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A propositive method of documental registration in 3D modeling and digital decal: case study of archaeological sites with rock art in Camalaú, state of Paraíba, Brazil

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Abstract

This paper exposes the need in the archaeological record for the digital conservation of rock art in pre-colonial sites, located in the semi-arid region of the Brazilian Northeast. At this time, we propose a survey in three-dimensional modeling and digital tracing of rock panels and their geoenvironmental contexts. These processes are part of methods for preserving the information generated by research in institutions that safeguard the archaeological heritage, understood as essential to access documents, promoting the sharing of information on digital platforms, with pedagogical purposes, virtual exhibitions in museums, continuation of archaeological studies and access to the public. As a result, we show that digital photographic processing was essential in the observation of pictorial and conservation data, since the majority of the graphic corpus analyzed is in an advanced state of decay and low visibility. Through aerial photogrammetric survey and image processing, it was possible to generate different products to assist in the analysis of graphic traces, their environmental insertions, and the distribution of information through 3D modeling.

KEYWORDS: Documentation of Archaeological Sites; Digital Conservation; 3D Modeling and Digital Decal

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Un método propositivo de registro documental en modelación tridimensional y calco digital: Estudio de caso de sitios arqueológicos con arte rupestre en Camalaú, estado da Paraíba, Brasil

Resumen

El artículo demuestra la necesidad de la conservación digital para la documentación de registros arqueológicos en dos sitios precoloniales con arte rupestre, ubicados en la región semiárida del nordeste brasileño. En este punto se propone un levantamiento del registro documental mediante modelado tridimensional y calco digital de los paneles rupestres y sus contextos geoambientales. Estos procesos de trabajo forman parte de los métodos de preservación de la información generada por la investigación en instituciones, que salvaguardan el patrimonio arqueológico y son fundamentales en el acceso a la producción documental, promoviendo el intercambio de información en plataformas digitales con fines educativos, tales como exposiciones en museos virtuales, estudios continuos para la ciencia arqueológica y el público en general. Como resultado, se demuestra que el procesamiento fotográfico digital fue fundamental en la observación de datos pictóricos y del estado de conservación, considerando que la mayoría del corpus gráfico analizado se encuentra en un avanzado estado de degradación y baja visibilidad. A través del levantamiento fotogramétrico aéreo y el procesamiento de imágenes fue posible generar diferentes productos para ayudar en el análisis de huellas gráficas y sus inserciones ambientales, así como para la difusión de la información mediante modelado tridimensional.

PALABRAS CLAVE: Documentación de Sitios Arqueológicos; Conservación Digital; Modelado 3D y Calco Digital

Introduction

The article discusses the documentation of archaeological records of rock art at pre-colonial sites in the semi-arid region of northeastern Brazil. In this study, the production of archaeological documentation is understood as the actions of the propositional methods developed by archaeological research in order, initially, to guide instrumental forms of documentary records and, later, to manage the primary data obtained during archaeological prospecting (Ballardo and Mendonça, 2018; Fernandes and Costa, 2019).

As a result, the documentation produced is a way of recording and managing the data produced by the research, making it an essential procedure for the archaeological field (Bea, 2012). For Le Goff (2013), the document is the result of the historical production of societies, which are preserved over time after their production. Therefore,

> [...] a document is not something that remains in the past; it is a product of the society that produced it according to the relations of forces that held power there. Only the analysis of the document as a monument allows the collective memory to recover it (Le Goff, 2013, p. 497).

In general, and often since the mid-nineteenth century, techniques for capturing image information, such as photography, have been associated with archaeological

documentary recording: for collecting data and information, as well as for storing it in databases (Hissa, 2016; Silva, Müutzenberg y Cisneiros, 2012). At first, photography is an essential procedure for recording rock art; afterwards, it can be incorporated into other documented data to develop systematic research of these remains in a geographically delimited archaeological area (Bea, 2012).

When it comes to rock paintings, there are many different ways of producing them, such as by adding different colored pigments, dry or pasty, using brushes, fingers, blows or stamps (Gaspar, 2006), or even by previously preparing the support, as indicated by Martin and Guidon (2010). The most widespread method of documentation was the decal, which in short is a method of applying paper or plastic to the rock support and using a pencil to trace the outline of the rock art. However, this method has fallen into disuse in the archaeological field since the procedure caused deterioration both in the condition of the rock support (rock disintegration) and the pigments found in the rock paintings, as well as for the lack of professionals who use this documentation (Del Toro, 2012).

On the other hand, archaeological science –with the advent of computer technologies, specifically computer graphics and digital geoprocessing methods (total station, GPS, 3D laser scanning, among others)– has been using drones (unmanned aerial vehicles-UAVs) as a significant tool for documenting archaeological records. By making it possible to generate a three-dimensional model with the archaeological artifacts and contexts (the excavations and geoenvironments), with the help of specialized software (Botica, et al., 2023; Kipins, et al.2013; Mackinnon, 2023; Muñoz-Muñoz et al., 2023; Zarankin, et al., 2022).

According to Arias et al. (2022), associated with educational tools, 3D modeling makes it possible to produce knowledge and educational resources, in the classroom, presentations of public and private institutional archaeological projects, and museums, among other functions. For archaeological science, it favors accessibility while visualizing the analyses produced in the laboratory, and reconstructing a model of the archaeological sites (Dell'Unto, 2014). Therefore, documenting archaeological data in the field makes it possible to record and preserve archaeological heritage through preservation and sharing.

> Finally, we can say that 3D technologies modify various stages of archaeological and conservation-restoration practice, being present in data collection (field and laboratory), information recording, analysis and interpretation of remains, sites and landscapes, data management, communication and teaching (Zarankin et al., 2022, p. 5).

The methods of managing the documentation process and creating documentary collections permeate institutional policies through actions that amplify the knowledge produced in the past. Since they produce a huge collection on cultural heritage, however, not always organized and available to all interested parties. With the new tools that come from the internet, numerous possibilities for organizing and sharing information are created through public access to knowledge, and this is associated with public policies on culture and democratization of access to it (Kansa, 2022).

The central objective of archeology in the digital age, like in this work, is to contribute to the dissemination and protection of humanity's cultural heritage, when producing documentation of the degradation processes of archaeological sites and particularly rock art. The article suggests a survey of three-dimensional modeling and digital decals of rock panels from archaeological sites. As a conservation tool, modern digital tool dissemination facilitates access to information generated by research institutions safeguarding archaeological heritage. Therefore, its specific objectives are:

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» Photogrammetric survey of rock art and context of archaeological sites;

» To produce the digital decal with the photographic records of the rock art panels;

» To produce three-dimensional models of the rock art panels of the archaeological sites and their environmental contexts.

