

## Prehistoric art: rock varnish as a canvas for petroglyphs

If varnish is something we paint on wood, how can rocks have varnish? Who paints it?



Coso Rock Art sheep designs at Basalt Lowlands Site 3, Panel 9, courtesy Amy J. Gilreath Far Western Anthropological Research Group <https://farwestern.com/rockart/site3/site3.htm>

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### Storyline

Imagine a "living paint" so slow-growing that it takes *thousands of years* to form—a mysterious dark glaze called rock varnish, crafted by tiny microbes feasting on manganese in desert winds and mountain rains. This natural coating, thicker than a coin but tough as armour, became the perfect canvas for ancient artists. From the sun-baked cliffs of Australia to the icy fjords of Norway, early humans peered at these glossy rocks and saw something magical: a way to etch their stories into eternity.

Who "painted" this varnish? Not people, but bacteria and fungi! These microscopic artists worked in secret, layer by layer, turning ordinary stones into gleaming black-and-orange masterpieces. When ancient civilizations discovered these canvases, they carved petroglyphs: spirals, animals, and warriors frozen in time. Some of these artworks are older than the pyramids—sharing secrets about forgotten hunters, shamans, and even climate changes from 10,000 years ago!

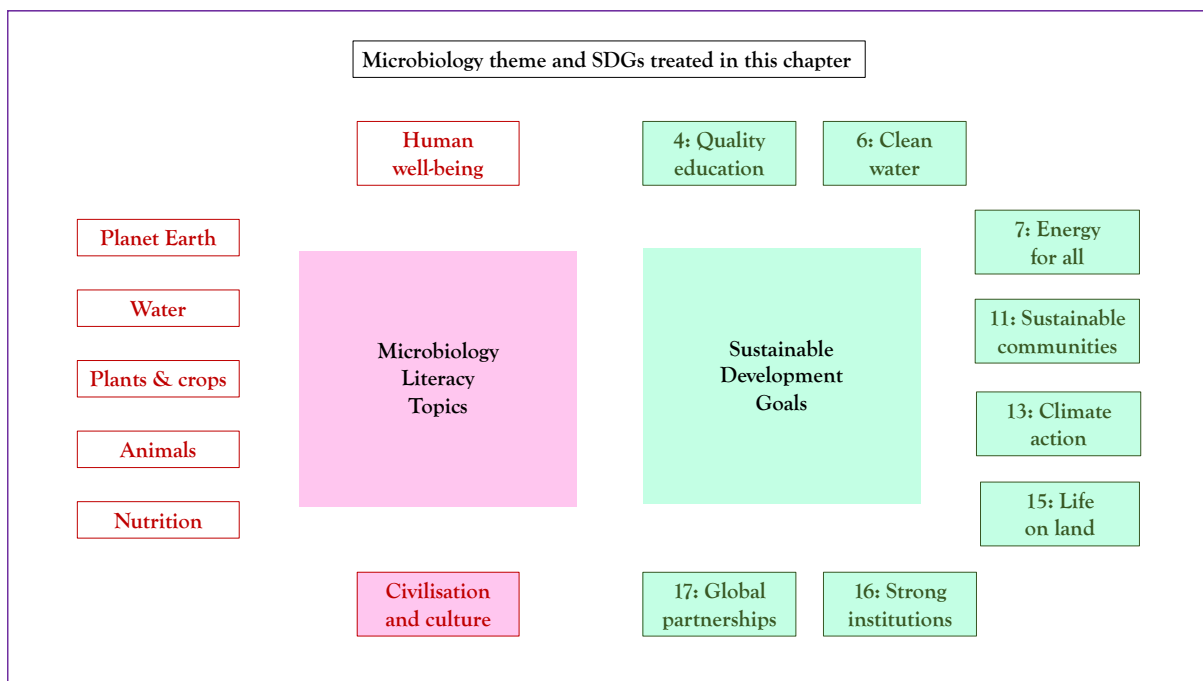
But here's the mystery: *Why do some rocks have varnish while others stay bare?* And how did artists without metal tools scrape through this microbial "paint" to reveal the bright rock beneath? *Grab your explorer's hat—we're starting on a journey where geology, biology, and human history collide!*

