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Review

Old and New Approaches in Rock Art: Using Animal Motifs to Identify Palaeohabitats

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Abstract: Humans are well known to have made paintings and engravings on rock surfaces, both geometric motifs with an unclear representation, and representative motifs that refer to their activities and aspects of their environment. This kind of art is widespread across time and space and has throughout history been subjected to various kinds of approaches. Typically, rock art research focuses on its role in the development of the hominin brain and the capability of abstract thinking, as well as on interpreting representative and non-representative motifs. Ethnography and cognitive research have often stressed that rock art is the result of ritual practises and the expression of a shamanic belief system. However, representative motifs may also shed light on a region's ecological and human prehistory. Here, we give an overview of the general development of rock art study: we highlight the development of artistic behaviour in humans by discussing aesthetic preferences, and the creation of simple geometric motifs and eventually representative motifs, before describing the theories that developed from the earliest study of rock art. These have largely focused on classification and interpretation of the motifs, and often centred on Palaeolithic material from Europe. We then move on to discuss how ethnography among rock art creating communities often suggests important relationships between specific animals in both the realms of spiritual belief systems and within the local environment. Lastly, we highlight how rock art reflects the local penecontemporaneous environment when it comes to depictions of animals, plants, technologies, humans and their activities. We argue that animal depictions are a useful subject to study on a large scale, as it is the most widespread representative motif, and the most appropriate subject to study when the goal is to draw conclusions on environmental changes. Rock art can fill gaps in the local archaeological record and generate new questions of it, but also offer new insights into the history of local human–animal interaction: animal species depicted and/or referred to in rock art are likely to have been a selection of spiritually important animals and a comparison to known information on human interactions with local species may reveal patterns among which animals are selected for local rock art depictions and which are not. Interregional comparison can in turn shed light on whether humans in general tend to ascribe meaning to the same types of animals. We end the review with suggestions for future study, with a special role for computational methods, which are suitable for the analysis of large databases of visual imagery.

Keywords: rock art; shamanism; ethnography; environmental studies; environmental change; animal depictions

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1. Introduction

Rock art, the creation of paintings or engravings on open rock surfaces or in caves, is a worldwide phenomenon. Two common high-level groupings are geometric motifs, which are shapes with an unclear representation, and representative motifs, which clearly

depict identifiable animals, humans, plants or objects. Both types of motifs have been the subject of scientific study for several decades. Palaeolithic cave art in Europe was initially the most popular subject of study for rock art researchers before other regions, such as several African and Asian countries and Australia, were considered [1–3]. However, these early studies focused on understanding the meaning behind the images and a shamanic interpretation often predominated, since non-European populations that practiced, or still practice, rock art creation allegedly suggested that rock art images were often the result of a shamanic trance practice or were otherwise a reflection of a spiritual belief system [1,4,5]. Subsequently, more thorough study among rock art creating populations strengthened this view [5,6]. This vision of rock art as an expression of a shamanic belief system is still quite popular and is sometimes even speculatively applied to aforementioned Palaeolithic cave art in Europe from a comparative perspective [7].

However, representative rock art images such as animals, human inventions (weapons, boats, ritualistic attributes), activities and plant depictions may provide useful information about the environment of a rock art-creating community around the time the art was made. In recent times, this type of rock art study has been increasingly applied [8–10], although not yet on a worldwide scale. In this paper, we present an overview of the history of rock art studies, with a focus on how the early interpretive method of rock art research changed throughout time. We then focus on how rock art as a proxy of its (palaeo-)environment introduces not only a new possibility of looking at rock art, but could also potentially be a valuable addition to the traditional archaeological record of a region's socioenvironmental history. We aim to argue that a large-scale analysis of rock art motifs that depict aspects of the environment may provide insight into a region's palaeoenvironmental history, both natural and cultural, and that a comparison between regions (using animal motifs in particular) will shed light on how this history varies depending on ecology and history.

2. Rock Art as a Challenging Subject of Research

2.1. The History of Art

Many rock art studies, particularly the early ones that focused on cave art from Europe, researched rock art with the intention of finding out what caused ancient humans to start producing rock art. A preference for interesting-looking yet non-functional objects may already have been present among some ancient human ancestors: the South African species *Australopithecus africanus* apparently carried the anthropomorphic Makapansgat cobble around, although this cobble is unlikely to have been modified and its resemblance to a face seems to have been natural [11].

Another early case of interest in aesthetics is the use of perforated shell beads, which were possibly used as decoration, from 82,000 BP in Morocco and from 75,000 BP from South Africa, as well as an early use of pigments, which were also used by Neanderthals [12–14]. This could suggest that the use of certain objects and bright colours such as red was the result of undefined aesthetic preference, or of possible ritual practice and thus symbolic thinking.

The first type of rock art seems to have been non-representational, resembling simple lines, dots, and zigzags, leaving scholars to speculate on whether this was even intentioned to be "art", or whether it was simply meant to mark certain locations. The creation of non-representational paintings and engravings was practised by multiple human species: examples include a shell engraved with a zigzag motif likely to have been made by *Homo erectus* in Trinil (Southeast Asia) (Figure 1) [15], and square motifs in red ochre from caves on the Iberian peninsula (Europe) made by Neanderthals long before the arrival of *Homo sapiens* in the region (Figure 2) [16,17]. It should be noted that some reservations should be made regarding these cases: it is always difficult to confidently state that such motifs are in fact artistic expressions, especially in the case of engravings, since these could also be butchery marks or tool-making marks that accidently form a composition [18]. Additionally, the red ochre motifs from the Iberian peninsula were dated using a method that has been

widely critiqued, causing the possible Neanderthal origin of these motifs to be heavily debated [19].

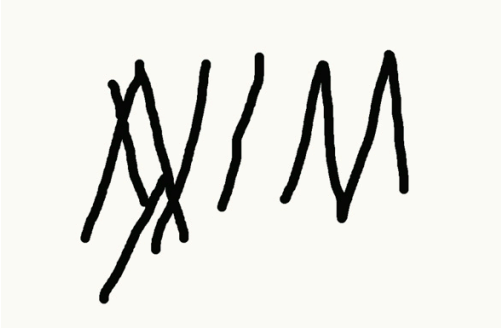

Figure 1. A trace of the crosshatch carved into a shell at Trinil, likely by a Homo erectus. Copyright M. Korpershoek. Traced from the original image in Joordens et al. [15].

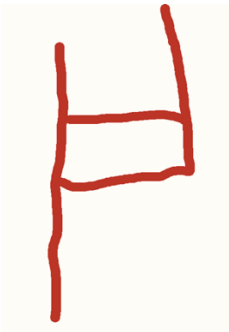

Figure 2. A trace of the motif painted in red ochre from the Iberian Peninsula, likely by Neanderthals. Copyright M. Korpershoek. Traced from the original image in Hoffmann et al. [16].

Until recently, the earliest example of non-representational art that was likely made by *Homo sapiens* was estimated to be a 77,000 year-old engraving in Blombos Cave, South Africa, where shell beads and ochre engravings from the same time period have also been found [20,21]. However, a recently discovered piece of cemented sand with a triangular shape and minimal carvings from the Cape south Coast of South Africa is now suspected to be a depiction of a ray. This "sculpture" could be 140,000 years old, and would in that case be both the oldest example of artistic expression and the oldest animal depiction made by (likely) *Homo sapiens* [22].