By proposing methods for recording, safeguarding and disseminating rock art, this methodological stance falls under the Open Science umbrella, as it seeks to share the database and archaeological analyses, favoring their accessibility and making it possible to replicate this process in future studies (Silva and Silveira, 2019). This whole process was conceived within the idea of Open Science in the digital production of archaeology, through the use of open source software and the dissemination of the procedures and materials produced in the repositorys: Sketchfab and QGIS.

This is based on the possibility of collecting a large amount of information about these records, such as the peculiarities of environmental insertion, a survey of factors that act on the degradation process, and possible details with classificatory functions of the graphic records. It also subsidizes preservation measures and serves as material for disseminating information to communities.

Therefore, laboratories and their databases must become an open space as a proposal for digital transformation, seeking new methodological tools that support the construction and dissemination of the cultural, scientific and artistic collections of these institutions. This also makes it possible to build educational tools that enable society to gain knowledge of these heritage sites and, consequently, contribute to their conservation processes.

Location and brief geoenvironmental and archaeological context of the study area.

The article investigates the archaeological heritage of two sites with rock paintings in the Cariris Velhos archaeological area, in the south of the state of Paraíba, which is located between the microregions of Western and Eastern Cariri, belonging to the Borborema mesoregion (Figure 1). Among the municipalities in the region is Camalaú, with an estimated population of 6,048 inhabitants, an area of 541,841 km², and is located between the municipalities of São João do Tigre (to the south), São Sebastião do Umbuzeiro (southwest), Monteiro (west), Sumé (north) and Congo (northeast), and on the border with the state of Pernambuco (to the east).

In general, the area has geoenvironmental characteristics with low but concentrated rainfall, with around 60 to 75% of the rain falling between March and June. This favors a unique type of biome called Caatinga, characteristic of the semi-arid climate, with variations in vegetation due to the geomorphological formations, originated by the outcrop of the Precambrian crystalline basement composed of igneous and metamorphic rocks, generally granites and gneisses, and featuring hydrographic networks that maintain a very important intermittent flow of water to the region.

In chronological terms, and not directly associated with rock art, the region of the current state of Paraíba had a range of dates between 6921 ± 33 BP (human bones, CSIC 1390) and 540 ± 30 BP (ceramic fragment, BETA 601168), respectively in the municipalities of Vieirópolis and Cuité. On the other hand, the burial dates provide a chronological understanding of the study area in the Cariri region of Paraíba, adding the ages of 1220 ± 30 BP (human bones, BETA 400646) for the Barra site, in the municipality of Camalaú, and 1880 ± 30 BP (human bones, BETA 400647) for the Serrote da Macambira site, in the municipality of São João do Cariri (Azevedo Netto et al., 2023)

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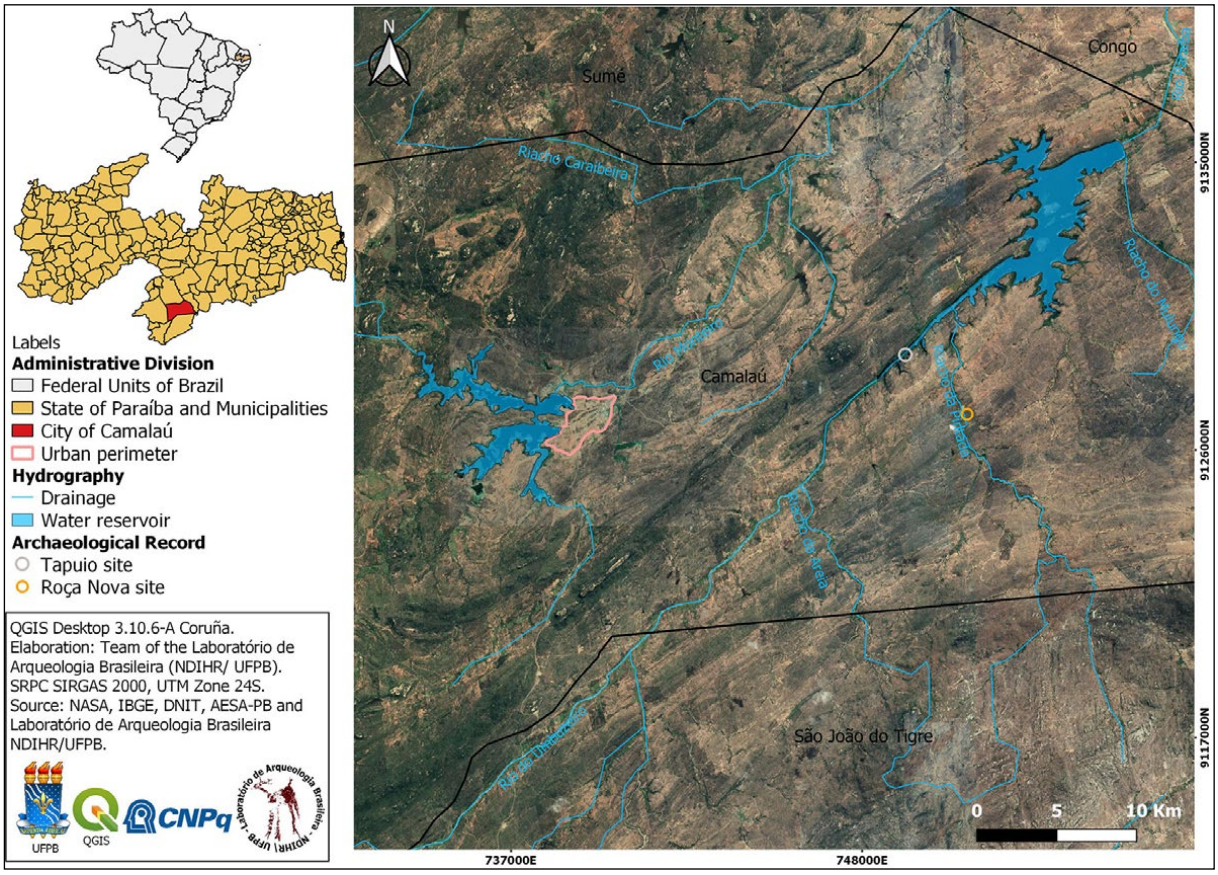

Figure 1. Location map of the study area and archaeological sites. Source: authors, LAB.