### The Microbiology and Societal Context

*The microbiology:* Beneath the desert sun and Arctic winds, an invisible artistic collaboration unfolds. Manganese-oxidizing bacteria (like *Pedomicrobium*) and fungi work in slow motion, transforming ordinary rock surfaces into gleaming canvases through biochemical alchemy. These microbes build their manganese-rich masterpieces one molecular layer at a time, creating biofilms that interact with mineral dust and rainwater over centuries. The varnish they produce - part microbial excretion, part mineral deposit - becomes nature's most durable art supply, with some formations dating back 50,000 years. Recent studies even suggest these microbial communities may communicate through "electrical signaling" as they construct their metallic murals. *The social context:* For indigenous cultures worldwide, varnished rocks became sacred storybooks. The Paiute people of North America saw these glossy surfaces as living skins holding ancestral wisdom, while Aboriginal Australians recognized varnish patterns as Dreamtime maps. When 19th century archaeologists first documented petroglyphs, they missed the crucial microbial backstory - dismissing varnish as simple weathering. Today, a paradigm shift is occurring as Western science begins weaving traditional ecological knowledge with cutting-edge geomicrobiology. However, tensions persist between researchers seeking samples and native communities protecting cultural patrimony, raising profound questions about who "owns" these biogenic artworks. *Sustainability issues:* The preservation of rock varnish presents complex sustainability challenges that intersect with climate science, cultural heritage management, and environmental policy. As global temperatures rise, accelerated desertification may paradoxically increase varnish formation in some arid regions while intense rainfall events in others wash away millennia of microbial accumulation. Industrial activities compound these threats—manganese mining operations not only destroy varnished rock surfaces but contaminate groundwater with heavy metals, disrupting both the delicate microbial communities that create varnish and the ecosystems that indigenous communities depend upon. The growing ecotourism industry creates another tension, as the very foot traffic and vehicle emissions that fund local economies also degrade petroglyph sites through physical abrasion and particulate deposition. Perhaps most

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critically, renewable energy projects like solar farms and wind installations increasingly compete for space with varnished landscapes, forcing difficult choices between green energy infrastructure and cultural preservation. Emerging solutions show promise, from nanoparticle-based varnish stabilizers that reinforce microbial biofilms without altering their appearance, to "digital preservation" initiatives that use photogrammetry to create high-resolution 3D models before sites are impacted by development or climate change. *And, peripherally for completeness of the storyline:* Beyond its archaeological significance, rock varnish serves as a Rosetta Stone for interdisciplinary discovery, bridging seemingly unrelated fields through its unique biological and mineralogical properties. Materials scientists now study the self-assembling nanostructure of varnish to develop smarter surface coatings that could one day lead to buildings that "heal" their own weathering, inspired by how microbial biofilms continuously renew rock coatings. Astrobiologists treat desert varnish as a terrestrial analog for potential extraterrestrial biosignatures, using its chemical patterns to refine instruments for future Mars missions. The semiconductor industry has taken interest in varnish's manganese oxide layers, which demonstrate remarkable electron storage capacities that could revolutionize battery technology. Even contemporary artists have entered this space, collaborating with microbiologists to create "living artworks" using varnish-forming bacteria that evolve over years in gallery installations. These unexpected applications demonstrate how rock varnish—a phenomenon once studied only by desert geologists—has become a nexus of innovation, reminding us that nature's solutions often address challenges we haven't yet imagined. From informing climate models through its paleoenvironmental records to inspiring new forms of biomimetic technology, the full story of rock varnish continues to unfold across disciplines, proving that some of humanity's most cutting-edge advancements may literally be written in stone.



## Rock Varnish: the Microbiology

**1. Introduction.** Prehistoric art encompasses a wide range of artifacts from cave paintings, to carvings, sculptures, and petroglyphs (rock engravings), that reveal the development of human craftsmanship by capturing aspects of their daily lives, and their interactions with the natural world. Often embodying the beliefs and spiritual practices of early human cultures, these artworks may also offer clues about the social structures, gender roles, and technological advancements of early societies.

Within these practices the term "rock art" encompasses non-utilitarian human-made markings found on natural rock surfaces, created either through additive processes such as pictograms (application of material) or reductive processes like petroglyphs (removal of rock material). Additive rock art includes forms like rock paintings, pigment drawings, stencils, and beeswax figures, while petroglyphs encompass engravings, percussion petroglyphs, and finger flutings. Rock art can be found in nearly all countries, and its varying distribution is influenced by cultural conventions as well as preservation biases affecting its survival over time.

**2. Petroglyphs.** Petroglyphs are abraded into the surface of rocks or cave walls by removing the outer layer of the rock using sharp tools to reveal the lighter colour of the underlying rock surface. Rock varnish is a natural phenomenon that refers to a thin, dark coating that develops on the surfaces of rocks over long periods of time. The dark color and durability of rock varnish made it a desirable canvas for early artists to work with, allowing their images to stand out and endure over time.

The use of rock varnish as a natural canvas by ancient artists likely emerged from close observation of its distinctive qualities—its smooth, dark, and durable surface stood out against the lighter rock beneath. This discovery was probably curiosity-driven, as early peoples experimented with various surfaces and techniques for expression. In regions such as the American Southwest, the Sahara, and parts of Australia, ancient artists would have noticed that scraping or etching away the dark varnish revealed striking, high-contrast images. Over time, they developed tools and methods—ranging from sharp stones and chisels to bone or antler implements—to selectively remove the varnish and create enduring petroglyphs. These practices reflect both artistic innovation and a deepening understanding of the natural materials in their environment. In some cases, abrasive techniques, or 'pecking' which involves repeatedly tapping or striking the surface with a sharp implement, might have been used to create petroglyphs. Artists may have utilized rough stones or sand to wear away the varnish layer, gradually revealing the desired imagery or patterns. This method could involve rubbing or grinding the surface until the desired depth and shape of the petroglyph were achieved.

