fields of the Paris Basin. Study, archiving and promotion.*
[2] *Group for the Study, Research and Preservation of Rock Art*

The programme on prehistoric engravings has three objectives: preserving, studying, and raising awareness of this heritage (Robert et al., submitted). These objectives are all closely linked, as study requires the preservation of the sites, and promoting and raising awareness of the heritage necessarily requires study. This outdoor heritage is extremely fragile. A simple entry into the shelters is not without risk for the conservation of the engravings, as sandstone is a very fragile rock, which disintegrates little by little into sand. The environment in which it is situated is very popular for tourism, rock climbing, hiking, etc. The open-air decorated shelters (Fig.3), which are hidden and little known of, are often vandalized and degraded both by people and the passing of time (cf. Fig.5). Conservation is therefore a major aspect of our programme.

Figure. 3 Open-air rock art shelter (La Touche aux Mulets 1). Photo E. Lesvignes/PCR ARBap.

2. Documenting methods and techniques

These three objectives require the particularly abundant and diverse documentation of the engravings and their contexts, whether in the form of graphic, photographic or three-dimensional media. Moreover, the whole decorated shelters are extremely numerous. Different documenting techniques and methods have been used to compile data acquired at several different scales, through a series of multiple approaches: photography and macro-photography, photogrammetry and 3D imaging, video, topography, aerial photography using drones, LiDAR (Light Detection and Ranging). In parallel, a GIS (Geographic Information Systems) programme is developed to combine the results of all or part of these media.

2.1 Photography

Photography has been applied to archaeology ever since they both emerged in the 19th century, the former as a technique and the latter as a science (Lesvignes, 2015). It is a means of documenting and defining the different stages of archaeological operations and is of particular use in establishing inventories and representing the sites and collections, while contributing a unique perspective.

Applied to rock art, photography is a key means of contextualizing and representing graphic elements. Given the considerable number of often similar shelters and engravings within this programme, it is essential that they are clearly represented, located and contextualized (Fig.4).

Figure. 4 From the shelters context to the engravings (La Ségognole). a. Panoramic photomontage of the site. b. Ségognole 4 rock shelter. c. Small entrance of the Ségognole 4 rock shelter. d. Interior of the Ségognole 4 rock shelter and localisation of the engraved panel. e. One of the engraved panels of the Ségognole 4 rock shelter, located on the floor. Photos and doc. E. Lesvignes/PCR ARBap.

Photography is also used to produce precise and accurate analytical material with which to carry out rock art *relevés* and image analysis (in particular colour evaluations) (Fritz, Tosello, 2007; Robert et al., 2016). However, the creation of this material is subject to constraints of framing and distance, orthogonality with respect to the average plane of the subject, resolution, and lighting. Respecting these principles is a matter of technical choice and equipment (type of camera and lens, settings, type of lighting, etc.), which varies according to the subject photographed.

Photography also allows the evolution of the state of conservation of the photographed subjects to be assessed and is particularly useful in documenting the progression over time of such or such a phenomenon, alteration, destruction, etc. As such, reviewing old photographic archives is an important opportunity to ensure the continued conservation of the sites (Fig.5).

In these sandstone contexts, photography is not the easiest to implement for several reasons, which we shall return to below.

Figure. 5 Schematic cervid depiction (Sables du Cul du Chien). a. 1985. b. Today. Photos a. Archives GERSAR; b. E. Lesvignes/PCR ARBap.

2.2 Photogrammetry

Photogrammetry, based on photographic techniques, allows three-dimensional images to be produced by triangulating points (in this case, pixels) and correlation algorithms between the photographic views in order to reconstruct the volume of a subject (Egels, 2011; Pierrot-Deseilligny, Clery, 2011).

Nowadays it is very widely used in the context of rock art, offering significant advantages in terms of cost, usability, texturing, and making it the subject of numerous applications (e.g. Chandler et al., 2007; Domingo et al., 2013; Berquist et al., 2018; Carero-Pazos et al., 2018; Strasser et al., 2018).

This technique allows us to create reliable digital archives, offering virtual copies of the shelters and their engraved panels (Fig.6). Until the recent popularization of 3D tools, moulding techniques were used to create these copies and unfortunately may have been abused. While very precise, moulding techniques pose many problems when used in the context of rock art. In the specific context of our studies, several engraved panels currently present significant deterioration marks made by moulding (traces and prints, residues, surface films, tearing of the substrate, pollution of the rock, etc.) (some white residues are visible on Fig.4 e.). The serious consequences visible today have incited us to focus on non-invasive techniques.