The earliest example of representational rock art worldwide would be the depiction of a pig from Sulawesi, Indonesia, dating to 51,200 BP [23], significantly later than the creation of non-representational motifs. This is a trend that can be observed on every continent (Figure 3). Apart from South America, where the potential oldest rock art includes animals but not geometric motifs, simple geometric shapes such as zigzags, crosshatches and cupule marks predate representational motifs by thousands of years. This gap is particularly large for Asia, Africa and Europe. This may be explained by the fact that the oldest geometric motifs are attributed to other hominin species, such as *Homo erectus* in Asia and Neanderthals in Europe [7,15,16].

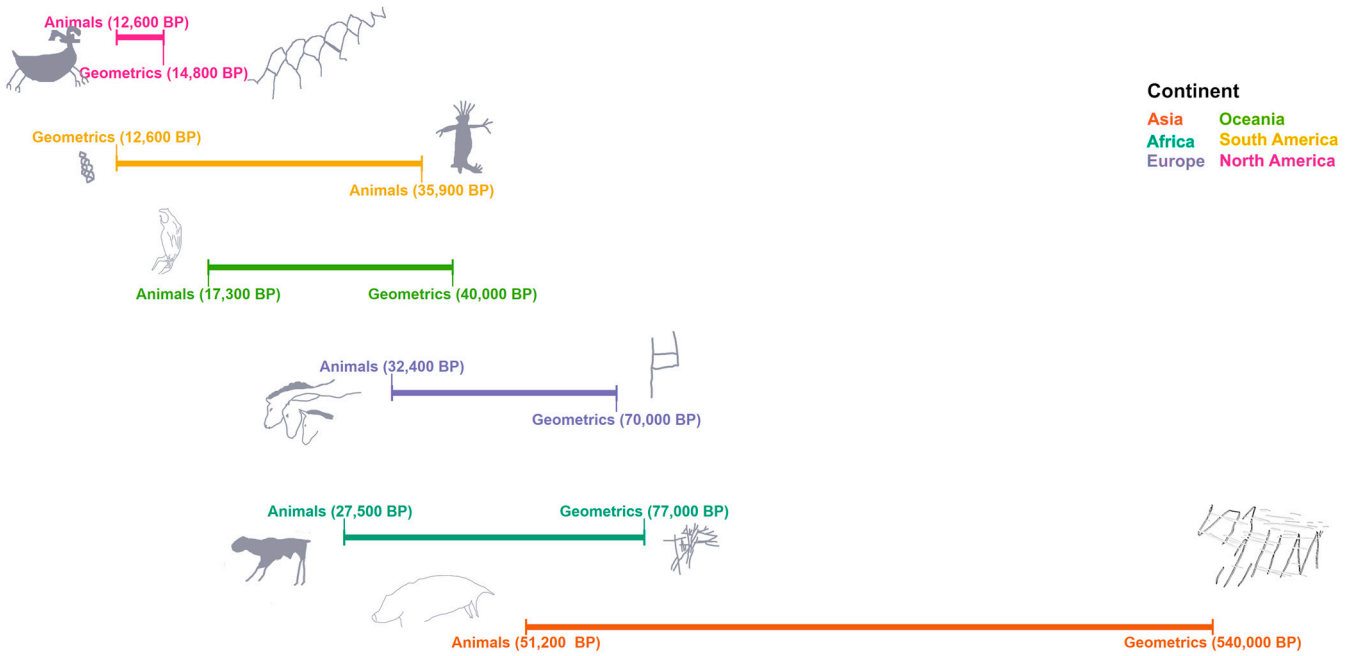

Figure 3. A timeline of the earliest occurrences of geometric and animal motifs in rock art on each continent. The X-axis is based on a logarithmic scale (base 10). Images by Mirte Korpershoek, traced from the following citations: [15,18–20,23–31]. The oldest example of non-representational rock art from Oceania is a painted rock fragment, not suitable for tracing.

On all continents, animals are the oldest representational motifs. In Southeast Asia, this appears to be the aforementioned pig depiction (Figure 4), in Oceania, it is likely to be the depiction of a kangaroo dating from 17,500 BP [28] and in Europe, it is multiple kinds of animals from Chauvet cave [26]. In Southern Africa, the oldest representational rock art depictions seem to be depictions of animals at Apollo 11 Cave, Namibia (Figure 5). The depictions are of quadrupeds that are not clearly identifiable, dating from around 25,000 years ago [27,32]. In North America, the oldest animal depictions are likely to have been bighorn sheep from the Mojave desert [30] and in South America, there are various animal motifs from the Serra da Capivara national park [25].

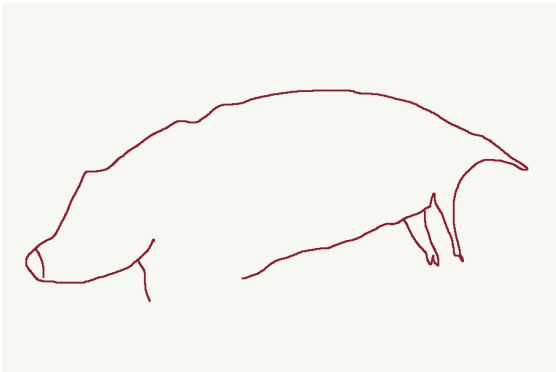

Figure 4. A trace of the depiction of a pig figure from Indonesia, now possibly the oldest depiction of an animal in rock art. Copyright M. Korpershoek. Traced from the original image in Oktaviana et al. [23].

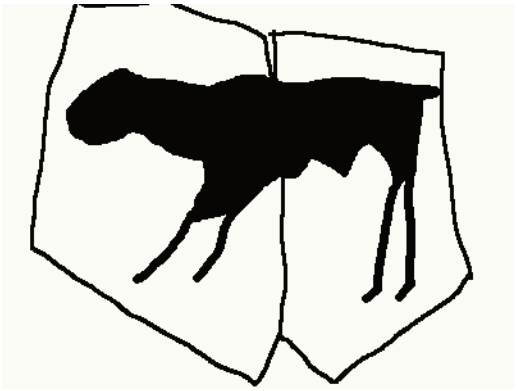

Figure 5. A trace of the depiction of an unknown quadruped from a slab of stone at Apollo 11 Cave, Namibia. The oldest depiction of an animal in Africa. Copyright M. Korpershoek. Traced from the original image in Wendt [27].

In The Mind in the Cave, David Lewis-Williams notes the possibility that the development of representational rock art by *Homo sapiens* was caused by the Aurignacian culture's wish to distinguish themselves from the Châttelperonian Neanderthals in southern France and northern Spain who they were sharing their environment with at the time, and who may not have had the capabilities of creating realistically drawn images [7]. It is indeed curious that so many representative instances of rock art in Europe can be found in a region where *Homo sapiens* and *Homo neanderthalensis* may have coexisted. It could after all mean that the development of the creation of representational art was the consequence of different kinds of human species interacting with each other and wishing to set themselves apart from each other. However, this theory does not account for the first rock art creation on the other continents: there is no evidence, for example, that *Homo sapiens* coexisted with other hominin species in Indonesia around the time the pig depictions were created. The point that the creation of representational rock art is a skill that seems to be uniquely possessed by our own hominin species still stands, no matter what prompted them to start making it. The fact that animal depictions are so prevalent in the oldest rock art suggests that animals played an important part in prehistoric communities on a worldwide scale. Since the beginning of rock art studies, various types of research have been undertaken to investigate the reasons for this.