Regarding the state of conservation of archaeological sites, damage caused by physical and chemical weathering and human actions are risk factors for preservation and conservation (Pessis and Martin, 2002). With the increase in population density and the actions that impact on the semi-arid region, there has been an expansion in desertification, a problem that greatly affects the local ecosystem, as well as jeopardizes the conservation of rock art (Azevedo Netto et al., 2021), in the surroundings of the hydrographic basins of the Paraíba, Taperoá and Umbuzeiro rivers, there are livestock activities[1], plant and mineral extraction. However, for Azevedo Netto et al. (2021), the factors that contribute to the greater or lesser degree of preservation of archaeological sites should still be the subject of particular research for the study region. Therefore,

> The problems of desertification and alteration of the region's landscape require the involvement of the competent authorities to regulate predatory actions against the environment. The need to share productivity with environmental preservation is a priority when implementing a heritage preservation program (Pessis and Martin, 2002, p. 204).

The studied sites present physical-chemical weathering on the shelters that suffer from significant humidity due to the presence of water (perennial rivers) nearby, also accelerating the process of biological weathering such as the increase of fungi and the action of animals like mocó (*Kerodon rupestris*), fox, and vulture droppings, as well as exposure to the actions of rain, wind, and sunlight; in addition to the fact that the rock blocks suffer from scaling, fractures, mineral salts, patina, and water stains. Furthermore, it is associated with a highly anthropized space with areas used for

1 Goat farming is the most common and has a major impact on archaeological sites and rock art.

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agriculture and animal breeding, in the vicinity of contemporary occupations (Azevedo Netto et al., 2021).

The Tapuio site, with an advanced stage of degradation, is exposed to rain, wind and sun; with a strong presence of biological weathering, associated with anthropic actions, such as livestock farming (cattle and goats), and the fauna of the environment, such as the mocó, vulture, fox, among others. The Roça Nova site, on the other hand, is exposed to rain, wind and sun; with a strong presence of biological weathering such as goats and mocó.

The Roça Nova site is located in the middle of a shelter formed by 4 gneissic blocks, close to an intermittent stream –Pintada creek– in the drainage of the Paraíba River Basin, where the paintings are found all over the outcrop. It has five graphic panels with a predominance of red (with two shades –ochre and clear–) and the presence of yellow. The set is very heterogeneous, with a large number of hands and geometric motifs, as well as the existence of a large concentration of representations associated with anthropomorphs and zoomorphs, with possible interactions of scenes between the types.

The Tapuio site is located in a small sheltered area, formed by two large, long outcropping blocks of vertical gneissic rock near the main course of the Paraíba River. It consists of two graphic panels with a predominance of hand and geometric figures in panel 1 (the largest concentration of rock art) and small graphic stains in panel 2. In general, the paintings are in two shades of red (ochre and light).

A methodological proposal for the documentary and photogrammetric recording of archaeological sites with rock art

The digital decal method applied to rock art

With the milestone of high-resolution digital photography, the record of cave paintings brings the need to address and debate the methodological procedures, and their tools, related to the computerized processes inherent in the institutional databases that safeguard this information (Del Toro, 2012).

Currently, there are computer procedures, such as digitals decals, which use the resources of tools with techniques for isolating and processing (treating) digital images through software, inserting these works into modern recording procedures, and the documentary establishment of archaeological heritage (Bea, 2012).

Starting (Figure 2) with the digital photographic records, we used the *DStretch* tool[2], which helps to highlight the pixels in the pigmentation of the rock paintings by processing the images through chromatic variables, as seen in Gunn et al. (2014). This process in the photographic image can be better understood by applying different filters and color scales, resulting in a visual enhancement of the pictorial representations (Harman, 2020).

In the next phase, the photographic documentation goes through a segregation process, using GIMP 2.10[3], to better highlight the representations considered visually relevant[4]

2 DStretch is an image enhancement tool for rock art. It is a plugin for ImageJ, the Java image processing and analysis program. The plugin can be found at: http://www.dstretch.com/

3 GNU Image Manipulation Program (GIMP) is an open source software aimed at creating and editing images, as well as vectores drawings. For more details consult: https://www.gimp.org

4 Relevance is subjective to the archaeologist, however, and sometimes some unrecognizable graphic stains are presented in the result, which end up being excluded from the process.

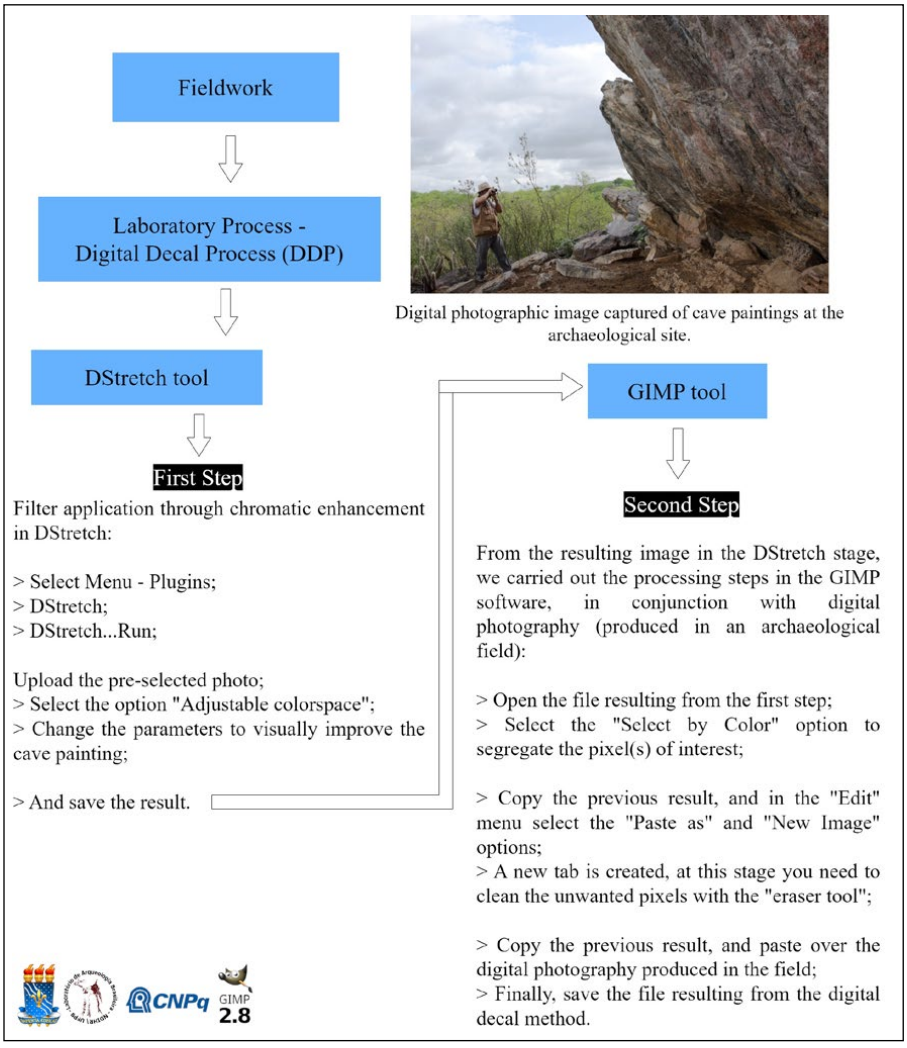

Figure 2. Flowchart showing the Digital Decal method. Source: authors.

