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Rock, pigments, and weathering. A first assessment of challenges and potentials of physical and biochemical studies from southern Ethiopia

Marina Gallinaro[1,2]*, Andrea Zerboni[3]

1) Permanente Address: Dipartimento di Scienze dell'Antichità, Sapienza Università di Roma, Italy
2) Present Address: Cotsen Institute of Archaeology, University of California, Los Angeles (UCLA)
3) Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Italy
* Corresponding author: marina.gallinaro@uniroma1.it

Abstract

In the last decade, physico-chemical analyses have been largely applied to the study of rock art contexts, in particular to examine the composition of rock art paintings and obtain direct radiometric dating. Different sampling and analytical methods have been applied on rock art from different parts of the world. However, in Africa these analyses are still on an embryonic stage. The results are often problematic in terms of their reliability, mainly for what concerns the chronology. This is due to a wide range of fossil and active biodegradation processes affecting rock surfaces and pigments; such processes are still widely underestimated. This paper aims to discuss the state of the art of the physico-chemical analyses carried out on rock art African contexts, and the urgency to establish protocols and best practices of sampling and analysis. The preliminary results of a new project in southern Ethiopia are here presented as an example of an integrated study of rock art context, combining Archaeology and Earth Sciences. Preliminary field observations and SEM-EDS analyses, run on samples coming from two rock shelters in the Borana zone, highlight the presence of a complexity of physical, chemical, and biological weathering processes that have manifold effects on the rock art evidence.

Key words

Rock art; Pigments; Rock weathering; Scanning Electron Microscope; Minerals-microorganism interaction; Ethiopia.

1. Introduction

Rock art is one not most fascinating world's cultural heritage spanning from at least the Upper Palaeolithic, up to present ethnographic contexts (e.g. Whitley, 2011; McDonald and Veth, 2012; Bruno and McNiven, 2018). Rock art tells us about the lifestyle of our ancestors and the landscape they settled, as much as about their symbolic world. Indeed, the preservation of rock art is one of the most challenging issues that a conservation scientist has to manage with studying rock paintings and petroglyphs (e.g. Gibbons, 1984; Hygen, 1996; Walderhaug Saetersdal, 2000; Loubser, 2001; Lambert, 2007). World rock art is one of the most endangered evidence of the past, due to the direct exposition to atmospheric agents and surface processes. In many cases, it was created under different environmental conditions, and today it is no more in equilibrium with extant climatic settings (e.g. Hoerle, 2006; Cremaschi et al., 2008; Bednarik, 2012; Darvill and Batarda Fernandes, 2014; Giesen et al., 2014; Zerboni et al., in press). Beyond natural damages, too often artworks are threatened by human actions related to economic development programs (e.g. oil exploitations, buildings, mining, intensive agriculture programs and sudden intense fluxes of tourism), carried out without any awareness about the cultural issues, or by deliberated vandalism (e.g. di Lernia et al., 2010; Gallinaro et al., 2018; Taruvinga and Ndoro, 2003). African rock art is an emblematic example of these issues. The main concentrations of African rock art are from arid to sub-arid ecological contexts, often in remote areas hard to control and manage.

Many recent papers attempt at discussing the properties of pigments used to depict African rock art galleries in order to (i) assess the occurrence of ancient organic matter in binder and pigments, (ii) characterize the properties of organics and eventually non-organic constituents, and (iii) select the fraction to submit to radiocarbon dating. If we consider the recent literature on these topics, we note that the detailed characterization of the state of preservation of pigments, and the investigation on the interaction between the rock substrate and pigments are poorly examined. But many questions arise if we go deeper in the field of preservation of African rock art: what happened (or what is happening) to pigments? Are those weathered or undergoing any kind of diagenesis? Or, on the contrary, they are stabilised for any reason? Which kind of processes is suffering the geological support of rock art? A part of climate, how are microorganisms influencing these processes? Is there any biogeochemical interaction between pigments and minerals constituting the rock support?

Starting from our recent experience on southern Ethiopian rock art from the area of Yabelo, here we preliminary report on the state of preservation of local rock art galleries, with special emphasis on the preservation of the rock substrate and evidence of biogeochemical processes acting at the interface between pigments and the bedrock. We do not want to give a comprehensive assessment on the preservation of rock art at Yabelo, as many analyses are on-going. In this paper, we mean: (i) to review the state-of-the-art on analytical approaches to characterize African rock art – with special attention to those not propaedeutic to radiocarbon dating –, and (ii) to propose a protocol to assess rock weathering and identify evidence of interaction between pigments, minerals of the bedrock, and microorganisms, trying to elucidate how physical, chemical, and biological weathering is menacing the preservation of rock art.

2. Brief review on the physico-chemical analyses on Africa rock art

The application of physico-chemical analyses in the study of African rock art started in the late 1980s, with the first tentative of radiocarbon dating in South Africa, by Van der Merwe et al. (1987).

In more than thirty years, a variety of analyses has been applied to investigate three main issues: (i) direct or indirect dating of paintings and petroglyphs; (ii) characterization of pigments; (iii) investigation of weathering and biodegradation. After Van der Marve et al. (1987), a long series of attempts to dating paintings and engravings, through direct or indirect methods followed. These include accelerator mass spectrometry radiocarbon dating (AMS-^{14}C) of organic binders or their organic by-products for paintings (e.g. Mazel and Watchman, 1997; Mori et al., 2006; Bonneau et al., 2011, 2017a, 2017b; Pecchioni et al., 2019), organic matter trapped in rock varnish microlayers covering petroglyphs (Zerboni, 2008; Huyge et al., 2001), or optical stimulated luminescence (OSL) dating of sediments covering engravings (Huyge et al., 2011; Mercier et al., 2012). Dating remains the main and most ambitious aim of scientific analyses applied to rock art, even when researches focuses on pigments characterization and degradation (e.g. Conard et al., 1988; Zerboni, 2008; Gomes et al., 2013; Lofrumento et al., 2012).

A systematic survey of the literature, among the main international journals, allows proposing a synthetic overview of the main trends and areas of research. We considered the main international publications, using the search tools provided by the SCOPUS and ISI Web of Knowledge databases, as well as on the various publishers' websites. The literature survey followed the methodology described in Gallinaro and Biagetti (2016). To give a more balanced and

comparable results between the different research areas, we exclude journals focused on defined areas. On a total number of 221 papers on African rock art, 16% includes physico-chemical analyses It is interesting to observe that the frequencies by area and by area and topics show the same trend (Fig 1). We grouped the papers in four main macro-regions, based on geographical position: southern, northern, and eastern Africa. Southern Africa shows the highest score of papers on rock art (44%) and the largest use of physico-chemical analyses (49%), followed by northern (27 and 31%), and eastern Africa (20 and 17%). These percentages reflect the role that rock art has played in the different areas, as recently discussed (e.g. Smith, 2013; di Lernia, 2018). The investment in research, conservation projects, and the continuity of research on the San rock art, is not comparable with any other contexts in Africa (e.g. Smith, 2013). If we look in more detail at the data by topic, in southern Africa we have indeed the widest variability, with a significant incidence of analyses focused on weathering and biodegradation processes affecting rock art. In particular, the research of Prinsloo (2007) and Prinslo et al. (2008) represents a sort of cornerstone of the physico-chemical research on African rock art (Fig. 2). For the first time the weathering of rock faces depicting rock art are investigated as "a complex mechanism encompassing interdependent mechanical, geological, physical and biological processes" (Prinsloo 2007: 502). Furthermore, since then the researchers began to apply a major care in reducing the impact on sampling technique (Prinsloo et al., 2008), followed by the experimental use of non-destructive and non- invasive techniques, such as the *in situ* application of Raman spectroscopy (Tournié et al., 2011). More recently, Bonneau et al. (2011, 2012, 2017a, 2017b) proposed a multi-technique analysis of rock art with a specific procedure of sampling, and pretreatment and analytical protocols aimed at reducing the impact of sampling and isolating the pigment to weathering products (e.g. calcium carbonates, calcium oxalates, or humic acids).

In northern Africa, physical and chemical analyses mainly focused on dating (e.g. Mori et al., 2006; Zerboni, 2012; Huyge et al., 2011; Mercier et al., 2012), and on the characterization of pigments for reconstructing the *chaîne opératoire* in the preparation and use of pigments for the parietal rock (e.g. Darchuk et al., 2011; di Lernia et al., 2016). Only a recent study approached the problem of the impact of sampling, with the experimental use of Micro-Raman spectroscopy in Western Sahara contexts (Iriarte et al., 2018). This delay is also due to the political turmoil resulting from the so-called Arab Springs that highly reduced or completely denied the access to the main rock art contexts, especially in the Saharan massifs.

Eastern Africa is the third macroarea interested by the application of physico-chemical analyses to rock art. Setting apart a first characterization of pigments on Eritrean samples, collected in the 1940s by Graziosi (Zoppi et al., 2002), in the last ten years a few sporadic analyses were carried out in sparsely contexts, mainly focused on dating and characterization of pigments, particularly in Ethiopia, even if often without clear project backgrounds.

It is clear that a fully integrated approach is far to be a standard procedure in rock art studies, and the divide between archaeology and Earth and chemical sciences is still wide.

3. Settings

3.1. Geographic information

The study area is located in the Yabelo woreda, part of the Borana Zone of the Oromia Region, about 600 km south of Addis Ababa (Fig. 3). It lies in a semi-arid ecological zone, with a bi-modal rainfall pattern exhibiting an average annual range of 400–700 mm and a mean annual temperature of c. 19 °C (minimum c. 9 °C and maximum c. 27°), presenting high seasonal variability due in part to the altitude, 450 to 2500 m above sea level (Coppock, 1994; Sutter 1995). The past few decades have been characterised by erratic patterns of rainfall and drought, with a strong impact on the availability of natural resources. In the region, the geological bedrock consists of granite intrusions and granitic gneiss, the product of low-grade metamorphism (Clark, 1945; Williams, 2016) belonging to the Adola Belt formations. As a consequence of intense tropical weathering, the local landscape alternates among inselbergs, piles of boulders, tors and large isolated boulders of granite/metagranite. Many rock shelters open along the rocky slopes and at the foot of tors; on investigation, some of these revealed the presence of a human occupation dating from at least the Middle Stone Age (MSA) (Spinapolice et al., 2017; Gallinaro et al., 2018; Carletti et al., in press).

3.2. Background on local rock art

Rock art study in Ethiopia had a marginal role (e.g. Gallinaro et al., 2018; Negash, 2018) and was substantially ignored in the research area. In 1943, John Desmond Clark rapidly surveyed the area during his military service in East Africa in the Second World War, recording a few quantities of schematic red paintings, highly weathered. Only in the mid of 1990s, new researches carried out by Hundie (2001) allowed to locate new rock art sites. However, this evidence remained substantially unpublished and scarcely known until the last few years. A new season of research started in 2016

is revealing an unexpected density of rock art in the area, possibly covering a broad chronological range spanning over the last IV millennia BP (e.g. Spinapolice et al., 2017; Gallinaro et al., 2018). The rock art sites recorded in the area during the first two field seasons (2016-2017) include exclusively paintings that vary in size, subjects and forms, and are hosted on the walls of rock shelters or isolated boulders. The recorded artworks show figures and decorative patterns unknown in the area, that are opening new perspectives in the study of rock art in East Africa adding significant information about the occupation history of the Middle and Late Holocene. In particular, the presence of possibly different cattle species, including humped and humpless specimen, as in the case of the site YAB6, is an important data for the spread of herding in the region. The state of preservation is highly problematic, in some cases the paintings have been damaged by the combined action of natural and anthropic processes, whereas at least in the case of the site YAB6 the damages seem to be exclusively referred to natural processes.

4. Material and methods

To assess the state of preservation of rock art substrate and the interaction with pigments we selected two rock shelters, intensively surveyed and recorded: YAB6 and BOR1 (Fig. 3). YAB6, discovered by Hundie (2001) and known by the local name of Dhaka Kura (Crow's Rock), is located ca. 2 km NW of the town centre of Yabelo. It is the largest of a series of rock shelters open into an alignment of (meta)granite hills, cut by the deep incision of a stream. The site and the neighbouring area are still highly frequented by the local communities, including herders and their livestock, due to the presence of a well fed by a spring. The site has a high potential for the archaeological research as well as for conservation and cultural heritage issues (Gallinaro et al., 2018).

The wall and the ceiling of the shelter host tens of paintings different for shape, size, technique and figures. We recognised five main panels, three on the main wall and the other covering part of the wall and the ceiling. The panels show different state of preservation with figures almost invisible at naked eyes to more visible paintings. The represented figure mainly consist of domestic cattle, wild animals and geometric signs are present as well (Fig 4).

The other site, named by Hundie (2001) BOR1, is located about 6 km south of Yabelo. The site is a large rock shelter opened at the foot of an inselberg developed on low-grade metamorphic rock. Rock art covers the back wall of the shelter with two main clusters (Fig. 5). Area 1 mainly hosts black painted camels and wild animals (ostriches and giraffes); whereas the other large area shows

a complex palimpsest of vanished figures and white painted figures representing anthropic figures, giraffes and cattle. Differently from YAB6, humans have heavily damaged paintings at BOR1 with modern graffiti made with charcoal and chalk that cover a large portion of the paintings.

We collected very small samples of rock surface from many parts of the shelter and a few pigments samples. To reduce as much as possible any possibility to damage rock art galleries, we decided to sample each kind of weathering surfaces or other damages evident on the rock surface far from paintings. In a few cases, we collected samples of pigments, to assess their characterisation, state of preservation and interaction with the bedrock.

Small samples were removed with a sterile bistoury or a small chisel and preserved in sterile containers. In some cases, we decided to remove weathering products and efflorescence from the rock surface peeling it with a sterile tape, then preserved in sterile containers. The same technique was also employed to collect minimal samples of pigments. In the laboratory, samples were subdivided into smaller pieces, observed under the Scanning Electron Microscope (SEM). Subparts of the same samples were preserved for the analysis of the biological fraction with the help of a confocal microscope after selective staining, and to obtain (after consolidation) thin sections for the petrographic optical microscope.