We elaborate on this in the section "The History of Rock Art Study", where we also describe the first scientific interpretations of rock art motifs. After a description of methods used to date rock art and their implications and limitations, we move on to discuss the caveats of animal identification in rock art, followed by the role of ethnography in interpretive rock art study and how it offers insight into the meaning of rock art images for the communities that created it. We then describe what representative rock art can tell us about the environment and potentially the social context of the artists, and then argue for new methods that can identify patterns among rock art creation on a worldwide scale and what these potential patterns might imply.

2.2. Dating Rock Art

Before discussing the potential meaning of rock art, and how it reflects its physical environment, there are some things that should be discussed regarding the dating of rock art. Rock art is notably difficult to date, not least because it is usually found on open rock surfaces or rock shelters and not among excavated material. The process often depends on how suitable the taphonomic and preservational circumstances are for dating methods. Direct dating methods, where materials directly associated with the rock art are dated, are usually preferable. However, direct dating involves physical sampling and risks damaging the art [33]. The best-known example of this would be radiocarbon dating which, if carried out directly, is only possible for drawings containing enough

dateable organic matter, e.g., charcoal or a plant- or animal-based pigment medium [34]. Examples of this are the dating of beeswax and calcium oxalate coatings, or an analysis of relative patination [35–37]. If no such material is present, attempts can be made to date the rock art by analysing the weathering of the material, if the rock art was created at an open-air site [34,37]. Luminescence methods can also be used, such as optical stimulation luminescence (OSL). Here, materials such as quartz grains and feldspar are subjected to radiation which determines the last time the material has been exposed to sunlight [34]. This may be combined with other methods, such as petrography, to gain further insight into the details of sedimentation and last sunlight exposure. This has, for example, been attempted on a quartz-arenite sandstone clast from a cave in India where cupules can be found. OSL techniques were applied to determine when the material had been buried, and a complex petrographic examination on mineral, chemical and structural composition supported the conclusion that the examined material must have been buried twice, around both 46,000 BP and 71,000 BP [38].

A similar method is thermoluminescence, which uses heat instead of light and is the most suitable for materials such as flint or calcite. It has, however, not yet been used often for rock art dating [34]. Lastly, a method that measures the ratio between uranium and thorium isotopes during the process of decay when calcite precipitates on a rock surface, can also be used when determining the age of rock art [33,34]. This method was used on Iberian cave art that, as a result, was ascribed to Neanderthals [16]. However, circumstances such as calcite mobility caused by water pathways, climate variability or damage of the calcite layer can result in inaccurate dates. The possibility of additional loss of uranium in Nerja cave due to natural mineralogical transformation is one of the reasons the ages of these motifs are so disputed [19,34].

A combination of methods at the painted rock shelters at Serra da Capivara in Brazil yielded both dates younger than 4000 BP and dates older than 30,000 BP [25,39–41]. This situation makes it unclear whether the rock art sites at Serra da Capivara should be considered among the oldest rock art sites in the world, and even whether it challenges the popular theories surrounding the first peopling of the American continent. It should therefore be noted that these kinds of direct dating methods are heavily dependent on circumstances and can be flawed when applied without developing knowledge of the formation processes affecting rock art.

If there are no opportunities for direct dating at all, other dating methods can be considered. These methods are often relative, which means they are contextual in nature, but they can nevertheless offer insights into rock art history and chronology. Due to the fact that direct dating is often not possible or reliable when it comes to rock art, relative dating methods offer a less ideal, but useful alternative. One possibility is to make an estimation of rock art age by association: in such a case, a stylistic comparison can be made to other rock art in the region which may have been possible to date, or the rock art may be compared to portable art or other diagnostic objects that are found nearby in a dateable layer of soil [42–44]. Rock art may also be subjected to relative dating, such as the study of superimposition: here, the conclusion can only be drawn that the overlaying motif is younger than the one underneath [43,45], which in combination with stylistic comparison, may shed light on sequences in rock art tradition.

Another example would be an analysis of sea-level changes if the rock art is made on a shore. Shore displacement curves, such as the ones near the petroglyphs in Alta, Norway, provide information on the earliest time when parts of the shoreline were exposed for rock art creation. However, in the case of the Alta petroglyphs, this was applied in combination with the aforementioned stylistic comparison of the motifs [46].

Finally, animal depictions in rock art can be assumed to signify the presence of those animals at the time of creation, and may thus indicate the age of the rock art, if it involves species that were not always present in the region, but whose presence during some time in prehistory can be confirmed by other archaeological evidence, such as preserved bones and teeth of these species [43,44]. It should be noted that these methods are heavily dependent

on interpretation of diagnostics, which are at risk of misinterpretation. Use of scientific dating methods, such as microerosion analysis, radiocarbon analysis and colorimetric analysis on Saudi Arabian rock art led to substantially different conclusions on their age than had previously been presented based on motif interpretation [37].

The criticisms of and comparisons between all these methods result in interesting pieces of research that without a doubt contribute to the development of rock art dating methods. However, as long as the difficulties surrounding rock art dating are present, it will remain a challenge to directly relate rock art to an exact temporal period and therefore to palaeoenvironmental conditions. However, rock art depictions of environmental aspects can still provide information on a region's history in a more general fashion, rather than describe a specific point in time. This may not be as ideal as the possibility of using rock art to reconstruct a specific time-period, but it is still useful nonetheless. That being said, it may not be surprising that rock art studies have traditionally focused not so much on the environment of the artists—from an unknown time-period—but rather on the meaning behind the images and the intention of their creation.

2.3. Motif Identification in Rock Art

It should be noted that rock art motifs are not always easy to identify or categorise. Even when they seemingly are, mistakes may be made during identification because the intention behind rock art creation is usually unclear. Perspectives the artists had on their environment are likely to have been very different from those of people with different backgrounds, ontologies, and lifestyles, which may lead to misinterpretations from the Western "scientific" perspective. Without any input from the rock art creating population, if possible, interpretations on the meaning behind depictions or scenes are likely to be false. This can be mitigated by involving the population that has ties to the images in rock art research, as they can provide insight into the reason behind their creation, as well as the meaning of any depicted animals [6,7,47]. However, as perspectives and cultures change over time, even interpretations by such populations may vary between people, or misinterpretations may occur whenever descriptions are mistranslated or not fully understood by the outsider [48]. Conclusions on the meaning of rock art and its animal depictions will thus unfortunately never be completely solid.

The same may be said about animal identifications specifically: sometimes animals in rock art are painted in such an abstract style that any diagnostic features are difficult to identify, and sometimes rock art depicts non-existent animals [49] or images that are related to animal transformation (therianthropes) [50]. In such cases of unclear species, any identification that goes beyond pointing out the diagnostic features of the animal may seem inappropriate. Often diagnostic features are present in animal depictions and a consensus on their identification can be reached, especially if indigenous input is present and if there is sufficient reason to believe these species are or have been present in this region. This may be aided with any additional methods, such as adding a "confidence score" to any animal identifications, in order to describe the certainty with which an animal species can be identified. This was, for example, used by Maria Guagnin while categorising animal species in rock art from the Central Sahara [51]. Although caution is appropriate when it comes to drawing conclusions on the meaning of the animals, the identification of animals in rock art can be achieved if there are sufficient diagnostic features present.