(GIMP, 2019). The use of this resource proved essential when observing the rock paintings, given that sometimes part of the graphic *corpus* is in an advanced state of degradation. Finally, we have the result of the segregation superimposed on the original photographic record, making it possible to better visualize the motifs and identify areas with a higher degree of degradation.

The 3D modeling method for archaeological sites

The methodological procedures can be divided into two stages (Figure 3): the field survey and the data processing. The first consists of an aerophotogrammetric survey using drones, both manual and automatic. The manual survey consists on obtaining images manually with the DJI Mavic Pro drone, at a low altitude (2 to 3 m), adapting according to the morphology of the sites, taking into account the angles of the supports, the vegetation present and the state of conservation of the paintings, to generate a three-dimensional model of the sites.

For the automatic survey, polygons covering the areas of the sites and their immediate surroundings were generated in QGIS, then saved in .kml format and exported to the flight automation application, Drone Deploy (trial version). For this study, flights at

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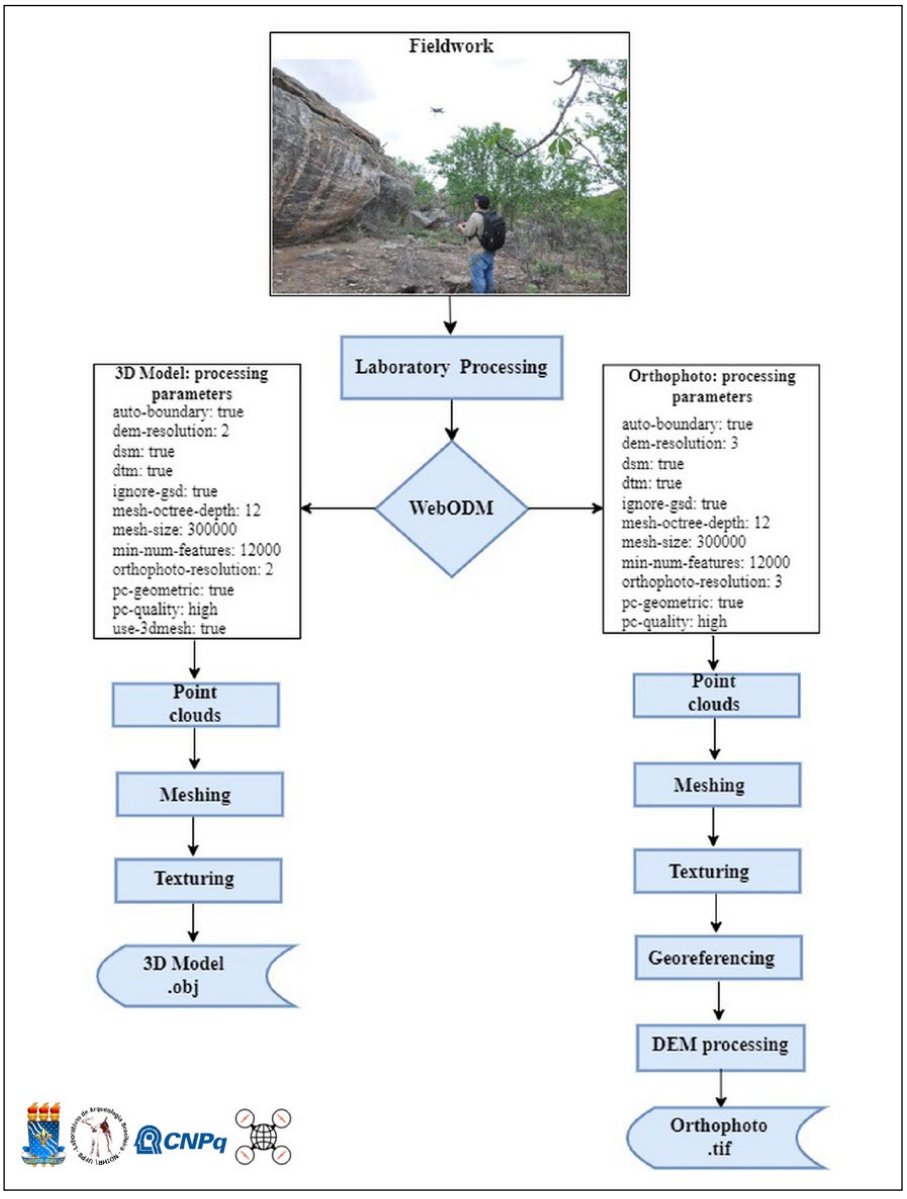

Figure 3. Flowchart presenting the 3D Modeling method. Source: authors.

altitudes of 15 m and 80 m were adopted for each area, to observe the environmental insertion of each unit and its particularities, through the generation of orthomosaics, DSM (Digital Surface Model) and DTM (Digital Terrain Model).

Each of these products provides specific information, such as a better observation of the environmental characteristics of the site, calculation of the possibilities of flooding in the site areas, proximity to drainage sources, and site deposition processes, among others (QGIS, 2023).

The second stage consisted of processing the data in the laboratory and generating photogrammetric products. Photogrammetry was carried out using the Open Drone Map (ODM) software[5], an open-source project that makes it possible to generate digital

5 For more details consult: https://opendronemap.org

photogrammetric products using images captured by drones and/or other machines (ODM, 2020).

The software allows generating three-dimensional point clouds by aligning the photos obtained in the surveys, using different algorithms, such as SIFT (Scale Invariant Feature Transform). It is responsible for identifying common features between images, establishing spatial relationships between them, and building the point cloud, the basis for generating photogrammetric products (Almeida, 2018). The point cloud serves as a support for the creation of a three-dimensional model, which is then textured, and a Digital Elevation Model (DEM), which gives rise to the production of a DTM, enabling the generation of the orthophoto (Guedes, 2016; Pessis et al., 2019).

Results and discussions

Results of the digital decal process applied to rock art

The result of the digital treatment process in photographic documentation, in general, achieved a higher visual quality by favoring the highlighting of rock paintings and their diversity of production techniques. Initially, the use of this resource was essential in observing pictorial data, considering that the majority of the analyzed graphic corpus is in an advanced state of degradation and low visibility.