SEM observations employed a Cambridge 360 scanning electron microscope imaging both secondary and back-scattered electrons. Energy dispersive X-ray analysis (EDS Link Isis 300) required carbon-coating samples. Energy dispersive X-ray spectroscopy with an accelerating voltage of 20 kV, filament intensity 1.70 A, and probe intensity of 280 pA. Every analysed element has been previously standardised by using several single element standards (Micro-Analysis Consultants Ltd). Elemental concentrations measured by EDS are reported as oxide weights normalized to 100%. We observed samples on their external and internal parts, and in some cases, we observed them along a transverse section. Peeled pigments and rock surface were observed after transferring the material removed from the rock surface onto a special carbon-coated tape. All samples were analysed after carbon coating to allow EDS measurements, but in specific cases, we performed additional observations on gold covered samples to obtain high-resolution images.

5. Results

5.1. Field observations

The local rock substrate corresponds to granites and granitic gneiss with different degree of metamorphism (Williams, 2016). At both sites, bedrock outcrops display a variety of surface weathering and surface coatings, almost encompassing the whole possibility of surface processes effecting rocks: physical, chemical, biological weathering and eventually combinations of them.

At a general scale, weathering processes on crystalline rocks (solutional weathering) are the main factors triggering the formation of the extant landscape. The latter consists of rounded or sub-rounded hills (inselbergs), and residual accumulation of rounded to sub-rounded blocks (chaos of block and tors), partially still covered by weathering products (granitic coarse sand). Rock shelters formed due to solutional processes creating alcove-type cavities, or due to the accommodation of large, rounded, residual boulders after the removal of weathering products. At the meso-scale, a main difference is evident comparing the effects of weathering inside and outside rock shelters. The part of rock shelter out of the drip line, in fact, appears to be less protected by external agents and displays two different type of weathering resulting in the mechanical disaggregation of minerals. From the one hand, we notice the occurrence of granular disaggregation, possibly controlled by local thermal regime and difference in seasonal insulation to rock surface. On the other hand, a main part of rock surfaces out of rock shelters displays a variety of lithobiontic organisms, including epiliths (many species of macroscopic lichens), and greenish biofilms in the pore space within rock (cryptoendoliths). The main effect of epiliths is enhancing granular disaggregation, whereas cryptoendoliths possibly play a major role in exfoliation.

Surprisingly, inside the drip line of rock shelters the stability of rock surface is greater, thus permitting the preservation (at least partial) of paintings. Inside the rock shelters, the insolation is minimal and rock walls are almost sheltered from rainfall. Locally, humidity is enhanced by laminar fluxes and percolation along rock cracks and vertical faults. As a consequence, the microclimatic conditions inside rock shelters are less suitable for the growth of lichens. On the contrary, in a few cases at YAB6 we noticed the occurrence of weakly developed biofilms related to cryptoendoliths. The internal parts of the rock shelters display evidence of desquamation and exfoliation; these two processes are similar, and likely a biologic contribution in their effectiveness is likely, but the main control is played by the type of rock. In fact, exfoliation seems to be more intense on granitic gneiss with higher degrees of metamorphism, as at YAB6 site. Granular disaggregation is less evident inside the rock shelter.

Other processes affect the rock surfaces and are mostly related to the formation of rock coatings and other external disturbances. To the latter, we ascribe the occurrence of wasp (and other insects) and a whitish efflorescence found at site YAB6. Wasp's nests are built with local soils and in some cases they can cover pigments; their disaggregation leaves semi-cemented ground on rock walls. The nature of the whitish efflorescence will be discussed in the following section, as field observation was not definitive for its interpretation. Observed rock coatings consists of whitish, 1–2-mm-thick crusts covering large patches of the rock walls, reddish accumulation of Fe-rich oxides along discontinuities and where exfoliation is more intense, and less common dark Mn-rich rock varnish evident in correspondence of desquamation (brilliant gray coatings below desquamation flakes). On rock shelves formed along discontinuities, the uppermost surface looks smooth and vitrified as covered by glossy precipitates and from the vitrified surfaces leakage of whitish precipitates are present. Likely, these are related to the occurrence of rock hyraces (*Procavia capensis*) and are the consequence of urine precipitation as reported from elsewhere in Africa (Prinsloo, 2007).

5.2. Preliminary SEM-EDS analyses

Preliminary SEM observations coupled with EDS chemical characterization of compounds suggested the main properties of the weathering products found onto and into the rock support of paintings, and showed the complex interaction between the bedrock, pigments and microorganisms. In the following parts, we describe the results of analyses on rock fragments removed from the rock wall and analyses on pigments collected after peeling.

A whitish crust covers a large part of the rock wall and under the SEM it appears as a continuous coating, with irregular to smooth surface, occasionally organized as tabular, flat bipyramidal or acicular crystals; in many cases, crystals seem to be smoothed by subsequent dissolution events. The coating covers the rock surface and drape discontinuities among mineral grains; in some samples, the coating seems to be multi-layered as it accreted after subsequent events. Some organics are trapped within the crusts, including for instance very well visible fungal hyphae, likely still living. Chemical analyses suggest that gypsum (or anhydrite) is one of the main mineral constituents of the crust (Fig. 6); in fact, EDS detected a Ca and S content up to 40% and 55% respectively. Additionally, other chemical elements are well represented, as for instance concentrations of Cl and K that can be related to inorganic phases of urine precipitates (KCl), as those identified in western and southern Africa (Prinsloo, 2007; Mazel et al., 2010). A higher

concentration of KCl was observed at YAB6 in correspondence of whitish efflorescence, which composition is phosphatic. Under the SEM, the efflorescence consists of ca. 10-μm large spheroidal objects, initially interpreted as bacteria, but most likely corresponding to urine precipitates (Fig. 6). The latter appears as concentration of spheroidal precipitates of spheroids distributed on a continuous phosphatic crust (Fig. 6). In a few samples from YAB6 and BOR-1 sites, the outer parts of the rock walls present a more complex configuration, alternating different mineral coatings and organic remains. In particular, the SEM-EDS analyses detected the occurrence of discontinuous gypsum coating alternated with small mineralizations with tabular, acicular, or lamellar crystal aggregates (FIG. 6). In the case of the latter mineralization, chemical analyses detected the occurrence of Ca, K, and S as major elements, and smaller amounts of P and Mg. P can be related to organic matter, and the mineral fraction consists of calcium and potassium sulphates, such as syngenite or görgeyite. For instance, syngenite is the sulphate double salt found at San rock art sites of southern Africa (Prinsloo, 2007). The content of Ca may also suggest the occurrence of calcium oxalates. In a few cases, organic remains have been detected by imaging on top or among the above-described mineralizations. Fungi hyphae in form of elongated filaments and likely other parts of lichens are the most common organic remains; spores, pollens, and remains of arthropods were also found.

Under the scanning microscope, the internal part of the rock wall of the YAB6 rock shelter discloses a complex assortment of in situ weathering of minerals, neoformation of minerals, and organic remains (Fig. 7). Moreover, imaging also disclosed a tight interaction between the mineral and the biological components. In situ weathering is evident on exfoliated samples, and affects mostly feldspar and quartz grains, but in many cases crusts of secondary minerals or organic remains cover its effects. Dissolution pits and micro/nanno-runnels are present on single crystals, sometimes in the vicinity of encrusting organic matter (for instance the remains of hyphae), as much as more complex kinds of dissolution features, likely related to solutional processes triggered by microorganisms (Fig. 7). As common in the case of weathering of crystals, the effects of weathering are mostly evident according to the orientation of cleavage planes. At YAB6, inside the discontinuities of the rock wall, we detected small concentration of halite in form of very small cubic crystals, distributed on the surface of quartz grains, and discontinuous coatings of Mn-rich minerals associated to phosphates (Fig. 8). NaCl and Mn-bearing crystals are likely mineral neoformation. The most common neoformation of minerals within the rock surface – up to 1 cm inside – consists

of flat bipyramidal crystals (Fig. 8) rich in S (24%), Ca (20%), and K (20%), and crusts rich in Ca and S (ca. 40% and 55% respectively) or Ca and P (24% and 15% respectively). Crusts can be interpreted as gypsum (Fig. 8) and phosphate precipitated inside the rock as crystals and possibly weathered onto smoothed crusts. The habit and chemical properties of bipyramidal crystals (rich in Ca) suggest attributing them to the presence of calcium oxalates. In particular, the flat bipyramidal and acicular druses have been attributed to the monohydrate (whewellite) and the dihydrate (weddelite) calcium oxalates (Saffo and Lowenstam, 1978; Glasauer et al., 2005; Echigo and Kimata, 2010). Whewellite and weddelite extensively occur in relation to a variety of biomineralization processes, including those driven by fungi and lichens as suggested by their interaction with hyphae (Verrecchia et al., 1993; Gadd, 1999), and have been identified also related to rock paintings (Watchman, 1993; Russ et al., 1996; Hernanz et al., 2007; Prinsloo, 2007; Bonneau et al., 2012), occasionally associated to gypsum (Russ et al., 1999) as in the our case.

Organic matter detected in the inner part of samples mostly consist of the remains of endoliths, and especially fungi hyphae encrusting minerals, tubular and spiral algal structures, and thallus remains (Fig. 9). All remains are tight connected to minerals of the host rocks of newly formed minerals, as in the case of bipyramidal crystals and surface crusts. The concentration of algae remains is occasionally very high, forming a carpet at the interface between the solid rock and the exfoliation flake (Fig. 9). Smaller organic features such as bacteria are less distinguishable in observed samples.

Samples peeled from paintings permitted to remove a minimal part of pigments to submit to SEM and EDS analyses. At both sites collected samples of red and whitish pigments and underling rock support or crust. In samples from YAB6 (Fig. 10), for instance, the underlying crust dominates in most of samples and only in one case small crystals are detectable; they are organized in a very thin sheet and chemical analyses detected, beside the dominance of Ca and S due to gypsum and oxalates, a moderate concentration of Si and Fe (Fig. 10). This may suggest that the red pigment is extremely thin and consists of iron oxides; the occurrence of Si can be related to the presence of quartz and clays, as local soil is the main source of iron oxides. At YAB6, one of the whitish pigments consists of spheroidal features in a matrix (Fig. 10). Spheroids are very similar to the above-described urine precipitates, and chemical analyses detected the occurrence in spheroids and the encrusting matrix of dominant Ca. Therefore, we attributed their composition to calcite or at least a mixture of calcite and Ca-oxalates. Calcite, for instance, in form of its polymorphs vaterite is common in the

rock art of San of southern Africa and possibly related to the occurrence of hyraceum (a mixture of hyrax faeces and urine) (Prinsloo, 2007). As above described, calcium oxalates are the by-products of many biological processes related to the metabolism of many lithobiontic organisms. In other samples, EDS analysis found abundant phosphates that possibly were used in pigments.

6. Discussion

Fieldwork and laboratory observations highlighted a large and variegated set of different weathering and bio-chemical actions still active on rock painted surfaces. According to our experience in the region and in the whole African continent, multiple weathering phenomena affect each site and they are the product of the interaction among physical chemical and biological alteration processes.

At YAB6 and BOR1 we had the opportunity to collect information on many of these processes: from one hand, bio-physical and bio-chemical weathering of rock support menace the stability and preservation of rock art; on the other hand, the occurrence of bio-mineralized crusts is likely protecting the paintings. Processes promoting physical, chemical, and biological weathering of rock support are more severe outside the drip line of rock shelters. Therein, insolation and water availability are grater thus enhancing the intensity of desquamation and disaggregation. The same processes can be observed at limited scale in the inner part of rock shelters and generally weathering processes are much more evident under the microscope. Likely, the absence of thick organic anthropogenic infilling within the rock shelters prevents or hampers a number of biological processes, which elsewhere have been identified as substantial in the disaggregation of rock art support (di Lernia et al., 2016).

The formation of mineral crusts is a further main feature affecting rock art at YAB6 and BOR1; the presence of external crust is evident at both sites, but its role and relationship with pigments is not completely clear. In fact, sometimes it seems to cover – and thus protect (?) – paintings, whereas elsewhere paintings overlap the crust, that appears to be a sort of preparatory layer for the paintings.

The role of surface processes triggered by microorganisms is likely the most important, but evidence is evanescent, and its relevance can be assessed only under the scanning microscope. SEM observation of rock and pigments samples highlighted very complex interaction among the mineral rock support and microorganism. The occurrence of organics is suggested by the presence of a

variety of biological remains, the most important of which are fungi hyphae, which suggest the growing of endolithobionts today and/or in the past. Elemental analysis of mineral neoformation from both the investigated sites also confirms the major role played by microorganisms. The systematic occurrence of Ca-oxalates crystals beneath the rock surface suggests that endolithic lichens and/or fungi actively colonized the walls supporting rock paintings. On the other hand, their occurrence on the present-day surface may suggest a rejuvenation of the rock surface (see for an interpretation of the process: Mergelov et al., 2012). Further chemical signatures for organic matter are related to peaks in the concentration of P, Ca and S, which are generally related to the occurrence of phosphates or P-bearing sulphates (Prinsloo, 2007; Zerboni, 2008), and Cl and K related to inorganic phases of animal urine precipitates (Prinsloo, 2007; Mazel et al., 2010). Calcium phosphates associated to oxalates can be related to the occurrence of endolithic microorganism, whereas is very interesting the occurrence of phosphorus sulphates analogous to those identified in the San rock art. The occurrence of these minerals on and within rock support is likely related to natural processes as the growth of endolithic communities. Furthermore, the presence of urine precipitates and P-sulphates can be related, as described by Prinsloo (2007), by the contamination form the dejections of rock hyraces (*Procavia capensis*) that still live in the area. The occurrence of mineral constituents typical of the hyraceum detected in the peeled white pigment sample may be related to natural contamination, but the intimal occurrence of urine precipitate spheroids in the Ca-bearing matrix suggests a possible intentional use of hyraceum or other kinds of animal urine as pigment in rock art, as in the case of the San and Dogon rock art (Prinsloo, 2007; Mazel et al., 2010).

These observations point to several fundamental questions needing to be addressed when investigating the role played by biological process in the preservation or deterioration of rock art. Which is the main role of biofilms in rock art conservation? Have biofilm a negative influence because they degrade pigments and weather the rock support? Or are biomineralized mineral neoformation protecting pigments and rock surfaces from severe weathering? How are on-going/fossil biological processes affecting our attempts to direct radiocarbon dating of rock art?