Figure. 6 3D model of a decorated shelter, views at different scales and points of view (La Butte du Puits). Model F. Bougnières and B. Touchard/Summum 3D/PCR ARBap.

Beyond the conservation aspect, 3D modelling provides us with useful data on the relief and contexts of the engravings and helps us to analyse certain figures which are difficult to study because of their location and access. In addition, it allows us to place the engraved figures in a volumetric context, and not only in a two-dimensional plane. This 3D modelling is used to complement a photographic approach when carrying out *relevés* of the engraved figures. We also took into account the microscopic scale in the degree of resolution of the three-dimensional acquisitions. At present, macrophotography remains the best way to obtain accurate information and a good texture. New investigations into the 3D documenting of microscopic and use-wear information are also underway within the programme (Plisson, Zotkina, 2015; Zotkina, 2016).

Regardless of their scale, from the macro to the shelter in its context, the three-dimensional models created have been georeferenced with topographic laser tacheometer readings (X, Y, and Z coordinates) (Fig.7).

Figure. 7 Topography recording of the calibration points for 3D reconstruction (La Ségognole 3). Photo E. Lesvignes/PCR ARBap.

2.3 Topography

Documenting the topography of the shelters and the sectors they are located in allows us to georeference the three-dimensional models to give them an orientation and a position in space. This technique also makes it possible to create links between a delineated 3D model (a shelter for example) and the wider sector in which it is located, in which there may be other documented models (other neighbouring shelters). This information allows precise locations to be established within a very large area, makes it possible to document the geometry of the shelters and their location within the environmental landscapes, and enables the scaling of the documented subjects to provide realistic metric references. Finally, this topographic information represents the basic data on which we can rely to situate the other documentary (photography and photogrammetry) and scientific (*relevés* and analyses) approaches. This combination forms a precious documentary substrate upon which to contextualize the decorated sites (Boche et al., 2014).

For the external surfaces, in addition to the topography, we also carried out photography using drones, and LiDAR (Fig.8) to document spatial and physical data on a medium to large scale. Drones are used for photography and photogrammetry, while LiDAR is a remote laser sensing technique allowing for the acquisition of high-resolution, three-dimensional data for mapping purposes. Post-acquisition data processing allowed us to distinguish the points on the ground and those representing the surrounding vegetation. Once isolated, the points identified as part of the ground are used to produce a very detailed model of the topography through the creation of a Digital Elevation Model (DEM). These techniques allow us to produce precise material with which to carry out spatial analyses and geographical and topographical observations over extensive areas (Georges-Leroy, 2011; Trouvé et David, 2015). In the context of the shelters of the Paris Basin, it will be used for a variety of purposes: establishing the distribution of the shelters and sandstone boulders, large-scale geological observation, locating historic quarries which have destroyed engraved shelters, and creating maps (exposure, slope, remains, etc.).

Figure. 8 LiDAR view of a sector in the south of the Paris basin (Gorges Houx). LiDAR S. David/ONF.

Thanks to this multi-scale body of data, the shelters and their engravings can be apprehended within their contexts and environments, from the level of the territory itself down to the engraved panel, like an optical zoom.

Compiled in a Geographic Information System, this data represents our raw material with which to answer several scientific questions. Offering a shared mapping interface, this GIS format favours a dynamic and collaborative approach by making a wide body of data and documentation available to the whole team as a single living document. This allows for the storage, processing, analysis, management and presentation of spatial, geographic, archaeological and contextual data. This type of unifying document makes it possible to compare and contrast the data resulting from the different approaches and scales of documentation, to foster new perspectives, and to gain a better overview of the different, but closely related, data (Boche et al., 2012).

3. Technical constraints: photography and photogrammetry

The shelters formed in the sandstone boulder fields are usually small in size; both in height and in width. Their depth is variable. The interior space of the shelters is often small and very constraining. The relief is varied and sometimes very uneven. Significant difficulties were encountered in framing, positioning the photographer, lighting and, to the least extent possible, installing a tripod, given the available space and the fragility of the sandstone. In addition, photo coverage for 3D modelling the interior of a shelter requires access, within reasonable focal distance, to all the areas and reliefs involved, which is not always easy (cf. Fig.7).

