JSBS Journal of Sistan and Baluchistan Studies
Volume 6, Issue 2 (2026) 1-13
Doi: 10.22034/jsbs.2026.579980.1145

BEYOND VISIBILITY: DSTRETCH-BASED DIGITAL ANALYSIS OF ROCK ART AT SEPANTASH, UZBEKISTAN

Olimjon Khayitboevich UROKOV [1] ✉, **Sanjar Iskandarovich ANORKULOV** [2], **Sitora Fazldinovna TURAKULOVA** [2], **Kamol MUSTAEV** [3], **Freshta GAYOUMI** [4]

[1] Samarkand State Architecture and Construction University, (pourarch@gmail.com).
[2] Samarkand State Institute of Foreign Languages.
[3] "Silk Road" International University of Tourism and Cultural Heritage, Department of History and Cultural Heritage.
[4] Tashkent State University of Economics.

Received: 29 November 2025 Accepted: 17 February 2026 Available online: 10 June 2026

Abstract: Over the past few decades, archaeological research in Uzbekistan has led to the identification of more than 200 rock art sites. However, the studies conducted so far have been mainly limited to site identification, iconographic analysis, and relative dating, with little emphasis on in-depth analytical approaches and the application of modern scientific methods. In this context, the use of advanced technologies in digital documentation, image processing, and absolute dating plays a critical role in advancing the quality of rock art research. These approaches not only allow for higher-resolution recording of the motifs, but also help reveal details that are not visible due to erosion. This is particularly important given that rock art heritage is facing significant destruction and fading due to natural weathering and anthropogenic impacts and requires urgent conservation measures. Accordingly, the present article aims to document, interpret, and analyze rock art discovered at the Sepantash site near the village of Koruksoy in the Kashkadrya region. In this research, modern tools such as DStretch have been used to enhance and reveal faded motifs. The results show that the use of this technology allows for more precise identification of visual features and provides more reliable data for subsequent analysis. Both pictographs and petroglyphs have been identified at the site. The pictographs were drawn using red and black pigments. Digital analysis also showed that a significant part of the visual data can only be identified through image processing, and the overlapping motifs and color differences confirm the existence of several temporal stages in the formation of these works. This research emphasizes the importance of using modern technologies in the documentation and analysis of rock art and highlights Sepantash as a significant case study for reconsidering symbolic systems in Central Asian rock art traditions.

Keywords: Central Asia, Rock Art Pictographs and Petroglyphs, Digital Enhancement, DStretch.

چکیده: پژوهش‌های باستان‌شناختی انجام‌شده در ازبکستان طی چند دهه گذشته به شناسایی بیش از ۲۰۰ محوطه هنر صخره‌ای منجر شده است. با این حال، مطالعات صورت‌گرفته تاکنون عمدتاً به شناسایی محوطه‌ها، تحلیل شمایل‌نگارانه و گاهنگاری نسبی محدود بوده و کمتر به رویکردهای تحلیلی عمیق و کاربرد روش‌های نوین علمی توجه شده است. در این میان، بهره‌گیری از فناوری‌های پیشرفته در مستندسازی دیجیتال، پردازش تصاویر و تاریخ‌گذاری مطلق نقش بسزایی در ارتقای کیفیت پژوهش‌های هنر صخره‌ای دارد. این رویکردها نه تنها امکان ثبت دقیق‌تر و با وضوح بالاتر نقوش را فراهم می‌کنند، بلکه به آشکارسازی جزئیاتی کمک می‌کنند که در اثر فرسایش و عوامل محیطی از دید مستقیم پنهان مانده‌اند. اهمیت این موضوع از آن‌رو دوچندان است که میراث هنر صخره‌ای در معرض تخریب و محوشدگی ناشی از هوازدگی طبیعی و مداخلات انسانی قرار دارد و نیازمند اقدامات فوری حفاظتی است. بر همین اساس، مقاله حاضر با هدف مستندسازی، تفسیر و تحلیل نقوش صخره‌ای کشف‌شده در محوطه سپنتاش، واقع در نزدیکی روستای قوروق‌سوی در منطقه قشقه‌دریا، تدوین شده است. در این پژوهش از ابزارهای نوین، از جمله نرم‌افزار *DStretch*، برای تقویت و آشکارسازی نقوش کم‌رنگ و محوشده استفاده شده است. نتایج نشان می‌دهد که بهره‌گیری از این فناوری امکان شناسایی دقیق‌تر ویژگی‌های بصری را فراهم کرده و داده‌های قابل اعتمادتری را برای تحلیل‌های بعدی در اختیار پژوهشگران قرار می‌دهد. در این محوطه، هم نقاشی‌های صخره‌ای و هم سنگ‌نگاره‌ها شناسایی شده‌اند. نقاشی‌های صخره‌ای با استفاده از رنگ‌دانه‌های قرمز و سیاه اجرا شده‌اند. تحلیل دیجیتال همچنین نشان داد که بخش قابل توجهی از داده‌های بصری تنها از طریق پردازش تصاویر قابل شناسایی است و هم‌پوشانی نقوش و تفاوت‌های رنگی، وجود چندین مرحله زمانی در شکل‌گیری این آثار را تأیید می‌کند. این پژوهش بر اهمیت به‌کارگیری فناوری‌های نوین در مستندسازی و تحلیل هنر صخره‌ای تأکید دارد و محوطه سپنتاش را به‌عنوان مطالعه موردی مهمی برای بازاندیشی در نظام‌های نمادین سنت‌های هنر صخره‌ای آسیای مرکزی معرفی می‌کند.

کلیدواژه: آسیای مرکزی، هنر صخره‌ای، نقاشی‌های صخره‌ای و سنگ‌نگاره‌ها، بهبود دیجیتال تصاویر، DStretch.

I. Introduction

Rock art is one of the most fundamental sources for reconstructing the symbolic, cultural, and social dimensions of past societies and, in the absence of written texts, plays a key role in interpreting human cognition, belief systems, and subsistence practices (Whitley, 1998; Clottes, 2008; Bahn, 2010; Sarhaddi-Dadian et al., 2015; Bonneau et al., 2017). These arts, which include petroglyphs and pictographs, not only reflect human daily activities and the environment, but also express symbolic structures and social identities across time (Moradi et al., 2013; Sarkhosh et al., 2015; Mohammadi Sefidkhani & Sarhaddi-Dadian, 2022).

In Central Asia, despite the identification of hundreds of rock art sites, a significant portion of these data remains at the descriptive level and has received

limited systematic and interdisciplinary analysis based on modern scientific methods (e.g., Rogozhinskiy, 2011; Amanbaeva et al., 2011; Bobomulloev et al., 2011; Muradova, 2011; Khujanazarov, 2011; Rozwadowski & Lymer, 2012). However, such sites have a high potential for examining cultural interactions, patterns of movement, and ideological developments on a regional scale. Uzbekistan, as one of the important centers of rock art in Central Asia, has a rich but relatively understudied collection of these types of sites (Francfort, 1998; Lasota-Moskalewska & Hudjanazarov, 2000; Khujanazarov, 2001; Kolobova et al., 2011; Augustinová & Stančo, 2016).

This region has been continuously occupied and utilized by human societies since prehistoric times, resulting in the formation of thousands of archaeological sites. These include a wide range of archaeological evidence, from caves (Gunz & Bulygina, 2012; Pavlenok et al., 2022), settlement sites (Nishiaki et al., 2022; Khanipour et al., 2026), and historical monuments (Kadirova & Abduvakhidova, 2025) to rock art sites identified across Uzbekistan. Among them, the Sepantash rock art site, due to its presence of both petroglyphs and pictographs, is considered a prime example for comparative analysis of production techniques and expressive patterns in a single spatial context. This feature allows for simultaneous examination of technological, stylistic, and semantic differences and provides a more accurate understanding of the artistic and cultural traditions of the region. However, one of the main challenges in the study of rock art is natural weathering, erosion, and anthropogenic impacts, which have caused the gradual destruction and fading of the motifs. In many cases, a significant part of the visual information is no longer discernible to the naked eye, which further emphasizes the need for new methods of documentation and analysis. In recent years, the application of digital technologies to the study of rock art has brought about a fundamental transformation in the methods of recording, analyzing, and interpreting these works (Horn et al., 2022). Meanwhile, DStretch software, as one of the effective image processing tools, uses the decorrelation stretch algorithm to enhance subtle color differences and help identify poorly visible motifs (Quellec et al., 2015; Quesada & Harman, 2019). This method not only enhances the accuracy of documentation but also allows the identification of motifs and details that are not visible under normal conditions. However, the use of these technologies is not without limitations. The results of digital processing can be influenced by user settings and parameter selection, and in some cases, lead to over-enhancement or the creation of false visual motifs. Therefore, researchers emphasize the need for a critical approach to the careful interpretation of digital data, with comparisons to field observations and archaeological evidence.