It also generates a database of digital images that can be made available quickly and accessible for future research. Therefore, there are some points to consider about the results provided by digital decal processes:

» It can help in the composition of the different phases of the pictographic layers found in the rock support. The results observed through the chromatic variations of colors or shades should be analyzed to find possible overlaps present in the rock art panels.

» In addition, the permanence of the apparent characteristics of the rock support in the photographic result (Figure 4) is a mechanism that helps in identifying the recurring problems of weathering processes. In this way, allowing an evaluation that emphasizes the physical-chemical and biological aspects embedded in the rock panels and/or directly associated with rock art, which are mentioned in the subtopic *Location and Brief Geoenvironmental and Archaeological Contextualization of the study* área.

» By no means posing a risk to the conservation or wear and tear of this heritage, this non-intrusive method is an essential tool in the preservation of rock art. When combined with the digital process, it offers the possibility of sharing the data documented in the archaeological field.

» It enables the particular segregation of the types (Figure 5) of 'recognizable representations', such as zoomorphs, anthropomorphs, geometrics and so on, helping the continuity of studies on rock art by looking for details associated with this phenomenon in 'scenes' and relationships contained between the types in the graphic *corpus*.

» As a proposal of permanent need, with a less subjective method, therefore, making it possible to establish a comprehensive database and sustained by the extension of the next studies establishing an instruction as a specific phenomenon, which can be related, for example, by the similarity and dissimilarity of the rock object[6].

6 Some results of the decal process can be seen at the LAB-NDIHR-UFPB (2024).

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Figure 4. A) At the top, digital photograph of the documentary survey; B) Bottom, final result of the digital decal on 2nd rock panel at the Roça Nova site. Source: authors, LAB.

Results of the 3D modeling method for archaeological sites

As a result of the aerophotogrammetric survey and image processing, different products were generated to help analyze the graphic remains, their environmental insertions, and the dissemination of the information produced with the three-dimensional modeling. For each archaeological site, a 3D model was generated of the morphological configurations of the rock support with the graphic panels presente (LAB-NDIHR-UFPB, 2023a, 2023b), the environmental insertion (LAB-NDIHR-UFPB, 2023c, 2023d), and an orthophoto of each site.

For the Roça Nova site, the three-dimensional modeling of the support and graphic panels were carried out using 157 photos taken by manual flight, while 240 photos were needed for Tapuio. Next, a dense three-dimensional point cloud was generated for each site through processing, by aligning all the photos taken for each unit and extracting the homologous points, which served as the basis for generating the three-dimensional

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Figure 5. A) Top, digital photograph of the documentary survey; B) Bottom, final result of the digital decal of the 4nd rock panel at the Roça Nova site. Source: authors, LAB.

models that were later textured (Figure 6). The same procedure was applied to the 3D modeling of their geoenvironmental insertion.

The orthophotos were generated based on 250 photos for the Roça Nova site and 118 for Tapuio, taken with automatic flights at a height of 80 m. The dense point clouds were used to generate Digital Terrain Models (DTMs) which were used to calculate the orthoimages for each unit (Figure 7).

The general results of this documentary survey using orthoimages of the sites can be accessed through the profile on the Sketchfab platform of the Laboratório de Arqueologia Brasileira, associated with the Núcleo de Documentação e Informação Histórica Regional by the Universidade Federal da Paraíba (LAB-NDIHR-UFPB)[7].

7 Profile on the Sketchfab platform: https://sketchfab.com/LAB-NDIHR-UFPB/models

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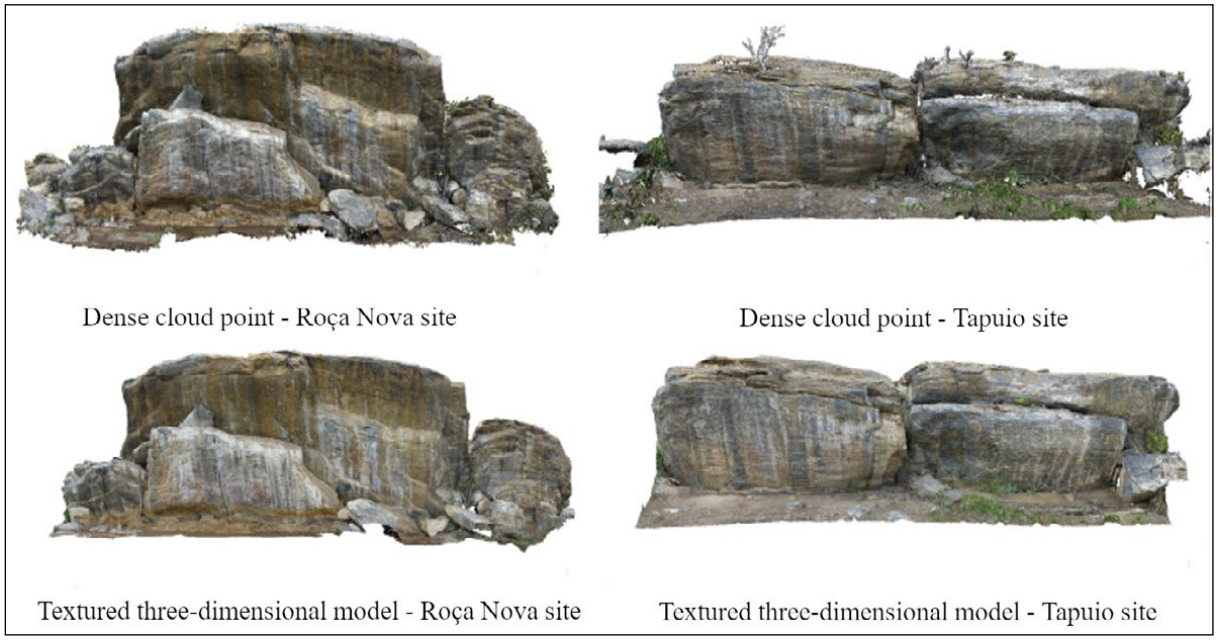

Figure 6. Results of 3D modeling of rock panels. Source: authors, LAB.