3. The History of Rock Art Study

In the Western world, interest in rock art dates back to the late nineteenth century, with the discovery of the Palaeolithic paintings in the Altamira cave in Spain by Marcelino Sanz de Sautuola in 1868 [52]. At the time his findings were not deemed believable, and were heavily criticised, in particular by prehistorians Émile Cartailhac and Edouard Harlé: the latter even published a report on the Altamira paintings, concluding that they were fake [53,54]. Palaeolithic humans were deemed too "primitive" by the scientific community

of that time to have created the impressive depictions of bison that could be seen on the ceiling of the Altamira cave [52,55].

The discovery of other caves, starting with Pair-non-Pair and La Mouthe in France, with similar rock art changed this eventually: Cartailhac even published an article where he admitted to having been wrong about prehistoric cave art and acknowledging that the animal depictions must have been made by prehistoric people [56].

This shift eventually became solidified with the discovery of the world-famous Lascaux cave, also in France, in 1940. This cave is not only among the most thoroughly studied sites containing palaeolithic rock art, but also among the most visited rock art sites, which eventually led to the cave being closed to the public only twenty-three years after its discovery due to microbial contamination caused by the presence of so many visitors [52,57]. The Lascaux cave contains images of various species, such as aurochs, horses, felines and deer, as well as geometric motifs and a potential "conflict scene" between a buffalo and a therianthrope (a figure that appears part human, part animal). The cave can be divided into multiple sections, each section seems to have its own "theme", such as the hall of the bulls, the axial gallery that depicts mostly horses, the Nave which contains two running bison drawn in a way that invokes perspective, a part that only includes engraved motifs and a section that depicts a possible "conflict scene" [7]. This interesting selection of animals and the mysterious layout of this cave has been the reason Lascaux has throughout the years been the subject of many expeditions of rock art research, including the works of the aforementioned early rock art researchers. Other subjects of research undertaken at Lascaux include the creation and use of pigments and the influence of light and sound in caves on rock art creation [58,59]. Thus, cave paintings from southern Europe have been studied quite extensively and are arguably the most studied rock art sites in the world, not least because they are among the oldest among all the rock art sites.

Many of these studies, particularly the first ones conducted in the mid-twentieth century, are of an interpretive nature: rock art researchers would study the images depicted in the caves and speculate about the intentions of the artist, mostly about the belief systems that could have inspired the creation of such paintings. In 1906, Carthailhac and Breuil already made comparisons between European cave art and artistic animal depictions made by hunter–gatherer societies on the American continent in order to highlight the importance of animals in such societies, and how this is often tied to a belief system that uses rituals to increase success during the hunt (also known as hunting magic or sympathetic magic) [4]. Both Max Raphaël and Anette Laming-Emperaire studied Palaeolithic European animal depictions in the context of their composition and critiqued the application of ethnography when interpreting Palaeolithic rock art. Raphaël believed the animals represented different clans within hunter–gatherer societies, and the way the depictions interact—including stylistic interactions such as superimpositions and inaccurate size differences when compared to real life—and represent the way these clans interacted with each other, for example, by conflicts and marriages [60]. Laming-Emperaire was less convinced that animal depictions were totemic representations of clans, but did agree that there must be a certain intention behind which species are depicted and how they interact with each other, and that scenes painted in rock art should be studied as such [2,52]. André Leroi-Gourhan built on this when he stated, after statistically analysing species' presence and interaction in scenes, that the species most frequently encountered as a pair in Palaeolithic cave art—the horse and the bison—could represent the male and the female, respectively, not in the least because these species depictions were often accompanied by geometric motifs that he also interpreted as representing maleness and femaleness [3,52].

These early studies of rock art reflect various methods of analysis, including quantitative analysis [3], stylistic analysis of both individual motifs and motifs considered a part of a scene [2,60] and even the application of ethnography and comparison to more recently made non-Western rock art [4]. However, their focus remained on the meaning of the rock art depictions and less on what the depictions of certain animal species meant for the archaeological context of Palaeolithic Europe, as Cartailhac and Breuil [4] had attempted

before. The rock art sites that are studied by rock art scholars have since become far more diverse, extending far beyond Europe. Vinnicombe [61] undertook research on the categories and quantities among South African rock art in the 1960s. Additionally, the nature of rock art study has become more diverse as well: instead of focusing solely on the meaning of rock art images, rock art researchers now consider other aspects, such as the cognitive, spatial and socio-cultural contexts as well [62–71]. Rock art is researched more and more in the context of its physical and social environment, considering the exact location and total assemblage of natural features of a rock art site, and—whenever possible—not only its spiritual, but also its social significance for a community.

For example, research by Ponomareva and Taçon [63] and Vogt [64] studied rock art in association with ethnic and/or class identity and subsequently the cultural influence of certain cultural groups in a region. Something similar can be said of research that studies depictions of European colonisers in South African and Australian rock art [36,65,66]. Rock art may be used to analyse migration patterns: studies of the paintings from Serra da Capivara suggested a human presence on the American continent that predates the migration via the Bering Strait, and a perceived similarity in style between a warty pig in Sulawesi and the earliest depictions of macropods in Australia introduces new perspectives on potential interaction and migration between Southeast Asia and Australia [67]. Additionally, there are similarities between North African rock art and southwestern European rock art from the late Pleistocene, which di Lernia suggests could be the result of human migration caused by environmental conditions, such as hyper-aridity in the Sahara region [68]. Sometimes the specific locations of rock art sites, as well as the precise locations of drawings and engravings on the rock surface, are the subject of rock art study: Bradley et al. [69], Acevedo et al. [70] and McCall [71] drew conclusions on the various kinds of purposes various rock art sites may have had for the humans using them, based on the quantity, types and visibility of rock art motifs. In this context, rock art is suggested to have had the purpose of marking certain locations where important ecological resources could have been found, or used to indicate what kind of use the rock art shelters had for the artists. Such rock art shelters may have been inhabited, used for meat processing, or used for ritual purposes.

Turpin and Eling [72] analysed where exactly on a rock surface motifs were drawn, mostly comparing motifs high up on a rock surface to motifs situated closer to the ground. It should be noted that even when rock art is studied in its context as such, the goal is often nevertheless to draw conclusions of an interpretive nature, especially when the rock art motifs are representative.

4. Motives Behind the Motifs

4.1. Ethnography in Rock Art Study

Although ethnography can provide insight into the reasons for rock art creation, attempts to offer an explanation with a more neurological background have famously been made. Reichel-Dolmatoff [5] described drug-induced shamanic trances among the Tukano tribe in the north-western Amazon, Colombia, and linked the visions experienced through these trances to expressions of art among the Tukano, although not necessarily focusing on rock art. Lewis-Williams and Dowson [73] undertook a similar description of hallucinogenic visions, naming the geometric shapes the optic system causes people to see when triggered "entoptic phenomena", and linked them to geometric shapes that are often seen in rock art accompanying representative images. They compared these to geometric rock art images created by the San from South Africa and the Coso Shoshone from the Californian Great Basin, and subsequently to Palaeolithic European cave art, a type of rock art whose meaning has been lost in time. Von Petzinger [74] in turn noted that these types of symbols, such as crosshatches, zigzags and dots, can be found at Pleistocene sites all over Europe. The universality of these type of geometric shapes in rock art may indeed suggest these shapes are not subjected to any cultural origins, but rather neurological ones, and could therefore be seen by anyone regardless of ethnic origin. Geometric shapes as

entoptic phenomena, being the first visions seen when entering a trance, is one possibility, although Bednarik [75,76] critiqued the perceived connection between entoptic phenomena and shamanism by highlighting that such geometric shapes are also among the frequently made drawings of small children. The fact that evidence from the Pleistocene European caves containing rock art suggests that children were sometimes present in these caves may thus offer an alternative theory for the origins of these universal shapes.