Accordingly, the present article aims to introduce the Sepantash rock art site and provide a more accurate documentation of its motifs using digital methods, in particular DStretch. Based on these objectives, this research seeks to answer the following questions: What types of rock art motifs (pictographs and petroglyphs) can be identified at the Sepantash site, and what stylistic and technical characteristics do these motifs have? To what extent can the use of digital methods, especially DStretch software, help to reveal and document more accurately the faded and worn motifs? What is the place of this site in the broader context of Central Asian rock art, and what similarities or differences does it show with other sites in the region? This research, by combining field data and digital analysis, aims to provide a deeper understanding of the stylistic, technical, and cultural characteristics of this site and to explain its place in the broader context of Central Asian rock art.

II. Methodology

This research adopts a mixed-method approach, integrating both fieldwork and digital analysis to investigate the rock art of the Sepantash rock art site. In the first stage, a field survey was conducted, and panels with motifs, including petroglyphs and pictographs, were identified and documented. Images were captured using a high-resolution camera under variable lighting conditions, including direct light and raking light, to maximize the capture of visible detail. In the second stage, digital images were processed using DStretch software to enhance clarity and reveal faded motifs. This software employs a decorrelation stretch algorithm to enhance subtle color variations and allows the identification of motifs that are not visible to the naked eye (Quesada & Harman, 2019). The outputs from this processing were used for enhanced documentation and digital tracing. However, due to the interpretive nature of digital processing methods, the results obtained were not the sole basis for analysis. To improve data reliability, the enhanced images were compared with raw images and field observations, and any ambiguous features were critically evaluated using a critical interpretative approach. This approach was adopted to reduce errors due to over-enhancement or false motif generation. Finally, the identified motifs were analyzed within a regional archaeological framework, and the study further examines their relationship with the cultural patterns and environmental context of prehistoric societies in Central Asia.

III. The Sepantash Rock Art Site

The Sepantash Rock Art Site is located in the foothills of the Karatagh Range, part of the Zarafshan

Mountains, near Koruksai Village in Chirakchi District, Kashkadarya Region (Fig. 1). This geographical location places the site in a rocky mountainous landscape that provides suitable conditions for the creation and preservation of rock art.

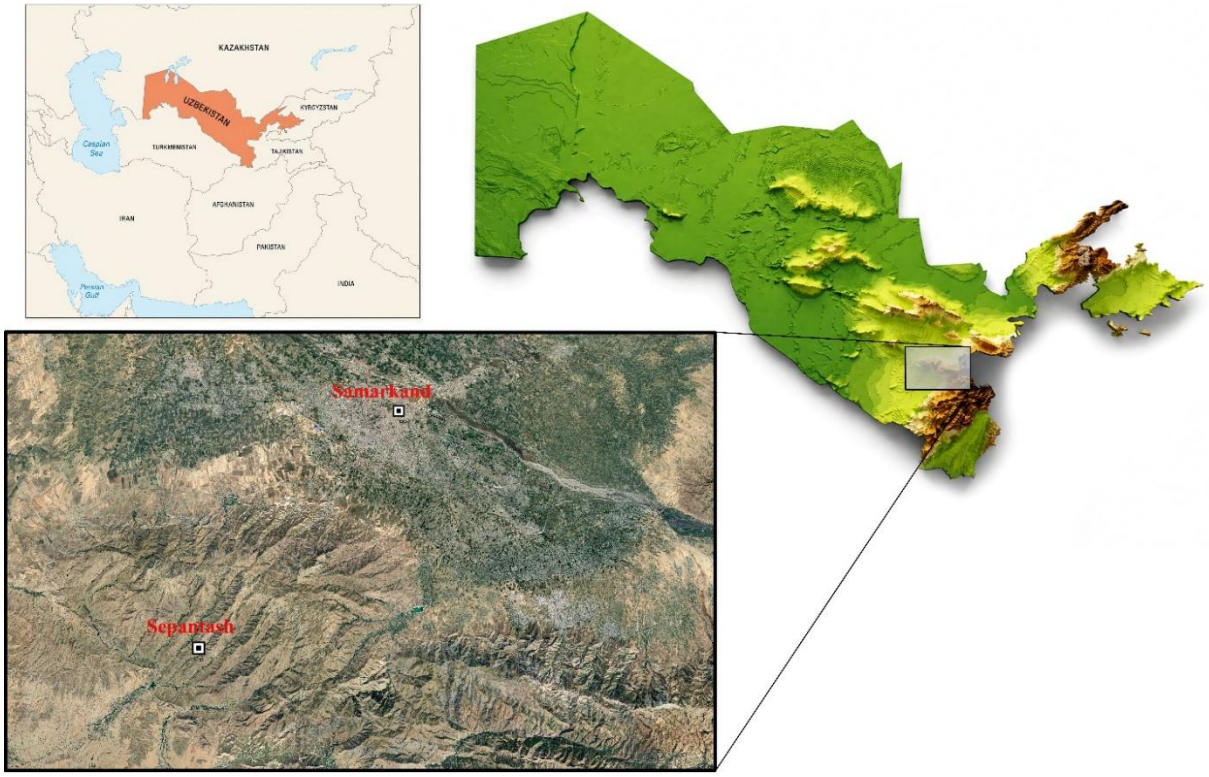

Figure 1: Geographic setting of the Sepantash site, Uzbekistan.

Sepantash is located in a micro-landscape with sandstone and limestone outcrops that naturally provide rock shelters and suitable surfaces for the creation of motifs (Fig. 2). Such geomorphological conditions are widely associated with the production of rock art throughout Central Asia, as these spaces provide a suitable surface for the creation of motifs, both from a protection and visual prominence. The presence of painted panels beneath the protected surfaces at Sepantash can also be interpreted within this framework, suggesting that the selection of these spaces was intentional. The motifs identified at the site are mainly located in two spaces or two main panels, each located beneath large rock overhangs (Figs. 3 & 4). This feature makes Sepantash a coherent yet spatially complex rock art site suitable for integrated analysis. Many of these motifs have undergone fading and weathering due to the passage of time and environmental factors.

The Sepantash rock art was first identified in 2001 by R. Kh. Suleymanov. Since then, the site has been identified in various studies as one of the most important Central Asian rock art sites. However, most of the research has remained at the level of preliminary reports and relative chronology, and no laboratory analysis or advanced digital methods have been applied to establish an absolute chronology or systematically document these works.

IV. Rock Art Techniques at the Sepantash Site

Two main types of rock art have been identified at the Sepantash site: petroglyphs and pictographs, with pictographic motifs being more abundant. This technical diversity indicates the use of different modes of visual expression within a single cultural context.

IV.1. Petroglyphs

Although limited examples of recent carvings, such as graffiti inscriptions, have been observed at the Sepantash site in recent years, the main petroglyphs at the site include three zoomorphic motifs carved on the wall of Panel 1. These motifs are depicted as three sequential zoomorphic motifs, all in profile view and all oriented to the right. The motifs are highly simplified and schematic, and only the main elements of the body, including the trunk, legs, and head, are recognizable (Fig. 5). Technically, these motifs were created using a scratching technique, and therefore they exhibit limited depth and their surface has a relatively shallow relief. This feature may suggest an early or relatively conservative phase in the production of petroglyphs in this region.

