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The Digital Future of Prehistoric Rock Art in India

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Introduction

Samuel Taylor Coleridge (1772-1834) was, supposedly, the last person to have read all books printed in the English language, before the number of published volumes was simply too large for any one person to read in a lifetime. In India, the opportunity for one researcher to visit every rock art site has long since passed. Alongside southern Africa and Australia, India preserves one of the largest concentrations of prehistoric art in the world. This heritage vibrantly communicates aspects of prehistoric life in the Indian subcontinent that not only augments the archaeological record but also captivates the public's imagination, bringing the distant past to life. Unfortunately, rock art sites are constantly under threat through changing practices in land use, such as quarrying of the rock or deforestation increasing accessibility, making sites prone to vandalism.

Studies of Indian rock art have traditionally been restricted to a small group of scholars due to the difficulties of accessing key sites and specialised methodologies used to record the imagery. The widespread availability of digital cameras and growing access to the internet has the potential to revolutionise the goals and practices of rock art research in the Indian subcontinent that can bring together both academic and public archaeology. Here, I set out a vision for how digital approaches to rock art can enable researchers to study rock art imagery from more sites than it is possible to visit, offer new means for public presentation of India's prehistoric art history and present strategies to preserve and protect the globally significant heritage of India.

'Standing on the shoulders of giants'

Before proceeding to review the potential of a number of digital approaches to rock art recording and analyses, we must acknowledge the critical steps taken by earlier researchers. Rock art has been a focus of academic study in India since the late 19th century. Some regions with particularly dense concentrations of painted rock shelters have dominated research, particularly in the Vindhyan Range of central India, most famously known from the UNESCO world heritage site of Bhimbetka. Yet ongoing research has led to the discovery of rock art sites across the Indian subcontinent. A number of scholars have focused their research efforts in the meticulous documentation both of the imagery and the sites themselves, such as V.S. Wakankar, Y. Mathpal and

others. While supported by traditional photography, the costs of recording, processing and printing photos in publications are high, limiting the potential to create extensive, public archives.

Having visited and documented numerous rock art sites across India, Erwin Neumayer is, perhaps, the closest the field has to a figure such as Coleridge, and this experience is laid bare in the synthetic volumes he has published over the past 30 years. It is his combination of photography, tracing and freehand painting of rock art sites from across the country that most clearly define his approach. This is then supported by the rich array of illustrations that document and support his synthesis of the rich diversity of imagery evident in the prehistoric rock art of India, making them as appealing to those with a casual interest in the topic as they are important to the student and specialist alike. While the history of research has illuminated the wealth of prehistoric imagery India has to offer, contemporary theoretical perspectives demand new methods of recording and analysis are applied. These digital approaches offer key means engage wider audiences with India's prehistoric rock art heritage and adapt to emerging threats to its conservation.

Digital Photography

The widespread availability of digital cameras, not only as stand-alone pieces of equipment but as integral features of smartphones and tablets, has revolutionised how people, from professionals to the general public, engage in photography. Beyond driving down the cost of producing high resolution photographs, the widespread availability of high definition digital cameras facilitates the documentation of rock art sites by researchers that may not have been able to afford the costs of a similar film camera, including the requisite film and costs of processing. While film photography can still play an important role in the documentation of rock art, digital photography enables researchers to take more photographs of the subject that can easily and cheaply be stored on a computer and displayed on a computer, over the internet, or printed (Figure 1). Critically, the provision of many cameras with a screen to review photos that have just been taken is a vital tool when recording rock art imagery that may be difficult to access, demanding lengthy travels both on the road and through jungle. Processing a roll of film of rock art imagery at a difficult to access site that is out of focus is fortunately a costly problem that can be easily avoided.

The ability to review photographs during the process of recording is particularly important for conducting photography beyond the visible light spectrum. Photographic recording of rock art imagery in infra-red yields a number of benefits, but traditional infrared photography was problematic due to the difficulties in handling the highly sensitive film, particularly in the field, and the unpredictable results. Lacking the need for film and offering the ability to instantly review results, digital photography avoids these issues and can be achieved with most easily with a digital SLR camera, a tripod and an infrared filter. In return, infrared photography can reveal portions of a pigments colour spectrum that are difficult to see or invisible to the naked eye, clarify patterns of

superimposition, and differentiate varied pigment types and their inclusions. While red pigments dominate the corpus of prehistoric rock art imagery in India, infrared approaches can improve the visibility of other pigment colours that may assist to expose the variability of how paints were produced, what they were made from, and how they were used. Depending upon the pigments involved, such methods can also help to reveal prehistoric rock art imagery from overlying modern graffiti.



