Impacts of scientific approaches on rock art research: global perspectives. Editorial.

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Introduction

Rock art is one of the most fascinating and widespread cultural expression in human history, constituting a unique, special and significant visual archive of past and present societies, their environments and landscapes, their material culture and their practices, as well as their symbolic worlds. This cultural form of non-verbal communication has been used by many generations of artists and their counterparts to exchange information about the natural, the cultural and the symbolic worlds, offering a more permanent platform for sharing messages and experiences than oral communication (Domingo, 2020). Rock art has an extensive global presence, and shows a significant variability in terms of chronologies, techniques, subject matters and geo-cultural contexts, with iconic and world-renowned sites (like Altamira in Spain, Chauvet in France or Cueva de las Manos in Argentina) and concentration of sites (like Levantine rock art in Spain, Valcamonica in Italy, Tassili n'Ajjer and Tadrart Acacus rock art sites in north Africa, Kakadu National park rock art in Australia, Mountain Huashan in China, to name a few).

Ever since the acceptance in the scientific community of the prehistoric origin of this form of visual communication, when the authenticity of Altamira was finally recognised

by Emile Cartailhac (1902), these particular cultural expressions have been worldwide the focus of attention of scientists, 'amateurs', administrations and stakeholders, and more recently of tourist operators interested in using this heritage to promote tourism. However, and despite the general recognition of the historical, scientific, cultural and aesthetic values of these masterpieces of the past, for a long time and in many parts of the world, rock art research has been marginalized from the mainstream archaeological and anthropological debates. Critical to this scientific exclusion have been the challenges to obtain reliable absolute dates to place rock art in specific contexts and times, the frequent lack of accurate recording of the represented motifs, or particular emphases on speculative interpretations.

As a consequence of these assumptions in some international discussion forums, such as the annual meetings organized by the European Association of Archaeologists (EAA), rock art sessions were mainly focused on management and conservation or on the realms of religion and symbolism, and resulted in a separation from scholars advocating for the scientific study of rock art.

However, the 'Third Science Revolution' (Kristiansen 2014) of the last few decades also reached down to rock art studies, changing the way rock art is analysed today. The use of physicochemical and isotopic analysis of pigments and rock surfaces, different dating techniques, state of the art digital technologies to record and analyse rock art as well as landscape approaches based on quantitative and GIS modelling are becoming standard tools in approaching rock art. The rock art literature is showing a significant shift towards scientific approaches, with an increasing number of regional case studies going in this direction.

The challenge now is to reflect on the real contributions of this variety of approaches to improve our understanding of rock art or to open new research questions, that we could never have imagined without these interdisciplinary methods.

This volume emerges from a session held at the 23rd Annual Meeting of the EAA conference *Building Bridges* which took place in Maastricht (Netherlands) between the 30th August and 3rd September 2017. Under the title *Rock art research is archaeology or it is nothing* and as part of Theme *'Third Science Revolution' in Archaeology,* this session intended to break a long-term inertia of these and other major international congresses of archaeology to limiting the discussion on archaeological and scientific approaches to rock art. It brought together international scholars from more than 10 countries to discuss how

and to what extent recent science and interdisciplinary approaches to rock art and other forms of ancient art are improving our understanding of this particular and fragile cultural heritage. Papers presented at this session included discussions on:

- the potential of digital technologies not just to improve rock art recording but also as a tool to explore old and new research questions from a new perspective, such as, for example, to analyse the 'chaîne operatoire' for rock carvings, as a tool to explore and monitor rock art conservation; etc.
- different analytical techniques applied for dating and characterizing pigment and bedrock components in rock art, of use to advance knowledge on painting compositions, to identify raw materials and potential sources, to explore the painting technologies and practices of past artists and to understand the conservation history of this heritage.
- the contribution of quantitative and spatial analysis and GIS applications to understand and analyse the locations and landscapes of rock art, and to identify potential features bringing prehistoric artists to choose specific places and no others.

The current volume includes a selection of the papers presented at this session, as well as some new invited papers by leading international researchers. These supplementary papers were added to achieve a more global representation and to complement some of the topics addressed in this volume.