Figure 2: Regional landscape and the spatial distribution of panels at the Sepantash site.

Figure 3: Overview of Panel 1 showing the spatial distribution of pictographs.

Figure 4: Overview of Panel 2 showing the spatial distribution of pictographs.

Figure 5: Zoomorphic petroglyphs from the study area.

IV.2. Pictographs

The Sepantash pictographs make up the majority of the rock art at the site and are scattered on the ceiling and northern wall of Panel 1 and on the ceiling of Panel 2. There is no particular pattern in the shape and location of the motifs, and motifs are created in different parts, namely the vertical and horizontal surfaces. These motifs are drawn using two primary colors, namely red and black pigments, although red is dominant and includes a range of tones from light to dark. In prehistoric, ochre was used to make red (Alirezazadeh & Heydarian, 2022; Holakooei et al., 2025; Khanipour & Holakooei, 2025), and it appears that ochre was used here as well. The use of pigments at Sepantash can be understood within a broader tradition of color use in prehistoric societies of Central Asia and Southwest Asia. In Iran (Masuda et al., 2013; Azizi Kharanaghi et al., 2016; Abe et al., 2022; Khanipour, 2023; 2024c; 2025; Khanipour & Nishiaki, 2024; Khanipour & Abe, 2025a-b) and southern Turkmenistan (Masson & Sarianidi, 1972; Kohl, 1984; Pollock et al., 2025), painted pottery traditions emerged during the Neolithic period and expanded significantly during the Chalcolithic (Alizadeh 2003; Karimikiya et al., 2022; Poodat, 2023; Jamshidi Yeganeh & Khanipour, 2025a-b; Khanipour et al., 2026;), reflecting the growing importance of color and visual symbolism in material culture. In contrast, painted pottery traditions became more prominent in many parts of present-day Uzbekistan during the Bronze Age, particularly with the development of settled agricultural societies. The use of pigments in rock art therefore represents another aspect of this ancient tradition of visual expression, in which color played an important role in communication, symbolism, and artistic production. The pictographic motifs are highly diverse and include geometric forms, handprints, circular, sun-like motifs, and abstract motifs (Figs. 6 & 7).

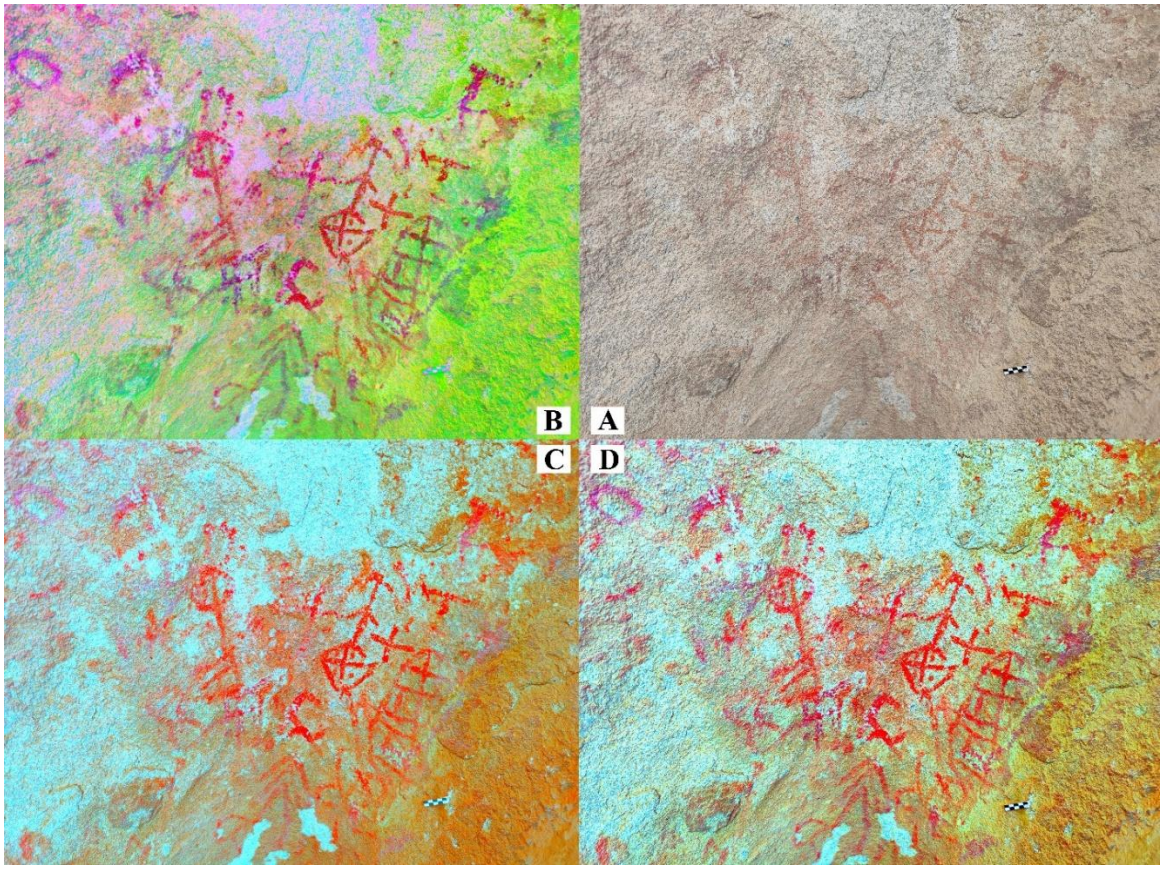

Figure 6: Pictographs from Panel 1. (A) Original photograph; (B–D) digitally enhanced images produced using DStretch in CRGB (B), YWE (C), and YRD (D) modes.

