Additional archaeological and scientific study of the Laas Geel heritage site for the project to protect and promote the archaeological heritage of Somaliland.

Year 2025



Groupe de Recherches Archéologiques d'Agde

Expertise France (groupe AFD)

Acknowledgments

The authors of this report would like to express their sincere thanks to all the individuals and institutions who made it possible for this December 2025 mission to take place under the best conditions and for the present document could be drawn up, which we hope will make a useful contribution to the preservation and promoting the Laas Geel site and Somaliland's rock art heritage.

Our thanks go above all to the highest authorities of Somaliland, H.E. Mr. President Abdirahman Mohamed Abdullahi, H.E. Mr. Minister of Trade and Tourism Abdirahman Hassan Nur. We would also like to thank the ministerial team who welcomed us and accompanied us with kindness and efficiency, in particular the Director of Tourism and Archaeology, Aïdarous Abdi Ismael, his deputy Ahmed Abdisalan Aidid, and Mr. Mohamed Abdi Ali, a ministry official and tireless discoverer and defender of Somaliland's cultural heritage.

We would like to thank the Expertise France team for the trust they placed in us and for the invaluable and highly efficient logistical and administrative assistance provided throughout this mission, but also well in advance. Thank you to Edwige Sauzon-Bouit, Maria Elisa Ordonez, and Tristan Lesage de La Haye.

We have a special thought for our fixer Saïd Maxamud Daahir, whose suddenly passed away shortly after our return to France. We will never forget that he was for years that he accompanied the French team, providing extremely effective assistance and special attention to us. Our deepest sympathy goes out to his loved ones.

This mission and the project of which it is a part would not have been possible without the decisive support of the management team of the Agde Archaeological Research Group, whom we would like to thank here: its President Gérard Druart, its treasurer Jean-Marc Rouzet, and its secretary Jean-Paul Cros.

To the latter, whose family obligations prevented him from joining our team of experts for this December 2025 mission, but who has worked so hard and continues to do so to develop knowledge about the Laas Geel site and the rock art of Somaliland.

Preamble

This report is the result of a purchase contract between Expertise France (EF, AFD group) and the Agde Archaeological Research Group (GRAA), signed in November 2024 (No. 25-MR2062), the purpose of which is "Complementary archaeological and scientific study of the heritage site of Laas Geel for the project to protection and promotion of the archaeological heritage in Somaliland." This objective required a return to the field study initially planned for April 2025 but finally carried out from December 5 to 15 of the same year, which led to the drafting of an amendment to the initial contract (amendment no. 1 of 3/12/2025). This December 2025 mission resulted in the drafting of an initial report submitted in early January 2026 to Expertise France, which described the progress of the operation, the actions carried out during this stay in Somaliland and their respective objectives. It followed a series of missions and studies aimed at providing a detailed analysis of the health status of the Laas Geel site, the risks it faces, and the various measures needed to ensure its study, preservation, and promotion:

- November 2016 mission carried out by two of us (L.B. and X.G.) at the request of the French Embassy in Nairobi and with the support of UNESCO;
- One-off private mission in 2019 (X.G. and J.-P. Cros);
- Preliminary evaluation report submitted in October 2023 as part of the contract between AFD and the GRAA (L.B., J.-P.C and X.G.).

The field mission and this report were carried out by a team of GRAA experts: Laurent Bruxelles, Didier Cailhol, Xavier Gutherz, and Luc Jallot. This report complies with the terms of reference established by Expertise France, which aim to define our intervention and the objectives sought. These are fully in line with the spirit of the partnership between Expertise France and the Somaliland Ministry of Trade and Tourism, implemented to carry out the "*Protection and Promotion of Somaliland Heritage*" project with the financial support of AFD. The terms of for the *Protection and Promotion of Somaliland Heritage* project include the objectives defined by the contract between EF and the GRAA for the years 2025 and 2026, involving two field missions, are as follows as follows:

- Study the cultural context and historical significance of the rock paintings;
- Analyze the rock formations, sedimentary layers, and mineral composition;
- Understand landscape evolution and its effects on the site;
- Evaluate other factors, including the impact of tourism and livestock farming;
- Study condensation phenomena and humidity levels;
- Measure temperature variations and their effects on the rock surfaces;
- Use modern dating techniques to determine the age of the paintings;
- Propose effective preservation solutions for the site while ensuring public access.

The report details the objectives achieved in 2025, in accordance with the terms of the contract. These will be completed in 2026 at the end of the mission scheduled for September and will benefit from the complementary results obtained on that occasion, as well as the conclusions of laboratory analyses relating to the radiocarbon dating of the site. At the end of these various stages, a presentation document will also be submitted on the Laas Geel site and the rock art of Somaliland, intended for publication in a monographic work.

To facilitate the reading of the detailed content of this report, summaries by chapter highlighting the The main results are summarized at the end of the document.

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Chapter 1.

Geographical, geological, structural, and geomorphological framework of the Laas Geel site (Somaliland).

Introduction

At Laas Geel, the morphology of the inselberg, characterized by steep rock faces, rock shelters and natural caves, reflects the interaction between the internal structure of the granite (diaclases, joints, planes of weakness, lithological variation) and subaerial erosion processes. These forms are not only of geomorphological value, but also influenced prehistoric human occupation of the site, providing natural shelters conducive to the preservation of cave paintings. These are shallow, widely open cavities that form protective overhangs protective overhangs.
This geomorphological context largely explains the exceptional preservation of the cave paintings. It is therefore important to understand how these shelters were formed and evolved in order to better protect them, in particular by taking care not to alter the environmental conditions that have allowed the preservation of the cave paintings to this day.
The Laas Geel site is located in northwestern Somaliland, about 50 kilometers east of Hargeisa, in a region of gently dissected plateaus belonging to the hinterland of the east of Hargeisa, in a region of gently dissected plateaus belonging to the hinterland of the southern margin of the Gulf of Aden. The regional landscape is dominated by structural plains and sub-planes, punctuated by isolated inselberg-type rock formations, of which Laas Geel is a particularly emblematic example

1.1. General geographical and environmental context.

Little work has been done on the detailed geology and even less on the geomorphological evolution geomorphological evolution of the area around Laas Geel. Unfortunately, we were unable to carry out a true geomorphological survey of the surrounding area, but the few observations made during various missions and the scarce bibliographic data available nevertheless allow us nevertheless establish the geological framework and geomorphological context of the site's surroundings.
Physiographically, Laas Geel is part of the Somaliland plateau, a vast area of gently undulating highlands, characterized by altitudes between 800 and 1,300 m, and cut by a network of dry valleys. This plateau is a major morphostructural unit of the Horn of Africa, gradually sloping northwards towards the Gulf of Aden and southwards south towards the Somali inland basins (Gasse & Van Campo, 1994; Abbate *et al.*, 2015).
The current climate is arid to semi-arid, with low and highly irregular annual rainfall, generally less than 300 mm/year, and high interannual variability. Rainfall is concentrated in short seasonal periods, controlled by latitudinal shifts in the intertropical convergence zone, and frequently take the form of intense episodes with high runoff (Nicholson, 2018). These climatic conditions play a decisive role in current geomorphological dynamics, particularly in the retreat of the of Mesozoic and Cenozoic rocks covering the weathered bedrock. However, the current morphology is the result of a much longer and

more complex history, inherited from tectonic and climatic conditions that have varied greatly over time.

1.2. Regional geological context: the Horn of Africa.

Somaliland belongs to the Somali block, a lithospheric entity that became isolated during the Cenozoic era when the dislocation of the East African Plate and the gradual opening of the Red Sea and the Gulf . This region is located at the interface of several major rift systems (**Fig. 1**), including the Red Sea Rift, the Gulf of Aden Rift, and, further south, the East African Rift System (Bosworth *et al*., 2005; Leroy *et al.*, 2012).This orogeny corresponds to a major phase of crustal accretion and continental collision, leading to the formation of a vast crystalline complex stretching from East Africa to the Arabian Peninsula.

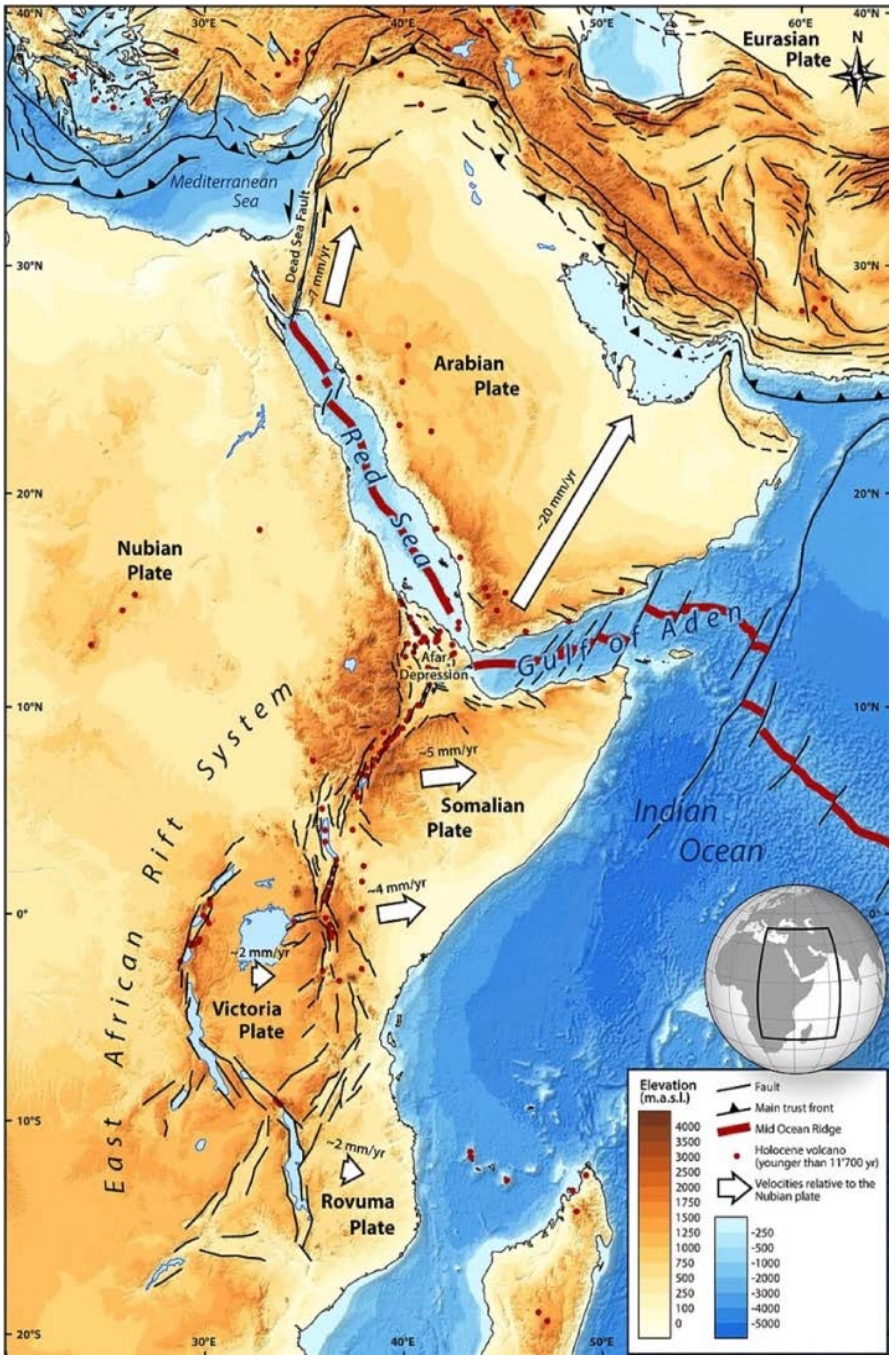


Fig. 1 : *Tectonic map of the Afro-Arabian rift system, showing the triple junction between the Red Sea rift, the Gulf of Aden rift, and the East African Rift. (Wikipedia).*

1.3. Different geological components of the Laas Geel area.

1.3.1. The Pan-African Precambrian basement.

The Laas Geel site is part of an ancient crystalline basement landscape dominated by Precambrian granitoids and gneisses, characteristic of the southern margins of the Arabian-Nubian Shield Arabian-Nubian Shield. In this type of context, the current morphology is not solely the result of recent geomorphological processes, but reflects a polyphasic history combining episodes of planation, sedimentary burial, exhumation, and long-term differential erosion (Twidale, 1982; Summerfield, 1991).

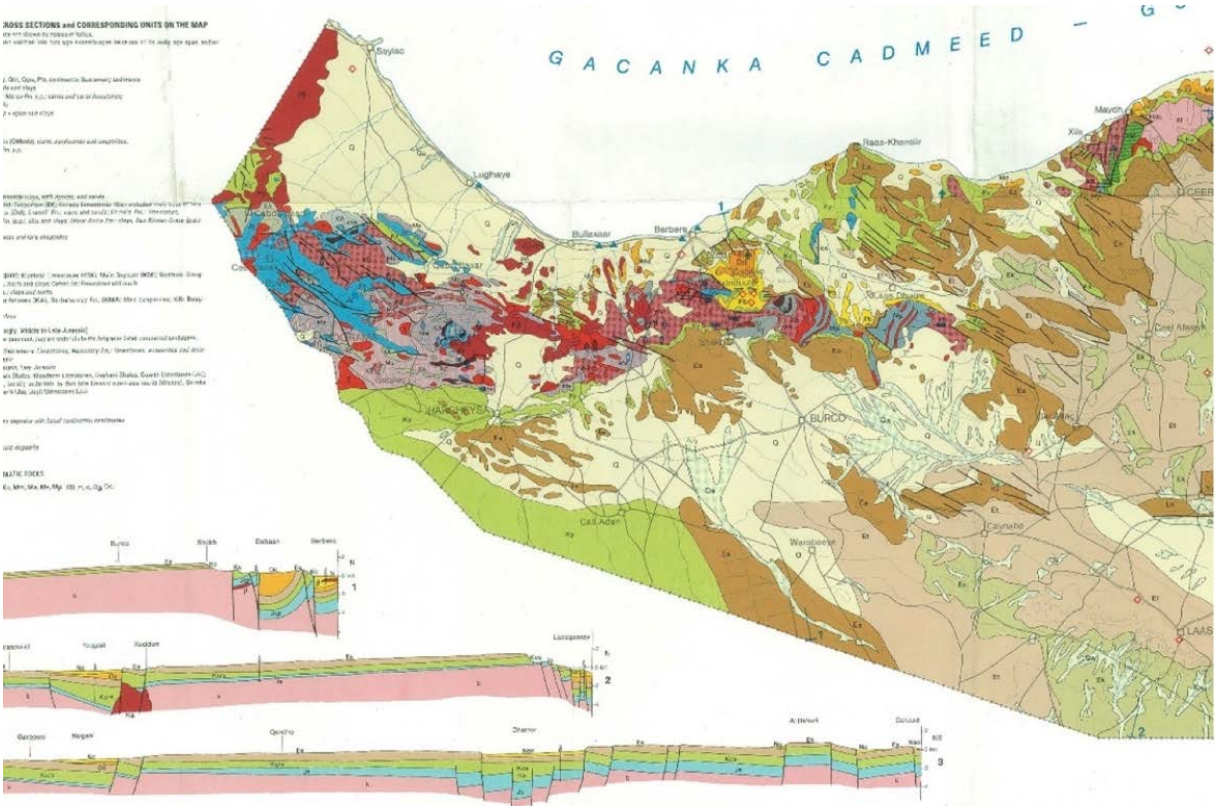


Fig. 2: *1:50,000 geological map showing the main lithological units (Precambrian basement, sedimentary formations, and Quaternary deposits), as well as the main tectonic structures (UNESCOIHP-WINS; Abbate, Sagri & Sassi 1994).*

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The geology of northwestern Somalia is therefore dominated by a Precambrian crystalline basement, belonging to the Arabian-Nubian Shield, formed mainly during the Pan-African orogeny between approximately 850 and 550 Ma. This basement consists of a complex assemblage of metamorphic and magmatic rocks, including gneiss, migmatites, amphibolites, as well as extensive granitic late-orogenic intrusions (Abbate et al., 1994; Johnson et al., 2011). These rocks form the Laas Geel hill and whose particular nature is responsible for the formation of the shelters.

In the Laas Geel region, this bedrock is widely exposed and constitutes the dominant lithological unit (Fig. 2). The rocks observed are mainly massive granites, medium to coarse-grained, with a relatively homogeneous composition. Their high mechanical strength and low susceptibility to chemical weathering explain their persistence in the current landscape. We will see that they are nevertheless quite sensitive to weathering, as is the case with many granular rocks. These granites frequently

contain migmatite veins. Darker in color because they are richer in black micas (biotites), they are also more susceptible to weathering. With the fractures that run through the massif (see *below*), these migmatites constitute the weak point of the bedrock and, in particular, the starting point for the formation of most shelters. Finally, the granites and migmatites are traversed by veins of orange quartz, ranging in thickness from a few centimeters to several meters. They reinforce the granites but can also constitute points of weakness. Although they are highly resistant to chemical weathering, their mechanical resistance is lower due to their intense fracturing.

1.3.2. Regional sedimentary cover.

After the stabilization of the Pan-African basement, the region underwent long phases of denudation and planation, leading to the development of a major erosion surface on the crystalline basement. This ante-Mesozoic surface was then partially covered by Mesozoic sedimentary deposits, linked to the gradual opening of the Gulf of Aden and the evolution of the associated marginal basins. The sedimentary formations that make up this cover rest unconformably on the crystalline basement, representing a significant stratigraphic and morphogenic hiatus. These include Jurassic and Cretaceous sandstones, limestones, and marls, deposited during phases of extension and subsidence linked to the evolution of the passive margins of the Gulf of Aden (Abbate et al., 2015). These formations mainly outcrop on the periphery of the plateau and in certain structural depressions.

In the immediate vicinity of Laas Geel, these coverings are absent or reduced to superficial formations, with the granitic bedrock directly exposed at the surface. They are only found further south, where they are still preserved, although largely eroded by the regressive erosion initiated from the Gulf of Aden. It is in these sandstones that the Dhambalin site is located, for example.

1.3.3. Local structural context.

Sur le plan structural, le socle présente une fracturation complexe (diaclases, joints sub-verticaux, plans de cisaillement anciens), qui joue un rôle déterminant dans le contrôle de l'altération, de l'érosion et du façonnement des formes rocheuses actuelles. Ces structures ont notamment conditionné la genèse ou l'orientation de certains abris sous roche et des baumes ayant servi de support aux peintures rupestres.

1.3.3.1. Structural heritage of the bedrock

Le socle précambrien de la région conserve un héritage structural marqué, issu des déformations panafricaines. Il se caractérise par des réseaux de fractures, diaclases et failles anciennes, dont certaines ont pu être partiellement réactivées lors des phases extensives cénozoïques (Johnson et al., 2011).

At Laas Geel, the granite is affected by dense and organized fracturing, including:

- subvertical, often orthogonal joints;
- subhorizontal or slightly inclined planes of discontinuity.

These structures have a decisive influence on water circulation, differential weathering of the massif, and the development of erosion forms. They are clearly visible in the aerial photo (*below*) where they affect the granites in a NW-SE orientation, at very regular intervals.

1.3.3.2. Influence of Cenozoic rifting.

Although the site is not directly located on a large active fault, the regional uplift associated with the opening of the Gulf of Aden has contributed to the uplift of the relief and the exhumation of the bedrock. The preferential orientations of certain fractures are compatible with the extensive regional stresses regional stresses, generally oriented NE–SW, characteristic of the Gulf of Aden context (Bosworth *et al*., 2005). The influence of this rifting, and the associated fractures, is barely noticeable on Laas Geel hill Laas Geel, whose fracturing is mainly a legacy of Pan-African deformations.

1.3.4. Gemorphological context : relief and surface dynamics.

It is worth returning in more detail to the morphological context of the site and its surroundings, as some of these elements will make it easier to understand the formation and evolution of the shelters.

1.3.4.1. The pre-Mesozoic surface and the erosive discordance between the bedrock and the cover.

One of the major elements of regional geomorphological evolution is the existence of an ancient erosion surface, developed on the crystalline bedrock, before the formation of the. This surface, often referred to as the ante-Mesozoic or ante-Cretaceous surface, is the result of a long phase of denudation and planation affecting the Precambrian basement after the last major tectonic and orogenic events (King, 1962; Guillocheau *et al.,* 2018).
The subsequent formation of Mesozoic and Cenozoic sedimentary deposits, linked to the opening of the Gulf of Aden and the evolution of marginal basins, locally sealed this surface, creating a major erosional unconformity between the crystalline basement and the sedimentary cover. This unconformity marks a significant temporal and morphogenic hiatus, frequently observed in African and Arabian margins African and Arabian margins (Bosworth et al., 2005; Guiraud et al., 2010).

1.3.4.2. Burial, deep alteration, and relief preparation.

During phases of partial burial under sedimentary cover, the crystalline basement may have been subjected to processes of deep chemical alteration. These processes led to the development thick alteration profiles, controlled by lithology, fracturing, and mineralogical contrasts of granitoids (Ollier, 1984; Thomas, 1994).
This phase, known as pre-modeling (*etching*), is essential in the subsequent genesis of inselbergs: the The most massive and least fractured rock volumes are more resistant to weathering, while the more fractured areas are more deeply weathered and subsequently removed by mechanical erosion mechanical erosion. The relief is thus prepared in depth, well before its topographic expression (Twidale & Bourne, 1975).

1.3.4.3. Exhumation of the bedrock surface and regressive erosion of the cover.

From the Cenozoic era onward, regional tectonic reactivation linked to the East African Rift and the opening of the Gulf of Aden led to a gradual uplift of the bedrock and associated coverings. This uplift promoted the regressive erosion of Mesozoic and Cenozoic sedimentary formations, leading to their gradual dismantling (Bosworth *et al.,* 2005; Guillocheau *et al.,* 2018).
The area is drained by a network of temporary wadis, which are only active during rainy periods. These shallow channels ensure the periodic stripping of weathered material and the transport of coarse sediments, while limiting deep incision. The absence of permanent drainage contributes to the long-term morphological stability morphological stability of the relief in the long term.

The north-south oriented hydrographic network was therefore established by regressive erosion from the Gulf of Aden. It has allowed the stripping away of the Mesozoic and Cenozoic sedimentary cover and then the clearing of the weathered material, allowing the inselbergs to emerge. Thus, if we take a transect from south to the north, we pass from the sedimentary cover undergoing erosion south of Laas Geel to the inzelbergs being exposed at the site, then to the increasingly deeply and carved out towards the Gulf of Aden (**Fig. 2**).

1.3.4.4. Exposure of the inselbergs and individualization of the reliefs of Laas Geel.

The gradual retreat of this cover has led to the exhumation of the pre-Mesozoic surface, now observable in the form of sub-flat or slightly undulating surfaces, locally punctuated by residual reliefs. This process of exhumation is generally diachronic and spatially heterogeneous, controlled by the initial topography of the buried surface, the thickness of the cover, and lithological contrasts (Summerfield, 1991). This surface, previously altered along lithological and structural weaknesses, will therefore have differential resistance to weathering.
The final exposure of inselbergs, such as Laas Geel, is therefore the result of prolonged differential erosion, combining pediplanation, scarp retreat, and the removal of weathered material by wadis (King, 1962; Thomas, 1994). The most resistant rock volumes, often consisting of massive, slightly fractured and less weathered granites, remain as isolated reliefs dominating the surrounding plains.

1.3.4.5. The Laas Geel inselberg in its landscape.

The Laas Geel site is a granitic inselberg, a term used to describe an isolated rocky feature that clearly detached from a surrounding gently undulating or sub-flat surface (King, 1962; Thomas, 1994). Well known in the ancient bedrock regions of southern Africa and the central Sahara, these formations are characteristic of regions with ancient bedrock that have undergone a long history of weathering and erosion under contrasting climates (Twidale, 1982). They are of tropical and subtropical bedrock landscapes.

The Laas Geel inselberg is therefore a modest but clearly individualized positive relief feature, dominating the adjacent plains. In a largely open and low-contrast landscape, it forms, along with the other surrounding inselbergs, a major topographical landmark, visible from several kilometers away.

Chapter 2.

The rock shelters of Laas Geel: review, formation, and evolution

At Laas Geel, the morphology of the inselberg, characterized by steep rock faces, rock shelters and natural caves, reflects the interaction between the internal structure of the granite (diaclases, joints, planes of weakness, lithological variation) and subaerial erosion processes. These forms are not only of geomorphological value, but also influenced prehistoric human occupation of the site, providing natural shelters conducive to the preservation of cave paintings. These are shallow, widely open cavities that form protective overhangs protective overhangs.
This geomorphological context largely explains the exceptional preservation of the cave paintings . It is therefore important to understand how these shelters were formed and evolved in order to better protect them, in particular by taking care not to alter the environmental conditions that have allowed the preservation of the cave paintings to this day.

2.1. Taffonis: a geomorphological feature that is still poorly understood.

2.1.1. General information.

While taffonis, the hollow formations that make up the shelters of Laas Geel, can be found all over the planet in a wide variety of contexts, they remain poorly understood. This review of the literature shows the current state of research and highlights the elements that will then be used in our reflection on the shelters at the site. It appears that many of our observations are innovative and that only the fieldwork we have carried out, supported by a solid analytical component, will enable us to correctly characterize the context in which these shelters were formed and how they evolved. However, it is precisely this evolution that matters to us, because the slightest resumption or acceleration of this dynamic would directly result in the destruction of the cave paintings. It is precisely this long, complex, and polygenic past long, complex, and polygenic past that must be kept in mind in all our future actions.
The shelters at Laas Geel can be attributed to a geomorphological form and processes described in several parts of the world known as taffonis **(fig. 1).** This term, of Corsican origin, refers to weathering forms in rounded cavities in massive, often granular rocks, ranging from a few centimeters to several meters in diameter. These cavities are often found in vertical or steeply inclined walls. Long interpreted as forms essentially related to coastal haloclasty[1], taffonis are now beginning to be recognized as polygeneous, resulting from the combination of several mechanisms such as salt crystallization, wetting-drying cycles, condensation of atmospheric moisture, and microclimatic and biological feedback loops (Sunamura, 1996; Huinink et al., 2004).

1 Haloclasty (also called salt weathering) is *a type of physical weathering* caused by the growth and thermal expansion of salt crystals.



Fig. 1: *Taffoni vary in size and shape, but are characterized by hollow, very rounded, and sometimes coalescing forms, most often located at the base of escarpments (Shelter 7, Laas Geel).*

2.1.2. Definition and global distribution.

Taffoni (or *taffoni*) are forms of cavernous weathering developed in coherent rocks coherent rocks, mainly granites, sandstones, and volcanic tuffs, and characterized by rounded cavities rounded cavities with concave walls, either isolated or coalescing. Observed in a variety of climatic contexts (coastal, arid, semi-arid, and temperate), they are privileged markers of interactions between lithological properties, microclimatic conditions, and physicochemical weathering processes (Mustoe, 1982; Turkington & Phillips, 2004). Their main characteristics are:

- rounded or bowl-shaped cavities, sometimes coalescing or nested,
- overhanging margins (visors),
- smooth, flexible, non-angular walls,
- floors often sloping slightly outward, more or less covered with debris (sand, scales, blocks).

These structures have been detected in many regions of the world (French and Guglielmin, 2021): Corsica, of course, Sardinia, Spain, Namibia, Australia, but also Antarctica, the Thar Desert (India), Petra (Jordan), and California (USA). For our part, we have been able to study them in various around the world: Egypt, Zimbabwe, USA (California), Cyprus, and France.
Taffonis are therefore widespread throughout the world in a variety of climates: temperate, humid, hot and arid, or cold and arid, as well as at different altitudes, from sea level to over 2,200 meters

above sea level (in South America). Tschang (1974) and Mustoe (1982) provide excellent descriptions of their global distribution. Despite the diversity of environmental and geographical contexts in which taffoni are found, the literature generally agrees that temperate coastal environments and arid deserts (cold or hot) are the most favorable places for their development. Among the notable studies on taffoni, their presence in the following climatic zones:

Temperate (coastal) zones: Italy (Penck, 1894; Martini, 1978); Greece (Kelletat, 1980; Hejl, 2005); Australia (Young, 1987); Hawaii (Palmer and Powers, 1935); Hong Kong (Tschang, 1974); Spain (Mellor, Short, and Kirkby, 1997); United States (Mustoe, 1982; Pestrong, 1990)

- **Wetlands**: northern Portugal, Elba Island, and Aruba (Goudie, 2003); Hong Kong (Tschang, 1974); US Midwest (Sallman, 1996);
- **Hot desert areas**: Mojave Desert (Blackwelder, 1929); Colorado Plateau (Mustoe, 1983); Australia (Bradley, Hutton, and Twidale, 1978; Dragovich, 1969; Winkler, 1979); Sahara (Smith, 1978);
- **Cold desert areas**: Antarctica (André and Hall, 2004; Calkin and Cailleux, 1962; French and Guglielmin, 2000; Matsouka, 1995; Prebble, 1967; Wellman and Wilson, 1965); Finland (Kejonen, Kielosto, and Lahtiand, 1988); the interior of the Asian continent (Goudie, 2003) and even on Mars (Smith, 1983; Rodriguez-Navarro, 1998).

2.1.3. Historical hypotheses and conceptual model

These are therefore very widespread forms, found in a wide variety of geological and geomorphological contexts, from coastlines, which were thought to be strictly contingent, to mountainous areas in the heart of the African continent, regardless of latitude considered. To explain the presence of these forms in such varied contexts, different modes of formation have been proposed in the scientific literature.

2.1.3.1. Alteration by salt crystallization.

Since the mid-20th century, many authors have considered that alteration by salts (growth of crystals in pores and microcracks) is a major mechanism in the formation of taffoni, particularly where salts carried by sea spray or saline water are available. In this model, salt water penetrates the pores. Its evaporation causes the crystallization of salts (NaCl, gypsum, etc.), and the growth of these crystals generates mechanical stresses that break down the grains and enlarge the cavities. This mechanism is often proposed to explain the prevalence of taffonis along rocky coasts, such as in Corsica, the coast of Namibia, or Cap de Creus in Spain. But in the case of the Laas Geel site, the coastline is more than 70 km away in a straight line and its influence, especially with regard to the arrival of salt spray, can be considered as negligible.

2.1.3.2. Differential weathering and surface crust.

Another concept widely discussed in the literature is differential weathering combined with concept of surface crusting (*case hardening*). A hardened surface crust (due to mineral precipitation mineral precipitation or cement remobilization) forms on the surface. Under this crust, the internal material is more susceptible to weathering and disintegration, and when the crust breaks, the internal rock weather more rapidly, creating deep cavities by hollowing out the weathered fringe. This mechanism can operate with or without saline inputs, and is often used to explain taffonis far from coastlines or in sedimentary lithologies. It is observed in many desert areas, but this is not the case at the Laas Geel site, where this crust does not exist. We must therefore find another explanation.

2.1.3.3. Internal microclimate and weathering feedback.

Some more recent models emphasize the role of microclimates inside the cavities, created as soon as the start of excavation. The air inside the cavity may be more humid or cooler than outside, promoting more pronounced wetting/drying cycles in the shelters, more significant chemical reactions (mineral hydration/hydrolysis) and positive feedback phases: the larger the cavity becomes, the more the microclimatic conditions promote additional alterations. Thus, once a cavity begins to develop, it creates an internal micro environment, distinct from the external atmosphere. This microclimate is characterized by lower and more stable temperatures than outside (fewer diurnal fluctuations, thermal inertia of the rock), higher relative humidity favored by shade and lower temperatures condensation and water retention, as well as a reduction in direct convective Ces conditions facilitent des réactions d'altération chimiques et physiques plus actives à l'intérieur de la cavité qu'à l'extérieur. Cette idée permet d'expliquer pourquoi certains taffonis se développent sur des roches apparemment homogènes, sans discontinuités évidentes (fractures, plans de stratification), mais aussi sans croûte indurée et loin du littoral. C'est cette hypothèse de formation qui répond le mieux au contexte et aux observations réalisées ces dernières années sur le site de Laas Geel et que nous avions proposée dans nos précédents rapports (Gutherz et Bruxelles., 2016 et 2023).



Fig 2: *Shelter 3: Two levels of migmatites have been eroded away (Dhagax Kure).*

2.1.4. Factors common to the formation of taffoni.

2.1.4.1. Arid and azonous climates.

An article by Hall & André (2006) suggests that taffoni are azonous: they therefore appear in very different contexts, particularly in arid climates (dry Antarctica, Australian desert), in very ancient and geomorphologically stable areas (Brazil, African shield) and sometimes far from any marine salt source. In these cases, three dominant conditions are put forward, depending on the situation:

- Presence of salts, even non-marine (transported by wind or present in the substrate),
- High temperature ranges, contributing to mechanical and chemical weathering,
- Aridity, which promotes the accumulation of salts but above all allows regular cycles of wetting/drying.
-

These different models explain why taffoni can also be identified far from direct marine influence (Hall & André, 2006). This is also the conclusion of our observations at the of Laas Geel. In this case, in the absence of salt inputs, alteration is only possible due to:

- High daily temperature ranges,
- Rapid variations in relative humidity,
- Low but frequent water inputs (dew, fog, nighttime condensation at night).

These conditions are precisely conducive to the rapid cycles of wetting and drying mentioned above and to which we will return (Goudie, 1986; Hall, 1999).

2.1.4.2. Role of rock, fractures, porosity, and lithological heterogeneities.

For the formation of taffonis, the presence of granular rock seems to be a constant that is found fairly regularly. Thus, the granites of Laas Geel, often with large crystals, are very well suited to this. In several studies, the internal structure of the rock (fractures, joints, heterogeneities) is considered as a starting point for the location of cavities. Thus, taffonis often form in near areas that are already weakened, where water, salts, and air can get in more easily. In fact, microclimatic conditions develop earlier and the formation of a taffonis takes precedence over healthier areas. In the case of Laas Geel, it is the presence of migmatite passes (see below), which are more sensitive to weathering, that constitutes the starting point for the formation of shelters. These levels will play this role throughout the evolution of the taffonis, whose general shape is often guided by the levels of migmatites. Fractures and quartz veins also contribute to this, but to a to a lesser extent. However, it is important to add a nuance, as not all taffonis are systematically associated with lithological weakness. In this case, it is mainly factors humidity, exposure, and thermal contrast that will determine the location of a taffonis.

2.1.5. Summary of the different processes.

Based on the scientific literature, it appears that the physical processes involved in the formation of taffonis are polygenic but not exclusive:

- Alteration by salts (marine or otherwise) and haloclasty;
- Differential weathering and *case hardening*;

- Internal microclimates producing weathering feedback loops leading to combined physicochemical processes (hydrolysis, hydration, dissolution;
- Environmental factors (aridity, temperature, ventilation, salinity).

Thus, although a coastal origin has long been favored (particularly in the Mediterranean), it is clear established that no single factor is sufficient to explain all cases of taffoni. Their presence in non-marine, desert, or polar environments indicates that local physicochemical conditions (salts, heat/cold, wet/dry cycles) are often more decisive than proximity to the sea alone. We will therefore focus our attention on the physicochemical, microclimatic, and environmental aspects focus our attention with regard to the formation of the Laas Geel shelters.

2.2. Observations on the formation of the Laas Geel shelters.

2.2.1. General datas.

La mission de terrain réalisée en décembre 2025 a permis de confirmer l'essentiel des observations The field mission carried out in December 2025 confirmed most of the observations recorded in previous reports. We reproduce them here, supplemented with new forms or new insights. Based on the bibliographic review of taffonis presented above, these observations allow us to define the processes underway. We are now able to accurately describe the sequence of processes that led to the formation of the Laas Geel shelters, with new but fundamental elements fundamental elements seen for the first time at this site. The distribution of rock shelters on the Laas Geel hill is neither spatially homogeneous nor random. Their preferential location on certain slopes, their organization in terraced chains and the marked differences in size and morphology indicate the existence of closely intertwined lithological, structural, and microclimatic controls

These cavities developed mainly in granites traversed by darker migmatite veins, which constitute levels of weakness within the massif. Previous work carried out on the site (Gutherz and Bruxelles, 2016; 2023), supplemented by comparative observations conducted in France, Sardinia, Egypt, and Zimbabwe, and then by the 2025 field campaign, suggest that these shelters are the result of a long-term process of progressive subaerial weathering that requires very specific conditions. Their morphogenesis is closely related to the processes described for taffonis and other alveolar weathering cavities developed in a continental granite context (see *above*). In these non-coastal environments, evolution is dominated by repeated cycles of condensation, wetting, and drying, which lead to slow but cumulative granular disintegration but cumulative disintegration (Mustoe, 1982; Turkington & Phillips, 2004; Paradise, 2013; Goudie & Viles, 2015). In the case of Laas Geel, far from any marine influence, haloclasty can be considered negligible, giving hygrometric mechanisms a central role.

2.2.2. Migmatites : a weak point at the origin of the formation of shelters.

The recurring presence of migmatite levels at the bottom of the cavities clearly shows that these play a decisive role in the initiation of shelters (**Figs. 3 and 4**). These banded metamorphic rocks, rich in biotite, are more susceptible to chemical weathering than the surrounding granite. Their high ferromagnesian mineral content promotes hydrolysis and fragmentation, leading to rapid loss of cohesion.