The small size of the shelters also lead to strong contrasts between the interior darkness and the intensity of the outside light (cf. Fig.9 b.). This created difficulties in two areas. Firstly, problems were encountered in measuring the colour temperatures and associated colour values. At the same time, obstacles were encountered in lighting up the engravings when they were exposed to daylight.

While framing is less essential in photogrammetry than in photography, the physical installation, the topography of the shelters, and the strong light contrasts presented the same difficulties. Furthermore, the powerful frontal lighting required for photogrammetry is little compatible with the constraints of these small and fragile shelters.

It is necessary to constantly adapt to these particular constraints, which differed in each case, by making technical compromises and, at best, having recourse to a wide range of photographic equipment and portable lighting, which is not always possible.

4. An adapted methodology of *relevé*

In the context of the documentation and analysis of the engravings, and to minimize our presence in the shelters, we are conducting methodological tests to develop a strategy adapted to each shelter, panel and engraving. This involved the complementary use of both photography and photogrammetry.

The "classic" method is derived from proven procedures established over the course of numerous studies in Palaeolithic art, and is based on the analytical logic of never breaking the link with the direct observation of the decorated panel (Fritz, Tosello, 2007). However, a significant amount of time is required for the observation and production of photographic *relevé* material, in particular to take into account the reliefs and the morphology of the elements to be represented in 2D. For this reason, 3D tools offer a significant advantage to allow a better speed of execution, and also for working off site and limiting our own presence in the shelters. Furthermore, digital tools and technologies are increasingly used to meet the needs of rock art research (e.g. Aujoulat, Pérazio, 2005; Bourdier et al., 2007; Feruglio et al., 2015; Fritz et al., 2010; Robert et al., 2014 et 2016; Jalandoni et al. 2018).

The choice of documenting method for creating the analytical material results from its feasibility, since the small size and the morphology of the shelters did not always favour the use of photography alone. It was the photographic conditions that determined the use of one or other method: when there was not sufficient space to allow for the orthographic photography of the subject (Fig.9), we favoured photogrammetry. Photogrammetry offers a methodology which allows the subject to be approached by overlapping oblique views. This makes it possible to overcome the framing constraints related to photography and to produce an orthoimage from the 3D model suitable for an analytical reading and the production of a *relevé*. It is also these highly practical aspects that has formed the basis of our methodology.

Figure 9. a. Oblique view of an engraved panel on the floor. b. Situation of the panel: the lack of distance above the panel does not allow orthographic photography. Photos and doc. E. Lesvignes/PCR ARBap.

The methodological tests that are currently being developed make use of both of these techniques and involve carrying out observations and *relevés* on both types of media.
With photographic media, the *relevé* is carried out on site, facing the wall (Fig.10 a.). With the 3D models, the readings are carried out with and without prior observation of the subject in order to compare the results and assess the limits of this work at a later date off site (Fig.10 b.). We also tested a blind reading of a 3D model by a person who had never seen the engravings before. The next step is to carry out an on-site control of the observations and readings made in the laboratory.

Figure 10. a. Classic method of *relevé*, on a layer placed on an ortho-photographic document, on site and face to the wall. b. Example of desk situation for the *relevé* with 3D tools, facing the model and taking the reading on an orthoimage from the 3D model. Photos a. E. Lesvignes/PCR ARBap; b. E. Robert/PCR ARBap.

Finally, a comparison was drawn between the readings made on photographic media and those taken from the three-dimensional models, which has thus far revealed some relatively significant differences. Continuing these tests in order to achieve a reliable methodological strategy necessarily requires carrying out new, more localized modellings with a very high degree of resolution, for purely analytical purposes.

It should be noted that at present no software allows for a *relevé* to be carried out directly on a 3D model, even if innovative methodological developments have been proposed, notably by the research team at Grotte de Cussac (Feruglio et al., 2015) by volume selection, by recent innovations with *Blender* software (Pinçon et al., submitted) or on the Gavrinis cairn (Cassen et al., 2014). It is therefore currently necessary to carry out a manual *relevé* from readings on a computer screen and from an orthoimage taken from the 3D model before reintroducing it as a superimposed texture (Fig.11).