While rock varnish itself was primarily used as a natural canvas, some petroglyphs were further enhanced with pigments or paints. Ancient artists may have used natural pigments, such as ground minerals, ochre, charcoal, or plant extracts, to add color to the engraved or carved designs. These pigments could be applied directly to the varnished or exposed rock surfaces. In some cases, ancient artists created petroglyphs through a process of repeated layering. They would engrave or carve the varnish layer, and over time, as new varnish layers formed, the engravings would become more pronounced.

Over time, artists would have refined their techniques, assessed the visual impact of their creations and developed a deeper understanding of how to best work with rock varnish for their craft. The knowledge and techniques for using rock varnish as a canvas would have been passed down through generations within ancient communities, where aspiring artists would have learned from experienced individuals and been trained in the techniques of engraving or carving

the varnish layer. This cultural transmission would have contributed to the development and refinement of artistic practices involving rock varnish, possibly being regarded as a transformative act, symbolizing the creation of imagery or conveying a deeper spiritual meaning. The use of rock varnish as a canvas could have been tied to specific rituals, ceremonies, or cultural traditions.

3. ***Nature of Rock Varnish.*** Chemically, it is a complex substrate consisting of a combination of clay minerals, oxides, and organic matter that forms slowly through "manganese oxidation." Manganese is a trace element that is present in small amounts in rocks and soils. In arid and semi-arid environments, microorganisms, particularly bacteria and fungi play a crucial role in catalysing the oxidation process. Manganese oxidation is the result of the interaction between airborne dust particles and these microscopic organisms on the rock's surface. Understanding the microbial processes involved in rock varnish formation and preservation helps us understand the scientific and biological processes that contribute to the creation and longevity of these ancient artworks. These microorganisms facilitate the oxidation of manganese ions present in the dust particles. As manganese oxidizes, it precipitates as dark-colored manganese oxide minerals, such as birnessite, todorokite, or hollandite. These minerals form successive layers over time through the cycling of manganese, building up the dark coating characteristic of rock varnish, which slowly accumulates over thousands of years. The presence of rock varnish on petroglyphs can help determine their age, the process providing insights into the environmental conditions and the geological history of the area.

4. ***Microbial Formation of Rock Varnish (Microbial Cycling of Manganese).*** The microbial activity involved in manganese oxidation creates a suitable environment for the accumulation and growth of microorganisms on the rock surface. This, in turn, influences the composition and structure of the varnish, including the incorporation of organic matter and other trace elements.

The microbial cycling of manganese begins when dust particles containing manganese are deposited on the rock surface. Microorganisms colonize these particles and create a biofilm, which acts as a microhabitat for microbial activity. Within this biofilm, bacteria and fungi facilitate the oxidation of manganese ions ( $Mn^{2+}$ ) to manganese oxides ( $MnOx$ ) through a series of enzymatic reactions via both aerobic and anaerobic metabolisms, where a combination of microbial enzymes and extracellular polymeric substances (EPS) play important roles in the process.

Aerobic bacteria, or manganese-oxidizing bacteria (MOB), such as members of the *Actinobacteria* and *Proteobacteria* phyla, are known to oxidize  $Mn^{2+}$  to  $MnOx$  using oxygen as an electron acceptor to its insoluble form ( $Mn^{3+}/Mn^{4+}$ ), which contributes to the deposition of manganese oxides in the varnish layer. The microbial oxidation process occurs through enzymatic reactions and is influenced by environmental factors such as temperature, pH, and oxygen availability.

Anaerobic bacteria, or manganese-reducing bacteria (MRB), including certain species of *Geobacter* and *Shewanella*, can utilize alternative electron acceptors, such as iron or nitrate, for manganese oxidation under low-oxygen conditions.

The microbial cycling of manganese provides a mechanism for the slow and continuous formation of rock varnish over long periods of time. The gradual accumulation of manganese oxide minerals through microbial activity contributes to the growth and preservation of the varnish layer. Manganese oxide coatings act as a protective barrier, shielding the underlying rock surface from weathering, erosion, and other deterioration processes. The presence of manganese oxides can enhance the longevity of petroglyphs by stabilizing the artwork.