Figure 1: Rock art panel from KatavaniKunta Valley, Andhra Pradesh

Digital Image Processing

Producing a digital photographic archive of rock art imagery easily lends itself to digital image processing methods. At their simplest, this may include altering an image's contrast, brightness or saturation in software such as the free to use, open-source GNU Image Manipulation Program (www.gimp.org), which can help to adjust the visibility of particular figures (Figure 1). More advanced, but easy to apply, methods for digital image processing that are of particular importance for studying prehistoric paintings involve transformations of digital images. The most commonly used application for conducting this work is the DStretch plugin for ImageJ (<http://imagej.nih.gov/ij/>), developed by Jon Harman (www.DStretch.com). A digital image is converted from RGB by diagonalising

the covariance matrix of the colours (a Karhunen-Loeve transformation), colour variances are equalised, and the image is returned to RGB by applying the inverse transformation. The DStretch plugin conducts this at the press of a button, allowing rock art images to be transformed using a number of colourspaces that are specifically designed to enhance red, white, black and yellow pigments. The results of these methods of digital image processing are striking, and can bring out pigments that are faint to the naked eye and help to differentiate pigments from the rock surfaces they are painted on. This is particularly pertinent as frequently the use of red pigments on pinkish sandstone and quartzite rockshelters can make painted figures difficult to differentiate from features of the rock surface (Figure 2). Digital image processing offers a critical means to illuminate evidence for prehistoric painting activity beyond that which is directly visible, and as a result must now be considered necessary to complement careful recording of imagery at a site, which may otherwise miss out key features of the rock art.