Figure 11. Engraved panel of Segognole rockshelter. a. *Relevé* from 3D model readings on a computer screen and made on an orthoimage from the model. b. *Relevé* superimposed to the orthoimage. Model A. Lureau/PCR ARBap; *relevé* and doc. E. Robert/PCR ARBap.

However, the tests made on the orthoimages drawn from the 3D models have revealed several limits, in terms of the technical constraints, resolution and readability of the engraved lines. Regarding the technical aspects, aside the choice of photographic equipment, the main difficulty lies in the type of lighting and its orientation, which is particularly difficult to accomplish in these cramped spaces. In terms of resolution, it is the quantity of photos and the object focal distance that determines the accuracy and zoom capacity of a model.

A three-dimensional model created to meet the objectives of preserving and raising awareness of the sites does not necessarily come close to meeting the requirements of an analytical reading. Thus, the off-site interpretation of the results, based exclusively on a 3D model, sometimes leads to information gaps and does not always allow for the analysis of the fine details of the superimpositions or the overlapping of the engraved lines, whose interpretation constitutes one of our main scientific objectives. Other limits have also been encountered in terms of the wall texture, notably in the poor rendering of alteration phenomena and geomorphological deposits.

Despite developing this methodological strategy, the diversity of the subjects inevitably lead to technical compromises that had to be adapted to each site, shelter and engraved panel, according to their location and context, their state of conservation and fragility, the observation conditions, etc.

5. Usage

Techniques of photography, macro-photography and 3D modelling are combined to produce several types of document with which to answer the scientific issues involved in the study of rock art. These issues concern both the chronology of the figurative and abstract depictions, and the internal structuring of the grid patterns.

Given the large number of decorated sites and the considerable documentation involved, a classification and archiving strategy was also developed to safeguard the data. The elements of nomenclature, classification and archiving are part of a long-term perspective and are necessary regarding the large number of sites, shelters and engravings. Also designed as part of a transdisciplinary approach, the classification of the documentation functions as an indexing by site rather than by discipline or recording technique. The tree structure is divided first by site, then by shelter and finally by technique, thematic or discipline. The nomenclature of the files is systematic, and their precise metadata are entered, on the one hand to guarantee a follow-up of the recorded information, and on the other hand to make the link with the database of the Regional Archaeology Service of Ile de France (French Ministry of Culture and Communication). It is a question of guaranteeing the durability of data, beyond the preservation of the heritage itself.

All documentation is stored on two servers. Huma-Num server, which is supported by the CNRS (the French National Center for Scientific Research), Aix-Marseille University and the Campus Condorcet. Huma-Num is a French Very Large Research Infrastructure ("Très Grande Infrastructure de Recherche", TGIR) with international reach devoted to Social Sciences and Humanities. This service provides a shared, secure and professional storage space with high access availability. The second server is located at the National Centre for Prehistory (CNP), which is a research department of the French Ministry of Culture and Communication specialising in the multidisciplinary study, conservation and archiving of decorated caves and rock art sites.

The objectives of preserving and promoting these decorated shelters imply the multiple use of this documentation, in an attempt to respond to the issues of this very dense and fragile open-air rock art. The difficulty lies in finding a balance between preservation and promotion, so that knowledge of this heritage does not drive new potentially destructive visits.

The three-dimensional models were first archived in their digital form, allowing for the subsequent production of replicas, in particular through computer numerically controlled milling. These digital documents can also be used to create virtual reality and augmented reality interactive programmes or scripted videos. In terms of virtual and augmented reality, the documentation (photos, *relevés*, pan shots, videos, 3D models, etc.) forms a body of resources that can contribute to the creation of virtual discovery trails. This type of interactive and educational resource requires a specific kind of text and script. The fragility of the sites, their difficult access, their very wide distribution over a large geographical area and the sometimes difficult reading of the engravings can all be overcome through the use of this type of virtual discovery trail, provided that it is designed in close connection with the research objectives.

Photography also contributes to preserving the sites in their current state of conservation by means of regular and targeted recordings and through the classification and archiving strategy. In addition, reviewing old photographic archives enables conservation monitoring to be carried out over several decades. The photographic documentation also allows publics to discover and see interior shelters and engraved panels without any contact, near by the sites or even at great distances, as well as raising awareness of the sites through original perspectives and points of view, writing with light and presenting narrative subjects. A photographic approach in natural light reveals the shelters and their engravings as they can be observed today and taking into account their current environment (Fig.12), which is also a way to approach perceptions and representations during times. Virtual tours based on panoramic photos (360°) goes beyond the photographic frame and allows to explore the inside of these decorated shelters and their surroundings.

