Science, Education and Innovations in the Context of Modern Problems
Issue 8, Vol. 8, 2025

Title of research article

Methods and Mechanisms for the Protection and Preservation of Rock Art: The Case of Djelfa Province

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Issue web link https://imcra-az.org/archive/375-science-education-and-innovations-in-the-context-of-modern-problems-issue-8-vol-8-2025.html

Keywords Rock art preservation; Djelfa province; archaeological heritage; cultural conservation; preventive conservation; Saharan Atlas; heritage management; Algeria.

Abstract

The rock art of Djelfa Province constitutes one of Algeria's most valuable archaeological and cultural legacies, reflecting a complex prehistoric civilization that flourished in the Saharan Atlas. This research investigates the mechanisms for preserving and protecting this fragile heritage against the natural and human factors that threaten its integrity. Through extensive fieldwork, visual documentation, and geological and climatic analysis, the study explores the composition, state of conservation, and patterns of deterioration of major rock-art sites such as Zaccar, Ain Naga, and Khamk El-Hilal. The research identifies three principal categories of deterioration factors: (a) natural factors including wind erosion, rainfall, and temperature fluctuations; (b) human factors such as vandalism, unregulated tourism, and urban expansion; and (c) chemical and biological factors involving mineral efflorescence and microbial colonization. Using a multidisciplinary methodology combining archaeology, geology, and conservation science, the study assesses the physical and chemical properties of the host rocks and the pigments used by prehistoric artists. The paper proposes a preservation framework that includes preventive conservation, continuous monitoring, and the use of digital technologies such as 3D scanning, photogrammetry, and geospatial mapping to ensure sustainable documentation and restoration. Moreover, it argues for integrating local communities and educational programs into heritage protection strategies, emphasizing that safeguarding rock art is not only a scientific endeavor but also a cultural and social responsibility. The results underline the urgent need for a coordinated conservation policy in Algeria that aligns with UNESCO's recommendations on safeguarding cultural landscapes and intangible heritage. Rock art in Djelfa stands as both an artistic archive of human evolution and a potential driver of cultural tourism. Its protection is thus essential for preserving the historical identity and collective memory of the region.

Citation. Khlifa A. (2025). Methods and Mechanisms for the Protection and Preservation of Rock Art: The Case of Djelfa Province. *Science, Education and Innovations in the Context of Modern Problems*, 8(8), 1063–1077.
https://doi.org/10.56334/sei/8.8.91

Received: 20.02.2025 | Accepted: 03.07.2025 | Published: 22.08.2025 (available online)

Introduction

The region of Djelfa contains important archaeological sites that bear witness to human presence from ancient times up to the modern era. It is also distinguished by a vast number of archaeological remains that reflect a

mastery of technical and economic innovations unique to this region. Among the most significant of these is rock art, which stands as compelling evidence of its antiquity and cultural authenticity.

Rock engravings and paintings represent a visual record of the life of prehistoric humans in this area. Through them, we can understand the lifestyle of ancient peoples, the animals they domesticated, and the evolution of their environment particularly during the Neolithic period.

This archaeologically rich region, with its numerous rock drawings and inscriptions (around 37 recorded sites such as Zaccar, Ain Naga, and Khamk El-Hilal), provides undeniable evidence that early humans inhabited the area and practiced various aspects of daily life there. These depictions feature animals such as lions, horses, and elephants, reflecting a once vibrant and diverse ecosystem.

In this research, we explored the origins and historical significance of rock art, and examined the factors contributing to its deterioration, especially given the specific environmental and climatic conditions of Djelfa. Like other archaeological remains, these artworks are exposed to multiple agents of decay and the inevitable effects of time, leading to distortion and eventual disappearance even for sites classified as national heritage. This conclusion is supported by photographic evidence collected in the field.

Before analyzing the causes and effects of deterioration, we identified the types of rocks bearing these engravings, as understanding their chemical and physical properties helps determine the most effective conservation approaches. Consequently, our final inquiry focused on key questions: What factors affect them? How can they be treated? What are the best methods and mechanisms to ensure their preservation?

Rock art occupies a leading position among the cultural and civilizational traces left by prehistoric humans. It served as a means of expression through which they conveyed emotions, experiences, and aspirations. Moreover, it is an invaluable historical record that must be studied and protected.

In conclusion, we emphasized the importance of cultural heritage in general and rock art in particular as a tangible legacy that indirectly carries intangible heritage. It serves both as a cultural archive and as an economic resource through tourism. Raising public awareness about the value of archaeological heritage starting from early education, alongside organizing exhibitions, events, and study days remains the strongest safeguard for preserving and transmitting this heritage to future generations. Our heritage is our legacy, and a reflection of our identity that must be protected and promoted.

Algeria is home to numerous archaeological features that highlight the deep relationship between humans and their natural environment. Since the dawn of humanity, people have sought ways to express their emotions and perceptions. Before the invention of writing or structured language, early humans turned to visual representation as a means of communication imitating nature and depicting the surrounding animals and their interactions with remarkable precision and realism.

These artistic expressions became an integral part of their environment and, at the same time, tangible documents that scientifically reveal insights into the societies of our ancestors who lived and utilized the land in past eras. Rock art thus stands as both a historical record and a source for multidisciplinary research, underscoring the necessity of its conservation and protection.