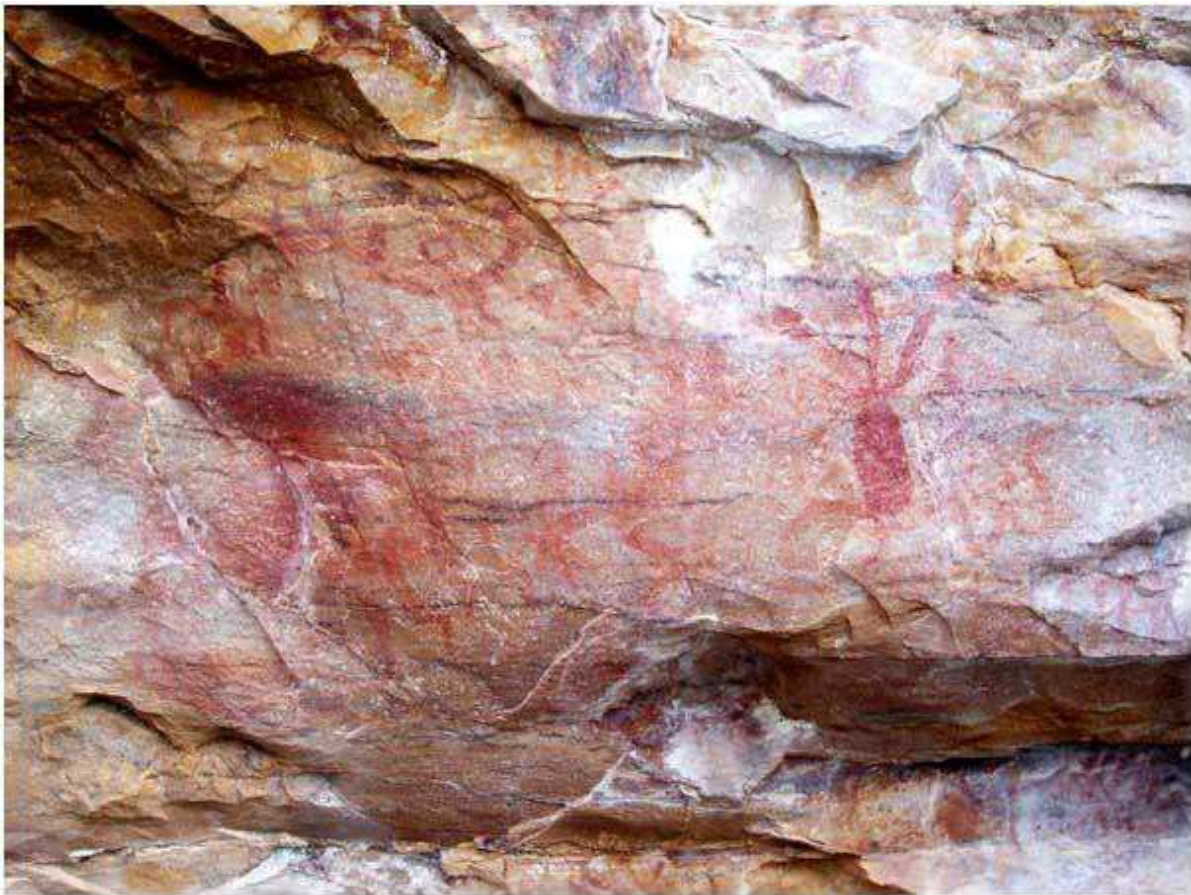


Figure 2: Rock art panel from KatavaniKunta Valley, Andhra Pradesh with enhanced contrast.

Geographical Information Systems

Geographical Information Systems (GIS) provide tools to manage and explore spatial data, which for rock art researchers can be employed both at the scale of a single site or panel, or investigating how rock art sites sit within wider landscapes. While a range of

different programs can be used to undertake such analyses, QGIS (www.qgis.org) and GRASS (www.grass.osgeo.org/) offer freely available and open source platforms to undertake geospatial analyses. One means to employ them in rock art research is as a way to explore how rock art images are placed on a single surface. Designating each individual rock art figure or motif allows a GIS analysis to examine the relationship between different figures, which is particularly pertinent for comparing different panels, or exploring the relationships between densely painted panels with common superimpositions. Such approaches can help to formalise noted relationships between different motifs and their position on the rock surface, as well as the relative chronologies of different sites.



Figure 3: Rock art panel from KatavaniaKunta Valley, Andhra Pradesh that has been digitally enhanced using DStretch.

An alternate use for GIS analyses of rock art is at the level of the site, exploring how rock art sites are situated within the landscape. In order to do this, accurate information regarding the location of a site is required. Previously, a handheld GPS was a specialist, stand-alone piece of equipment. However, GPS capabilities are now a standard feature of smartphones and many digital cameras, which makes the ability to accurately record the location of rock art sites widely available. This is further supported by the widespread availability of satellite imagery with live location tracking, such as Google

Earth and Maps. Such live imagery can be used to support navigation to potential sites for survey that have been identified through examination of the satellite imagery. Given the difficulties in conducting exploration of remote areas, or even trying to return to particular sites located in jungle settings, such digital technologies have become an indispensable tool.

Analyses of the position of rock art sites within their landscape play to the strengths of GIS studies, in which multiple strands of geospatial evidence can be combined and compared. Huge volumes of satellite and climate data are freely available for GIS based studies to download from the internet (e.g. <http://geodata.grid.unep.ch/>). A range of data such as topography, geology, river networks, ecology, or the location of archaeological sites can be contrasted with the location of rock art sites or the presence of particular motifs or groups thereof to explore how they vary with respect to one another. This allows researchers to question and quantify how rock art sites fitted within their physical, social and ecological landscape. More complex analytical procedures include viewshedanalyses that can identify both inter- and intra- site visibility, and prioritise features of human experience as central in the analyses of prehistoric rock art.