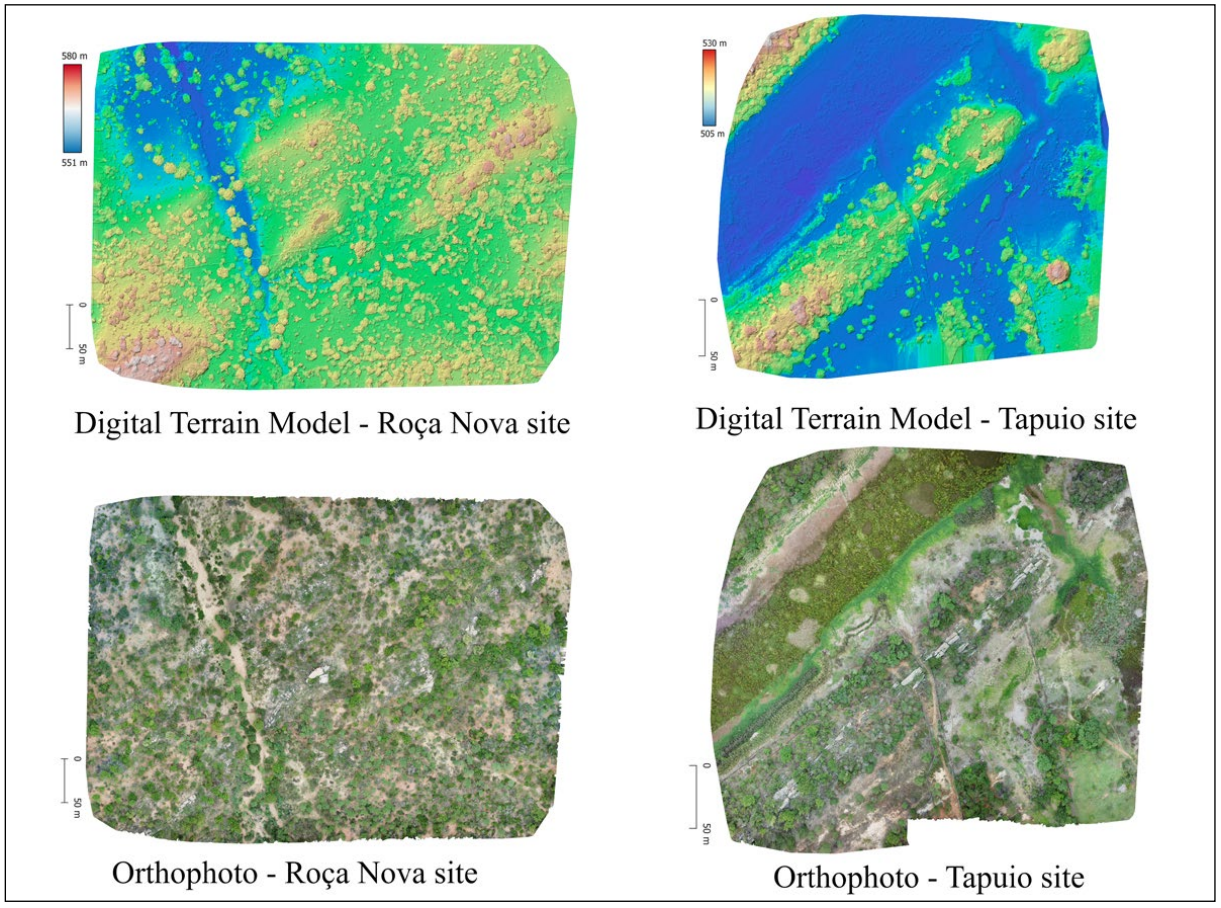

Figure 7. Results of DTM and 3D modeling of the geoenvironments of insertions of archaeological sites. Source: authors, LAB.

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With this, the products generated can be used for different demands/discussions on graphic and geoenvironmental traces in archaeological science:

» The three-dimensional model of the site's geomorphology and the graphic panels present enables analysis of the distribution of the graphics on the support, the sizing of the panels and the support, analysis of the weathering processes affecting the rock, among other information (LAB-NDIHR-UFPB, 2023a, 2023b, 2023c, 2023d).

» By 3D modeling the environments where the sites are located, it is possible to obtain information about the geoenvironment present, proximity to drainage networks, the layout of the supporting rock on the slope, anthropogenic actions in the vicinity of the sites (human occupations and their varieties), among other information (LAB-NDIHR-UFPB, 2023c, 2023d).

» With orthoimagery it is possible to create more detailed maps of the sites and their geoenvironmental insertions, producing cartographic models with resolutions that are more suitable for the specific analyses required by archaeological studies, and the results obtained are more favorable than those processed using satellite orthoimagery databases (LAB-NDIHR-UFPB, 2023c, 2023d).

» Sharing the three-dimensional models generated through platforms, as proposed in this work, in order to disseminate this cultural heritage with the community and, consequently, safeguard the information on these sites and their environments for future studies.

» Another advantage is that the databases generated during the documentary survey can be accessed via the Internet, making them easy to view for teaching purposes in the classroom, archaeological analysis, exhibitions in virtual museums or any activity that requires visualization of documentary collections;

» The final results of the 3D models produced on the *Sketchfab* platform, there was a high potential for linking various archaeological and geoenvironmental information. By interweaving this data into the models, it is possible for the observer to obtain contextual details ranging from reports on other types of archaeological records in photographs, the location of sites on maps, specific indications of relevant information in the production and demonstration of the models.

Conclusions

Through public actions that amplify knowledge, by promoting access for the society to institutional documentary collections, often represented by Archaeological Laboratories, it is necessary to be committed to drawing up accessible procedures for the data prospected in the field, since these databases contain relevant information about cultural heritage. However, it is not always organized and available to all interested parties.

With the new tools coming from the internet (or a global system of computer networks), countless possibilities are created for organizing and sharing information through public access, and this is associated with public culture policies and democratizing access to it. Therefore, institutions and their databases must become an open space, as a proposal for digital transformation, by looking for new methodological tools that support the construction and dissemination of cultural, scientific, and artistic collections.

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What has emerged from this study, as a proposal for methods to survey the documentary record of archaeological sites where rock art is present, is the potential for uncomplicated digital possibilities for the results. Here we found that they can help with the (visual) safeguarding of conservation status and contextualization of archaeological site data in institutions, such as IPHAN (the Brazilian National Historical and Artistic Heritage Institute) or Archaeological Laboratories promoting their results by sharing the information on digital platforms (Open Source and Open Science) for educational purposes, offering didactic content in the classroom, virtual exhibitions in museums, and access to the general public.

The results of methodological processes, in general, should contain, a concern for social responsibility towards public investments, by providing access to the collection. For this case study, the visual quality of the digital decal processes for rock art was investigated, enabling other specific analyses of the phenomenon, such as wear and tear on the paintings, analysis of pictorial details on the rock supports. In addition, the results obtained by 3D modeling (of the panels and the geoenvironmental context of the archaeological sites) make it possible to explore geomorphological, water, plant, and wildlife analyses that are associated with the archaeological heritage.