The Wilaya of Djelfa is one of Algeria's most important regions in this regard, containing a significant number of such artistic works. While some have been studied, many remain neglected or forgotten, leaving them vulnerable to damage and even total loss.

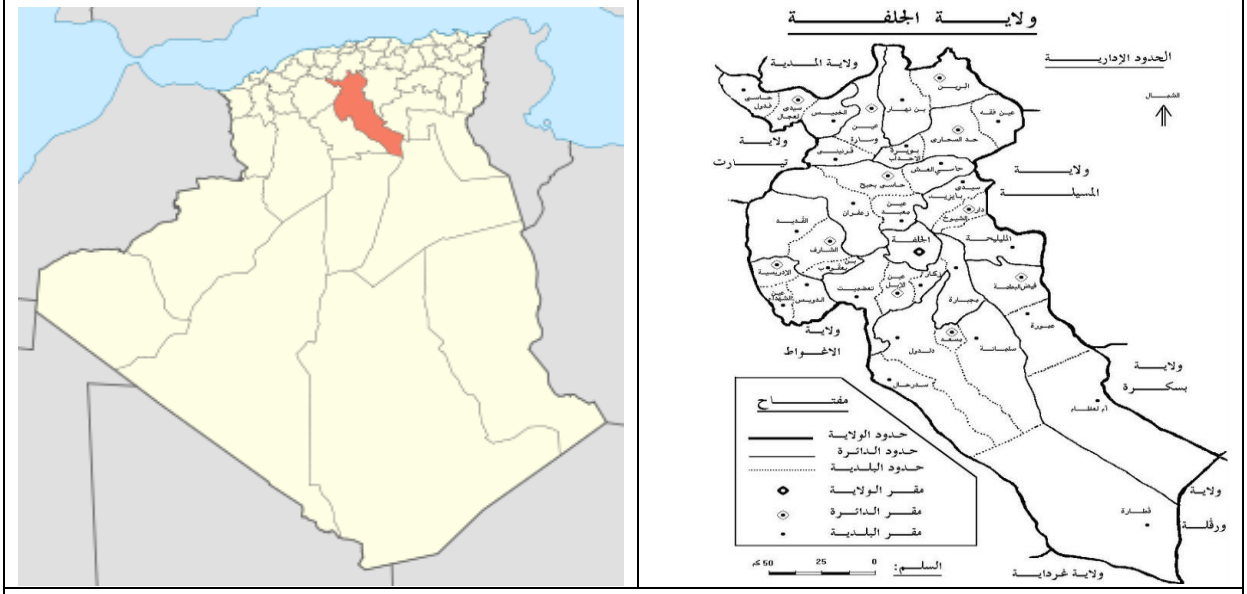
This raises several key questions:

What is the nature of this rock art? What are the main factors causing its deterioration? And what are the optimal methods and mechanisms for its protection and preservation?

I- OVERVIEW OF THE CITY OF DJELFA

1- Astronomical and Geographical Location:

The city of Djelfa is one of the Algerian provinces, located in the northern part of the inland region at the foot of the Saharan Atlas Mountains (Ouled Naïl Mountains) (Devillaret, 1995, p.03). It lies between longitudes 2° and 3° East and latitudes 33° and 35° North, serving as a link between the north and the south. Its area is 32,280.41 km². According to the administrative division of 1974, it became a province comprising 12 districts and 36 municipalities. It is bordered to the north by the provinces of Médéa and Tissemsilt, to the east by Biskra and M'sila, to the west by Tiaret, to the southeast by Ouargla and El Oued, and to the southwest by Laghouat and Ghardaïa. (Map 1)



Map 1: Location of Djelfa Province and its Districts

Given its geographical location and the area it occupies, the province is characterized by natural diversity. Morphologically, it consists of mountainous terrain covering an area of 12,000 km², extending from the southwest to the northeast, with elevations exceeding 1 km. Among these mountains are Mahassen, Boukhel, Serdoun, Seba El Hadid, En Nadhour, Ez Zerka, Zenzach, and others. Djelfa is also a steppe province with several plains nestled between the mountains, such as Messaad Plain, Ain El Ibel, and Faïd El Botma.

Not far from these, we also find depressions and plateaus. Among the former are Tekrassen, Teslwin, and several basins such as Zaghez East and West and Netssila. As for the latter, they include Oued Djeddi Plateau and the Saharan Plateau. These landforms, in general, are the result of successive geological periods the region has undergone in ancient times.

2- Ancient and Current Climate

Climate represents the primary factor influencing the movement and stability of natural phenomena, as well as the variation of vegetation cover and the hydrological system; thus, it plays a significant role in arid regions.

2-1 Ancient Climate

Djelfa, as part of the Saharan Atlas region, has experienced several climatic fluctuations. Among these was a dry period during which sand advanced over an area estimated at 400 km, followed by a humid period that lasted from 12,000 B.C. to 3,500 B.C. During this time, the desert areas experienced limited evaporation and sufficient seasonal rainfall to form lakes (Faure, 1963, p.533).