While it is true that the meaning of European cave art will never be explained by first-hand accounts, it should be noted that among communities with a history of rock art creation, shamanism and/or a direct connection to a spiritual belief system is often mentioned as being directly related to rock art images. Such studies on rock art meaning have mostly taken place in North America, Southern Africa and Australia and may include representative rock art depictions, such as animals. In the aforementioned study among the Tukano, ethnography allows for some interpretations on the meaning of certain geometric motifs, which often contain symbolic references to local myth or ritual custom [5]. In central Australia, ethnographic research clarified that circle-shaped petroglyphs were part of an "increase ritual" meant to increase prey animals [24]. This is related to the aforementioned "sympathetic magic"/"hunting magic", and thus an additional example of rock art being connected to hunting rituals. Additionally, ethnography clarifies that representative images in Australian rock art, which may look like humanoid or (partially) animal figures, can refer to ancestral or spiritual beings [77]. Similar examples exist among Native American rock art, such as the owl depictions in Southern Oregon that refer to the deity "Old man Owl" within the Klamath–Modoc communities [78].

The most elaborate research on animal depictions in rock art related to shamanism was arguably carried out by David Lewis-Williams in Southern Africa: multiple of his studies involving ethnography focus on how rock art scenes among the San relate to the shamanic trance, transformation into animals and descent into the underworld [6,7,48]. Nevertheless, even among the communities that have a relationship to rock art that is at least multiple decades old, the original meaning might not be completely clear. Most of the aforementioned studies involving ethnography base their conclusions on the testimony of only one or a few members of a rock art-creating community. However, further dialogue with rock art-creating communities can at least provide a point of reference for the stories behind certain rock art scenes and/or the meaning of certain animals depicted in rock art.

This can also be achieved by members of indigenous communities co-authoring on rock art related research, such as a study by Patterson and Duncan [47], where Clifford Duncan provides the meaning behind bear depictions among the Ute as a Ute spiritual elder. Another example would be consultation of Indigenous Australian populations on stylistic and thematic variation in rock art aiding with an analysis of the effects of social networks and environment on the history and development of rock art creation within two different Australian regions [79]. Indigenous involvement, as a means to understand and interpret rock art, is only possible in areas where such ethnography exists. Unfortunately, this resource of data is lost for rock art created in Europe, Northern Africa and parts of South America.

Knowing that ethnography suggests that rock art is often tied to a spiritual belief system, it should be kept in mind that the animals depicted will not be a complete reflection of the natural environment of the artists, but rather a selection of animals with some sort of spiritual/cultural significance. For the San, one of the most depicted animal species is the eland antelope (*Taurotragus oryx*), which was also known to have a spiritually significant role due to its fat containing "potency": the eland antelope was among the species hunted by the San and its fat was often used in ritual practises (Figure 6) [6]. Something similar can be said about bees, whose honey is also said to contain potency: bees and honeycombs are also depicted in San rock art, albeit not to the same extent as the eland antelope [80]. Such examples can be found in other rock art regions as well: lizards are an animal species often depicted in Native American rock art in California, and ethnographic study suggests that these animals were believed to have the ability to quickly enter and exit the supernatural

world, as they were also able to easily enter the crevices in rock surfaces [81]. This too, can be observed among the San beliefs in South Africa, where rock surface is often considered the interface between the physical world and the spirit world [82].

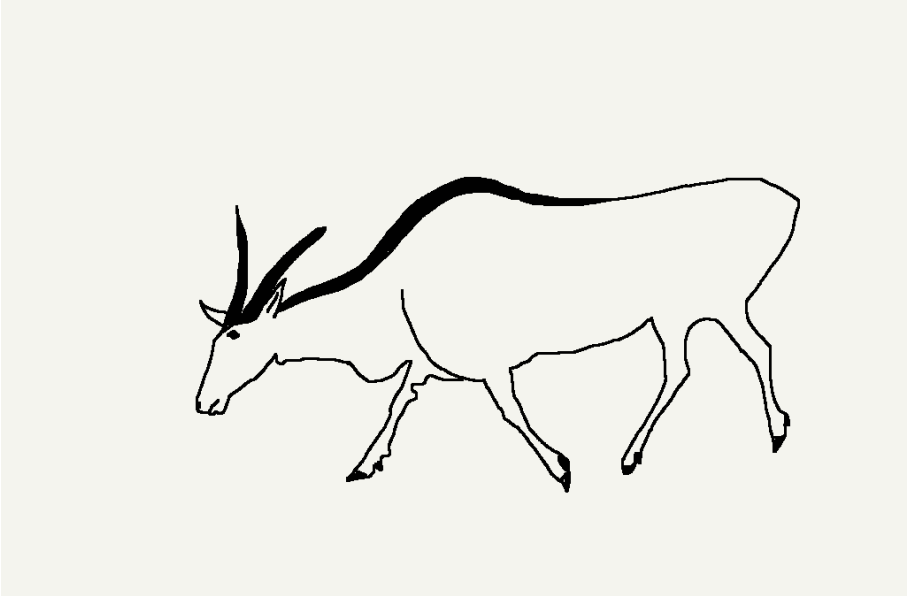

Figure 6. A trace of an eland antelope depiction from the East Cape Province, South Africa. Copyright M. Korpershoek. Traced from the original image in Lewis-Williams [7].

4.2. The Cultural Significance of Animals in Rock Art

Animal species that have cultural significance among a population may have (had) a special meaning for a reason, and possibly an origin in ecological importance for a society/community. For example, food taboos, or the prohibition of eating certain plants or animals according to local custom, may sometimes be rooted in health risks such as allergies and zoonotic diseases and not always be just random consequences of a local belief system [83]. Studying local beliefs as a potential consequence of ecological events has tentatively been applied to rock art as well: Chippindale and Taçon [49] speculated that the "rainbow serpent" often depicted in rock art made by Australian Aborigine societies (Figure 7) may have been based on the sudden widespread presence of pipefish that accompanied the rising sea levels of 6000 years BP, although this cannot be confirmed by ethnographic research.

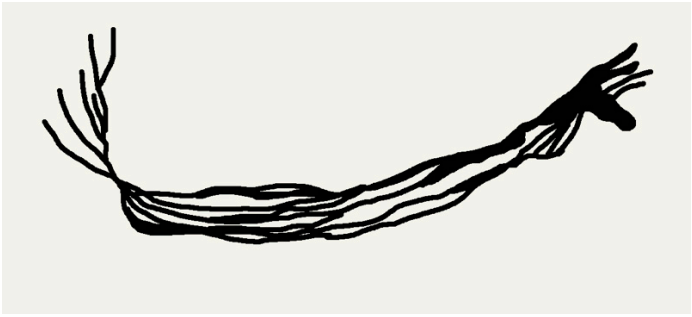

Figure 7. A trace of a rainbow serpent depiction in Australian rock art. Copyright M. Korpershoek. Traced from the original image in Chippindale and Taçon [49].