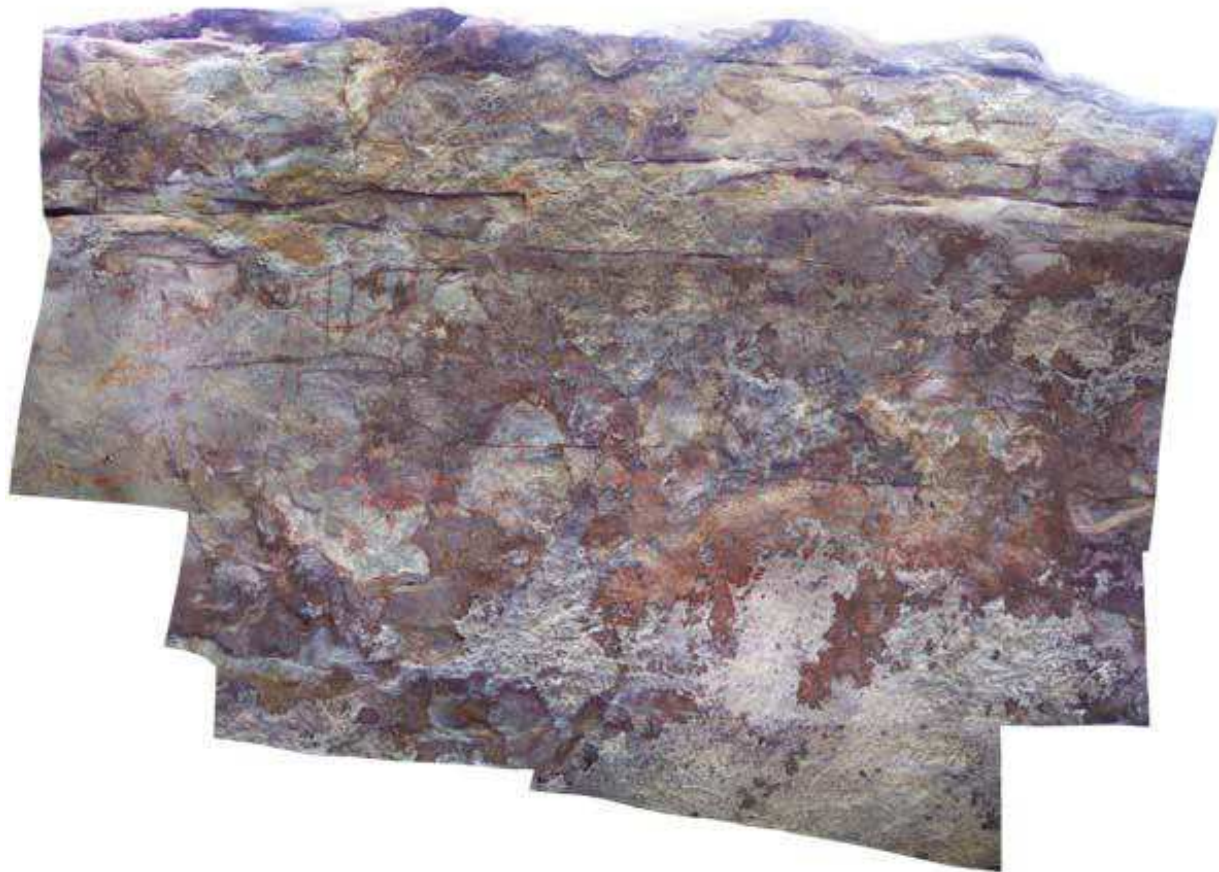
Recent research has also illustrated how GIS studies present a vital tool for evaluating the threats that exist to India's prehistoric rock art heritage, focused upon Mirzapur and Rewa Districts, located Uttar Pradesh and Madhya Pradesh respectively. Here, Banerjee and Srivastava (2013) have used freely available satellite data (enhanced thematic mapper [ETM+]; <http://landsat.gsfc.nasa.gov/>) alongside other materials to classify patterns of land use between 1989 and 2011 and evaluate the impact of these changes upon prehistoric rock art sites. The authors identify a trend of rapid deforestation up to 2000, followed by extensive mining of sandstone and development of agriculture and forest plantations. Fieldwork to corroborate patterns from analysis of satellite data lead to the discovery of numerous new rock art sites, but also illustrated how mining and deforestation had led to the destruction not only of rock art sites, but also the physical landscape in which they were created. While many rock art researchers can present similar anecdotal stories from across India, this quantified GIS approach helps to provide suitable evidence to develop schemes of cultural resource management.

3D Modelling

Producing 3D models of rock art sites offers new means to analyse, conserve and present the rock art heritage of India. Traditionally, the production of 3D models has demanded specialist hardware, such as laser scanners, that were difficult to transport to sites and demanded significant time investment to record a site. The advent of widespread digital photography has promoted new ways of approaching rock art in three dimensions, two of which are discussed here: photogrammetry and reflectance transformation imaging.