To understand the role of biofilms we need to consider the occurrence of extensive biomineralization (oxalates for instance), which have a twofold effect. Oxalates precipitated by endolithic organisms increase the instability of the rock support promoting exfoliation; but once the surface is rejuvenated, they represent a surface crust offering protection to the rock surface. Probably, the mineral crusts deriving from hyraxes' dejections offer the same protection to paintings.

In the perspective of radiocarbon dating rock art, our work suggests the occurrence of a very intense biological activity within pigments and in the surrounding rock support. As in the case of the biofilms, also biological activity may result in a bidirectional process in terms of organic matter preservation. Microorganism living in pigments and on/within the rock support on one hand may decompose pristine organic compounds, but on the other hand, they actively contribute to supply the system with fresh organic matter. This may result in alternate enriching or depauperating the carbon system that cannot be considered close and thus reliable for radiocarbon dating. Radiocarbon dating need therefore to be proceeded by a careful assessment on the quality and quantity of available organics as suggested for instance by Bonneau et al. (2011). Alternative options of dating Ca-oxalates were performed (e.g. Watchman, 1993; Mazel and Watchman, 2003 Pecchioni, et al 2019). But also, in this case we need to be aware that the oxalate system is not stable: oxalates crystals can be well preserved or resulting by multiple episodes of deposition or recrystallized in subsequent phases. The ^{14}C system within rock art cannot be considered close without specific investigation on the mineralogy and crystallography of calcium oxalates.

7. Conclusion

The application of physical and chemical analyses to the study of rock art evidence in Africa is still in an embryonic phase. The primary focus of the analysis performed in different areas of the continent was – and still is – referred to the chronological issue. However, in the last years a few works highlight the need to change perspective in terms of aims and procedure of sampling, pointing at a multi-analytical investigation of rock art.

Yet, our work on the rock art of southern Ethiopia presents the preliminary results of an integrated approach to the rock art, combining archaeology, geology, paleoenvironmental study, with microscopic, bio-chemical and microbiological study. The first results (field observations and preliminary SEM-EDS analyses) revealed the complexity and multidirectionality of processes acting on the rock faces depicting rock art and promoting physical, chemical, and biological weathering. Desquamation and disaggregation of the rock supports, formation of mineral crusts, and microorganisms living in pigments or within the rock support have manifold impacts on rock art, destructive as much as protective. Further analyses will allow clarifying the role of each process – and its triggering factor – on the current characterisation of the pigments, as well as on the processes of deterioration or preservation of the artworks.

Acknowledgments

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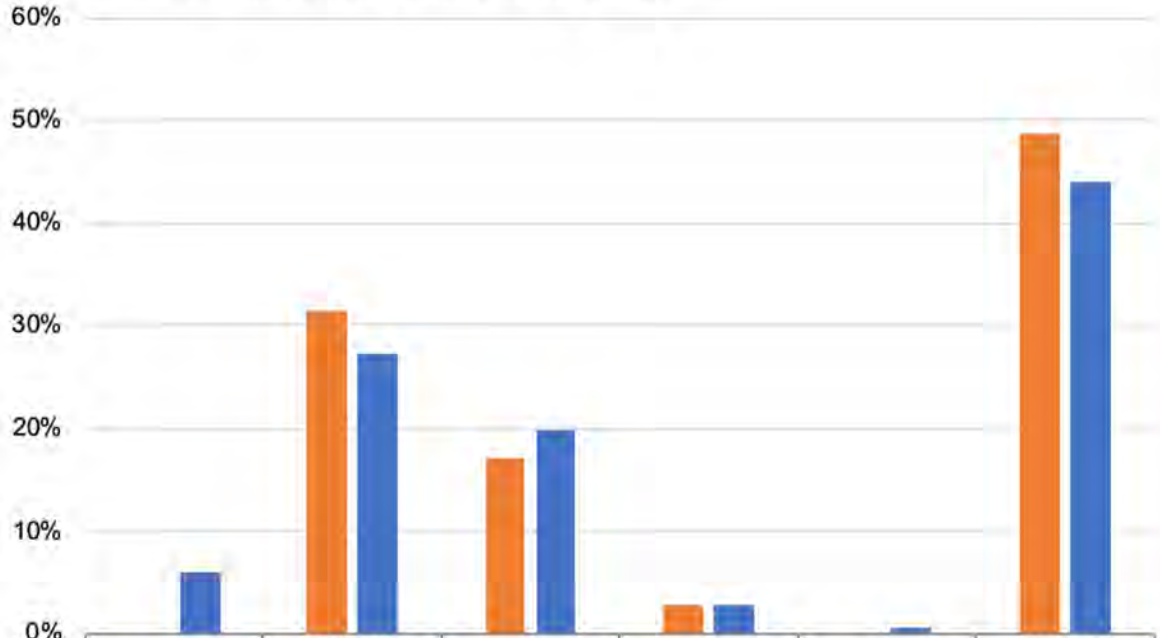
Figure 10 – SEM pictures illustrating examples of small portions of pigments removed with tape. (A) Red pigments consisting of Fe-bearing material. (B) Whitish pigment consisting of a

mixture of gypsum and likely hyraceum (notice the spheroids similar to those showed in figure 'D').

Publications African rock art



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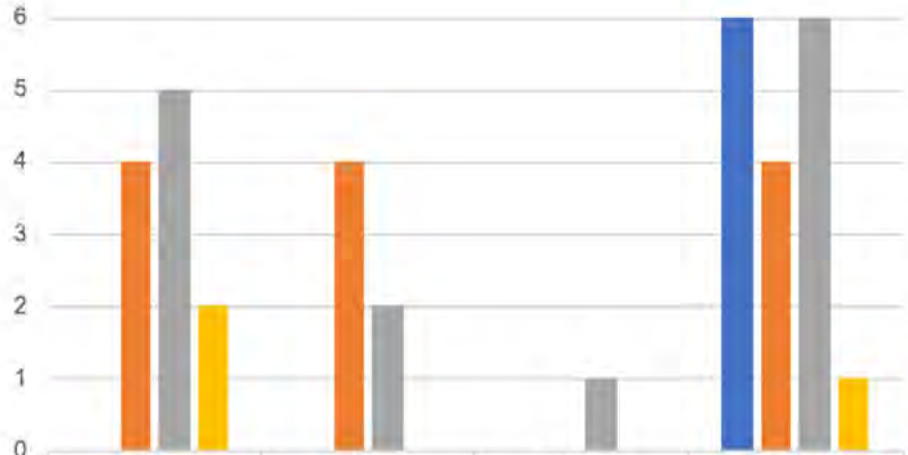
% other	6%	27%	20%	3%	0%	44%