The ecological importance of certain animal species does not necessarily need to be about food: it seems an obvious choice to assume that animals depicted in rock art would be the local prey animals, possibly drawn because human populations wished to increase

their numbers. However, there are some locations where the local archaeological record suggests that the prey animals most often used for food were not the same species that were depicted in the local rock art. Horses and bison were popular themes in Pleistocene cave art in France, while it was mostly reindeer remains that were found to be processed for food in the same area, while these were not depicted in rock art as commonly [52,84,85]. Similarly, among rock art on the Northwestern Plains in North America, bison were not as well represented as one might expect from a species that played an important part in the economic lives of the Native population on the Plains during the Late Prehistoric period (prior to 1730 CE) [86,87], although some hunting scenes including bison do exist [86]. Additionally, among Saharan rock art there seems to be a prevalence in large herbivores, which were very likely the type of animals that could easily be seen by humans in broad daylight, contrary to smaller herbivores and predators [51]. This would suggest a selection of animals that is not (directly) rooted in any belief system. Although a connection between rock art and important prey animals should not be ruled out completely for every location, it is safe to assume that in many cases the importance of animal species depicted has more complex origins, which could nevertheless be influenced by ecological circumstances.

The idea that such circumstances may have had an influence on belief systems involving animals, or beings depicted with features of animals from the natural environment, is therefore an interesting subject to explore, as it could shed light on patterns of human spiritual beliefs. This could be achieved by comparing species depictions in rock art on large, multicontinental scales. Similarities between regions in what types of animals occur in rock art could offer insight into what animals humans tend to ascribe meaning to, and possibly what kind of ecological circumstances cause these types of belief.

5. Rock Art as a Paleoenvironmental Index

5.1. Cultural Circumstances Depicted in Rock Art

Setting spiritual beliefs aside for a moment, there are other reasons to believe that changes in the environmental status quo are frequently depicted in rock art: a possible early example of this would be a potential depiction of a volcanic eruption during the Aurignacian period in France [88]. Frequent boat and metal themes in Scandinavian rock art from the Bronze Age could signify the integration of a community in the European metal trade [89]. The most obvious examples of drastic changes in the environment of a population depicted in rock art would be images referring to European colonists found in Australian, South African and Native American rock art. This is a record of historical contact between different ethnic groups [35,65,66]. Conflict is another theme that occurs in rock art among multiple regions. Depictions of conflict scenes rarely refer to known battles or conflicts, but may provide insight into weapon use and preferences, as well as the potential nature of the conflict or any attack or defence strategies. An example of this is a comparison of battle scene depiction in Arabian rock art by Aksoy [90], which found that such scenes usually contained combat on foot. It contains depictions of humans carrying both a bow and a dagger, suggesting a need for both long range and close-range combat possibilities, and depictions of small shields may suggest a need for rapid movements in such conflicts.

Examples of rock art indirectly referring to conflict by depiction of weapons include the long-necked spearthrower in Australian rock art [91] (Figure 8), as well as rifles in Australian and North American rock art [86,92]. In the case of the latter, it should be noted that rifles in this case were likely newly introduced weapons in the region at the time their depictions in rock art were created, rather than weapons with a long history of local use. This again signifies a type of environmental change, albeit a socio-cultural one rather than an ecological one. References to weapons can signify both changes in hunting styles as well as conflict and warfare. Conflict and warfare, however, may be the result of resource scarcity [93] and competition and may therefore also suggest certain environmental circumstances, albeit indirectly and not very reliably.

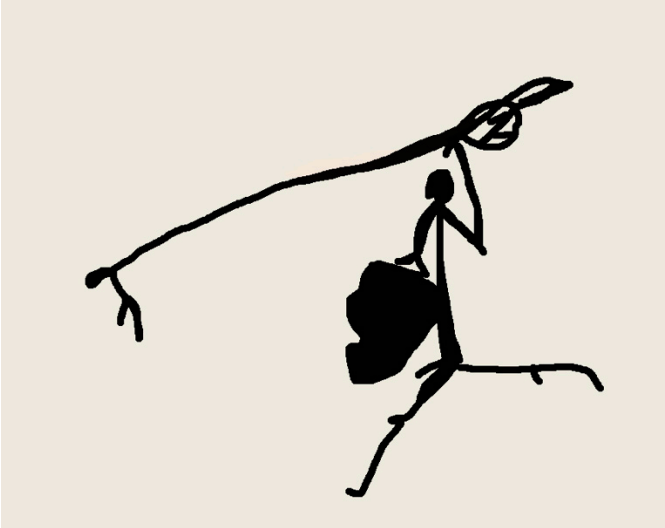

Figure 8. A trace of a human figure using a long-necked spear thrower in a conflict scene in Australian rock art. Copyright M. Korpershoek. Traced from the original image in Hayward [91].

It is, however, interesting to note that it is unclear why people felt the need to depict scenes of conflict in rock art. For example, Levantine rock art (Spain) is well known to have various depictions of conflict between humans, and the assumption is often that these must be documentations of real-life events. This may appear likely, because there are reasons to believe that the rock art was made around the time that hunter–gatherer groups and agro-pastoralist groups coexisted, as well as an increase in population numbers. Both of these phenomena could have caused inter-populational conflict [94]. However, conflict scenes cannot always be assumed to be documentational. For example, a rock art scene from South Africa that was believed to be a documentation of a conflict between a group of San and a Boer commando that really occurred is more likely to be a panel of a shamanistic nature. This is because some of the attributes of the human figures in the scene resemble shamanistic objects, and partly because ethnographic research on San rock art predominantly suggests that rock art is usually created for shamanistic reasons and not documentation [95].

5.2. Rock Art as a Reconstruction of Environment and Environmental Change

Rock art may therefore also be able to aid with the reconstruction of a region's environmental past and changes. One example of this would be rock art signifying the presence of certain animal species: in the Colombian Amazon, rock art suggests the coexistence of extinct Ice Age megafauna, such as the giant ground sloth (possibly *Megatheriidae*), with humans [31]. Meanwhile, the depictions of certain species, such as the kudu (*Tragelaphus imberbis*) and aurochs (*Bos primigenius*) in rock art on the Arabian Peninsula prove their presence in the region, which was not represented in the osteological record [96].

Rock art depictions adding to the traditional archaeological record do not only apply to animal depictions: Veth et al. [97] were, for example, able to compare plant depictions throughout time to the local archaeological record in order to challenge assumptions on forager to agriculture transitions in the Kimberley region (Australia). However, plant depictions are a less common theme in rock art on a worldwide scale. Additionally, animal species, including humans, can be both affected by environmental change as well as actively be the ones to affect it.

Rock art analysis can aid with the reconstruction of transitions caused by or affecting human practises involving animals. One example can be observed in Egypt, where overhunting and resource competition with humans in the Nile floodplain caused by the shift to agriculture likely caused the extinction of some animals [8]. The reverse, environmental change leading to a change in species' interaction, can also happen: this can be seen in some

rock art from the Sahara, which neatly reflects not only the various episodes of climate change in the region, but also the relationship of the human population with the environment and its animals. For example, the introduction of cattle depictions may describe the developments of local pastoral cultures from hunter-gatherer culture [68]. A subsequent transition from cattle to ovicaprid depictions coinciding with an increase in aridity, suggesting a shift from cattle farming to sheep and goat farming, the latter two being more resistant to a drier environment [10,68,98]. Similarly, depictions of savannah-adapted species in the same region eventually decline, while depictions of Sahel- and arid-adapted species increase. This coincides with the local transition from a savannah to a more desert-like climate [51]. An analysis of the locations of rock art sites in southwest Libya resulted in the conclusion that rock art creation strongly correlates with patterns in human settlement and pasture exploitation, which also reflected the climatic change in the region [99].