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5. **Petroglyph examples.** The following examples represent just a fraction of the diverse and culturally significant petroglyph sites around the world. Several culturally significant sites that continue to inspire awe and curiosity, inviting us to explore and appreciate the rich heritage of ancient cultures, have been analyzed using the processes related to the formation of rock varnish and the study of microbial activity including:

a. **Coso Rock Art District (California, USA):** The Coso Rock Art District is renowned for its extensive collection of petroglyphs created by indigenous peoples.

b. **Burrup Peninsula (Western Australia):** The Burrup Peninsula is home to the Dampier Archipelago with one of the world's largest concentrations of rock art. Created by Aboriginal cultures over thousands of years, the petroglyphs feature engravings of animals, human figures, tools, and abstract motifs.



Rock carvings on the Burrup Peninsula, near Karratha, Western Australia. CREDIT: MURUJUGA ABORIGINAL CORPORATION

c. **Tassili n'Ajjer (Algeria):** Tassili n'Ajjer is a UNESCO World Heritage Site known for its extensive rock art, including thousands of prehistoric paintings and engravings. The Tassili n'Ajjer region in the Sahara Desert contains a vast collection of petroglyphs and cave paintings dating from around 10,000 BCE to the medieval period. The artwork at Tassili n'Ajjer depicts a wide range of subjects, including scenes of daily life, hunting, dancing, and mythical beings. These petroglyphs offer valuable insights into the prehistoric cultures of the Sahara region and their connection with the surrounding landscape.

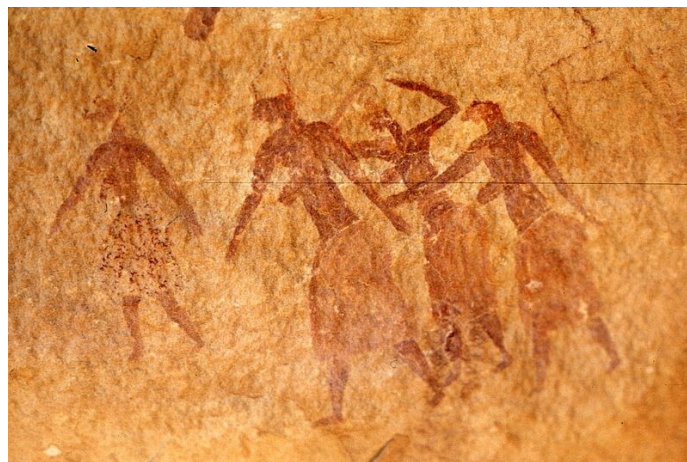


Photo credit: [Patrick Gruban/Wikimedia](#), This file is licensed under the [Creative Commons](#)

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d. Côa Valley (Portugal): The Côa Valley is home to one of Europe's most important collections of prehistoric rock art.



Prehistoric Rock-Art Site of the Côa Valley - Penascosa – Bull, photographer Reino Baptista, 2011.  
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e. **Kakadu National Park (Northern Territory, Australia):** Kakadu National Park is known for its Aboriginal rock art sites, some of which date back thousands of years.



Aboriginal rock art at Ubirr Art Site, Kakadu National Park, Northern Territory, Australia.,  
courtesy [Luke Durkin](#), 2012, This file is licensed under the [Creative Commons](#)

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f. **Valcamonica (Italy):** The rock art of Valcamonica, a UNESCO World Heritage Site, is one of the largest collections of petroglyphs in the world. Dating back over 8,000 years, these engravings depict a wide range of subjects, including animals, humans, tools and symbols.



Petroglyph of a couple in duel with a "symbol" in the middle. Foppe Area, R. 6, Rock Art Natural Reserve of Ceto, Cimbergo and Paspardo. Nadro, Rock Drawings in Valle Camonica. [This illustration](#) was made by Luca Giarelli, 2007, This file is licensed under the [Creative Commons](#)

g. **Alta (Norway):** The rock art of Alta, also a UNESCO World Heritage Site, consists of thousands of petroglyphs created by hunter-gatherer societies around 7,000 to 2,000 years ago.



The Rock carvings at Alta are part of an archaeological site near the town of Alta in the county of Finnmark in northern Norway. Photograph courtesy of [Jensvins](#), This file is licensed under the [Creative Commons](#)

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h. **Bhimbetka (India):** Located in central India, the rock shelters of Bhimbetka are renowned for their extensive collection of petroglyphs and cave paintings, dating back more than 30,000 years. The artwork at Bhimbetka showcases a variety of subjects, including animals, human figures, rituals, and mythical creatures.



Bhimpedika Raisen Madhyapradesh Courtesy [Sunilidamana](#), 2019, This file is licensed under the [Creative Commons](#).

i. **Sego Canyon (Utah, USA):** Sego Canyon is home to numerous petroglyph panels created by Native American cultures, particularly the Fremont and Ute peoples, dating back over a thousand years. The petroglyphs at Sego Canyon feature anthropomorphic figures, animals, hunting scenes, and intricate geometric patterns generated via the artistic traditions of the Native American tribes in the region, their relationship with the environment, and their spiritual beliefs.

j.