Photogrammetry involves making precise measurements from photographs. Photogrammetry software is capable of comparing the location of features between a series of photographs of a rock art panel or site and generating a 3D point cloud. The

coloured and textured surface recorded by the digital photographs can then be integrated with the point cloud to generate a 3D model of a rock art site or panel. A range of free software is available to generate 3D point cloud models from digital photographs (e.g. Visual SFM; <http://ccwu.me/vsfm/>) and add colour and texture to create realistic models (e.g. MeshLab; <http://meshlab.sourceforge.net/>), whereas paid-for software tend to integrate these functions within a single platform. Whereas traditional approaches document rock art in 2D, exacerbated by methods such as tracing, photogrammetry offers a means of recording rock art imagery that maintains the connection between the rock art image and its placement on a 3D, textured rock art surface that may have been integral in its creation. In the face of destruction of rock art sites by mining or defacement through the actions of vandals, recording rock art sites to enable photogrammetric reconstructions offers one means to preserve sites for the future. Creating 3D models of rock art panels and sites also allows wider audiences to appreciate the prehistoric rock art heritage of India in new ways without the need to visit the site directly.



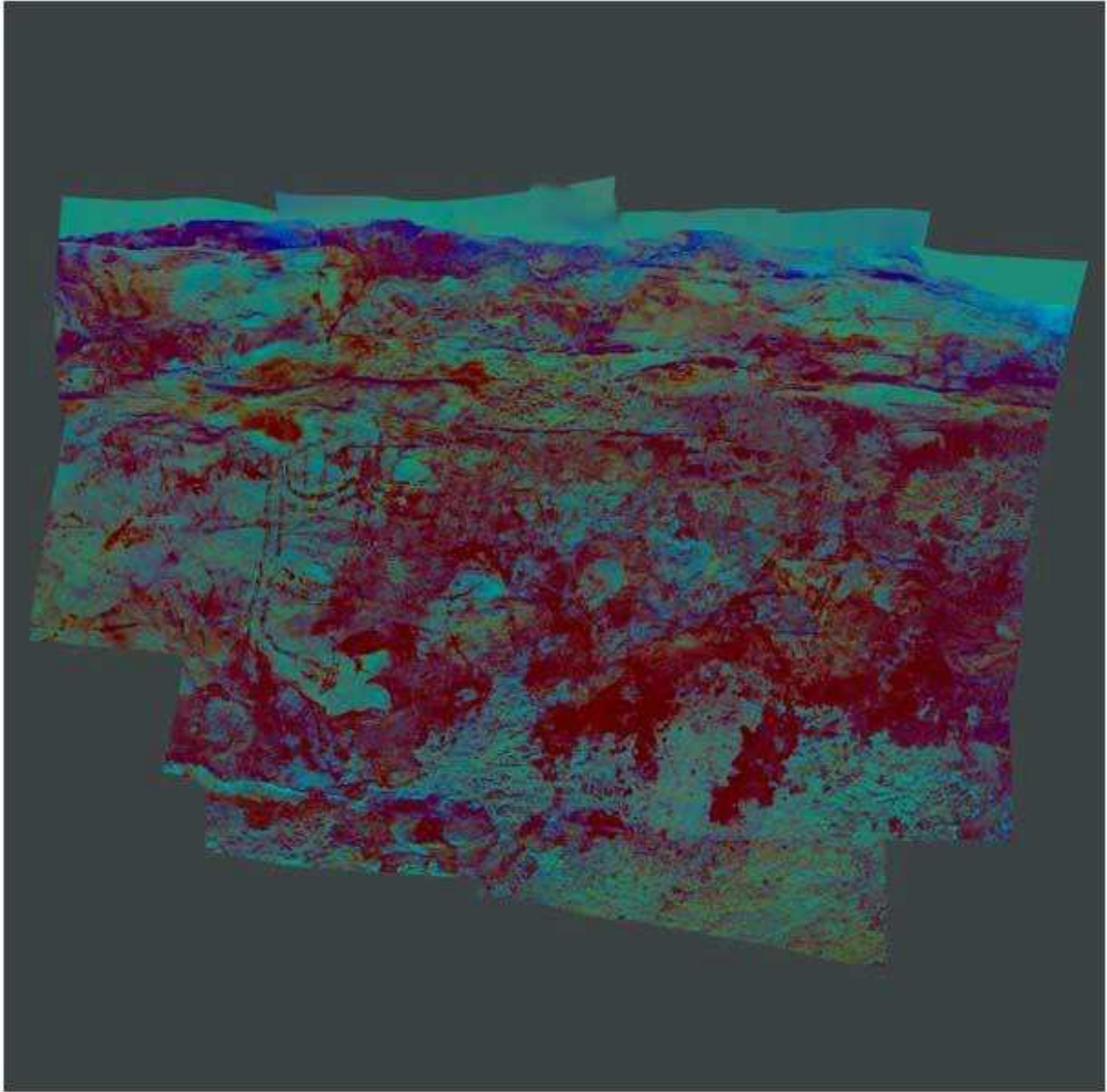


Figure 4: 3D model of rock art panel from KatavaniKunta Valley, Andhra Pradesh, created using photogrammetry. The rock art panel was located on a narrow shelf of an overhang in a rock shelter and cannot be viewed in its entirety in person. 3D modelling has enable the whole panel to be viewed for the first time, without (above) and with (below) DStretch enhancement.

In contrast to photogrammetry that requires changes in the angle of photography to create a 3D model, reflectance transformation imaging (RTI) uses photographs from a fixed location combined with a moving light source in known locations. Integration of these photographs within a computer model efficiently records both colour and 3D shape information within a reflectance transformation image. Examination of this image allows interactive relighting of the subject, as well as mathematical enhancement of the surface shape and colour attributes. RTI demands more equipment in the field than photogrammetry, as it is necessary to control and record the direction of lighting and

ensure the stability of the camera. However, RTI is particularly suitable for recording rock art created in light relief by pecking or bruising the rock surface (petroglyphs). Again, software to support RTI analyses is freely available (<http://culturalheritageimaging.org/>).

Digital Image Presentation