The southern slope of the Saharan Atlas, including the Amour Mountains and Ouled Naïl Mountains, also underwent a dry stage dated between 12,000 B.C. and 8,000 B.C., corresponding to the Lower Holocene, characterized by wind-blown sandy deposits (Hachid, 1992, p.47).

Understanding this ancient climate helps explain the adaptation and interaction between humans and their environment, which imposed various challenges over time (Galan, 1998, p.31).

2-2- Current Climate

The Saharan Atlas today is characterized by a continental climate, extremely cold in winter and dry and hot in summer. Given its location, Djelfa's climate is transitional between the Mediterranean and Saharan climates.

- **Precipitation:**
  The region is known for its aridity, fluctuating rainfall, and irregular precipitation patterns. In the Saharan Atlas in general, rainfall averages between 200–400 mm. More recent statistics show an average of 284.6 mm, with monthly averages of 18.6 mm, 60.6 mm (February), 11.4 mm, and 5.3 mm (July). Snowfall and frost waves may last up to ten days, especially in winter, with varying snow quantities between high and low areas **(Kasmi, 2011, p.23)**.

- **Temperature:**
  In the 1960s, the annual average temperature across the Saharan Atlas ranged between 13°–17°(Dubief, 1963, p.243). According to 20th-century statistics, the annual average varies between 13.35° and 17°, with temperatures rising to 30° (June–September) and dropping below 10° (January), in addition to noticeable day–night temperature differences.

- **Winds:**
  Winds are defined as air currents associated with atmospheric pressure and temperature (Fedjal, 2003, p.17). The region experiences winds blowing from various directions, the most notable being the Sirocco (Chili), which is characterized by moderate speed and high temperature, causing plant damage and increasing soil salinity due to evaporation (Al-Arbi, 1983, p.16). These winds come from the southeast, sometimes lasting twelve days, reaching a maximum speed of about 7 km/h in January.

3- The Djelfa Region: Historical and Archaeological Overview

3-1- Historical Sequence

As in all parts of the Saharan Atlas, human settlement in the Djelfa region dates back to prehistoric times, when ancient peoples lived there long before the Christian and Hijri eras. Archaeological discoveries, including stone tools, ceramic fragments, and bone remains, attest to this early human presence. Based on pottery shards and ostrich eggshells discovered by Grébénart at Ain Naga, the region was dated to the period between 5550 B.C. and 200 B.C. (Grébénart, 1969, p.315).

Moreover, rock art sites have been found in various locations such as Zaccar, Ain Naga, and Safia Brounen, among others. Prior to these discoveries, Magny had identified the Zaccar site, specifically the Station of Dair ed-Digawine, in 1907 (Hachid, 1981, p.33). Since then, rock art in the region has continued to attract researchers, leading to the discovery of additional sites, such as Ras El Ahmar.

The region also contains remains from the Protohistoric and Ancient periods, including funerary monuments such as tumuli and dolmens in Kef Eddachra, Ain El Oukrif, and Guelta Essatl, among others. Inscriptions in ancient Libyco-Berber script are engraved on stones at Ain Naga and Safia El Baroud, along with rock carvings depicting domesticated horses and other animals.

During the Ancient period, Djelfa's location along the Limes (Roman defensive frontier) highlights its military and economic importance during the Roman presence, as the Romans were unable to penetrate beyond this line (Kaddash, 2007, p.135). Numerous fortresses from that period also remain in the region.

During the Islamic period, Djelfa served as a route for the Muslim conqueror Uqba ibn Nafi al-Fihri on his journey from Baghai to Tahert. The region later came under the influence of successive Islamic states the Rustamid, Idrisid, Zirid, and Hammadid dynasties followed by the Ottoman era and then the colonial period, all of which left archaeological traces attesting to their presence.

3-2- Results of Recent Archaeological Surveys

The most recent archaeological inventory identified 47 sites containing approximately 1,162 rock engravings of diverse forms and meanings (Table 1). Among the notable discovered sites are:

- **Zaccar Site:**

  Located 37 km southeast of the provincial capital, also known as "Dair ed-Digawine", it was classified as a national heritage site in 1982. The site contains a rock shelter displaying a remarkable hunting scene, depicting a gazelle being seized by a lion, along with other animals such as ostriches, elephants, bovines, and rams, totaling 37 engravings distributed over two rock panels.

- **Ain Naga:**

  Situated 33 km southeast of the provincial capital, near the built-up area of Ain Naga village (in the Mouadjebar municipality), this site includes six rock panels with a total of 71 engravings. It was discovered in 1965 by researchers Lottilio and Gdide Belkheir, and has been classified since 1979. The engravings depict a pair of ancient buffaloes, as well as a panel showing a hunter carrying an axe, accompanied by three dogs, and three round-headed human figures, one of whom raises his hands, alongside a ram with a circular disc.

  In 2016, additional rock paintings were discovered in Kheneg El Hilal (in Ain El Ibel municipality), not far from the classified site. These paintings, previously buried under soil and revealed by rain, depict what appears to be a partial figure of a woman (Najafov Shamil, 2025).

Several other rock art sites of great importance exist in the region. Unfortunately, many are being subjected to acts of vandalism, including graffiti and paint, reflecting a lack of awareness of the cultural and historical value of these artworks that have endured for thousands of years.