Sego Canyon Petroglyphs, photograph courtesy [Tracette](#), 2017.  
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6. *Deterioration of Petroglyphs.* As exposed rock art, petroglyphs are susceptible to natural deterioration processes over time. Several factors contribute to the degradation of petroglyphs, including weathering, erosion, salt-crystallization, colonization by organisms such as lichens, mosses, algae and fungi, and human activity. This may include:

- a. vandalism as in Newspaper Rock Utah;
- b. intentional or accidental touching where oils, dirt, and microorganisms from human skin can harm the fragile rock surfaces;
- c. uncontrolled tourism as in the Lascaux Cave (Dordogne, France) or at the Tanum Rock Carvings (Bohuslän, Sweden);
- d. air pollution as concerns the Gobustan Rock Art Cultural Landscape (Azerbaijan) that have faced challenges due to industrial activities; and
- e. improper conservation practices like over-cleaning, using harsh chemicals, or applying unsuitable coatings can inadvertently cause physical or chemical damage to the petroglyphs.

7. *Counteracting and Preventing Deterioration of Petroglyphs.* Conservation efforts and strategies focused on preserving petroglyphs and mitigating further deterioration are crucial to safeguard these valuable cultural heritage sites to achieve a balance between access and preservation, which include:

- a. monitoring and documentation using high-resolution imaging techniques, such as laser scanning or photogrammetry;
- b. implementing physical protective measures through the construction of shelters, canopies, or enclosures that shield the engravings from direct exposure to weathering agents, such as rain, sun, or wind;
- c. visitor education including codes of conduct, and guided tours;
- d. conservation treatments using techniques such as consolidation, using compatible adhesives or consolidants, can help stabilize fragile rock surfaces;
- e. community engagement to promote a sense of ownership and sustainable management of the sites;
- f. implementing environmental management practices around petroglyph sites helps minimize the impact of factors such as pollution, soil erosion, or water runoff; and
- g. ongoing research and collaboration between archaeologists, conservation scientists, local communities, and relevant authorities to foster a multidisciplinary approach to conservation, incorporating scientific knowledge, cultural perspectives, and community involvement.

By implementing these solutions and recommendations, it is possible to actively protect petroglyphs, striking a balance between access and preservation, and promote responsible engagement with these ancient art forms, and ultimately contributing to their long-term conservation and the appreciation of their cultural and historical significance.

8. *Life on Other Planets.* Rock varnish has emerged as a compelling focus in the search for extraterrestrial life. The biogenic component of rock varnish makes it a potential biosignature—an indicator of past or present life.

In astrobiology, rock varnish is significant because it may preserve evidence of microbial life in extreme environments like those found on Mars. The Martian surface, particularly in regions like Jezero Crater, shows geological features that resemble varnish-like coatings. NASA's Perseverance rover has identified dark, manganese-rich spots—nicknamed “leopard spots”—on Martian rocks that bear a striking resemblance to microbial patterns seen in terrestrial varnish.

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These features are chemically rich in iron and phosphorus; elements often associated with biological processes. Moreover, the durability of rock varnish makes it an excellent candidate for preserving biosignatures over geological timescales. On Earth, microbial communities embedded in varnish have been found to survive in hyper-arid deserts, such as the Atacama and Mojave—environments considered analogs to Mars. This resilience suggests that if microbial life ever existed on Mars, traces of it might still be detectable within similar varnish-like coatings.

NASA's Curiosity and Perseverance rovers have been equipped with instruments capable of analyzing rock surfaces for such biosignatures. For example, Curiosity's exploration of boxwork formations—mineral-filled cracks in Martian rock—has raised questions about past groundwater activity and its potential to support microbial life. Similarly, clay minerals found in ancient Martian bedrock by Perseverance suggest long-term water presence, a key ingredient for life as we know it. While no definitive evidence of life has been found, rock varnish remains a promising target. Its formation through microbial processes on Earth provides a model for what scientists might look for on other planets—making it a natural canvas not just for ancient art, but for the story of life itself.



This image, taken by the Spirit rover in 2006, shows a potential rock varnish site on Mars. Image credit: NASA

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This is an example of one of the Mars rocks with a purple-colored coating on it. This photo, from May 2021, showcases a rock that scientists named Nataani. You can see tiny holes in the coating where the Perseverance rover analyzed it with its laser. What made these purple rocks on Mars? Image via NASA/JPL-Caltech/ [National Geographic](#).