One of the contributions is the possibility of diagnosing and visualizing the geoenvironmental context of locations. This allows understanding and visualizing through these models, assisting in the interpretation and explanation of archaeological studies, as also disseminating and promoting educational actions for the general public, by creating realistic, interactive virtual models of these places, they enable people to "visit" and explore "lost historic environments".

Using digital methods in heritage conservation also brings benefits to academic research, through the analysis of large amounts of digital data. This makes it possible to carry out analyses and correlations that would be difficult to identify and measure in the archaeologist's *in situ* observation. Besides, conservation in archeology also involves the protection of archaeological sites and their contexts, which are often targets of various degradative processes. Therefore, these results collaborate with conservation measures and multidisciplinary research, encouraging the protection of these sites in the implementation of public preservation policies so that they can be studied and appreciated in the future.

Finally, we aim to conserve archaeological heritage through innovative methodologies that are part of the recent processes of safeguarding and sharing the information generated by archaeological studies. With software tools that make it possible to digitize databases, by thinking about and producing digital methods for treating documentary collections. Therefore, reflecting on this issue leads to the importance of public policies for scientific, technological, and innovation development in the country, relevant to archaeological science.

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References

» Almeida, P. (2018). *Avaliação de Métodos de Mosaico de Imagens Aplicados em Imagens Agrícolas obtidas por meio de RPA* [Tesis de Maestría inédita]. Universidade Estadual de Ponta Grossa, Brasil.

» Arias, F., Enríquez, C., Jurado, J. M., Ortega, L., Romero-Manchado, A. y Cubillas, J. J. (2022). Use of 3D models as a didactic resource in archaeology. A case study analysis. *Heritage Science*, 10, 112. https://doi.org/10.1186/s40494-022-00738-x

» Azevedo Netto, C., Matos, F. S. y Souza, T. (2021). Patrimônio arqueológico: uma proposta metodológica a partir dos processos ocupacionais Pré-Coloniais do Cariri Ocidental Paraibano com suas interações e conflitos. En F. Magalhães, L. Ferreira da Costa, F. Hernández Hernández, A. Curcino (Eds.), *Museologia e Património* (Volumen 7, pp. 171-193). Leiria: Escola Superior Educação e Ciências Sociais (ESECS), Campus do Politécnico de Leiria. https://www.ipleiria.pt/esecs/wp-content/uploads/sites/15/2021/09/Volume_7.pdf (Acceso: 12 de de marzo, 2024).

» Azevedo Netto, C., Matos, F. S. y Souza, T. (2023). Panorama pré-histórico sobre as pesquisas arqueológicas no estado da Paraíba. *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas*, 18(3), e20220078. http://10.1590/2178-2547-BGOELDI-2022-0078

» Ballardo, L. and Mendonça, E. (2018). Struthioniformes e Paquidermes: considerações sobre a musealização do patrimônio arqueológico em instituições de salvaguarda. En *Encontro Nacional de Pesquisa e Pós-graduação em Ciência da Informação*, 19(9), 103293. http://hdl.handle.net/20.500.11959/brapci/103293 (Acceso: 12 de de marzo, 2024).

» Bea, M. (2012). Documentando el Arte Rupestre Pictórico en Aragón. En Comarca de Somontano de Barbastro (Ed.), *Jornadas Técnicas para la Gestión del Arte Rupestre* (pp. 53-59). Aragón: Ministerio de Cultura. https://jornadastecnicasarterupestre.wordpress.com/wp-content/uploads/2012/04/jornadas-tecnicas-arte-rupestre.pdf (Acceso: 12 de de marzo, 2024).

» Botica, N., Luís, L. y Bernardes, P. (2023). Use of photogrammetry to survey Iron Age rock art motifs in the Côa Valley: the Vermelhosa Rock 3 case study (Vila Nova de Foz Côa, Portugal). *Virtual Archaeology Review*, 15(30), 97-109. https://doi.org/10.4995/var.2024.19725 (Acceso: 12 de de marzo, 2024).

» Costa, J. (2003). *Impactos Socioambientais das Políticas de Combate à Seca na Paraíba* [Tesis de Doctorado inédita], Universidad de São Paulo, Brasil.

» Del Toro, M. (2012). Documentación Gráfica del Arte Rupestre Postpaleolítico para un Plan de Gestión. En Comarca de Somontano de Barbastro (Ed.), *Jornadas Técnicas para la Gestión del Arte Rupestre* (pp. 23-43). Aragón: Ministerio de Cultura. https://jornadastecnicasarterupestre.wordpress.com/wp-content/uploads/2012/04/jornadas-tecnicas-arte-rupestre.pdf (Acceso: 12 de de marzo, 2024).

» Dell'Unto, N. (2014). 3D Models and Archaeological Investigation. En Huvila, I. (Ed.), *Perspectives to Archaeological Information in the Digital Society* (pp. 55-71) Uppsala: Uppsala University. https://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-240334 (Acceso: 12 de de marzo, 2024).

» Fernandes, L. y Costa, C. (2019). Procedimentos Iniciais de Documentação em Coletas Arqueológicas no Laboratório de Documentação e Arqueologia - UFRB. *Habitus. Revista do Instituto Goiano de Pré-História e Antropologia*, 16(2), 345-360. https://doi.org/10.18224/hab.v16i2.5992

» GIMP (2019). *GIMP. GNU Image Manipulation Program* (2.10.36) [Software]. GIMP Development Team. https://www.gimp.org (Acceso: 12 de de marzo, 2024).

» Guedes, C. M. (2016). Tecnologias de Processamento Fotogramétrico e Restauro Digital como Ferramenta de Preservação e Conservação do Patrimônio Arqueológico: um estudo de caso do contexto brasileiro. En G. do Nascimento Campos and M. Granato (Eds.), *Anais do 4º Seminário Preservação de Patrimônio Arqueológico* (pp. 253-267). Rio de Janeiro: Museu de Astronomia e Ciências Afins. http://site.mast.br/hotsite_anais_ivsppa/pdf/03/16%20Guedes_REVISADO_padrao.pdf (Acceso: 12 de de marzo, 2024).

» Gunn, R., Douglas, L. C. and Whear, R. L. (2014). Interpreting polychrome paintings using DStretch. *Rock Art Research*. 31, 101-104. https://rockartresearch.com/index.php/rock/article/view/392/319 (Acceso: 12 de de marzo, 2024).

DOI: 0.34096/arqueologia.t30.n3.13343
ISSN 1853-8126 (en línea)
Arqueología 30(3), 13343 / septiembre-diciembre (2024)

» Harman, J. (2020). *DStretch: Rock Art Digital Enhancement*. http://www.dstretch.com (Acceso: 12 de de marzo, 2024).

