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“Applications of digital photography in the study of Paleolithic cave art”

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ABSTRACT

Developments in digital methods of rock-art study in Western Europe have considerably diversified and enriched this field of research in the last 25 years. This is especially the case for microanalyses of artistic materials (datings, pigment characterization, etc.), and also for the study of the images themselves, their topography, their positioning and their contexts. 3D analyses, software with colorimetric filters, and macro-microscopic imaging represent examples of promising new tools for the study of rock art.
The object of this article is to show some of these tools' applications in the context of decorated caves through specific cases taken from the study of several caves in France: Blanchard (Indre), Les Gorges (Jura), Rouffignac and especially Les Bernoux (Dordogne). The contributions of several applied techniques highlight the importance of their use in combination. This includes first of all photography, and multiple scientific applications of digital photographs such as photogrammetry, macrophotography and decorrelation stretch (colorimetric treatment).
This article provides a synthesis of different results, in order to show the potential of these methods, especially for their use in combination. We emphasize in particular the contribution of decorrelation stretch, used to enhance the reading of color and pigments.

1. Introduction and objectives

The development of digital methods in the study of prehistoric art, especially in rock art, has considerably diversified and enriched this field of research in the last 25 years. This is especially the case for microanalyses of the artistic materials (in particular for dating and pigment-characterization), but also for the study of the images themselves, their topography, positioning, and contexts.

Large and immovable surfaces like cave walls are frequently digitally modeled, largely to address conservation or mediation concerns. The applications for research are maybe less common and have shown increasingly significant results, with clear contributions to scientific knowledge.

Several of these processes are based on photography: it provides a high degree of flexibility and precision in recording and different substantial possibilities for data extraction assisted by efficient software programs.

We aim to demonstrate how these tools have been applied in decorated caves and their utility for research issues: the discovery of new figures, discernment of “technical facies” and drawing techniques, plotting of the organization of representations in the cave, and restitution of their contexts. We present here a synthesis of some selected recent results to show how these processes can be adapted to different kinds of cave contexts in Paleolithic rock art, and why their combination is profitable to scientific data-collection and research.

2. Approaches and digitalization

Digital techniques of analysis have been applied to prehistoric art to meet three primary areas of interest: the context of the art, the identification and analysis of representations, and finally, the technical gesture and traceological approaches.

Primarily, 3D modeling allows for the recording of large areas, especially significant volumes of decorated surfaces (topography, galleries, walls) with high precision. This is also particularly necessary for recording and rendering at a smaller scale, such as fine works like engravings. The scale and resolution of the observation as well as the tools employed have to be adapted to scientific objectives. Modeling could be used in particular for reconstitution of cave context, or large decorated panels. In general, the scope of the analysis must be increasingly constrained by the level of desired details (Delannoy et al., 2010; Burens et al., 2011; Pastoors and Weniger, 2011; Azema et al., 2013).

Secondly, digital approaches have been particularly efficient in identification and analysis of representations (Fritz et al., 2010; Pinçon

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et al., 2010), and can be used for survey as well (Feruglio et al., 2015). In the area of colorimetry, decorrelation stretch has been applied to further the identification and interpretation of paintings and pigments. These methods reveal recovered, obscured, or altered pigment representations, even if they are nearly invisible to the naked eye. Different systems of algorithms have been applied, first of all in the context of open-air rock art (among examples Le Quellec et al., 2013; McDonald et al., 2014). This method was also applied to the study of cave art (Ruiz-Redondo et al., 2015; Man-Estier et al., 2015). It allows for the enhancement of faded paintings and aids in their systematic survey.

Lastly, macro- and microscopic analyses are applied to the identification and characterization of technical stigmas and traces. These approaches have been applied on Paleolithic portable art in laboratory settings (D'Errico, 1994; Fritz, 1999; Mélard, 2010, Rivero, 2011). Other new approaches provide original and non-invasive means of analysis of engravings (Bello et al., 2013). A large part of the equipment employed in laboratory settings (notably electron microscopes) cannot be used in cave contexts. Alternative approaches are currently being investigated (Plisson, 2014), especially the use of very high resolution photography.

The methods developed from digital photography and software allow investigations in these three techniques: photogrammetry, macrophotography, and decorrelation stretch. They offer a large variety of scales, from overviews to high-precision details, increased perception of colors, and allow more flexibility in response to the many constraints of cave environments. They also present the advantage of being cheaper than alternative approaches.

Additionally, ultraviolet or infrared photography have been used for the analysis of paintings, primarily to assist in the recognition and reading of red and black pigments (for example Fredlund and Sundstrom, 2007). These digital tools and the development of specialized software applications have presented improved possibilities for the application of photography in archaeological research, especially for the study of prehistoric representations.