Fig. 3: *Shelter 6: residual pillar of migmatites. This rock is preferentially excavated by erosion.*

.



Fig. 4: *Shelter 3: two levels of migmatites have been eroded away.*

Migmatites are metamorphic, banded rocks rich in black mica (biotite), hence their dark color. They are more susceptible to weathering than granite precisely because of this richness in mica. These rocks will therefore tend to weather and erode faster than the granite that surrounds it and therefore recede more quickly. Our observations at the site show a flaky appearance, particularly in the shelters, which is a sign of weathering. Furthermore, the alternating periods of moisture and dryness cause the rock to disintegrate relatively quickly rock. This mechanism corresponds to the cyclic mechanical fatigue models described for rocks in semi-arid environments (Hall, 1999; Hall & Thorn, 2011). The result is fine, dark sand that easily carried away by wind and runoff (**Fig. 5).**



Fig. 5: *Shelter 6: Migmatites undergoing erosion at the bottom of a shelter.*

It should be noted that it is possible that these past events, which may be more weathered than the surrounding granite, may also be the site of small water flows, which accelerates their removal. In most cases, this is the starting point for the formation of the shelter. This explains their morphology is often wider than it is high, and why they are aligned and staggered, following the passes of migmatites. Residual pillars still bear witness to the initial presence of these passages, even though they have already receded by several meters in some cases (**fig. 6**). This incipient void can measure several tens of meters in length along the slope and extend several meters into the granite massif.It therefore constitutes a real weakness within the granites, which becomes increasingly marked as the erosion of migmatites. This is the starting point for specific aerological phenomena that take advantage of the thermal inertia of the rock.



Fig. 6: *West side of the hill: ongoing erosion of a layer of migmatites prior to the formation of a shelter*

2.2.3. The first stage of shelter formation

As the migmatites recede, the surrounding granite is exposed to the internal microclimatic conditions of the nascent cavity. No linear incision or abrasion morphology suggests excavation by concentrated flow. The enlargement of the void results mainly *in situ* alteration.
Thus, as the migmatite levels receded, the main process appears to have been attributable to weathering phenomena occurring both at the roof and floor of the initial void.
As shown in Figure 7 (**Fig. 7**), this results in the flaking of small granitic scales, certainly coupled with granular disintegration. At the ends of several shelters, horizontal cracks can be seen widening, with successive flakes detaching from both the floor and the roof successive scales in the process of detaching. While thermal variations may contribute marginally to this fragmentation, the sheltered environment greatly limits direct thermal contrasts. On the other hand, the temperature difference between the rock mass and the outside air promotes regular condensation phenomena, which we will return to in detail in the later in the report.

Thus, as the cavities formed by the erosion of migmatites penetrate deep into the rock mass rock mass, they have relatively high thermal inertia. This is the best context for condensation phenomena to occur, whereas surfaces directly exposed to the air, and *especially* to the sun, will quickly rise in temperature. It therefore became clear to us, from the very first fieldwork sessions, that it is rather the alternation of wetting and drying that are responsible for enlarging the initial voids. Their frequency can vary from seasonal to daily, depending on weather conditions. This was confirmed by the site guards, who regularly see the upper part of the shelters covered with water droplets or even a film of water. This point is essential: the internal surfaces, which are colder due to the thermal inertia of the rock mass, thus becoming preferred sites for atmospheric moisture deposition. This condensed water is the main agent of chemical weathering, as has demonstrated for other continental taffonis (Mustoe, 1982; Turkington & Phillips, 2004).



Fig. 7: *Open shelter on the western slope of the hill: flaking of granite near a band of migmatite undergoing erosion*

2.2.4. Enlargement of the cells (Conches) and formation ceiling domes.

At this stage, this condensation phenomenon is the most likely explanation for the alteration along the former migmatite levels. From the development of the first cracks due to the retreat of migmatites, the phenomenon becomes increasingly active and allows the development of voids where characteristic shapes already identified in various contexts (the Sardinian coast, the Egyptian desert, the Chimanimani Mountains in Zimbabwe, etc.). In the case of these shelters, wind, thermoclasty, or haloclasty, sometimes cited as causes for the formation of taffoni, are not relevant, and it is precisely

the study of the shapes of the walls and ceiling that allows us to favor an evolution through condensation/alteration of the surrounding granites, a phenomenon well in karstic rocks, which are much more susceptible to this phenomenon (Bruxelles *et al.,* 2016 and 2021).
Thus, once the void has been created, the most pronounced thermal contrast zone is always located at the bottom of the cavity. The shelter will therefore develop towards the interior of the massif. Initially, the entire perimeter of the cavity is affected by flaking and granular disintegration (**Fig. 8**). But as soon as the shape reaches several decimeters in diameter, a differential evolution is observed: the ceiling rises faster than the floor lowers. Two phenomena may combine to explain this: as the wetting/drying cycles continue, the scales and grains of rock in the vault and walls fall rapidly, each time exposing a new surface of rock to weathering. In contrast, the floor is less easily cleared of the successive flakes that fall onto it (**Fig. 7**). In addition, it receives those that have fallen from the roof and walls, forming a protective cover protective cover. Therefore, when this loose material is not removed by erosion, it shows a delay in evolution compared to the rest of the shelter. This explains why the migmatite level that forms the shelter is often located in its lower part, with most of the void subsequently developing upwards.



Fig. 8: *Shelter 2a: Flaking of granite wall.*

In a second stage, when the shelter is large enough for a regulated climate and at the same time air convection phenomena are made possible, the walls and roof in turn undergo differential evolution. Depending on the geometry, exposure, and dynamics of air currents, condensation phenomena preferentially moisten certain parts of the shelter. These are most often the roof and the part upper wall that are affected (**Fig. 9**).

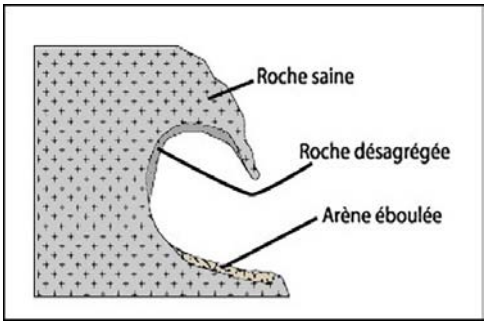


Fig. 9: *Diagram illustrating the development of ataffoni in granite rock. www.web.accorse.fr/saint_florent/attachment/5929/*

At the vault, large, shallow domes measuring around one meter in diameter deep, form. These are the preferred points of condensation where deterioration will concentrate, with the highest points offering the greatest contrast. We will see later that some of these domes then undergo a biological evolution. On the walls, conches or lateral alveoli develop and disrupt the initial wall. Here too, these points deepest points within the rock are those that offer the greatest thermal contrast and therefore the greatest potential for condensation. This asymmetry leads to preferential growth towards the top and towards the interior of the massif, generating domes, conches, and lateral alveoli typical of taffoni-type morphologies (Sunamura, 1996; Huinink et al., 2004; Goudie & Viles, 2015).

2.2.5. Wall returns, "visors" and spoilers.

These phenomena of granular disintegration and flaking have the same origin and can be explained in both cases by the swelling of mica in the wettest parts of the shelters. On the other hand, the dry parts or those exposed to the sun are virtually unaffected by this phenomenon. The temperature measurements taken this year clearly show this temperature difference (see below). The entrance of the shelters therefore experiences a slower evolution compared to the bottom of the cavity. The layer of rock close to the surface, which warms up more quickly, does not have the same thermal inertia as the deeper areas. They therefore present less contrast and are in fact less prone to condensation. Some shelters are therefore larger inside than at the entrance, which is narrowed by the return of walls.

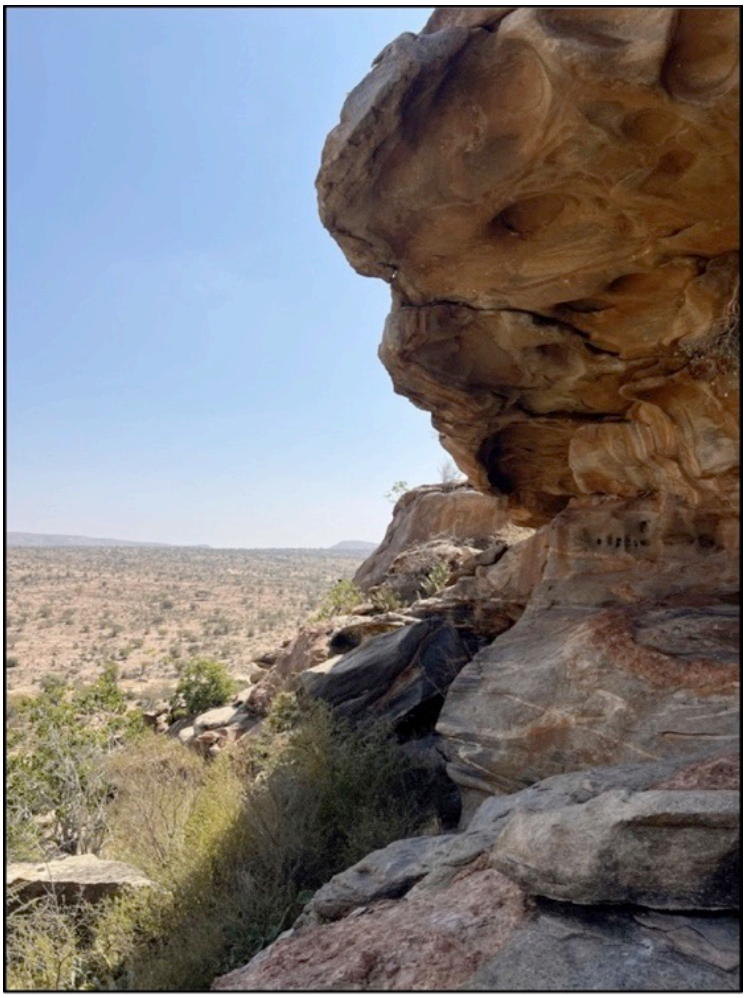


Fig. 10: *The top of shelters often ends with a return wall, sometimes called a “visor.”*

This differential evolution can also be observed in the vault: at the edge of the shelter, in contact with the wall above it, the vault systematically lowers (**Fig. 10**). This shape, never described to our knowledge before 2016, has been named a "visor," sometimes even forming a ledge or a spoiler facing the interior of the shelter. This original shape can be explained by the fact that the fringe rock near the surface did not experience the same condensation phenomena. The circulation of outside air, but above all the daytime warming of this fringe of rock by the sun, have greatly limited the possibility of condensation. Immune to this relative dryness, this part of the vault has been less affected by disintegration and flaking. This confirms that these forms are not due to thermoclasty or wind erosion, since it is precisely the part closest to the surface, the most exposed to these processes, that is the least affected.

2.2.6. Bell holes.

On the ceiling of many shelters, particularly shelters 1a and 1b, there are numerous small domes, sometimes coalescing (**Fig. 11**). Measuring a few decimeters in diameter, they sink vertically, more or less deeply into the rock. These shapes are unusual because they are not found in all shelters and are not present in most of the taffoni we have observed around the world. This means that their formation is not solely due to the classic processes common to taffoni, but that there is an additional phenomenon at work.Our recent work on biocorrosion in caves, caused by bat colonies, has concerned very similar formations: *bell holes* (Bruxelles *et al.,* 2024).

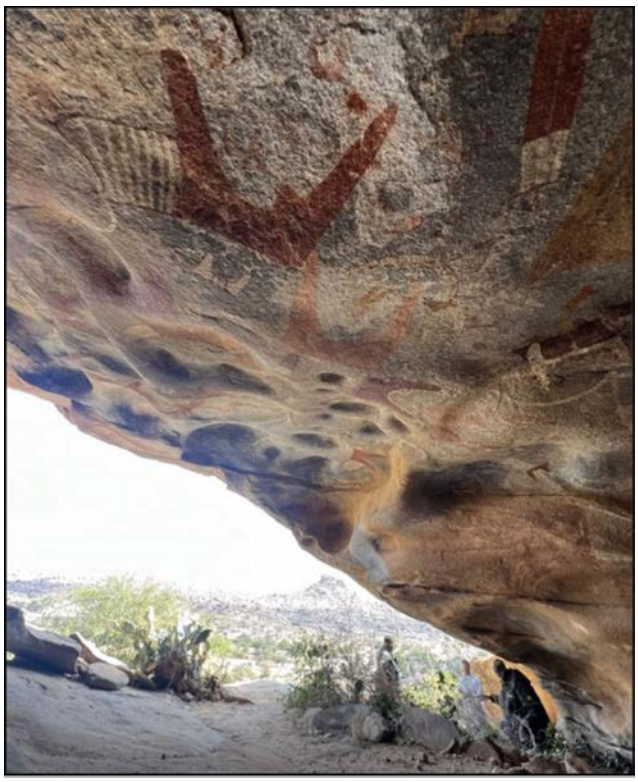


Fig. 11: The roof of shelter 1a is perforated with numerous bell-shaped holes. These could be of biogenic origin.

The presence of one or more bats in the same place causes the dissolution of the limestone around it. Limestone around it. It is the bat's respiration, which releases water vapor and CO2, which is solely responsible for this shape. Gradually, a bell-shaped form develops and can rise several decimeters, perforating the ceiling of the cavity with a multitude of *bell holes,* some of which may coalesce.
Here we find all the characteristics of these *bell holes,* which could therefore have a biogenic origin. In the context of open shelters such as those at Laas Geel, it seems difficult to attribute these shapes to

bats. However, we have observed numerous swallow nests that could be the cause of these shapes. In this case, it would be the water vapor released by the swallows that would be responsible for the alteration of the granite. In the warm, humid environment of the nest, this vapor must inevitably condense against the roof and promote the alteration of the granite through successive cycles of wetting and drying.

2.2.7. Successive collaspe of the vault.

The retreat of migmatites and the subsequent development of voids of varying sizes can eventually lead to the collapse of the overlying granite. This is all the more frequent when several levels of migmatites are superimposed. Thus, we find numerous cavities in various stages of evolution (Fig. 12). Several generations of superimposed blocks sometimes illustrate successive collapses of the vault and thus the formation of an increasingly larger shelter.



Fig. 12 : *Southwest slope of the hill: Collapse of granite blocks following erosion of the migmatite level.*



Fig. 13 *: Southwest slope. Gradual collapse of the granite vault.*

In areas of active collapse, few ceiling domes are present. Their formation clearly requires a certain amount of time and therefore depends on the relative stability of the vault. Often, “young” cavities, which are not yet stabilized, reveal scars on the vault. Nevertheless, under some collapsed blocks, there are small cavities or taffonis, probably initially developed on the ceiling of the shelter (**Fig. 14**).

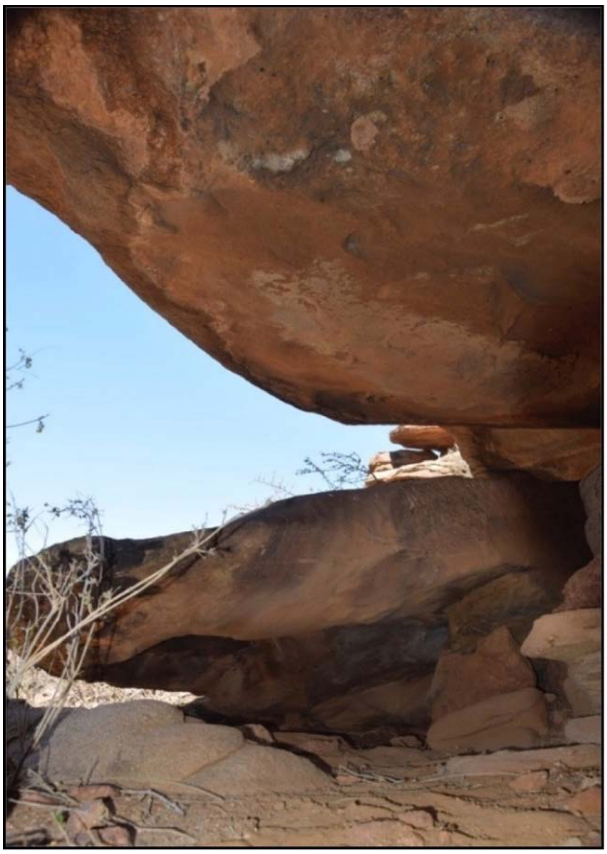


Fig. 14: *Southwest slope of the hill: Collapsed section of the vault where the old ceiling potholes can still be seen on the ground.*



Fig. 15: *Shelter 2: It developed along a vein of rose quartz.*

However, the example of Egyptian and Zimbabwean taffoni shows that these cells can also form once the block on the ground. Even if its volume is smaller, it has a certain thermal inertia that allows it to remain cold longer than the ground. The underside is therefore the preferred location for condensation. On the scars left by the removal of the vault, new domes are forming, smoothing the surface of the granite and gradually erasing the traces of collapse.T
he distribution of the collapsed shelters does not seem random, and it is quite clear that those on the southwest slope that are most affected by the collapses. We will expand on this point in the following paragraph.

Finally, locally, the presence of quartz veins seems to have played a role both in the development of the rock shelter but above all in its subsequent evolution. For example, rock shelter 2 differs from the others in its morphology (**Fig. 15**). It is not a low vault following the slope, but rather a high opening directly overlooking the valley. Here, the different mechanical behavior of the two rocks (granite and quartz) seems to have constituted a weakness exploited by successive collapses, followed by flaking and granular disintegration. We will see later that this phenomenon also affects a painting in this shelter. It is clearly an active and relatively rapid phenomenon, which at least partly explains its original size and morphology.

2.3. Central role of the microclimate at Laas Geel: external evaporation, internal condensation, and weathering.

2.3.1. General datas.

These forms are therefore mainly the result of microclimatic processes. Although they constitute a legacy, carved out over thousands or even tens of thousands of years, it is now important to ensure their stability. Indeed, it appears that since the creation of the cave paintings, some of these shelters have changed little, as evidenced by the cave paintings that have survived to this day. But this is a very fragile balance, as sadly demonstrated by the example of the Lascaux cave in the Dordogne. Changing just one of the identified parameters can irreparably jeopardize this heritage. It is therefore essential, before taking protective measures at the level of the hill or the shelters, to define the role of each of the processes involved. Only on this tangible basis can decisions on preventive protection measures can be made without risking upsetting the chain of phenomena in constant interaction. In hot, semi-arid deserts, nocturnal radiative cooling can lower the surface temperature below the dew point, leading to almost daily condensation.

Several studies show that these discrete contributions can represent a significant annual water flow, sufficient to feed weathering processes (Agam & Berliner, 2006).The model we propose for the Laas Geel shelters is that of a microclimatic feedback loop where air entering a cavity cools, causing moisture to condense on the internal walls, promoting chemical and physical weathering. Water condensation often follows day ight or seasonal cycles and can come from dew, fog, or directly from atmospheric humidity rather than direct rainfall. Alternating evaporation and hydration then become key drivers of disintegration (wetting/drying cycles). A key characteristic of taffoni is their uneven growth: slightly more porous areas porous or simply initially depressed undergo increased weathering, which initiates formation of a taffoni and amplifies the formation of cavities (differential condensation and/or differential weathering).

This is followed by a series of positive feedback loops: a cavity carved in the rock mass is cooler, so it becomes relatively more humid, which promotes condensation and weathering. Taffonis therefore develop preferentially towards the bottom of the shelter (the coolest wall) and towards the top (no

covering of weathering residues that have fallen to the ground, the walls are always exposed to condensation).

2.3.1. Evaporation and condensation: the impact of microclimates.

2.3.1.1. Origin of condensation water.

The condensation water required for this process can come from several sources: a supply along migmatite passes, evaporation from the ground, and transpiration from plants near the entrance.
As mentioned above, the water supply from the migmatite levels appears to be very low and we favor the other two sources of water in the atmosphere: evaporation and transpiration.
Evaporation occurs when the ground is heated by the first rays of the sun, causing the water it contains to evaporate the water it contains and any nighttime dew. In contrast, the rock mass will take longer to warm up, *especially* at the foot of walls and in shaded areas. This phenomenon can vary over time, being quite significant when the soil is still moist in the days following showers and almost non-existent in dry periods. This is why in sub-desert regions, soils are sometimes structured from bottom to top, with the evaporation of groundwater causing an of minerals. The cover of alluvium and granitic sand, which is locally quite thick, is also conducive to trapping this water and its gradual release during periods dry. It is therefore this phenomenon that provides the water that causes the cycles of wetting and desiccation of the walls of shelters, which can occur on a daily basis in certain seasons. In our the main phenomenon responsible for the formation of shelters, as we have seen in the literature but also in the field, in other regions of the world. Thus, in the Egyptian desert Egyptian desert and in the mountains of Zimbabwe, it is mainly the faces of the walls facing towards the ground that are affected by the phenomenon of large-scale alveolarization. This is also true for fallen blocks resting on sand or alluvium (Paradise, 2013).
Plant transpiration, although not as significant as evaporation from the soil at present from the soil, can contribute to condensation in shelters. Moreover, some alveoli may be inherited from wetter periods when the vegetation cover was denser. Currently, the vegetation is rather sparse and adapted to drought. We can therefore assume that its contribution to condensation in shelters is minimal. However, care must be taken to ensure that this situation does not change, particularly due to the cessation of grazing by goats on the hill, which could allow certain species to develop or even invasive species to colonize the entrances to the shelters. We will see more on the potential contribution of evapotranspiration alone to water supply and the risks this may pose on the resumption of wall weathering (**Fig. 16**).

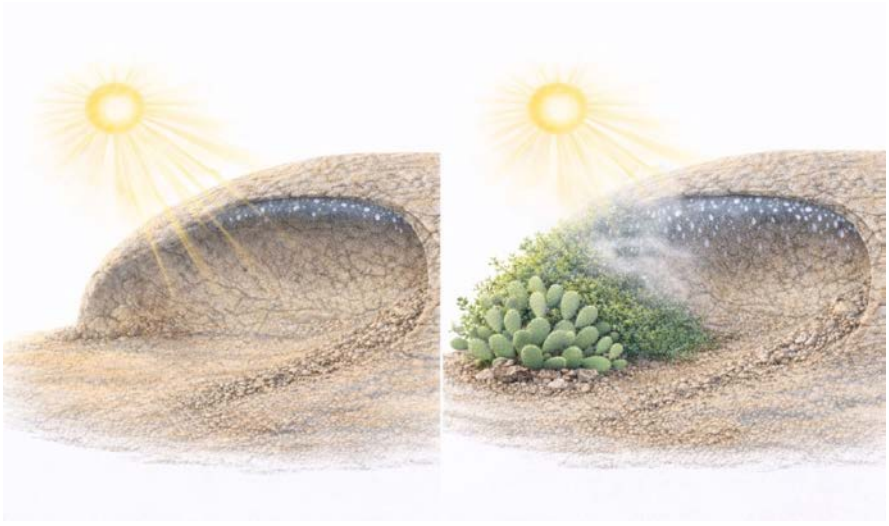


Fig. 16: *In addition to the morning evaporation of dew, vegetation contributes a significant amount of water through transpiration. This water is often deeper and could not have been mobilized by evaporation alone. It therefore constitutes water that is likely to condense on the walls of shelters.*

Moisture-drying cycles are therefore not solely controlled by precipitation. Numerous studies highlight the decisive role of variations in relative air humidity, nighttime condensation, dew, or fog, particularly in arid and semi-arid environments (Hall, 1999; Turkington & Phillips, 2004).
In taffoni, microclimatic gradients between external surfaces and internal cavities promote frequent but low-intensity humidification, prolonged drying phases with rapid repetition of cycles on a daily or seasonal scale. These conditions are considered particularly effective for fatigue weathering, compared to rare but intense wet events (Hall & Thorn, 2011).
In this model, the development of taffoni is strongly controlled by very small-scale microclimatic gradients, often independent of regional climatic conditions. Key parameters include:

- Diurnal and nocturnal temperature variations;
- Relative air humidity;
- Air circulation within the cavity;
- Differential sunlight between exposed surfaces and sheltered areas.

This last point is very important because it is at sunrise, when the ground is, depending on the season, moistened by dew, that maximum evaporation occurs. The first rays of the sun hit the damp ground in front of the shelters and accelerate evaporation. It is also at this time that the rock is coldest and therefore maximum condensation is possible on the walls. Conversely, the surfaces touched later by the sun's rays emit less evaporation because by the time the sun arrives, the dew has long since evaporated. The surrounding rock is also less cold because the daytime temperatures have already started to warm up the walls. Thus, evaporation will be more diffuse over time and condensation will be less significant. It is probably this dichotomy that explains the difference in the number and size of shelters between the two slopes of the Laas Geel Inselberg (see below).

2.3.2.2. Condensation in cavities and weathering

When warm, humid air enters a cavity with cooler walls, condensation of atmospheric moisture occurs on the internal surfaces (Turkington & Phillips, 2004).

This mechanism, documented in both coastal and arid continental contexts, allows for water supply even in the absence of direct precipitation (Mustoe, 1982; Paradise, 2013).
Condensation promotes:

- Dissolution of primary minerals;
- Mobilization of salts;
- Maintenance of persistent water films;
- Intensification of chemical reactions at the rock-air interface swelling and shrinkage phenomena in weathered clays.

These processes explain why weathering is often more intense inside taffonis than on the external surface, despite being less directly exposed to atmospheric agents. In fact, in a taffoni, this water persists longer than on exposed surfaces, evaporates more slowly, and the wet/dry microcycles multiply, sometimes occurring daily in certain seasons. Thus, the cavities function as hygrometric traps, maintaining a chemical activity that is disproportionate to the arid regional climate

2.2.2.3. Evaporation-condensation coupling and morphological feedback

Regardless of the saline nature of the solutions, repeated cycles of wetting and drying lead to volumetric variations in clay minerals, capillary pressures, and progressive mechanical fatigue mechanical fatigue of the rock. These processes are particularly effective in porous or granular rocks porous or granular rocks (McBride & Picard, 2000), such as the granites of Laas Geel.
The contrast between rapid external evaporation and persistent internal humidity generates a coupled system where the cavity acts as a microclimatic reactor. As the taffoni enlarges, the internal surface area available for condensation increases, reinforcing the process and accelerating locally alteration (Sunamura, 1996; Huinink et al., 2004). Thus, this model shows that:

- Condensation provides water on the walls opposite the entrance;
- Wetting allows the alteration of minerals (biotite, feldspars) that can be transform into clay;,
- Alternating wetting and drying of these clays generate mechanical stresses;
- Salts can amplify the damage but are not essential.

Taken individually, each of these mechanisms is relatively moderate. Combined, they produce a significantly greater degree of alteration (**Fig. 17**). This synergy explains why taffoni can develop in environments without significant water supply but subject to significant variations in local temperature and relative humidity (Turkington & Phillips, 2004; Huinink et al., 2004).

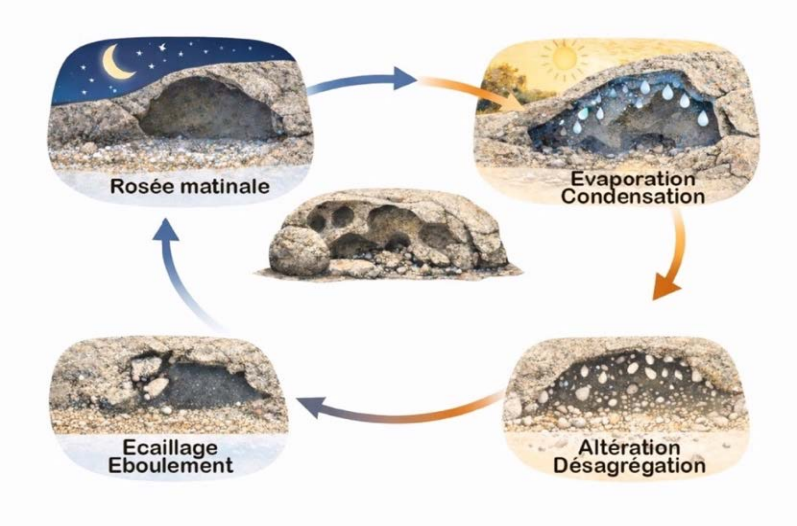


Fig. 17: *Diagram illustrating the successive processes involved in the formation and evolution of taffoni. It is the repetition of this cycle, sometimes on a daily basis, that is responsible for all the shelters at Laas Geel.*

2.3.2.4. Impact of wetting–drying cycles on taffoni formation.

Wetting–drying cycles are therefore a fundamental process in the physical and physicochemical weathering of rocks, particularly in environments characterized by intermittent availability of liquid water and high variations in relative humidity. In the context taffoni, these cycles therefore play a central role in controlling both water circulation in the pores, the dynamics of dissolved salts, the alteration of certain mineral phases, and the mechanical stresses on the rock matrix (Goudie & Viles, 1997; Hall, 1999).

Unlike continuous weathering under stable humid conditions, the repeated alternation between wet and dry phases induces progressive fatigue of the rock material, promoting granular disintegration and enlargement of existing cavities (McBride & Picard, 2000).

Variations in capillary stresses: During wetting phases, water penetrates the pores and micro-cracks by capillary action. Conversely, during desiccation, the removal of water generates negative capillary pressures negative capillary pressures, which can exert tensile stresses on the porous walls. These stresses, repeated over thousands of cycles, contribute to the rupture of intergranular contacts, particularly in rocks with interconnected porosity (Hall & Thorn, 2011).
These effects are accentuated in sheltered areas of taffoni, where water can persist longer in the form of thin films before slowly evaporating.

Swelling and shrinkage of secondary minerals: In many lithologies favorable to the development of taffoni, the initial weathering of primary minerals leads to the formation of secondary phases (clays, oxides, hydroxides). These minerals exhibit volumetric behavior sensitive to variations in humidity, with swelling phases during wetting and shrinkage during desiccation (Goudie, 1986). Even in small proportions, these minerals can generate micro-stresses sufficient to disrupt the rock structure, facilitating granular disintegration and the removal of weathered material weathered material out of the cavity.

The role of salt crystallization: Even though the Laas Geel site is not influenced by sea spray , salts from the surrounding rock can nevertheless contribute to the degradation process degradation process. When moistened, the salts present in the rock or brought in by the atmosphere dissolve and migrate to the most humid areas, often the interior of cavities. During desiccation, evaporation causes an increase in ionic concentration, followed by the crystallization or hydration of the salts (Doehne, 2002). The repetition of these cycles leads to recurrent recrystallization of salts in the same areas, a cumulative increase in mechanical stress, and localized weathering inside the taffonis rather than on the exposed surface. In this context, wetting-desiccation acts as a forcing mechanism, while salts act as an amplifier of the disintegration (Goudie & Viles, 1997; Steiger et al., 2011).

2.3.2.5. Rates of taffoni development.

In arid/desert environments, cavities can evolve slowly over thousands to millions of years, especially in the absence of external saline water. In humid saline coastal areas, growth can be faster (on the order of a few millimeters per year or per decade), due to frequent wetting/drying cycles and high salinity. Physical models (Sunamura, 1996) propose mathematical expressions linking depth/time under conditions of progressive disintegration (McBride & Picard, 2000).

Estimates of growth rates remain rare and highly variable. Available studies suggest rates of around 0.01 to 0.1 mm/year in arid or semi-arid continental environments arid or semi-arid environments and potentially higher speeds in humid coastal and saline coastal environments, locally reaching one millimeter per year (Norwick & Dexter, 2002). The weathering rates measured or modeled in these contexts are consistent with speeds of the order of one hundredth to one tenth of a millimeter per year, consistent with morphological observations (Norwick & Dexter, 2002; Huinink et al., 2004). On a geological scale, the formation of large taffoni involves periods ranging from several thousand to several hundred thousand years, depending on the lithology and the intensity of the dominant processes. Of course, when climatic conditions are not favorable to their development, their formation may freeze for a shorter period of time short period of time. This may be what happened at Laas Geel, which explains why, under the conditions of the last few millennia, the paintings have been preserved. But the modification of a single parameter fear restarting the taffonization process which, as certain studies show, can be very rapid and, in any case, irreparable for parietal works.

2.3.2.6. A dichotomy at the scale of the massif.

The shelters, their size, and their morphology are not evenly distributed across the Laas Geel hill.
Laas Geel. This seems to be directly related to their exposure: shelters exposed to the northeast are larger and strongly marked by the development of taffoni. Conversely, those that open onto the southwest are smaller and mainly show signs of collapse, while condensation/alteration forms are much less developed. As the lithological setting is the same, this difference can be attributed at least in part to the microclimatic conditions that have influenced the development of these forms. On the southwestern slope, exposed to the afternoon sun, humidity was lower and condensation was, in less significant. In addition, the rock had more time to warm up before the sun's rays sun, screened by the hill, reached the ground. As the conditions for flaking and granular disintegration in the shelters were less frequent, the ceiling formations are not or only slightly developed. On the other hand, the northeast slope is hit by the first rays of the sun. The ground warms up quickly while the rock is still cold from the previous night. Condensation conditions condensation are at their maximum and occur more frequently, resulting in larger shelters and more pronounced parietal morphologies. In addition, an inverse correlation can be made between the presence of boulders and the occurrence of collapses. Predominant along the southwest slope, they are rarer in the shelters on the northeast slope, which are larger. Given that the geological context is exactly the same, these forms collapse do not necessarily indicate greater structural instability of the roof of these shelters, but rather a different evolution. First of all, the southwest slope, exposed to the afternoon sun in the afternoon, is most prone to thermoclasty. It can therefore be assumed that the phenomena of expansion and contraction contribute to the mechanical fatigue of the rock. In addition, condensation/weathering processes are less active, these forms are less altered subsequently and the blocks on the ground are less subject to disintegration.

2.3.2.7. Rates of taffoni development.

In arid/desert environments, cavities can evolve slowly over thousands to millions of years, particularly in the absence of external saline water. In humid saline coastal areas, growth can be faster (on the order of a few millimeters per year or per decade) due to frequent wetting/drying cycles and high salinity. Physical models (Sunamura, 1996) propose mathematical expressions linking depth/time under conditions of progressive disintegration (McBride & Picard, 2000). Estimates of growth rates remain rare and highly variable. Available studies suggest rates of around 0.01 to 0.1 mm/year in arid or semi-arid continental environments and potentially higher rates in humid and saline coastal environments, reaching locally up to one millimeter per year (Norwick & Dexter, 2002). The weathering rates measured or modeled in these contexts are compatible with speeds of around one hundredth to one tenth of a millimeter per year, consistent with morphological observations (Norwick & Dexter, 2002; Huinink et al., 2004). On a geological scale, the formation of large taffoni takes anywhere from several thousand to several hundred thousand years, depending on the lithology and intensity of the dominant processes. Of course, when climatic conditions are not favorable to their development, their formation can be suspended for a shorter or longer period of time. This may be what happened at Laas Geel, explaining why the paintings have been preserved under the conditions of the last few millennia. However, a change in a single parameter can restart the taffonization process which, as some studies show, can be very rapid and, in any case, irreparable for cave art.

2.3.2.8. dichotomy across the massif

The shelters, their size, and their morphology are not evenly distributed across the Laas Geel hill. This seems to be directly related to their exposure: shelters exposed to the northeast are larger and strongly marked by the development of taffoni. Conversely, those opening onto the southwest slope are smaller and mainly show signs of collapse, while condensation/weathering is much less developed.

Since the lithological matrix is the same, this difference can be attributed at least in part to the microclimatic conditions that influenced the development of these forms. On the southwestern slope, exposed to the afternoon sun, humidity was lower and condensation was therefore less significant. In addition, the rock had more time to warm up before the sun's rays, screened by the hill, reached the ground. As the conditions for flaking and granular disintegration in the shelters were less frequently met, the ceiling forms are not developed, or only slightly so. In contrast, the northeast slope is hit by the first rays of the sun. The ground warms up quickly while the rock is still cold from the previous night. Condensation conditions are at their maximum and occur more frequently, resulting in larger shelters and more pronounced parietal morphologies. In addition, an inverse correlation can be made regarding the presence of blocks and forms of collapse. Predominant along the southwest slope, they are rarer in the shelters on the northeast slope, which are nevertheless larger. Given that the geological context is exactly the same, these forms of collapse do not necessarily indicate greater structural instability in the roof of these shelters, but rather a different evolution. First of all, the southwestern slope, exposed to the afternoon sun, is more prone to thermoclasty. It can therefore be assumed that the more significant expansion and contraction phenomena contribute to the mechanical fatigue of the rock. In addition, as the condensation/weathering processes are less active, these forms are less altered subsequently and the blocks on the ground are less subject to disintegration.

Conclusion : geomorphological dynamics, microclimatic functioning of shelters and conservation issues.

