Understanding the past, Protecting the future: A study on the preservation of petroglyphs created by the indigenous people of Guadeloupe

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Cover: Diversity of petroglyphs in the Parc Archéologique des Roches Gravées in Guadeloupe. Several petroglyphs representing rock art in Guadeloupe can be seen on this rock named *"La Tortue".* Recognizable are geometric patterns and faces of people and animals (A. Dekker, 2023).

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1. Introduction

1.1 Context

Rock art are images and symbols created on natural rock surfaces (Jönsson Marquet, 2002, p. 1). They represent one of humanity's earliest forms of artistic expression. This type of art includes different techniques and materials, such as painting, engraving, carving and drawing depending on the location and period in which they were made (Dubelaar, 1995, p. 3). Petroglyphs are one of the types of rock art in which engravings are made on natural rock surfaces using techniques such as pecking, grinding, sanding and scratching (Dubelaar, 1995, p. 3). The images range from abstract patterns to detailed depictions of people, animals and symbols. They are not only noteworthy for their aesthetic value, but also for their connection to the places where they were created and for the meaning given to them by indigenous people (Denyer, 2006, p. 1).

Figure 1.1.1. Map of the greater Caribbean Archipelago. This map shows all the islands of the Caribbean Archipelago and the surrounding continental mainland, with a special focus on the islands of the Lesser Antilles on the right side (M. J. LeFebvre et al., 2018).

An archipelago which is known for its rich concentration of petroglyphs is Guadeloupe, located in the Lesser Antilles in the Caribbean (Figure 1.1.1). One of Guadeloupe's most famous petroglyphs is located in the southern island of Basse-Terre in the municipality of Trois-Rivières. This petroglyph, nowadays knows as one of the *"roches caraïbes"*, was discovered at the beginning of the 19th century and quickly attracted the attention of scientists and the general public. In 1901 this rock was removed from its original location and brought to the United States. There it was

exhibited at the Pan-American Exposition in Buffalo (Delpuech, 2021, p. 18), before arriving in its final place at the American Museum of Natural History in New York (Delpuech, 2021, p. 22). The relocation of the rock highlights the global cultural significance of the petroglyphs of Guadeloupe.

However, this international recognition also raises questions about the repatriation of cultural heritage. In the current era, where the restitution of cultural artifacts is receiving increasing attention, it would be appropriate for this valuable petroglyph to return to its original place in the park of the engraved rocks of Trois-Rivières (Delpuech, 2021, p. 30). Clottes (2008, p. 2) argues that rock art is part of the historical landscape and that you cannot see it in isolation if you want to understand its original context. Therefore, rock art should remain in its original location.

Guadeloupe's climate plays a role in the conservation challenges facing these petroglyphs. The islands have a tropical climate with high temperatures and significant rainfall, creating dense vegetation and varied relief. This climate, combined with frequent hurricanes that sweep across the island, poses a significant threat to the integrity of petroglyphs (Rad et al., 2013, p. 333). Moreover, the direction and location of the rock affects its weathering, further complicating conservation efforts. Natural factors such as weathering, vegetation growth and erosion, along with human-caused threats such as rock displacement and uncontrolled tourism, exacerbate the risks to these petroglyphs (Agnew et al., 2015, p. 20). Effective conservation strategies must address these multifaceted threats to ensure the preservation of Guadeloupe's petroglyphs. Recent global studies (Monney, 2022 [2008], p. 3; Zerboni et al., 2022, p. 18) claim that improving conservation methods extends the life span of historic sites.

There has been significant archaeological research in Guadeloupe over the years. Early studies by researchers such as Breton (1665), Langin (1848), Guesde (1884) and Hamy (1902) laid the foundation for our understanding of the petroglyphs of Guadeloupe. Subsequent studies by Froidevaux (1920), Merwart (1922), Bouge, Bassette (1984), Dubelaar (1995), Petitjean Roget (2009), and Richard (2009), among others, have contributed to a comprehensive inventory and analysis of these petroglyphs (Monney, 2020, p. 674). However, these studies have focused primarily on the documentation and cultural significance of the petroglyphs. Relatively little research has been done on the best conservation strategies for these valuable artifacts. This research gap represents a significant gap in current scientific knowledge. By addressing this gap, this research aims to provide a comprehensive understanding of the current state of petroglyphs, examine their potential threats, and develop and recommend conservation strategies.