Thanks to these productions, several projects are underway to promote the sites among the general public, in particular in schools, through mediation, workshops, events, exhibitions, conferences, and publications. Beyond providing an archaeological knowledge of this heritage, these educational projects raise awareness of these prehistoric sites and engravings, which is essential to their preservation.

Figure. 12 Photographic approach of the shelters and their engravings in natural light, long exposure (La Ségognole 4). Photo E. Lesvignes/PCR ARBap.

6. Conclusion

The different digital methods and techniques employed in the context of this programme are a real means of meeting the objectives of preserving, studying and raising awareness of the sites.

The production of multi-scale data provides the necessary documentation to support numerous approaches and address the scientific issues involved in this programme, while ensuring the archiving and preservation of the sites.

However, the implementation of these techniques and the methodological experiments involved have demonstrated the limitations of some of these tools, in particular 3D modelling for research objectives, for which the level of resolution and texture rendering have proven insufficient or even ineffective. As such, the consistent use of conventional photographic and macrophotographic documenting processes allows these scientific objectives to be achieved and shows that it is essential that these different methods are continuously applied in parallel.

This documentation, which can also be used for educational purposes, comprises images that reveal an extremely fragile and often hidden heritage. The density and richness of this open-air rock art, which is

comparable to that of the most internationally renowned rock art sites, incites us to protect it by educating the public and raising awareness of the sites.

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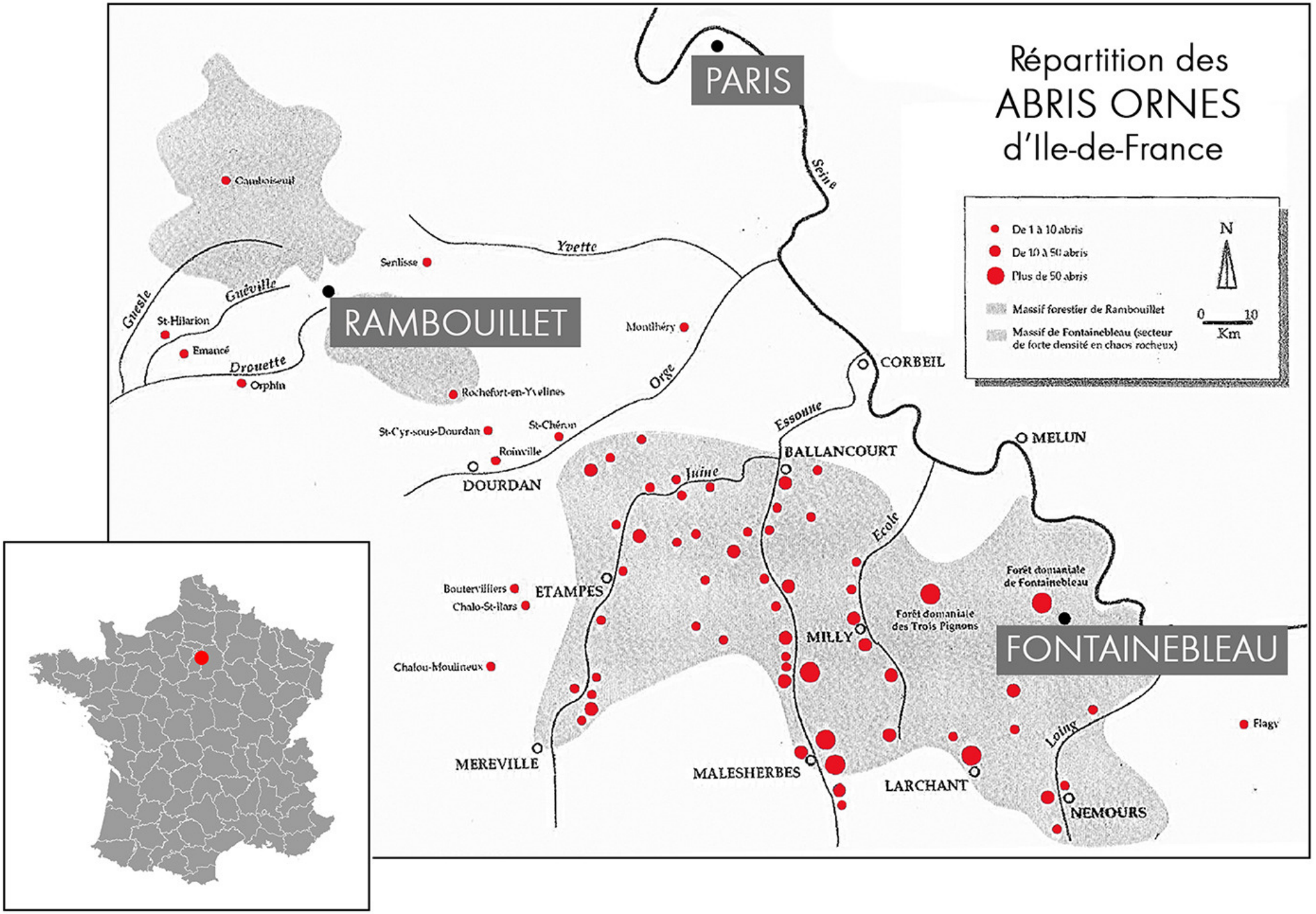