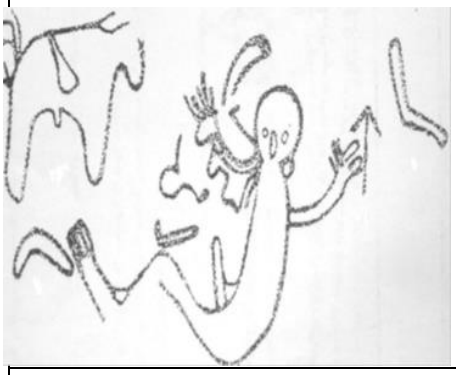
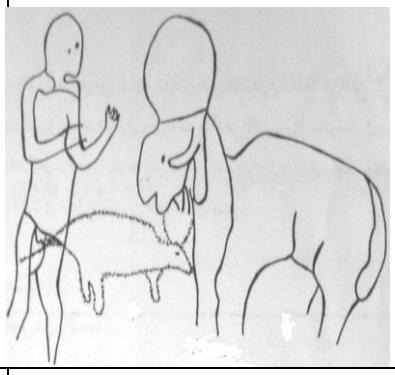
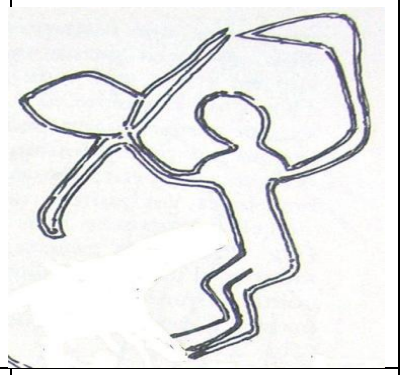
		
Inscriptions of Ras El Ahmar	Inscriptions of Ain Essatl	Inscriptions of Ain Naga

Table 1: Samples of Representations of Engravings from the Djelfa Region

II- General Overview of Rocks and Rock Heritage

1- General Concepts about Rocks

1-1- Definition of Rocks

In geology, the term "rock" refers to an Earth material composed either of a single mineral aggregate, such as quartz, or of a consolidated and lithified mineral assemblage, such as sandstone or limestone, which is mainly composed of calcite. Other rocks consist of two or more minerals, such as granite, which is formed from quartz, feldspar, and biotite.

Although the common understanding of a rock refers to a solid and compact material, unconsolidated volcanic ash is also considered a rock (Youcef Alghunaim, 1998, p. 217). Thus, the Earth's crust is composed of natural rocks, which are relatively homogeneous mineral materials. A rock may be composed of a single mineral (monomineralic) or of several minerals (polymineralic) (Hazzard and Dabboura, 1997, p.155). Therefore, a rock is a solid material composed of a mixture of minerals that coexist while each retains its own properties.

1-2- Types and Cycle of Rocks

a- Types of Rocks:

According to their nature, composition, and texture, rocks are classified into three main types:

- **Igneous Rocks:**

These rocks solidified or crystallized from magma, the parent material of igneous rocks, which consists of a silicate melt mixed with small amounts of water and volatile substances (Youcef Alghunaim, 1998, p.218).

The Earth's interior contains molten materials that, during tectonic movements, or through weak zones of the crust, or due to volcanic activity, are expelled toward the surface. Once solidified, they form what is known as igneous rocks (Youcef Alghunaim, 1998, p.75).

The most common examples include granite and basalt.

- **Metamorphic Rocks:**

The complexity of the textures and components of metamorphic rocks results not only from the diversity of metamorphic processes but also from the varying degrees of metamorphic influence on numerous calcareous rocks, encompassing both igneous and sedimentary types (Najafov Shamil, 2025).

When these rocks are exposed to tectonic movements accompanied by high temperature and pressure, their physical properties, mineral compositions, and geological structures change (Mohamed Ali, 2007, p.127), forming what is known as metamorphic rocks.

The most common examples include marble and quartzite.

- **Sedimentary Rocks:**

These are the most significant rocks used for engraving and artistic carvings. Sedimentary rocks originate when igneous rocks are subjected to erosion, breaking down into small grains that are transported by water or wind. When the velocity of these agents decreases, their carrying capacity diminishes, and the sediments are deposited in layers that are highly heterogeneous in mineral composition, physical properties, and geological structures. This process gives rise to sedimentary rocks, which are raw materials formed through mechanical and chemical weathering.

Based on their origin, sedimentary rocks can be classified as mechanically formed, resulting from the disintegration of igneous or sedimentary rocks through physical erosion, followed by deposition elsewhere and cementation by binding materials such as clay, iron oxides, or carbonates (Boussad, 1994, 115).

Figure (01) illustrates the stages of sedimentary rock formation. Over time, under the influence of air, water, and rain, the rock grains become cemented by lime, iron, or silica, producing stones of sufficient hardness suitable for use in construction, sculpture, and other applications (Zoheir Fadl-Allah, 2006, p.75).

Common examples include limestone, sandstone, and dolomite.