1.2 Scientific and Societal Relevance

The societal impact of this research is multifaceted. First, it promotes the cultural awareness and identity of local communities by highlighting the island's rich historical and cultural heritage. By making this knowledge available, communities are encouraged to appreciate and protect their heritage. Moreover, preserving this cultural heritage can stimulate tourism, providing economic benefits while educating and engaging the public (Duval et al., 2018, p. 12). The urgent need for a sustainable conservation program is highlighted by current challenges in conservation management. At the beginning of the 21st century, it was determined that more than 35 engraved rocks have disappeared since their discovery, due to natural phenomena such as hurricanes and floods, as well as human activities such as theft (Monney, 2022 [2008], p. 3).

Successful examples of sustainable management strategies for petroglyph sites in the Americas, including Puerto Rico and the United States demonstrate the potential for the global application (Landon & Brent Seales, 2009; Wright, 2018). These strategies not only protect petroglyphs, but also preserve the integrity of the natural and cultural landscapes in which they are located.

My personal interest in this subject, which is conservation and preservation of petroglyphs with a preference for Guadeloupe, was sparked during a June 2023 visit to three archaeological petroglyph sites in Guadeloupe: Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou. Conversations with Susana Guimarães, the archaeological curator at Musée Edgar Clerc and Parc Archéologique des Roches Gravées, revealed the challenges of preserving the petroglyphs. The decision to stop cleaning the petroglyphs to prevent further damage (S. Guimarães, personal communication, June 28 2023), as confirmed by Haviser and Strecker (2006, p. 51), inspired me to explore management strategies more deeply. Cleaning can cause damage by wearing down the rock surface and exposing the engravings to further weathering, but can also flush the rock clean of minerals that may accumulate on the rock due to weather conditions. So a trade-off must always be made in which preservation strategy is best at the time. Cleaning is thus among the ways in which damage can be done or, on the contrary, to prevent damage. Besides cleaning, there are many other methods of conservation that are debatable. This has led to questions about the sufficiency of current preservation practices, the risks to which petroglyphs are exposed and the possibility of developing alternative methods that keep the visibility of petroglyphs intact.

1.3 Research Questions

The primary objective of this study is to effectively manage the risks and protect the petroglyphs created by the indigenous people of Guadeloupe, with a focus on three specific petroglyph sites; Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou. The research aims to develop sustainable management strategies that both preserve the cultural integrity of these petroglyphs and ensure their accessibility to future generations.

The central research question guiding this study is: *How to effectively manage human and natural hazards that threaten petroglyphs created by the indigenous people of Guadeloupe in Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou be effectively managed to ensure both their protection and sustainable management for future generations?*

This central question is further divided into several sub-questions to better understand the influences and activities that threaten the petroglyphs:

1) *What natural influences and human activities affect the physical integrity of petroglyphs in Guadeloupe?*
2) *How have successful conservation strategies for rock art been applied across the Americas?*
3) *Which conservation methods are most effective for petroglyph sites in Guadeloupe, considering (potential) threats and strategies already implemented?*

The research focuses on the conservation of petroglyphs in Guadeloupe, with the aim of formulating recommendations for sustainable conservation strategies suited to the needs of the sites. This research not only hopes to contribute to the broader discussion on the management and conservation of archaeological sites worldwide, but also advocates for targeted efforts at the selected archaeological sites. The overall goal is to ensure the conservation of Guadeloupe's indigenous cultural heritage by proposing sustainable management strategies and connecting local engagement with global best practices.

1.4 Methodology

The methodology for this study outlines the methods used to address the complexity of conservation issues concerning petroglyphs in Guadeloupe. It combines visual and literature analysis with field research to provide a holistic understanding of both the current state of the petroglyphs, their potential threats, and viable conservation strategies to answer the central research question and sub-questions.

Data collection methods

1) The visual approach includes photographic documentation taken during my visit to the archaeological sites in June 2023. Photographs were taken from various positions along the designated paths, which sometimes meant taking photos from below, above, directly in front of, or from the side of the petroglyphs. The primary aim of these photos was personal archival, which introduces certain limitations. The scale is not visible in the images due to the photos' original purpose. During the visit, I recorded observations of the petroglyphs' condition, including damage, physical state, vegetation presence, and site management practices. Historical references, such as Dubelaar's (1995) inventory and recent research by Delannoy et al. (2022), provide a basis for comparison. By comparing these historical images with recent photograph and observations, I identified recent and long-standing damage, offering insights into the progressive nature of erosion and other forms of degradation over time.