Répartition des
ABRIS ORNES
d'Ile-de-France
De 1 à 10 abris
De 10 à 50 abris
Plus de 50 abris
Massif forestier de Rambouillet
Massif de Fontainebleau (secteur de forte densité en chaos rocheux)
N
0 10
Km
PARIS
RAMBOUILLET
FONTAINEBLEAU
Seine
Yvette
Guesle
Guéville
Drouette
Orge
Essonne
Juine
Ecole
Loing
Cambaiseuil
Senlisse
St-Hilarion
Emancé
Orphin
Montlhéry
Rochefort-en-Yvelines
St-Cyr-sous-Dourdan
St-Chéron
Roinville
DOURDAN
CORBEIL
MELUN
BALLANCOURT
ETAMPES
Boutervilliers
Chalo-St-Ilars
Chalou-Moulineux
MILLY
Forêt domaniale des Trois Pignons
Forêt domaniale de Fontainebleau
MEREVILLE
MALESHERBES
LARCHANT
NEMOURS
Flagy

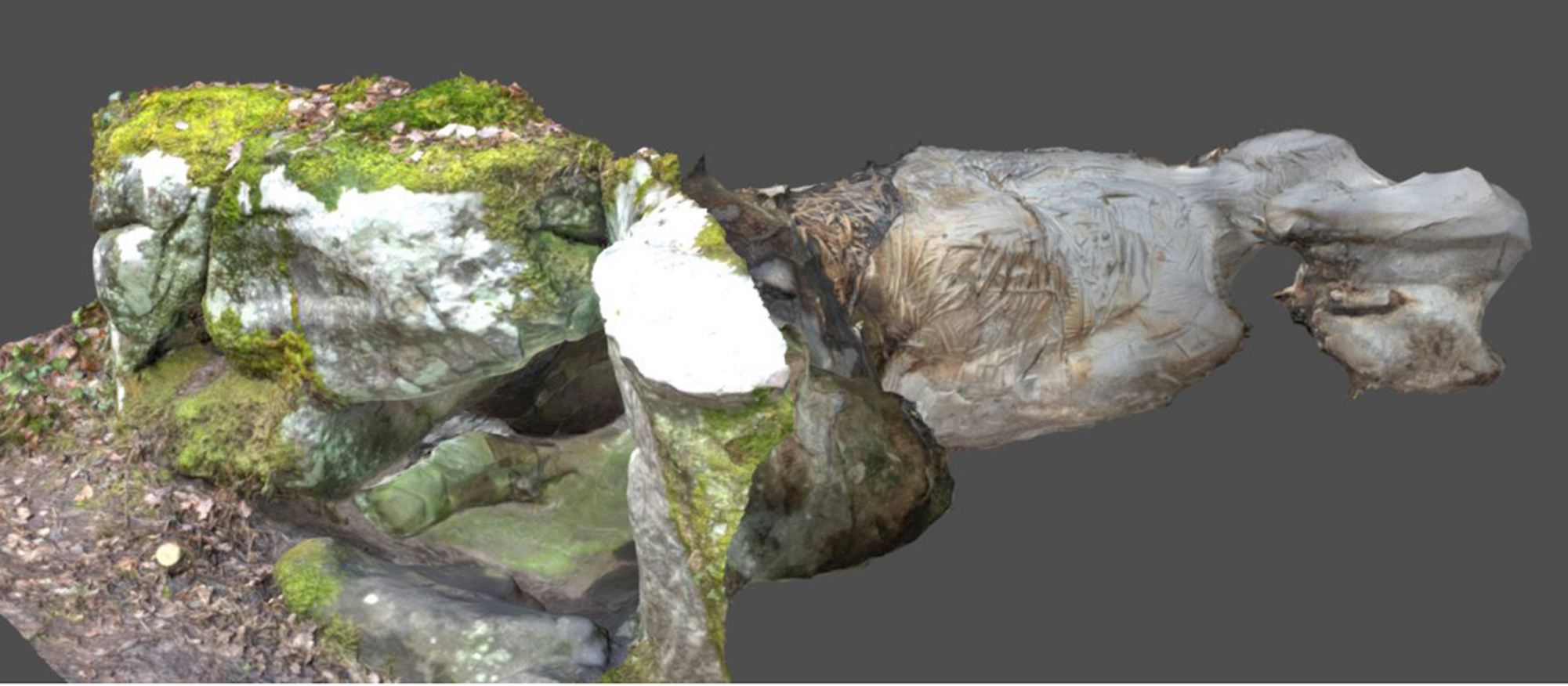
a.