Leopard spots on Martian rocks captured by the Perseverance Rover, 2024. The pictured spots measure only millimeters across and were discovered on a larger rock named Cheyava Falls. The exciting but unproven speculation is that long ago, microbes generated energy with chemical reactions that turned rock from red to white while leaving a dark ring, like some similarly appearing spots on Earth rocks. Although other non-biological explanations may ultimately prevail, speculation focusing on this potential biological origin is causing much intrigue. Image Credit: [NASA](#), [JPL-Caltech](#), [MSSS](#), [Perseverance Rover](#)

9. **Conclusion.** Petroglyphs are ancient rock engravings that hold significant artistic and cultural value. They provide insights into the beliefs, practices, and societal structures of ancient cultures, offering a priceless view of our collective human past. However, the rock varnish that forms their canvas—a natural phenomenon formed slowly through complex microbial and geological processes—is subject to deterioration, leading to physical damage, fading, or loss of petroglyphs over time. To prevent further damage, several strategies can be employed that require collective action and shared responsibility. It is imperative that individuals, communities, and governments come together to safeguard these significant prehistoric artworks for the benefit of present and future generations. Importantly, rock varnish is not only a window into the past but also a bridge to the future. Its unique microbial and mineral composition has drawn the attention of astrobiologists, as similar varnish-like coatings on Martian rocks may hold clues to ancient extraterrestrial life. The study of rock varnish on Earth informs the design of future planetary missions, helping scientists identify potential biosignatures on other worlds. Thus, preserving and studying rock varnish has dual value: it protects our cultural heritage and advances our understanding of life's potential beyond Earth. In this way, rock varnish serves as both a record of human expression and a scientific frontier in the search for life in the universe.

### Relevance for Sustainable Development Goals and Grand Challenges Sustainability

Rock varnish, though often overlooked, has surprising connections to multiple UN Sustainable Development Goals (SDGs) and global grand challenges. Its preservation and study contribute to sustainability, cultural heritage, and scientific innovation in ways that align with several key SDGs:

- **Goal 4 (Quality Education)**

Rock varnish provides a tangible link between geoscience, microbiology, and anthropology, making it an excellent educational tool. Studying petroglyphs and varnish formation fosters interdisciplinary learning, bridging STEM and cultural heritage education.

- **Goal 6 (Clean Water and Sanitation)**

Manganese pollution from mining (used in varnish formation) threatens water quality. Sustainable manganese extraction and bioremediation research can help protect freshwater ecosystems.

- **Goal 7 (Affordable and Clean Energy)**

The semiconductor properties of manganese oxides in varnish inspire research into next-generation battery materials, potentially improving energy storage for renewables.

- **Goal 11 (Sustainable Cities and Communities)**

Petroglyph sites are cultural heritage landmarks, and their preservation supports sustainable tourism, while protecting Indigenous histories.

- **Goal 13 (Climate Action)**

Varnish layers act as natural climate archives, recording past atmospheric changes. Studying them helps refine climate models and predict future shifts.

- **Goal 15 (Life on Land)**

Rock varnish ecosystems host unique microbial life adapted to extreme environments. Protecting these sites conserves biodiversity and offers insights into desertification resilience.

- **Goal 16 (Peace, Justice, and Strong Institutions)**

Indigenous land rights and ethical research practices around petroglyph sites promote inclusive governance combat cultural erasure.

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- **Goal 17 (Partnerships for the Goals)**

Collaborations between scientists, Indigenous communities, and policymakers are essential for balancing conservation, research, and sustainable development.

By recognizing rock varnish's role in these global goals, this niche scientific topic can be turned into a powerful tool for sustainable development.

### Grand Challenges Addressed by Rock Varnish Research

- Climate Change Mitigation (via paleoclimate data in varnish layers)
- Sustainable Resource Management (manganese mining alternatives)
- Cultural Heritage Preservation (protecting petroglyphs from erosion and vandalism)
- Biomimicry & Green Technology (bio-inspired materials from microbial-mineral interactions)

### Potential Implications for Decisions

#### 1. *Individual*

- a. Weighing up scientific curiosity vs. preservation ethics. Should researchers take micro-samples of varnish for study, knowing it may alter ancient petroglyphs?
- b. Visiting petroglyph sites vs. protecting them. Does the educational value of seeing rock art in person justify the risk of tourist damage?
- c. Supporting conservation efforts. Are individuals willing to donate to or volunteer for varnish preservation projects?
- d. Non-microbial factors. How do personal beliefs about cultural heritage influence attitudes toward varnish research and conservation?

#### 2. *Community policies*

- a. Local environmental management. Should communities restrict development near varnished rock sites to preserve microbial ecosystems?
- b. Tourism vs. conservation. How can towns balance economic benefits from petroglyph tourism with long-term preservation needs?
- c. Indigenous collaboration. Should local policies require scientists to obtain tribal consent before studying culturally significant varnish sites?
- d. Non-microbial considerations. How can communities promote responsible visitation (e.g., guided tours, protective barriers) without limiting access?

#### 3. *National policies*

- a. Research funding priorities. Should governments invest more in varnish microbiology or focus on immediate climate challenges?
- b. Environmental regulations. How can mining laws be adjusted to protect manganese-rich areas where varnish forms?
- c. Cultural heritage laws. Should vandalism of petroglyphs carry stricter penalties, similar to other art crimes?
- d. Climate change adaptation. How can national parks prepare for increased erosion or desertification at petroglyph sites?
- e. Global collaborations. Should countries with major varnish sites (e.g., USA, Australia, Algeria) share preservation strategies?