2) Fieldwork was conducted in June 2023, involving direct observation and recording of the petroglyph sites. This included detailed notes on the site's conditions, and visible signs of deterioration or threats. Constraints such as weather conditions and access limitations were noted to acknowledge potential biases or gaps in data collection. The fieldwork, initially not intended for this research, presents limitations due to incomplete focus on certain weathering forms or specific damage variances among rocks. Visits included:

    - Afternoon of June 20, 2023: Anse des Galets
    - Morning of June 28, 2023: Parc Archéologique des Roches Gravées and Capesterre Petit-Pérou

    At Parc Archéologique des Roches Gravées, fieldwork consisted of walking through the park in the company of a staff member, stopping at each petroglyph to have a discussion on it and taking photographs. At Capesterre Petit-Pérou, the guide (Guimaraes, conservator Parc Archéologique des Roches Gravées) provided information about the site. At Anse des Galets, where we looked for petroglyphs without a guide, we relied on the information board and our own vision. This limited our ability to ask questions or be directed to specific features. For example, *"Femme des Galets"* was not noticed during our visit despite being depicted on the information board (see infra § 3.2.2).

3) The methodology includes analyzing natural and human-caused threats such as biological and chemical weathering and erosion, to understand the long-term impact this will have on petroglyphs in Guadeloupe (Delannoy et al., 2022; Delpuech, 2021; Dubelaar, 1995; Mazière and Mazière, 2022 [1998]; Rad et al., 2013; Richard & Petitjean Roget, 2006; Rad

et al. (2013)). Additionally, climate information about Guadeloupe highlighted how the tropical climate fosters rapid weathering and biological growth, and how climate change might accelerate these processes.

4) A comprehensive literature review forms the basis for studying conservation strategies. Sources were selected based on their relevance to rock art conservation, focusing on peer-reviewed articles, hardcopy books from the Leiden University's library, online books, archaeological reports and case studies. Key search terms included "rock art preservation", "petroglyph conservation", "Guadeloupe archaeology", and the names of the specific archaeological sites. I primarily accessed literature by starting with key literature and examining their references and in-text citations for additional relevant sources. This review substantiates the study's findings and recommendations by examining successful conservation strategies from other regions.

1.5 Structure of Chapters

Each chapter contributes to the overall aim of the research; which is to create effective and sustainable strategies for safeguarding the petroglyphs made by the indigenous people of Guadeloupe. The research is outlined as follows:

The first chapter is the introduction to the subject of the research. It provides an overview of the context of rock art in Guadeloupe, emphasizes the importance of petroglyph conservation, and introduces the methodology and theoretical framework applied in the rest of the research.

The second chapter introduces the context of rock art in Guadeloupe, focusing on the origins, historical and cultural significance, and contemporary role of petroglyphs in society. It includes an introduction on the presence of petroglyphs in the Caribbean, a detailed description of the archaeological sites in Guadeloupe with attention to their unique characteristics and the significance they have for the original population as local communities and scholars.

Chapter three describes in detail the three selected petroglyph sites - Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou - followed by an analysis of both natural and human risks that threaten the petroglyphs. How these risks affect the physical integrity and accessibility of the petroglyphs is discussed.

The fourth chapter presents an overview of sustainable management strategies implemented on different petroglyph-sites in the Americas and other continents through case studies that reflect relevant lessons and practices. Based on the risk analysis from chapter three and the comparative

analysis of the case studies, site-specific strategies against natural and human risk are proposed to manage petroglyphs in Guadeloupe.

Chapter five provides the opportunity for critical reflection on the research results. Discussion points include the interpretation of the findings, the methodological limitations of the study, and the validity and reliability of the results. Next, an idea for future research is presented.

The conclusion, which is provided in chapter six, summarizes the main findings of the study. The effectiveness of the proposed management strategies is assessed and the research questions are answered. It also reflects on the research's contributions to the field of heritage conservation and the broader implications for similar archaeological sites worldwide.

Finally, the abstract is presented which can be read in three different languages: English, French and Dutch.

2. Petroglyphs in Guadeloupe

2.1 Introduction

This chapter provides background information on the petroglyphs in Guadeloupe. It focuses on the first people in the Caribbean archipelago and the dating of petroglyphs in Guadeloupe. It then gives a summary of the several petroglyph locations that may be found in Guadeloupe. The discussion that follows centers on the historical and cultural significance of petroglyphs, drawing on the interpretations of Delpuech (2021), Lenik (2007), Richard (2009), Petitjean Roget (2001; 2009), and myself. Finally, the contemporary role of petroglyphs in Guadeloupian society is examined. In order to comprehend the context of petroglyph sites and the necessity of risk analysis in Chapter 3, a thorough grasp of the value of petroglyphs is provided by this description.