More than bringing together particular case studies to show how scientific methods and digital technologies have been introduced in different regions, as already addressed in other recent volumes or handbooks (Pastoors et al., 2017; Ontañon and Utrilla, 2017; or David and McNiven, 2018), **our aim with this volume is to assess the real practical impacts of this science revolution in rock art research.**

- How are new technologies and scientific approaches really contributing to expand the frontiers of archaeological knowledge on rock art?
- Are the introduced analytical methods really furthering our understanding of rock art?
- Are they opening new research questions that were previously unthinkable?

This volume feeds current debates on the benefits and the limits of this "Third Science Revolution" in the archaeology of rock art, underpinned by the experiences of leading scholars from the five continents.

This collection of papers includes a mixture of review and research papers dealing with three major topics: the contribution of physicochemical approaches to material analysis, the contribution of physicochemical approaches to rock art dating, and the contributions of digital imaging, GIS and spatial analysis to record the art, the sites and the surrounding landscapes.

Section 1. The contribution of physicochemical approaches to material analysis

This section includes five papers offering both general and site-specific approaches to rock art and reflecting on the potential and limits of physicochemical analysis to explore the nature of the rock surfaces, the pigments, the crusts and the varnishes related to rock art in order to identify raw materials, techniques, châine operatoires, as well as the processes and agents acting on surfaces and art after its production. The results inform us on the practices of rock art artists and on changes in site preservation, of interest to understand and contribute to the long-term conservation of this heritage.

Sepúlveda reviews in detail 40 years of research on physicochemical analysis and characterization of pigments in Argentina and Chile (2020, this volume). The author pays particular attention not only to the techniques used, but more interestingly to the complexities of interpreting the results to achieve meaningful archaeological information on the socio-cultural practices of the authors and their contemporaries. More importantly, her paper demonstrates how studies in this particular part of the world (with similarities and specificities in colours and practices) can contribute to global debates on the archaeology of arts and colours.

Domingo et al. (2020, this volume) provide a more regional perspective, based on a critical review of physicochemical analysis applied to a particular tradition unique to Mediterranean Iberia and listed in the UNESCO World Heritage list since 1998: Levantine rock art. In this paper the authors explore how more systematic approaches to the materiality of this rock art tradition conducted in the last two decades are contributing to understand the practices of Levantine artists, as well as the many aspects influencing the preservation of this art. While the focus is a particular rock art tradition, their critical review of the previous works and techniques used and the experiences shared are of global interest, especially for open-air rock art studies.

Gallinaro and Zerboni's paper (2020, this volume) bring us to the developments and challenges of physicochemical analysis applied to African rock art, stressing the need to develop appropriate protocols. While this sort of approaches is still at an early stage in

this continent, their case study in southern Ethiopia reflects the growing interest in extending multi-analytical research to advance knowledge on rock art practices and conservation issues in this part of the world. In particular, they discuss the fossil and biodegradation processes affecting rock surfaces and pigments - largely underestimated in open-air contexts-, leading to further analyses on the role of biofilms in the preservation of artworks and rock surfaces.

A multi-technique program (combining in-field and laboratory-based methods) is also used in the Pilbara region of Western Australia by Huntley et al. (2020, this volume) to illustrate what scientific approaches can add to research on rock art, and particularly to understand the production within broader archaeological landscapes. This papers also emphasizes the need to analysis other materials used in rock art production (stone artefacts, grinding tools and others) to achieve a more complete picture of the processes and practices involved in producing art and of other potential uses of colouring materials.

Also the paper by Martínez-Pabello et al. (2020, this volume) is site-specific, focusing on the characterization of rock varnish associated to petroglyphs of the world-famous La Proveedora site in the Northwestern Sonoran Desert (México). Using a physicochemical approach, the authors aim to understand the nature of this varnish used as a resource to produce engravings as well as the factors affecting the preservation of this type of art in desert environments.