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f. Non-microbial policies. Should access to fragile petroglyph sites be limited to researchers, or remain open to the public?

Key Decision-Making Challenges:

- Science vs. Stewardship: How much sampling is ethical if it damages varnish layers?
- Access vs. Preservation: Should some sites be completely off-limits to protect them?
- Traditional Knowledge vs. Modern Science: How should Indigenous perspectives shape research priorities?

This framework helps policymakers, scientists, and communities weigh trade-offs in studying and protecting rock varnish—a resource that bridges microbiology, cultural history, and environmental sustainability.

### Potential Implications for Decisions

1. *Class Discussion of Rock Varnish Issues*
  - a. What makes rock varnish a "living artwork"?
  - b. Why did ancient cultures choose varnished rocks for their petroglyphs?
  - c. How do microbes and humans *both* contribute to these natural-artistic landscapes?
  - d. Should we prioritize scientific study or preservation of these sites?
  - e. How can we balance scientific research with cultural preservation at petroglyph sites?
  - f. Could rock varnish microbes help clean up mining pollution?
  - g. What can ancient rock art teach us about long-term sustainability?
2. *Pupil Stakeholder Awareness*
  - a. Rock Varnish and the SDGs. Which Sustainable Development Goals are most connected to varnish preservation (e.g., SDG 11 – Sustainable Cities, SDG 15 – Life on Land)? Vote as a class on which to focus.
  - b. Reducing Damage. How can we minimize harm to petroglyphs from tourism or climate change? Brainstorm solutions.
  - c. Personal Action. What can you do to help protect rock art? (e.g., social media awareness, fundraising for conservation).
3. *Exercises*
  - a. Design a Sustainable Tourist Plan. Imagine your town has a fragile petroglyph site. Create visitor rules, protective barriers, or virtual tours to preserve it.
  - b. SDG Debate on the topic of: *Should this site be open, restricted, or studied?*

Split into groups representing different stakeholders:

- Scientists (want to sample varnish for research)
- Indigenous Communities (prioritize cultural preservation)
- Tourism Officials (need economic benefits)

4. Bonus Activity

Petroglyph Detective: Analyze images of real petroglyphs (e.g., from Utah or Australia). Guess their meanings and compare with archaeological interpretations.



A painting of a series of connected waterholes, source: Watersource (Witek, 2021)

**The Evidence Base, Further Reading and Teaching Aids**

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Videos:

Science in a Nutshell: Rock Varnish (2014).

<https://www.youtube.com/watch?v=Njp3rQDFTEM>

Clear and accessible documentary on rock varnish.

What is rock varnish and what does it have to do with petroglyphs? (2023) Trail Mix'd @Arizona PBS

<https://www.youtube.com/shorts/uyxFFD2uYE8>

Short but accessible video on vulnerability of rock varnishes to human interference

Is this coating evidence of microbial activity? (2023) Mars guy.

<https://www.youtube.com/watch?v=tZawXhZys5s>

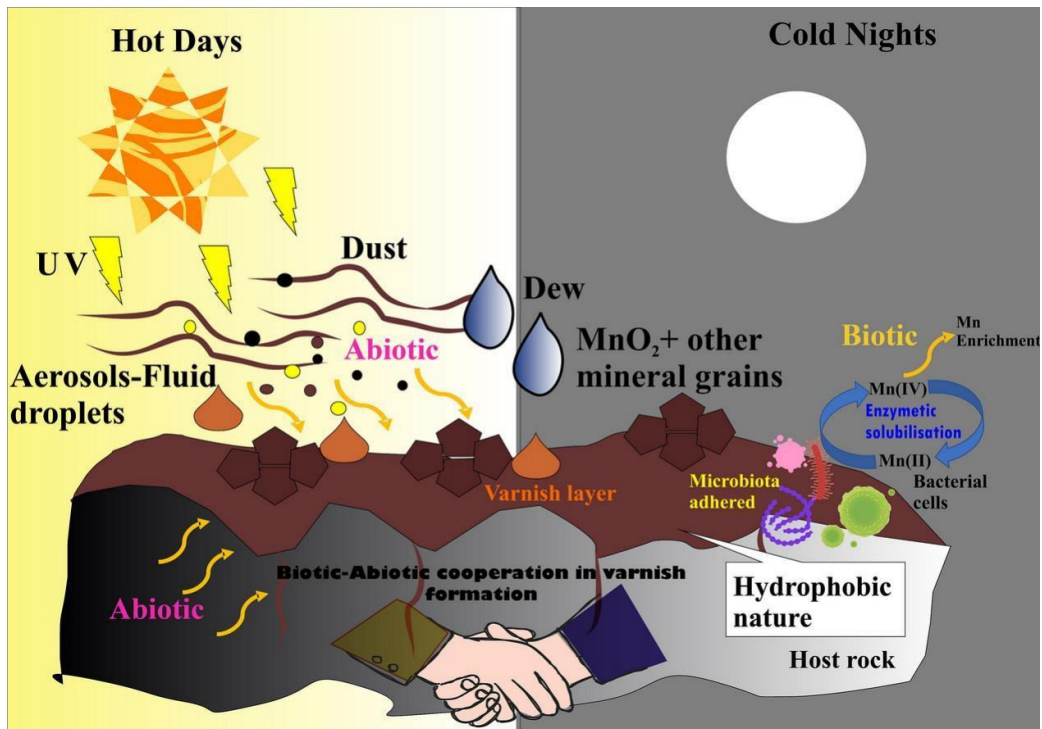
The discovery of mysterious dark patches on Mars by NASA's Perseverance rover has scientists wondering: could this be extraterrestrial rock varnish? On Earth, similar dark coatings called desert varnish form in arid regions through a combination of mineral deposition and - crucially - microbial activity. These glossy veneers develop over millennia as manganese-oxidizing bacteria slowly "paint" rock surfaces. Now, the rover's detection of comparable coatings in Jezero Crater raises a tantalizing possibility: if Martian varnish forms through the same geobiological processes as Earth's, it might hint at past or present microbial life on the Red Planet. While abiotic explanations remain possible, these findings add compelling new evidence to the ongoing search for life beyond Earth.