2.2 Origin of Petroglyphs in the Caribbean Archipelago

The first traces of human presence in the region were found in Trinidad and Tobago[1]. One important find is a spearhead, suggesting that people have lived on the current island since the Paleo-Indian era. During this period, Trinidad was still connected to the South American mainland by a land bridge. Around 7000-6000 B.C., the land bridge disappeared due to sea level rise and then never returned (Hofman & Hoogland, 2018, p. 34). The earliest documented habitation of the Lesser Antilles occurred later during the Archaic Age, from about 6000-4000 B.C. to 100 A.D. (Hofman & Hoogland, 2018, p. 37). These early inhabitants were mainly hunter-gatherers who lived along the coast and engaged in fishing and collecting shellfish, as evidenced by archaeological finds of hooks made from bones and teeth (Hofman & Hoogland, 2018, p. 38; Keegan & Hofman, 2017, p. 200).

Early settlements in the Caribbean show a gradual cultural development. The Early Ceramic Age (ca. 800/400 B.C. to 600/800 A.D. (Hofman & Hoogland, 2018, p. 37)) followed the Archaic Age. During this period, Saladoid peoples migrated to the Caribbean from northeastern South America. These migrants introduced new agricultural techniques and made clever use of the land. The Saladoid culture is additionally characterized by specific pottery styles such as "white-on-red" painted ware (Hofman & Hoogland, 2018, p. 45; Keegan & Hofman, 2017, p. 210). This people soon spread throughout the Caribbean islands, establishing social and trade networks that reached across the Lesser Antilles to Puerto Rico (Hofman & Hoogland, 2018, p. 44). These

[1] Use Figure 1.1.1 to reference the location of these and other islands in te Caribbean Archipelago.

migrations were driven by a combination of quests for new farmland and the need for social bonding and exchange, which were facilitated by the varied ecology of the islands and the variety of resources scattered across them (Hofman & Hoogland, 2018, p. 34).

The dating of petroglyphs specifically is challenging among scientists due to the circumstantial character of the available evidence (Hayward et al., 2013, p. 492). This complexity is underscored by different approaches and findings as described by Hayward et al. (2013, p. 492) and Monney (2020, p. 681). To achieve accurate results, scientists rely on indirect methods. Monney (2020, p. 681) bases his assumptions on surface finds from nearby settlements on Marie-Galante around 2,500 B.C., which allows him to speculate that the rock art on Guadeloupe can be attributed to the period between 300 B.C. to 1,200 A.D. Based on this time period, the creation of rock art probably began during the Early and Late Ceramic Age (Hayward et al., 2013, p. 492), but cannot be attributed to a specific indigenous people group.

2.3 Location, Characteristics, and Notable Features

In Guadeloupe, nearly 1,200 pre-Columbian petroglyphs have been found over the years distributed among 27 different sites (Richard, 2009, p. 137). In addition, the archipelago of Guadeloupe has a growing number of rock art sites—more than 380 in 2019 compared to 210 before the start of the 21st century (Monney, 2019, p. 2). Compared to neighboring islands like Dominica and Martinique, where only one or three sites have been documented, this constitutes more than fifty percent of all rock art sites found in the Lesser Antilles (Dubelaar, 1995, p. 25).

Main locations

Most petroglyphs are concentrated in the south of the island of Basse-Terre, at the base of volcano La Soufrière (see Figure 2.3.1). The municipality of Trois-Rivières contains the most engraved rocks, which is why it has been declared by Petitjean Roget and Richard (2005, p. 61) as "the capital of rock art of the Lesser Antilles." The most prominent site in this municipality is the Parc Archéologique des Roches Gravées. This park is home to one of the most impressive collections of rock art in the Caribbean with a collection of 142 rocks containing 623 petroglyphs (Ruig, 2022 [2000], p. 5). Whereas petroglyphs are distributed throughout the island in clear concentrations, this is not the case in Trois-Rivières. Site boundaries are difficult to map because the rocks are less than 500 meters apart (Monney, 2020, p. 679). According to the United Nations Educational, Scientific and Cultural Organization [UNESCO], all engravings that are less than 500 meters apart belong to a single site. However, for the Trois-Rivières region, I believe an exception can be made,

as there are hundreds of rocks, and these form their own separate sites in clusters with stones that are much closer to each other.

In addition, the sites in Trois-Rivières and Capesterre are known not only for their engravings, but also for the presence of round grinding stones, which often are identified as rocks used by indigenous peoples for sharpening their tools. Perrot-Minnot (2016, p. 18) indicates that there is no clear evidence for this function, however, so their exact use remains subject to speculation. These grinding stones have been found not only in Guadeloupe, but also in other parts of the Caribbean, including Martinique (Perrot-Minnot, 2016, p. 30), St. Lucie and Granada (Jönsson Marquet, 2002, p. 172) (see Figure 1.1.1).