The morphogenetic study of the shelters at Laas Geel shows that these cavities are neither accidental formations accidental forms or simple local irregularities in the relief, but that they are part of a coherent geomorphological system, controlled both by the structural heritage of the granite massif and by weathering processes. Their development results from a hierarchical succession of mechanisms, from initiation along migmatitic levels that are more susceptible to weathering to progressive enlargement through granular disintegration sustained by cycles of condensation, wetting, and desiccation cycles. These dynamics, comparable to those described for continental taffoni in many arid and semi-arid contexts (Mustoe, 1982; Turkington & Phillips, 2004; Paradise, 2013; Goudie & Viles, 2015), give the shelters a specific microclimatic function that remains potentially active today.
Beyond the local scale of the cavities, the geomorphological evolution of Laas Geel is part of a very long-term regional dynamic. The current relief is the result of the gradual exhumation of ancient surfaces, inherited from tens of millions of years of geological history, then remodeled under the combined influence of tectonics, climatic fluctuations, and differential erosion. The granite inselbergs and residual volumes that remain bear witness to this long morphological trajectory, marked by the selective preservation of the most resistant rocks. The recognition of these inherited surfaces provides an essential framework for understanding the distribution of archaeological sites, the methods of conservation of decorated shelters and, more broadly, the close relationships between landscape dynamics and human occupation. By offering natural cavities, prominent topographical landmarks, and protected spaces, this residual morphology directly conditioned the settlement and continuity of prehistoric human groups. Laas Geel thus appears as a remarkable example of inherited relief where the long-term geological history has shaped the very conditions of human occupation.

At the scale of the walls, the genesis and evolution of the shelters are based on a fundamental principle of differential weathering. Minor initial heterogeneities (variations in porosity, cementation, fracturing, or mineralogical composition) lead to preferential alteration of certain areas of the granite. These weakened areas gradually evolve into micro-depressions which, by modifying the local conditions of temperature, humidity, and air circulation, create positive feedback loops that promote their own deepening. This self-sustaining dynamic, described in detail for taffoni by Turkington and Phillips (2004), explains how cavities can develop even in apparently homogeneous rocks. The

emerging geometry of the cavity then acts then acts as a microclimatic trap: it promotes the stagnation of humid air, prolongs the duration of wall wetting, and amplifies internal condensation. This hygrometric trapping is a key point in understanding the respective importance of external evaporation from the soil and internal condensation on cold rock surfaces.

Observations made at Laas Geel confirm that these microclimatic mechanisms play a major role. Even minimal water inputs from dew or condensed atmospheric humidity condensed humidity, are sufficient to trigger mineral hydrolysis reactions, the formation of secondary clays and differential swelling responsible for internal stresses. The repetition of wetting–drying cycles induce cumulative mechanical and chemical fatigue, marked by the gradual breaking of intergranular bonds, increased porosity, and increased permeability to water. The cavity then becomes increasingly effective at trapping atmospheric moisture, further enhancing weathering in a positive feedback process (Sunamura, 1996).This logic explains the directed growth of shelters towards the interior of the massif, the formation of domes and honeycombs, and the persistence of these morphologies in very contrasting environments, whether desert, coastal, or mountainous.

The microclimatic paradigm thus goes far beyond older interpretations based exclusively on the action of sea salts and places the internal dynamics of the cavity at the center of the geomorphological explanation. This detailed understanding of the mechanisms of alteration is not only of theoretical interest theoretical interest, it also has direct implications for the conservation of cave art.
The decorated surfaces are based on walls that are not stable on a human timescale but engaged in a continuous, albeit slow but irreversible, evolution. The processes responsible for the formation of the shelters remain potentially active and can be reactivated by slight environmental variations. Any change in the internal microclimate, whether resulting from a change in vegetation cover, a modification of natural ventilation, increased visitor numbers, or anthropogenic developments, is likely to alter the frequency and intensity of the condensation-desiccation cycles, and thus accelerate the disintegration of the decorated walls thus appear to be dynamic supports whose stability depends directly on a fragile microclimatic balance.

Therefore, effective protection of the site requires not only the physical conservation of the works, but also control of the physical parameters that govern the functioning of the shelters.
Understanding the geometry of the cavities, their depth, orientation, degree of confinement, and ventilation conditions is essential in order to anticipate the location of areas of condensation and areas of preferential alteration. Similarly, precise climate monitoring such as we have implemented (*see below*), combining measurements of surface temperature, relative humidity, dew point, and wetting duration, is essential for detecting any changes that could affect the kinetics of deterioration. Correlating these parameters with the condition of the walls will make it possible to identify critical thresholds beyond which the conservation of the works would be compromised. Thus, the geomorphological study of shelters is not a simple descriptive exercise: it constitutes the scientific basis for a preventive conservation strategy. By establishing links between structure geological structure, microclimate, and weathering, it provides the conceptual tools necessary to anticipate risks and guide site management.

Understanding the mechanisms of formation and evolution appears to be a prerequisite for any sustainable protection policy. It is precisely in this perspective that the following chapter is devoted to the geometric characterization geometric characterization of shelters and detailed monitoring of their microclimatic parameters.The quantitative control of these variables is an essential step in transforming geomorphological diagnosis int an operational conservation tool capable of ensuring the sustainability of these exceptional works in the face of present and future environmental changes.

Chapter 3.

Understanding Aerological phenomena responsible of Condensation-Related-Corrosion Process.

This chapter analyzes the aerological and thermal processes responsible for the corrosion of rock walls in the decorated shelters of Laas Geel, Dhambalin, and Dhagax Kure (Somaliland). Daily and seasonal thermal variations, combined with the morphology of the shelters (orientation, degree of openness, volume, multiple entrances), generate air circulation through convection and advection. When the temperature of the walls becomes lower than that of the ambient air, condensation occurs, forming an infra-millimetric water film. Although very thin, this water film induces active geochemical processes: dissolution and hydrolysis of the most soluble minerals in granites and sandstones, ionic migration, recrystallization, and, at various stages, the development of biofilms. These mechanisms result in characteristic forms of weathering (domes, tafoni, arenization) and directly influence the state of preservation of rock paintings. Field measurements (infrared thermometry, anemometry, photogrammetry) show that concave areas are systematically colder and thus more prone to condensation. Continuous climate monitoring (temperature and relative humidity recorded every 30 minutes over a full seasonal cycle) is underway and will quantify these dynamics.Using thermo-hygrometric modeling, it is possible to estimate an annual input of approximately 0.33 L/m² of condensation water, concentrated directly on the walls, without initial runoff. Although quantitatively modest, this daily repeated input produces localized but sustained chemical weathering. These results demonstrate that condensation is a major, discrete, yet continuous factor in the morphological evolution of shelters and also contributes to the degradation of decorated surfaces.

3.1. Context

The rock walls of decorated shelters are subject to daily temperature variations of several degrees, which gradually evolve throughout the day and with the seasons. Temperature variations in the air between warm and cold periods range from ten to fifteen degrees Celsius. However, areas directly exposed to sunlight may experience greater variations depending on the orientation of the slope and the position of the shelter within it. Some shelters are not directly open, and collapsed blocks or vegetation partially obscure them. This creates temperature gradients between the interior of this partially enclosed space and the outside air temperature. Such conditions favor the establishment of convection loops. Colder, denser air settles in the lower parts, while warmer, lighter air rises. These density differences cause gravitational movement of air masses. Significant directional airflows may develop depending on the temperature conditions of the external environment. At the atmospheric level, seasonal and meteorological conditions contribute to the circulation of warm or cold air flows, more or less rapidly, through advection phenomena powerful enough to alter seasonal temperatures and precipitation conditions. These flows are responsible for more or less rapid variations in temperature and hygrometry in different parts of a shelter. The temperature difference between the air and the wall causes condensation of air humidity on the wall when the wall is colder than the air. The resulting water film initiates geochemical processes in which minerals present in the granite are

altered and exported through corrosion and/or dissolution. The most soluble minerals are exported through hydrolysis, causing material loss within the rock structure and the formation of characteristic erosion zones. The resulting forms include domes, tafoni, spherical weathering, and the production of sandy arenas. The studied sites (Laas Geel, Dhambalin, Dhagax Kure) present varied geological contexts (granites, granodiorites, sandstones), allowing for a comparative approach.

3.2. Methodology.

To address the complexity of the phenomena involved and the diversity of situations, the implemented approach combines: (i) thermal measurements of walls using infrared thermometers to identify temperature gradients and areas prone to condensation, (ii) aerological measurements with a hot-wire anemometer to characterize internal air circulations, (iii) photogrammetric surveys to correlate the morphologies of shelters and walls with thermal dynamics, (iv) continuous climate monitoring using temperature and humidity probes, recording every 30 minutes over a full seasonal cycle in several representative shelters, and (v) thermo-hygrometric modeling based on the dew point to estimate the fluxes of condensed water on the walls.

3.3. Temperature and Aerology Measurements.

Significant work on temperature profile measurements was undertaken along the walls to identify temperature variations likely to generate condensation processes on the walls (**Fig. 1**).



Fig.1*: Rock temperature measurements in the northern dome of shelter 2B at Laas Geel.*

At the level of decorated panels, temperature measurements with an infrared thermometer identified areas where the influence of condensation-related corrosion is strong. Moreover, condensation produces an infra-millimetric water film that allows the fixation of clayey dust suspended in aerosols and carried by the wind. These processes are clearly visible on the surfaces of rock walls in many shelters.

Temperature measurements were supplemented by photogrammetric surveys to describe and qualify the studied areas. This inventory will be completed with the analysis of temperature data recorded by temperature and hygrometry sensors installed at strategic locations identified during temperature profile measurements.

Alongside temperature measurements, air current velocity measurements were carried out at the scale of the shelter and the wall using a hot-wire anemometer. This allowed the characterization of airflow velocities and corresponding flow rates for the most enclosed shelters and the associated air temperature. These measurements will need to be supplemented by a measurement campaign conducted during the hot period to establish a thermodynamic model for each shelter. This approach was conducted at the Laas Geel site for all decorated shelters along the visitor path and two undecorated ones to compare climatic and aerological dynamics and assess their influences on the conservation states of decorated areas. The same approaches were conducted at the Abri du Prophète (Dhagax Nabi Galey), in shelters 2 and 3 of Dhagax Kure, and in the large shelter of Dhambalin.

3.4. Temperature Measurements at the Laas Geel Site.

The Laas Geel site is developed in granodiorites and migmatites of the Qabri Baxar formation of Proterozoic age. This inselberg is located at an altitude of 1100 m. Temperature measurements show variability depending on their position within the shelter. The most concave areas of the domes are generally colder than the surfaces located at the extremities of the forms. The morphological result is a kind of visor or overhang in the inner zone of the dome's end and nested domes that develop in the highest inner parts (**Fig. 2**).

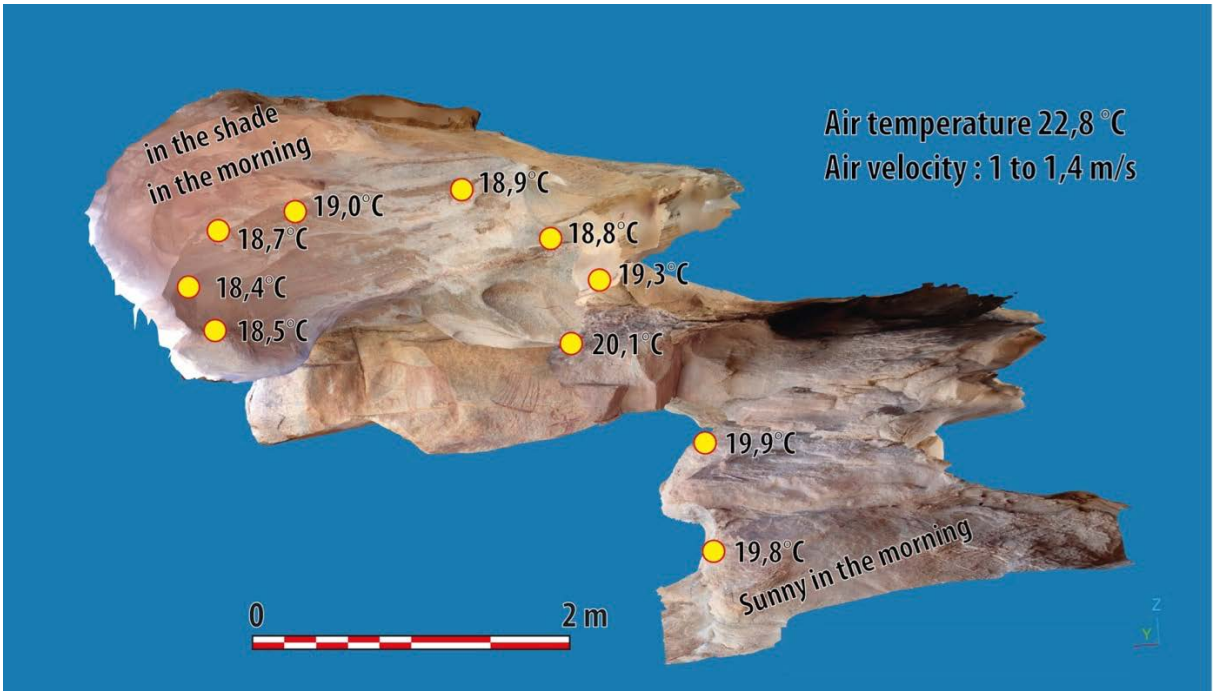


Fig. 2: *The evolution of temperatures measured in the morphologies of the domes of Shelter 2B at Laas Geel highlights the effects of corrosion processes linked to condensation in the evolution of the shapes and sizes of these interlocking structures.*

Shelter 2B is widely open and exposed to the east and southeast. The series of measurements taken in this shelter on the morning of December 9, 2025, clearly illustrates the dynamics of the processes leading to rock corrosion due to increased condensation on these cold parts of the walls. Measurements were taken for shelters 1, 7, 9, 11 A and B, and 15, with a similar protocol, on the mornings of December 9 and 11. In Shelter 1, the morphology is more complex than in the open shelters. It has a more pronounced confinement due to collapsed blocks and vegetation. However, the measured temperature variations follow the same logic of variability as in the open shelters. This distribution of temperatures, with the coldest areas near or within the most marked concavities,

highlights the complexity of the nested domes that served as supports for the numerous painted figures (**Fig. 3**).

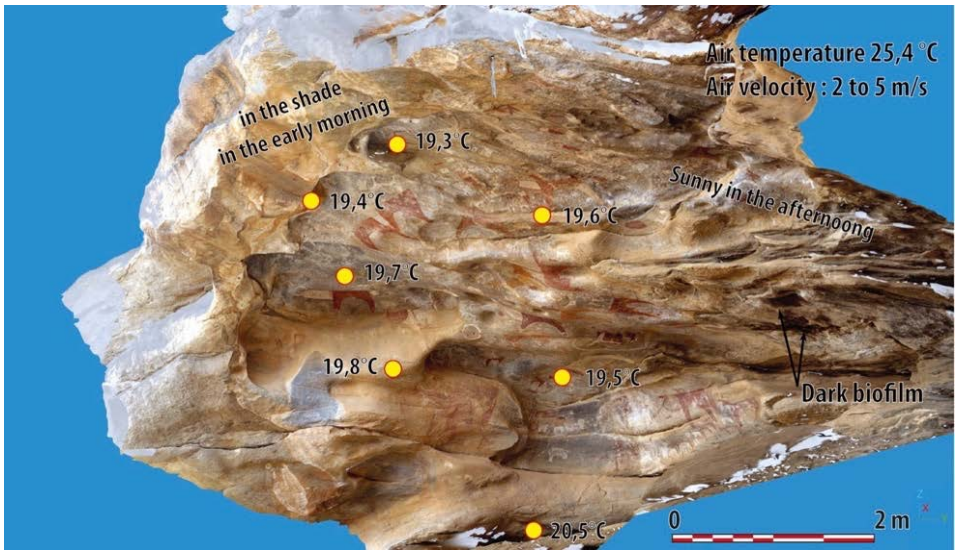


Fig. 3: *Location of temperature measurement points in Shelter 1. The dark biofilm is located at the edge of a dome in the lower part of the shelter.*

3.5. Temperature Measurements Near Swallow Nests

In the upper part of Shelter 3, a large pink quartz vein cuts through the rock structure. Temperature measurements on the border of the granites and the quartz show a difference of 0.2°C, with the quartz being colder than the granite (**Fig. 4**).



Fig. 4: *Morphology of the imposing vault of Shelter 3, crossed by a vein of rose quartz. This lithology causes temperature variations between the granite surfaces and that of the quartz vein. The swallows' nests are located in the cold areas of the vault, which is important during the summer season for raising their young*

This thermal behavior could explain the position of the quartz veins relative to the granite surfaces observed on the hill. Increased condensation on the quartz could generate larger water films that, by running off, contribute to facilitating the alteration of the granite at its contact.
The exposed quartz is then subject to erosive or gravitational processes. Swallow nests are installed in the cold parts of the vault or wall, at a height sufficient to be out of reach of terrestrial predators. This

thermal condition is important for raising juveniles during the hot season. Temperature measurements at various nest locations on the Laas Geel site show that the temperatures sought by swallows for nest installation ranged between 17.6 and 17.8°C at the time of our surveys.

3.6. Les mesures de température sur la paroi pour le site de Dhambalin.

The rock cornice of Dhambalin is developed at the edge of a pediment installed in the sandstones of the Yesomma Sandstone formation of the Upper Cretaceous, at an altitude of 250 m. The mineral assemblage is predominantly silicate. This cornice measures 70 m in length and about ten meters in height. The depth of the shelter varies between 9.5 m and 17.2 m. At the level of the large decorated panel, it is 11 m. The volume of the shelter is 9,000 m³ for a wall surface of 5,000 m² (**Fig. 5**).

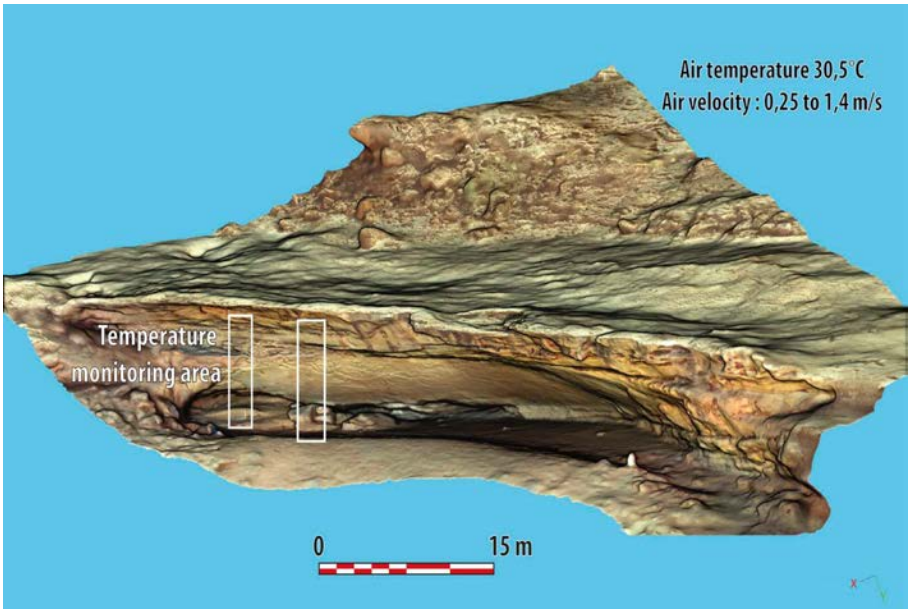


Fig. 5: *Position of the cornice where the shelter decorated with Dhambalin is located, at the base of the pediment in the Yesomma Sandstone formation.*

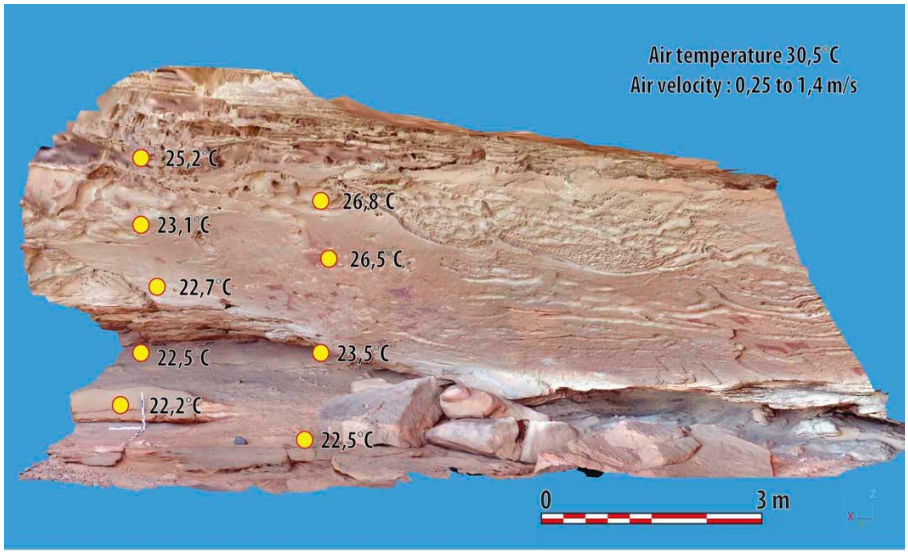


FiG.6 : *Location of the temperature measurement series, at the level of the main decorated panel of the Dhambalin shelter.*

In the area of the large decorated panel, temperature measurements show variations similar to those observed in the Laas Geel shelters. The coldest areas are located in the most pronounced concavities. The action of weathering processes on the sandstones is strongest due to the effects of condensation, which corrode the most soluble silicate minerals in the sandstones (**Fig.6**).

3.7. Dhagax Kure shelter and the Prophet's Shelter (Dhagax Nabi Galey).

3.7.1. The Dhagax Kure site.

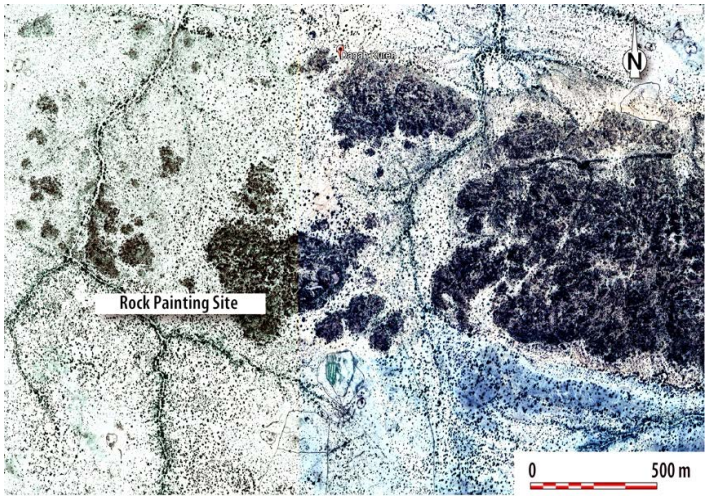


Fig. 7: *Satellite view of the granite chaos within the inselberg at the Dhagax Kure site. Source: Google Earth*

The Dhagax Kure site consists of a set of granite chaos and blocks resulting from the dismantling of an inselberg, affected by dense regional fracturing in an east-west direction. It consists of granite and gneiss whose emplacement occurred from the Proterozoic to the Cambrian (**Figs 7 and 8**). The site is located at an altitude of 1300 m, in a semi-arid steppe with very sparse vegetation, consisting of small acacias and thorny shrubs. The work focused on photogrammetric surveys of the shelters and temperature measurements to compare wall morphologies with evolving climatic contexts.

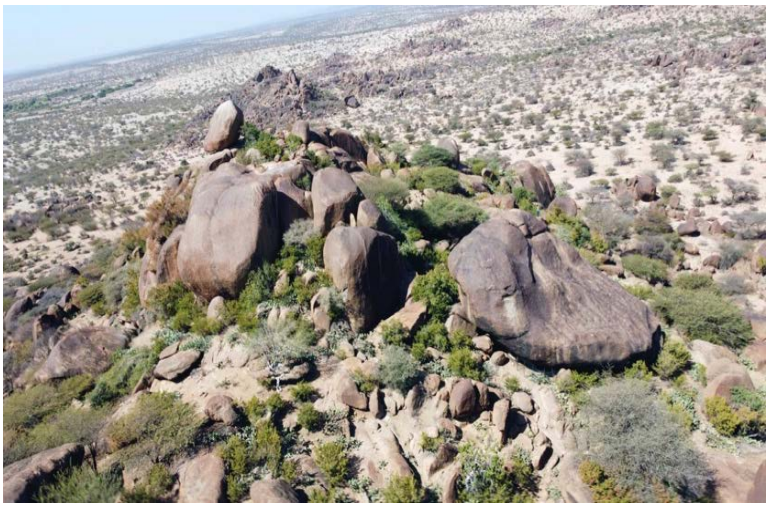


Fig. 8: *Landscape of chaos and dismantled structures in blocks of the Dhagax Kure inselberg*

3.7.2. Shelter 1 of Dhagax Kure.

Shelter No. 1 is installed in a block tilt within a chaos. It extends over 15 m in length and 3 to 5 m in height. It also has multiple entrances that favor air circulation inside. As with Shelter 1 of Dhagax Kure, the formation of the shelter began with the alteration of granite surfaces near the ground (**Fig. 9**).

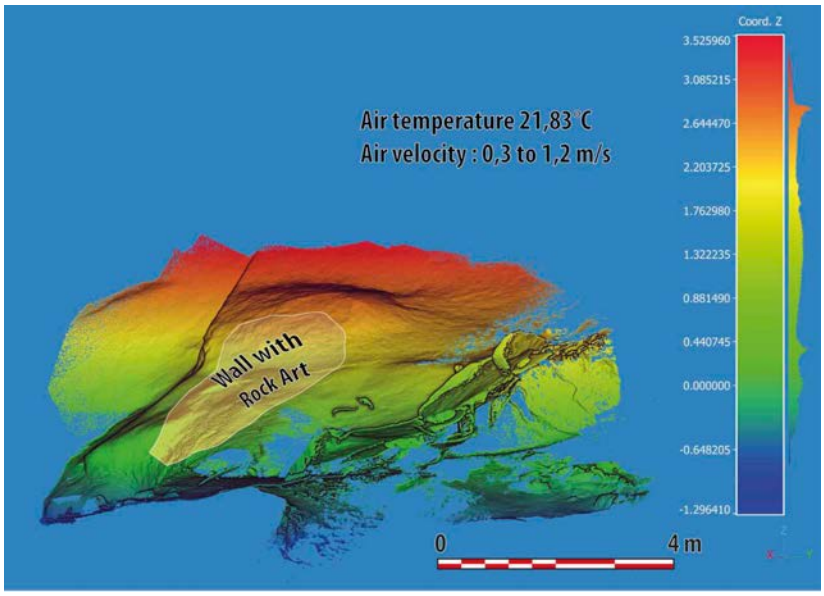


Fig. 9: *Morphology of Shelter 1 highlighted from the point cloud obtained from photogrammetry, with colorimetric processing by scalar fields of altitude classes.*

The corrosion from air condensation and upward moisture from the soil is responsible for the void created at the contact surface. The airflow circulating inside the shelter was 0.3 to 1.2 m³/s, depending on the intensity of the wind gusts that swept the site during our measurement work. Temperature measurements were taken in the decorated area, where the wall has the greatest concavity. The recorded values also show the effects of condensation depending on the temperature gradient at the wall in the evolution of the main dome (**Fig. 10**)). Due to the microfilms of water on the wall surface generated by these processes, dark biofilms form locally, as in Shelter No. 1 of Prophet's Shelter (Dhagax Nabi Galey).

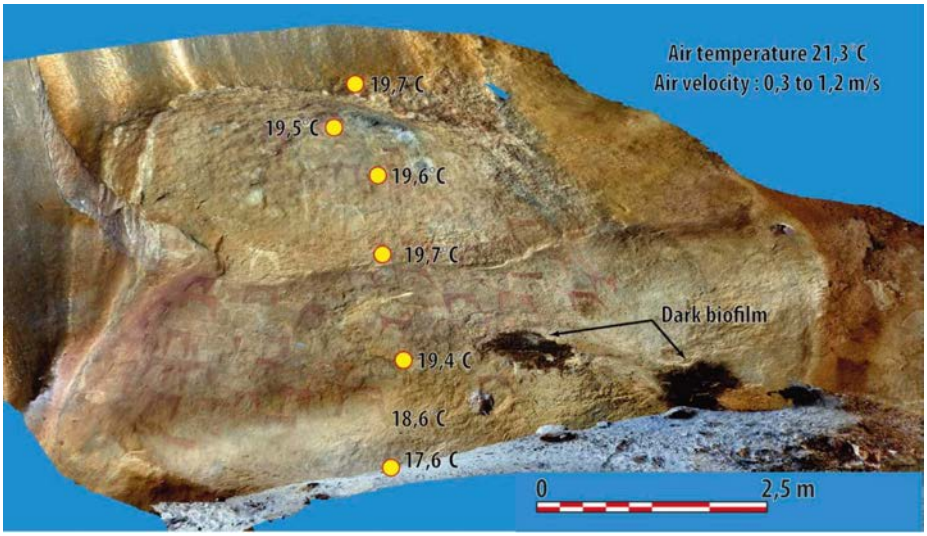


Fig. 10: *Location of temperature measurement points along the decorated wall of Shelter 1. Dark biofilms are located at the base of the wall's concavity.*

3.7.3. Shelter 3 of Dhagax Kure

This shelter is located in the upper part of the granite chaos. It also results from the tilting of boulders and the same alteration processes that led to the formation of the internal space. It has five modest-sized entrances that influence the internal air circulation. Its morphology differs from the other two, with superimposed nested domes related to the position of the different entrances (**Fig. 11**).
The wall of the decorated area results from the evolution of the initial alteration of the block, which started after its tilting near the ground. The upper dome was then formed from the enlargement of the main dome and the establishment of aerological conditions linked to the multiple entrances.

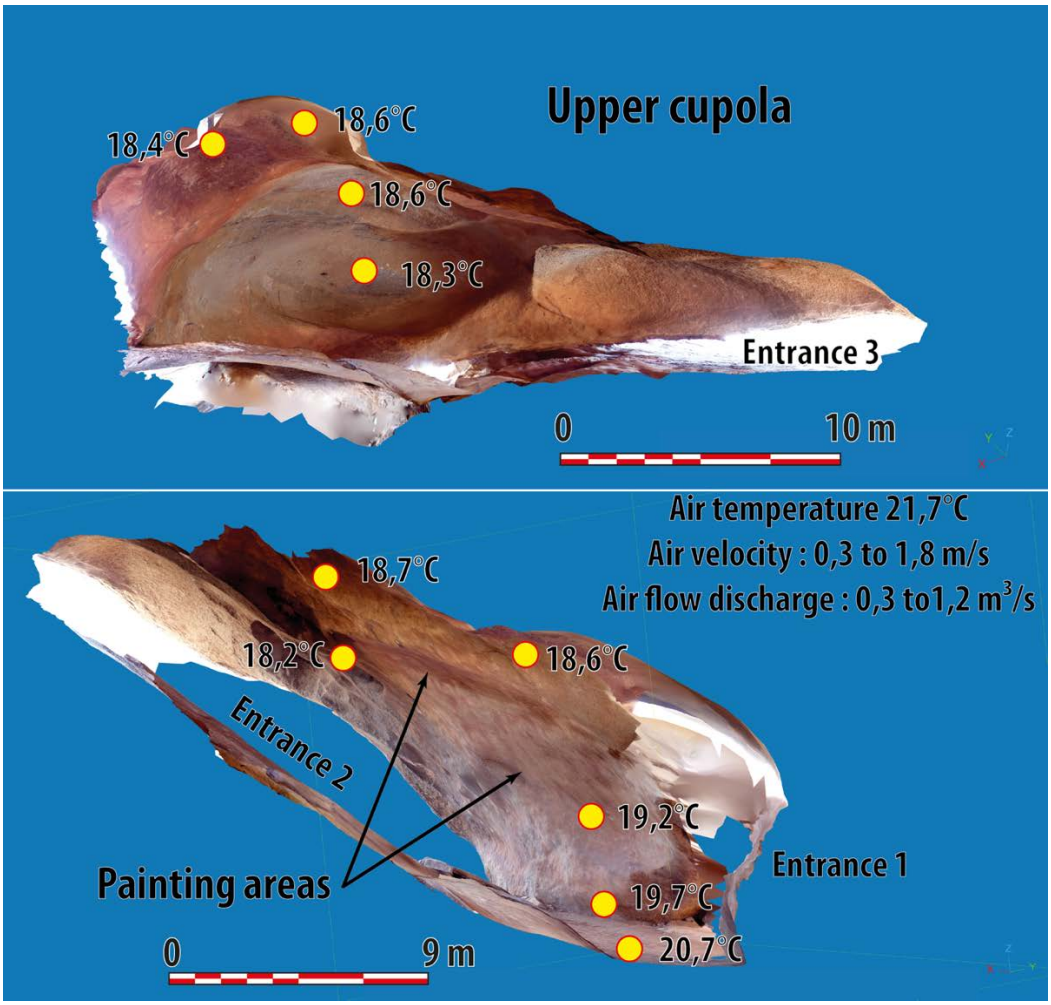


***Fig. 11** : Morphologies of the domes of Shelter 3 and location of temperature measurement points.*

3.7.4. The Prophet's Shelter (Dhagax Nabi Galey)

The Prophet's Shelter, locally known as Dhagax Nabi Galey, is located about ten kilometers northeast of the village of Dhubato. This shelter formed in the flank of a granite boulder that tilted due to arenization. It forms a continuity with three others that evolved concomitantly in the same granite chaos before their tilting. This occurred long after their exposure by ancient erosion phases (Fig. 12).
The volume of the shelter results from the alteration processes of the granite parts near the ground. The corrosion from air condensation and upward moisture from the soil has been effective in creating the void at the contact surface. Currently, the process is still active; temperature measurements show

these variations, with colder areas in the concavities here as well. The two openings favor air circulation, which reinforces the process by functioning like a venturi.

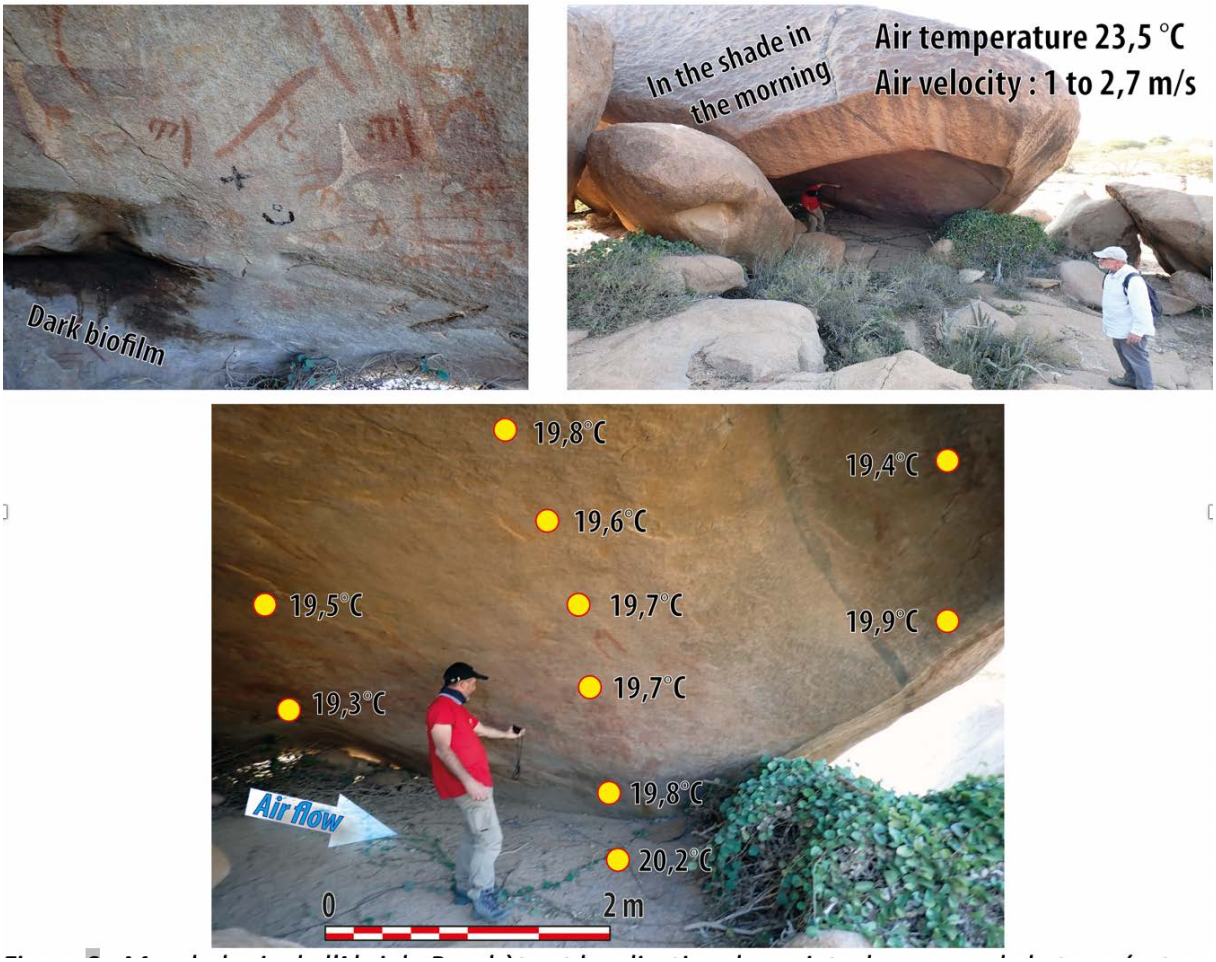


Fig. 12 : *Morphology of the Prophet's Shelter and location of wall temperature measurement points.*

3.8. Climate Monitoring of Key Shelters at Laas Geel.

Following the campaign of wall temperature measurements, three shelters were equipped for continuous monitoring of temperature and humidity. They were chosen based on their morphology, ongoing alteration processes, and the state of preservation of the paintings. The objective is to measure the climatic phenomena that have allowed the preservation of the paintings, as well as those responsible for their degradation, in order to deduce the main factors that could threaten the artworks. The sensors were placed at several levels in these shelters, according to the aerological processes visible or measured in situ (see above). These Tiny Tag probes measure temperature and relative humidity with high precision, every 30 minutes. They were installed for a full seasonal cycle, depending on these questions and the possibilities offered by each shelter. It is obviously not possible to mechanically fix them to the walls, and the interest these objects might arouse among baboon colonies had to be taken into account. The selected sites are: Shelter 1b, characterized by an exceptional state of preservation. A probe was placed in a niche near the paintings. Shelter 7 has the advantage of presenting a part where the paintings are well preserved and another where they are very degraded or even erased. Two measurement profiles were therefore installed to document these

two distinct dynamics. Shelter 9a is strongly impacted by the presence of baboons above and inside the shelter. Probes were therefore placed inside and outside the cavity to assess this impact, particularly due to respiration and urine flow in the shelters. At the end of the seasonal cycle, the analysis of these data will provide important information on daily thermal amplitudes, seasonal variations, and the site effects that the different shelters may or may not constitute. The measurement density at a 30-minute interval provides good statistical representation. At the end of the measurement cycle, the analyses will be based on series of 17,000 recordings per probe. Rainfall data from the Dhubato station, installed as part of the FAO SWALIM program and located 8 km away, will complement the data necessary for understanding the corrosion processes related to condensation that affect the decorated shelters.