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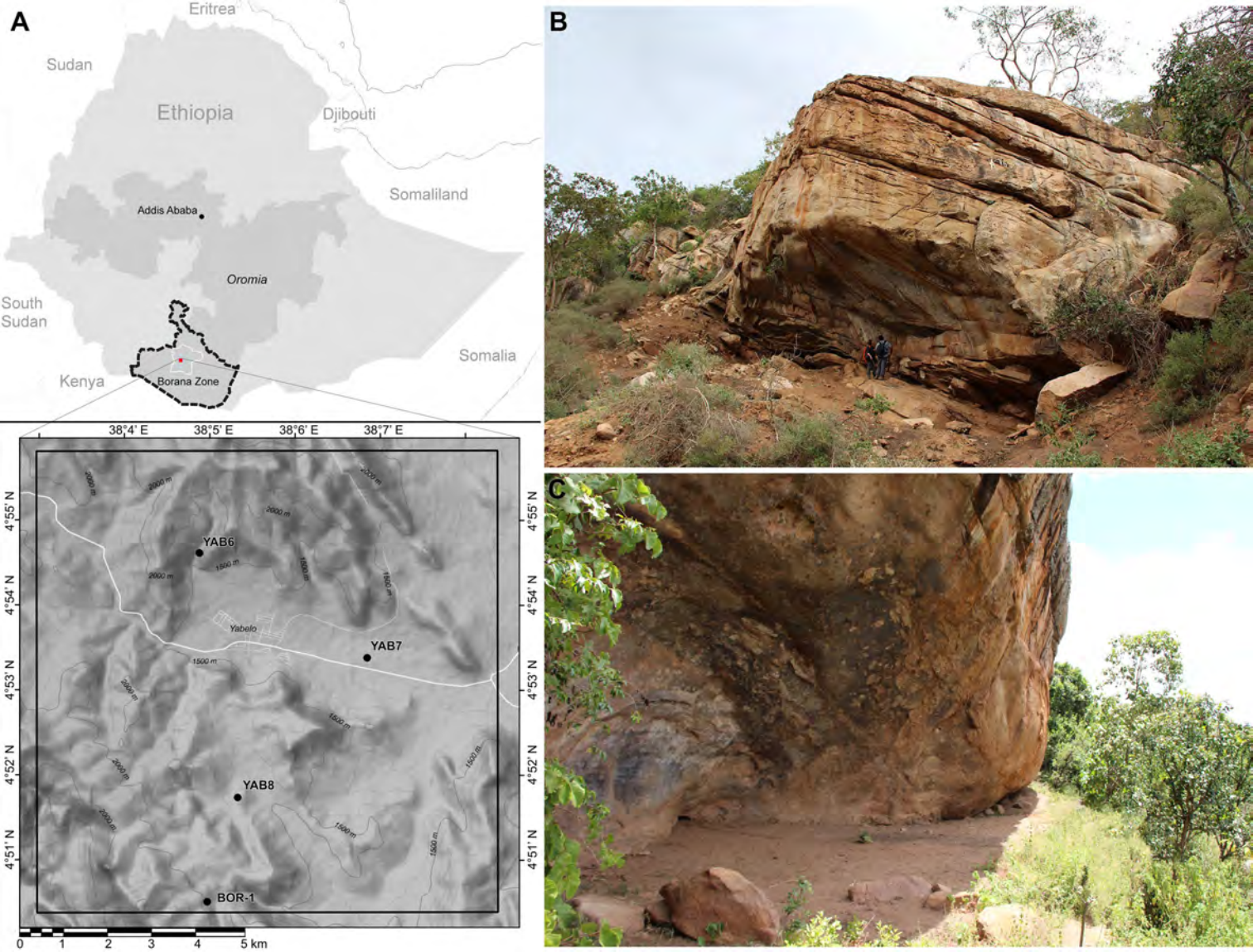
biodegradation/weathering				6
characterisation of pigment	4	4		4
dating	5	2	1	6
varnish	2			1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Sudan
Ethiopia
Djibouti
Somaliland
Addis Ababa
Oromia
South Sudan
Somalia
Kenya
Borana Zone
38°4' E
38°5' E
38°6' E
38°7' E
4°55' N
4°54' N
4°53' N
4°52' N
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0 1 2 3 4 5 km
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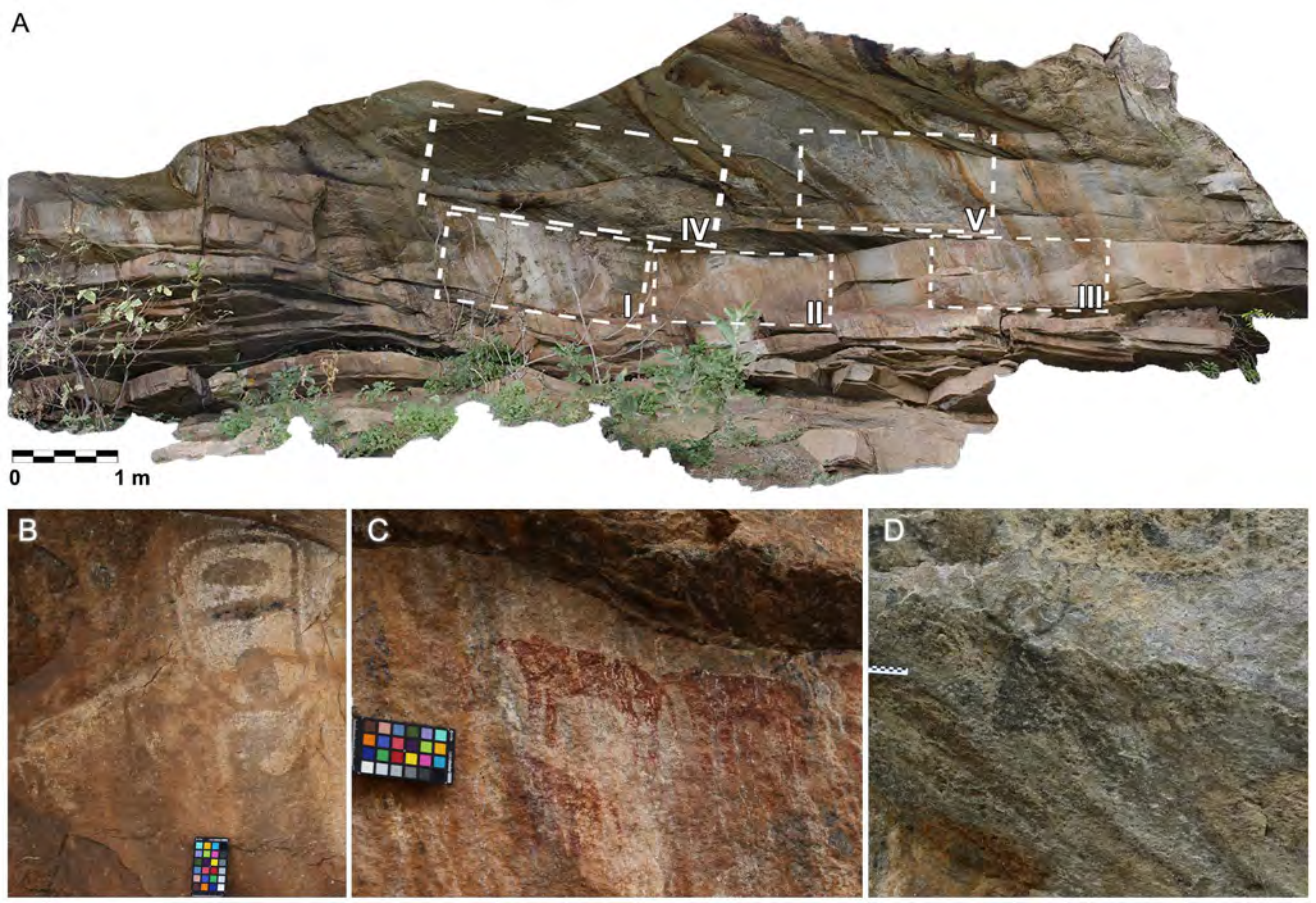
C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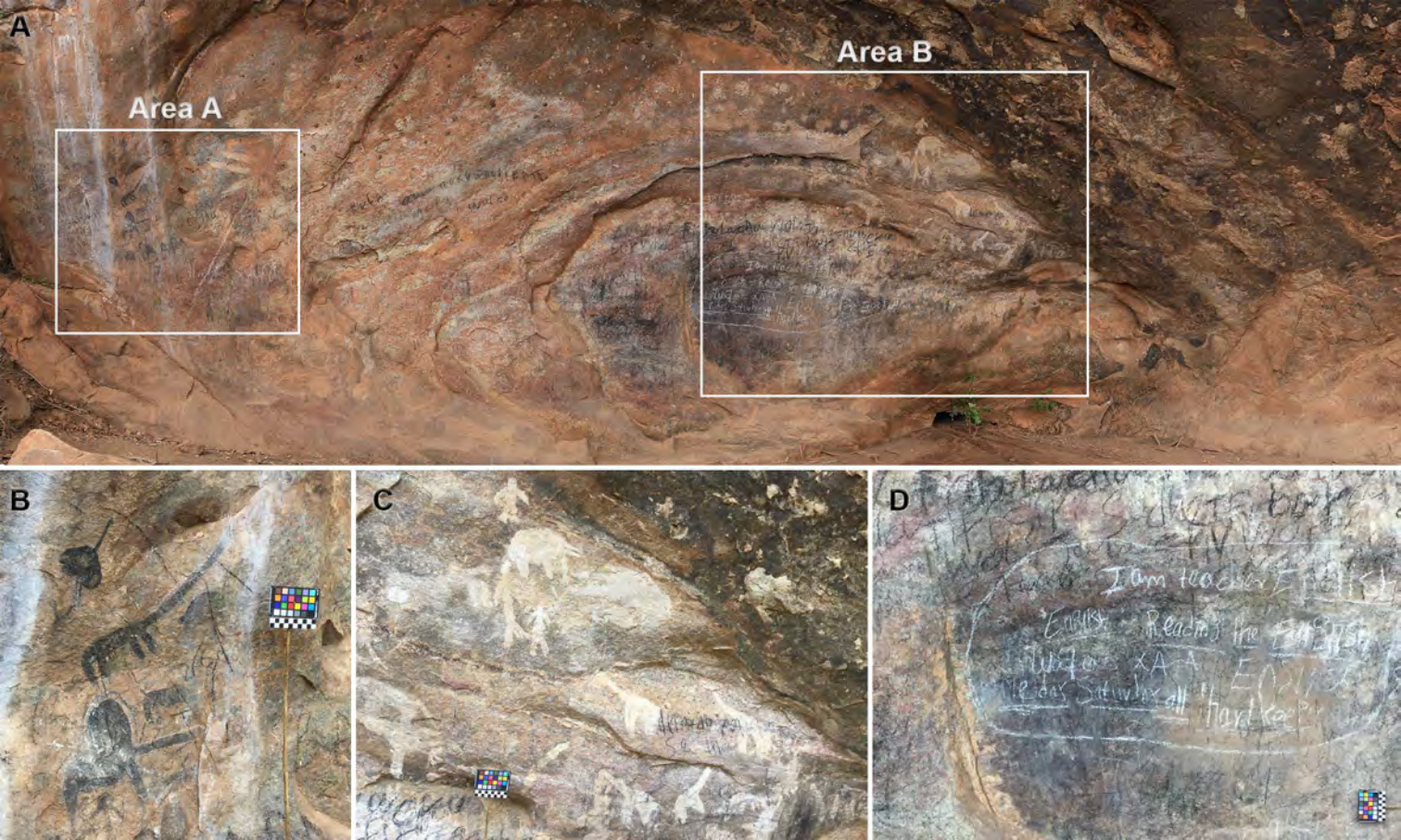
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Area B
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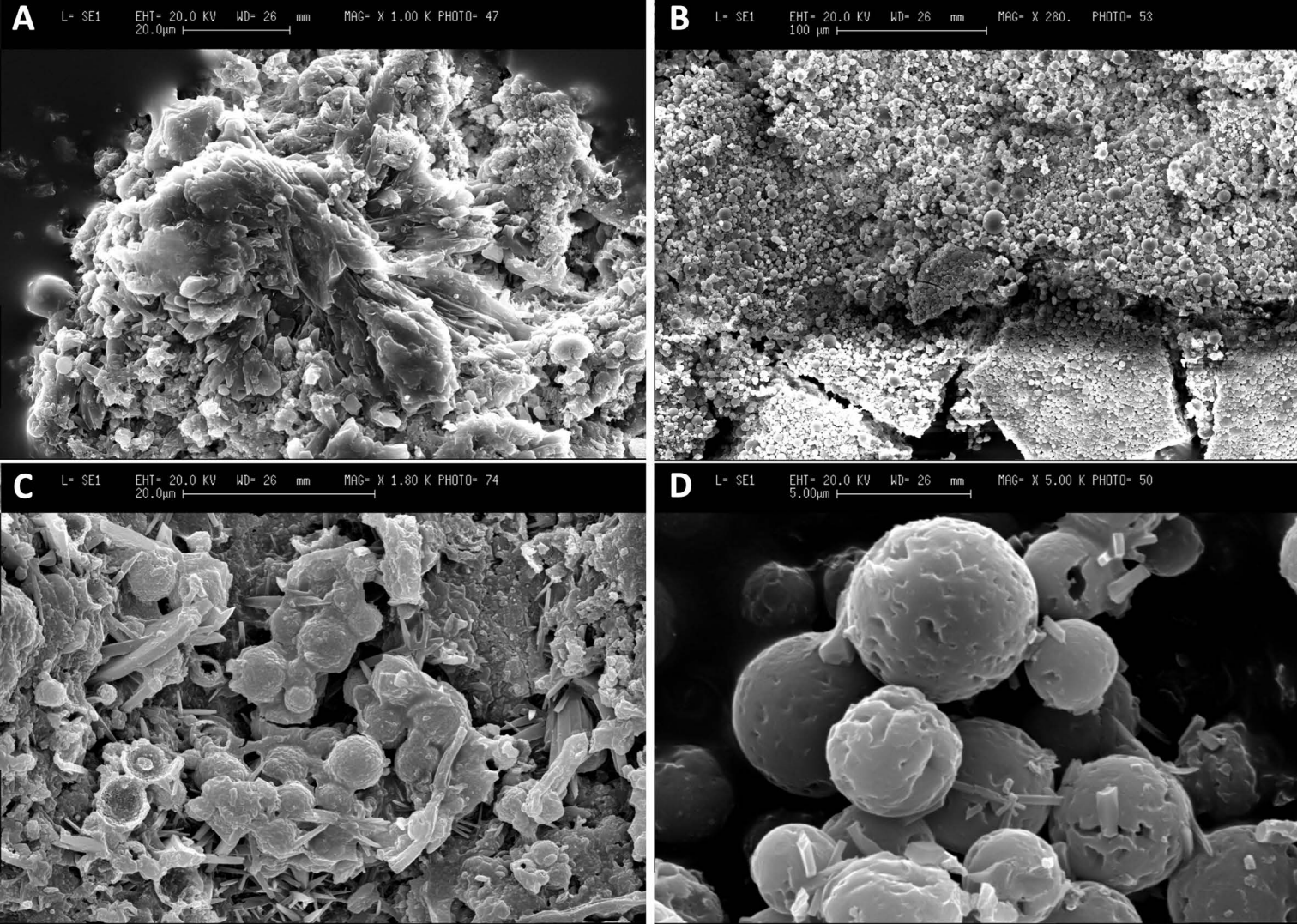
C
D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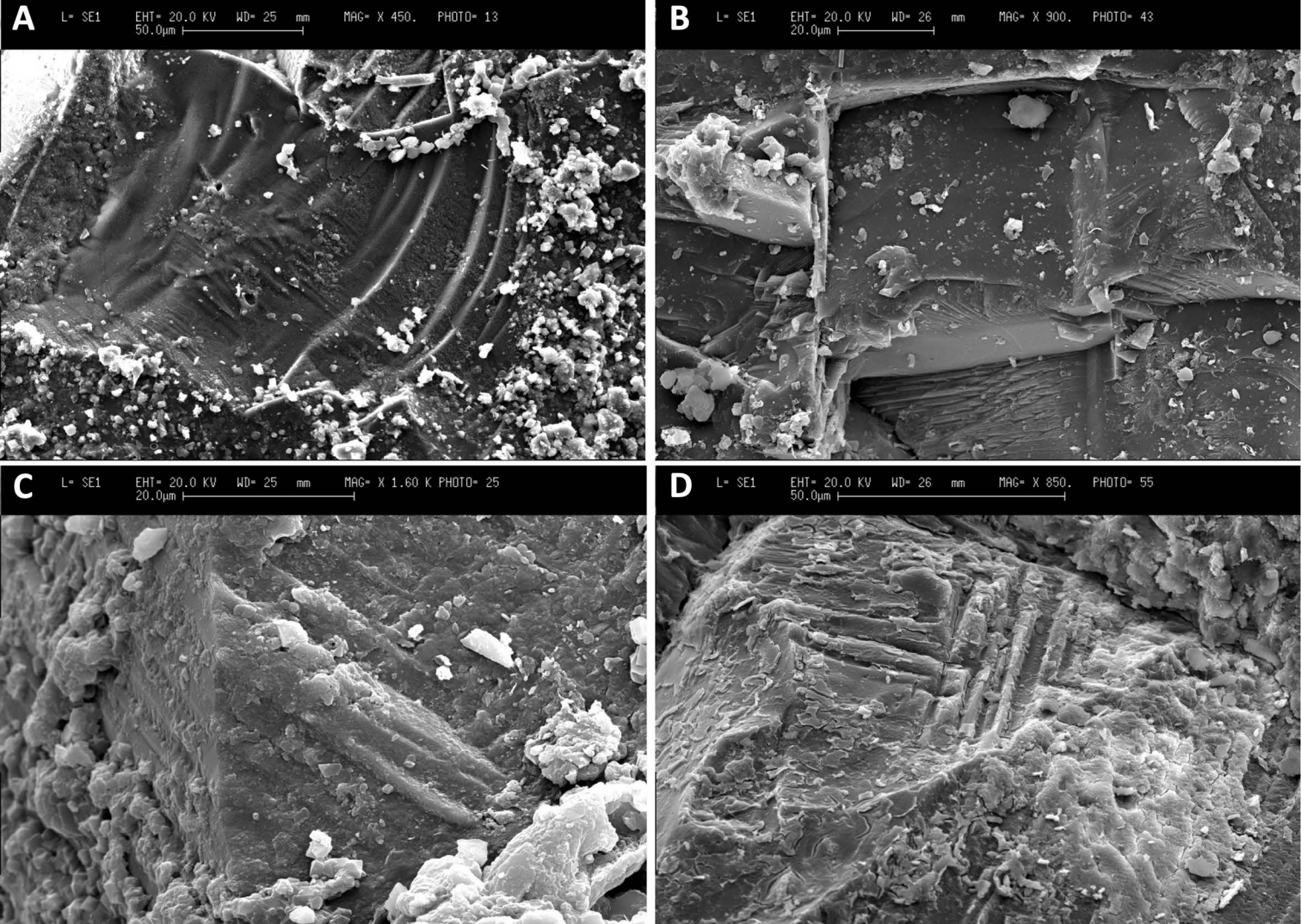
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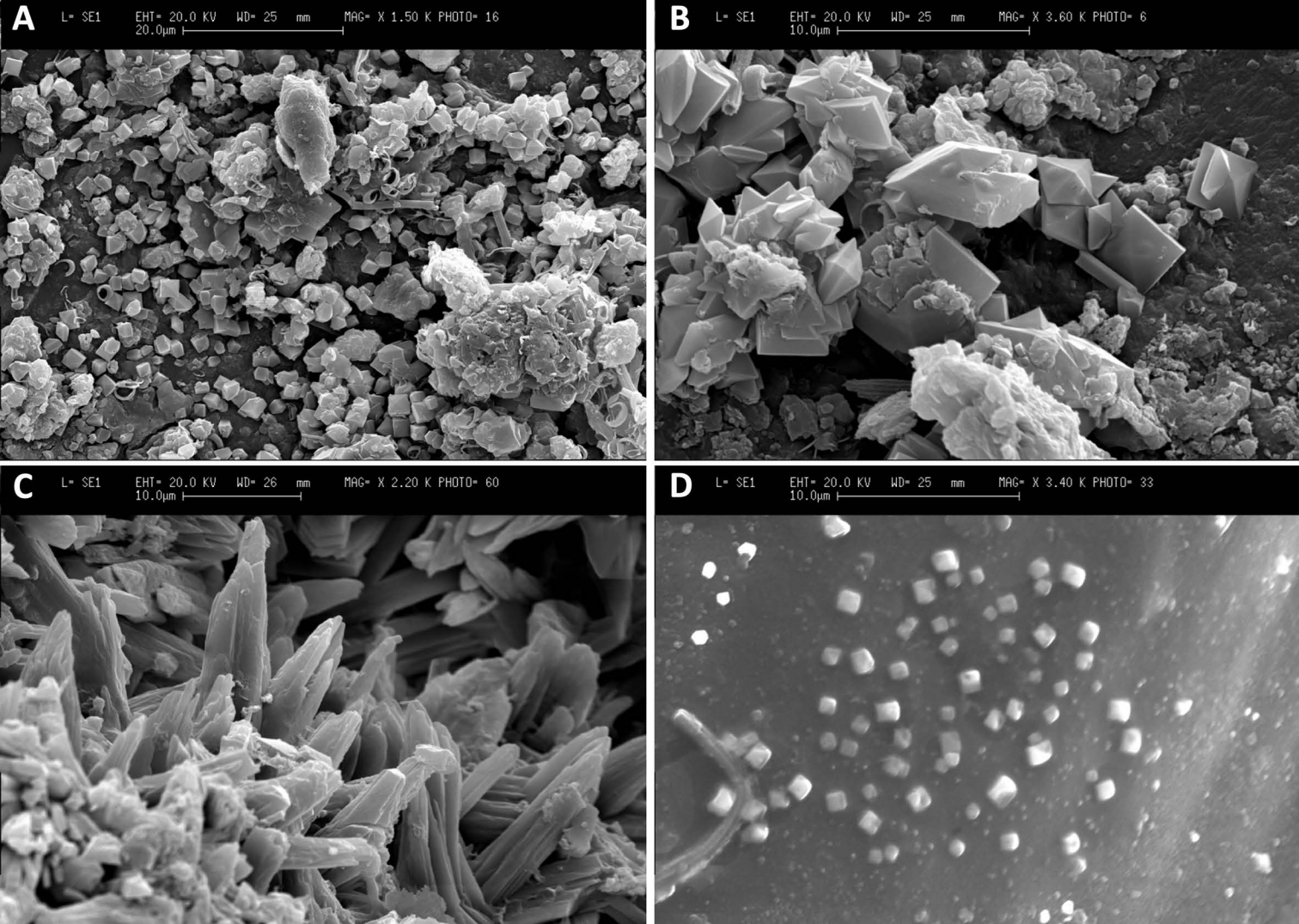
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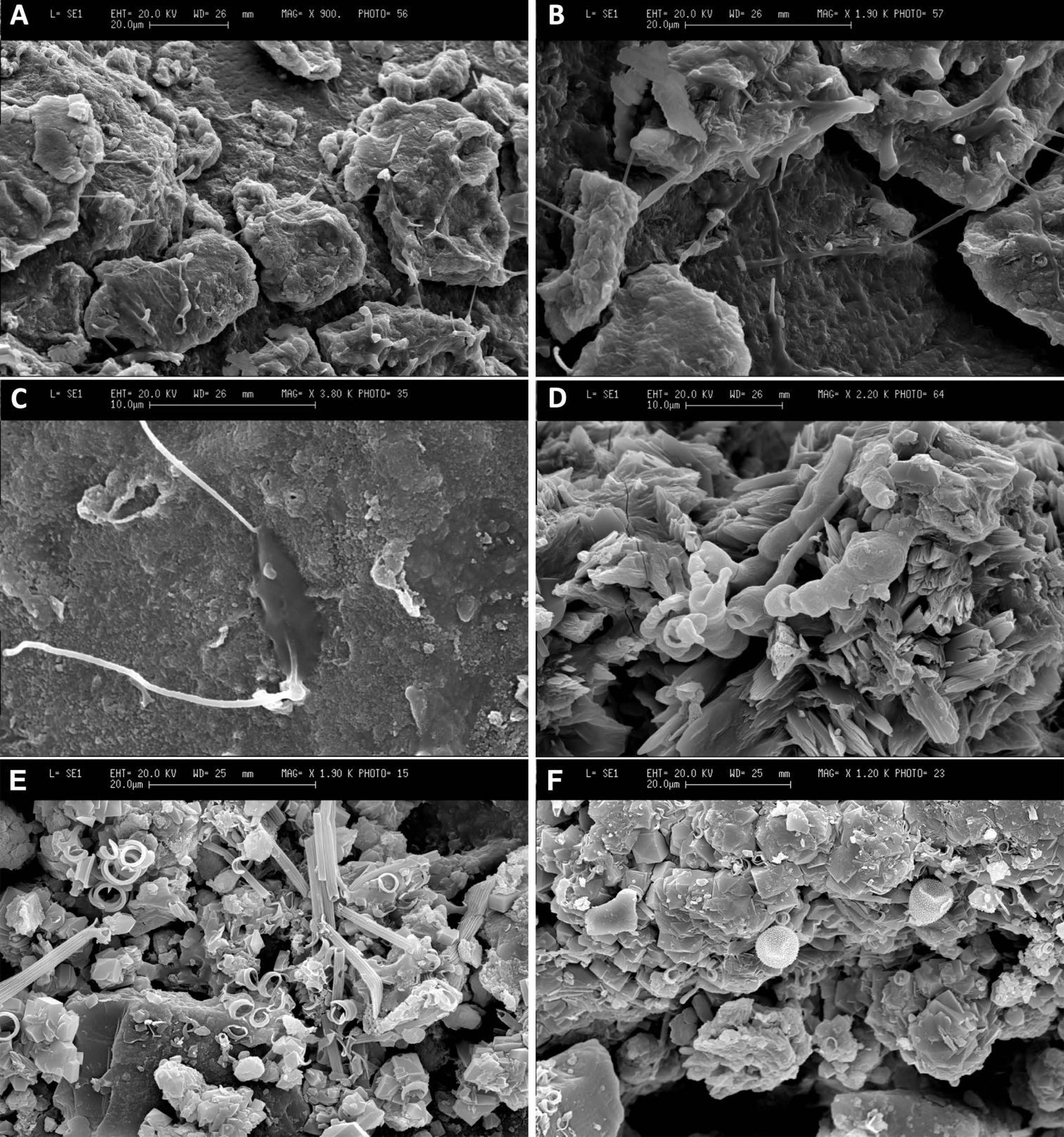
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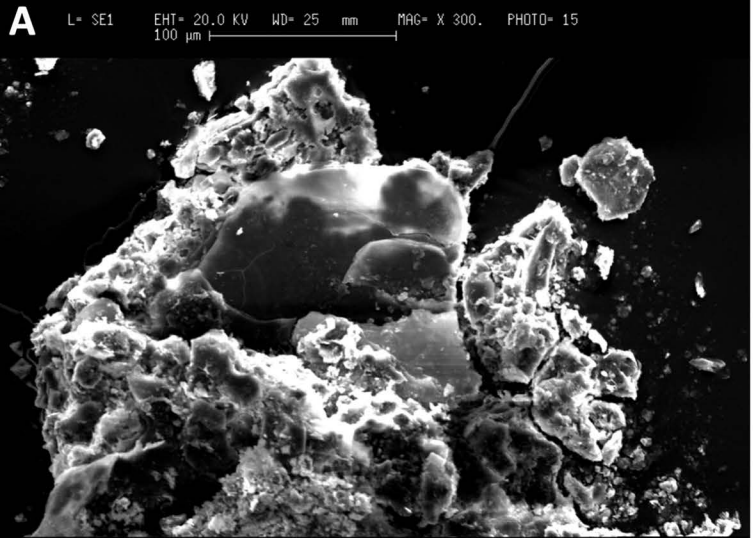
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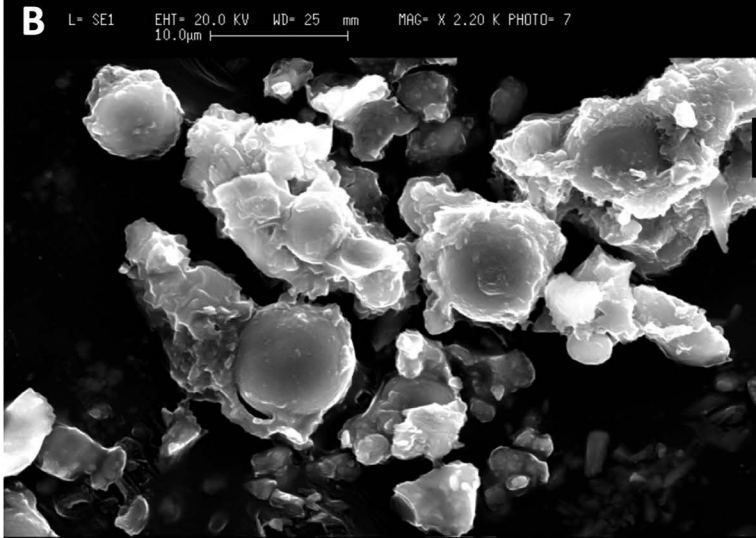
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Author	Year	Title	Area	Physico chemical analysis	Publication Title	Pages	Volume	Issue	Edited book
Burkitt, M. C.	1927	Rock Paintings in South Africa	southern Africa		Antiquity	226-228	1	2	
	1927	Saharan Rock-Paintings	northern Africa		Antiquity	353-355	1	3	
Newbold, D.	1928	Rock-pictures and Archaeology in the Libyan Desert	northern Africa		Antiquity	261-291	2	7	
Shaw, W. B. Kennedy	1936	Rock Paintings in the Libyan Desert	northern Africa		Antiquity	175-178	10	38	
Peel, R. F.	1939	Rock-paintings from the Libyan Desert. An Appendix to Dr H. A. Winklers's 'Rock-drawings of Southern Upper Egypt II'	northern Africa		Antiquity	389-402	13	52	
Malan, B. D.	1957	Old and New Rock Engravings in Natal, South Africa: A Zulu Game	southern Africa		Antiquity	153-154	31	123	
Graziosi, P.	1964	New Discoveries of Rock Paintings in Ethiopia Part I and II	eastern Africa		Antiquity	187-190	38	151	
Paradisi, U.	1965	Prehistoric Art in the Gebel el-Akhdar (Cyrenaica)	northern Africa		Antiquity	95-101	39	154	
Chaplin, J. H.	1967	Rock-drawings from the Lake Victoria Region	eastern Africa		Antiquity	146-147	41	162	
Hamo Sasson	1967	The Masange bowmen: a rock painting in central Tanzania	eastern Africa		Azania: Archaeological Research in Africa	193-194	2	1	
Posnansky, M.; Nelson, C.M.	1968	Rock Paintings and Excavations at Nyero, Uganda	eastern Africa		Azania: Archaeological Research in Africa	147-166	3	1	
Soper, R.C.	1968	Petroglyphs in northern Kenya	eastern Africa		Azania: Archaeological Research in Africa	189-191	3	1	
Soper, R.C.; Golden, B.	1969	An Archaeological Survey of Mwanza Region, Tanzania	eastern Africa		Azania: Archaeological Research in Africa	15-79	4	1	
ten Raa, E.	1969	Sandawe Prehistory and the Vernacular Tradition	eastern Africa		Azania: Archaeological Research in Africa	91-103	4	1	
Collinson, J.D.H.	1970	The Makalo Rock-Paintings of Nyamwezi	eastern Africa		Azania: Archaeological Research in Africa	55-63	5	1	
Odner, K.	1971	An Archaeological Survey of Iramba, Tanzania	eastern Africa		Azania: Archaeological Research in Africa	151-198,	6	1	
Phillipson, D.W.	1972	Early Iron Age Sites on the Zambian Copperbelt	central Africa		Azania: Archaeological Research in Africa	93-128	7	1	
Vinnicombe, P.	1972	Motivation in African rock art	southern Africa		Antiquity	124-133	46	182	
Willcox, A. R.	1972	Solar symbols in prehistoric rock art	all		Azania: Archaeological Research in Africa	167-169	1	7	
Bower, J. R. F.	1973	Seronera: Excavations at a Stone Bowl Site in the Serengeti National Park, Tanzania	eastern Africa		Azania: Archaeological Research in Africa	71-104	1	8	
Bower, J. R.F.	1973	Early Pottery and Other Finds from Kisii District, Western Kenya	eastern Africa		Azania: Archaeological Research in Africa	131-140	8	1	
Chaplin, J. H.	1974	The Prehistoric Rock Art of the Lake Victoria Region	eastern Africa		Azania: Archaeological Research in Africa	18264	1	9	
Mori, F.; Ponti, R.; Messina, A.; Flieger, M.; Havlicek, V.; Sinibaldi, M.	1974	The earliest Saharan rock-engravings	northern Africa		Antiquity	87-92	48	190	
Gramly, R.M.	1975	Meat-feasting Sites and Cattle Brands: Patterns of Rock-shelter Utilization in East Africa	eastern Africa		Azania: Archaeological Research in Africa	107-121	10	1	
Bower, J. R.F.	1976	Notes on rock art, and cord-rouletted pottery at the Seronera stone bow	eastern Africa		Azania: Archaeological Research in Africa	176-179	11	1	
Lynch, M.; Robbins, L.H.	1977	Animal Brands and the Interpretation of Rock Art in East Africa	eastern Africa		Current Anthropology	539	18	3	
Odak, O.	1977	Kakapeli and Other Recently Discovered Rock Paintings in the Western Highlands of Kenya	eastern Africa		Azania: Archaeological Research in Africa	187-192	12	1	
Soper, R.t; Lynch, M.	1977	The Stone-Circle Graves at Ng'amoritung'a, Southern Turkana District, Kenya	eastern Africa		Azania: Archaeological Research in Africa	193-208	12	1	
Milburn, M.	1978	Towards an absolute chronology of certain Saharan rock art	northern Africa		Antiquity	135-136	52	205	
Robertshaw, P.T.; Mawson, A.	1981	Excavations in Eastern Equatoria, Southern Sudan 1980	eastern Africa		Azania: Archaeological Research in Africa	55-95	16	1	