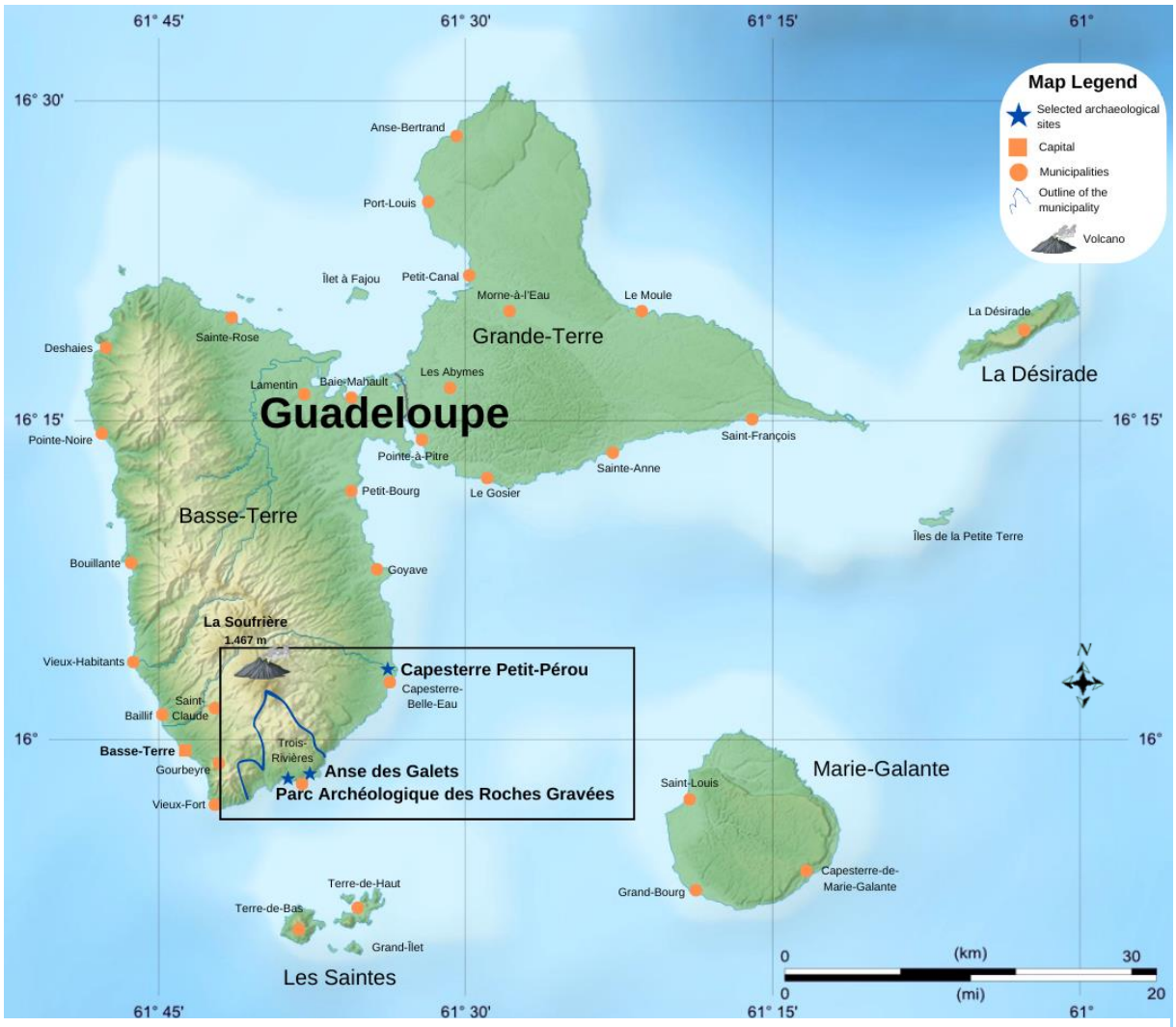

Figure 2.3.1. Map of Guadeloupe. This map shows the locations of the three petroglyph sites Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou on the island of Basse-Terre in Guadeloupe. Also shown are the municipalities, capital, volcano and the outline of the municipality of Trois-Riviéres (A. Dekker).

The significance of rock art is not appreciated or understood by all human-beings. Ruig (2022, [2000]) conducted a thematic prospecting campaign between 1998 and 2000 in which the rock art of southern Basse-Terre was accurately identified. During the fieldwork, Ruig (2022 [2000], p. 5) observed that in the municipality of Trois-Rivieres, 47 rocks with petroglyphs previously documented by Gilbert (1995) and Dubelaar (1995) were no longer present at or around the documented site, and another 10 rocks that were in a different location than where they were previously found. One reason for this may be that rocks were not found due to low visibility because of vegetation growth, but it cannot be otherwise that some of these have disappeared and others have been relocated, making it clear that large amounts of rock art are being lost in a relatively short period of time, due to inadequate management.