3.9. Calculating the Fluxes Involved in Condensation Phenomena in the Shelters

3.9.1. Estimation of the annual Balance.

The amount of water condensed on a rock wall can be estimated using a simplified thermo-hygrometric model, which compares the surface temperature of the rock with the dew point of the ambient air. At Laas Geel, when the temperature is 25°C with a relative humidity of 50%, the dew point temperature is 13.85°C. This value indicates that condensation processes are primarily effective at night. It also allows, using meteorological data from the FAO SWALIM program, to define nocturnal atmospheric conditions (air temperature and relative humidity) for a tropical mountain context (latitude 9.56° N; altitude 1,100 m), distinguishing between a dry season and a wet season. The mass of condensable water per unit volume of air is calculated as the difference between the actual water vapor content of the air and the saturated vapor content at the wall temperature. The amount of water condensed per unit area is estimated by considering a boundary layer of air in contact with the wall, with a thickness between 1 and 2 cm, depending on the degree of confinement of the rock shelter. The renewal of this air layer is accounted for over the nighttime period by an empirical renewal coefficient (30 to 40 renewals per night), integrating a coefficient that takes into account the combined effects of diffusion, micro-thermal convection, and weak air exchanges under the shelter.

Daily Balance

	Dry Season	**Wet Season**
East-facing rock shelter – 1100 m – 9.56° N	0.3 to 0.5 g/m² per night	1 to 1.5 g/m² per night

Annual Balance

Calculations for the wet season are made excluding effective rainfall runoff.

	Dry Season (200 nights)	**Wet Season** (120 nights)
East-facing rock shelter – 1100 m – 9.56° N	80 g/m²/year	230–260 g/m²/year

The annual balance is around 330 g/m²/year, which is equivalent to 0.33 L/m²/year of precipitation applied exclusively to the wall, without initial runoff, with a high residence time of the water. In terms of wall alteration, this often equates to several mm/year of vertical rain, as the water is concentrated on these surfaces continuously, at the interstitial level of the micro-topography. It is also very active, as condensation water is not saturated and can initiate hydrochemical processes. These results show the almost permanent installation of a very thin but continuous water film, often invisible, but hydrologically active at the level of the coldest wall areas. This state establishes a regime that favors active chemical alteration of the granite, through processes of dissolution and recrystallization of the most soluble minerals. This also has an effect on ecosystems with the development of persistent

biofilms that present a dark patina. These values may seem low, but over time, they have a significant effect. The actions are highly localized at a micro-surface scale and repeated daily. There is no runoff at this level. This favors differential dissolution, very short-distance ionic migration, and recrystallization (amorphous silica, Fe oxides). This results in superficial cementation in some places and rock disintegration in others. These chemical and mineral variations also allow the establishment of biofilms that take on the appearance of crusts or more or less dark coatings.

3.9.2. Wall Alterations.

The shelters of Laas Geel and the decorated surfaces undergo alterations linked to the environmental context. These were identified and documented during the 2023 expertise. During the 2025 mission, the work consisted of characterizing and quantifying the processes at play, whether linked to the climatic context or the interactions of local fauna and flora.

3.9.2.1. Methodology

- Photographic documentation,
- Photogrammetric model,
- Analysis of colorimetric spectra of alteration processes,
- Inventories of bird and baboon occupation zones,
- Mapping of impacts.

3.9.2.2. Study of Shelter 2b

Shelter 2b is located in the upper third of the Laas Geel hill, at an altitude of 1070 m (**Fig. 13**). It is oriented towards the east. It is structured by two diaclases, one in the north-south direction and the other in the east-west direction. This fracturing organization affects the entire relief and favors the formation of rock shelters. This shelter measures 13 m in length and 5 m in width. Its height varies from 1 to 2.1 m. It has a wall surface of 67 m². The decorated surface occupies 15 m² in the ceiling of the easternmost part of the shelter.

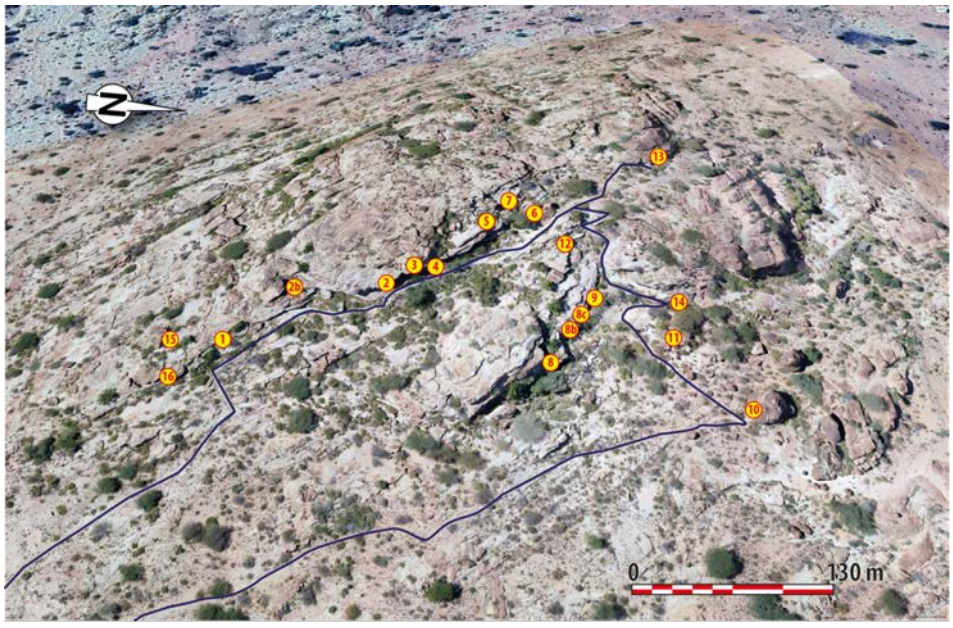


Fig. 13: *Location of the various shelters on the eastern slope of Laas Geel hill.*

The east-west diaclase marks a limit in the compositions (**Fig. 14**). Due to its openness and orientation, the walls and figures are subject to various forms of alteration that can be well discriminated and analyzed for their effects on the rock and the coloring material of the parietal works. On the outer edge of the decorated area, traces of a swallow's nest are still present on the rock of the shelter's ceiling. Its footprint measures 32 cm in length and 25 cm in width. It is attached, in the upper part of the vault, to a ledge 8 cm high, 1.8 m from the ground (**Fig. 14**).

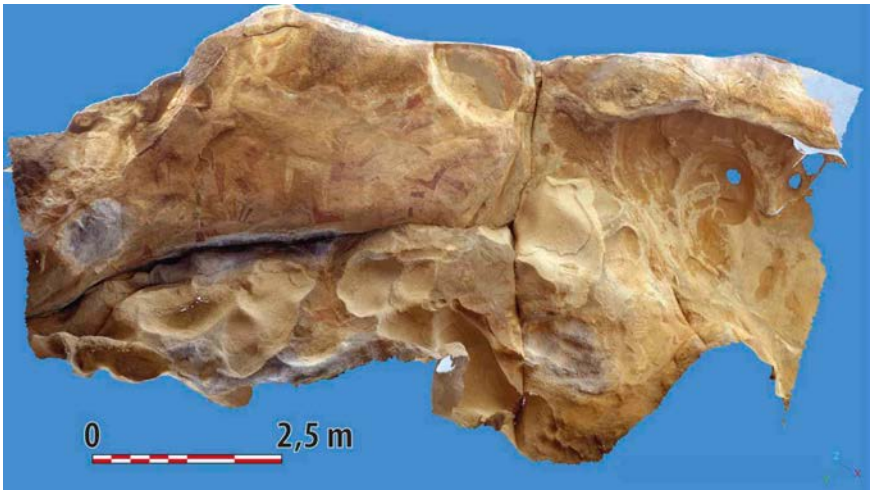


Fig. 14: *Morphology of the vault of Shelter 2b with the two joints that gave rise to its structure. The decorated area extends across the part of the ceiling located between the two fractures and the outer wall that forms the slope.*

Inside the nest's footprint, the rock surface is smooth and light in color. At a millimetric and infra-millimetric scale, there is an attack on the biotite (black mica) and feldspar, while the quartz grains are in slight relief as they are more resistant. Along the exit corridor and along the painted figure, the rock structure also shows alteration characteristics, but more limited. The area outside the nest is affected by a white deposit that marks the limit of the biogenic alteration by swallows (**Figs. 14 and 15**). Part of the nest covered a portion of the painted surface. The clay mortar did not attack the coloring material; it remains on the surface.

To characterize the forms of rock alteration due to the presence of nests over more or less long periods, a zone subjected to the effects of condensation-related corrosion, located a few meters away, was compared. An initial analysis was conducted using comparative image analysis methods in colorimetric saturation using GIMP software. A zoning of the reference surfaces to be analyzed is drawn. Then, using the colorimetric analysis filter, it is possible to export the histogram of this image into a text file so that it can be used in other programs and loaded into style sheets. The histogram is created for the selected area of the image. Fully transparent pixels are not taken into account. Areas with the same characteristics can then be found on one or more images using command-line instructions in Python. This technique was implemented for the photos of the lower part of Figure 15 (**Fig. 15**). The photo of the remains of the swallow's nest shows more or less corroded surface states depending on whether one is inside the nest or in its immediate vicinity, on the exit side. The yellow pixel areas indicate angular surfaces with a colorimetric spectrum that includes less red and green, indicating biotite, which is more soluble in the granite's mineral assemblage. The blue areas are those that are less altered, or even covered with deposits resulting from the export in solution of the minerals corroded in the areas subjected to the effects of condensation. Thus, in the 2025 photo, in the dome near an anthropomorphic figure, the action of condensation-related corrosion is weak compared to the ongoing deposition processes (**Fig. 15**). The same protocol was applied to compare the 2025 photo of the dome next to the figures with one from 2012, taken during the 3D survey operations of the shelters by laser scanning (**Fig. 16**). In 2012, a large yellow surface indicates a corrosion phase. A detailed examination of the photograph shows irregular wall surfaces, with over-thickened elements,

especially on the left side. The roughness is relatively pronounced in the yellow areas. The 2025 shot shows a blue dominance of these surfaces. The surfaces are smoother, and a large part of the rough structures observed in the 2012 photo have disappeared.

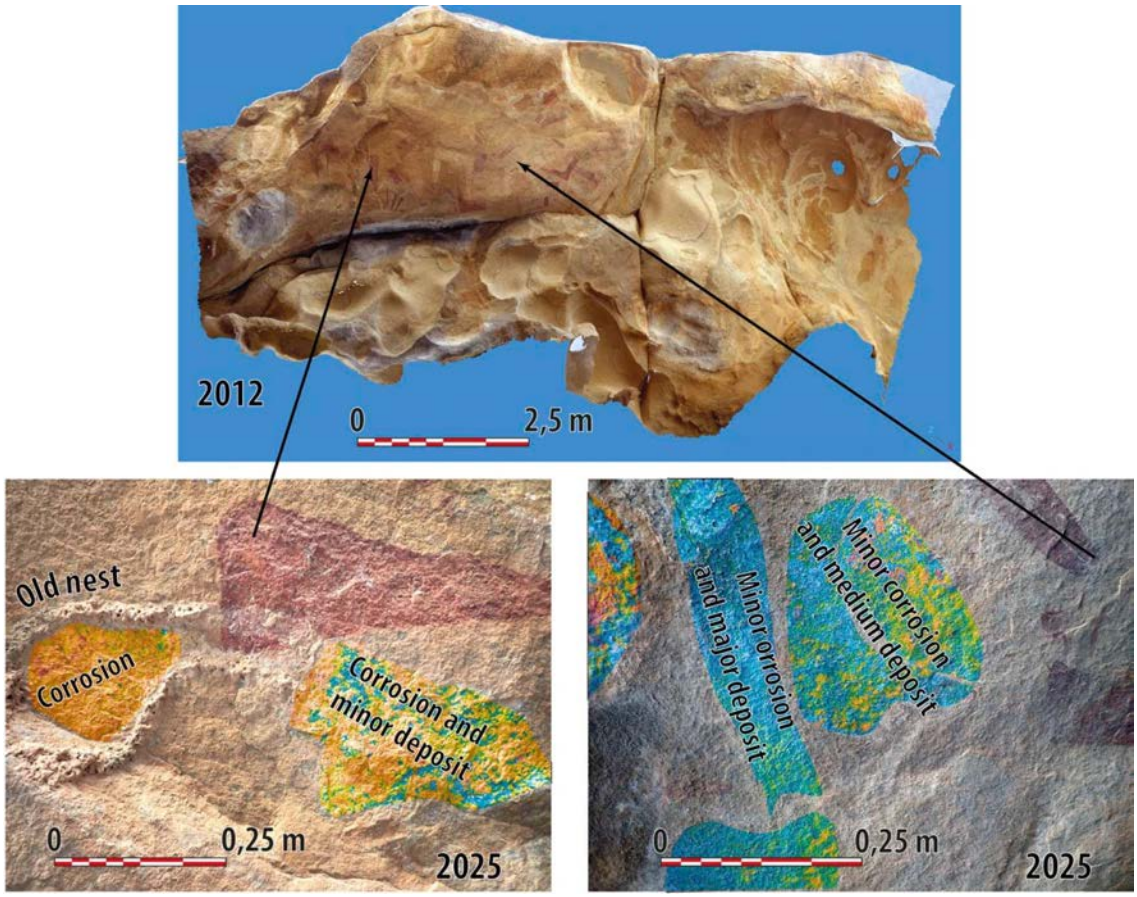


Fig.15: *Location of the swallow's nest in the border of the decorated dome of shelter 2b. At the location of the nest, the yellow spectrum indicates corrosion, while at its edge, the small blue areas show mineral deposits in the process of forming. In the dome with an anthropomorphic figure, the blue spectrum is dominant, indicating less corrosion compared to the deposition process linked to corrosion phenomena related to condensation.*

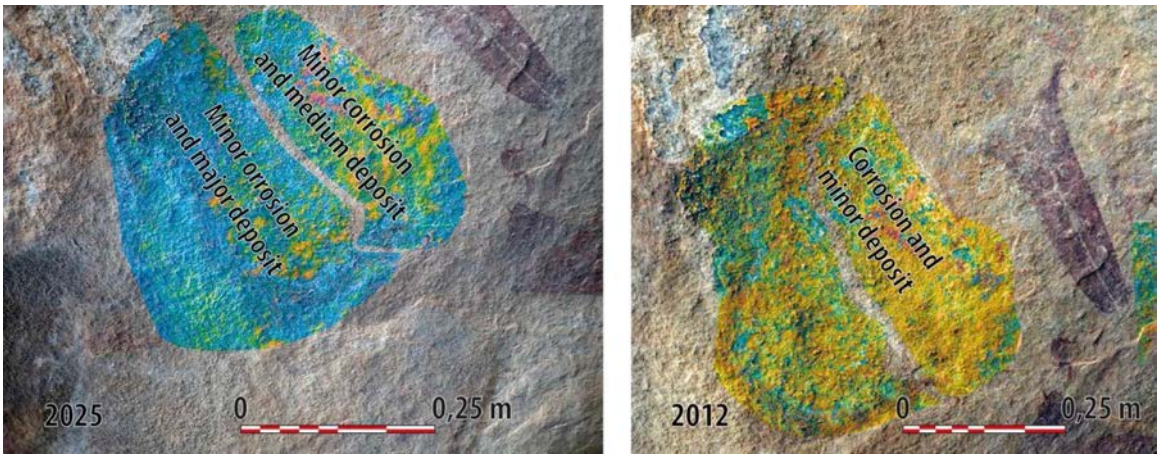


Fig. 16: *Comparison between 2012 and 2025 of corrosion or condensation-related deposition processes within the dome, with an anthropomorphic figure. The 2025 image also shows the deterioration of painted elements compared to the situation in 2012*

The morphology of the dome has evolved; it has widened, and the edge shapes have softened. The tones of the paintings have faded, and parts of the design are less visible in 2025 than in 2012. These methodological tests show that it is possible to differentiate the various modes of alteration of the walls and paintings and to effectively monitor the states of the walls and parietal works from simple data acquisition, here, photos taken in a structured manner and colorimetric calibration. The analyses of this area near the diaclase were also an opportunity to characterize the forms of alteration affecting the migmatite near the decorated panels and how the edges of surfaces sensitive to condensation become sites of covering by very fine aeolian silts that settle in the existing humid film in this area and form a coating that wraps around the rock's asperities (**Fig. 17**).

Macro-photographs show the disintegration of biotite (black mica) at the origin of the evolution of the wall and the formation of domes. When this disintegration spreads, it affects the adhesion of pigments to the wall and contributes to the damage of the figures (**Fig. 17**).

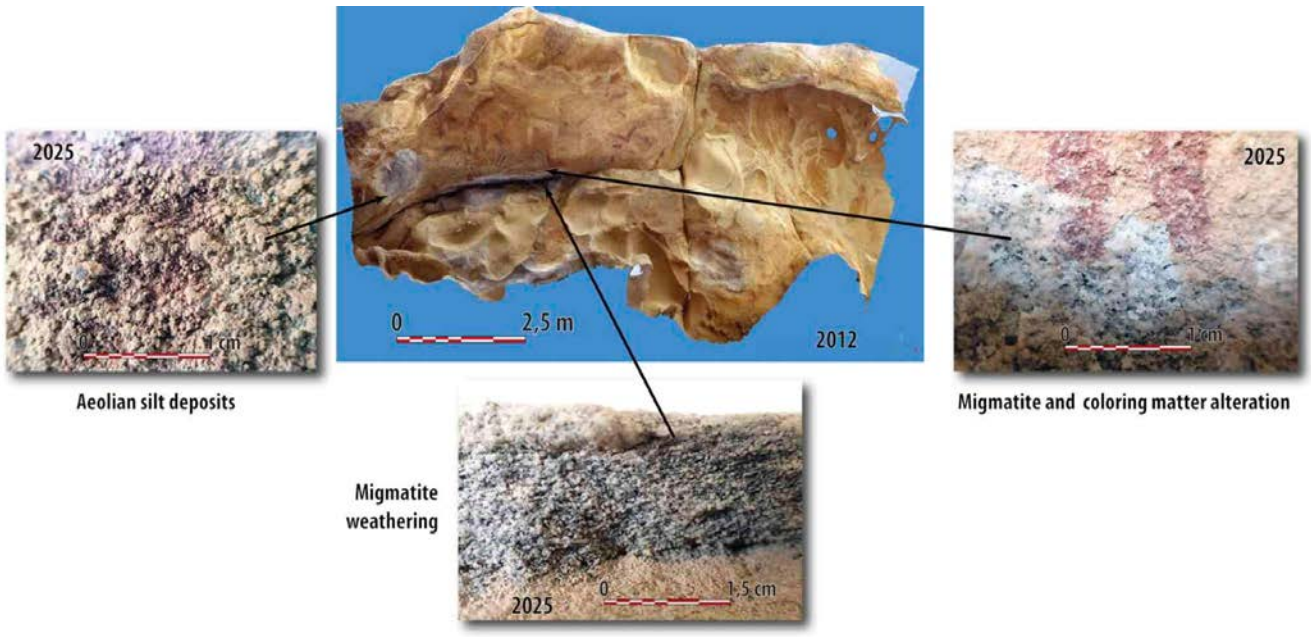


Fig. 17: *View of the various forms of alteration of the migmatite at the roof of shelter 2a and the impact on the coloring material. In the outer zone, wind-blown silts settle on the edges of the wet areas of the wall. They have a desiccating effect and, with evaporation, eventually form a thin hardened coating.*

3.10. Avian Fauna Impacts : Nesting and Roosting Zones.

While several shelters, such as 1 and 2b, show traces of ancient nesting, others, particularly between Shelter 2 and 4, show current use. They are located relatively high but still have an impact on the walls and decorated areas (**Fig. 18**). In other shelters, nests are installed directly near the decorated walls. They are accompanied by roosts that further increase the occupation of wall surfaces. In this context, the consequences for the artworks are significant, with areas of corrosion and covering by precipitates carried by water runoff (**Fig. 18**). Biocorrosion phenomena occur due to the presence of numerous birds and the accumulation of droppings.

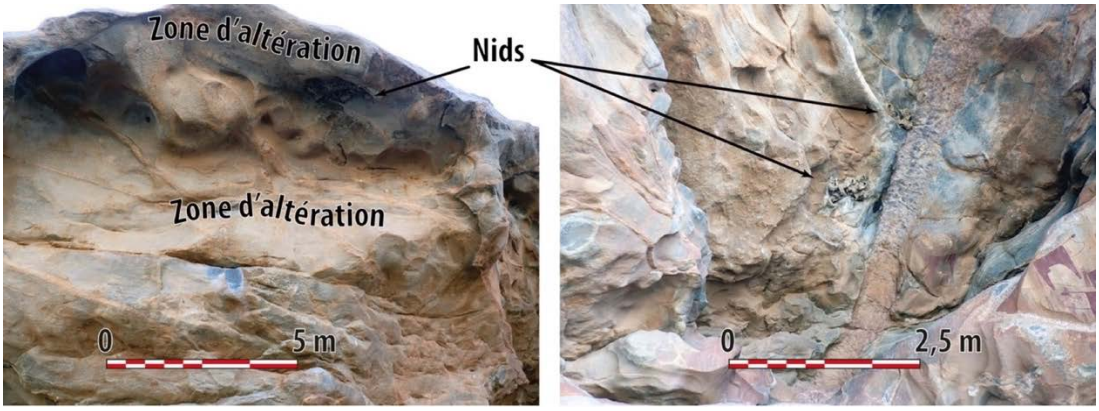


Fig. 18: *Location of swallow nests in the area between shelters 2 and 4 (upper part of shelter 3)*

Their respiration produces CO_2, and their numbers constitute a localized heat source. The rock walls are corroded and exhibit more or less nested dome forms. The wall is smoothed by acidic aerosols circulating throughout. This is particularly the case between Shelter 2 and Shelter 4, where the cornice under the nests served as a roost (**Fig. 18**).

In Shelter 2b, a roost accumulates droppings. Biocorrosion phenomena also occur here, though less intense than in Shelter 2, due to the available space. The decomposition of guano leads to the creation of biofilms that develop on the paintings (**Figs. 19 and 20**).



Fig. 19 *: impacts of nesting near parietal art.*

The combination of acidic aerosols and biofilms degrades the coloring material, and acidic fluxes corrode the rock. The rock corrosion processes are intense, attacking the mineral structures in depth. Again, the most soluble minerals, such as biotite and feldspar are dissolved first. The effects on the rock lead to the disappearance of the most sensitive structures, leaving only quartz, whose grains lose coherence and detach (**Fig. 20**).

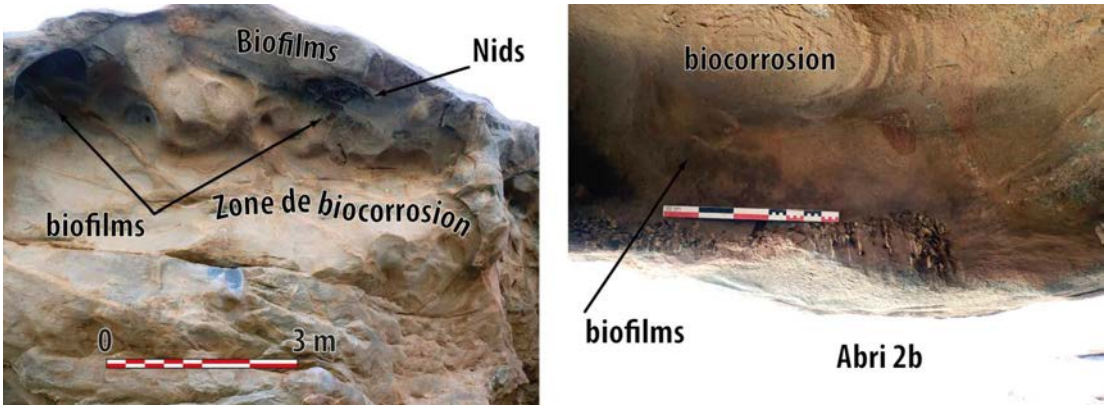


Fig. 20 *: Effects of biocorrosion and biofilm growth on the walls and rock art near Shelter 2 and in a dome of Shelter 2b.*

Biofilms develop in the areas most influenced by condensation. Near swallow droppings, there are mainly white alkalophilic bacterial biofilms, then dark algal biofilms at the margins if conditions are humid, and fungal biofilms in drier and leached conditions. The dark algal biofilms are the most corrosive; they interact with available water to form complexes aggressive to the rock depending on temperature variations and the thickness of the water film. This largely contributes to the detachment of pigments and the alteration of the coloring material (**Fig. 21**).

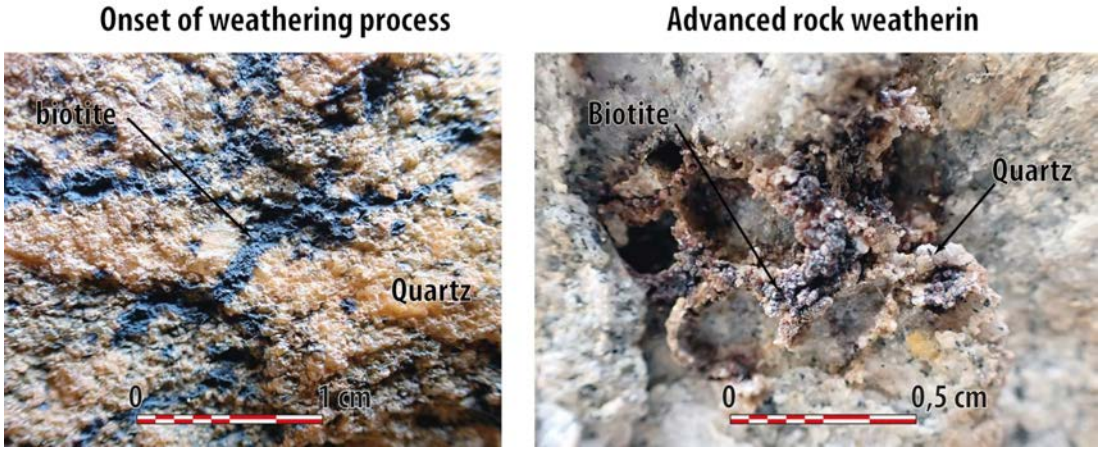


Fig. 21 *: Rock structure during corrosion phases linked to bird droppings. At the onset of attacks, mineral degradation is superficial. At an advanced stage, the feldspar crystals have disappeared and only their imprint remains in the matrix. A few smaller biotite structures remain in the middle of the more resistant quartz.*

Monitoring their development is essential, with genomic analyses to identify them and regular photographic monitoring to assess their spread. Treatment of these biofilms can be carried out through regular exposure to UV-C. The treatment is simple and can be performed using small, portable, autonomous lamps positioned precisely on the surfaces in question (Pfendler, 2017; Pfendler et *al.*, 2018; Cailhol et *al*., 2020). The mineralization of droppings also presents a point to monitor. This type of deposit is visible on roosts and nearby. This is clearly visible above Shelter No. 2, with a roost located just above the decorated area, near a significant nesting zone. Runoff from the wall leaches these deposits, which flow in solution to the painted figures (**Fig. 22**).

In this inaccessible area, the use of ultrasonic repellent devices should be implemented to keep birds away from these locations and mitigate the consequences of their droppings on the decorated panels.

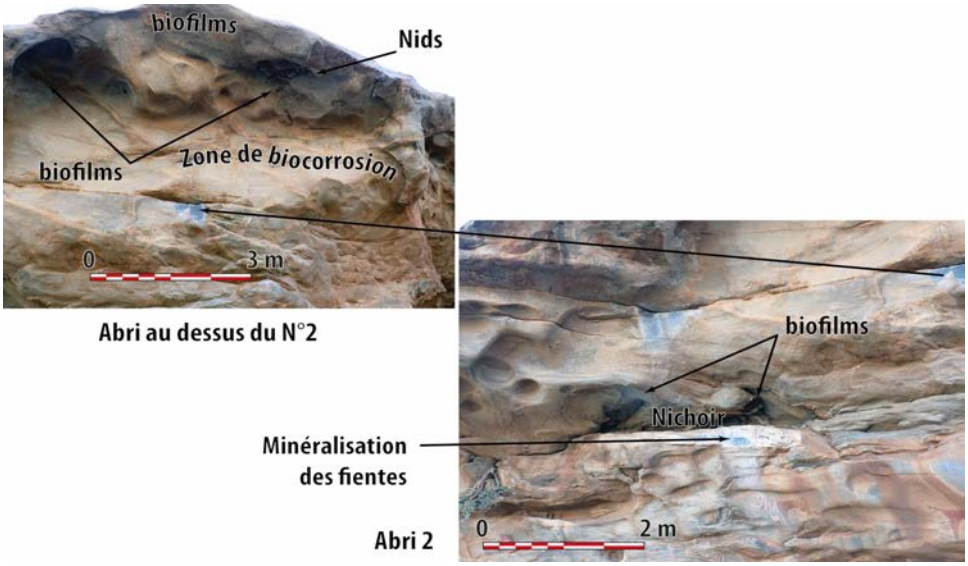


Fig. 22: *Mineralization of droppings*

These developments are significant; the comparison between 2012 and 2025 at Shelter 2b shows a major change with direct effects on the domes and walls and, consequently, on the painted figures located nearby. The frequenting of the dome's visor by birds develops biocorrosion processes with flaking of the vault and deposits of acidic droppings on the lower edge (**Fig. 23**). A biofilm develops on the decorated parts and alters the coloring material. In the most concave part of the dome, due to the humidity linked to condensation, a crust of aeolian silts forms and then hardens.

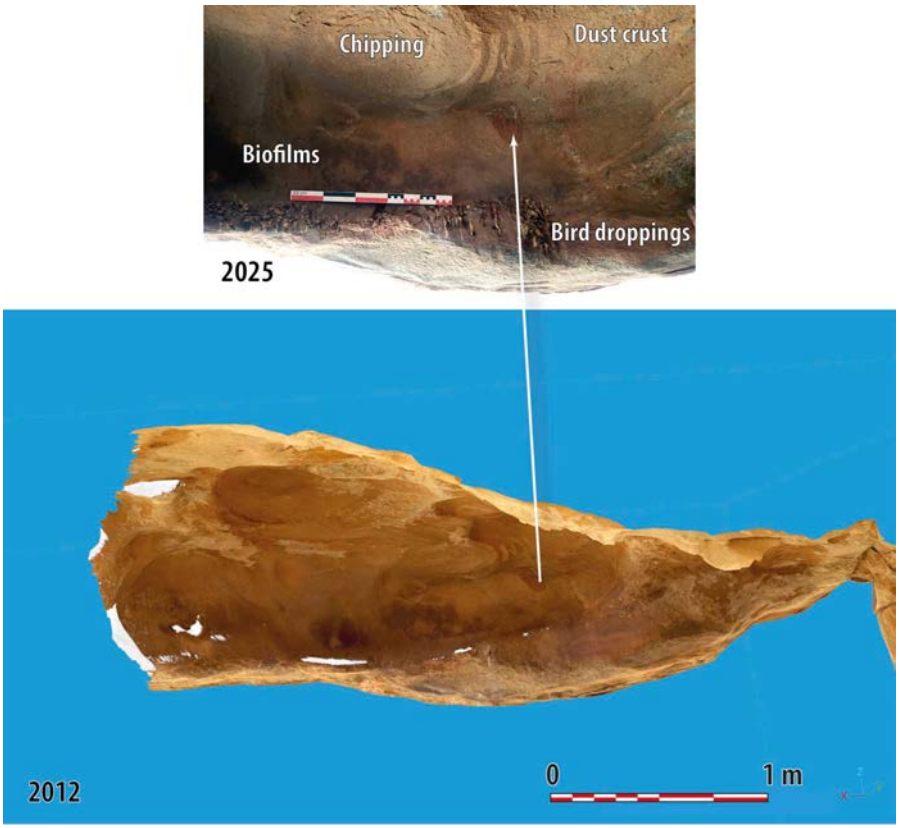


Fig. 23 ***:*** *Comparison of wall conditions between 2012 and 2025, in the eastern dome of Shelter 2b*..

3.11. Baboon impact

The groups of baboons living around the site come at certain times of the day to high places where they have observation points. An inventory of frequented places made it possible to locate the sites used in the hill and the shelters occupied (**Fig. 24**).

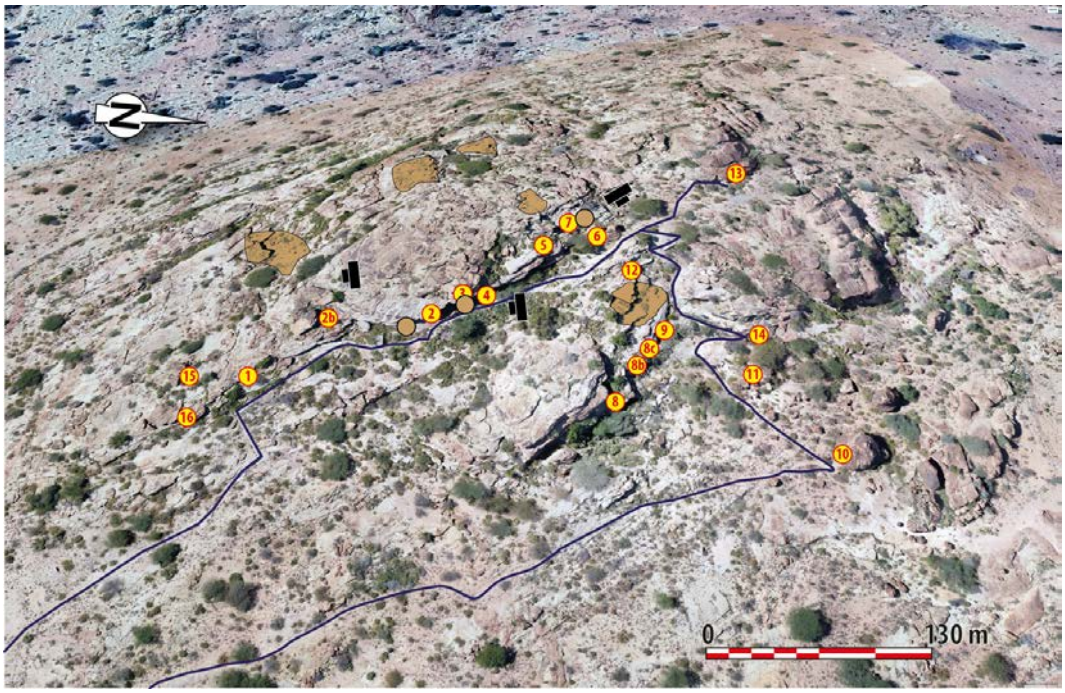


Fig. 24 : *Location of baboon gathering sites at Laas Geel. The brown areas indicate surface gathering stations and the dots indicate shelters that appear to be the most frequented, based on traces (rubbing and droppings). The black cameras indicate the locations and orientation of trap cameras.*

This is particularly the case around the summit of the hill and on the cornice of the eastern edge. The location above Shelter 9 is an important gathering place. It is divided into zones with different uses. The upper part allows for gathering and observation of the surroundings. The edge zone of the escarpment, where shelters 9a, b, and c are located, serves as a toilet. Given the topography, the excrement falls at the foot of the rock wall, and the leachates flow towards Shelter 9. They then seep through the cracks to infiltrate the walls of Shelter 9. Inside the shelter, the traces are significant, and the odor is strong (**Fig. 25**).