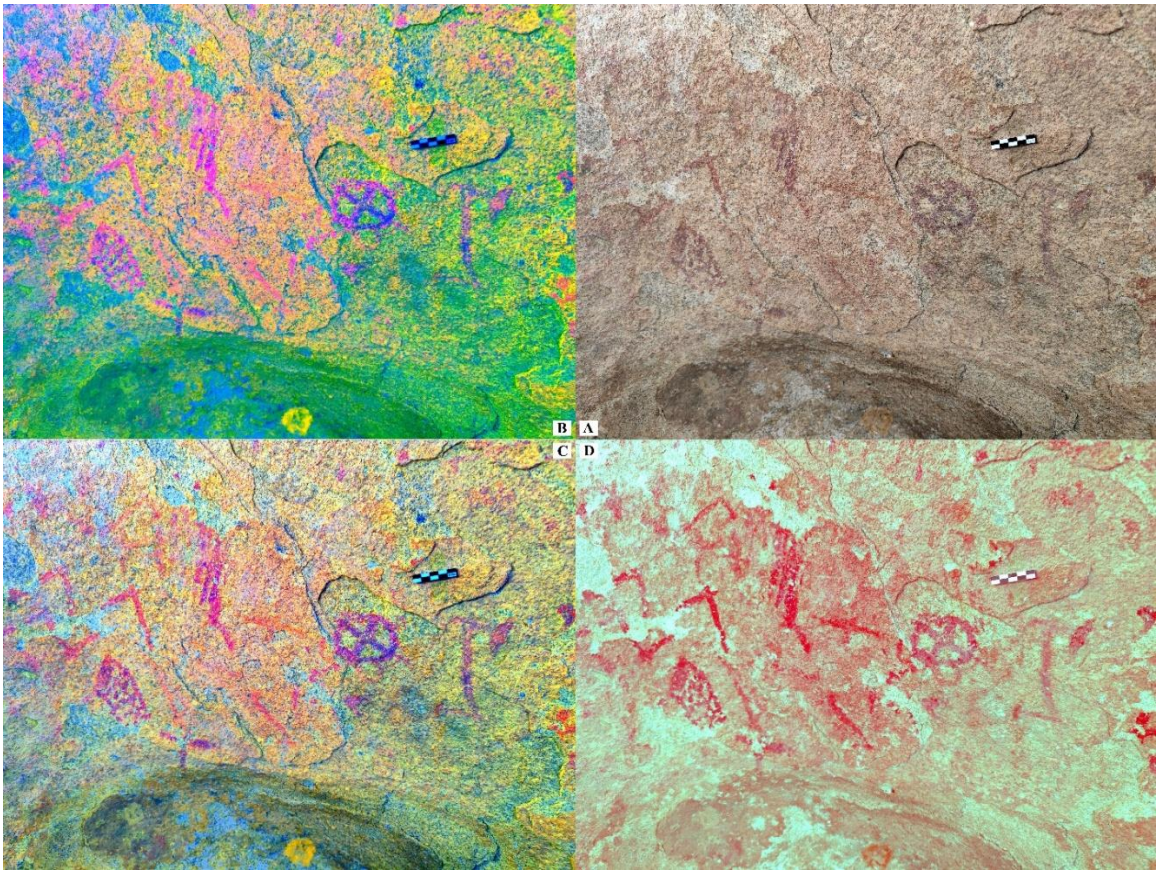

Figure 7: Pictographs from Panel 1. (A) Original photograph; (B–D) digitally enhanced images produced using DStretch in YBK (B), YDT (C), and YRE (D) modes.

The presence of handprint motifs at the Sepantash site is of particular importance because this group of images is considered one of the most widespread and ancient symbolic patterns in rock art in the world and has been widely observed in various regions from Central Asia to Iran (Sarhaddi, 2013) and even Europe (Beltran, 1995; Brady et al., 2022). This geographical and temporal continuity shows that the role of the hand was one of the fundamental elements in expressing identity, human presence, or rituals in prehistoric societies (Anick, 2019). At Sepantash, these motifs include handprints and sometimes finger impressions. Unlike some other sites where hands were created using a negative stenciling technique, here the evidence suggests that the technique appears to involve positive application, with pigment likely applied to the palm of the hand and then pressed directly onto the rock surface. This technical difference could indicate cultural diversity or differences in rock art traditions in the region. The highest density of handprints is found in Panel 1, particularly in the upper section and on a nearly vertical surface. In this section, about 15 handprints have been identified, arranged in a clustered pattern (Fig. 8). This spatial focus may indicate the symbolic importance of this part of the panel and possibly suggest its potential function as a ritual or ceremonial space.

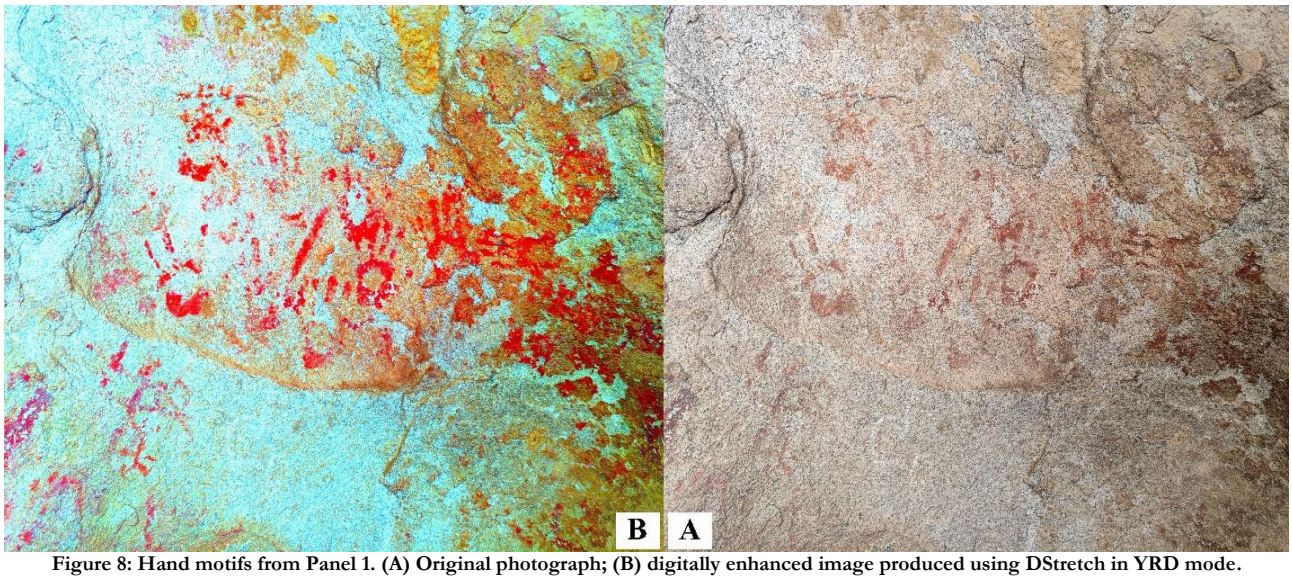

Figure 8: Hand motifs from Panel 1. (A) Original photograph; (B) digitally enhanced image produced using DStretch in YRD mode.

Another noteworthy point is that this group of motifs, compared to other motifs in the site, is located in a position that is relatively inaccessible. Their high position indicates that, in order to create these works, the creators probably needed to use a supporting platform or scaffolding to gain access to the desired surface. This not only indicates planning in the execution of the motifs, but also may indicate the special importance of these motifs in the symbolic structure of the site. In contrast, other motifs in Sepantash were created mainly on more accessible surfaces, and this difference in spatial distribution may indicate a functional or semantic separation between the types of motifs.

Overall, the hand motifs in Sepantash are not only remarkable from a technical and technical perspective, but also from a symbolic interpretation perspective, and can be an important key to understanding the ritual behaviors and semantic systems of the societies that produced this rock art. The pictographs of this site are highly diverse in form, including circles, rhombuses, polygons, lines, cross-hatched patterns, dots, plus signs, with some motifs containing dots within circles or rhombuses (Fig. 9).

This diversity may indicate complex or multi-stage symbolic systems in the production and use of these motifs.

IV.3. Chronology

One of the fundamental challenges in rock art studies is the issue of chronological attribution of these works. Unlike cultural materials such as pottery or stone tools that can be relatively dated based on typology, rock art, due to its visual nature and long temporal continuity, has a wide stylistic and temporal diversity and cannot be precisely dated based solely on style. In such circumstances, the most reliable method for determining the age of the motifs is to use laboratory-based dating methods (Bonneau et al., 2017), including radiocarbon dating, uranium-thorium (U-series dating), or modern methods related to mineral accretions (e.g., rock varnish dating). However, these methods are not always applicable, especially in cases where there is no organic material or dateable sediments in direct contact with the motifs.

In the case of the Sepantash site, although an information board at the site dates it to the 9th–14th centuries CE and some studies have attributed it to the

prehistoric period, no absolute dating has been performed on the works, and their precise timing remains uncertain. Analysis of the visual characteristics of the motifs, including color variability, degree of fading, and superimposition of motifs, suggests that these works were likely created in multiple periods (multi-period execution). This suggests a long-term tradition of using this space for rock art rather than a single cultural event. As a result, a definitive attribution of these motifs to a specific time period, whether prehistoric or historic, is not currently possible. Given the importance of the Sepantash site in understanding the rock art traditions of Central Asia, especially in the field of pictographs, laboratory studies and the use of advanced chronological methods are essential to more accurately determine the age of these works.