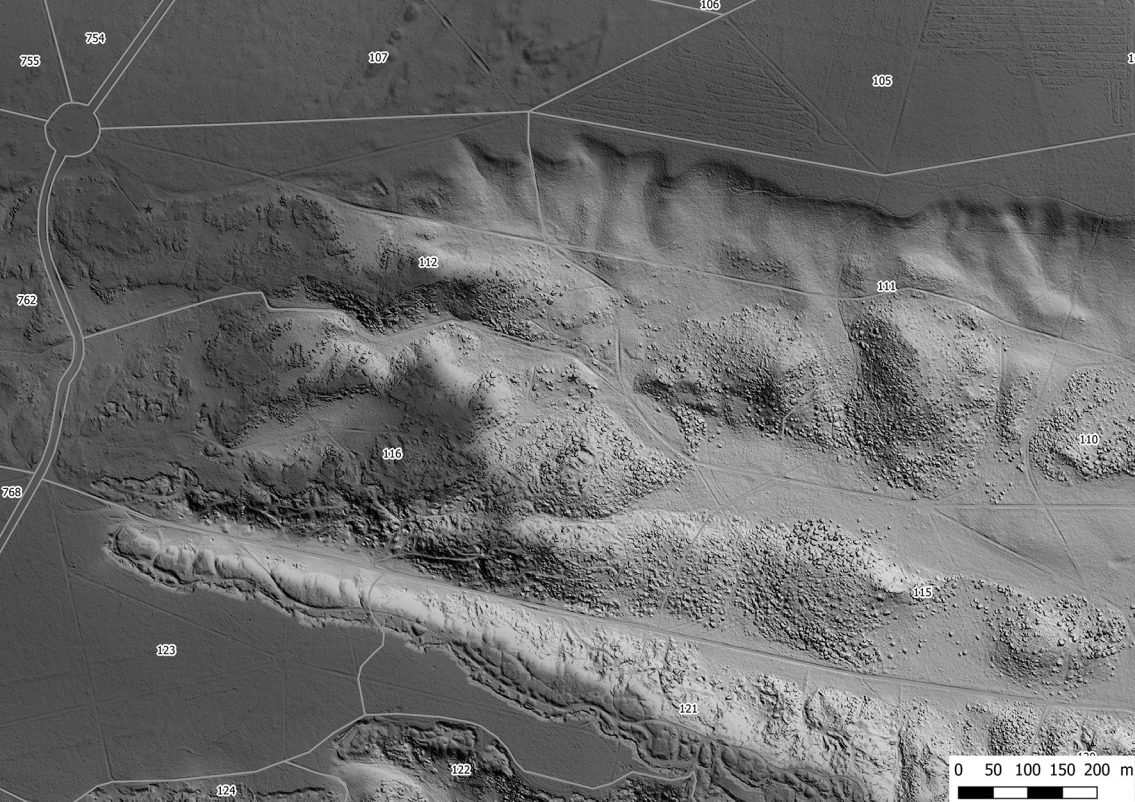
b.

a.
b.
c.
d.
e.