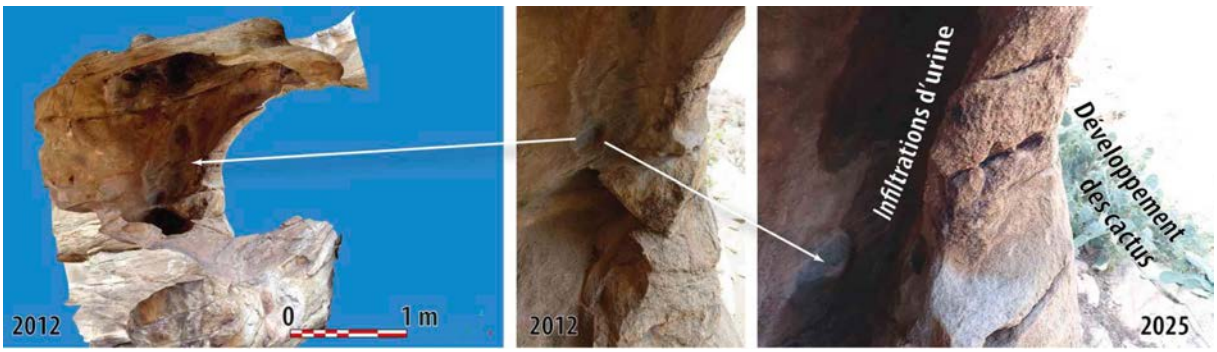


Fig. 25: *View of the northern part of Shelter 9. Baboon urine observed in 2025 spreads on either side of the vertical crack located in the upper part of the vault. In 2012, these flows were not present at the time of the topographic surveys.*

Comparing the wall conditions between 2012 and 2025, based on data from the laser scanning survey, shows that these flows were not present at the time of the survey. Is this seasonal use of the platform above the shelter that results in these infiltrations, or is it recent use linked to a behavioral change in the monkey groups or their environment? Seasonal use is possible; indeed, in the 2012 photo, a halo is visible on either side of the crack. In any case, the consequences are significant for Shelter 9, and conservation measures must be considered quickly. This could involve keeping baboon groups away from this area using ultrasonic repellent devices. The droppings falling from the top of the platform promote the growth of cacti at the foot of the wall, below the series of shelters 9. These must be imperatively cut and destroyed to prevent any regrowth. Vegetal debris must not remain in place, as this maintains the possibility of regrowth.

Stationing areas are observed on the benches of shelters 2, 4, and 7. Characteristic polishes are visible at the stationing locations, and halos and encrustations are linked to the flow of urine or the decomposition of droppings. Below Shelter 4, the decomposition of droppings provides a substrate conducive to the development of vegetation (particularly cacti) on the rock blocks (**Fig. 26**).

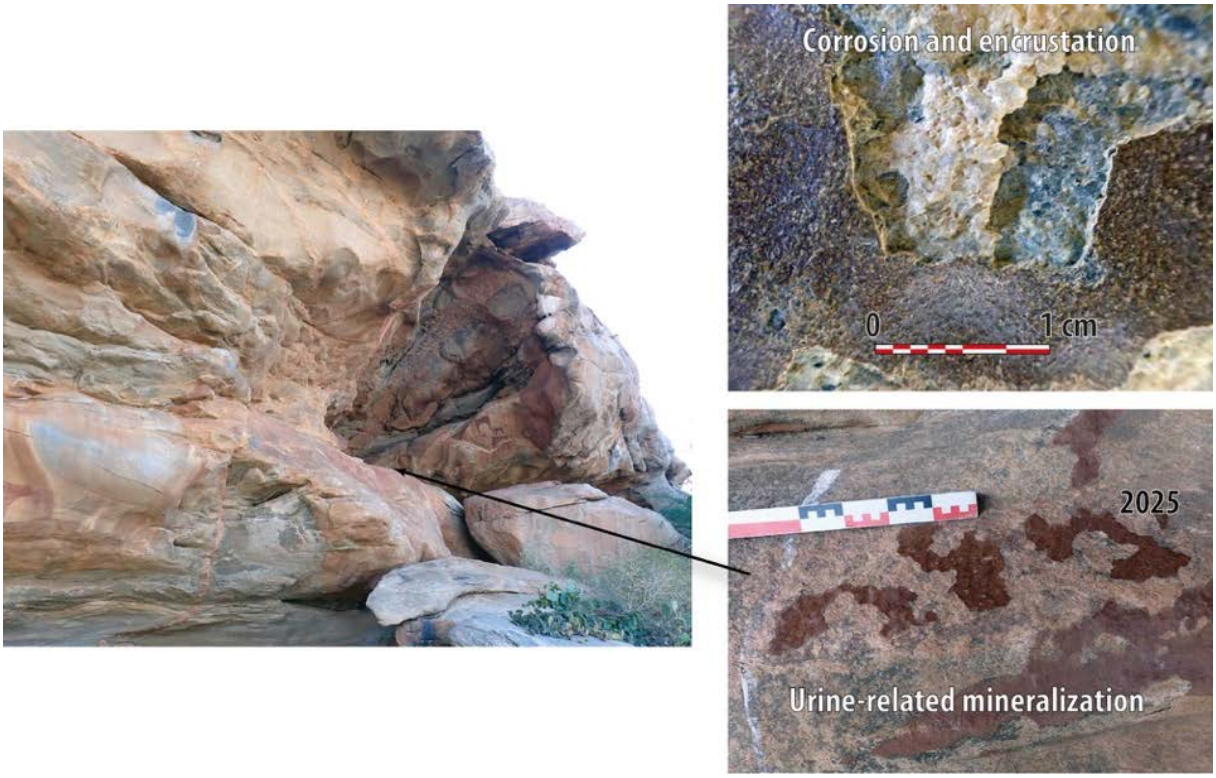


Fig. 26 *: Localisation des emplacements fréquentés par les babouins. L'impact des urines est bien visible avec des encroûtements minéralisés et la corrosion de la roche sous-jacente. La décomposition des déjections favorise l'emprise de la végétation sur les blocs de rocher.*

Chapter 4.

Recording of Rock Art Figures

This section of the report addresses the actions undertaken to meet several objectives. Additional information and a shelter-by-shelter review complement the existing records. New in-situ observations document the macroscopic and visual evolution of the paintings and their substrates since 2003. For the observation of faded or poorly legible figures, we use an image enhancement process developed in 2003. This method yields results equivalent to DStretch® but requires manual control, making the archaeologist the operator of the observation rather than merely an observer. Initially based on the use of filters in Photoshop software, this process is now applied manually using the "Preview" application, supplemented more recently by the colorimetric capabilities of "Keynote." These developments also open the possibility of using other open-source software, such as Blender software, to project 2D surveys onto 3D matrices and preserve volumetric effects. Although primarily descriptive, these techniques can also renew the analysis of rock art and the history—or biography—of painted shelters (Fuentes et al., 2019). We also conducted sampling of red and white pigments for ^{14}C dating of the paintings

4.1. Observations Conducted in Shelter 1A

This verification involved confirming observations regarding the overlaying of paintings for relative dating of styles (**Fig. 1**) and assessing their general condition.

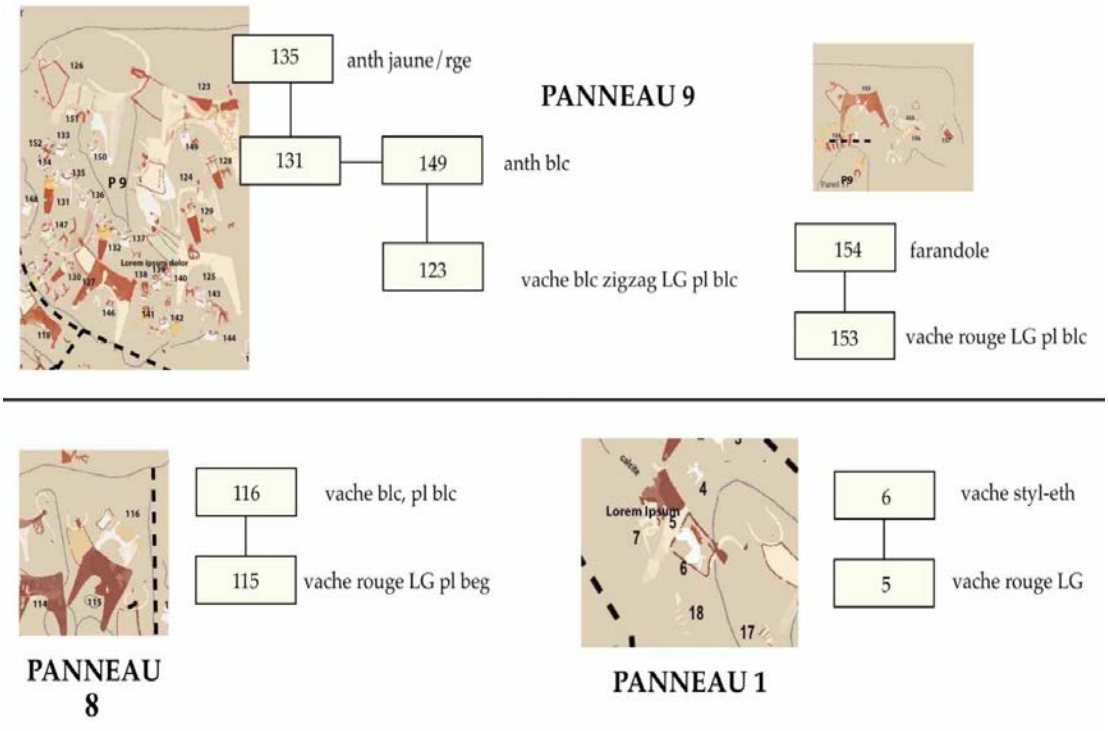


Fig. 1 *: Example of overlap diagrams in shelter 1.*

The use of 3D recordings highlights the influence of domes and reliefs, which create irregularities on the walls. This provided an opportunity to restore three-dimensional renderings in line with field observations and renew the analysis of the compositions. While this acquisition technique has now become relatively common, the use of smartphones in the field and the direct display of these 3D captures alongside the paintings offer new observation possibilities. It should be recalled that over twenty years, technological evolution has been considerable, and the first recordings were based on images assembled almost manually. Direct surveys were conducted on paper prints with measurements taken to unfold the figures in a planar space (**Figs. 2 and 3)**.



Figs. 2 et 3 *: left: excerpt from the 3D scan of shelter 1 showing the arrangement of the figures in relation to the domes of the ceiling. This photogrammetric technique offers the advantage of highlighting the use of natural reliefs and searching for possible anamorphoses (2025). Right: excerpt from the still photo capture of shelter 1. Multiple shots are necessary, without being able to vary the lighting (Gamma, 2003).des clichés est alors nécessaire, sans pouvoir faire varier l'éclairage (Gamma, 2003)*

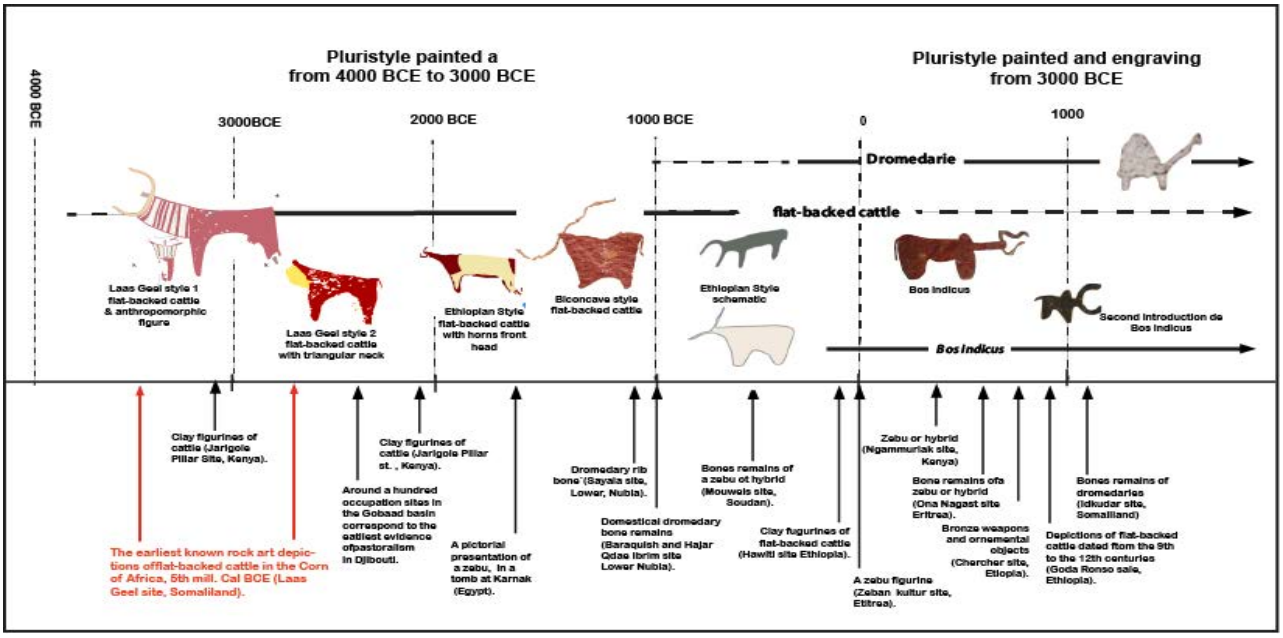


Fig. 4 *: Timeline of the main stages of rock art in Somaliland, based on the style of representation of domestic animals*

A return to the figures in Shelter 1 confirmed an interesting observation: the overlaying of squat Ethiopian-style cows over lyre-horned, post-acephalous cows of the Sourré style (Joussaume, unpublished), already considered older. The horns of these cows with triangular or thickened necks are placed at the front of the head, unlike the Laas Geel style, where the horns develop at the back of the head.
This information also allows us to place the paintings of a newly discovered shelter, located between Erigavo and Xiis, in a period later than Laas Geel. It also confirms the seriation of Shelter 4 at Dhagax Kure (Lion Shelter). In the latter, Sourré-style cows are overlaid by zebu (Bos indicus) with long tails (another characteristic of more recent depictions). This seriation also confirms the status of bovines with triangular necks, sometimes bearing a narrow neck ornament, as a slightly later type of the Laas Geel style. At the end of this mission, these elements enabled the creation of a chronological frieze (**Fig. 4**).

4.2. Observations conducted in Shelters 1B and 1C

L'abri 1B est situé dans le prolongement de l'abri 1, au sud-est. Durant la mission de décembre 2025, il a fait l'objet d'un enregistrement 3D relié directement à celui de l'abri 1 (**Fig. 5).** Les peintures assez bien conservées ont déjà fait l'objet d'observations complémentaires. Les enregistrements réalisés auPlus étroit et moins accessible que l'abri 1.

Abri 1C : Sans intérêt particulier pour les visiteurs, il demeure inaccessible à cause des cactées qui envahissent la pente d'accès. De nouvelles peintures ont été identifiées, très effacées sur le fond : vaches rouges alignées de style éthiopien trapu (style Laga Oda, Joussaume). La présence antérieurement supposée d'un dromadaire n'est pas retenue.



Fig. 5 : *Three-dimensional photogrammetry of shelters 1 and 1B. The photogrammetric junction was completed during the 2025 mission.*

4.3. Observations conducted in Shelters 2B, 2C et 3

The verification of manual records in Shelter 2B had already been carried out. A complete 3D survey was conducted this year and will complement the verification of the position of figures on a highly irregular ceiling, complicating their interpretation. Shelter 2C contains an isolated painting of little interest to visitors; it opens onto a slope that has become inaccessible due to the invasion of cacti. It is not included in the tour circuit.

Verification in Shelter 3 had been carried out during previous missions, but several pieces of information needed confirmation. Photos were taken of the panel of red-painted cows. They are intended to verify the doubling of a dewlap and the presence of a dewlap on an Ethiopian-style cow, as well as the superimposition of two cows in Panel 2. The examination of the curious figure in Panel 4 confirms previous observations. It is indeed an overlay of three figures. Note that for the examination of the figures, we use a process identical to DStretch® but with proprietary methods that highlight certain characteristics of the figures, especially in detail (**Fig. 6**).

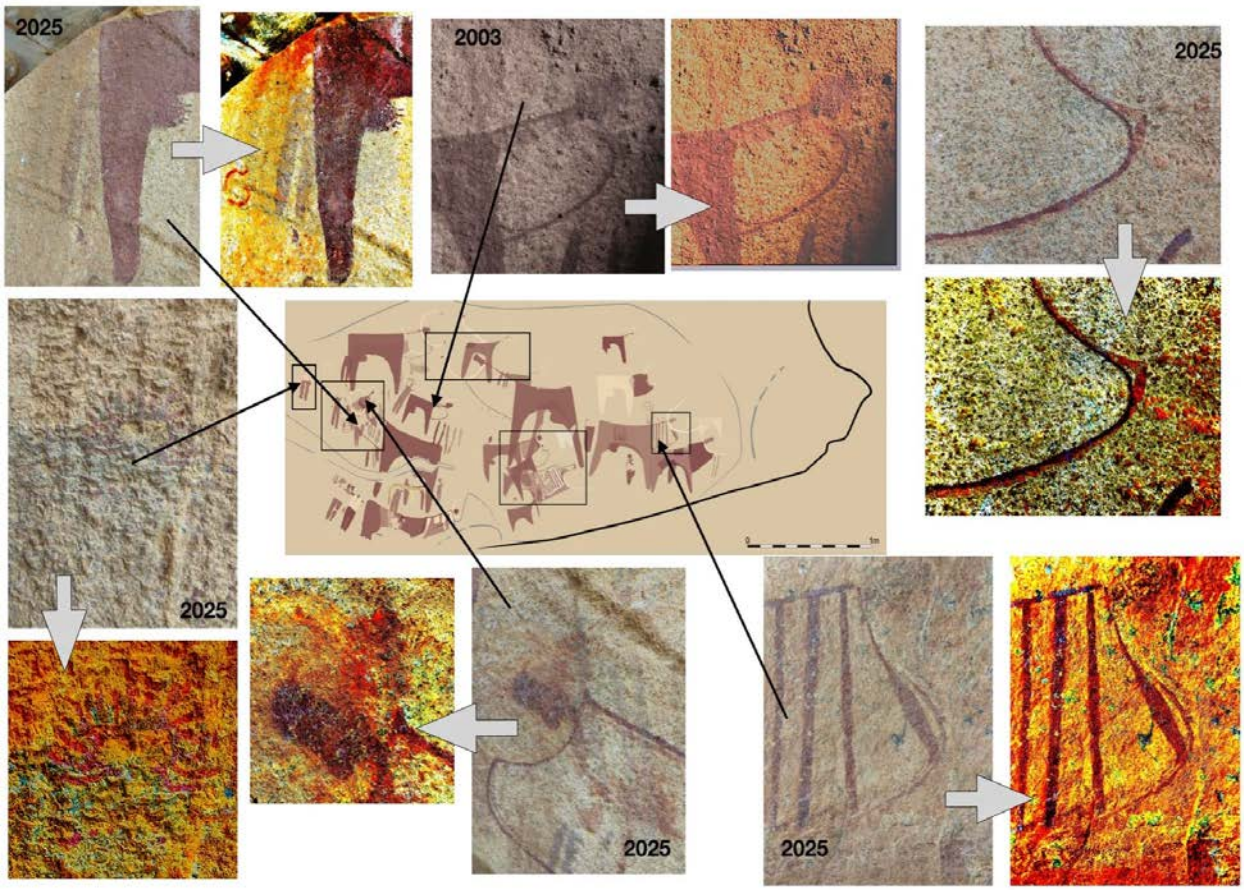


Fig. 6 : *Shelter 3: examples of digital image processing*

Another verification concerned the heavily faded figures at the back of the shelter, called “helmets,” and another called “the beast.” Indeed, the latter recalls a well-known painting from the “Cave of the Beast” in the Gilf el-Kebir in southwestern Egypt. The three aligned helmet-shaped figures rather evoke tortoises (**Fig. 7A**): the front and rear legs are indeed distinguishable. The second figure remains enigmatic (**Fig.** 7**B**). It seems that an anthropomorphic figure overlays the arched silhouettes of one or two unidentifiable animals.

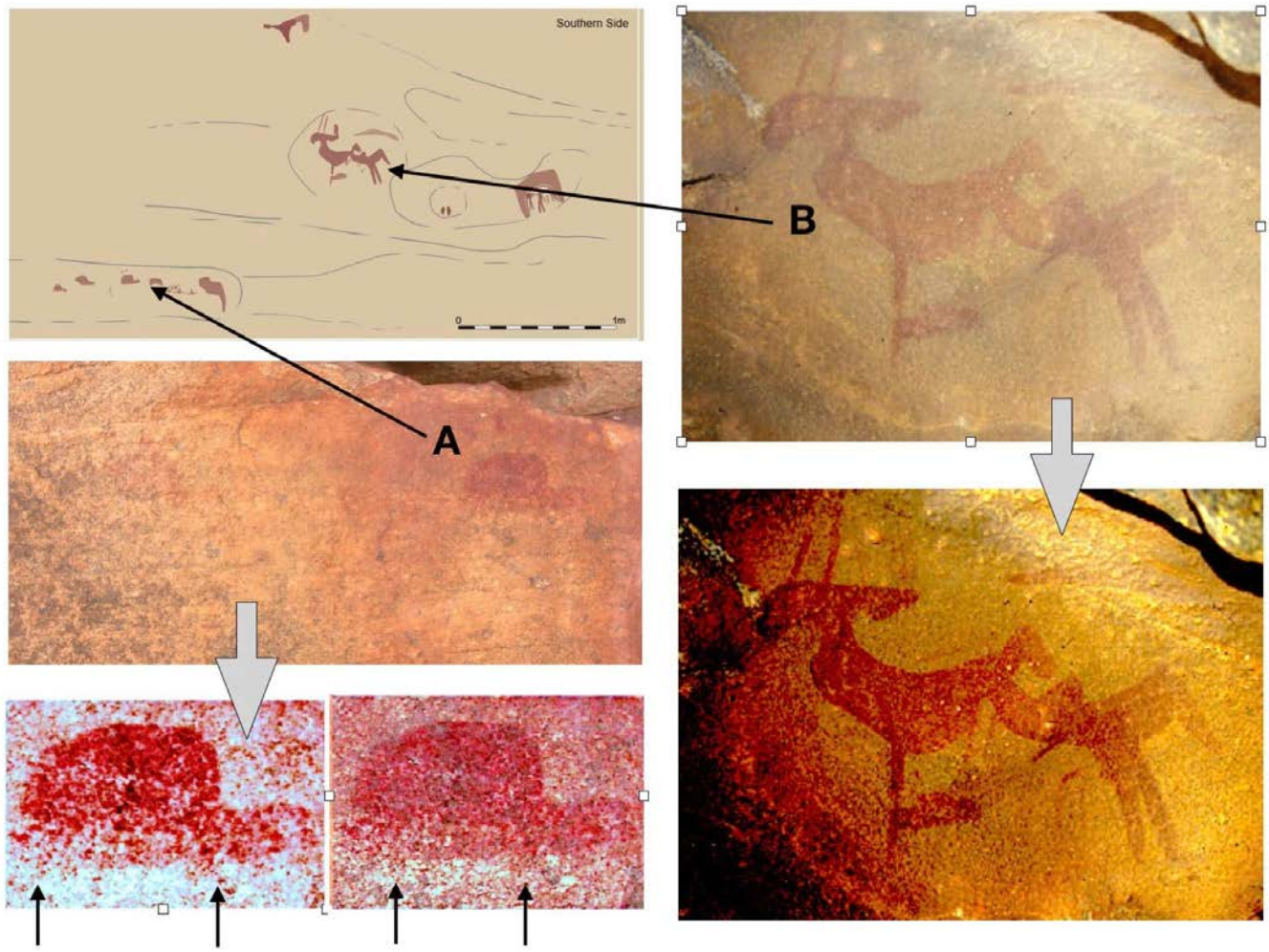


Fig. 7 *: Two enigmatic representations from Shelter 3: a turtle (A) and the superimposition of an anthropomorphic figure and two intertwined animal figures (B).*

4.4. Observations conducted in Shelters 7D, 8 et 11.

À During the return to Shelter 7 for 3D recordings, previously unreported traces of red paint were discovered (Shelter 7D). The paintings in Shelter 8 are poorly preserved. Several verifications were necessary, particularly to specify the location of the panels and the general topography. The laser scanning carried out during this campaign will provide the missing details.Samples of white and red colorants were taken from Shelter 11. They were imported to France, with the approval of the MoTT, for a new attempt at carbon-14 dating. Indeed, the first samples taken in 2003 and analyzed at the research laboratory of the Museums of France had not revealed the presence of organic matter. As analytical methods have evolved, it was decided to take new samples.

This shelter is remarkable for its depiction of a cow with a richly ornamented dewlap and a unique scene at Laas Geel, possibly representing a mating (**Fig. 8A**). To support this interpretation, a detailed examination of the figures was conducted. The figure on the right is that of a bull, but it cannot be excluded that it results from the transformation of a cow whose udder is erased (**Fig.8**).

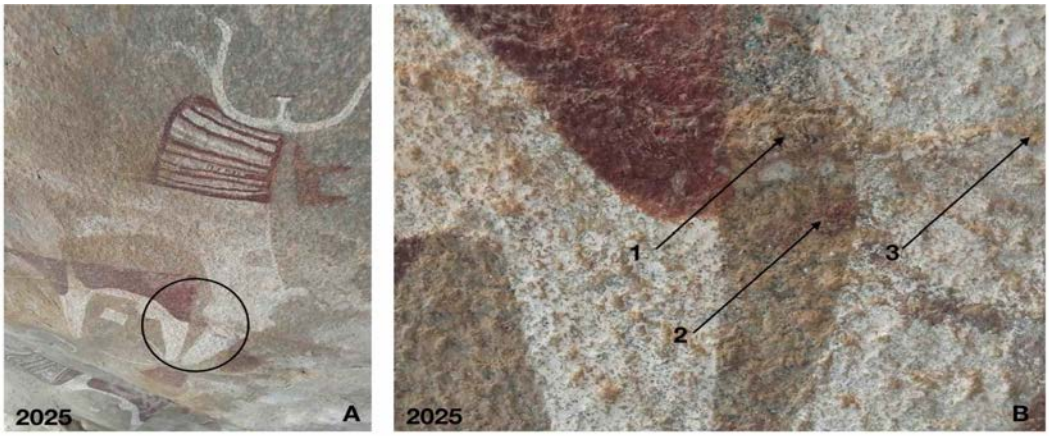


Fig. 8 *: Shelter 11: mating scene (B) and detail of the bull's penis (1) painted over the white coat (3), highlighted by a red spot (udder erased?). The animal does not have a clearly drawn udder but a bulge of the same color as its coat, unlike the cow it is covering (A).*

4.5. Observations conducted in Shelters 10.

Old manual surveys can be compared with the three-dimensional recording of the shelter carried out during this mission. A rare issue at Laas Geel was the use of green paint, recognized on a cow in Shelter 1. It seemed possible that this hue was the result of scraping the walls, revealing a greenish tint beneath the rock patina. A first macroscopic observation involved comparing the color of rock chips caused by impacts on the rock surface under natural light and through image processing of an anthropomorphic figure whose neck and arms appear green (**Fig. 9**).

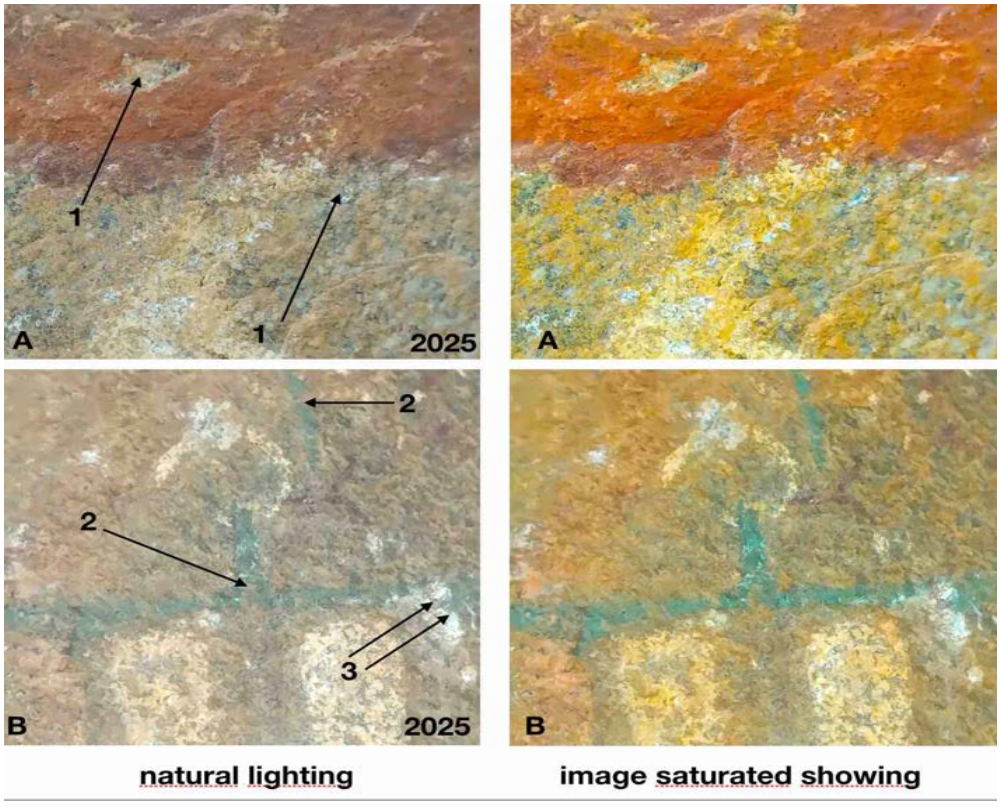


Fig. 9: *Upper part of an anthropomorphic figure from shelter 11 and colorimetric treatment to highlight the green paint.*

The result is quite conclusive in macroscopic versions, showing that the natural coloration of the rock (1, 3) is not identical to that of the drawing. Colorimetric processing also reveals the deposition of green paint over the patina and its destruction by impacts, indicating the contrast between the light color of the natural rock and the dark color of the patina (3).

A engraving is located on the side of the rock block in which Shelter 11 is opened (**Fig. 10**). We compared photos from 2003 and the current appearance (2025), examining the evolution of cracks at the base of the rock (A, B, C) as well as the engraving itself. Visual and macroscopic comparisons (1 to 5) show no notable evolution, nor any recent impact on the rock

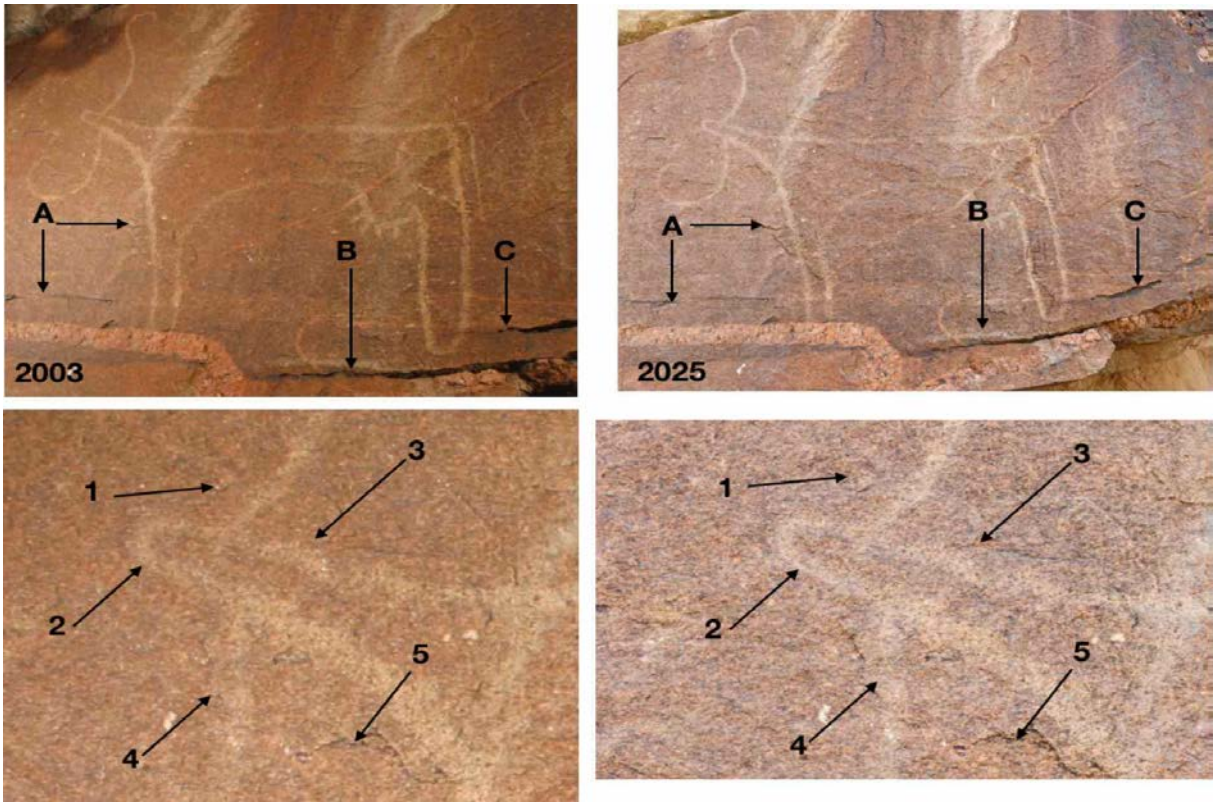


Fig. 10 *: comparaison entre des photos de la gravure de la vache et de l'anthropomorphe à une vingtaine d'années d'intervalle derrière l'abri 10. Les points indiqués par des flèches sur les photos ne montrent pas d'évolution marquante du support ni de la gravure.*

Chapter 5

Managment and Development of Laas Geel Site

In this chapter, we examine the current management system of the Laas Geel site, placing it within its institutional framework, highlighting its weaknesses, and proposing avenues for improvement and consolidation. Translating into public policy the challenge of being responsible for one of the jewels of African cultural heritage involves articulating heritage protection, territorial development, and institutional strengthening. This first involves not only inscribing Laas Geel but also, more broadly, the archaeological sites of Somaliland within clear legal frameworks, integrated into territorial planning and environmental management policies. The establishment of national inventories, monitoring systems, and heritage impact assessments constitutes an essential basis. Simultaneously, the development of local capacities through professional training, national and international academic partnerships, and international cooperation ensures sustainable scientific management. Finally, the involvement of local communities and the integration of heritage into reasoned economic development strategies (cultural tourism, educational enhancement) promote conservation that is both socially legitimate and economically sustainable.

5.1. The Archaeological Heritage of Somaliland: Governance Issues.

5.1.1. An Unstable institutional framework

Following the scientific identification of the Laas Geel site in 2002, the management of archaeological heritage in Somaliland has gradually been structured within an institutional context still under construction. Initially lacking dedicated archaeological devices, the ministerial apparatus has undergone several successive reorganizations, marked by transfers of competence between different ministries and the punctual creation of specialized services. These developments have contributed to integrating archaeology into public policies, often in connection with tourism development prospects. However, the rapid succession of administrative reforms and service managers has limited institutional continuity, particularly regarding the conservation of scientific archives and the capitalization of achievements. The absence of university programs specializing in heritage professions has also restricted local training of executives, making it necessary to rely on partnerships and academic cooperation, particularly at the regional level. In this perspective, the consolidation of recognized training programs and the stabilization of administrative missions appear as structuring conditions for ensuring sustainable and coherent management of archaeological heritage. Certainly! Here is the continuation of Chapter 5, maintaining the technical and professional tone suitable for an archaeological conservation report.

5.1.2. Where to place archaeology and cultural heritage in the state organization?

The primary objective when addressing the management of archaeological remains within the Somaliland state seems to be tourism development. This is why the management of this heritage, with Laas Geel as the flagship site, is entrusted to the tourism service within a ministry itself responsible for commerce. While this tourism objective is commendable and fully justified, it should not be the sole

driver of a heritage policy that should first prioritize the knowledge and protection of archaeological remains.

To achieve this, the first objective must be to establish a legal framework that governs and strengthens archaeological research through planned programs. This framework should allow for diagnostic and preventive archaeological excavations prior to development projects and implement long-term protection measures for heritage elements to be preserved. To be effective and deterrent, this legal framework must also provide for criminal penalties for those responsible for the destruction or looting of archaeological remains, both on land and underwater. These fundamental principles have led most states, across all continents, to entrust the sovereign missions related to cultural heritage to the Ministry of Culture. In Africa, the African Union adopted the Cultural Renaissance Charter in Khartoum on January 24, 2006, which had previously been approved by the first conference of African Union Culture Ministers on December 13-14, 2005, in Nairobi. This charter states in its Title 1, "Objectives and Principles," Article 3d: "to preserve and promote African cultural heritage through conservation, restitution, and rehabilitation." We suggest that a reflection be conducted within the state to redefine the scope of action of the ministries responsible for Culture and Tourism, respectively. The Ministry of Culture should be responsible for archaeology in its multiple fields of intervention:

- Control of field research, Identification and protection of sites and monuments;
- Prevention of risks of destruction linked to territorial development and urbanization;
- Conservation of movable heritage, which implies responsibility for the management of museums and their reserves;
- Management and maintenance of protected sites.