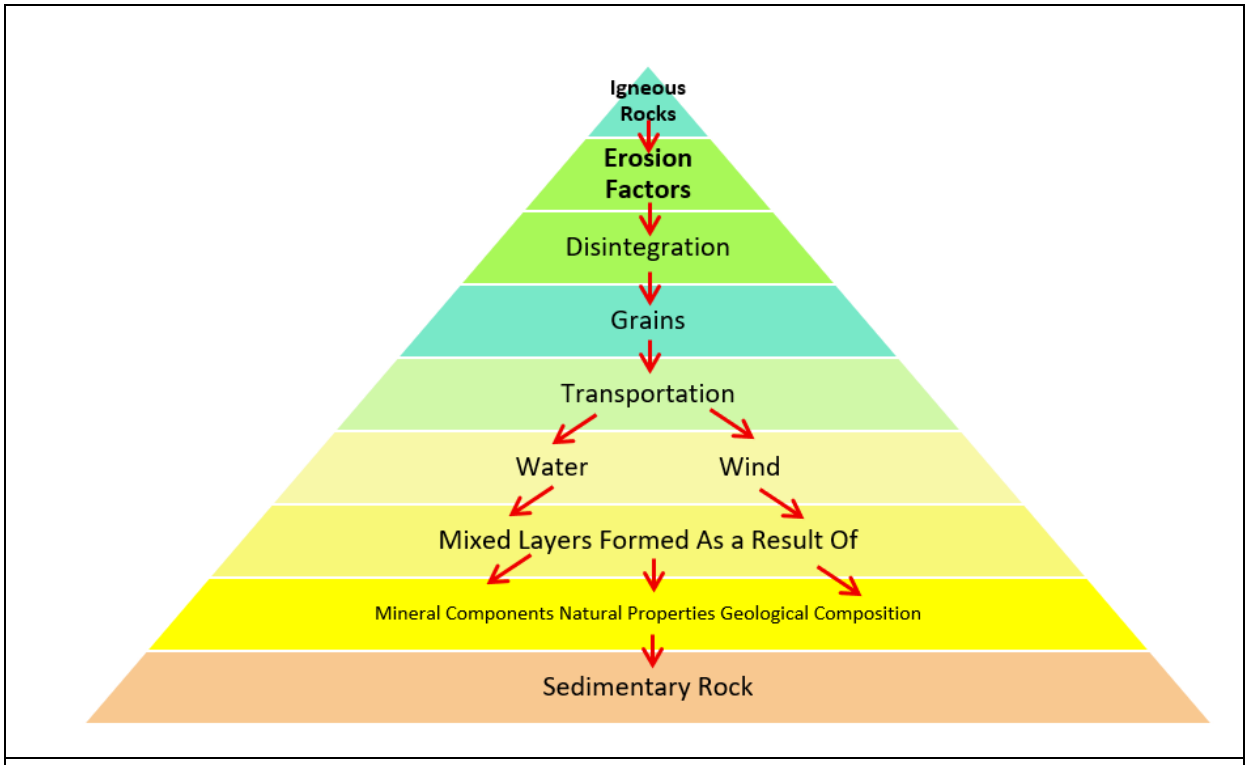


Figure 1: Stages of Sedimentary Rock Formation

b- The Rock Cycle:

The rock cycle illustrates the relationship between the different types of rocks. Igneous rocks, formed by the solidification and crystallization of magma, undergo chemical and physical weathering when exposed to surface conditions. These processes break them down into fragments and dissolved materials, which are then transported, deposited, and cemented to form sedimentary rocks. When these sedimentary rocks are subsequently subjected to pressure and heat, they transform into metamorphic rocks.

Figure (02) represents the rock cycle, showing these transformations. However, the mineral composition of these rocks—particularly sedimentary ones—is often subject to harmful physicochemical alterations during their formation periods (Mohamed Abdelhadi, 1996, p.86).