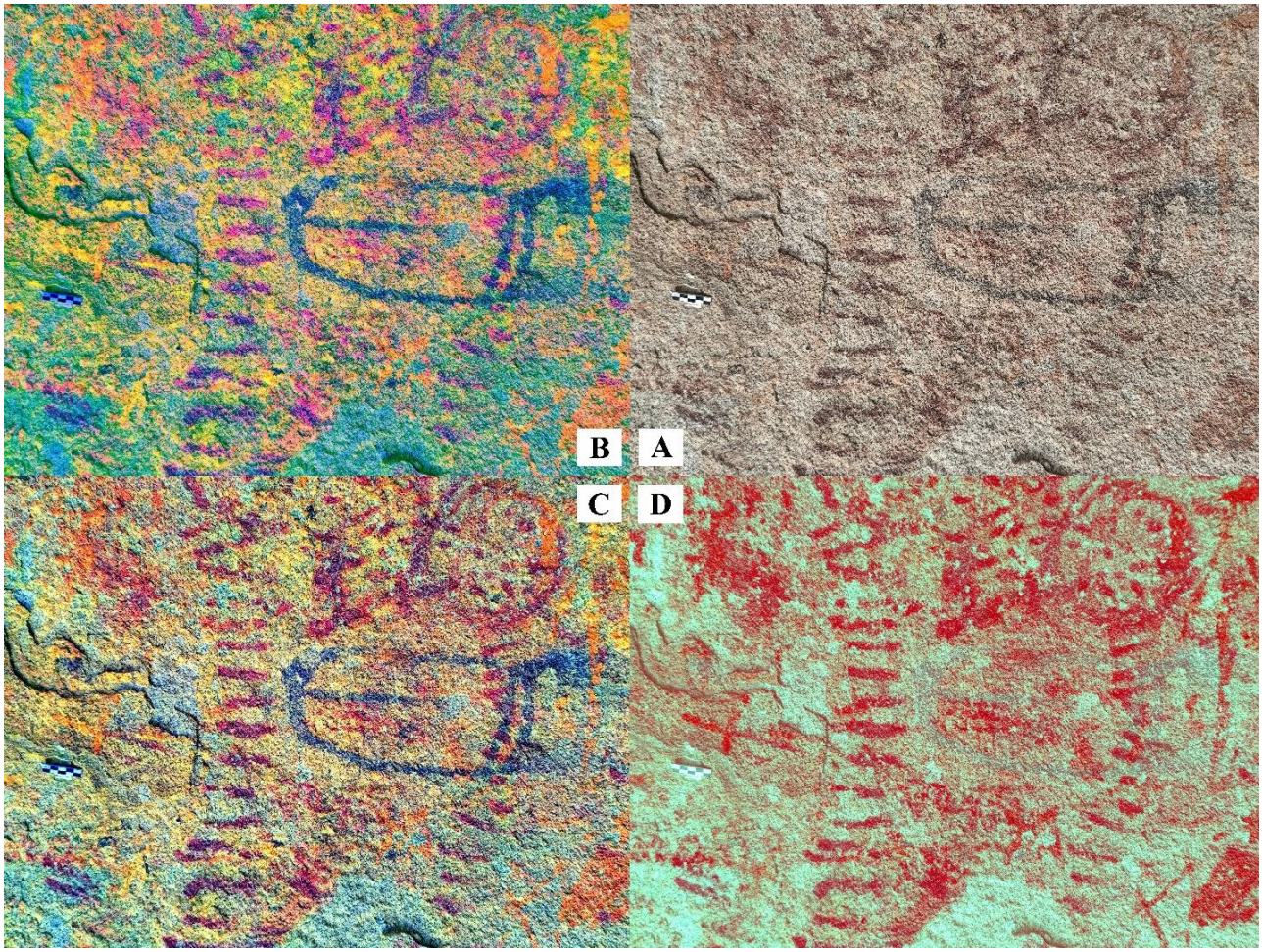

Figure 9: Red and black petroglyphs from Panel 2. (A) Original photograph; (B–D) digitally enhanced images produced using DStretch in YBK (B), YDT (C), and YRE (D) modes.

IV.4. Conservation

Since most of the Sepantash rock art motifs are located under rock shelter overhangs, they are somewhat protected from direct rain and severe erosion. However, field investigations show that this natural protection is not complete, and some parts are still exposed to water infiltration and surface weathering. As can be seen in Figure 10, areas exposed to water runoff have experienced severe fading, while beyond a certain boundary where the water flow stops, the motifs are clearly visible. This pattern suggests that parts of the motifs that are no longer visible today may have existed in the past but have gradually been lost through taphonomic processes. This situation indicates that the Sepantash pictographs are in a fragile condition and, if appropriate conservation strategies are not implemented, the risk of gradual deterioration is significant. Similar studies in other rock art sites have also shown that climate change, humidity, and human activities are the most important factors threatening this type of cultural heritage (Agnew et al., 2015).

Figure 10: Weathering effects on the rock surface and their spatial relationship to the pictographs.

IV.5. Tourism Potential and Cultural Heritage Management at the Sepantash Rock Art Site

In addition to its archaeological significance, the Sepantash Rock Art Site also has significant potential for the development of cultural and archaeological tourism. The location of the site in a mountainous landscape and the simultaneous presence of rock paintings and petroglyphs have made it one of the most significant rock art sites in Central Asia. In recent years, researchers have emphasized that rock art sites are not only valuable resources for studying past societies, but can also serve as important cultural tourism attractions in introducing the history, culture, and identity of human societies (Duval & Smith, 2013; Srivastava, 2021), and many tourists are interested in visiting these sites.

Although the tourism industry in Central Asian countries has grown significantly in recent decades, the majority of tourists still visit historical cities such as Samarkand and Bukhara, and architectural monuments. In the meantime, sites such as Sepantash can help diversify tourism destinations and develop rural tourism. Also, the use of modern digital documentation methods, including image processing with DStretch software, can play an important role in better introducing these works, increasing public understanding of their value, and developing educational and research programs.

Since rock art is very vulnerable to natural erosion, temperature changes, biological growth, and human intervention (Rogozhinskiy, 2021), tourism development in such sites should be accompanied by appropriate conservation programs. Field observations at Sepantash show that field observations at Sepantash indicate the presence of modern graffiti and recent inscriptions on and around several rock surfaces, indicating the vulnerability of this cultural heritage to human activities. Such interventions not only cause the gradual destruction of ancient motifs but, in some cases, also make it difficult to recognize and interpret the original motifs. The experience of many rock art sites in the world has shown that the lack of appropriate conservation programs and uncontrolled access by visitors can lead to the gradual destruction of these works. Hand contact with these designs can gradually cause them to deteriorate and fade. Therefore, any planning for the introduction and development of tourism in the Sepantash site must be accompanied by a comprehensive management and conservation program. Creating specific visitor routes, installing educational and interpretive panels, continuous monitoring of the condition of the designs, and the participation of local communities in the protection of the site are among the most important measures that can help in the long-term preservation of this valuable heritage.

V. Discussion

The Sepantash rock art site presents a diverse collection of visual expressions in the form of pictographs and petroglyphs that appear to have been created over a relatively long timespan and in multi-period cultural phases. One of the notable features of the site is the predominance of non-anthropomorphic and non-zoomorphic motifs, especially geometric motifs, in the pictographs. This is a distinctive feature compared with many rock art traditions in Central Asia and neighboring regions, where zoomorphic motifs and hunting scenes predominate (Rozwadowski & Lymer, 2012).

In most Asian rock art assemblages, particularly in Iran (Ghorbani et al., 2022; Molaie Kordshouli et al., 2022; Khanipour, 2024a-b; Salimi & Azizi Kharanaghi, 2025; Sadeghi et al., 2023), Siberia, Mongolia (Jacobson-Tepfer, 2025), and parts of Central Asia, animal representations are significant not only in terms of numbers but also in terms of species diversity and scene dynamics, and are often interpreted in terms of hunter-gatherer subsistence systems or associated ritual

traditions. However, at Sepantash, the relative lack of zoomorphic and anthropomorph motifs in the pictographs and the focus on geometric, circular, and abstract forms could indicate a different symbolic system, perhaps more focused on abstract expressions, spatial marking, or ritual concepts. The limited number of zoomorphic petroglyphs may reflect a different chronological phase or functional tradition within the site.

The only notable exception to this pattern is the presence of handprints, which have been interpreted as one of the earliest forms of human symbolic expression in many global rock art traditions, including well-known examples such as Lascaux Cave in Europe, Africa, and Central Asia (Clottes, 2008). Importantly, at Sepantash, some of these handprints are positioned at relatively high altitudes, suggesting that they may have been created using supports or temporary scaffolding. This could indicate spatial awareness and planning in the execution of the motifs.