Lewis-Williams, J. D.; Bardill, P. N.; Biesele, M.; Yearwood, S.; Clegg, J.; Davis, W.; Groenfeldt, D.; Inskeep, R. R.; Jones, T.; Pretty, G.; Sauvet, G.; Sieveking, A.; Trbuhović, V.B.; Van Noten, F.; Vastokas, J. M.; Walker, N.	1982	The Economic and Social Context of Southern San Rock Art [and Comments and Reply]	southern Africa		Current Anthropology	429-449	23	4	
Soper, R.C.	1982	Archaeo-astronomical Cushites: Some Comments	eastern Africa		Azania: Archaeological Research in Africa	145-162	17	1	
Cooke, C. K.; Willcox, A. R.; Lewis-Williams, J. D.	1983	More on San Rock Art	southern Africa		Current Anthropology	538-545	24	4	
Davis, W.	1984	Representation and knowledge in the prehistoric rock art of Africa	all		African Archaeological Review	7-35	2	1	
Roset, J-P	1984	The prehistoric rock paintings of the Sahara	northern Africa		Endeavour	75-84	8	2	
Woodhouse, H. C.; Lewis-Williams, J. D.	1984	On the Social Context of Southern African Rock Art	southern Africa		Current Anthropology	244-248	25	2	
Doyle, L.R..; Wilcox, T.J.	1986	Statistical Analysis of Namoratunga: An Archaeoastronomical Site in Sub-Saharan Africa?	eastern Africa		Azania: Archaeological Research in Africa	125-129	21	1	
Conard, N.J.; Breunig, P.; Gonska, H.; Marinetti, G.	1988	The feasibility of dating rock paintings from Brandberg, Namibia, with 14C	southern Africa	dating	Journal of Archaeological Science	463-466	15	4	
Schepartz, L.A.	1988	Who were the latter Pleistocene eastern Africans?	eastern Africa		African Archaeological Review	57-72	6	1	
Fuchs, G.	1989	Rock engravings in the Wadi el-Barramiya, Eastern Desert of Egypt	northern Africa		African Archaeological Review	127-153	7	1	
Holl, A F.C.	1989	Social issues in Saharan prehistory	northern Africa		Journal of Anthropological Archaeology	313-354	8	4	
Parkington, J.	1989	Interpreting paintings without a commentary: meaning and motive, content and composition in the rock art of the western Cape, South Africa	southern Africa		Antiquity	13-26	63	238	
Bednarik, R.G.; Lewis-Williams, J. D.; Dowson, T. A.	1990	On Neuropsychology and Shamanism in Rock Art	southern Africa		Current Anthropology	77-84	31	1	
Thackeray, J.F.	1990	On concepts expressed in southern African rock art	southern Africa		Antiquity	139-144	64	242	
Mitchell, P.J.	1992	Archaeological research in Lesotho: a review of 120 years	southern Africa		African Archaeological Review	3-34	10	1	
Solomon, A.	1992	Gender, representation, and power in San ethnography and rock art	southern Africa		Journal of Anthropological Archaeology	291-329	11	4	
Lewis-Williams, D.; Dowson, T. A.; Deacon, J.	1993	Rock art and changing perceptions of southern Africa's past: Ezeljagdspoort reviewed	southern Africa		Antiquity	273-291	67	255	
Mazel, A.D.	1993	Rock art and Natal Drakensberg hunter–gatherer history: a reply to Dowson	southern Africa		Antiquity	889-892	67	257	
Prins, F.E.; Hall, S.	1994	Expressions of fertility in the rock art of Bantu-speaking agriculturists	southern Africa		African Archaeological Review	171-203	12	1	
Cremaschi, M	1996	The rock varnish in the Messak Sattafet (Fezzan, Libyan Sahara), age, archaeological context, and palaeoenvironmental implication.	northern Africa	varnish	Geoarchaeology	393-421	11	5	
Jolly, P.	1996	Symbiotic Interaction Between Black Farmers and South-Eastern San: Implications for Southern African Rock Art Studies, Ethnographic Analogy, and Hunter-Gatherer Cultural Identity	southern Africa		Current Anthropology	277-305	37	2	
Mabulla, Z.P.A..	1996	Tanzania's endangered heritage: A call for a protection program	eastern Africa		African Archaeological Review	197-214	13	3	
Mitchell, P.J.	1996	The late Quaternary landscape at Sehonghong in the Lesotho highlands, southern Africa	southern Africa		Antiquity	623-638	70	269	
Mazel, A.D.; Watchman, A.L.	1997	Accelerator radiocarbon dating of Natal Drakensberg paintings: results and implications	southern Africa	dating	Antiquity	445-449	71	272	
Dirk, H.	1998	'Battered Bulls': Rock Art Destruction in Egypt	northern Africa		African Archaeological Review	3-11	15	1	