The Ministry responsible for Tourism would have complementary missions:

- Promote and regulate cultural tourism in close collaboration with the Ministry of Culture;
- Train tour guides to improve the quality of services offered by private tourism agencie;
- Promote the heritage image of Somaliland through all available promotional means.

5.1.3. The absence of legislation on Cultural Heritage.

Somaliland currently has a very limited legal framework to legally protect its cultural heritage. However, this issue has been deemed important by the state authority, which has included general provisions on the promotion of culture, arts, and cultural heritage in the constitution. However, there is no list of classified monuments or precise conservation regime. Planning documents mention the current absence of specific laws but recommend their adoption. Thus, the Environmental and Social Management Framework (ESMF), developed by the Ministry of Information, Communication, and Technology (MICT) in 2024, specifies in Article 3-7-8 regarding cultural heritage that this heritage, in its multiple forms, is very important as a source of scientific and historical information. It represents an economic and social asset for development. It indicates that this heritage must be protected against the risks of destruction that development projects may cause. To this end, measures must be applied as soon as an accidental discovery is made during work, which implies immediately informing the competent authorities in matters of cultural heritage: The procedure will include the obligation for cultural heritage experts to report discovered objects or sites to the competent authorities, to fence off the area of discoveries or sites to prevent further disturbance, to conduct an assessment of the discovered objects or sites by cultural heritage experts, to identify and implement measures in accordance with the requirements of this ESS and national legislation, and to train project staff and workers on procedures related to accidental discoveries.

In its Annex 2, the same document insists on the procedures to be implemented, which must comply with World Bank ESS 81 standards. These procedures are modeled on the 1972 Malta Convention (European Convention for the Protection of Heritage), which encouraged signatory states to establish legislation introducing the preventive archaeology system. In 2022, at the initiative of the NGO Horn Heritage, chaired by Dr. Sada Mire, a draft law was written to establish legal procedures for the preservation, registration, and treatment of immovable cultural property. This draft is currently under discussion and must be evaluated by competent experts.

5.1.4. Resources that do not meet Needs and Objectives.

Deprived of significant financial resources that could be granted by public donors due to its unrecognized state status by major international institutions, starting with the African Union and the United Nations, the Somaliland state struggles to provide the various ministries with the budgetary means necessary to fully accomplish their missions. The logistical resources allocated to the ministerial service responsible for archaeology remain very limited, particularly in terms of mobility. This forces agents to occasionally resort to external solutions to ensure their travel. This situation can restrict the frequency of site monitoring missions, the identification of new sites or remains, or urgent interventions in the face of degradation threats. Regarding the Laas Geel site, entrance fees constitute a non-negligible resource, but their management appears to need improvement. The observed variations in attendance figures and collection methods testify to a need for clarification and harmonization of procedures. Furthermore, the collected revenues are transferred to the state's general budget and are not directly reallocated to the services in charge of heritage. In this context, strengthening monitoring mechanisms, transparency, and resource reallocation could contribute to more effective and sustainable management of the site and, more broadly, archaeological heritage.
The Dhagax Kure site, rightly considered by the MoTT as the second rock art site with real tourist potential, also receives visitors but has no obligation to charge an entrance fee. It therefore generates no revenue for the state, although it is guarded. However, several private tourism agencies include it in their Somaliland tour packages and thus generate income that does not benefit the maintenance and protection of the site.

During this consultation, an interview with the Director of Tourism and Archaeology at the MoTT identified needs he considers priorities:

- Training programs to strengthen staff capacities,
- 4x4 vehicles to facilitate travel to archaeological sites,
- Construction of protective fences for certain sites.

5.2. Laas Geel, a Heritage Site Open to the Public: Critical Examination and Remediation Propos

5.2.1. Preface.

The development of the Laas Geel site began in 2004 at the initiative of the then Minister of Culture and Tourism, Osman Ali Bile. It received support from a Danish NGO, Danish Refugee Council (DRC), which built a single-room building for public reception and an annex for storing tools and archaeological artifacts from future local research. In 2019-2020, the European Union, at the initiative of its ambassador to Somalia, Nicolas Berlanga, and in collaboration with the Redsea Cultural Foundation, led by Dr. Jama Musse, Director of the Hargeisa Cultural Center, and the Ministry of Trade,

Industry, and Tourism, financed a significant program of works to substantially complete the site's development. This included the construction of new buildings, fencing of the entire site, removal of invasive vegetation, signage, and the creation of a checkpoint located near the national road. Finally, a pedestrian path was built for visiting the decorated shelters. The mission carried out in December 2025 made it possible to assess the physical condition of these developments and their suitability for the operational project that led to their implementation. We are examining in turn: the development work carried out and the existing structures, with proposals for remediation where necessary. Then, after this overview, which will enable us to propose specifications for the planning of future developments, we will suggest possible ways of improving the site's management by redefining levels of competence and steering governance in a more participatory direction.

5.2.2. Site Acces: The issue of Fencing.

In 2016, experts from the French Embassy/UNESCO mission (L.B. and X. G.) proposed a layout delineating the perimeter to be fenced. The primary purpose of this fencing project was to prevent the regular and uncontrolled passage of goat herds on the site. Traces of their passage were visible in the form of smoothing of the shelter walls due to repeated rubbing of the animals' flanks. The second consequence of these frequent passages was the regression of the vegetation cover on the Laas Geel rock. Although recommendations were made and a barbed wire barrier was installed at the entrance of Shelter 1, the presence of livestock did not cease, and the installation of fencing was considered urgent. The first fence installed consisted of a concrete base, reinforced concrete pillars spaced 2 to 3 meters apart, and a flexible plastic-coated mesh with a height of 2 meters. However, this first fence quickly deteriorated:

- The concrete base and pillars cracked and crumbled, exposing the oxidized rebar;
- The mesh sagged in places, was lifted or torn, and in some cases was voluntarily cut or knocked down.

The guards attempted to patch the holes by piling up thorny branches (**Fig. 1**).
Repairs were undertaken by installing metal stakes to reinforce the damaged mesh supports, and a second, more rigid metal mesh was installed, supported by these new metal posts. However, this repair was only carried out on two-thirds of the fenced perimeter.



Fig.1: *Attempt at basic repair using thorny branches*

During the December 2025 mission, we observed that, despite these repairs, the mesh still showed multiple points of weakness, including forced passages, sagging, and even localized disappearance (**Figs. 2 and 3**).



Figs. 2 and 3 ***:*** *Left, collapsed wire mesh and damaged post. Right, damaged fence foundation.*

The causes of this fence deterioration are multiple:

- **Damage Caused by Wildlife.** The primary non-domestic species responsible is the Hamadryas baboon (Papio hamadryas), which returns to the Laas Geel rock in the evening to spend the night. These baboons attempt to climb over the fence, causing it to sag (Fig. 4), or tear and lift the lower sections. We witnessed this firsthand in the late afternoon on the northern side of the enclosure. Other wild mammal species, such as warthogs and tortoises, also contribute to the damage, although to a lesser extent. In the May 2025 environmental study by Ibrahim Awale and Thomas Masuch (Sustain Enviro-Consulting Ltd.), the authors identified these species and noted that for the fence to be effective, the spacing between posts should not exceed 2.5 meters. They also emphasized that the fence must withstand the physical pressure exerted by camel;
- **Damage Caused by Herders** should be recalled that due to the presence of a permanent water source, the Laas Geel area not only hosts local livestock but also frequently accommodates, during dry periods, numerous heads of cattle from elsewhere. Herders have poorly accepted the restriction of this grazing area and have themselves created forced passages in the mesh or taken advantage of openings made by wildlife to let their animals through. The situation is complicated by the fact that these herders often have close family ties with the site guards, leading to significant tolerance or even complicity. During our stay, we observed goats inside the fenced perimeter without any reaction from the guards. This issue will be addressed later when proposing more suitable solutions for protecting the site's perimeter.

5.2.3. What type of Physical Protection for site Acces?

The previous assessment is clear: Spatial control of the area constituted by the Laas Geel inselberg and its immediate surroundings is necessary to ensure the protection and effective management of this exceptional and fragile natural and heritage site.

To achieve this, there is no alternative material solution other than installing a fence. We have seen that the type of fence installed since 2019 and partially restored afterward is not adapted to animal-related damage or the anthropogenic pressure linked to traditional extensive livestock farming practices.
The specifications for new work aimed at improving site protection must integrate the prior search for the most technically suitable solution to defend against animal-related risks. The most problematic non-domestic species is the baboon, followed by warthogs and tortoises. The solution of building a high cinder block wall, possibly topped with barbed wire, would undoubtedly be the most effective. However, it would strongly compromise landscape preservation, the physical integrity of animals attempting to cross it, and the perception of the local population.
For these reasons, it is rightly prohibited by the ethics guiding the development aid of AFD (French Development Agency) and Expertise France. Therefore, we recommend the option of a mesh fence suitable for protection against the risk factors listed above. For example, the company Clearvue offers numerous models of highly resistant fences to pressure and mesh cutting (**Fig. 4**).



Fig. 4 ***:*** *Predator fence model Scotia Wildlife Sanctuary (Australia*

The upper part of the fence can be equipped with electrified wires powered by a battery. While not lethal or harmful to animals, these wires are very effective in deterring baboons from crossing the obstacle. This method also avoids the need for extremely high fences, as recommended in zoological parks (6 to 8 meters for small species and over 10 meters for larger species like gorillas or chimpanzees).

The choice of stainless steel for the mesh is recommended for several reasons:

- Its resistance to corrosion,
- Its non-toxicity.

If a complementary development project for the site is decided, the project owner must choose the best possible option from those proposed by suppliers. Detailed documentation is available online, and several published works are dedicated to this issue (see attached bibliographic references).
The perception of the fence by local herders, a community to which the site guards belong, must be revisited. It is crucial for adapting regulations to the social impact they generate. It is easy to observe

that the numerous openings in the current mesh allow, in several places, ruminants grazing near the site to enter. The guarding staff does not oppose this.

Additionally, the rapid proliferation of vegetation inside the site has been observed in recent years (see Chapter 3). In a previous assessment, we recommended banning grazing on the site to protect both the decorated shelters, which goats frequently visited, and to prevent the eradication of vegetation by grazing, which facilitated the mobilization of dust that the wind then plastered against the walls during humid periods. The progression of studies on the factors of paint deterioration has shown that this process is much more complex. As for the rapid progression of the inselberg's vegetation cover, consulting meteorological data has shown that one of the causes of this progression is linked to the significant increase in rainfall observed in the country since 2019. Another cause is the drastic reduction in the passage of herds on the site since the fence was installed.

Today, in light of all these observations, it appears that new regulations must be considered for the movement of herds. The rapid and significant recovery of vegetation poses several problems:

- Several shelters are no longer accessible because their access is totally or partially obstructed by vegetation.
- Some species insert themselves into the rock cracks and accelerate its dismantling.

Cacti have proliferated to such an extent that the access path to the shelters is itself partially obstructed in several places. These cacti and other shrub species are responsible for the progression of condensation, a factor in paint deterioration (see Chapters 2 & 3). It therefore seems preferable to regrant local herders, under the control of the site managers (the guards), a limited grazing right in time and space. The spatial limitation concerns the decorated shelters, which must be made inaccessible to livestock. The limitation of the weekly opening time of the site to livestock must be discussed with local communities, administrative authorities, and customary leaders, and evaluated taking into account the scientific opinions of specialists. This form of compromise has the merit of considering the interests of local populations while encouraging them to appropriate the management of fragile heritage whose future largely depends on them. This interest in the protection and enhancement of the site will be better understood and shared by the community if the central administration finds a way to implement real co-management, whose implementation, long recommended, has not yet been realized. This issue will be addressed further below.

5.2.4. Condition and Functioning of buildings ans Annexes on Laas Geel Site.

The complementary work carried out from 2019 on the Laas Geel site aimed at several objectives:

- Organizing and securing the tour route of the decorated shelters;
- Completing the signage;
- Improving the reception and management conditions for the permanent team on-site.

After the first set of buildings constructed in 2004, which included a reception room for visitors and an annex called the "reserve," the program financed by the European Union allowed for the addition of new facilities:

- A building serving as accommodation for the guards;,
- Behind it, a meeting room and an office equipped with a compute;
- A little further away, a set of toilets and showers for the guards;
- For visitors, toilets and a pergola were built;

- A water reservoir supplied by the permanent water table of the wadi was added;
- Solar panels were installed behind the reception building to provide electricit

The December 2025 mission revealed that this system has malfunctions that render it largely inoperable:

- The oldest buildings lack maintenance: door frames are weakened, fixtures are degraded, one toilet block is dilapidated, and the second is extremely run-down;
- The toilet flushes are not operational;
- The absence of building maintenance, which gradually deteriorates, and the lack of maintenance of the electrical supply—provided by solar panels—are prohibitive.

The creation of an office equipped with a computer was a commendable intention, but this computer has never been used. The absence of electricity does not allow it, and there is no one on-site capable of using it. However, it could have been very useful, particularly for using an application to rigorously record the number of visitors and their countries of origin. This recording is currently done manually in a register located in the reception building, and as we have pointed out above, it remains largely random.

In this reception building, the six explanatory panels placed there in 2005 by the French team (funded by the University of Paul Valéry Montpellier) are now degraded and need to be replaced. A set of printed tarpaulins had been offered by France in 2017 (funded by the French Embassy in Nairobi) to replace them, but they were never installed.

The creation of a new set of tarpaulins (kakemono type) integrating the site's graphic charter must be included in the next development program. Additionally, this same building, which requires refreshing, does not have furniture suitable for a public reception facility.
The last point to mention is not the least: The supply of electrical energy is completely deficient in its current state. On the one hand, the solar panels need to be relocated to benefit from optimal sunlight, which is not currently the case. On the other hand, the electrical service installation supplied by these panels is deficient and non-compliant.

Apart from the issue of deficient electrical energy in the buildings, it should also be noted that the absence of maintenance and repair also affects the nocturnal baboon deterrent device, which was installed a few years ago. It has been partially dismantled, and only the metal mast remains.
This observation leads us to think that it is not enough to find donors to launch a development program but that it is necessary to do so based on a usage project that takes into account the necessary and available human skills for its implementation.

5.2.5. Development of pedestrian Visitor routes on the Site.

The development of circulation routes between the various shelters for tourist visits led to the construction of paths and stairs (**Figs. 5 and 6**) to facilitate and secure walking, as well as to channel visitor flows to limit trampling and erosion. For this purpose, flat areas are marked with alignments of flat stones, and paths in the rocky blocks are equipped with stair steps and inclined planes made of concrete.



Figs. 5 and 6*: Roadside signs and dilapidated sign at the start of the visitor trail.*

These installations, although recent, show signs of deterioration that could pose risks to people's safety. Additionally, they tend to give a degraded impression of the site and its state of conservation. The damage comes from the cracking of the concrete binding the flat stones used to make the stair steps or to form the landings and platforms necessary for crossing the steepest slope levels on the hillside. Cracks appear in the constructed structures, and the rock blocks detach from the stair steps or the blocking of platforms installed in the steepest sections.

Diagnosis of the causes of deterioration and construction recommendations for concrete structures:

The examination of the built structures reveals construction techniques poorly adapted to this environment and poorly controlled concrete implementation (**Figs. 7 and 8**). Indeed, the structures are installed on the granitic substrate, and the sand used consists of granite arenas. Their geochemical composition includes high levels of alkaline hydroxides, primarily responsible for the premature deterioration of concrete. The dissolution reaction of silica leads to the formation of sodium and potassium silicates, which significantly affect the lifespan of concrete. This causes swelling of the concrete due to microscopic cracking under the pressure of reaction products, which are gels that swell by absorbing water. Microscopic cracking develops depending on the local loading of the concrete. These reactions are amplified depending on the composition of the cement used and its dosage during concrete production.



Figs. 7 and 8 *: Poor construction of the stairs and rapid deterioration within a few years.*

5.2.6. Recommendations for the realzation an maintenance of Circulation Route on the Site.

5.2.6.1. Improving the Current State.

The development of circulation routes responds to objectives of landscape enhancement of the site, with the creation of developments that guide, orient, and structure visits (Chiron, 2025).
Beyond its utilitarian dimension and its function of territorial interpretation, the path is also a vector of orientation, structure, and storytelling of the territory. The development is designed to correspond to the physical and landscape characteristics of the site so that its implementation is as unobtrusive as possible. To create the most discreet developments possible, it is important to take advantage of the site's characteristics. It will be essential to follow the terrain's curves, use hollows or vegetation when installing imposing equipment (toilets, rest areas, water or educational points, etc.).
The developments must allow access to high areas and the different slopes of the hill to clearly mark the unity of the site. This avoids creating a dominance effect and drawing attention only to the part accessible from the access road, neglecting the conservation of other slopes

5.2.6.2. Alternative Construction Solutions to Concrete Infrastructure

This proposal takes into account the environmental context of the site: an arid savanna with shrubby areas where wood availability is locally reduced, limited to small acacia trees.
The steps and the progression path to access shelters 1 and 2 must be redone. Indeed, the regularization of the slope and standardization of the steps must be carried out.
The concrete elements are particularly affected by the chemical degradation effects described in the previous paragraph. The slope variations are too numerous, and the irregular size of the steps makes progression uncomfortable. A path with lateral stone blockages and a sand circulation surface can be an alternative to the current path. The same applies to the descent back from shelters 6 and 7 toward shelter 1.

5.2.6.3. Proposed Remediation

The step levels are made with half wooden logs, blocked by wooden or metal stakes installed in holes drilled into the granitic substrate. These stakes, once installed, have a height of 2 to 3 cm recessed relative to the wooden log. This avoids creating a tripping hazard during walking (**Fig. 9**).

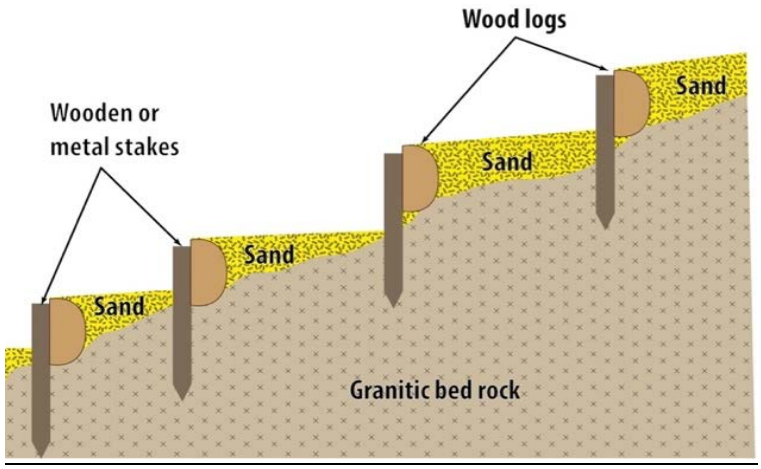


Fig. 9 : *Diagram of a hiking trail staircase constructed using local natural materials and simple construction methods*

5.2.7. Proposal for a visitor circuit adapted to the topography and Accessibility of the Shelters.

In the 2023 expertise document, we proposed improving the viability of the visitor circuit by integrating several additional facilities, notably a platform for accessing shelter 9. The December 2025 mission allowed us to reconsider the viability of the visitor circuit.

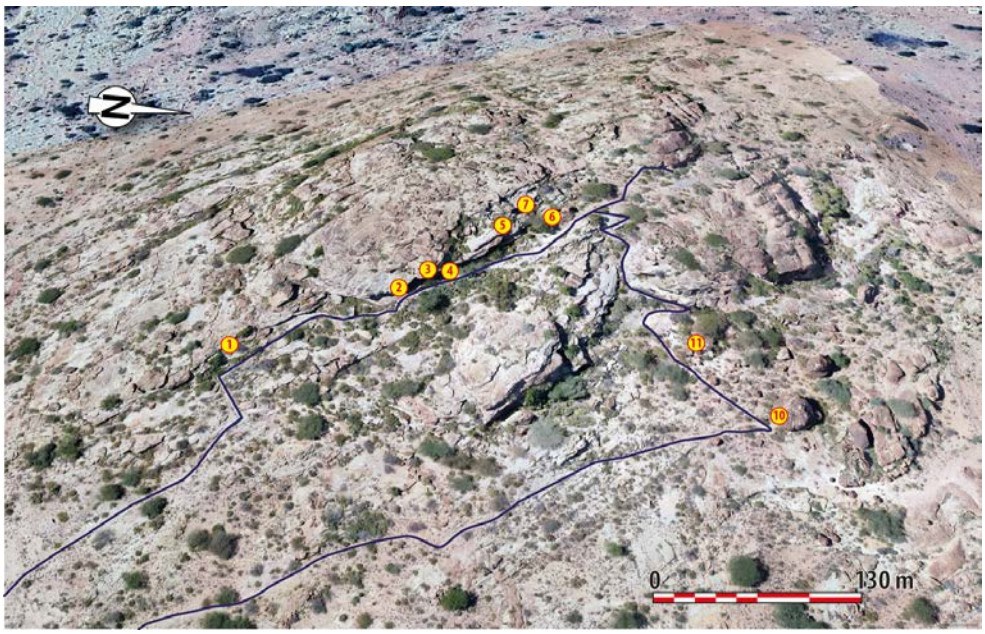


Fig. 10: *Panoramic oblique view of the Laas Geel rock. Overview of the route set up for visitors. The numbers correspond to the shelters accessible to the public.*

Regarding shelter 9, despite its aesthetic quality, originality, and state of conservation of the paintings, a reassessment of its access shows that it should not be integrated into the visitor circuit. It is indeed poorly adapted to visits and difficult to access (risk of falls, vegetation obstruction) (**Figs. 11**).

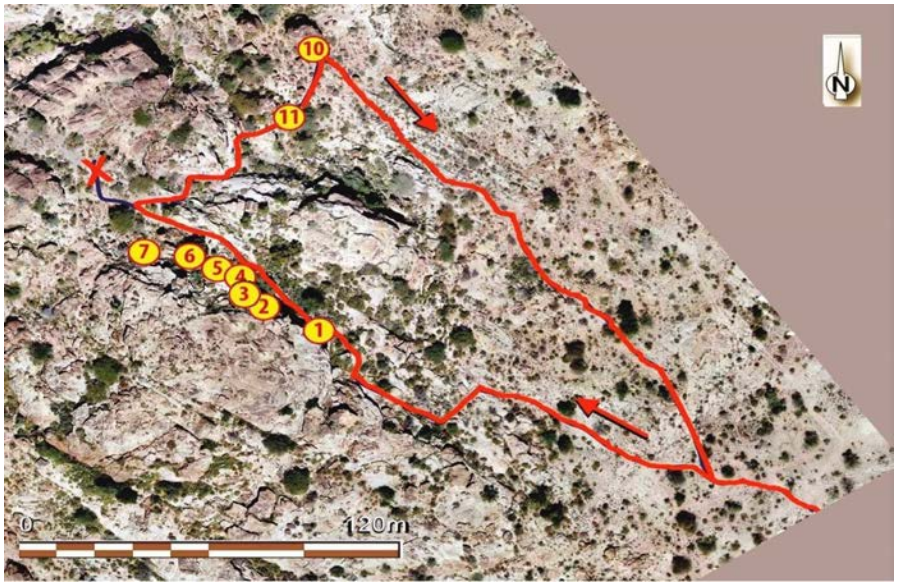


Fig. 11 : *Panoramic zenithal view of the Laas Geel rock. Overview of the route set up for visitors. The numbers correspond to the shelters accessible to the public.*

It has a small volume, and the confined internal space of the shelter does not allow a group of people to enter without risk to the paintings. Shelter 8 is also difficult to access and overgrown with vegetation. It should also be excluded from the visit. Therefore, it is advisable to keep the current route, which first leads to shelter 1, then to shelter 2A, then to shelter 3, followed by shelters 4, 5, and 6, with access to shelter 6 requiring the crossing of a sub-vertical slab, which can be the subject of specific development (via ferrata type). Access to shelter 7A is only practicable for people trained in rock hiking. It is possible to improve this access by installing a handrail. The visit continues with the descent toward shelters 11 and then 10. After visiting the latter, a path along the base of the Laas Geel rock allows returning to the reception building.

5.2.8. Reformulated Signage.

The signage installed on the Laas Geel site has so far been placed in two locations:

- First, at the start of the track leading to the site from the national road, just before the checkpoint;
- Then, on the site itself, near the reception building and at the beginning of the path leading to the first steps of the visitor trail.

Several observations can be made:

- There is no homogeneous and specific graphic charter for the Laas Geel site.
- The two signs indicating the site on the national road are redundant, have a minimalist layout, and are in poor condition. Their base is very fragile;
- The explanatory panels installed inside the enclosure, near the fence, about twenty meters from the buildings, contain text that is too long and probably not read by visitors. Here again; the layout is minimalist (**Figs. 12 and 13**)

The panel on regulations placed at the beginning of the trail, not far from the first steps, is in very poor condition, oxidized, and folded, making it inoperative. Its anchoring to the ground. There was a first uprooting that led to a new installation one meter back, but the anchoring remains fragile.From the start of the visitor trail, there is no more signage.



Figs. 12 and 13: *Signs at the roadside near the checkpoint and a dilapidated sign at the start of the visitor trail.*

Proposed Remediation:

The signage of a site as important as Laas Geel, a flagship of the archaeological heritage open to the public in Somaliland, requires reflection and choices agreed upon by the concerned parties to define a graphic charter valid for all signage. The second axis of reflection concerns the signage appropriate for the visitor circuit. Currently non-existent, it appears necessary while needing to be as discreet as possible. In the terms of reference for a future call for tenders intended for the realization of a complementary project for the development of the site, this point must be mentioned imperatively.

For now, we can only make recommendations:

- Avoid cluttering the site with large explanatory panels at each stopping point of the route;
- Propose very small panels placed along the discovery trail to provide orientation indications toward the shelters accessible to the public, as the visit progresses;
- Design an explanatory panel of modest size, judiciously placed near the entrance or inside each shelter open to the public. This panel could include very short text and an overall view by graphic restitution of the painted figures in the shelter.

5.3. How to Improve the Management of an Exceptional Heritage Site?

5.3.1. Preface

We have emphasized several critical points regarding the nature of the equipment present on the Laas Geel site and the malfunctions that are either the consequence of a lack of maintenance, an inadequate design, or a flagrant lack of financial and technical means available to the institution in charge. These funds must be sought, in the absence of finding them in the state budget, from public donors and private patronage. Ensuring the installation of equipment adapted to conservation and public access needs is not enough. One of the priorities is to give heritage agents, at all hierarchical levels, the skills necessary to fulfill their respective missions. A general training plan with pathways adapted to different levels of responsibility is essential. This wish has already been expressed several times in the past. It remains to be fulfilled. Let us recall here that one of the conditions for the success of this endeavor lies in the consolidation of the careers of these heritage agents. Their professional trajectory should no longer be brutally interrupted by ministerial reshuffles and a certain institutional nomadism, which means that the responsibility for this site and other cultural assets passes from one administration to another with each reshuffle. We will also propose some new directions in the site's governance mode.

5.3.2. The Issue of image rights and the Land Status of Laas Geel Site.

A simple search for the theme “Laas Geel” on the internet reveals the immense notoriety of the site, now known worldwide. Admittedly, the current number of visitors (between 500 and 1000 per year) does not reflect this notoriety, but many reasons explain this gap. One might estimate that—in the current state—it is not desirable for the number of visitors to increase significantly. To achieve this, it will be necessary to remedy all the structural weaknesses and deficiencies mentioned above and others that will be discussed below. This notoriety is not only due to the enthusiastic accounts of Somaliland and foreign visitors disseminated on social networks but also to the canvassing of tourism agencies, which are increasingly numerous in integrating Laas Geel as a focal point in their Somaliland tour offers, sometimes even coupled with visits to tourist sites in Djibouti.

In fact, thousands of photos of the Laas Geel rock paintings circulate on social networks. They are not only taken by tourists but also by photography agencies, some of which trade these photos. The most frequently used image is that of the large cow coupled with the anthropomorphic figure, which is the central figure of shelter 2. This image has become a real logo that has great success in Hargeisa, as it is widely used to decorate the walls and floors of the now-famous Laas Geel café in the city center, as well as its mugs and letterhead. Other establishments in Hargeisa have also taken the name Laas Geel. Thus, it can be observed that the right to use images of the Laas Geel site is currently not subject to any rules. It does not seem that this issue can currently find a legal answer in Somaliland law. However, it appears essential.

The Laas Geel site is an archaeological site of exceptional cultural and artistic value. Its management is entrusted to the MoTT, i.e., the state administration. It remains to verify the land status of the site. If this is not yet the case, land ownership must be attributed to the state. Indeed, legally, no one today can claim to be the heir by filiation of the authors of the painted works of Laas Geel. It is not on this basis that the state can claim a right over the use of images of these works. But it could certainly do so as the owner of the land. This is a line of reflection that must be imperatively pursued. According to the Somaliland Constitution, land is a “public property belonging to the nation.” However, the right to private property is recognized provided it is legally acquired.
There remains some legal ambiguity in the fact that there are two types of land:

- Urban lands, governed by a law on urban land management (2001, revised in 2008;
- Agricultural lands, governed by a law on agricultural property (1999).

There is a third category considered as “common public land.” Laas Geel can be classified in this last category since it is not agricultural land. According to legal classification, the Laas Geel inselberg and its surroundings belong to the category of pastoral lands, which are neither urban, agricultural, nor mining but are grazing and transhumance lands.

Currently, these pastoral lands are managed by the Ministry of Rural Development and Environment, but they are also subject to customary law, which is very prevalent.

Legal clarification therefore seems necessary to define the land status of the Laas Geel site. In any case, it is recommended that the site be egally recognized as the inalienable property of the state. To strengthen the legal protection of the Laas Geel site and legally ensure control over image rights, it is also necessary to give the most important archaeological sites of Somaliland, exceptional witnesses to the country's past, a special status that confers on them the title of national historical monument or site.This legal aspect must be included in future legislation. The management of these assets should logically fall under the Ministry responsible for Cultural Heritage.

5.3.3. Governance : Decentralize or Deconcentrate ?

For nearly twenty years, the Laas Geel site has been open to the public. Its management has, from the beginning, been entirely the responsibility of the central administration. Local elected officials and the population of the Laas Geel district perceive this as a form of exclusion. In December 2025, a community day on the site brought together the ministerial team, local elected officials, customary leaders, and part of the community of inhabitants from the Laas Geel-Dhubato and Dharburuk sectors. The public speeches of the elected representatives and local notables recalled the desire to see this district community more closely associated, through its representatives, with the management of the site. They also emphasized that they had not seen any economic benefits for the local populations until now.

There are several avenues to explore to respond to this demand, which would be wrong to ignore. We can propose at least three:

- **1)** Ensure that the permanent team(i.e., 5 guards), which is rarely complete on the site and has self-organized to set up a rotation system, is led by a manager with administrative skills and team leadership experience. It would be judicious to seek this team leader among young people from the district who already have management experience and some administrative skills.
- **2**) Create a local management committee that would assist and advise the central administration but would also have a permanent oversight role on the site's operation. This committee could take technical initiatives to respond to material malfunctions or requests formulated by the guard team. This local committee could be composed of state representatives exercising their functions in the district, local elected officials (district and commune), representatives of customary leaders, and a spokesperson for the guard team. This committee would meet several times a year in ordinary sessions, with the possibility of convening exceptionally to address an urgent problem. The central administration would participate in the meetings of this committee by delegating one of its executives.
- **3)** Involve the villagers. The choice to locate the Laas Geel visit checkpoint on the national road, 300 meters before the first houses of the village, is far from the most judicious. Indeed, this location is penalizing for the inhabitants of Dhubato, who already feel excluded from the site's management. Relocating it to the heart of the village, by opening a new section of the track, would allow the activation or reactivation of commercial activities: food, catering, and sale of local craft products near or at a medium distance from a new access control post to the site's track.

In this new participatory system, the role of the central administration (ministerial level, archaeology department) remains essential because it holds the sovereign missions and the primary responsibility for protecting the site as a national heritage site.

5.3.4. Improving visitor reception.

Improving visitor reception is not just a matter of investment capacity to upgrade existing facilities to address the deficiencies we have outlined above. It is also about strengthening the skills of the staff assigned to the surveillance and operation of the site. It has already been suggested several times to enable the guard staff to acquire the professional skills indispensable for fulfilling their mission. For several reasons, this training should preferably be conducted on-site and provided by external trainers with the help of a translator.

To remedy a very poorly defined operation by the employer (the state), as well as the absence of precise directives and any control over the proper execution of tasks, the appointment of a site administrator, residing in a nearby locality (Dhubato, Darburuk), must be a priority option. We have mentioned above that this administrator will be the hierarchical superior of the guards and should, as far as possible, come from the district.

5.3.5. Establishing Scientific Monitoring : creating a Scientific Council.

The successive expert assessments carried out at Laas Geel have only confirmed that, by its very nature, this rock art site belongs to a category of cultural property that requires extreme attention and constant monitoring to best ensure its integrity and sustainability.
For this reason, it should not be considered as a simple tourist object, capable of generating revenue and enhancing a country's reputation, but as an extremely fragile heritage object. Its management and

any modifications made to improve public reception, regulate the number of visitors, and implement the necessary regulations to best protect the parietal works make attentive scientific monitoring indispensable. The most effective response is the creation of a scientific council that will assist and advise the central administration so that any decision made is compatible with the protection of the site, which remains the priority.
This scientific council will be composed of national researchers and recognized external experts in the field of study, management, and conservation of rock art sites.

Chapter summary.

This synthesis highlights the importance of understanding the geological, geomorphological, and environmental factors influencing the site, as well as the need for continuous monitoring, community involvement, and scientific oversight to ensure the preservation of Laas Geel's unique heritage.

Chapter 1: Geographical, Geological, Structural, and Geomorphological Framework.

Key Points:

- Laas Geel is located in northwestern Somaliland, characterized by an arid to semi-arid climate with low and irregular rainfall.
- The site is part of an ancient crystalline basement landscape dominated by Precambrian granitoids and gneisses.
- The geomorphological context includes inselbergs, which are isolated rock formations, with Laas Geel being a notable example.
- The formation of the site is influenced by tectonic and climatic conditions, with the current relief being a result of prolonged differential erosion.
- The site's morphology, including steep rock faces and rock shelters, is crucial for the preservation of cave paintings.

Implications for Conservation:

- Understanding the geological and geomorphological context is essential for the preservation of the site's unique features and cave paintings.
- The site's geomorphological dynamics must be considered in any conservation strategy to prevent altering the environmental conditions that have preserved the paintings.

Chapter 2: Formation and Evolution of Laas Geel Rock Shelters.

Key Points:

- Rock shelters at Laas Geel are primarily formed by taffoni, a type of cavernous weathering.
- Taffoni formation is influenced by microclimatic conditions, including condensation, wetting-drying cycles, and internal microclimates.
- Migmatites, which are more susceptible to weathering, play a crucial role in the initiation of shelters.
- The shelters' evolution involves processes like granular disintegration, flaking, and the formation of domes and alveoli.
- The microclimate within the shelters is central to their formation and ongoing evolution.

Implications for Conservation:

- Conservation efforts must focus on maintaining the microclimatic conditions that have allowed the preservation of the cave paintings.
- Any changes to the site's environment could disrupt the delicate balance and lead to the deterioration of the paintings.

Chapter 3: Aerological Phenomena and Condensation-Related Corrosion Processes.

Key Points:

- Condensation within the shelters leads to the formation of a thin water film that promotes geochemical processes and weathering.
- Temperature and humidity variations, along with the morphology of the shelters, contribute to condensation and corrosion.
- Condensation is a significant factor in the morphological evolution of the shelters and the degradation of decorated surfaces.
- Continuous climate monitoring is essential to quantify these dynamics and understand their impact on the site.

Implications for Conservation:

- Monitoring and controlling the microclimate within the shelters is crucial to prevent condensation-related damage.
- Understanding the aerological phenomena can help in developing strategies to mitigate the effects of condensation and corrosion.

Chapter 4: Rock Art Studies.

Key Points:

- The report details observations and studies conducted on the rock art in various shelters at Laas Geel.
- Techniques such as 3D recording and image enhancement are used to study and document the rock art.
- The rock art includes various styles and figures, with some paintings showing signs of fading and deterioration.
- Sampling of pigments for radiocarbon dating aims to provide more information on the age and history of the paintings.

Implications for Conservation:

- Documentation and analysis of the rock art are essential for understanding its historical and cultural significance.
- Conservation strategies should include measures to protect the paintings from environmental factors and human impact.

Chapter 5: Management and Development of the Laas Geel Site.

Key Points:

- The current management system of Laas Geel involves various challenges, including an unstable institutional framework and lack of specific legislation.
- The site's development includes fencing, buildings for visitor reception, and pedestrian paths, but these require maintenance and improvement.
- There is a need for better governance, including community involvement and the establishment of a scientific council for oversight.
- Improving visitor reception and ensuring sustainable management are key objectives for the site's future.