» Hissa, S. (2016). A Fotografia Arqueológica: entre a Mimese e a Criação. *Habitus*. *Revista do Instituto Goiano de Pré-história e Antropologia*, 13(2), 71-88. https://doi.org/10.18224/hab.v13.2.2015.71-88

» Kipnis, R., Santos, H., Tizuka, M., Almeida, M. y Corga, M. (2013). Aplicação das tecnologias de modelagem 3D conjugada às técnicas tradicionais para o registro das gravuras rupestres do rio Madeira, Rondônia, Brasil. *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas*, 8(3), 605-619. https://doi.org/10.1590/S1981-81222013000300008

» LAB-NDIHR-UFPB (2023a). *Painéis Rupestres Sítio Arqueológico Roça Nova* [3D Model], por Laboratório de Arqueologia Brasileira, Núcleo de Documentação e Informação Histórico Regional, Universidade Federal da Paraíba. Sketchfab. https://sketchfab.com/3d-models/paineis-rupestres-sitio-arqueologico-roca-nova-833b59869e184ee080413bc047213a6b [CC BY 2.0] (Acceso: 12 de de marzo, 2024).

» LAB-NDIHR-UFPB (2023b). *Painéis Rupestres Sítio Arqueológico Tapuio* [3D Model], por Laboratório de Arqueologia Brasileira, Núcleo de Documentação e Informação Histórico Regional, Universidade Federal da Paraíba. Sketchfab. https://sketchfab.com/3d-models/paineis-rupestres-sitio-arqueologico-tapuio-aece92ba58f9486c87d50e58ab9691e0 [CC BY 2.0] (Acceso: 12 de de marzo, 2024).

» LAB-NDIHR-UFPB (2023c). *Inserção ambiental Sítio Arqueológico Roça Nova* [3D Model], por Laboratório de Arqueologia Brasileira, Núcleo de Documentação e Informação Histórico Regional, Universidade Federal da Paraíba. Sketchfab. https://sketchfab.com/3d-models/insercao-ambiental-sitio-arqueologico-roca-nova-e4778d743fb3429d9e2c12bb3e4ff769 [CC BY 2.0] (Acceso: 12 de de marzo, 2024).

» LAB-NDIHR-UFPB (2023d). *Inserção ambiental Sítio Arqueológico Tapuio* [3D Model], por Laboratório de Arqueologia Brasileira, Núcleo de Documentação e Informação Histórico Regional, Universidade Federal da Paraíba. Sketchfab. https://sketchfab.com/3d-models/insercao-ambiental-sitio-arqueologico-tapuio-45393a8e6ecb41919000eab1a7590b94 [CC BY 2.0] (Acceso: 12 de de marzo, 2024).

» LAB-NDIHR-UFPB (2024). *Digital Decal* [Photography]. Laboratório de Arqueologia Brasileira, Núcleo de Documentação e Informação Histórico Regional, Universidade Federal da Paraíba, MS. https://drive.google.com/drive/folders/1dwJq3wqn-5Rx_wuLH38aOzHpyRP_bqoh [CC BY 2.0] (Acceso: 12 de de marzo, 2024).

» Le Goff, J. (2013). *História e Memória* (7th edition). Campinas: Universidad Estadual de Campinas (UniCamp).

» Mackinnon, S. (2023). The Ontological Multiplicity of Digital Heritage Objects: 3D Modelling in the Cherish Project. *Heritage*, 6(2),1397-1410. https://doi.org/10.3390/heritage6020076

» Martin, G. y Guidon, N. (2010). A Onça e as Orantes: uma revisão das classificações tradicionais dos registros rupestres do NE do Brasil. *CLIO - Arqueológica,* 25(1), 11-30. https://periodicos.ufpe.br/revistas/index.php/clioarqueologica/article/view/246813 (Acceso: 12 de de marzo, 2024).

» Muñoz-Muñoz, A., Fernández-Sánchez, D., Vijande-Vila, E., Becerra-Martín, S., Cantillo-Duarte, J. J., Domínguez-Bella, S., Martínez Enamorado, V., Rengel Castro, F., Cantalejo Duarte, P., Espejo-Herrerías, M. del M., Suárez-Padilla, J., Martín-Ruiz, J. A. y Ramos-Muñoz, J. (2023). Application of photogrammetry and laser scanner on the Bronze Age structures of the Castillejos de Luna cist tomb necropolis (Pizarra, Spain). *Virtual Archaeology Review*, 14(29), 26-44. https://doi.org/10.4995/var.2023.19126

» ODM [OpenDroneMap Authors] (2020). *A command line toolkit to generate maps, point clouds, 3D models and DEMs from drone, balloon or kite images*. Open Drone Map. https://github.com/OpenDroneMap/ODM (Acceso: 12 de de marzo, 2024).

» Pessis, A. M. y Martin, G. (2002). A área arqueológica de Seridó, RN. Brasil: Problemas de conservação do Patrimônio Cultural. *FUMDHAMentos,* 2, 187-208. http://fumdham.org.br/cpt_revistas/fumdhamentos-iii-2003-2/ (Acceso: 12 de de marzo, 2024).

» Pessis, A. M., Mutzenberg, D., Cisneiros, D., Martin, G. y Medeiros, E. (2019). Registro Tridimensional Georreferenciado do Sítio Arqueológico Pedra do Ingá, Ingá-PB. *FUMDHAMentos*, 16(2), 35-72. http://fumdham.org.br/wp-content/uploads/2020/10/fumdham-fumdhamentos-xvi-2019-n-2-_267352.pdf (Acceso: 12 de de marzo, 2024).

» QGIS (2023). *QGIS Geographic Information System (3.28.15 Firenze)* [Software]. https://qgis.org (Acceso: 12 de de marzo, 2024).

» Silva, S., Müutzenberg, D. y Cisneiros, D. (2012). Arqueologia Visual: O uso das imagens fotográficas na produção do conhecimento arqueológico e historiografia da arqueologia. *Revista do Museu de Arqueologia e Etnologia*, 22, 137-156. https://doi.org/10.11606/issn.2448-1750.revmae.2012.107048

» Silva, F. y Silveira, L. (2019). O ecossistema da Ciência Aberta. *Transinformação*, 31, e190001. http://dx.doi.org/10.1590/2318-0889201931e190001

» Zarankin, A., Soares, F., Radicchi, G. y Brabo, A. (2022). 'Tecnologia apropriada': reflexões e desafios das novas metodologias 3D em Arqueologia e Conservação. O caso do projeto "Paisagens em branco, arqueologia e antropologia antártica". *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas*, 17(3), e20210090. https://doi.org/10.1590/2178-2547-BGOELDI-2021-0090