Holl, A F.C.	1998	Livestock Husbandry, Pastoralisms, and Territoriality: The West African Record	western Africa		Journal of Anthropological Archaeology	143-165	17	2	
Jerardino, A.; Swanepoel, N.	1999	Painted Slabs from Steenbokfontein Cave: The Oldest Known Parietal Art in Southern Africa	southern Africa		Current Anthropology	542-547	40	4	
Saetersdal, T.	1999	Symbols of Cultural Identity: A Case Study from Tanzania	eastern Africa		African Archaeological Review	121-135	16	2	
Ferhat, N.; Striedter, K.H.; Tauveron, M.	2000	Les « Kel Essuf » : un nouveau faciès de l'art rupestre du Sahara central	northern Africa		Comptes Rendus de l'Académie des Sciences - Series IIA - Earth and Planetary Science	577-580	330	8	
Keenan, J.	2000	The theft of Saharan rock-art	northern Africa		Antiquity	287-288	74	284	
Stevenson, J.	2000	Shaman Images in San Rock Art: A Question of Gender	southern Africa		Representations of Gender from Prehistory to the Present	45-66			In: Donald M., Hurcombe L. (eds) Representations of Gender from Prehistory to the Present. Studies in Gender and Material Culture. Palgrave Macmillan, London
Williamson, B.S.	2000	Direct Testing of Rock Painting Pigments for Traces of Haemoglobin at Rose Cottage Cave, South Africa	southern Africa	dating	Journal of Archaeological Science	755-762	27	9	
Huyge, D.; Watchman, A.; Dapper, M. De; Marchi, E.	2001	Dating Egypt's oldest 'art': AMS 14C age determinations of rock varnishes covering petroglyphs at El-Hosh (Upper Egypt)	northern Africa	dating	Antiquity	68-72	75	287	
Kleinitz, C.	2001	Rock art in sub-Saharan Mali	northern Africa		Antiquity	799-800	75	290	
Mguni, S.	2001	Research into the formlings in the rock art of Zimbabwe	southern Africa		Antiquity	807-808	75	290	
Smith, B.W.	2001	Forbidden Images: Rock Paintings and the Nyau Secret Society of Central Mala≈µi and Eastern Zambia	central Africa		African Archaeological Review	187-212	18	4	
Wadley, L.	2001	Who Lived in Mauermanshoek Shelter, Korannaberg, South Africa?	southern Africa		African Archaeological Review	153-179	18	3	
Hendrickx, S.	2002	Bovines in Egyptian Predynastic and Early Dynastic Iconography	northern Africa		Droughts, Food and Culture	275-319			In: Hassan F.A. (eds) Droughts, Food and Culture. Springer, Boston, MA
Holl, A F.C.	2002	Time, Space, and Image Making: Rock Art from the Dhar Tichitt (Mauritania)	northern Africa		African Archaeological Review	75-118	19	2	
Ondimu, K. I.	2002	Cultural tourism in Kenya	eastern Africa		Annals of Tourism Research	1036-1047	29	4	
Zoppi, Angela; Signorini, G.F.; Lucarelli, F.; Bachechi, L.	2002	Characterisation of painting materials from Eritrea rock art sites with non-destructive spectroscopic techniques	eastern Africa	characterisation of pigment	Journal of Cultural Heritage	299-308	3	4	
Amara, I.	2003	Nouvelle approche de l'art rupestre de l'Atlas saharien : les figurations de la période tardive	northern Africa		L'Anthropologie	533-557	107	4	
Gutherz, X.; Cros, J-P; Lesur, J.	2003	The discovery of new rock paintings in the Horn of Africa: the rockshelters of Las Geel, Republic of Somaliland	eastern Africa		Journal of African Archaeology	227-236	1	2	
Lewis-Williams, J.D.	2003	Putting the record straight: Rock art and shamanism	southern Africa		Antiquity	165-170	77	295	
Parkington, J.	2003	Eland and Therianthropes in Southern African Rock Art: When Is a Person an Animal?	southern Africa		African Archaeological Review	135-147	20	3	
Lewis-Williams, J.D.; Pearce, D.G.	2004	Southern African San Rock Painting as Social Intervention: A Study of Rain-Control Images	southern Africa		African Archaeological Review	199-228	21	4	
Smith, B. W.; Ouzman, S.	2004	Taking Stock: Identifying Khoekhoen Herder Rock Art in Southern Africa	southern Africa		Current Anthropology	499-526	45	4	

van Schalkwyk, J. A.; Smith, B. W.	2004	Insiders and Outsiders: Sources for Reinterpreting a Historical Event	southern Africa		African Historical Archaeologies	325-346			In: Reid A.M., Lane P.J. (eds) African Historical Archaeologies. Contributions to Global Historical Archaeology. Springer, Boston, MA
Mabulla, A. Z.P.	2005	The Rock Art of Mara Region, Tanzania	eastern Africa		Azania: Archaeological Research in Africa	19-42	1	40	
Thackeray, J. F.	2005	The wounded roan: a contribution to the relation of hunting and trance in southern African rock art	southern Africa		Antiquity	5-18	79	303	
Badenhorst, S.	2006	Goats (Capra hircus), the Khoekhoen and Pastoralism: Current Evidence from Southern Africa	southern Africa		African Archaeological Review	45-53	23	3	
Chamberlain, N.	2006	Report on the Rock Art of South West Samburu District, Kenya	eastern Africa		Azania: Archaeological Research in Africa	139-157	1	41	
Deacon, J.	2006	Rock Art Conservation and Tourism	all		Journal of Archaeological Method and Theory	376-396	13	4	
Lewis-Williams, J.D.	2006	The Evolution of Theory, Method and Technique in Southern African Rock Art Research	southern Africa		Journal of Archaeological Method and Theory	341-375	13	4	
Mguni, S.	2006	King's monuments: identifying ‘formlings’ in southern African San rock paintings	southern Africa		Antiquity	583-598	80	309	
Mori, F.; Ponti, R.; Messina, A.; Flieger, M.; Havlicek, V.; Sinibaldi, M.	2006	Chemical characterization and AMS radiocarbon dating of the binder of a prehistoric rock pictograph at Tadrart Acacus, southern west Libya	northern Africa	dating	Journal of Cultural Heritage	344-349	7	4	
Hall, K. Meiklejohn, I.; Arocena, J.	2007	The thermal responses of rock art pigments: Implications for rock art weathering in southern Africa	southern Africa	biodegradation/weathering	Geomorphology	132-145	91	1	
Hœrlé, S.e; Huneau, F.c; Salomon, A.; Denis, A.	2007	Using the ground-penetrating radar to assess the conservation condition of rock-art sites	southern Africa		Comptes Rendus Geoscience	536-544	339	8	
McCall, G.S.	2007	Add shamans and stir? A critical review of the shamanism model of forager rock art production	southern Africa		Journal of Anthropological Archaeology	224-233	26	2	
Prinsloo, L.C.	2007	Rock hyraces: a cause of San rock art deterioration?	southern Africa	biodegradation/weathering	Journal of Raman Spectroscopy	496-503	38	5	
Challis, S.; Mitchell, P.; Orton, J.	2008	Fishing in the Rain: Control of Rain-Making and Aquatic Resources at a Previously Undescribed Rock Art Site in Highland Lesotho	southern Africa		Journal of African Archaeology	203-218	6	2	
Chami, F.A.	2008	Evidence of Ancient African Beliefs in Celestial Bodies	all		African Cultural Astronomy	121-133			In: Holbrook J.C., Urama J.O., Medupe R.T. (eds) African Cultural Astronomy. Astrophysics and Space Science Proceedings. Springer, Dordrecht
Dietzel, M.; Kolmer, H.; Pölt, P.; Simic, S.	2008	Desert varnish and petroglyphs on sandstone – Geochemical composition and climate changes from Pleistocene to Holocene (Libya)	northern Africa	varnish	Geochemistry	31-43	68	1	
Gutierrez, M.	2008	L'art rupestre de la province de Namibe, Angola: etude des sites par rapport à leur position topogrpahique	central Africa		Journal of African Archaeology	21-32	6	1	
Mire, S.	2008	The Discovery of Dhambalin Rock Art Site, Somaliland	eastern Africa		African Archaeological Review	153-168	25		
Prinsloo, L. C.; Barnard, W.; Meiklejohn, I.; Hall, K.	2008	The first Raman spectroscopic study of San rock art in the Ukhahlamba Drakensberg Park, South Africa	southern Africa	biodegradation/weathering	Journal of Raman Spectroscopy	646-654	39	5	
Solomon, Anne	2008	Myths, Making, and Consciousness: Differences and Dynamics in San Rock Arts	southern Africa		Current Anthropology	59-86	49	1	

Chennells, R.	2009	Putting Intellectual Property Rights into Practice: Experiences from the San	southern Africa		Indigenous Peoples, Consent and Benefit Sharing	211-229			In: Wynberg R., Schroeder D., Chennells R. (eds) Indigenous Peoples, Consent and Benefit Sharing. Springer, Dordrecht
Le Quellec, J--L. Fauvelle-Aymar, F-X; Bon, F.	2009	Essai de reconstitution d'un panneau rupestre : la scène de bataille de « Christol Cave », Afrique du Sud	southern Africa		L'Anthropologie	820-838	113	5, Part 2	
Lenssen-Erz, T.; Linstädter, J.	2009	Resources, Use Potential and Basic Needs	all		African Landscapes	159-197			n: Bubenzer O., Bollig M. (eds) African Landscapes. Studies in Human Ecology and Adaptation, vol 4. Springer, New York, NY
McCall, G.S.; Thomas, J.T.	2009	Re-examining the South African Middle-to-Later Stone Age transition: Multivariate analysis of the Umhlatuzana and Rose Cottage Cave stone tool assemblages	southern Africa		Azania: Archaeological Research in Africa	311-330	44	3	
Meiklejohn, K.I.; Hall, K.; Davis, J.K.	2009	Weathering of rock art at two sites in the KwaZulu-Natal Drakensberg, southern Africa	southern Africa	biodegradation/weathering	Journal of Archaeological Science	973-979	36	4	
Mguni, S.	2009	Natural and Supernatural Convergences: Trees in Southern African Rock Art	southern Africa		Current Anthropology	184-186	29	1	
Pearce, D. G.	2009	An introduction to the rock art of the Malilangwe Conservation Trust, southeastern Zimbabwe	southern Africa		Azania: Archaeological Research in Africa	331-342	3	44	
Poisblaud, B.	2009	Les Hommes d'Abourma (République de Djibouti)	eastern Africa		L'Anthropologie	848-860	113	5, Part 2	
Rifkin, R. F.	2009	Engraved art and acoustic resonance: exploring ritual and sound in north-western South Africa	southern Africa		Antiquity	585-601	83	321	
Rüther, H.; Chazan, M.; Schroeder, R.; Neeser, R.; Held, C.; Walker, S.J.; Matmon, A.; Horwitz, L.K.	2009	Laser scanning for conservation and research of African cultural heritage sites: the case study of Wonderwerk Cave, South Africa	southern Africa		Journal of Archaeological Science	1847-1856	36	9	
de la Rosa, A.J.F.; Pichler, W.; Rodrigue A.; Marín, S.G.	2010	The Libyco,ÄìBerber and Latino,ÄìCanarian Scripts and the Colonization of the Canary Islands	all		African Archaeological Review	13-41	27	1	
di Lernia, S.; Gallinaro, M.	2010	The date and context of Neolithic rock art in the Sahara: engravings and ceremonial monuments from Messak Settafet (south-west Libya)	northern Africa		Antiquity	954-975	84	326	
Marini, S.; de Faucamberge, È.; Katab, M.N.	2010	Découverte d'un site d'art rupestre en Cyrénaïque (Libye) : Kaf Tahr	northern Africa		L'Anthropologie	275-287	114	2	
Masseti, M.	2010	Holocene mammals of Libya: A biogeographical, historical and archaeozoological approach	northern Africa		Journal of Arid Environments	794-805	74	7	
Mazel, V.; Richardin, P.; Touboul, D.; Brunelle, Richard, C.; Laval, E.; Walter, P.; Laprévote, O.	2010	Animal urine as painting materials in African rock art revealed by cluster ToF-SIMSmass spectrometry imaging	northern Africa		Journal of Mass Spectrometry	944-950		45	
McCall, G.S.	2010	Changing Views of Drakensberg San Rock Art: Examining Landscape Use, Ritual Activity, and Contact through Multivariate Content-Based Spatial Analysis	southern Africa		American Antiquity	773-791	75	4	
Mol, L.; Viles, H.A.	2010	Geoelectric investigations into sandstone moisture regimes: Implications for rock weathering and the deterioration of San Rock Art in the Golden Gate Reserve, South Africa	southern Africa	biodegradation/weathering	Geomorphology	280-287	118	3	