In general terms, papers in this section exemplify the wide variety of physicochemical techniques used today in rock art analysis to explore a broad range of phenomena beyond the chronology or the simple identification of the raw materials used. Pigment analyses have the potential to provide information to explore the spatial dimension of raw material sourcing (Huntley et al., 2020, this volume), the sociocultural practices of the authors; and different aspects of the technologies of paint preparation and use and their change over space and time (Domingo et al., 2020; Gallinaro and Zerboni, 2020; Huntley et al., 2020; Sepúlveda, 2020, this volume). Moreover, most papers in this section highlight the need to properly understand the characteristics of the rock surfaces, crusts and varnishes, and the post-depositional processes affecting the rock and the art over time, to realize the complexities of interpreting the raw materials and recipes, to recreate the history of pigment and rock preservation, to identify the preferences of the artists regarding the characteristics of the media selected and to predict the long term behaviour of this fragile heritage (Domingo et al., 2020, this volume; Gallinaro and Zerboni, 2020, this volume; Martínez-Pabello et al., 2020, this volume; Sepúlveda, 2020, this volume). Similarly, they

are extremely useful to provide guidance to future studies by critically assessing the applications and limits of the different techniques used so far in each region and the sort of results achieved. Discussions on the limits of each technique included in these papers are also useful to keep improving research protocols and to help future scholars to pick the best techniques to answer their specific research questions. These papers also make a nod to the need to engage in continued reflections on the ethical dimensions in sampling this particularly artistic heritage, recalling the need of preserving the integrity of the art, of sampling only when there are no other methods to answer their research questions (Domingo et al., 2020, this volume) and of respecting the interests and desires of the communities related to it (Huntley et al., 2020, this volume). These papers also highlight the benefits of conducting multi-technical and multi-step multidisciplinary approaches and the need of using first non-invasive techniques as a measure to minimize impacts, to preserve the different values of this art and to guide future micro-sampling.

Section 2: Advances in rock art dating.

This section includes three papers dealing with an issue of significant relevance in rock art studies across the globe: the challenge of estimating the age of the art. Dating the art is necessary to establish relationships between motifs, techniques, patterns or styles and particular chronologies and cultural contexts. Only then we will be able to discover what sort of cultural, social or even environmental causes lie behind the changing geographies and practices observed through the analysis of this cultural phenomenon. While during the last century a variety of relative dating techniques has been used to estimate archaeological time and for sequencing, the introduction of scientific techniques to obtain numerical dates (whether direct or indirect) seemed to be promising to build more accurate chronological frameworks. Although considerable progress has been made, we are still a long way from achieving unquestionable chronological frameworks for most rock art traditions around the world. A good example of the challenges and limits still ahead of us are discussed in the first paper of this section.

Paper by Blanca et al. (2020, this volume) gathers all the numerical chronological information available so far for prehistoric art in the Iberian Peninsula (Spain and Portugal) including Palaeolithic, Levantine, Schematic and Megalithic art. Through a critical review of the potential and limits of the methods used and of the results published, the authors asses the reliability of the data available in this region for each

rock art tradition. The substantial record of dates available for Palaeolithic art contrasts with the low number of dates available for post-Palaeolithic art in this region, which remains almost undated.

In a different part of the world, the area of Salut in the northern Sultanate of Oman, Zerboni et al. (2020, this volume) use physicochemical approaches to characterize the nature of the bedrock and the crusts of a particular site and to understand postdepositional processes and weathering. Interestingly though, this type of analysis led to the identification of organics trapped within the rock varnish, allowing radiocarbon dating. According to the authors, the obtained dates are of particular relevance considering the lack of well-dated rock art in this specific region.

Finally, Šefčáková and Levchenko (2020, this volume) discuss how improvements in dating methods open the potential to date previously undatable remains. Through the application of micro-AMS technique developed at the Australian Nuclear Science and Technology Organisation (ANSTO) the authors successfully date several charcoal marks from different sites in South-Western Slovakia, confirming various phases of prehistoric settlement. Interestingly, these marks could not be dated before with routine AMS dating, as the paint layers were too thin. New developments such as this, expand the scope for rock art dating and provide a sobering reminder of how continued technological advances and critical thinking will help us to improve dating methods and to better place prehistoric art in time and space.

Section 3: Digital imaging, GIS and spatial analysis.

This section includes four papers showing how the use of digital technologies and quantitative approaches is contributing to significant developments in the rock art studies, through case studies from the Western Pacific region (Jalandoni, 2020, this volume), Europe (Valdez-Tullet, 2020, this volume), Africa (Vogels et al., 2020, this volume) and North America (Diaz Andreu et al., 2020, this volume). All these contributions demonstrate how interdisciplinary approaches are opening new perspectives for recording, interpreting and analysing rock art, contributing to change the role of rock art in archaeology.