From a temporal perspective, evidence from field surveys and digital analyses suggests that the Sepantash motifs were likely created over a long period of time and in sequential phases of production. Differences in color intensity, degree of weathering, and the superimposition of some motifs support the assumption that the site was continuously used over different periods. In this regard, the use of DStretch software has played a crucial role in the identification and analysis of the motifs. This software, using the decorrelation stretch algorithm, allows for the separation and enhancement of subtle chromatic variations, thereby revealing parts of the motifs that would not normally be discernible to the naked eye (Quesada & Harman, 2019). The use of different modes of this software showed that each rendering mode is suitable for a specific type of data. For example, the YRD and YRE modes are particularly effective in highlighting red pigments, but may lead to background enhancement and visual artifacts, and also blur black motifs. In contrast, the YDT and YBK modes perform more accurately in better separating black pigments and combining them with red motifs (Fig. 11).

This shows that digital analysis should always be done with a critical and multi-scalar interpretation approach to avoid misinterpretations. Although the DStretch software is very effective in enhancing and revealing pictographs, the results of this study showed that its application to petroglyphs is not always the same and error-free. In some settings and processing modes, especially when focusing on enhancing specific color spectrums, this software can reduce the surface contrast of the rock, resulting in a loss of visibility of engraved motifs (Fig. 5). This is especially true for motifs with shallow depth or high surface erosion. Therefore, using DStretch for petroglyphs requires careful parameter selection and multi-mode analysis to avoid incomplete interpretations or loss of visual data.

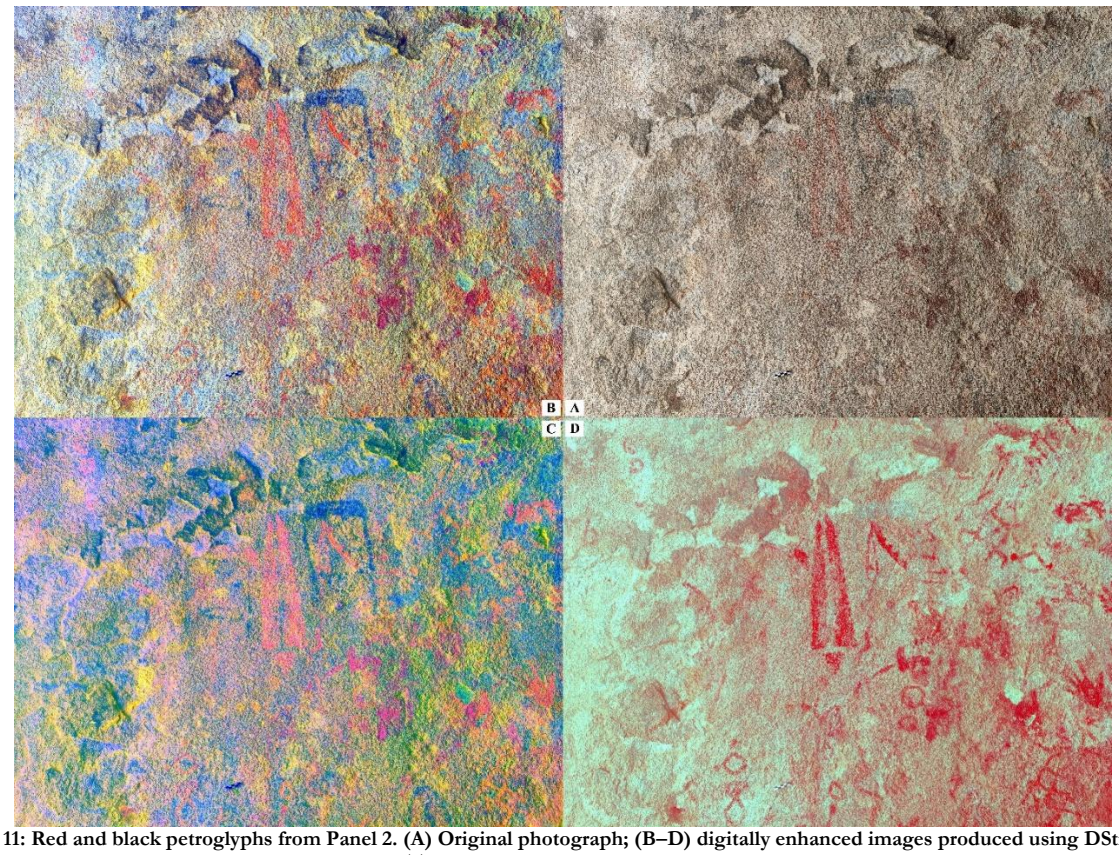

Figure 11: Red and black petroglyphs from Panel 2. (A) Original photograph; (B–D) digitally enhanced images produced using DStretch in YDT (B), YBK (C), and YRE (D) modes.

One of the important results of these analyses is the possibility of relative sequencing. As can be seen in the image data, some motifs that appear in lighter or orange tones in the DStretch output -rather than in the original image- are probably older (Fig. 6, no. B; 7, No. C; 9 No. B-C; 11, No. B-C), because some of these are covered by later superimposed red and black motifs. This pattern is one of the most significant pieces of evidence for understanding the chronological sequence of artistic activities at this site. The data obtained show that Sepantash is not merely a single-phase rock art site, but a multi-layered cultural landscape in which the interaction between technique, time, and meaning is visible. However, to achieve a more precise understanding of the temporal and cultural position of this site, the use of absolute dating methods and laboratory analyses seems necessary. Also, the use of modern imaging technologies and digital analysis can play an important role in the more complete reconstruction of this visual tradition.

VI. Conclusion

The study of the Sepantash rock art site shows that this site is a complex and multi-layered assemblage of visual expressions that includes both petroglyph and pictograph traditions. Pictographs include geometric motifs and handprints, and petroglyphs include zoomorphic motifs. From a chronological perspective, evidence such as color variation, weathering, and superimposition of motifs indicate that the site was used over a long period of time and in multiple phases. Therefore, Sepantash should be considered a multi-period rock art tradition, not a single-phase collection.

The application of DStretch software played a key role in revealing faint motifs and enabling more detailed analysis. This tool showed that a significant portion of the image information can only be recovered through digital processing, and its use can significantly increase the documentation quality. However, the results also emphasize that digital analysis should always be interpreted alongside field data and with a critical interpretive framework.

Finally, given the importance of Sepantash in understanding the rock art of Central Asia, particularly in relation to pictographic traditions, this site requires broader and interdisciplinary research. In particular, absolute dating and laboratory analyses are necessary to more precisely determine the time of creation of the motifs and better understand the cultural trends of the region. This research shows that the combination of field methods and modern technologies can contribute to a more accurate and comprehensive reconstruction of the artistic traditions of prehistoric societies in Central Asia.

References

Abe, M., Arai, S., & Khanipour, M. (2022). Returning to Hunting and Re-microlithisation during the Mushki Phase in Fars, Southwest Iran, In Nishiaki, Y., Maeda, O. and Arimura, M. (eds.), *Tracking the Neolithic in the Near East. Lithic Perspectives on Its Origins, Development and Dispersals*, (pp 575-588). Leiden: Sidestone Press.

Agnew, N., Deacon, J., Hall, N., Little, T., Sullivan, S., & Taçon, P. S. C. (2015). *Rock art: A cultural treasure at risk*. Getty Conservation Institute.

Alirezazadeh, M., & Heydarian, M. (2022). The Process of Constructing a Regular Hexagon in the Near East: From Neolithic Pottery to Euclid's Elements. *Persica Antiqua, 2*(3), 3-17. https://doi.org/10.22034/pa.2022.347319.1012

Amanbaeva, B., Suleymanova, A., & Zholdoshov, Ch. (2011). Rock Art in Kyrgyzstan. In J. Clottes (Ed.), *Rock Art in Central Asia: A Thematic Study* (pp. 43-72). Paris: ICOMOS publishers.