Ladakh's rock varnish could be key to finding habitable environments in space (2024).

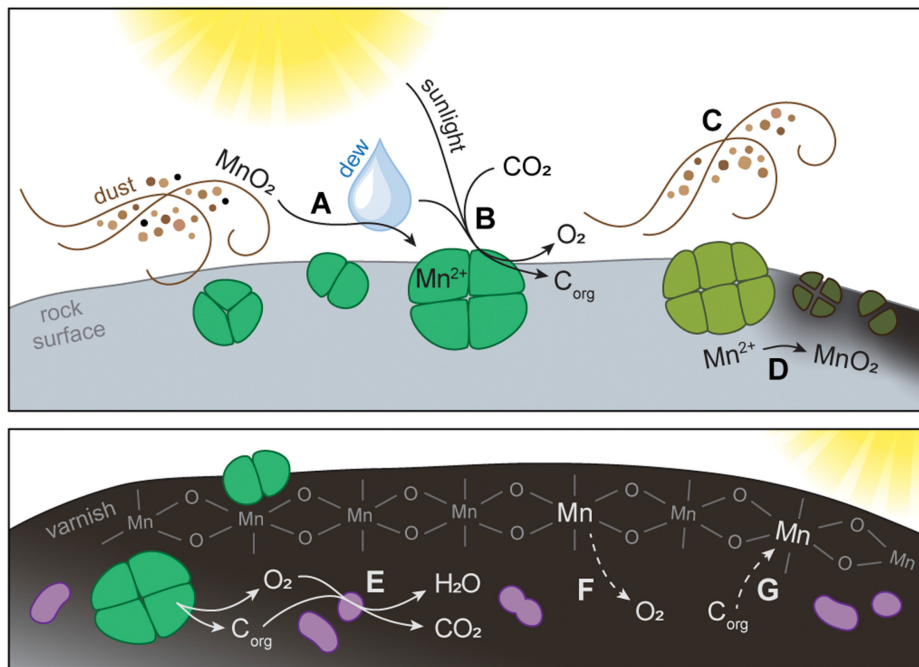
[https://www.youtube.com/watch?v=DtUH\\_QP2syc](https://www.youtube.com/watch?v=DtUH_QP2syc)

This accessible, short video documents the latest breakthrough from Ladakh: rock varnish that could unlock secrets about Mars! It discusses the significance of studying rock varnish for space exploration and astrobiology and how this ongoing research could revolutionise our understanding of geological processes both on Earth and beyond.

Diagram:



Graphical abstract showing the development of rock varnish from biotic and abiotic factors (Chadda et al., 2024)



Natural history of varnish. (A) Manganese is delivered largely as oxide particles in windborne dust, reduced by either photochemical or biological processes, and taken up by Chroococcidiopsis cells for use as a catalytic antioxidant. (B) Chroococcidiopsis grows with light and water, fixing carbon and trapping accumulated manganese. (C) Dust material not adhered to the rock surface is removed by wind or precipitation. (D) When Chroococcidiopsis cells die, the manganese-rich residue left behind by their biomass is oxidized to generate the manganese oxides that comprise varnish. This oxidation could be biologically catalyzed and/or abiotic. (E) Products from cyanobacterial photosynthesis serve as substrates for heterotrophic community members. (F and G) Manganese redox cycling continues in developed varnish, with abundant  $O_2$  as an electron acceptor (F) and organic matter as an electron donor (G). (Lingappa et al. 2021)