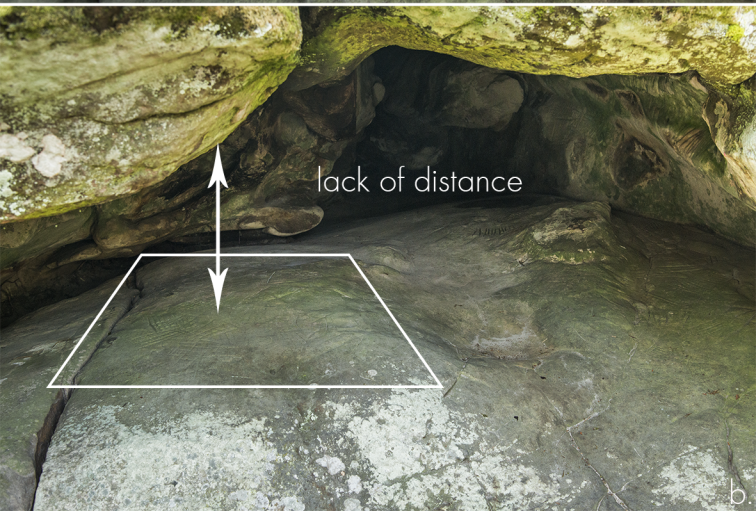
a.

b.



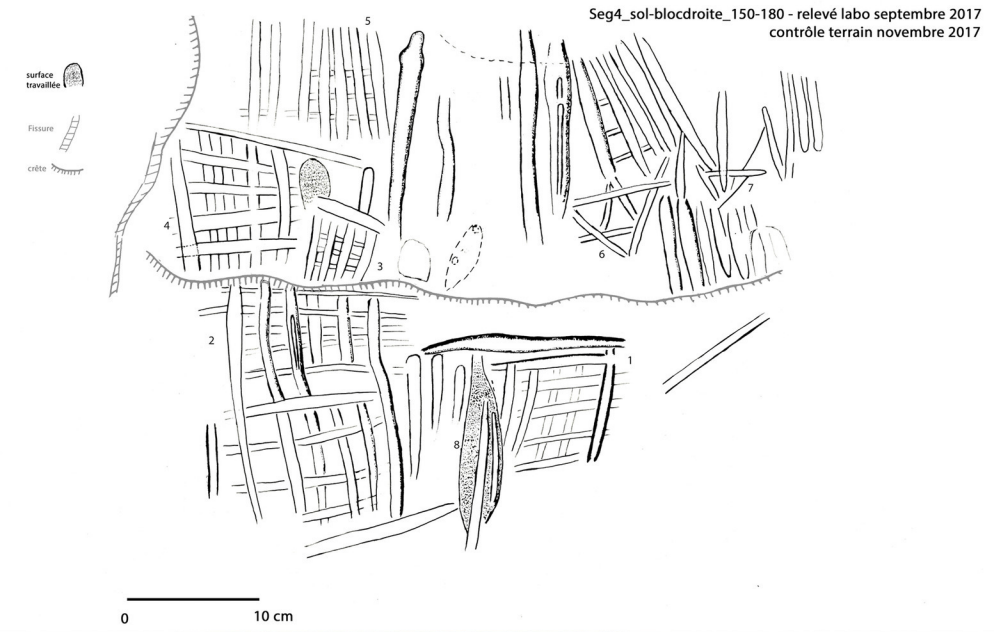

754
755
107
106
105
112
111
762
116
110
768
115
123
121
122
124
0 50 100 150 200 m

oblique view
a.


lack of distance
b.

a.

b.


Seg4_sol-blocdroite_150-180 - relevé labo septembre 2017
contrôle terrain novembre 2017
surface travaillée
Fissure
crête
5
4
3
2
1
8
6
7
0
10 cm

Seg4_sol-blocdroite_150-180 - relevé labo septembre 2017
contrôle terrain novembre 2017
5
4
3
2
1
8
6
7
0
10 cm