Anick, P. (2019). Shamans, sachems, or selfies: The carved hands of southeastern New England. In K. Hedges & A. McConnell (Eds.), *American Indian rock art* (Vol. 45, pp. 173–192). American Rock Art Research Association.

Augustinová, A., & Stančo, L. (2016). The petroglyphs of Pashkhurt Valley in the Surkhan Darya Province (South Uzbekistan): Preliminary report. *Studia Hercynia, 20*(2), 122–138.

Azizi Kharanaghi, M. H., Tomalski, J., Khanipour, M., & Jafari, J. (2016). Archaeological research at Tappeh Pahlavan, North Khorasan Province (Northeastern Iran): Report on the 2014 season, *Ancient Near Eastern Studies, 53*, 59-79. https://doi.org/10.2143/ANES.53.0.3154561

Bahn, P. G. (2010). *Prehistoric rock art: Polemics and progress*. Cambridge University Press.

Beltrán, A. (1995). The painted hands of the Clarillo Shelter (Quesada, Jaén, Spain). *INORA, 10*, 5–6.

Bobomulloev, B. S. (2011). Rock Art in Tajikistan. In J. Clottes (Ed.), *Rock Art in Central Asia: A Thematic Study* (pp. 73-92). Paris: ICOMOS publishers.

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. *Antiquity, 4*(91), 322–333. https://doi.org/10.15184/aqy.2016.271

Brady, L. M., Taylor, L., May, S. K., & Taçon, P. S. C. (2022). Meaningful choices and relational networks: Analysing Western Arnhem Land's painted hand rock art style using chaîne opératoire. *Journal of Anthropological Archaeology, 65*, 101396. https://doi.org/10.1016/j.jaa.2022.101396

Clottes, J. (2008). *Cave art*. Phaidon Press.

Duval, M., & Smith, B. (2013). Rock art tourism in the uKhahlamba/Drakensberg World Heritage Site: obstacles to the development of sustainable tourism. *Journal of Sustainable Tourism, 21*(1), 134–53. https://doi.org/10.1080/09669582.2012.699060

Francfort, H. P. (1998). Central Asian petroglyphs: Between Indo-Iranian and shamanistic interpretations. In C.

Chippindale & P. S. C. Taçon (Eds.), *The archaeology of rock-art* (pp. 302–318). Cambridge University Press.

Ghorbani, H. R., Arab, H., Sadeghi, S., & Heydarian, M. (2022). Considering Petroglyphs of Birjand in Arid Environments, East Central Iran. *Persica Antiqua, 2*(3), 19-34. https://doi.org/10.22034/pa.2022.322862.1008

Gunz, P., & Bulygina, E. (2012). The Mousterian child from Teshik-Tash is a Neanderthal: A geometric morphometric study of the frontal bone. *American Journal of Physical Anthropology, 149*(3), 365–379. https://doi.org/10.1002/ajpa.22133

Holakooei, P., Khanipour, M., & Karimy, A. H. (2025). Ochre and other pigments from the 7th millennium BC: Evidence from painted objects excavated at Tol-e Sangi and Hormangan archaeological sites in southern Iran. *Journal of Archaeological Science: Reports, 62*, 105041. https://doi.org/10.1016/j.jasrep.2025.105041

Horn, Ch., Ivarsson, O., Lindhé, C., Potter, R., Green, A., & Ling, J. (2022). Artificial Intelligence, 3D Documentation, and Rock Art -Approaching and Reflecting on the Automation of Identification and Classification of Rock Art Images. *Journal of Archaeological Method and Theory, 29*, 188–213. https://doi.org/10.1007/s10816-021-09518-6.

Jacobson-Tepfer, E. (2025). Rock art and the reconstruction of a palaeoenvironment: The case of *Alces alces* in the Mongolian Altai. *Rock Art Research, 42*(2), 157–168. https://doi.org/10.69978/ks5ys144

Jamshidi Yeganeh, S., & Khanipour, M. (2025b). Examining the Dalma culture in the northern Zagros of Iran: Insights from the excavation of the Belachak site, Archaeological Research in Asia, *43*, 100640. https://doi.org/10.1016/j.ara.2025.100640

Jamshidi Yeganeh, S., & Khanipour, M. (2025a). Absolute Chronology of the Dalma Period in Northwestern Iran: Insights from the Belachak 3 Site. Radiocarbon, *67*(6), 1289–1300. https://doi.org/10.1017/RDC.2025.10142

Kadirova, I., & Abduvakhidova, N. (2025). Tourism Competitiveness in Uzbekistan: Archaeological Tourism at Shah-i-Zinda and Sustainable Development. *Journal of Sistan and Baluchistan Studies, 5*(1), 59-72. https://doi.org/10.22034/jsbs.2025.515575.1080

Karimikiya, A., Rezaloo, R., Abedi, A., & Javanmardzadeh, A. (2022). Cultural Interactions of Azarbaijan in Northwest Iran and the South Caucasus in Chalcolithic Period Based on Archaeological Data. *Persica Antiqua, 2*(2), 3-25. https://doi.org/10.22034/pa.2021.312443.1003

Khanipour, M. & Nishiaki, Y. (2024). Dating the beginning of the Pottery Neolithic in South Iran: Radiocarbon dates from Tol-e Sangi, the Fars. Radiocarbon, *66*, 637–649. https://doi.org/10.1017/RDC.2024.92

Khanipour, M. (2023). Bizdan Pottery: New Evidence from The Neolithic Period at Forg, Southeast Fars, Iran. Journal of Sistan and Baluchistan Studies, *3*(1), 65-75. https://doi.org/10.22034/JSBS.2022.347327.1035

Khanipour, M. (2024c). Organization of pottery production at the Hormangan Neolithic site: Archaeological evidence of craft specialization in southwestern Asia. *Archaeological Research in Asia, 40*, 100556. https://doi.org/10.1016/j.ara.2024.100556

Khanipour, M. (2025). Emergence of Neolithic in the southern plains of Iran: Darab Plain. *Journal of History, Archeology and Ethnography of the Caucasus, 21*(1), 74-92. https://doi.org/10.32653/CH21174-92

Khanipour, M., & Abe, M. (2025a). Reflections of Neolithic Subsistence Changes in Lithic Industries: A Case Study of the Hormangan Site. *Ancient Iranian studies*, *4*(13), 3-29 https://doi.org/10.22034/ais.2025.515222.1156

Khanipour, M., & Holakooei, P. (2025). Food production and manufacturing tools of the Hormangan Neolithic society, Iran. *Lithic Technology, 50*(3), 356–372. https://doi.org/10.1080/01977261.2025.2451538

Khanipour, M. (2024a). The Rock Art of Tang-e Chek Chek in the Rostaq, Iran. *Journal of L'Antropologica, 128*, 103308. https://doi.org/10.1016/j.anthro.2024.103308

Khanipour, M. (2024b). Sangbor Petroglyphs in Bavanat County, Southern Iran. *Historia I Świat, 13*, 141-156. https://doi.org/10.34739/his.2024.13.09

Khanipour, M., & Abe, M. (2025b). From Seasonal Hunting Base to Permanent Settlement: Insights from the High-Altitude Hormangan Site. *Journal of Near Eastern Archaeology, 88*(1), 4-14. https://doi.org/10.1086/734596

Khanipour, M., Azizi Khaeanaghi, M. H., Khosravi, S., Emadi, H, & Ghasemi, Z. (2015). The Petroglyphs Discovered in the Naqsh-e Rostam, Marvdasht (Iran). *Inora, 73*, 13-18.

Khanipour, M., Mirghaderi, M. A., & Emadi, H. (2026). Evolution, Resilience, and Collapse of Prehistoric Settlements in the Bavanat River Basin, Southern Iran. *Near Eastern Archaeology, 89*(1), 4-14. https://doi.org/10.1086/739806

Khanipour, M., Sayfullaev, B. K., Ergashev, O.T., Ungalov, L., Djurakulova, D. M., Alisher Kyzy, S., Zhou, X., Shomurodova, S. J., G`afforov, S. S., & Radjabov, A. Y. (2026). Zardali Site: New Evidence from the Neolithic period in Uzbekistan. *Journal of Sistan and Baluchistan Studies, 6*(1), 53-62. https://doi.org/10.22034/jsbs.2025.553325.1112

Khujanazarov, M. (2011). Rock Art Sites in Uzbekistan. In J. Clottes (Ed.), *Rock Art in Central Asia: A Thematic Study* (pp. 99-112). Paris: ICOMOS publishers.