The first paper (Jalandoni, 2020, this volume) offers a review of the remote sensing deliverables of use to record, measure and trace rock art in 3D and 2D. These techniques are highly valuable for eluding physical contact, improving the accuracy, reducing the fieldwork time and favoring a flexible digital management of inventories,

spatial analyses of art motifs, and monitoring changes in the state of preservation of rock art sites.

The other papers in this section offer instead variegated examples of integrated methodologies combining GIS, computational and statistical methods with Landscape Archaeology, Social Network Analysis, Ethnography and Ethnohistory, and Acoustic Studies, to identify possible patterns in features and locations of rock art sites, at different scales of analysis.

Valdez-Tullet's article (2020, this volume) addresses the so-called Atlantic Rock Art (ARA), i.e. a Neolithic and Early Bronze Age rock carving tradition recorded in the Atlantic coastal province, including modern Spain, Portugal, Britain and Ireland. Through the analysis of local and regional patterns in the distribution of motifs, settings and techniques of rock art, and using a multi-scalar analysis (from the single motif to the landscape) the author outlines a hypothesis of connectivity and cultural transmission. While different regions share a common set of motifs, formal analyses show differences that the author interprets as resulting from the spread of an original package of motifs that were subsequently modified locally. The author emphasizes the strong connections across the ARA area and praises the results of Social Network Analysis. The GIS intervisibility study suggests caution in relation to former assumptions. The comprehensive toolbox of analyses demonstrates how much the rock art can contribute to the narrative of prehistoric Atlantic Europe.

The last two papers in this section focus on the analysis of the location of rock art sites, considering both tangible and intangible aspects of culture, trying to highlight the underlying patterns. Vogel et al. (2020, this volume) analyse the distribution of sites possibly referred to groups of hunter-gatherers inhabiting the Dâureb massif (Namibia) roughly dating between the 4th and the beginning of the 2nd millennium cal BP. Through computational and statistical models integrating environmental settings, frequency, density and variability of rock art motifs, archaeological remains and site clustering, the authors suggest that the use of the rock art sites by the hunter-gatherer communities was not straightforward, as could be assumed using simple ethnographic models. Community aggregation is not always associated with rock art intensity, and some main painted sites were likely ritually specialized sites, used for communal ritual by groups residing in different, close locations.

Diaz-Andreu et al. (2020, this volume) discuss the distribution of rock art sites in the Cañón de Santa Teresa, in Northern Baja California (Mexico), with a significant

concentration of the Great Mural rock art tradition, apparently dating back from the 7th millennium cal BP. The authors explore the relation between rock art sites and the surrounding landscape, applying science-based methodologies for the study of sound and acoustics. Ethnographic and ethnohistoric data are here combined with an acoustic survey, suggesting a correlation between the location of the rock art sites and rituals possibly involving the use of music and dance. The acoustic analysis remarks that the area where two of the most important rock art sites are located is the canyon sector with the most favorable acoustic conditions.

These papers demonstrate how a rigorous and theoretically sound use of digital technologies, GIS and computational analysis is contributing to a rapid revolution in rock art studies. The improvement in the recording of motifs, settings and landscapes, both in terms of accuracy and efficiency, as well as the possibility to manage and combine huge amounts of heterogeneous data are crucial in breaking the marginalization of rock art studies and in building a digital future for this heritage. The results here presented are an example of how rock art can be determinant in building new models on past socio-cultural dynamic, unhinging fossilized approaches and speculative interpretation.

To sum up, the articles in this volume provide fresh and updated reviews and data from different parts of the globe to reflect on the real contributions of the Third Science Revolution in rock art research.

This special issue was made possible thanks to funding from the European Union's Horizon 2020 research and innovation programme, under the European Research Council (ERC-CoG LArcHer project, grant agreement no. 819404, awarded to I. Domingo) and under the Marie Skłodowska-Curie Grant (H2020 MSCA-IF-2017 Global Fellowship, grant agreement 795744, awarded to M. Gallinaro). We would like to thank the European Association of Archaeology (EAA) for their agreement to publish selected papers from our session. We are grateful to all the colleagues who attended the session and accepted to contribute to this volume. We warmly thank Professor Thijs van Kolfschoten, Editor in Chief, and Bhuvaneshwari Jeyapandian, Journal Manager, for their support. Finally, we thank the many external experts acting as reviewers for the articles in this special issue.

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