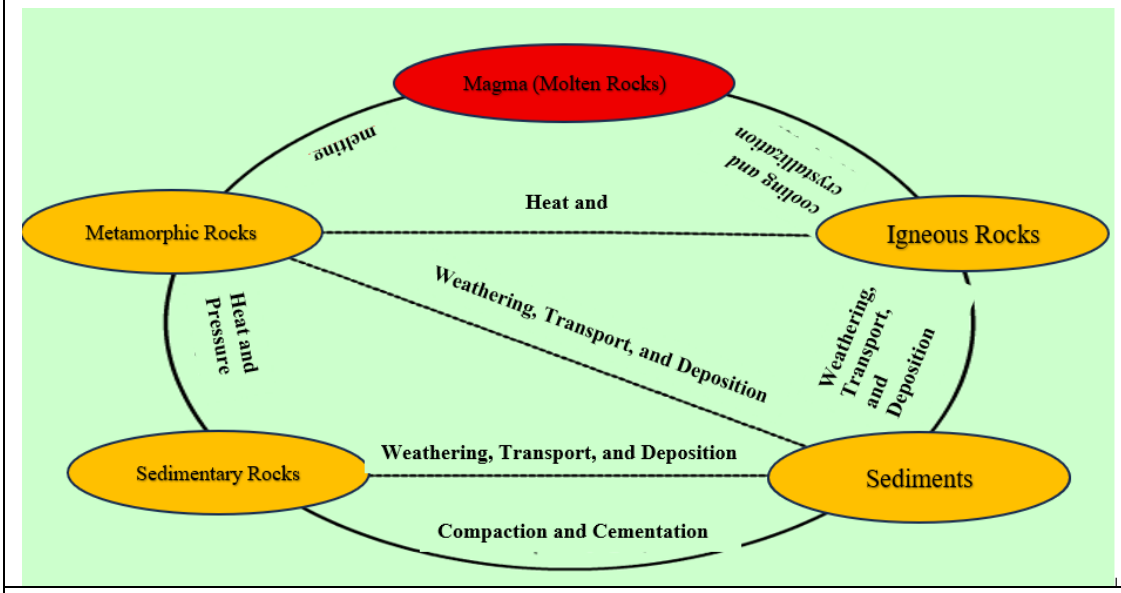


Figure 2: The Rock Cycle

2- The Nature of Rock Art

2-1- Definition of Rock Art

In general, rock art represents the continuity of ideas through movement, where the idea forms a superstructure of human societies transmitted through drawing and engraving.
In archaeology, the term rock art refers to any markings created by ancient humans on natural rock surfaces. These are divided into two main types:

a- **Petroglyphs:** carvings or engravings made on rock surfaces.

b- **Pictographs:** paintings or drawings on rocks and cave walls (Azhari Mostapha Saddik, 1433/2012, p. 1).

Thus, rock art constitutes one of the essential foundations upon which humans recorded their beliefs, perceptions, and self-representations as social beings, as well as their view of the surrounding world.

2-2- Importance of Rock Art

The importance of rock art sites is immeasurable. Among their key aspects are:

- **An Archaeological Heritage in Itself:**

  Article 2 of the 1990 Heritage Charter defines archaeological heritage as a component of material heritage, through which we learn about human activities and the archaeological remains found on the surface, underground, or underwater, along with all related phenomena **(ICOMOS, 1990, p.12)**.

  This heritage takes various forms—complexes, monuments, and archaeological sites. Within these sites, there exist protected areas and cultural parks, some of which contain visible rock engravings. Archaeological heritage is thus a source of collective memory and a scientific and historical resource for studying human civilization and identity, understanding political and economic environments, and exploring cultural and social contexts **(Maazouz, 2003, p.59)**.

- **Temporal Value:**

Rock art spans vast time periods reaching back centuries or even millennia and in some communities, it remains part of traditional rituals that maintain social balance within tribes and clans.

The Maghreb region is among the richest areas in the world in this regard, preserving some of the earliest forms of human expression. These sites cover a time range extending from the Pre-Neolithic period to the emergence of early writing systems in Northwest Africa.

This heritage is unique for several reasons:

- ✓ Its great antiquity, serving as evidence of ancient social life.
- ✓ Its continuity, as a long-standing chain of human expression that withstood time, bearing witness to early religious and conceptual beliefs from the dawn of history.

- **Scientific Value:**

The scientific importance of rock art lies in the data it provides about ancient lifestyles—in all their aspects—along with precise documentation of ecological realities accompanying those ways of life.

3- Threats to Rock Art

Deterioration occurs due to the combined effects of various natural factors such as water, temperature, wind, and storms, which not only cause rock disintegration but also lead to diverse damaging phenomena—including bacterial growth, salt migration, and leaching of soluble components. These factors result in physicochemical alterations (Arab Organization for Education, Culture and Science, 1991, p.63).

Like other archaeological sites worldwide, rock art locations face serious and irreversible threats of destruction.

3-1- First Threat: Natural Factors

Natural dangers affecting rock engravings and paintings are numerous, particularly those related to environmental conditions and climate variability, which cause oxidation and corrosion of rocks (Flamand, 1921, p.285).

The Djelfa region, like other areas of the High Plateaus, combines Mediterranean and Saharan climatic influences, shaped by its topography and geological composition. Among the main effects are:

- **Fading of Surfaces:**

This refers to color changes on rock surfaces and paintings. The phenomenon is caused by several factors, including sunlight exposure and high temperatures, which can produce black surface layers.

When part of a rock surface is exposed to sunlight while another part remains shaded, color variations occur.

Moreover, microorganisms such as bacteria and fungi contribute to these alterations through their biochemical activity, which interacts with rock surfaces.
Water pollutants can also cause discoloration of surfaces bearing engravings and paintings (Shahein, 2003, p.74).

- **Changes in Structure:**

Depending on altitude, two areas with differing levels of risk to rock art can be distinguished:

- ✓ **Highlands:**

Rock engravings in elevated areas are affected by erosion, mainly due to temperature fluctuations between day and night, especially during the cold, frosty winters and warm days. These contrasts cause cracking of limestone rocks that bear engravings.

Furthermore, strong seasonal temperature variations—freezing winters, rainy springs, and hot summers—alter the nature of the rocks and the artistic forms upon them.

The repeated expansion and contraction caused by thermal changes or water saturation—linked to the mineral composition of rocks—leads to the separation of surface layers (Kévin, 2006, 13).