Instead of using rock art as an addition to a region's archaeological record on species' presence, a comparison between species depiction and population can also lead to insightful conclusions: Garfinkel et al. [100] found that there was an increase in bighorn sheep depictions in rock art on the Coso range in California, which coincided with a decrease in the species' actual bighorn sheep population. In this case, ecological change may thus have caused a change in local rock art practice, rather than rock art merely reflecting the environment as if it were completely detached from these changes. Something similar may be observed in rock art at the Drakensberg in South Africa: Manhire et al. [101] found that depictions of wild animals, domesticated animals and conflict scenes between human figures pointed to interaction between local hunter–gatherers, agro-pastoralists and European colonisers. They suggest that an increase in rock art that is known to be part of shamanic practises coincided with these inter-group interactions, and thus signified a stressful environment for the creators, with more need for shamanic practises. These examples show that ecological change and changes in human–animal interactions usually go hand in hand: the frequency and/or fashion in which species are depicted by humans in rock art can thus offer additional insight into human use and interaction with species as well as reflect changes in the environment.

5.3. Cultural Practises Depicted in Rock Art

Lastly, representative rock art images may aid with an interpretation of cultural practises: a motif in Pinwheel Cave, California, depicts the hallucinogenic Datura plant (*Datura wrightii*) [102] (Figure 9). This is a plant with a long history of medicinal use on the American continent, but its hallucinogenic side effects made it suitable for ritual use in pre-Hispanic cultures: for example, it supposedly caused the ability to speak with deities and to invoke visionary states that allow insight into certain diseases and their cures [103]. The alleged presence of this plant in rock art may therefore allude to the use of Datura as a medicine for certain illnesses or conditions, or ritual practises occurring in the region (perhaps even the cave). Either way, it could suggest the importance of this certain plant in a rock art-creating culture.

References to dress may also signify cultural practises: depictions of non-natural looking faces have been speculated to refer to masks, possibly used in ritual practises. Similarly, depictions of therianthropes, humanoids with features of animals, have been theorised to refer to ritual dress, although animal transformation has also been considered (Figure 10) [50]. The earlier mentioned references to colonialism in rock art may also be identified by depicting items of clothes typical for the colonising population, such as the depictions of European hats on humanoid depictions from Arnhem Land, Australia [104] (Figure 11). Such references to dress are dependent on the amount of detail with which the humanoids are depicted, which may vary from region to region. Therianthropes and face-like motifs cannot with certainty be stated to refer to cultural dress and some items of clothes depicted on humanoids have no point of reference to aid with interpretation. Therefore, studying items of clothes in rock art will rarely be a reliable interpretation of cultural practice. Challenges like these demonstrate that animals are the most straightforward rock

art motif to study, and natural environments are usually easier to reconstruct based on rock art than culture.

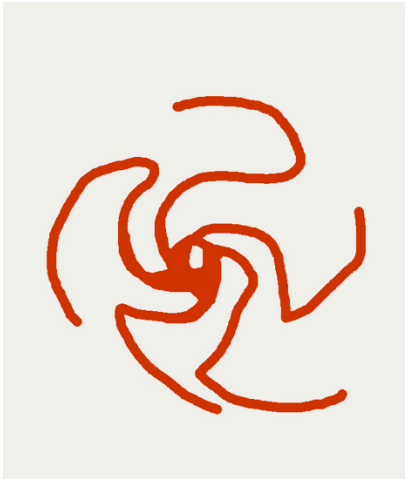

Figure 9. A trace of the geometric motif from Pinwheel Cave, now believed to be a depiction of the hallucinogenic Datura plant. Copyright M. Korpershoek. Traced from the original image in Robinson et al. [102].

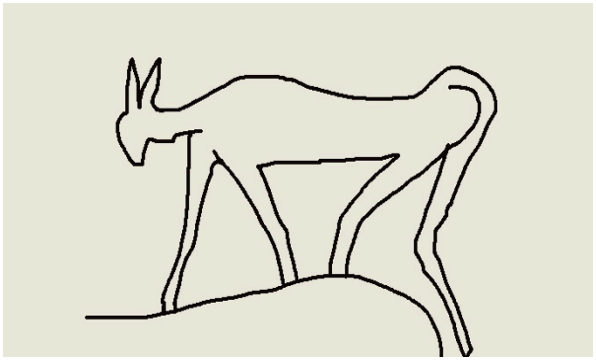

Figure 10. A trace of a depiction of a therianthrope in San rock art, possibly mid-transformation. Trace by Mirte Korpershoek. Traced from the original image in Blundell and Lewis-Williams [105].

Figure 11. A trace of a depiction of European colonists wearing hats and smoking pipes in Australian rock art. Copyright M. Korpershoek. Traced from the original photograph by Sally K. May [104].

5.4. Comparing Environmental Aspects in Rock Art

When representative rock art motifs are studied on a worldwide scale, it seems that animals are the most universal representative depictions. Humans are a popular theme on multiple continents, but are almost absent from Palaeolithic cave art in Europe, as

are plants [106]. Plant depictions exist in other regions, for example, the aforementioned hallucinogenic Datura depiction in California, which likely refers to ritual practice. Another example is tree depictions in Southern African rock art, which also seem to be connected to cosmological beliefs: they are often depicted in connection with humans and animals, and depictions of other plans are rare [107]. The record of plant depictions is a little richer in Australia, and diverse enough to be suitable for environmental reconstruction [93]. Human-made technologies are often depicted together with humanoid depictions, for example, boat depictions in Scandinavian Bronze Age art [108,109], but also the aforementioned examples of weapon depictions in the same region, as well as Australia and North America. References to technologies contain information on the cultural environment of a certain era more than the natural environment, as do references to dress and other human populations (also sometimes identified by depictions of dress [104]).

Table 1 presents an overview of the studies in this review, and groups them into four types of social, cultural and natural information on the living environment of the artists. It can be seen that depictions of natural events are rare, while there are many examples of animal depictions offering insight into local species' presence and interaction (plant depictions are rarer). Animal interactions (in these examples, all interactions with the human population) go hand in hand with environmental changes and are therefore especially interesting. Depictions of human activities and references to different ethnic groups are very dependent on the presence of material motifs, such as clothes and technologies, which may be susceptible to misinterpretation.

Table 1. An overview of what environmental information can be extracted from the rock art discussed in these studies.

Type of Environmental Information	Reference	Specific Environmental Information
Presence of and interaction with animal and/or plant species as a description of a (changing) environment	[23]	Pigs were already present in Indonesia around 51,200 BP
	[96]	Kudu, wild dromedary, aurochs and African wild ass were at some point present on the Arabian Peninsula, even though not represented in the osteological record
	[51]	Savannah animals were present in Sahara, as well as domesticated animals at some point
	[63]	Elk were present in Neolithic and Bronze Age Siberia, possibly important for human populations
	[78]	Owls were present in Southern Oregon and important to the Klamath–Modoc populations
	[47]	Bears were present in Western Colorado and important to the Ute
	[27,32]	Certain animals (albeit unknown quadrupeds) were present in Namibia 25,000 years ago, and depicted by humans
	[6]	Eland antelope were historically present in South Africa, were among the species hunted by the San and were spiritually important to them
	[81]	Lizards, bighorn sheep, centipedes, frogs, beavers and grizzly bears were historically present in California/the Great Basin
	[49]	The presence of pipefish in Australia might have increased during a period of rising sea levels
	[31]	Extinct Ice Age megafauna might have been historically present in the Colombian Amazon, coexistent with humans
	[69]	Deer and horses were historically present in Spain
	[80]	Bees are present in South Africa and have meaning among San groups