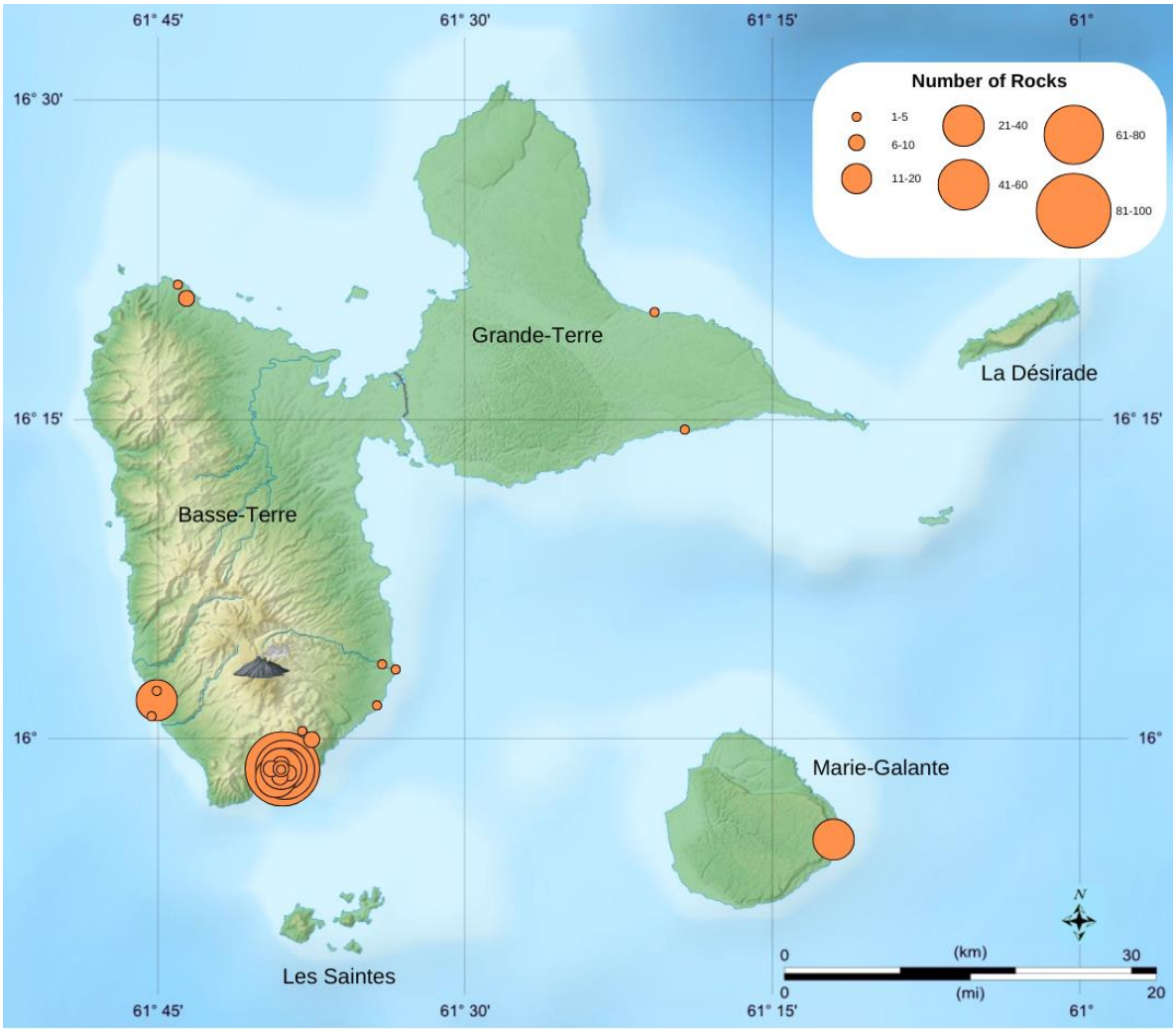

Figure 2.3.2. Map with the distribution of rock engravings on the islands of Guadeloupe. The map shows the geographic distribution of rock engravings on Guadeloupe, with the size of the circle corresponding to the number of documented rocks. The map shows the high concentration in the southern municipality of Trois-Rivières (A. Dekker, data retrieved from Monney, 2022 [2008], p. 4).