✓ **Semi-arid Plains:**

In these regions, the danger lies in imbalanced water flow, fluctuating rainfall levels, and dew condensation, which promote salt crystallization on rock surfaces (Hamed Kadous, 2005, 17).

These alternating dry and torrential conditions, accompanied by floods, often lead to the erosion, burial, or damage of engraved rocks due to colliding boulders. Moreover, sand dune encroachment with grains containing abrasive quartz particles causes the disappearance of many rock art traces.

Continuous wind erosion, laden with quartz-rich sand, gradually scrapes and deforms the engravings, making them difficult to interpret.

3-2- Second Threat: Human Factors

Despite natural hazards, the most significant threat to rock art sites remains human activity. Modern development, industrial projects, and employment-driven exploitation of natural resources have relegated rock art conservation to a secondary concern, thereby shortening the lifespan of these sites.

Atmospheric gases such as carbon dioxide, oxygen, nitrogen oxides, sulfur dioxide, hydrogen sulfide, water vapor, and motor exhaust particles adversely affect tangible cultural heritage (Hazzard and Dabboura, 1997, p.73).

Globally, expanding productive activities have caused severe and often irreversible damage to archaeological sites, summarized as follows:

– Complete disappearance of some sites, partial destruction of others, and imminent threats to most due to urban expansion, road construction, rock-crushing operations, and intensive grazing or agricultural development.

– Unregulated tourism, which has become one of the major causes of deterioration:

✓ Application of foreign substances or re-drawing of lines on rock surfaces to enhance photographic clarity, destroying the ancient patina accumulated over millennia.

✓ Creation of casts or molds using prohibited chemical materials, which weaken the rock's structure and cause it to crumble upon touch.

✓ Cutting engraved sections or adding modern graffiti, including names and contemporary drawings, on ancient panels.

These combined threats natural and human constitute a serious danger to the preservation of Djelfa's rock art, a priceless testimony to humanity's earliest forms of expression.

III- Methods and Mechanisms of Conservation and Intervention

1- Concept of Conservation

- **Linguistically:**

  The term *"conservation"* comes from the Arabic root *ṣawn*, meaning *to protect* or *to preserve something from harm*.

- **Terminologically:**
  Conservation refers to preliminary operations preceding restoration, thus considered an initial phase of preservation. It is defined as the protection of cultural heritage in all its forms from deterioration, along with its cleaning, safeguarding from risks (partially or entirely), and preservation in a secure location.

  The ultimate goal is to maintain this heritage as a lasting legacy for future generations in the best possible condition.

2- Methods of Conservation and Means of Intervention

The conservation of archaeological engravings is extremely delicate; therefore, a preliminary study must be carried out before any intervention, accompanied by adequate funding and appropriate technical equipment.

2-1- Cleaning

Cleaning, whether mechanical or chemical, constitutes the first step in conservation work. The method depends on the nature and sensitivity of the material being cleaned, using solid tools (brushes), liquids (water), or gaseous agents (sterilizing vapors).

It is essential that cleaning techniques undergo continuous evaluation before application.

The condition of the engraved surface must be examined beforehand, and if necessary, strengthening agents or stabilizers should be applied to prevent damage (Hamed Kadous, 2005, 219).

a- Mechanical Cleaning:

- **Water Cleaning:**

  This involves spraying rock surfaces with water to remove dust and dirt, combined with gentle brushing using soft brushes to avoid harming the rock surface.

  In some cases, steam cleaning is used, especially for uneven surfaces, by applying controlled pressure. However, it is crucial to assess the rock's tolerance to steam temperature beforehand (Hamed Kadous, 2005, p. 220).

- **Water Spray (Atomized Water):**

  This delicate method converts water into fine droplets that fall under low pressure onto the rock surface without mechanical impact. It increases the contact area between water and dirt, facilitating removal without damaging the surface (Mohamed Ali, 2007, 152).

- **Brush Cleaning:**

  Soft brushes are used to remove dust and superficial dirt while avoiding abrasion of sensitive engraved areas.

b- Chemical Cleaning:

This method is used when mechanical cleaning proves insufficient, employing distilled water and soap, or mild industrial detergents.

The use of acids and their salts, such as hydrochloric acid, must be strictly avoided to prevent chemical penetration into the rock and reactions with its components (Hamed Kadous, 2005, 223).

2-2- Salt Removal

For soluble salts, specific weak acids are applied gradually, followed by rinsing with distilled water (Galán, 1998, p.156).

For insoluble salts, a cellulose pulp paste moistened with distilled water is used. The water penetrates the rock's pores, dissolves the salts, and upon drying, evaporates, carrying the salts outward. The salts then crystallize on the cellulose pulp, which retains them since they cannot evaporate (Galán, 1998, p.158).

2-3- Strengthening

Several techniques are used to strengthen rocks in general, including:

- **Saturated Spraying:**

  Application of strengthening solutions using brushes or spray guns.

  Common examples include Paraloid solution (3–7%) in a mixture of acetone, toluene, benzene, and pure alcohol, and nylon solution dissolved in 90% alcohol and 10% water (Shahein, 2003, p.205).

- **Injection:**

  Strengthening can also be achieved by injecting consolidants into existing cracks, fissures, and cavities. If such openings do not exist, fine holes are drilled—preferably away from engraved areas—to introduce the solution (Shahein, 2003, p.202).