Namono, C.	2010	Resolving the Authorship of the Geometric Rock Art of Uganda	eastern Africa		Journal of African Archaeology	239-257	8	2	
Sealy, J.	2010	Isotopic Evidence for the Antiquity of Cattle-Based Pastoralism in Southernmost Africa	southern Africa		Journal of African Archaeology	65-81	8	1	
Vogelsang, R.; Richter, J.; Jacobs, Z.; Eichhorn, B.; Linseele, V.; Roberts, R.G.	2010	New Excavations of Middle Stone Age Deposits at Apollo 11 Rockshelter, Namibia: Stratigraphy, Archaeology, Chronology and Past Environments	southern Africa		Journal of African Archaeology	185-218	8	2	
Bonneau, A; Brock, F; Higham, T; Pearce, D G; Pollard, A M	2011	An Improved Pretreatment Protocol for Radiocarbon Dating Black Pigments in San Rock Art	southern Africa	dating	Radiocarbon	419-428	53	3	
Darchuk, L.; Rotondo, G. Gatto; Swaenen, M.; Worobiec, A.; Tsybrii, Z.; Makarovska, Y.; Van Grieken, R.	2011	Composition of prehistoric rock-painting pigments from Egypt (Gilf Kébir area)	northern Africa	characterisation of pigment	Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy	34-38	83	1	
di Lernia, S.; Gallinaro, M.	2011	Working in a UNESCO WH Site. Problems and Practices on the Rock Art of Tadrart Akakus (SW Libya, Central Sahara)	northern Africa		Journal of African Archaeology	159-175	9	2	
Fernández, V. M.	2011	Schematic Rock Art, Rain-Making and Islam in the Ethio-Sudanese Borderlands	eastern Africa		African Archaeological Review	279-300	28	4	
Huyge, D.; Vandenberghe, D.A.G.; De Dapper, M.; Mees, F.s; Claes, W.r; Darnell, J.C.	2011	First evidence of Pleistocene rock art in North Africa: securing the age of the Qurta petroglyphs (Egypt) through OSL dating	northern Africa	dating	Antiquity	1184-1193	85	330	
Juwayeyi, Y.M.	2011	Excavating the History of Archaeology in Malawi	central Africa		Comparative Archaeologies	785-805			In: Lozny L. (eds) Comparative Archaeologies. Springer, New York, NY
Mire, S.	2011	The Knowledge-Centred Approach to the Somali Cultural Emergency and Heritage Development Assistance in Somaliland	eastern Africa		African Archaeological Review	71-91	28	1	
Namono, C.	2011	Pongo symbolism in the geometric rock art of Uganda	eastern Africa		African Archaeological Review	275-295	34	2	
Tournié, A.; Prinsloo, L. C.; Paris, C.; Colomban, P.; Smith, B.	2011	The first in situ Raman spectroscopic study of San rock art in South Africa: procedures and preliminary results	southern Africa	biodegradation/weathering	Journal of Raman Spectroscopy	399-406	42	3	
Zerboni, A.	2011	Holocene rock varnish on the Messak plateau (Libyan Sahara): Chronology of weathering processes	northern Africa	dating	Geomorphology	640-651	102	3-4	
Biagetti, S.; Kaci, A.A.; Mori, L.; di Lernia, S.	2012	Writing the desert: the 'Tifinagh' rock inscriptions of the Tadrart Acacus (southwestern Libya)	northern Africa		Azania: Archaeological Research in Africa	153-174	47	2	
Bonneau, A.; Pearce, D.G.; Pollard, A.M.	2012	A multi-technique characterization and provenance study of the pigments used in San rock art, South Africa	southern Africa	characterisation of pigment	Journal of Archaeological Science	287-294	39	2	
Challis, S; Lewis-Williams, J. D; Loubser, J.H.N.; Pearce, D.G.	2012	Spatial Distribution of Rock Art Sites in Didima Gorge, South Africa	southern Africa		American Antiquity	808-812	77	4	
Edwards, D.N.; Osman, A.; Tahir, Y.F.; Sadig, A.M.; el-Zein, I. S.	2012	On a Nubian frontier — landscapes of settlement on the Third Cataract of the Nile, Sudan	northern Africa		Azania: Archaeological Research in Africa	450-487	47	4	
Hendrickx, S.; Darnell, J.C.; Gatto, M.C.	2012	The earliest representations of royal power in Egypt: the rock drawings of Nag el-Hamdulab (Aswan)	northern Africa		Antiquity	1068-1083	86	334	
Lewis-Williams, J. D.; Pearce, D.G.	2012	The southern San and the trance dance: a pivotal debate in the interpretation of San rock paintings	southern Africa		Antiquity	696-706	86	333	
Lofrumento, C.; Ricci, M.; Bachechi, L.; De Feod D., Castellucci E.M.	2012	The first spectroscopic analysis of Ethiopian prehistoric rock painting	eastern Africa	characterisation of pigment	Journal of Raman Spectroscopy	809–816	43		
McCall, G.S.	2012	Altitude Adjustments: More on Didima Gorge and New Directions in Rock Art Research	southern Africa		American Antiquity	813-817	77	4	

Mercier, N.; Le Quellec, J-L; Hachid, M.; Agsous, S.; Grenet, M.	2012	OSL dating of quaternary deposits associated with the parietal art of the Tassili-n-Ajjer plateau (Central Sahara)	northern Africa	dating	Quaternary Geochronology	367-373	10		
Pfeiffer, S.	2012	Conditions for Evolution of Small Adult Body Size in Southern Africa	southern Africa		Current Anthropology	S383-S394	53	S6	
Biagetti, S.; Cancellieri, E.; Cremaschi, M.; Gauthier, C.; Gauthier, Y.; Zerboni, A.; Gallinaro, M.	2013	The 'Messak Project': Archaeological Research for Cultural Heritage Management in Sw Libya	northern Africa		Journal of African Archaeology	55-74	11	1	
Blench, R.	2013	Methods and results in the reconstruction of music history in Africa and a case study of instrumental polyphony	all		Azania: Archaeological Research in Africa	31-64	48	1	
Brunton, S.; Badenhorst, S.; Schoeman, M.H.	2013	Ritual fauna from Ratho Kroonkop: a second millennium AD rain control site in the Shashe-Limpopo Confluence area of South Africa	southern Africa		Azania: Archaeological Research in Africa	111-132	48	1	
Challis, S.; Hollmann, J.; McGranaghan, M.	2013	'Rain snakes' from the Senqu River: new light on Qing's commentary on San rock art from Sehonghong, Lesotho	southern Africa		Azania: Archaeological Research in Africa	331-354	3	48	
Ewague, A. El Graoui, M.; Boumaggard, E H	2013	Les représentations gravées de rhinocéros dans le Haut Atlas marocain	northern Africa		L'Anthropologie	256-268	117	2	
Gomes, H.; Rosina, P.; Holakooei, P.; Solomon, T.; Vaccaro, C.	2013	Identification of pigments used in rock art paintings in Gode Roriso-Ethiopia using Micro-Raman spectroscopy	eastern Africa	characterisation of pigment	Journal of Archaeological Science	4073-4082	40	11	
Heimlich, G.; Richardin, P.; Gandolfo, N.; Laval, E.; Menu, M.	2013	First Direct Radiocarbon Dating of the Lower Congo Rock Art (Democratic Republic of the Congo)	central Africa	dating	Archaeometry	1383-1390	55	2	
Kessy, E.T.	2013	The Transition from the Later Stone Age to Iron Age in Kondoa, Central Tanzania	eastern Africa		African Archaeological Review	225-252	30	3	
Prinsloo, L.C.; Tournié, A.; Colomban, P.; Paris, C. Bassett, S.T.	2013	In search of the optimum Raman/IR signatures of potential ingredients used in San/Bushman rock art paint	southern Africa	characterisation of pigment	Journal of Archaeological Science	2981-2990	40	7	
Solomon, A-	2013	The death of trance: recent perspectives on San ethnographies and rock arts	southern Africa		Antiquity	1208-1213	87	338	
Barnett, T.; Guagnin, M.	2014	Changing Places: Rock Art and Holocene Landscapes in the Wadi al-Ajal, South-West Libya	northern Africa		Journal of African Archaeology	165-182	11	2	
Deacon, J.	2014	An Overview of the History of the Nomination of Cultural World Heritage Sites in Africa	all		The Management Of Cultural World Heritage Sites and Development In Africa	1-16			In: Makuvaza S. (eds) The Management Of Cultural World Heritage Sites and Development In Africa. SpringerBriefs in Archaeology. Springer, New York, NY
Guagnin, M.	2014	Patina and Environment in the Wadi al-Hayat: Towards a Chronology for the Rock Art of the Central Sahara	northern Africa		African Archaeological Review	407-423	31	3	
Hampson, J.G.	2014	Conflict on the Frontier: San Rock Art, Spirituality, and Historical Narrative in the Free State Province, South Africa	southern Africa		Rock Art and Sacred Landscapes	103-115			In: Gillette D., Greer M., Helene Hayward M., Breen Murray W. (eds) Rock Art and Sacred Landscapes. One World Archaeology, vol 8. Springer, New York, NY

Hollmann, J.C.	2014	'Geometric' Motifs in Khoe-San Rock Art: Depictions of Designs, Decorations and Ornaments in the Gestoptefontein-Driekuil Complex, South Africa	southern Africa		Journal of African Archaeology	25-42	12	1	
King, R.; Arthur, C.	2014	Development-led archaeology and ethics in Lesotho	southern Africa		Azania: Archaeological Research in Africa	168-183	49	2	
Rosina, P.; Gomes, H.; Nash, G. H.; Solomon, T.	2014	Dating beeswax pictograms from Gode Roriso in Ethiopia	eastern Africa	dating	Journal of Archaeological Science	206-212	49		
Zubieta, L.F.	2014	The Rock Art of Chinamwali and Its Sacred Landscape	southern Africa		Rock Art and Sacred Landscapes	49-66			In: Gillette D., Greer M., Helene Hayward M., Breen Murray W. (eds) Rock Art and Sacred Landscapes. One World Archaeology, vol 8. Springer, New York, NY
Auclair, L.; Hoarau, B.; Ewague, A.	2015	Les chasseurs du Sahara atlantique ont-ils inventé la métallurgie ? Les haches « à tranchant en éventail » dans l'art rupestre du sud marocain	northern Africa		L'Anthropologie	72-88	119	1	
Goudie, A.; Viles, H.	2015	Twyfelfontein and its Desert Varnish	southern Africa	varnish	Landscapes and Landforms of Namibia	67-68			In: Landscapes and Landforms of Namibia. World Geomorphological Landscapes. Springer, Dordrecht
Hollmann, J.C.	2015	Allusions to Agriculturist Rituals in Hunter-Gatherer Rock Art? eMkhobeni Shelter, Northern uKhahlamba-Drakensberg, KwaZulu-Natal, South Africa	southern Africa		African Archaeological Review	505-535	32	3	
Hollmann, J.C.	2015	Bees, honey and brood: southern African hunter-gatherer rock paintings of bees and bees' nests, uKhahlamba-Drakensberg, KwaZulu-Natal, South Africa	southern Africa		Azania: Archaeological Research in Africa	343-371	50	3	
Le Quellec, J-L; Duquesnoy, F.; Defrasne, C.	2015	Digital image enhancement with DStretch®: Is complexity always necessary for efficiency?	northern Africa		Digital Applications in Archaeology and Cultural Heritage	55-67	2	2	
Lewis-Williams, J.D.; Pearce, D.G.	2015	San rock art: evidence and argument	southern Africa		Antiquity	732-739	89	345	
Mire, S.	2015	Mapping the Archaeology of Somaliland: Religion, Art, Script, Time, Urbanism, Trade and Empire	eastern Africa		African Archaeological Review	111-136	32	1	
Olojede, A.; Suleman, H.	2015	Investigating Image Processing Algorithms for Navigating Cultural Heritage Spaces Using Mobile Devices	southern Africa		Digital Libraries: Providing Quality Information	215-224			In: Allen R., Hunter J., Zeng M. (eds) Digital Libraries: Providing Quality Information. ICADL 2015. Lecture Notes in Computer Science, vol 9469. Springer, Cham
Russell, T.; Lander, F.	2015	'The bees are our sheep': the role of honey and fat in the transition to livestock keeping during the last two thousand years in southernmost Africa	southern Africa		Azania: Archaeological Research in Africa	318-342	50	3	
Russell, T.; Lander, F.	2015	'What is consumed is wasted': from foraging to herding in the southern African Later Stone Age	southern Africa		Azania: Archaeological Research in Africa	267-317	50	3	
Tomášková, S.	2015	Digital technologies in context: Prehistoric engravings in the Northern Cape, South Africa	southern Africa		Digital Applications in Archaeology and Cultural Heritage	222-232	2	2	