Another remarkable find of petroglyphs is a site located on the border of the municipality of Ballif and Vieux-Habitants, on the west coast of Basse-Terre (See Figure 2.3.1 and 2.3.2). This site is the only known site of petroglyphs on this side of the island and contains more than 102 engravings on 10 rocks. This underscores the unique distribution of petroglyphs across the island (Ruig, 2022 [2000], p. 5). Petroglyphs have also been documented on the islands of Marie-Galante and to a lesser extent in northern Basse-Terre and Grande-Terre (Richard, 2009, p. 138), as shown on Figure 2.3.2.

Physical characteristics and materials

Rock art in Guadeloupe is found along rivers and streams, valleys and ravines, and in rock shelters (Dubelaar, 1995, p. 27; Richard, 2009, p. 138; Ruig, 2022 [2000] p. 1). The sites are usually located near a freshwater spring, a feature that is common in Guadeloupe (Monney, 2020, p. 685; Petitjean Roget, 2009, p. 484). The volcanic nature of the island, limits the choice between different type of rocks when creating a petroglyph. The volcanic rock on which we find the petroglyphs is primarily basaltic andesitic (Mazabraud, 2019, p. 10). Basaltic andesite is a type of volcanic rock that occupies an intermediate position between basalt and andesite in terms of composition and mineralogy. In Guadeloupe, basaltic andesite is characteristic because of the volcanic activity of the La Soufrière volcano, located in southern Basse-Terre (Metcalfe et al., 2021, p. 3). Although it is not the hardest rock type, it is also not the softest (Kroonenberg as cited in Dubelaar, 1995, p. 34). These rocks contain silica and are resistant to weathering, significantly more so than the limestone found in Grande-Terre. It is likely that the indigenous people also used limestone for carvings, but erosion has erased those rock drawings (Mazabraud, 2019, p. 10). This hypothesis is supported by the fact that pre-Columbian inhabitants lived in some karst caves on the other islands Grande-Terre and Marie Galante, where a number of petroglyphs have been preserved (Grouard et al., 2014, p. 245).

Style and symbolism

Regarding the motifs of the engravings, anthropomorphic figures predominate, mainly with essential facial features such as eyes, mouths and ears (Monney, 2020, p. 676). Notable are the minority of zoomorphic (animal) representations in these engravings (Dubelaar, 1995, p. 28) and of absent also are the engravings of plants and material culture (Jönsson Marquet, 2002, p. 117) and figurative scenes (Monney, 2020, p. 677). An exception must be made with the latter, as a birth scene appears to be depicted in Anse des Galets according to Mazière et Mazière (1999, p. 678). But, the engravings never depict human actions, including hunting, fishing or running. These

features of the engravings show that there are certain stylistic and thematic patterns that remain consistent within the region. In fact, the style and form of engravings in Guadeloupe show similarities with those in other Caribbean islands, from Puerto Rico to Grenada, indicating cultural connections in the Caribbean (Richard & Petitjean Roget, 2006, p. 74).

Considering these stylistic and thematic consistencies, the orientation of the engravings is also interesting. Despite assertions by Dubelaar (1995, p. 31) and Ruig (2022 [2000], p. 2) that engravings in Guadeloupe do not consistently orient themselves with respect to cardinal directions, my analysis of statistical data from Dubelaar's (1995) inventory of rocks in Le Parc Archéologique des Roches Gravées suggests that the western direction is the most common orientation, with more than 46% of cases, followed by the northwestern direction with 26%. This observation supports the findings of Froidevaux (1920, p. 129) and Monney (2022, p. 3), who indicate a preference for western orientations in engraving. However, the significance of this preference remains unknown.

2.4 Historical and cultural significance

Petroglyphs in the Lesser Antilles are considered symbolically important within indigenous communities by several archaeologists. Petitjean Roget (2009, p. 479) describes the significance of petroglyphs as sacred signs for communication with gods and ancestors, and recorded important mythical stories and cultural values. Associating the common figures of frogs and bats with their male and female ancestors, they became associated with totems and emphasized the allocation of power and status within the group. In addition, according to Petitjean Roget (2009, p. 482), these symbols contributed to the transmission of knowledge within the community and acted as an expression of their identity. He further argues that petroglyphs protected humanity from impending dangers such as droughts and floods, acting as microcosms at the intersection of opposites (Petitjean Roget, 2009, 474).

Another important aspect cited by Petitjean Roget (2009, p. 484) is the proximity of almost all petroglyph sites to (fresh) water sources. He argues that this is not a coincidence, but a strategic choice to protect against the threat of a world without water, a theme often found in South American oral traditions. Richard (2009, p. 146) supports this by pointing to the myths that speak of a parched world in indigenous history, while Monney (2020, p. 697) interprets the waterfront location as a means of communication by villagers that would be used as a place to pause while in transit. In addition to its spiritual and protective functions, Delpuech (2021, p. 12) notes that the motifs on petroglyphs can be seen as means of communication with the spiritual world. However, he notes that the meaning of some engravings remains very cryptic, despite the fact that some

symbols are interpretable. Lenik (2007) offers a broader perspective by suggesting that petroglyphs could also contain social and political messages, such as marking territory or indicating power dynamics within and between communities. This broader interpretation suggests that petroglyphs may have had more layers of meaning depending on their context and use.