- **Microcrystalline Wax Strengthening:**

  A semi-synthetic wax, extracted from refined petroleum, white and hard, available in granules, soluble in toluene, xylene, or white alcohol. It is particularly effective on porous rocks, such as sandstone.

  Other materials include iron rods, lime milk, silicate esters, and acrylic resins (such as Paraloid B72), as well as epoxy resins, which penetrate rocks slowly but offer high mechanical resistance (UNESCO, 1987, p.220).

3- Protection and Preventive Measures

- Conduct a comprehensive inventory and survey of rock engravings, documenting every aspect—dimensions, images, type of engraving, rock nature, support condition, and type of deterioration.

  This detailed recording aids in local and international comparisons and supports objective investigation. A scientifically and technically equipped team should be assigned to this work.

- Ensure continuous maintenance and monitoring of archaeological sites by observing cracks and fissures that may expand due to rainfall or temperature fluctuations, especially heat.

  Epoxy resin can be used to seal cracks and reinforce internal structures, as it is water-resistant and suitable for reassembling broken stone blocks.

  During winter, engravings should be covered to protect them from frost and fog, which are among the most damaging factors.

- Organize regular visits to archaeological areas under official authorization, accompanied by qualified guides to raise visitor awareness.

- Hold public seminars and conferences to promote awareness of this cultural heritage and encourage appreciation of archaeology in educational institutions.

  Conduct diagnostic and academic studies, including documentation, comparison, and analysis of local and international rock art.

- Enforce cultural heritage protection laws, ensuring their adaptation to the spatial and temporal context of the heritage itself.

- Promote coordination among cultural and tourism associations, directorates of culture, tourism, education, and universities to publicize Djelfa's archaeological and cultural heritage, both tangible and intangible, for broader public recognition.

- Take specific measures to register unlisted sites in the additional inventory, then classify them within the national heritage list and eventually the World Heritage list.

- Launch a national initiative to integrate rock art into cultural exchange media, such as postage stamps, coins, and currencies, as it represents unique and historically significant stages in the country's past.

Conclusion

The attempt to propose solutions to the problems affecting the tangible cultural heritage in general, and particularly the rock art heritage of the Wilaya of Djelfa, has allowed us to explore a field of historical contribution that offers valuable insights into the true features of Algerian identity if only proper attention were given to the cultural richness it embodies. This heritage, however, faces numerous deterioration factors that could eventually lead to its complete disappearance unless urgent and well-planned preservation measures are implemented.

This modest reflection on the prehistoric rock engravings and the artistic works found within the archaeological sites of Djelfa has enabled us to answer several subsidiary questions, while emphasizing that awareness and public sensitization remain fundamental components of preservation efforts. At the same time, it raises essential questions that call for practical and concrete solutions that go beyond printed reports or written studies to become tangible actions on the ground.

Indeed, Djelfa stands as a remarkable model rich with a mosaic of material artistic expressions — some engraved upon rocks, others embodied in architectural structures such as houses and palaces — alongside an equally significant intangible heritage. Thus, the Wilaya of Djelfa can rightfully be regarded as an exceptional cultural and touristic hub of outstanding value.

Methodology

This study employed a qualitative and descriptive research design supported by empirical field observation. Fieldwork was conducted between March 2023 and May 2024 across the main rock-art sites of Djelfa, including Zaccar, Ain Naga, and Khamk El-Hilal. The research combined archaeological survey, photographic documentation, and geological sampling to analyze rock composition and weathering patterns. A non-invasive approach was used to avoid any damage to the engraved surfaces. Laboratory analysis was carried out to determine the mineralogical composition of the rocks and to identify micro-fractures or chemical residues causing pigment loss. The study also integrated climatic data (temperature, humidity, and precipitation averages) to assess environmental stress factors affecting preservation. Additionally, interviews with local heritage authorities, archaeologists, and community leaders provided socio-cultural insights into conservation awareness and management practices. Comparative analysis with similar North African sites (e.g., Tassili n'Ajjer, Tamanrasset) helped contextualize Djelfa's rock art within the broader Maghreb archaeological heritage system.

Ethical Considerations

All field investigations were carried out in compliance with Algerian national regulations governing archaeological research and heritage preservation. No artifacts were removed or altered during the study. Informed consent was obtained from all local collaborators and administrative institutions involved in site access and documentation. The

research respected the ethical principles of non-destructive study, cultural sensitivity, and community engagement in heritage research, following the ICOMOS and UNESCO ethical guidelines for heritage preservation.

Acknowledgements

The author expresses deep gratitude to the University of Mostaganem Abdelhamid Ibn Badis, the Laboratory of Media Studies and Discourse Analysis, and the Directorate of Cultural Affairs of Djelfa Province for their logistical and institutional support. Special thanks are extended to local guides and residents who facilitated field access and shared valuable oral histories related to the sites.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. It was self-funded by the author with institutional support from the University of Mostaganem Abdelhamid Ibn Badis.

Conflict of Interest

The author declares no conflict of interest related to this study. The views expressed are solely those of the author and do not necessarily reflect the policies of the affiliated institution.

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