Coulson, S.; Segadika, P; Walker, N.	2016	Ritual in the Hunter-Gatherer/Early Pastoralist Period: Evidence from Tsodilo Hills, Botswana	southern Africa		African Archaeological Review	205-222	33	2	
Currie, A.	2016	Ethnographic analogy, the comparative method, and archaeological special pleading	all		Studies in History and Philosophy of Science Part A	84-94	55		
di Lernia, S.; Bruni, S-; Cislaghi, I.; Cremaschi, M.; Gallinaro, M.; Gugliemi, V.; Mercuri, A.M.; Poggi, G.; Zerboni, A.	2016	Colour in context. Pigments and other coloured residues from the Early-Middle Holocene site of Takarkori (SW Libya)	northern Africa	characterisation of pigment	Archaeological and Anthropological Sciences	381-402	8	2	
Gallinaro, M, Biagetti, S.	2016	The role of mobility in Saharan archaeological research (1960-present)	all		Azania: Archaeological Research in Africa	435-452	51	4	
Hœrlé, S.; Pearce, D. G.; Bertrand, L.; Sandt, CH.; Menu, M.	2016	Imaging the Layered Fabric Of Paints From Nomansland Rock Art (South Africa)	southern Africa	characterisation of pigment	Archaeometry	182-199	58	SUPLL. 1	
Honoré, E.; Rakza, T.; Senut, B.; Deruelle, P.; Pouydebat, E.	2016	First identification of non-human stencil hands at Wadi Sūra II (Egypt): A morphometric study for new insights into rock art symbolism	northern Africa		Journal of Archaeological Science: Reports	242-247	6		
Morris, D.	2016	Revisiting the Parietal Art of Wonderwerk Cave, South Africa	southern Africa		African Archaeological Review	265-275	33	3	
Robbins, L.H.; Brook, G.A.; Murphy, M.L.; Ivester, A.H.; Campbell, A.C.	2016	The Kalahari During MIS 6-2 (190,Äì12¬†ka): Archaeology, Paleoenvironment, and Population Dynamics	southern Africa		Africa from MIS 6-2	175-193			In: Jones S., Stewart B. (eds) Africa from MIS 6-2. Vertebrate Paleobiology and Paleoanthropology. Springer, Dordrecht
Roubet, C.; Amara, I.	2016	From art to context: Holocene roots of an Initial Neolithic Pastoralism (INP) in the Atlas Ouled Naïl, Algeria	northern Africa		Quaternary International	103-122	410		
Soler, J.; Soler, N.	2016	Cattle without herdsmen: Animal and human beings in the prehistoric rock art of the Western Sahara	northern Africa		Quaternary International	93-102	410		
Zubieta, L.F.	2016	Learning through practise: Chewa women's roles and the use of rock art in passing on cultural knowledge	central Africa		Journal of Anthropological Archaeology	13-28	43		
Biittner, K.M.; Sawchuk, E.A.; Miller, J.M.; Werner, J.J.; Bushozi, P.M.; Willoughby, P.R.	2017	Excavations at Mlambalasi Rockshelter: a Terminal Pleistocene to Recent Iron Age Record in Southern Tanzania	eastern Africa		African Archaeological Review	275-295	34	2	
Bonneau, A; Staff, R A; Higham, T; Brock, F; Pearce, D G; Mitchell, P J	2017	Successfully Dating Rock Art in Southern Africa Using Improved Sampling Methods and New Characterization and Pretreatment Protocols	southern Africa	dating	Radiocarbon	659-677	59	3	
Bonneau, A.; Pearce, D.; Mitchell, P.; Staff, R.; Arthur, C.; Mallen, L.; Brock, F.; Higham, T.	2017	The earliest directly dated rock paintings from southern Africa: new AMS radiocarbon dates	southern Africa	dating	Antiquity	322-333	91	356	
Dumont, H.J.	2017	A freshwater medusa (Limnocnida) pictured in the Neolithic rock art of the Central Sahara (Tan Zoumaitek, Tamrit, Algeria)	northern Africa		Hydrobiologia	1-5	802	1	
Hardtke, F.E.	2017	Rock art interpretive approaches – Devising frameworks to maximally utilise independent lines of evidence	northern Africa		Journal of Arid Environments	22-27	143		
Kinahan, J.	2017	The Dancing Kudu: women's initiation in the Namib Desert during the second millennium AD	southern Africa		Antiquity	1043-1057	91	358	
Namono, C.	2017	Soaring spirits: rock art, initiation and the Sor secret society of spirit mediums of Karamoja, Uganda	eastern Africa		Azania: Archaeological Research in Africa	284-304	52	3	
Parsons, I.; Lombard, M.	2017	The power of women in dairying communities of eastern and southern Africa	all		Azania: Archaeological Research in Africa	33-48	52	1	
Riemer, H.; Kröpelin, S.; Zboray, A.	2017	Climate, styles and archaeology: an integral approach towards an absolute chronology of the rock art in the Libyan Desert (Eastern Sahara)	northern Africa		Antiquity	7-23	91	355	

Soukopova, J.	2017	Central Saharan rock art: Considering the kettles and cupules	northern Africa		Journal of Arid Environments	10-14	143		
Wessels, M.	2017	Qing and the Animals of the Drakensberg-Maloti	southern Africa		Indigenous Creatures, Native Knowledges, and the Arts	13-33			In: Woodward W., McHugh S. (eds) Indigenous Creatures, Native Knowledges, and the Arts. Palgrave Studies in Animals and Literature. Palgrave Macmillan, Cham
Zipkin, A.M.; Ambrose, S.H.; Hanchar, J.M.; Piccoli, P.M.; Brooks, A.S.; Anthony, E. Y.	2017	Elemental fingerprinting of Kenya Rift Valley ochre deposits for provenance studies of rock art and archaeological pigments	eastern Africa	characterisation of pigment	Quaternary International	42-59	430		
Anderson, H.; Galvin, E.; de Torres Rodriguez, J.	2018	Museological Approaches to the Management of Digital Research and Engagement: The African Rock Art Image Project	all		African Archaeological Review	321-337	35	2	
Barbaza, M.	2018	Cultures of peace and the art of war in Saharan rock art	northern Africa		Quaternary International	125-135	491		
Blundell, G.; Ferreira, A.	2018	Tusk and transformation in southern African San rock art: an iconographic analysis of WAR2	southern Africa		Azania: Archaeological Research in Africa	341-368	3	53	
Challis, S.	2018	Collections, Collecting and Collectives: Gathering Heritage Data with Communities in the Mountains of Matatiele and Lesotho, Southern Africa	southern Africa		African Archaeological Review	257-268	35	2	
Deacon, J.; Wiltshire, N.; du Plessis, R.	2018	Designing Digital Recording for Volunteers in Rock Art Surveys, Management Plans and Public Outreach in the Cederberg, South Africa	southern Africa		African Archaeological Review	225-239	35	2	
di Lernia, S.	2018	A (Digital) Future for Saharan Rock Art?	northern Africa		African Archaeological Review	299-319	35	2	
Gallinaro, M.; Zerboni, A.; Solomon, T.; Spinapolice, E.E.	2018	Rock Art Between Preservation, Research and Sustainable Development—a Perspective from Southern Ethiopia	eastern Africa		African Archaeological Review	211-223	35	2	
Hollmann, J.C.	2018	Digital Technology in Research and Documentation of Hunter-Gatherer Rock Art in South Africa	southern Africa		African Archaeological Review	157-168	35	2	
Hubbard, P.; Taruvinga, P.; Nyathi, P.; Makuvaza, S.	2018	Conservation, Stakeholders and Local Politics: The Management of the Matobo Hills World Heritage Site, South Western Zimbabwe	southern Africa		Aspects of Management Planning for Cultural World Heritage Sites	103-117			In: Makuvaza S. (eds) Aspects of Management Planning for Cultural World Heritage Sites. Springer, Cham
Iriarte, M.; Hernanz, A.; Gavira-Vallejo, J. M.; de Buruaga, A.S.; Martín, S.	2018	Micro-Raman spectroscopy of rock paintings from the Galb Budarga and Tuama Budarga rock shelters, Western Sahara	northern Africa	characterisation of pigment	Microchemical Journal	250-257	137		
Kinahan, J.	2018	A ritual assemblage from the third millennium BC in the Namib Desert and its implications for the archaeology and rock art of shamanic performance	southern Africa		Azania: Archaeological Research in Africa	40-62	1	53	
Laue , G.; Challis, S.; Mullen, A.	2018	Concerning Heritage: Lessons from Rock Art Management in the Maloti-Drakensberg Park World Heritage Site	southern Africa		Aspects of Management Planning for Cultural World Heritage Sites	119-130			In: Makuvaza S. (eds) Aspects of Management Planning for Cultural World Heritage Sites. Springer, Cham
Lenssen-Erz, T.; Fäder, E.; Jesse, F.; Wilmeroth, J.	2018	Digital Management of Rock Art: the African Archaeology Archive Cologne (AAArC)	all		African Archaeological Review	285-298	35	2	

Mazel, A.D.	2018	Managing the Rock Art of the¬†uKhahlamba-Drakensberg: Progress, Blind Spots and Challenges	southern Africa		Aspects of Management Planning for Cultural World Heritage Sites	131-145			In: Makuvaza S. (eds) Aspects of Management Planning for Cultural World Heritage Sites. Springer, Cham
Namono, C.	2018	Digital Technology and a Community Framework for Heritage Rock Art Tourism, Makgabeng Plateau, South Africa	southern Africa		African Archaeological Review	269-284	35	2	
Negash, A.	2018	Regional Variation of the Rock Art of Ethiopia: a Geological Perspective	eastern Africa		African Archaeological Review	407-416	35	3	
Polkowski, P.L.	2018	Working on Rock Art in the Dakhleh Oasis: Some Thoughts on Threats to Petroglyphs and Possibilities of Research in the Western Desert, Egypt	northern Africa		African Archaeological Review	191-210	35	2	
Quesada, E. ; Sanchidrián, J.L.; Mohamed, H.; Abderrahman, H.; Malainin, C.; Salem, M.; Abdalla, N.D.M.	2018	Empowering the Local Saharawi People: Training for Rock Art Documentation in Western Sahara (DARSSO Project)	northern Africa		African Archaeological Review	241-256	35	2	
Rosina, P.; Oosterbeek, L.; Pombares Martin, C.; Gomes, H.	2018	Dating and Raman spectroscopy of rock art paintings in Ebo, Angola	central Africa	dating	Azania: Archaeological Research in Africa	83-97	53	1	
Soukopova, J.	2018	Decorated boulders and other neglected features of the Central Saharan rock art	northern Africa		Journal of Arid Environments	96-105	156		
Urcia, A.; Darnell, J.C.; Darnell, C.M.; Zaia, S.E.	2018	From Plastic Sheets to Tablet PCs: A Digital Epigraphic Method for Recording Egyptian Rock Art and Inscriptions	northern Africa		African Archaeological Review	169-189	35	2	
Ventura, H.; Soler, J.; Narcís, S.; Serra, C.	2018	The Style of Blugzeimat and the ‚ÄúMasks‚Äù of the Prehistoric Rock Art of the Western Sahara: New Evidence for Long-Distance Contacts	northern Africa		African Archaeological Review	609-626	35	4	
Witelson, D.	2018	Frogs or people: Dorothea Bleek and a genealogy of ideas in rock art research	southern Africa		Azania: Archaeological Research in Africa	185-208	2	53	
Wojcieszak, M.	2018	Material processed with 58,000-year-old grindstones from Sibudu (KwaZulu-Natal, South Africa) identified by means of Raman microspectroscopy	southern Africa	characterisation of pigment	Journal of Raman Spectroscopy	830-841	49	5	
Bouajaja, M.; Ikhrizzi, M.; Lemjidi, A.	2019	Art rupestre de la région de l'Oued Eççayad-Noun, Sud marocain : nouvelles données	northern Africa		L'Anthropologie	170-179	123	1	
Ferentinou, M.	2019	Rockfall Hazard Assessment at the World Heritage Site of Giant, Castle Reserve, Drakensberg, South Africa	southern Africa		IAEG/AEG Annual Meeting Proceedings, San Francisco, California, 2018 - Volume 1	85-91			In: Shakoor A., Cato K. (eds) IAEG/AEG Annual Meeting Proceedings, San Francisco, California, 2018 - Volume 1. Springer, Cham
Graff, G.; Bailly, M.; Lemjidi, A.; Ewague, A.; André, G.; Loyer, M.; de Graa, A.; Simenel, R.; Billault, L.; Oulmakki, N.	2019	Azrou Klane (région d'Assa-Zag, vallée du bas Drâa, Maroc) : une nouvelle scène rupestre complexe attribuable à la phase « bovidienne » finale	northern Africa		L'Anthropologie	156-169	123	1	
Honoré, E.	2019	Prehistoric landmarks in contrasted territories: Rock art of the Libyan Desert massifs, Egypt	northern Africa		Quaternary International	264-272	503		
Lemjidi, F.; Oulmakki, N.	2019	Note sur la découverte de nouvelles gravures dans le nord d'Akka (Maroc)	northern Africa		L'Anthropologie	116-122	123	1	

Mauran, G.; Lebon, M.; Détroit, F.; Caron, B.; Nankela, A.; Pleurdeau, D.; Bahain, J-J.	2019	First in situ pXRF analyses of rock paintings in Erongo, Namibia: results, current limits, and prospects	southern Africa	characterisation of pigment	Archaeological and Anthropological Sciences	4123–4145	11		
Pecchioni, E.; Ricci, M.; Vaselli, O.; Lofrumento, C.; Levchenko, V.; Giamello, M.; Scala, A.; Williams, A.; Turchetta, B.	2019	Chemical and mineralogical characterization and 14C dating of white and red pigments in the rock paintings from Nyero (Uganda)	eastern Africa	dating	Microchemical Journal	329-338	144		
Soleilhavoup, F.	2019	Personnages dans l'art saharien : le réel et l'imaginé	northern Africa		L'Anthropologie	123-155	123	1	
Thackeray, J.F.	2019	L'apport de l'ethnographie au concept de « chasse magique par empathie » (ou compatissante) et de chamanisme dans l'art préhistorique d'Afrique australe	southern Africa		L'Anthropologie	180-188	123	1	
Guenther, M.	2020	Human-Animal Relationships in San and Hunter-Gatherer Cosmology, Volume II	southern Africa		Human-Animal Relationships in San and Hunter-Gatherer Cosmology, Volume II				