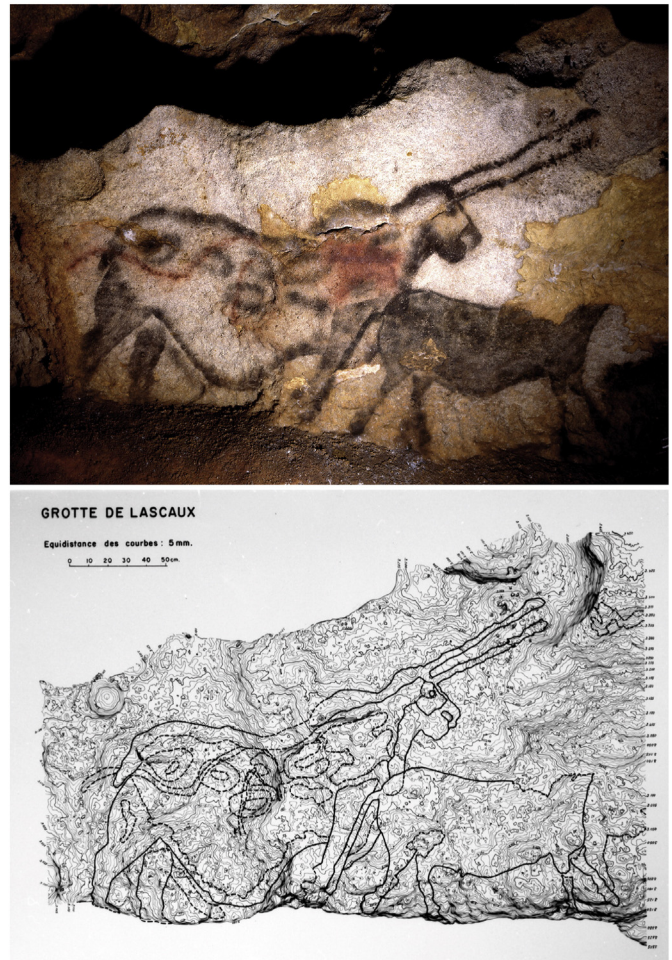

Fig. 1. Photo and digitalization by photogrammetry of Unicorn, Lascaux, IGN.

3. Methodologies implemented

3.1. Photogrammetry

Among available digital applications, photogrammetry has taken an important place in the study of rock art. It was experimented with during the 20th century, with the process of stereoscopic photography, at the cave of les Trois Frères in 1912 (Ariège), and by IGN in Lascaux cave (Dordogne) (Fig. 1), or as a more recent example, the *Frise Noire* in Pech Merle (Lot) (Lorblanchet, 1979). The underlying principles of photogrammetry remain the same, but new possibilities are offered with digital technologies, notably in the context of cave-art studies, where new applications of this methodology are being applied.

Here, we address close-range photogrammetry (or CRP), where the camera is close to the subject. Hand-held or with a tripod, this process responds to the requirements of computer analysis, instead of stereoscopic pairs, which are the origin of the methodology. The revolution of digital images has been expanded with increased computer capacity and access to free software (open source) since the 2000s. Photogrammetry is achieved by the combination of images taken from several angles in order to obtain a precise three-dimensional representation of any object that can be photographed (Egels, 2011). There are two phases: the initial digital photography and the software-aided treatment of the photographic data (the pixel).

In order to get exhaustive details of a decorated panel and to establish accurate pixel correlation between images, we followed a protocol based on successive photographs with large areas of overlap (more than 50%) between fields of view. This recording process also requires imaging from several angles (3 to 5 or more) to capture the depth and relief of form of the subject. Consistent camera settings have to be maintained, as well as stable lighting conditions without any zones of shadow, in order to achieve efficient correlation, enough detail, and satisfying textural information.

The resolution of the 3D model is determined by the frame size (which represents the number of pixels) of the camera sensor. The use of a full frame camera (24 × 36 mm) and the selection of an appropriate lens ensure accuracy. Photogrammetry also requires a consistent focal distance from the subject and a high focal length to maximize the depth of field. A very high resolution requires greater proximity with the decorated panel. A tripod is required for stability and maintenance of a consistent position. In order to obtain efficient 3D models of decorated walls, it is necessary to cover every visible part of the subject, hence the variety of angles, to promote aerotriangulation, which provides the background structure of the model, calculated by algorithms.

The second stage of the photogrammetry technique concerns the modeling process performed automatically by computing and calculating algorithms, pre-established by various software programs, such as Photoscan®, Arc3D® or 123D Catch®.

Regardless of the software employed, there are several phases to this operation. The first one, which is aerotriangulation, reconstitutes the image-capture configuration (orientation and position of the camera) based on the recognition in each image of corresponding landmarks. The second phase, dense correlation, builds a geometrically accurate volumetric model based on similar pixels in corresponding images. These two phases produce a point-cloud that is then meshed by triangulation, and finally textured with the same pictures which were used for each phase of construction of the 3D model.

This process has been applied in many caves, like Rouffignac (Dordogne) and Blanchard (Indre), through collaboration between

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