Khujanazarov, M. M. (2001). Petroglyphs of Uzbekistan. *In* Tashbaeva K., Khujanazarov M., Ranov V., Samashev Z. (Eds.), *Petroglyphs of Central Asia* (pp. 80-121). Bishkek.

Kohl, P. (1984). *Central Asia: Palaeolithic Beginnings to the Iron Age*. Éditions Recherche sur les Civilasions, Paris: Synthèse 14.

Kolobova, K.A., Krivoshapkin, A.I., Derevianko, A.P., & Islamov, U.I. (2011). The Upper Paleolithic site of Dodekatym-2 in Uzbekistan. *Archaeology, Ethnology and Anthropology of Eurasia, 39*(4), 2-21. https://doi.org/10.1016/j.aeae.2012.02.002.

Lasota-Moskalewska, A., & Hudjanazarov, M. M. (2000). *Petroglyphs of Mammals in the Sarmissaj Gorge, Uzbek Republic, Archaeozoological Analysis, Swiatowit Supplement Series P: Prehistory and Middle Ages,* vol III. Warsaw: Institute of Archaeology Warsaw University.

Masson, V. M., & Sarianidi, V. I. (1972). *Central Asia: Turkmenia before the Achaemenids*. Thames and Hudson.

Masuda, S., Goto, T., Iwasaki, T., Kamuro, H., Furusato, S., Ikeda, J., Tagaya, A., Minami, M., & Tsuneki, A. (2013). Tappeh Sang-e Chakhmaq: Investigations of a Neolithic site in northeastern Iran. In R. Matthews & H. Fazeli Nashli (Eds.), *The Neolithisation of Iran: The formation of new societies* (pp. 201–240). Oxbow Books.

Mohammadi Sefidkhani, R., & Sarhaddi-Dadian, H. (2022). Introducing Newly Documented Rock Art in Mianeh County of the East Azarbaijan Province in North-Western Iran. Annals of the Náprstek Museum, *43*(1), 125–138. https://doi.org/10.37520/anpm.2022.008

Molaie Kordshouli, H., Zare, Y., & Khosravanian, R. (2022). Ancient Pictographs in Bakhtegan County of Fars Province, Iran. *Journal of Sistan and Baluchistan Studies*, *2*(2), 53-61. https://doi.org/10.22034/jsbs.2022.346804.1032

Moradi, H., Sarhaddi Dadian, H., Soltani, M., Rahman, N. H. Sh. N. A., & Chang, B. (2013). Study and Typological Comparison of Petroglyphs in the Marzbanik Valley, Baluchestan, Iran. *Time and Mind: The Journal of Archaeology, Consciousness and Culture, 6*(3), 331–350. https://doi.org/10.2752/175169713X13673499387127

Muradova E. (2011). Rock Art Sites in Turkmenistan. In J. Clottes (Ed.), *Rock Art in Central Asia: A Thematic Study* (pp. 93-98). Paris: ICOMOS publishers.

Nishiaki, Y., Aripdjanov, O., Arai, S., Akashi, C., Nakata, H., Sayfullayev, B., Ergashev, O., & Suleimanov, R. (2022). Neolithization during the 6th millennium BCE in western Central Asia: New evidence from Kaynar Kamar Rockshelter, Hissar Mountains, Southeast Uzbekistan. *Archaeological Research in Asia, 30*, 100352. https://doi.org/10.1016/j.ara.2022.100352

Pavlenok, K., Kot, M., Moska, P., Leloch, M., Muhtarov, G., Kogai, S., Khudjanazarov, M., Holmatov, A., & Szymczak, K. (2022). New evidence for mountain Paleolithic human occupation in the western Tian Shan piedmonts, eastern Uzbekistan. *Antiquity, 96*(389), 1292–1300. https://doi.org/10.15184/aqy.2022.99

Pollock, S., Bernbeck, R., & Heit, I. (Eds.). (2025). *Village Life at Prehistoric Monjukli Depe, Turkmenistan: Microarchaeological, Archaeobiological, and Artifact Studies*. Leiden: Sidestone Press.

Poodat, A. (2023). Chalcolithic and Bronze Ages of Ahven in Bashkard County, Hormozgan, Iran. *Ancient Iranian studies*, *2*(7), 3-31. https://doi.org/10.22034/ais.2023.414982.1050

Quellec, J. L., Duquesnoy, F., & Defrasne, C. (2015). Digital image enhancement with DStretch: Is complexity always necessary for efficiency? *Digital Applications in Archaeology and Cultural Heritage, 2*(2–3), 55–67. https://doi.org/10.1016/j.daach.2015.01.003

Quesada, E., & Harman, J. (2019). A step further in rock art digital enhancements: DStretch on gigapixel imaging. *Digital Applications in Archaeology and Cultural Heritage, 13*, e00098. https://doi.org/10.1016/j.daach.2019.e00098

Rogozhinskiy, A. E. (2011). Rock Art Sites in Kazakhstan. In J. Clottes (Ed.), *Rock Art in Central Asia: A Thematic Study* (pp. 9-42). Paris: ICOMOS publishers.

Rogozhinskiy, A. E. (2021). Rock Art in Western Central Asia (2015-2019). In Bahn, P., Franklin, N. & Strecker**,** M. (Eds.), Rock Art Studies: News of the World VI, (pp.113-125). Bicester, Oxfordshire: Archaeopress Publishing Ltd.

Rozwadowski, A., & Lymer, K. (2012). Rock art in Central Asia: History, recent developments and new directions. In (P. Bahn, N. Franklin and M. Strecker (Eds.), *Rock Art Studies. News of the World IV* (pp. 149-63). Oxford: Oxbow.

Ruiz, J. F., & Pereira, J. (2014). The colours of rock art: Analysis of colour recording and communication systems in rock art research. *Journal of Archaeological Science, 50*, 338–349. https://doi.org/10.1016/j.jas.2014.06.023

Sadeghi, S., Javanmardzadeh, A., Rezaloo, R., & Hadian Dehkordi, M. (2023). Examining the Executive Structure and Morphology of Animal Motifs in the Pictographs of Lorestan Province (Case Study: Pictographs of Kuhdasht and Poldokhtar). *Paykareh, 12*(31), 68–87. https://doi.org/10.22055/pyk.2023.42766.1366

Salimi, M., & Azizi Kharanaghi, M. H. (2025). Petroglyphs of Chah Abdullah of Harat, Yazd Province, Iran. *Persica Antiqua*, *5*(9), 77-89. https://doi.org/10.22034/pa.2024.452592.1093

Sarhaddi, F. (2013). Pictographs and petroglyphs of Saravan (Sistan–Baluchistan, Iran). *Ancient Asia, 4*, 1–8. https://doi.org/10.5334/aa.12312

Sarhaddi-Dadian, H., Moradi, H., & Soltani, M. (2015). Preliminary Study of Rock Art at Negaran Valley in Baluchistan, Iran. *Rock Art Research, 32*(2), 8–11.

Sarkhosh, A., Nazari S., & Sharbaf, M. (2015). The introduction of new found petroglyphs with zoomorphic motifs in the archaeological survey of Sothern Fars region (Beyram). *Historia i Świat, 4*, 15–30.

Srivastava, S. (2021). Rock Art Tourism Development and Conservation Challenges. *South Asian History, Culture and Archaeology*, *1*(1), 89-101.

Whitley, D. S. (1998). Cognitive neuroscience, shamanism and the rock art of Native California. *Anthropology of Consciousness, 9*(1), 22–37. https://doi.org/10.1525/ac.1998.9.1.22