While digital approaches to recording and analysing rock art will change both how we study it and what we can learn about it, it is the capacity to share digital images that will have the greatest impact upon collaborative and public efforts to explore India's prehistoric art. For many researchers the costs of including figures, and particularly colour figures, in traditional print media are prohibitively high, making the lavishly illustrated *Prehistoric Rock Art of India* (Neumayer, 2013) a departure from the norm. Indeed, this volume is notable for including a DVD of digital media to support the publication, indicating that publishers recognise the importance of digital images for the study of rock art. However, the capacity to share images rapidly over the internet presents the most significant advantage that digital media have.

Websites provide an ideal platform for sharing imagery that is accessible to everyone. Two notable sites that have a present a diverse array of digital images of prehistoric Indian rock art are hosted by the Indira Gandhi National Centre for the Arts-Rock Art Unit (<http://ignca.nic.in/rockart.htm>) and the Bradshaw Foundation's Indian Rock Art Archive (<http://www.bradshawfoundation.com/india>). A wealth of free website hosting sites are now available that provide the means for individual researchers to quickly and easily produce a website to present imagery from sites they have recorded. Presenting 3D models on line is a more complex affair, but a range of free to use websites offer the ability to upload user generated 3D models (e.g. www.sketchfab.com). Looking toward the future, an integrated approach to archiving digital rock art data in all its diverse forms is required to help preserve India's prehistoric rock art heritage. Specialised open access digital archiving software such as DSpace (<http://www.dspace.org/>) can play a central role in cultural resource management strategies, which are particularly pertinent due to ongoing pressure from changing patterns of land use and resource exploitation in India.

Summary

Digital approaches to documentation, analyses and presentation offer the best opportunity to match Samuel Coleridge's feat in English literature by making it possible for researchers and the general public alike to examine and explore the entire corpus of prehistoric rock art from India. Surprisingly, many of the digital approaches outlined above require limited specialist equipment and are supported by free, open source software platforms, making them available to the majority of rock art researchers as well as more casual enthusiasts. Critically, increasing public accessibility is key to raising awareness of the pressing need to preserve India's rich prehistoric rock art heritage. Preservation of India's prehistoric rock art sites is a matter of global significance and the

digital methodologies outlined here will play a central role in the cultural resource management strategies that will enable for this unique body of artistic work to both inform and inspire future generations.

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