Table 1. *Cont.*

Type of Environmental Information	Reference	Specific Environmental Information
	[108]	Elks were historically present in Scandinavia during the Bronze Age
	[102]	The Datura plant was historically present in California, possibly consumed by human populations
	[97]	Plants, including fruits and yams, were consistently important to populations in the Australian Kimberley
	[98]	A depicted shift from cattle farming to goat farming suggests a shift to a more arid climate in Sahara
	[10,68]	Animal species' presence in Sahara describes how the region went from savannah-like to desert-like
	[9]	Animal species' presence in Shuwaymis describes a change from a humid to an arid climate
	[8]	Resource competition, potentially driven by a shift to agriculture, has caused a decline in large-bodied herbivores, which affected the presence of predators as well
	[100]	Bighorn sheep depictions in rock art coincided with a decrease in real-life bighorn sheep on the Coso range
Human activities, signified by the presence of technologies, such as weapons (hunting) or boats (sailing)	[108,109]	Scandinavian populations used boats during the Bronze Age
	[86,92]	Weapons, including firearms, and horse equipment are depicted in North American Rock art
	[91]	The long-necked spear thrower was used by Australian populations
	[64,89]	Metal was used and traded by Scandinavian populations during the Bronze Age; weapons, chariots and boats were used, suggesting at least occasional warfare among human populations
	[90]	Arabian populations used weapons, such as bows, arrows and daggers, according to battle strategy
Presence of different cultural groups, signified by attire/attributes	[104]	A European style hat was depicted in rock art in Australia
	[35]	A European prau ship was sighted by the Native population in Australia
	[65]	A European ship was sighted near the Attakwaskloof, South Africa
	[66]	Interaction with European colonisers was depicted among native populations of Australia, North America and South Africa
	[101]	Rock art describes interaction, and likely competition between hunter–gatherer and agro-pastoralist populations, as well as European colonisers around the Drakensberg, South Africa
Natural event	[88]	A historic volcanic eruption might have been witnessed by Aurignacian populations in France

References to animals may therefore be the rock art theme most suitable to use for not only comparison in rock art trends between regions on all continents, but also for rock art-based analysis of the natural environment. Analysis of species depictions can provide insights that are not only limited to species' presence, but also includes human–animal interactions and possibly what use certain animals served to humans, depending on what other information is available in a region regarding these interactions. Both species presence and their interactions with humans reflect the natural resources in a region, as these resources affect these interactions and vice versa. Subsequent comparison to other

regions may reveal patterns among rock art creation depending on environments and the way they change.

To summarise, animals may be the most useful rock art motif for palaeo-environmental reconstruction, as they signify the presence of certain species in a region and sometimes the nature of their interaction with humans. This provides insight into the local resources that attract these animals, and thus into the history of the natural environment in a region.

6. New Approaches to Rock Art Analysis

When data are collected on representative rock art images referring to aspects of physical environment on a large and worldwide scale, interesting patterns may potentially emerge. To achieve this, an approach that goes beyond ethnography and style analysis would be very useful. An appropriate start would be the analysis of the quantities of rock art animals per site/region. The conclusion that animal species depicted in Palaeolithic European Cave art did not reflect the animals that were the primary resource for humans from the same time period could not have been reached without Leroi-Gourhan classifying and counting rock art motifs, which also led to other interesting insights such as patterns in the positions of rock art motifs within the caves [3]. Similar studies have been conducted by Acevedo et al. [69] and McCall [70], who used statistical analysis of rock art motifs and their positions to determine what the shelters where they occur were most likely used for. Statistical analysis of rock art motifs allows both for easier comparison to animal species in the archaeological record and can aid with interpretive purposes. However, there are many other ways in which rock art studies can be further developed, particularly in the field of computational methods. As a visual phenomenon, rock art is suitable for various image analysis techniques.

An example of such a technique that may contribute to the existing body of quantitative rock art research is machine learning and computer vision. Paired with sufficiently large quantities of data, these approaches can provide additional insight into visual art, such as classifications based on time period or style. This has in some cases already been applied to rock art: Jalandoni et al. [110], for example, made suggestions such as automatic motif detection in images. Such methods may be further developed into automatic classification, which is a method that is already being explored when it comes to real animals in photographic images [111]. This would in turn lead to an easier and faster way of creating large databases on rock art motifs, which will allow for an increase in large scale data analysis on rock art patterns. Such analyses can be based on style, for example, determining historical chronology, which already has been attempted on a smaller scale among Australian rock art by Kowlessar et al. [112]. Larger scale attempts are possible and have been applied to determine style-based chronology and artist identification for landscape paintings, using a database of 15,000 paintings [113].

Machine learning-based methods, however, do not necessarily have to focus on image analysis: when databases with information on rock art motifs are present, for example, categories of depicted animal species, predictions may be made that relate to the relationship between these motifs and other aspects of the archaeological site or region. For example, decision tree algorithms may be used to attempt to predict a site, or even a type of biome or environment, based on which animal species are depicted in the local rock art. Sobol and Finkelstein [114] found that a decision tree algorithm such as Random Forest proved suitable for biome prediction based on pollen datasets. Animal species, like pollen, may serve as a proxy for vegetation and can therefore be used for biome prediction. The fact that animal species depicted in rock art are usually only a selection of local species may influence the accuracy of a predictive model, and therefore offer insight into the extent to which rock art systematically reflects the local environment.

Rock art data may also be used for other computational methods in archaeology: animal categories can form the basis of ecological network analysis such as the aforementioned study by Yeakel et al. [8], or as a source or material for comparison for simulation-based research, such as the aforementioned study by Garfinkel et al. [100]. Gravel-Miguel [115]

used style similarities, albeit in portable art, from different sites in the Cantabrian region as information to reconstruct social networks during the Lower Magdalenian, and subsequently used information on species distribution to reconstruct local environments and contextualise these networks. These types of methods can also contribute positively to the field of rock art study, particularly studies that consider the relationship between rock art and its environment.

7. Conclusions

In this review, we have given an overview of the historical study of rock art and its creation, and explained how these studies contributed to the field of rock art research, particularly when it comes to interpretive studies, which have been especially developed with the help of ethnography. We have also highlighted how researching rock art as a proxy of its environment can add to the record of a regions cultural and ecological history, by studying animal, plant, human, technology and attribute motifs, as well as scenes of activity, interactions and natural events. We argue that animal motifs are the most suitable for researching both the environmental history of a region's history, as well as interregional patterns among rock art creation as a reflection of an environment. This is largely because animals are the most prevalent representative motifs on all continents and because animal motifs are relatively easy to identify, as opposed to technologies and attributes. Additionally, animals arguably provide the most insight into the natural environment: herbivores signify the presence of certain types of vegetation and predators are attracted by the herbivores in the region. Vegetation in turn is dependent on the type of climate and it could therefore be interesting to analyse to what extend animal motifs in rock art represented the natural environment. Expanding this into a comparison of animal motifs in rock art between regions with different climatic histories could add insight into which animals were important in which climates. Further comparison between rock art from different continents may reveal whether any potential tendencies to depict animal motifs depending on climate are widespread or not. If they are, it could mean that humans universally tend to ascribe meaning to certain types of animals, depending on which environment they live in. This in turn contributes to theories on the meaning of animals in human cultures and rock art as a means of controlling the environment. These types of research into rock art as a reflection of the local environment could benefit from large databases on rock art motifs, and new computational methods, such as machine learning, can aid with both the creation of such databases in addition to subsequent large-scale analyses.

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