Implications for Conservation:

- Strengthening the institutional framework and involving local communities can enhance the site's management and conservation.
- Establishing a scientific council can provide expert guidance for the sustainable preservation of the site.

The effects of climatic processes, fauna, and vegetation

Impact of vegetation.

Key Observations:

- **Rapid Vegetation Growth:** Since the installation of the fence, vegetation has proliferated significantly, obstructing access to some shelters and accelerating the dismantling of rock cracks.
- **Cacti Invasion:** Cacti and shrubs have overgrown, blocking pathways and contributing to condensation, which exacerbates paint deterioration.
- **Microclimate Alteration:** Dense vegetation alters the microclimate around shelters, increasing humidity and condensation, which accelerates weathering and erosion of the rock surfaces.

Implications for Conservation:

- **Controlled Grazing:** Reintroducing limited, controlled grazing could help manage vegetation growth and reduce its impact on the site.
- **Vegetation Removal:** Regular clearing of invasive species, especially cacti, is essential to maintain access and reduce condensation-related damage.
- **Monitoring:** Continuous monitoring of vegetation growth and its impact on the microclimate is necessary to prevent long-term damage to the rock art.

Impact of Baboons.

Key Observations:

- **Physical Damage:** Baboons frequently climb and damage the fence, creating openings that allow livestock and other wildlife to enter the site.

- **Biocorrosion:** Baboon urine and droppings contribute to the formation of biofilms and acidic aerosols, which corrode the rock surfaces and degrade the paintings.
- **Occupation of Shelters:** Baboons use shelters as resting and observation points, leading to the accumulation of droppings and urine, which seep into the rock and accelerate deterioration.

Implications for Conservation:

- **Deterrent Measures:** Installing ultrasonic repellent devices or electrified wires on fences can deter baboons without harming them.
- **Regular Cleaning:** Implementing a cleaning protocol to remove droppings and prevent biofilm formation is critical.
- **Community Involvement:** Engaging local communities to monitor and manage baboon activity can help mitigate their impact on the site.

Condensation-Corrosion process.

Key Observations:

- **Microclimatic Feedback Loop:** The shelters act as microclimatic traps, where cooler internal temperatures promote condensation of atmospheric moisture on the walls.
- **Water Film Formation:** Condensation creates a thin, persistent water film that facilitates chemical weathering, including dissolution of minerals and the formation of secondary clays.
- **Wetting-Drying Cycles:** Repeated cycles of wetting and drying cause mechanical stress, leading to granular disintegration and the enlargement of cavities.
- **Accelerated Weathering:** Condensation is most active in concave areas, such as domes and alveoli, where water persists longer, intensifying weathering processes.

Implications for Conservation:

- **Climate Monitoring:** Continuous monitoring of temperature, humidity, and condensation is essential to understand and mitigate the corrosion process.
- **Microclimate Control:** Maintaining the natural ventilation and thermal conditions of the shelters is crucial to prevent excessive condensation.
- **Protective Measures:** Implementing physical barriers or coatings to reduce moisture penetration and protect vulnerable areas from condensation-related damage.

Conclusion.

The conservation of Laas Geel requires a **multifaceted approach** that addresses the impacts of vegetation, baboons, and condensation-corrosion processes. **Controlled vegetation management, baboon deterrent strategies, and rigorous climate monitoring** are critical to preserving the site's unique rock art and geological features. By integrating these measures, the site can be protected for future generations while respecting its natural and cultural significance.

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Appendix 1

The Laas Geel Site and the Rock Art of Somaliland

Visitor's Guide

Authors: Xavier Gutherz, Luc Jallot, Jean-Paul Cros, Laurent Bruxelles, Didier Cailhol, Yoann Thouvenot, with the contribution of Mohamed Abdi Ali

Warning:

This guide is primarily intended for visitors to the Laas Geel site, who can purchase it on-site from the guards or at the headquarters of the Ministry responsible for archaeology. Private tour guides would also benefit from acquiring it to better inform the people they accompany on-site.

Visiting Laas Geel or any other rock art site in Somaliland must be done with absolute respect for the rules of conduct and regulations designed to protect this extremely fragile and precious cultural heritage. The main rules aim to preserve paintings, some of which are 5,000 years old.

The first recommendation is to never touch the paintings, neither with fingers nor with any object. Visitors should also ensure, especially when in groups, not to brush against the walls or ceilings of the shelters with their clothing, hats, or backpacks. While photography is permitted, it is only for personal and family use as a travel souvenir. Any other use (commercial, advertising, etc.) must be the subject of a specific, justified request to the ministry managing the site.

The cleanliness of the site must be preserved. Therefore, it is forbidden to consume food or drinks other than water in the designated visitor area. All waste or empty water bottles must be kept by visitors and disposed of in the bins provided near the reception buildings at the end of the visit. Smoking and discarding cigarette butts in or near the shelters is prohibited throughout the entire visit route.

The Discovery of Laas Geel: The Beginning of a Long and Beautiful Story

The Laas Geel rock art site is located in the territory of the Dhubato commune, in the Laas Geel district, northwest of the village. From Hargeisa, Dhubato is easily accessible via the national road connecting the capital of Somaliland to Berbera. Access to the site is via a 6 km track that starts 300 meters to the left of the national road, before the first houses of the village. Laas Geel was discovered in December 2002 during an archaeological survey mission in Somaliland organized by a French team composed of Xavier Gutherz, Jean-Paul Cros, and Joséphine Lesur.

This mission was part of the archaeological research program titled "First Production Societies in the Horn of Africa," accredited by the French Ministry of Foreign Affairs, which continues today in Djibouti and Ethiopia. Mohamed Omar Ismaël, a technician at the CERD in Djibouti, and Mohamed Abdi Ali, then an officer in the Somaliland National Army and a great discoverer of his country's cultural heritage, accompanied the French researchers.

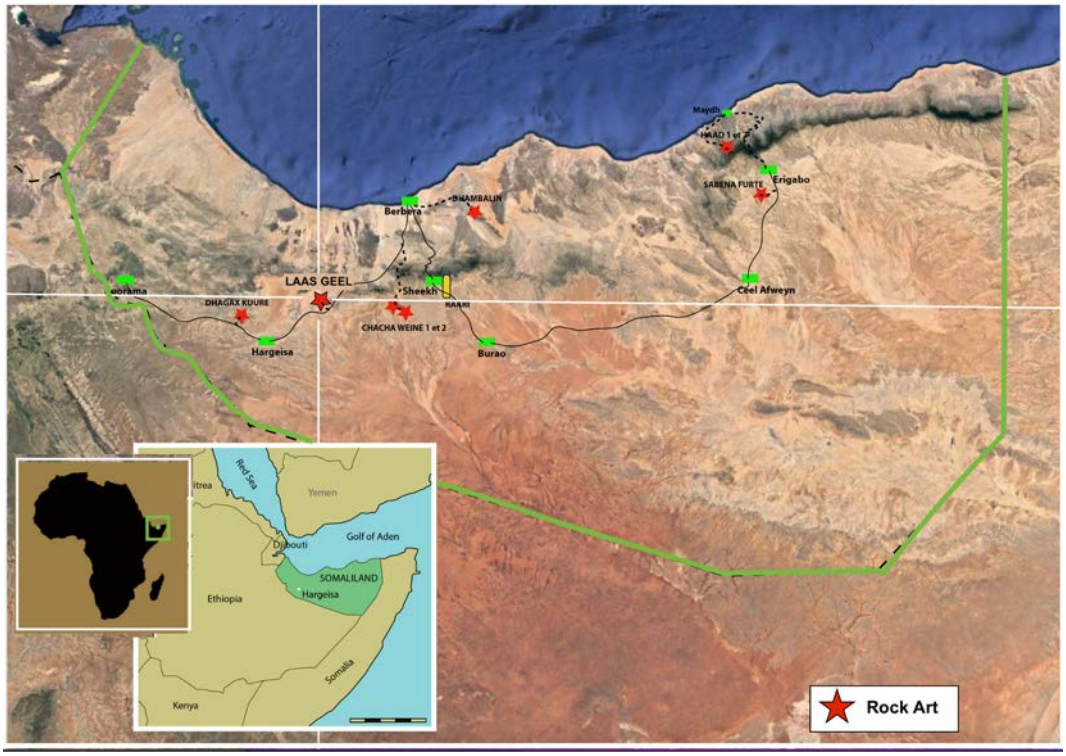


Fig. 1 : *Map showing the location of Laas Geel and the main sites mentioned in the text.*



Fig. 2 : *overview of the Laas Geel inselberg.*

The paintings were known to the villagers who brought their herds to Laas Geel. It was one of them, named Osman, who led the French team to the site. Its major importance was immediately perceived (Gutherz et al, 2003). In the following years, up to 2012, new missions were organized by the same team, expanded with new French researchers and in close association with the Somaliland authorities responsible for the site. These missions allowed the study of all 30 decorated rock shelters (Gutherz and Jallot dir. 2011). They revealed the great richness of Somaliland in terms of rock art. Indeed, while the Laas Geel site remains the most important, there are many other shelters decorated in the same style or from later periods and styles. Currently, about thirty rock art sites are well identified in Somaliland and very likely in the Horn of Africa.

After its discovery, the Laas Geel site was immediately perceived as a jewel of Somaliland's cultural heritage by the country's authorities and the international community. As early as 2003, the then Minister of

Culture, the late Osman Ali Bile, aware of the site's importance, was concerned with its development for public access while prioritizing its conservation and protection. The French archaeologists advised and supported him in this project.

A corps of guards was created within the ministry responsible for cultural heritage. A Danish NGO, the *Danish Refugee Council*, based in Hargeisa, financed the installation of a reception building at the foot of the Laas Geel hill. Subsequently, new works were carried out (fencing, sanitary facilities, and new management and accommodation buildings for the guards), thanks to funding from the European Union. Today, the Laas Geel site receives nearly a thousand visitors per year and is subject to close monitoring by the ministry responsible for archaeology. In 2025, with the support of the French public technical cooperation agency *Expertise France*, the Ministry of Commerce and Tourism launched an important project to study, safeguard, and enhance the site.

What is the Laas Geel Hill?



Fig. 3 : *the waterhole at the foot of the Laas Geel rock.*

Laas Geel first designates a location renowned among camel herders and caravaners. Why? Because at this point, located at the confluence of two wadis, the permanent water table that circulates beneath the surface emerges here in a kind of pond almost all year round. Herders know this place well for this reason. It is located exactly at the foot of the granite hill that houses the rock paintings and which, as a result, took the same name. This name means in Somali “the water point or the well of the camels.”

The Laas Geel hill, which we will call “the Laas Geel rock,” oriented northwest/southeast, is part of a series of inselbergs whose summit outlines an old generalized erosion surface. The Laas Geel Rock reaches 950 meters in altitude and fits into a large oval of 250 by 200 meters. The remarkable feature of the slopes of this hill is that they are dotted with natural shelters ranging from simple, shallow, and small-volume alcoves to large rock shelters. The latter are deep enough for their overhanging ceiling to have allowed prehistoric

humans to take shelter and, above all, to paint numerous animal and human figures that have remained naturally protected until today. On the northeast face of the rock, there are a little over twenty shelters with paintings, sometimes in very large numbers; to which we can add a few others, less than ten, located on the southeast slope.



Fig 4 : *close-up view of shelters 2, 3, 4, and 5.*

The formation of these shelters is linked to processes of water condensation and alteration of the walls and vaults from a zone of lithological weakness, under the repeated effects of condensation that appears due to temperature differences between the air and the rock wall. Indeed, the granite mass that composes the hill is traversed by migmatite beds, a metamorphic rock much more sensitive to alteration than granite. The alteration zones take on particular forms: domes, taffonis, spherical debris. Over time, erosion leads to gravitational phenomena with the tilting or sliding of blocks gradually detached from the overhangs of the shelters by a call to the void. These natural phenomena, essentially climatic, physicochemical, and then mechanical, can be the origin of the degradation or even the disappearance of rock paintings. In the most sensitive areas, they can be accentuated by the frequenting of the rocks by wild fauna, particularly with the urine of baboons, or the guano that accumulates in heaps and is then leached by infiltration or condensation waters.

To best preserve the rock paintings, studies have been conducted and continue to better understand the nature of these phenomena, their extent, and their evolution over time. The objective is to find the best possible responses to avoid or at least mitigate the factors of alteration.



Fig. 5 : *alteration of a migmatite outcrop (gray section).*

There are other sites in Somaliland where animal and human figures have been painted or engraved on rock walls protected from the elements by natural ceilings or blocks of chaos.

However, no hill concentrates on its flanks such a quantity of rock shelters. If we add to this the natural attraction that the presence of water at the foot of the rock and its position, well visible from afar in the little rugged landscape of the region, could constitute, we can understand that it is a particular place. The men of the late prehistoric times, the first livestock herders in the Horn of Africa, had decided to privilege this place to express, through the figures they painted there, their symbolic universe. This universe undoubtedly included a privileged relationship with cattle. It is not exaggerated to think that Laas Geel constituted a major sanctuary in the vast space traversed by these ancient populations. It is now time to look at how this symbolic universe is staged here.

What Can Be Seen in the Decorated Shelters of Laas Geel?

Among the many shelters, 25 of them contain figures painted on the rock walls using natural dyes. Among these 25 shelters, about ten, grouped on the northeast slope of the rock at different heights, concentrate the majority of the paintings that have remained in a very good state of conservation.

Animal and human representations dominate the common theme of all the panels. These are a combination of a large number of monochrome figures, the least numerous, and polychrome figures. The colors used, in order of frequency, are red ochre, white, yellow ochre, more rarely black, and exceptionally green. Based on analyses carried out by the research laboratory of the Museums of France on 45 samples, these are natural dyes from rocks or sediments present in the surroundings. The most numerous pictorial representations are those of flat-backed cows seen in profile. There are more than 300 of them. The art of Laas Geel lies mainly in its cows, whose strange stylization and chromatic richness constitute a unique case in world prehistory. The way they are represented is so original that it is easy to distinguish, among the many styles of rock art in the Horn of Africa, that of Laas Geel with its cows and its very particular anthropomorphs.

Let's talk first about the cows. Their head and horns are seen from above while the body of the animal is seen in profile. In prehistoric art, this convention is designated by the term “twisted perspective.” The head has the shape of a vase or tulip. It is located forward, in the hollow of the horns, which are most often majestic. These horns take on a lyre or pincer shape. They are more or less inward, open, straight, or with reverse curvature, sometimes adorned with small parallel lines or dots arranged in a halo around them. They can have pendants. These cows all have another common point that accentuates their singularity. They possess a sort of rectangular piece with a rounded rostrum forward that seems placed on the neck and whose front part follows the contour of the lower horn. These “fanons” are either simply outlined, filled with a single monochrome flat color, or decorated with alternating vertical stripes, red or brown and white. More rarely, this decoration is more complex and could evoke embroidery. This is indeed the hypothesis that has been privileged to interpret this very particular attribute, specific to what has been called the “Laas Geel style”: it could be a piece of fabric placed on the neck of the cows on the occasion of ceremonies or parades highlighting the animals, or a symbolic attribute whose function would be to give them a particular status.



Fig. 6: s*triped dewlap cow in shelter 9.*

The body, seen in profile, with the two legs merged at the front and back, is slender. The limbs and belly draw an arch where the udder with four prominent teats is distinguished, almost evoking a solar motif. The animal, whether it has a monochrome or bicolor coat, does not have a dorsal hump. These are therefore representations of cows belonging to the species Bos taurus, with a flat back, and not to the species Bos taurus indicus, with a hump (the zebu). This anatomical detail is somewhat important for dating the paintings, as is the bicolor aspect of the coats, which allows us to consider without hesitation that these are domestic animals. The term “cow” applies to the majority of the bovines painted in the Laas Geel shelters, but there are also a few rare bulls.

The latter do not have udders, and their coat is generally beige and monochrome, with their horns being long and straight. Slightly less numerous than the cows, painted representations inspired by the human silhouette, seen from the front and dressed, are qualified as anthropomorphs.



Fig. 7: *large white bull from shelter 1.*

Numbering about 200, they are depicted in very stereotyped positions: legs parallel and straight as in ample brown-red pants slightly tightened at the waist, the upper body dressed in a white tunic with vertical bands in darker shades.



Fig. 8: *dog and anthropomorphic figure from shelter 1.*

Their short arms are stretched at shoulder height. Above, a long neck, represented by a thick line, supports a head in the shape of a full or hollow circle, sometimes bordered by small parallel vertical lines. A finer line ending in a bifid point—perhaps a long pin—comes into contact with the head. These anthropomorphs are most often placed between the legs of a cow or behind and sometimes in front of or above them. They seem to float in space and are always smaller than the animals they accompany. On rare occasions, they brandish a bow. Sometimes one or more dogs, with a raised and rounded tail, accompany them. The anthropomorphs are inseparable from the cows and contribute to the originality of the compositions of the Laas Geel style. Indeed, they are different from the many anthropomorphic representations known elsewhere in the rock art of the Horn of Africa. The representations of wild animals are rare at Laas Geel: a giraffe, three antelopes, a few rare felines, a snake, a few monkeys, three tortoises. However, 300 meters north of the Laas Geel rock, near the wadi, there is a cavity whose ceiling has a set of giraffe figures painted in white in a schematic style that belongs to a later period. The other domestic animals present in the region during the Neolithic are depicted at Laas Geel but in small numbers: these are goats and dogs. There are no representations of sheep here, although these domestic animals are depicted in another site, Dhambalin, which we will discuss later.



Fig. 9: *the large cow with ornate dewlap and the large anthropomorphic figure from shelter 2.*

The Age of the Laas Geel Paintings

The French archaeologists who studied the Laas Geel site and compared it to all the other rock art sites in the Horn of Africa were able to show that the paintings it contains belong to a very particular style that they called the "Laas Geel style." It was then necessary to try to situate this school of rock art in time. The dating attempts made in 2003 from samples of small amounts of pigments on the paintings failed because they contained no organic matter that would have allowed the application of the carbon-14 method.

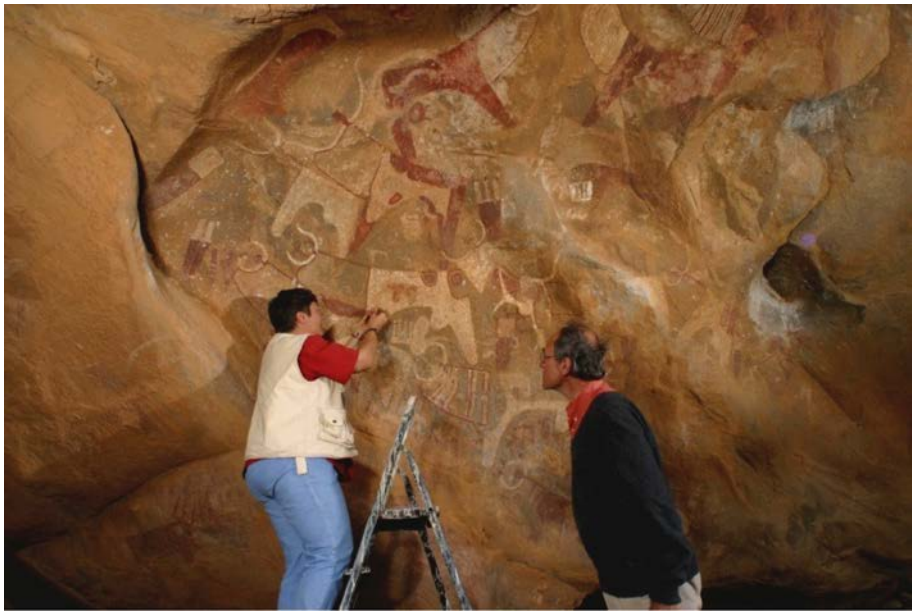


Fig. 10: *collection of dye samples in shelter 10 in 2003.*

A little later, an archaeological survey was carried out in the only shelter filled with sediments in which traces of ancient occupation were found: fragments of animal bones, flint tools and flakes, fragments of ostrich eggshells, and charcoal. This human presence in shelter No. 7 lasted for several millennia, although it was always temporary occupation by small groups of people practicing hunting and gathering.

It so happens that the archaeological layers in the upper part of the fill contained numerous fragments of a natural dye, hematite, a material that was used to color the paintings found in the decorated shelters of the site. Carbon-14 dating provided a fairly wide chronological range but gave a fairly reliable indication to establish the time frame during which the Laas Geel style paintings were made. This range is between 3,500 and 2,500 years before the common era, without being able to reduce the margin of uncertainty.

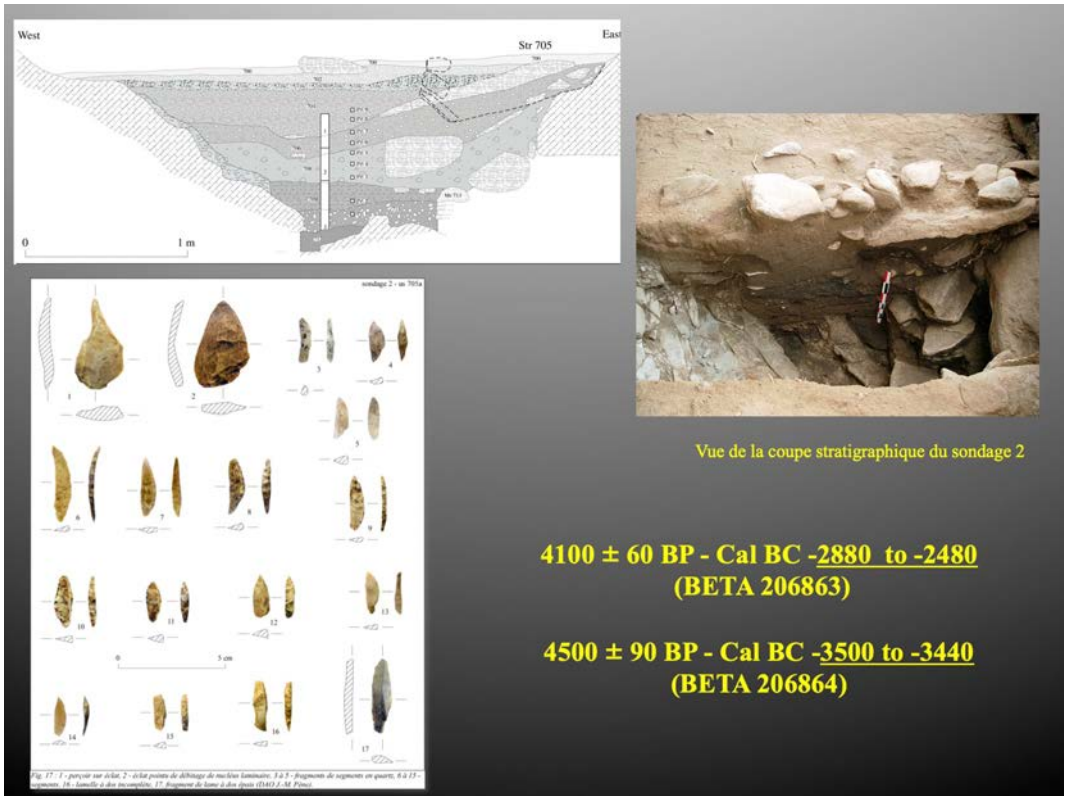


Fig. 11: e*xcavation in shelter 7: view of the excavation, stratigraphic section, flint tools, and radiocarbon dating.*

Given what is known about the first manifestations of cattle breeding in the Horn of Africa and the age attributed to the Laas Geel paintings, it can be argued that these figurations probably represent domestic animals. Moreover, solid-colored coats are very rare among wild bovines, and the Laas Geel painters particularly highlighted the udders, showing that they attached great importance to milk in their diet. These paintings could therefore be part of the oldest phase of the rock art of this region of the African continent and be the work of the first livestock herders.

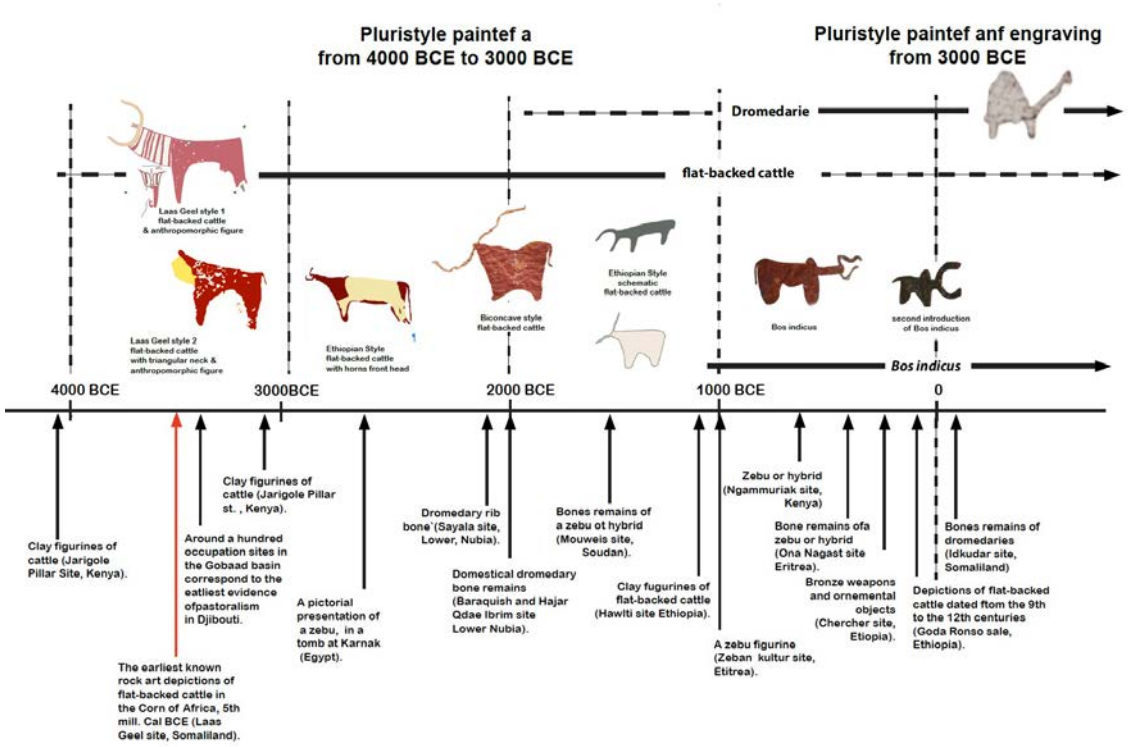


Fig. 12: *chronological timeline.*

A Fragile Site That Must Be Preserved

The factors of alteration of the Laas Geel paintings that we have mentioned are the cause of the total or partial disappearance of several of them. One can think, as shown by several representations of bovines or anthropomorphs, now incomplete, that the shelters once contained a much larger number. However, this process of erasure can be slowed down or even stopped in some cases if special measures are taken. To do this, it is first necessary to analyze and understand the mechanisms behind these alterations. In a second step, one can attempt to remedy them by implementing appropriate measures. These studies and works have been underway since 2016 and will continue over time. The site has benefited from development work that allows the visitor, equipped with their access pass obtained from the ministry service responsible for archaeology in Hargeisa, to follow a pedestrian route leading them to the main decorated shelters. The current regulations require every visitor to be accompanied by one of the site's guards or an approved guide. It is essential to strictly respect the instructions posted at the entrance of the site and the recommendations of the guards (see the warning). The most important of these rules is never to touch the paintings with your hand or any object, nor to wet them to revive colors deemed too pale for photos.

Visiting the Laas Geel Site

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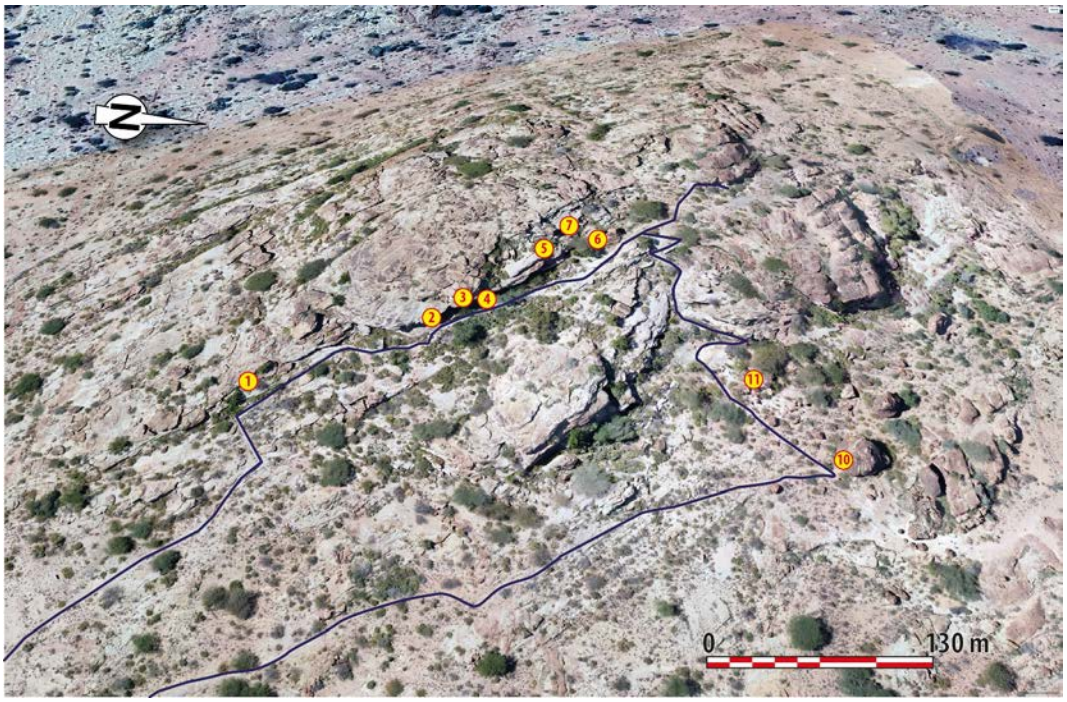


Fig. 13: *Laas Geel overview with the shelters propose to the visitation*.

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The visit begins with Shelter No. 1.

This shelter is the first that visitors can admire after climbing the first part of the stairs that lead them from the reception buildings to the foot of the northeast face of the Laas Geel rock.



Fig 14.: v*iews of the ornate sections of the main vault of shelter 1.*

Of medium size (170 m² on the ground), this shelter is one of the most important due to the density and richness of its painted figures. It is mainly its ceiling (97 m²) that bears many figures, but its walls also have some. A total of 350 identifiable representations and as many diverse painted signs and traces have been counted. The current state of the paintings is remarkable, and they have not been altered by visitors. Only the natural factors described earlier have partially erased or deteriorated a few figures on the shelter walls. The most visible ones, which attract attention due to their shape, the freshness of their color, and their volume, are the largest cows and the anthropomorphs characteristic of the Laas Geel style. Archaeologists have divided the complex ceiling into several panels (indicated in **Fig. 15**).

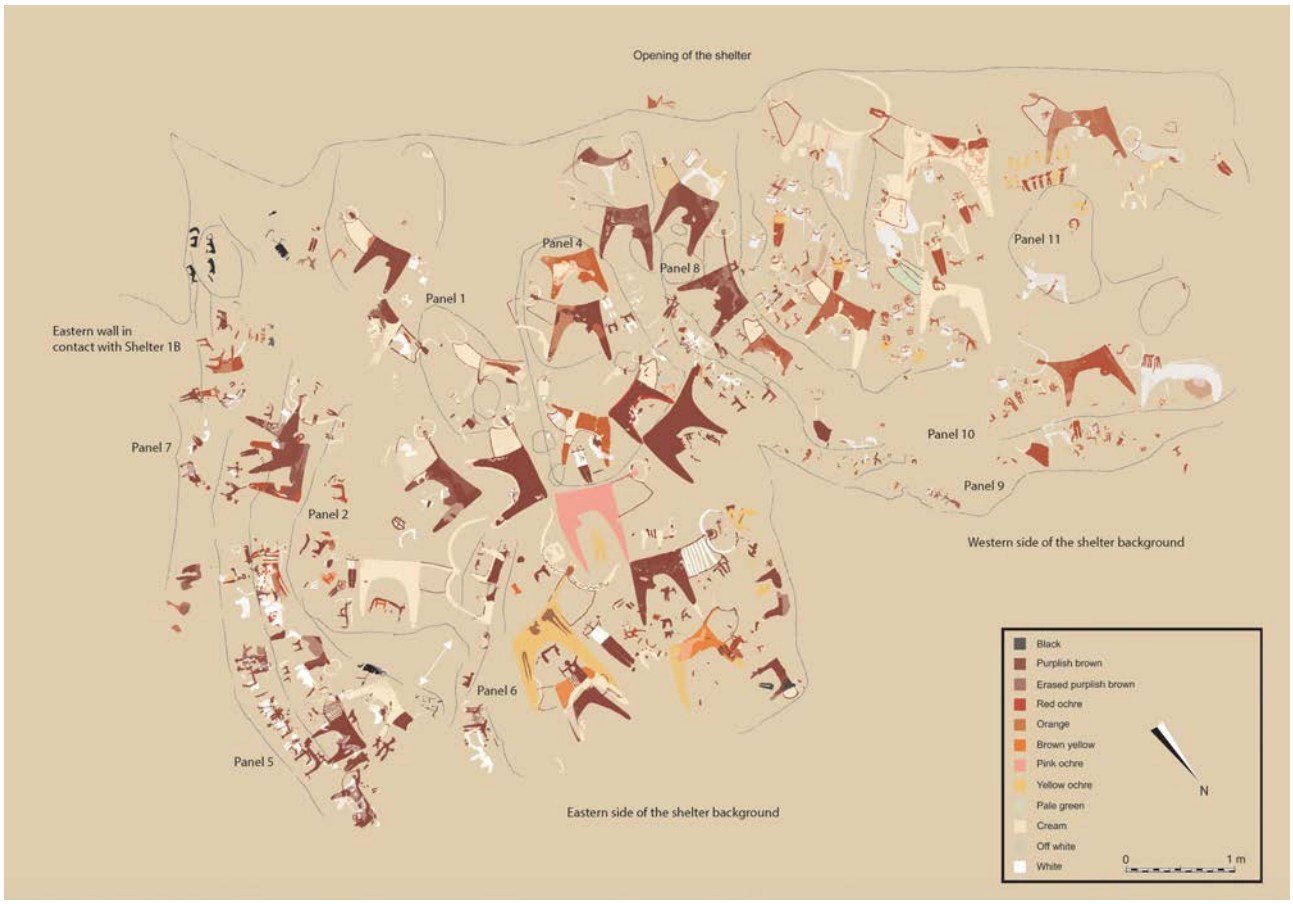


Fig. 15: *representation of the decorated panels uncovered by archaeologists for the study of the shelter.*

On the left, the paintings are distributed from the ceiling to the wall forming the back and side of the shelter; on the right, they occupy a large dome forming a kind of vault. The two parts are quite distinct, and each includes several panels: 8 to 11 on the left, 1 to 7 on the right. Between these two parts, the ceiling lowers to form a keel. At first glance, the high density of these painted figures, which are close together without leaving much empty space, does not reveal any particular organization. Only a spatial analysis of their distribution allows us to glimpse a non-random arrangement. Indeed, there is a fundamental partition between the right and left parts of the shelter. On the right, anthropomorphs with white tunics are grouped, while on the left, many cows with dark coats and white fanons are gathered. These two groups overlap in the center of the ceiling. Other oppositions exist, for example, between the light-coated cows in panels 10 and 11 on the right and the dark-coated cows in panels 4 to 8 on the left. At the bottom (panels 5 and 7), there are very crowded friezes, formed by multiple superimpositions of figures, including many small white bovines in the Ethiopian style, much smaller in volume than the large Laas Geel style cows. They

were painted several times over the Laas Geel style figures in shelter 1 and also in shelter 10. Finally, in shelter 1, one can see on the lower parts of the walls, especially on the left towards shelter 1b, several schematic figures, including rows of anthropomorphs. They belong to a final phase of the shelters' use by painters. In the right part of the ceiling, one notices these same figures in opposite lines facing each other, in a position that evokes that of dancers (**Fig. 16**).



Fig. 16: *probable dance scene in a schematic style.*

Next to shelter 1, immediately to its left, is shelter 1b, which is less deep than the previous one and has a more turbulent ceiling and walls. As a result, the paintings are often less visible at first glance. Some are almost erased. The shelter is not recommended for a detailed visit. The guide can point out the main figures visible from the entrance to visitors.

Shelter No. 2

After progressing along the discovery trail and climbing a few more steps, the visitor finds themselves at the foot of shelter No. 2. This is the largest shelter on the site. It is the most visible of all the shelters on the northeast face of the Laas Geel rock due to its size and central position (Fig.). The shelter is about fifteen meters deep and extends over a length of about 30 meters. The back wall is painted. Seven meters high, it has an irregular appearance, with flat and bulging parts. It is overhanging on its right half and almost vertical on its left half (**Fig.: 17**). The highest paintings are visible as soon as one climbs the northeast slope of the rock. Notably, a large cow with a striped fanon and a large anthropomorph painted below are among the most imposing figures on the site. These two figures, located in the central part of the decorated slope of the Laas Geel rock and of large size, seem to constitute the most central cow and anthropomorph pair, and it is probably not a coincidence that it is the only one visible from afar. This central composition of the site has indeed become emblematic today, as it is reproduced in Hargeisa on facades or objects.



Fig. 17 : *overview of shelter 2.*

The entire wall is crossed by narrow horizontal ledges that the painters seem to have taken advantage of. Indeed, the cows' legs are placed on these ledges, which can evoke ground levels. The ensemble includes 24 bovine figures and about fifteen Laas Geel style anthropomorphs.

The cow-anthropomorph pair is perfectly illustrated by the imposing central composition we have just mentioned. However, several figures are now barely visible, and others are partially erased, and it is likely that this wall once had many more. Their total or partial erasure is due to natural factors or the destructive effects of animal urine and droppings that flow down the walls during rainy periods.

After the first painters, authors of the Laas Geel style figures, frequented this shelter, others succeeded them and painted animals and anthropomorphs in different, much less elaborate styles: for example, horizontal friezes including several schematic figures: anthropomorphs as well as animals belonging to species that are difficult to determine. In the left part of the wall, one of the small anthropomorphs in the frieze holds a bow and a shield.

From the rocky platform that forms the floor of shelter 2, one can contemplate the vast landscape that unfolds before our eyes, with, at the foot of the hill, the confluence of the two wadis, a little further the granite peak that is opposite Laas Geel and which houses many colonies of baboons. In the distance, the few residual reliefs that dominate the low hills and their wooded savanna.

Shelter No. 3

To reach the next shelter, called shelter No. 3, one must descend from shelter 2 towards the discovery trail and go around a rocky promontory that supports this shelter 3. One then reaches the foot of shelter 4 and climbs this promontory, returning towards shelter 2. There is a very beautiful ensemble of cows and anthropomorphs of the Laas Geel type, which have the particularity of being painted with a single hue, red ochre. For those who would not dare or could not reach shelter 3 from shelter 4, as it requires some agility on the rocks, it is possible to contemplate this beautiful ensemble from the platform of shelter 2.

Shelter 3 is not limited to the red cows of this panel 1. It is much larger, with a high ceiling and widely open to the East. In total, 6 panels bear more or less well-preserved paintings, with the most important ensemble being that of panel 1. This panel includes a very dense group of bovine figures and a few isolated figures to the southwest. The densest sector has 21 bovines and 12 anthropomorphs, with some overlaps showing that painters intervened several times.



Fig. 18: *large panel of red cows in shelter 3.*

Shelter No. 4

Shelter 4 is located in the extension of shelters 2 and 3, to the north of the latter, with which it communicates via a lowered passage. It measures about fifteen meters in length, with an average height of three meters, and equivalent depth. It closes at its northern end and opens to the east.

The paintings in this shelter are heavily faded by the presence of beige carbonate concretions that can form more or less thick crusts. The visitor will therefore need to observe the painted wall for a long time to distinguish the painted figures. When facing the shelter, it has a sloping ceiling that lowers towards the back to form a nearly vertical lower wall. This ceiling is divided into two unequal parts by a crack; the left part being the largest, it forms an independent panel.

This panel, which is the most visible, is distinguished above all by the presence of a large bovine with very long horns. But this one is not alone, as there are a total of 18 for only 4 anthropomorphs.

Shelter No. 5

When leaving shelter 4, one takes a few more steps on the marked trail and finds themselves a little further in front of a small alcove shaped like a bubble, which will only be visited from the outside. Although its interior is generally rather dark, one can observe the presence of two bovines and linear signs.

Only the cow located on the left side of the shelter is well preserved. It is quite large, measuring about 70 cm in total length. One will recognize a cow of the Laas Geel style. To the right of the rocky niche, there are barely visible traces of a white bovine looking to the left.



Fig. 19: *giraffe and antelope from shelter 6.*

Shelter No. 6

To reach shelter 6, it is necessary to leave the trail about twenty meters after shelter 5 and climb an inclined slab to reach a shallow rocky platform about 15 meters long. Only people able to overcome the obstacle presented by the inclined slab can venture into this shelter. The slightly inclined wall is exposed to the elements. However, it has preserved several paintings, some of which are uncommon at Laas Geel. This shelter indeed has the particularity of presenting, alongside Laas Geel style cows, a set of wild animals: a giraffe painted in red with a long neck fringed at its base and a raised tail painted next to a group of 4 antelopes of the same color. Below the giraffe, a small animal with a curled tail is identified as a dog.

In the central part of the same shelter, there are several Laas Geel style bovines and anthropomorphs. To these clearly discernible figures, one must add a few traces of red color that are difficult to interpret. Finally, at the left end of the shelter, two figures painted in red represent a feline and a giraffe.



Fig. 20: *overview of shelter 6.*

Shelter No. 7

This shelter, located towards the top of the hill above shelter 6, is not easily accessible. To reach it, one must leave the main path to climb between the rocks for about ten meters. This route is only practicable by people experienced in this kind of exercise. We mention it here for two reasons:

First, its wall is adorned with paintings in the Laas Geel style. Second, it is one of the rare shelters on the site that has preserved archaeological layers and, as such, has allowed for an excavation rich in teachings about the ancient occupation of Laas Geel. The archaeological layers at the top of these deposits allow for an indirect dating of the rock paintings.

The shelter is 15 meters long. A very large block that collapsed from the upper part of the Laas Geel rock closes this space on the slope side. This particular morphology has allowed for the conservation of the thick filling, which includes a succession of archaeological layers.

The back wall of the shelter, with strong concavity and protected by an overhang, has allowed for good conservation of the painted figures. It bears three panels. The first brings together six Laas Geel style bovines, a complete anthropomorph, and the partially preserved remains of two others. Linear or circular signs from a more recent period are added. The second panel includes a large red bovine and an anthropomorph, as well as a small animal (goat or dog?). The third ensemble, a series of vertical red lines, is found in a small niche that extends shelter 7 to the East.



Fig. 21: *survey of painted wall of shelter 7.*

Shelter No. 11

One must follow the marked trail heading north to reach a fork. Then take the path to the right, which leads down the hill. The descent is quite steep and includes fairly high steps. One should proceed with caution under the guide's direction. A little further down, on the left, one reaches a flat area located in front of shelter 11. The ceiling of this shelter will particularly attract the attention of site visitors. On about 20 m², about fifteen bovines, four anthropomorphs, and canids have been painted. The central element of this ensemble is a probable mating scene, the only one confirmed on the Laas Geel site and more broadly in the rock art of Somaliland. It is a representation of a cow (60 cm long) with white pincer-shaped horns with red tips, a bicolor coat, and a well-marked udder. Behind the cow is the largest bovine in shelter 11, in a vertical position and seemingly standing on its hind legs. The coat is entirely white. It has a striped fanon.

Another remarkable feature of the ceiling of shelter 11, which immediately catches the eye, is the depiction of a large Laas Geel style cow that measures 80 cm long and 55 cm high. This bicolor cow (white and red) has a fanon with rich decoration. This immediately suggests a piece of fabric or wickerwork placed on the cow's neck. This supports the hypothesis of a valorization, or even a form of sacralization of livestock, with particular attention given to certain favorite animals. Another point of interest in this same shelter is the presence of 5 canids painted in red ochre. One can clearly distinguish their two ears, muzzle, and a small raised and forward-curved tail. Several other more or less well-preserved bovines and anthropomorphs complete the ornamentation of this astonishing ceiling.



Fig. 22: *overview of the main panel in shelter 11.*

Shelter No. 10

From shelter 11, one continues descending towards the bottom of the hill to find shelter 10, under a very large block of about 100 m³, formerly detached from the granite hill mass. This is the last shelter accessible to visitors. It is one of the most remarkable shelters due to the abundance and concentration of paintings. Different styles of figures, representing bovines, anthropomorphs, and signs in a wide range of colors, form a particularly dense ensemble that can be compared to that of shelter 1. The eye is first drawn to the tangle of Laas Geel style cows with all their characteristic anatomical attributes and the presence of decorated or undecorated fanons.



Fig. 23: *overview of the painting in shelter 10.*

One will notice large horns with pincer or lyre shapes, and in some cases, an asymmetry that evokes the practice of voluntary deformation of cows' horns, which is still found today among groups of herders in southern Ethiopia and Kenya and which has its roots in the distant past of East African pastoral societies. These cows are accompanied by anthropomorphs recognizable by their outstretched arms, their tunics with white stripes, and their red pants.



Fig. 24: *overview of the main panel in shelter 10.*

In this shelter 10, as is also the case in shelter 1, several figures representing bovines do not belong to the Laas Geel style. Generally much smaller than the previous ones, they are linked to a style well represented in Ethiopian decorated sites, particularly in the Harar mountains. As these bovines are superimposed several times on the Laas Geel style bovines and the reverse situation does not exist, one can confirm that they belong to a later period without being able to estimate the time that has elapsed between these two phases of rock art.



Fig. 25: *detail of meander patterns in shelter 10.*

Shelter 10 also offers a remarkable feature that exists much more rarely in the other shelters. These are long green barbed lines intersected by an alternation of red and green lines and clusters of dots. Sometimes, these dotted lines seem associated with the head of a Laas Geel style bovine. In another case, they surround the spherical end of thick sticks shaped like clubs, bearing striped bands. These motifs are enigmatic: scepters, hoof prints for the first, and very schematic representations of anthropomorphs for the second. Outside the shelter, on the left face of the block, are the only two engravings on the Laas Geel site. One can clearly distinguish a cow and an archer following it. The cow has a triangular neck, horns with reverse curvature, a four-teat udder, and a thin tail parallel to the hindquarters. The archer has a round head, filiform arms, a well-marked thorax, and lower limbs. He carries a double-curved bow.



Fig. 26: *Engraved figures in shelter 10.*

Why Does Laas Geel Have Such Heritage Value?

The Laas Geel site is undoubtedly one of the most impressive rock painting sites in the entire Horn of Africa, and for several reasons: the number of painted figures occupying some thirty natural rock shelters, the exceptional state of conservation of many paintings, and their originality both in the graphic style of the figurations and in the compositions of the panels and the use of polychromy. Moreover, it constitutes the most important and explicit testimony to the symbolic thought of the first herders in this region. The natural character of the site, distant from current settlements and well-preserved, as well as the beauty and tranquility of the landscapes that constitute and surround it, reinforce the visitor's overall impression, already charmed and surprised by the density and aesthetic quality of the painted works.

This site probably constituted, for the regional populations of herders in the 3rd millennium before the common era, i.e., 5,000 years ago, a central sanctuary surrounded by several small sites decorated in the same style within a radius of about thirty kilometers. The following information will help us understand its importance and significance.

To do this, we must be interested in human-animal relations at the time of the first herders.

Indeed, one cannot understand the reason for this sanctuary, created and undoubtedly venerated by cattle-herding societies nearly 5,000 years ago, without examining the general context in which it is situated. First, paleo-environmental research associated with archaeological excavations in the Horn of Africa has highlighted the major role of climatic changes in the modifications of the subsistence behavior of prehistoric societies. In this part of the continent, the last humid period (African Humid Period or AHP) began 14,000 years ago.

The lakes of the great lacustrine basins of the Rift took on considerable extension. Human groups during this period lived by hunting, gathering wild plants, and fishing. Natural resources were very abundant. From the 3rd millennium before the common era, the lakes receded, and the environment became increasingly arid. It was at this time, due to the decrease in wild resources, that hunter-gatherers felt the need to find new food resources and began to practice cattle and caprine (goats and sheep) herding. These species were domesticated much earlier in the Near East and were gradually introduced to Africa. The dates obtained from several archaeological sites in the Horn of Africa indicate that the first introduction of domestic livestock in this region occurred during the 3rd millennium before the common era.



Fig. 27 : *A young Dinka pastor and his favorite animal. Note the deliberate deformation of the horns (South Sudan). March 4, 2018. (AFP / Stefanie Glinski).*

Providing milk and its derivatives, livestock gradually became the main food resource for the populations of the region, who became producers after having been, since their origins, exclusively predators. After flat-backed bovines and caprines, new species were introduced from the Arabian Peninsula during the 1st millennium before the common era. These are: the zebu (bovine with a dorso-thoracic hump) and, a little later, the dromedary, a very resistant species perfectly adapted to long journeys in arid climates, including carrying heavy loads.

Anthropologists who have studied contemporary herding societies in southern Ethiopia and Kenya have shown the strong attachment of men to their domestic animals, an affection tinged with respect that means, among other things, that cows are killed for meat consumption only exceptionally.

It is not unreasonable to think that this particular human-domestic animal relationship appeared very early within the first herding societies, especially since there is a big difference between how the herder perceives the product of the hunt and the herd they raise with the greatest care. We can thus understand the reason for the rock paintings and engravings in which the representation of bovines occupies a primordial place.

At Laas Geel, this relationship, imbued with respect and affection for these animals, can be perceived by the attentive visitor to the site. This feeling is all the more present as the bovines are depicted in a very particular way and bear attributes that enhance them. Their over sizing compared to the size of the anthropomorphs that accompany them and their particular morphology reinforce this impression. These anthropomorphs themselves are not naturalistic figurations. These stagings also lead us to the idea that this relationship was of a sacred order.

A little later, around the turn of the era, aridity was largely established in the low-altitude zones, and it is not surprising to see that rock art reflects the adaptation of populations to this aridity with the increase in the theme of dromedaries, which are often represented in herds or caravans in many rock art sites, whether in Somaliland or Djibouti.

Laas Geel and the Rock Art of Somaliland

Most of the mountainous regions of Somaliland with rock walls are very rich in sites with mono- or polychrome paintings and, for a more recent period, numerous engravings representing mainly dromedaries. There is not enough data to know the extent of these graphic manifestations to the east (Puntland region). Indeed, northern Somalia is very likely part of this continuity, but the reliefs of this region, which contain many natural cavities, remain largely unknown to archaeologists.

In Somaliland, these paintings or engravings are found under more or less deep rock overhangs. Among these, we must mention the most important in terms of the number of figures and state of conservation: the site of Dhagax Kure, near Arabsyio, that of Dhambalin 50 km southeast of Berbera, discovered by Mohamed Abdi Ali and described by Sada Mire (Mire 2008), the small shelters under the blocks of Dhagax Nabi Galay, close to Laas Geel, the engraved rock block of Dhagax Maroodi, near Gabiley, the shelter of Karin Heegan near Laasgoray. These sites contain paintings, most of which can be linked to the Laas Geel style. This style is therefore well present from east to west in Somaliland. A few years ago, in the Chercher mountains in Ethiopia, more than 400 km southwest of Laas Geel, a survey mission identified a new site where cows are painted in the Laas Geel style. This is the site of Dagah Afandera, near Gelemso (Assefa et al., 2014). This discovery significantly extends the area of this style, which now occupies almost the entire Somaliland and extends southwest into Ethiopia.

The Inselberg of Dhagax Kure

The Dhagax Kure inselberg is located 43 km west of Hargeisa. To reach it, you must travel 28 km along the Borama road and then, just before Arabsiyo, take a northern track for about 15 km to reach the site—a vast granite chaos where very large, balanced boulders form shelters. It is an inselberg emerging from an eroded plateau, 3 to 4 km long and 2 to 500 m wide. From the mass of enormous boulders that compose it, several large granite pinnacles stand out, rising several tens of meters and inhabited by hamadryas baboons and frequented by numerous gazelles.



Fig. 28: *overview of Dhagax Kure.*

The highest of these formations features a narrow passage at its upper part, separating the main mass of the pinnacle from its rounded summit, giving rise to the place name: "the stone shaped like a head." Six shelters—chambers or passages formed beneath the boulders—have been identified, along with two rocks bearing more recent signs or figures.

Shelter 1 is the one that yielded the most significant collection of paintings. It is located on the northern flank of the inselberg and is the first shelter visited when starting a walking route from the guardian's house, situated west of the ridge. Shelters 2 and 3 are very close to Shelter 1 and contain several cattle figures in the Laas Geel style. At the eastern end of the inselberg is Shelter 4, locally known as the "Lion's Cave," where a group of superimposed cattle belonging to various styles later than Laas Geel can be seen. To reach Shelter 4, you must return to the guardian's house and take the right-hand track heading west, or walk along the northern slope of the inselberg.

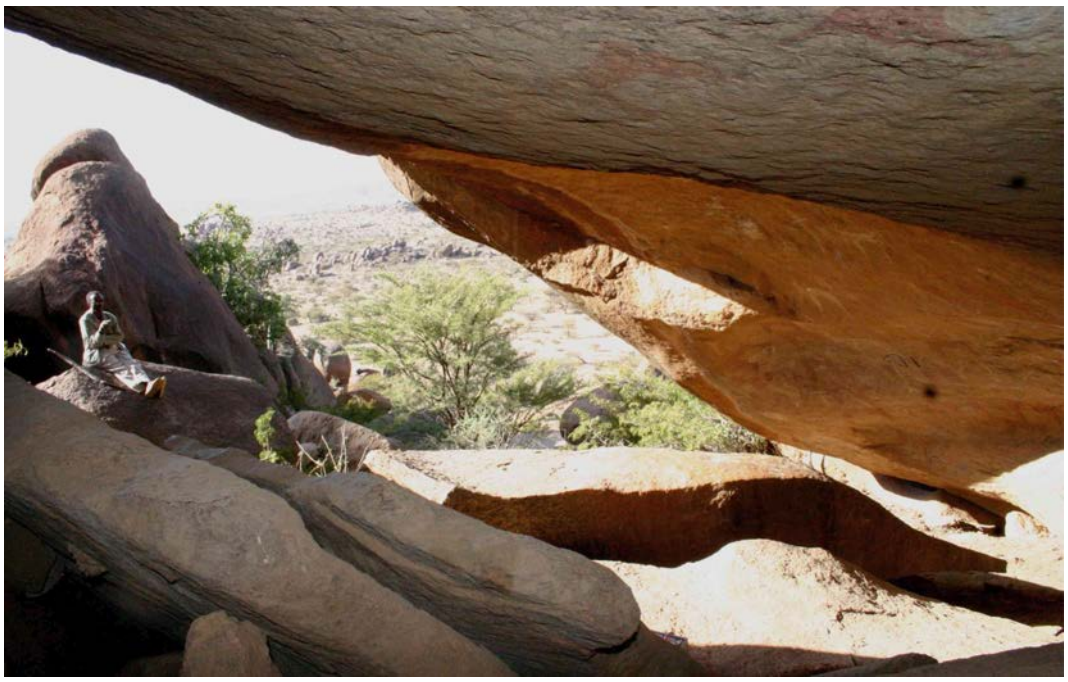


Fig. 29: *Dhagax Kure shelter 1.*

Shelter 1 consists of a huge collapsed boulder, tilted to form a roof over a pile of large, semi-buried fallen slabs. The steep wall of this large boulder is adorned with a beautiful ensemble of over 60 large cows in the Laas Geel style, accompanied by 23 other figures, including 14 anthropomorphic ones. This is the richest and most orderly composition of cows known in Somaliland. One might imagine the depiction of a herd on the move, as they all face the same direction.



Fig. 30: details of the painting in shelter 1.

A detailed study of the morphology of the cattle figures in Shelter 1 at Dhagax Kure revealed some unique features rarely found at Laas Geel: for example, round heads painted at the end of slender necks, or the udders of cows placed very low on the hind leg. A well-represented group of white cattle, lacking udders and sometimes featuring a slight protrusion under the belly that could be interpreted as a sheath, could be identified as bulls. These presumed male cattle all have long, straight, wavy horns pressed against their dewlaps. In addition to these cattle, other animal figures include a rare group of 3 or 4 red giraffes with all four legs clearly visible. One of them partially covers the body of a cow in the Laas Geel style, indicating that they are more recent. Some tribal marks and inscriptions, mostly drawn in charcoal, partially cover these figures.

Shelters 2 and 3 at Dhagax Kure are located a short distance from Shelter 1, but the path to reach them is not easy to find, and it is necessary to be accompanied by a guardian or an experienced guide. These two shelters are smaller than Shelter 1 but contain several figures of cows and human-like figures in the Laas Geel style that deserve attention.

Finally, Shelter 4, known as the "Lion's Cave," located at the western end of the inselberg, is particularly interesting because it features a group of cattle painted in red or brown ochre, superimposed and mostly belonging to styles other than Laas Geel, with massive forms, thick legs, and in at least two cases, a dorsothoracic hump. For these last two cattle, they are undoubtedly zebu, which means we are projected into a period later than the 3rd millennium BC. The humped ox (Bos taurus indicus), commonly known as zebu, was not introduced to the region before the second half of the first millennium BC. There is therefore at least a millennium separating the time when these animals were painted from the earlier period when the cows and anthropomorphic figures of the Laas Geel style were depicted.

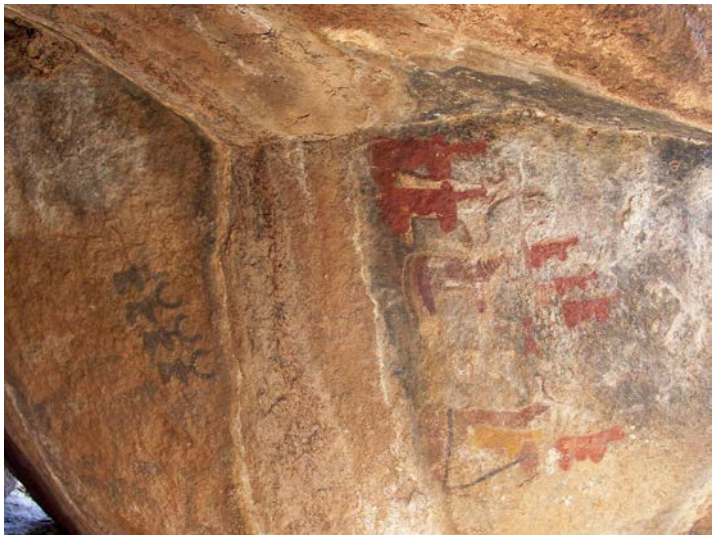


Fig.31: s*helter 4 Dhagax Kure.*

To the left of this panel, there is a superimposition of 4 humped cattle, painted in black, with regular pincer-like horns. Again, we find ourselves in a stylistic universe widespread in the Horn of Africa from the mid-1st millennium BC.

Dhambalin, the Shelter of the Fat-Tailed Sheep

To visit, it is absolutely necessary to be accompanied by a guide who knows the route perfectly, leading from Berbera along sandy or stony tracks to the foot of this site. It takes about an hour and a half to two hours to reach it. It is located 50 km southeast of the port city, in a remote area far from any settlement. Discovered in 2007 by Mohamed Abdi Ali, the shelter was the subject of a preliminary publication (Mire, 2008). Our team conducted two successive missions there in 2019 and 2025, which allowed for a comprehensive recording of the many paintings adorning its wall. From a distance, you can see a sandstone ledge, forming a sort of long shelter, standing out in the plain to the south of the track, hidden behind a large inselberg. It measures about forty meters long and ten meters high. The main group of paintings is located near the eastern end of the shelter, at the back to the left when facing the wall.

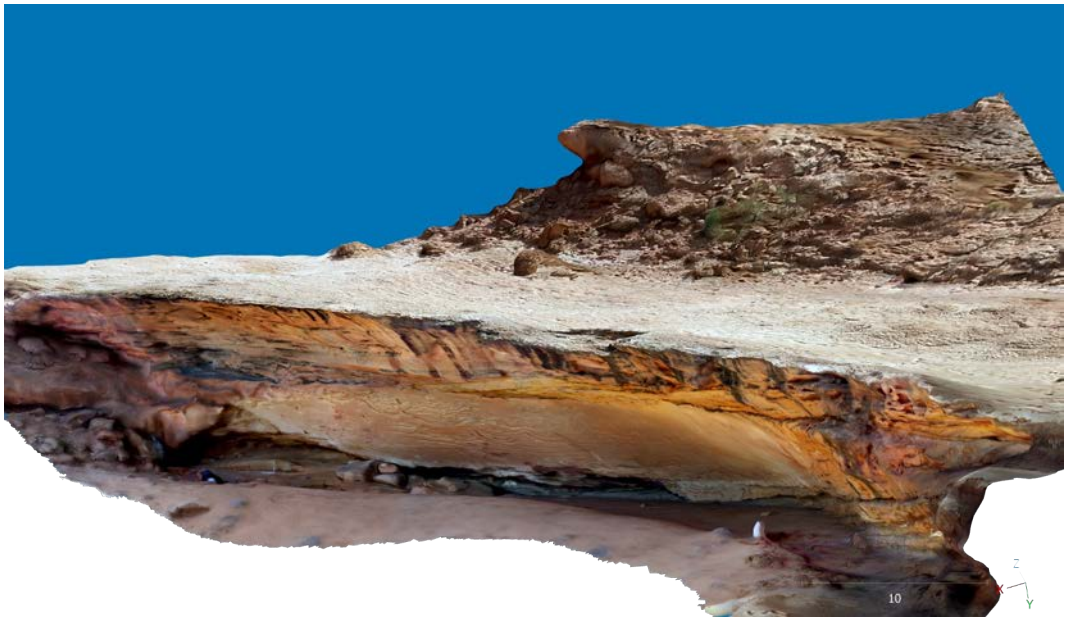


Fig. 32: *overview of Dhambalin shelter.*

A few meters to the west, returning toward the access path, there is a small panel of cattle, and further on, several more or less isolated and often poorly legible paintings spread over several meters. At the foot of the painted wall, the ground consists of sand from the degradation of the sandstone and is strewn with blocks that have fallen from the rock wall.

In addition to the presence of many painted cattle that are not depicted in the Laas Geel style, the uniqueness of the site, so far unparalleled in Somaliland, lies in the realistic depiction of fat-tailed sheep. Also represented are goats, dogs, and many wild animals (baboons, antelopes, giraffes, ostriches, snakes, tortoises). A wide variety of colors were used: white, various ochres ranging from light brown to red, black, and gray. About ten anthropomorphic figures, sometimes associated with dogs, are equipped with bows and arrows. Some of them appear to wear head ornaments.



Fig. 33: *details of the cows and fat-tailed sheep at the Dhambalin shelter.*

This site, set in a quasi-desert landscape of real beauty, offers a collection of high-quality painted figures. It also allows us to recognize artistic criteria that differ from those defining the Laas Geel style. It is likely that we are in a period later than the one that saw the flourishing of the Laas Geel style throughout the territory of present-day Somaliland. However, it should not be forgotten that the identification of the stages in the evolution of rock art in the Horn of Africa still suffers from the scarcity of isotopic dating (carbon-14 method). To advance in this direction, we can hope that the pigment samples taken from these sites by archaeologists will reveal, even in very small quantities, organic matter that was sometimes associated with mineral colorants to give them lasting consistency. The presence of this matter would indeed allow the application of the carbon-14 method and thus provide valuable indications about the age of these paintings.

Many Other Rock Art Sites Throughout the Country

A census of rock art sites published in 2015 by Dr. Sada Mire listed 25, but this number continues to grow with new discoveries. It is estimated that there are about fifty rock art sites in Somaliland. Archaeologists therefore have significant work ahead in terms of prospecting, recording, and interpreting these little-studied or unstudied sites. Their protection also requires the state to strengthen its capacities in the study, safeguarding, and enhancement of this exceptional cultural heritage, which provides irreplaceable insights into the very ancient history of Somaliland.



Fig. 34: *Dhagax Marodi: Large cow engraved in the Laas Geel style.*

This objective cannot be achieved without international aid, which remains largely insufficient. In the current state, it would not be prudent to facilitate access to this fragile heritage outside of the few sites that have already benefited from appropriate development and permanent monitoring. However, with the regulated and guided visits to the extraordinary site of Laas Geel, and the possibility of visiting the Dhagax Kure site, which is also monitored, a first step has been taken to the great satisfaction of visitors. There is also a risk that the uncontrolled use of social media could publicize these fragile sites, making them vulnerable to all kinds of depredations. Excessive visitation of rock art sites has already led to the near-complete disappearance of remarkable and rare paintings in other regions of Africa.

Glossary:

- **Rock Art:** The term rock art (from the Latin rupes = rock) refers to all paintings, engravings, or sculptures made by humans on rock walls or isolated rock blocks.
- **Bovids, Bovines:** Bovids are herbivorous ruminants with hollow horns, forming a family that includes bovines (bison, aurochs, taurine cattle, zebu) as well as antelopes, gazelles, goats, and sheep.
- **Carbon-14 Dating:** Carbon-14 dating is a method that determines the age of organic materials (wood, bone, charcoal, etc.) by measuring the amount of radioactive carbon-14 they contain, to estimate the time elapsed since the organism's death.
- **Indirect Dating:** Consists of estimating the age of an object or event through associated evidence.
- **Common Era:** A system used to count the years elapsed since the supposed date of Christ's birth, without reference to any religion.

- **Fanon:** This term was chosen to designate the piece that seems placed on the neck of the Laas Geel bovines and is often decorated. The same term is used in anatomy to designate the more or less wide fat rolls that hang along the neck in certain bovine breeds. It can also refer to a piece of fabric suspended and deployed at the end of a lance.
- **Inselberg:** An isolated hill in the middle of an erosion plain.
- **Tribal Mark:** A distinctive sign specific to a clan, tribe, or traditional community.
- **Metamorphic Rock:** Rocks transformed under the action of heat and pressure.
- **Neolithic:** A stage in the evolution of human societies during which a production economy (livestock farming, agriculture) appears.
- **Rift:** A rift is a zone of stretching of the Earth's crust where two continental plates move apart, causing fractures and volcanism.
- **Realistic Style:** In rock art, the realistic style refers to a way of representing subjects (human or animal) faithfully to reality (details, proportions, movement).
- **Schematic Style:** In rock art, the schematic style refers to a way of representing reality in a simplified, abstract, and codified manner, reducing forms to their essential elements rather than seeking visual realism. It can be contrasted with the naturalistic style, where attention is paid to movement, proportions, and certain anatomical details.
- **Tafoni:** A cavity formed naturally by erosion, due to wind, water, and salt.

Appendix 2

Text for 3 panels Leaflet

The illustrations used are the same as those in the guide.

Front

The Laas Geel site was discovered in December 2002 during a French archaeological research mission in Somaliland.

More than 20 rock shelters adorned with polychrome paintings primarily depicting domesticated cows and human-like figures with outstretched arms, the anthropomorphic figures.

Laas Geel belongs to a very early period of rock art in the Horn of Africa, dating back approximately 5,000 years. This is the era when domesticated animals (cattle, goats, sheep) first appeared in this region of Africa.

The populations, who had lived by hunting, gathering, and fishing since their origins, became livestock herders.

This art illustrates the mindset of these very ancient societies.

Other rock art sites have been discovered in Somaliland.

The style of the Laas Geel paintings is often present, but there are also several painted groups in different styles that relate to more recent periods.

Somaliland is now considered one of the most important centers of African rock art.

Back.

Reverse side In Shelter 1, the figures are dense and remarkably fresh, featuring cows of various shapes and coat colors, around which the anthropomorphic figures seem to float.

The partially effaced figures in Shelter 2 are arranged on a high wall.

On the right, the red cow with a dewlap striped with white bands has become the most famous of the site. It is impossible not to notice the large red cows in Shelter 3.

They appear to be suspended in mid-air. Shelter 4 features several large Laas Geel-type cows, but their interpretation is difficult because the wall is largely covered with a calcite encrustation.

The next shelter, Shelter 5, is a small, inaccessible niche. Two bovine figures can be seen from a distance.

Shelter 6 is more difficult to access. It contains the only giraffe figure on the Laas Geel rock, as well as a small group of antelopes.

Above the path, in Shelter 11, among the bicolored cows, a richly decorated dewlap stands out, resembling a piece of fabric suspended from the animal's neck.

The visit concludes with Shelter 10, spectacular for the intricate arrangement of its paintings and their polychromy. A keen eye can discern rare traces of green paint.

These paintings are fragile. Do not touch them with your hands or any other object.

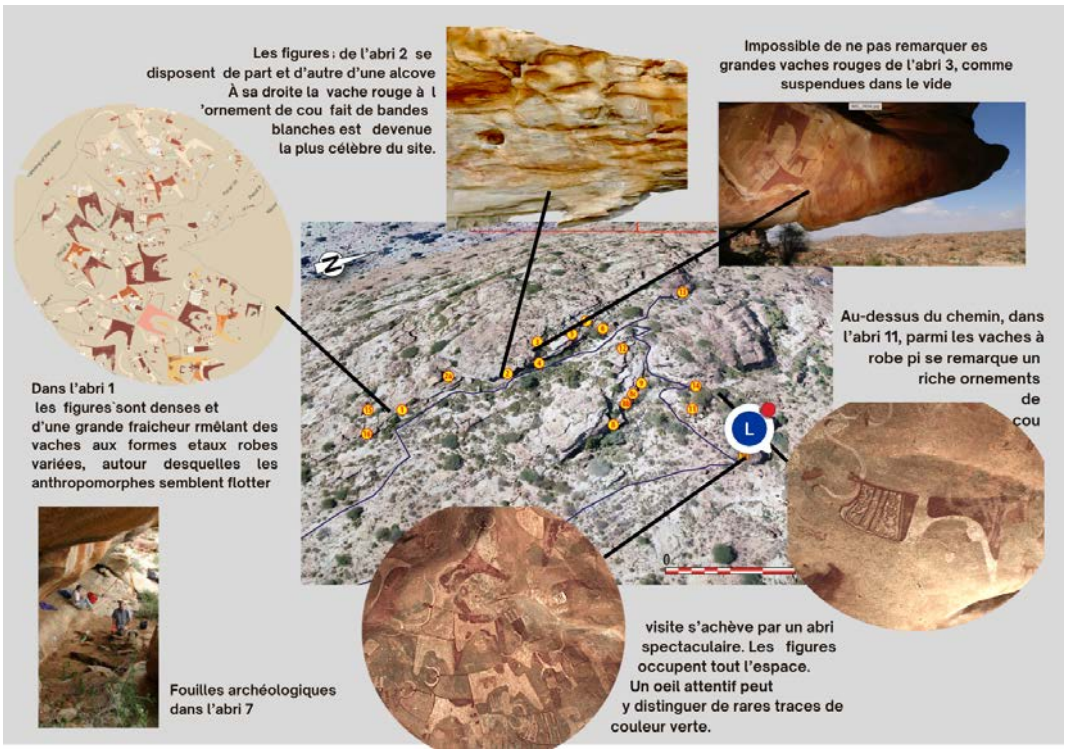
Do not rub your bags or clothing. Groups are limited to 10 people and must be accompanied by a licensed guide. Eating and smoking are prohibited on the tour route, as is littering.

Only water bottles are permitted and must be taken away once empty.

Do not leave anything behind on the site. Photography is permitted for strictly personal, non-commercial use.

Proposed layout for the 3-panel Leaflet





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LAAS GEEL

Rock Art of Somaliland



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Les figures en partie effacées de l'abri 2 se disposent de part et d'autre d'une alcove À sa droite la vache rouge à l'ornement de cou fait de bandes blanches est devenue la plus célèbre du site.



Impossible de ne pas remarquer es grande vaches rouges de l'abri 3, comme suspendues dans le vide







Dans l'abri 1
les figures sont denses et d'une grande fraicheur rmêlant des vaches aux formes etaux robes variées, autour desquelles les anthropomorphes semblent flotter

Au-dessus du chemin, dans l'abri 11, parmi les vaches à robe pi se remarque un riche ornements de cou





Fouilles archéologiques dans l'abri 7



La visite s'achève par un abri spectaculaire. Les figures occupent tout l'espace. Un oeil attentif peut y distinguer de rares traces de couleur verte.

Appendix 3

Proposal for a layout for a tourist flyer mainly intended for visitors to the site

Front

The Laas Geel site was discovered in December 2002 during a French archaeological research mission in Somaliland.

Over 20 rock shelters are adorned with polychrome paintings, primarily depicting domesticated cows and human-like fig ures with outstretched arms, known as anthropomorphs.

Laas Geel belongs to a very ancient period of rock art in the Horn of Africa, dating back approximately 5,000 years. This was the tim e when domesticated animals (cattle, goats, and sheep) first appeared in this region of Africa.

Populations that had lived by hunting, gathering, and fis hing since ancient tim es became livestock herders.

This art illustrates the mental universe of these very ancient societies.

Other rock painting sites have been discovered in Somaliland.

The style of the Laas Geel paintings is often present there, but there are also several painted ensembles of different styles that date from more recent periods.

Somaliland today appears as one of the most important centers of African rock art.

Back

In Shelter 1, the fig ures are dense and remarkably fresh, mixing cows of various shapes and coat colors, around which the anthropomorphs seem to flo at.

The partly erased fig ures in Shelter 2 are arranged on a high wall. On the right, the red cow with a dewlap striped with white bands has become the most famous fig ure at the site.

- Shelter 6 is more difficult to access. It features the only giraffe fig ure at Laas Geel, as well as a small group of piece of fabric hanging from the animal's neck.

- The visit ends at Shelter 10, which is spectacular for its intertwined paintings and polychromy. A keen eye can distinguish rare traces of green paint.

- These paintings are fragile. Do not touch them with your hands or any other object. Do not rub your bags or clothing against them. Groups may not exceed 10 people and must be accompanied by an authorized guide.

Eating and smoking are prohibited along the visiting route, and littering is not allowed.

Only water bottles are permitted and must be taken away once empty. Leave nothing on the site.
Photography is allowed for strictly personal and non-commercial use.

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