The interpretation of Lenik (2007), Petitjean Roget (2009), Richard (2009) rely on different methods. Whereas Petitjean Roget (2009) bases his statements on extensive analysis of archaeological finds and comparisons with South American myths and traditions, Richard (2009) uses historical sources and oral traditions to explain the strategic placement of petroglyphs. Based on this research, I do not dare to make statements about the meaning, nor to make my own interpretation. However, I would combine the perspectives of all researchers to see if this offers a new angle to understand the meaning. Clearly, petroglyphs are symbols that can have multiple layers of meaning depending on their context and use.

Finally, from a scientific perspective it is important to be careful about assumptions. The large presence of anthropomorphic figures, as opposed to lesser zoomorphic figures and absent engravings of material culture, may suggest that these figures were higher in rank or important to the community. However, we must always consider the possibility that current thinking may be different from that of the people who made these petroglyphs.

2.5 Contemporary role of petroglyphs in the society

In modern-day Guadeloupe, petroglyphs have become a part of the island, playing an important role in its history and culture. The protection of these engravings is guaranteed by French legal provisions. The regional government of Guadeloupe has been committed to the study and inventory of petroglyph sites, resulting in the classification of many as Historical Monuments (Petitjean Roget & Richard, 2005, p. 61). In addition, scientific interest in these sites has come a long way since the first European chronicles reported the presence of petroglyphs in 1640 (Petitjean Roget, 2009, p. 476). Initially, they were thought to have been made by Europeans, leading to an underestimation of their scientific importance (Froidevaux, 1920). Since then, numerous scholars and archaeologists have conducted extensive research on various aspects of the petroglyphs (Dubelaar, 1995, pp. 9-10).

An example of recognition of their value took place on June 28, 2015, when Le Parc Archéologique des Roches Gravées celebrated its 40th anniversary with various activities for the general public. This event highlighted educational efforts with schools, aimed at transmitting this heritage to youth and what it teaches us about Guadeloupe's history (Ville Trois-Rivières, 2015). Despite

these efforts, there is no contemporary use of the engraved stones by the locals themselves (Richard & Petitjean Roget, 2006, p. 75).

2.6 Conclusion

The first human occupation in the Caribbean was evidenced in Trinidad and Tobago, followed by migrations and cultural developments. These resulted in the creation of petroglyphs. Despite the challenges in dating these petroglyphs, circumstantial evidence indicates that they were probably created between 300 B.C. and 1200 A.D. Guadeloupe has a special position looking at the high density of petroglyphs compared to other islands in the Lesser Antilles. The concentration is particularly high in southern Basse-Terre, with a high density in the municipality of Trois-Rivières. The main site within this municipality is the Parc Archéologique des Roches Gravées, which contains the most extensive and diverse collection of petroglyphs in the Caribbean. To figure out the meaning, different interpretations by researchers such as Delpuech (2021), Lenik (2007), Petitjean Roget (2009) and Richard (2009) have been discussed. For example, it is suggested that they were made for communication with gods and/or ancestral spirits or for recording mythical stories. Although there is no active contemporary use of the engravings by local inhabitants, they are recognized as important parts of the historical heritage as well as being protected by law.

3. Risk assessment of petroglyph sites

3.1 Introduction

This chapter presents a detailed overview of petroglyphs in Guadeloupe, specifically analyzing the sites Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou, located in the municipality of Trois-Rivières in the southern part of Basse-Terre (see Figure 2.3.1.). The primary objective is to identify and categorize specific types of damage based on natural threats and human activities. Each site is discussed individually, detailing its geographic location, specific characteristics, existing threats and visible damage. Further, current conservation strategies for sustainable management are examined, highlighting efforts that have already been implemented or are underway to protect petroglyphs.

3.2 Description of the petroglyph sites

3.2.1 Le Parc Archéologique des Roches Gravées

Geographic location: 15° 58' 10" N, 61° 38' 17" W

Le Parc Archéologique des Roches Gravées is an important archaeological center within the Lesser Antilles, with a substantial collection of 29 groups of rock engravings totaling 100 individual engravings and 51 milling stones (Monney, 2022 [2008], p. 138). This collection has been described since the first half of the 19th century by Merwart (Dubelaar, 1995, p. 170) and has since received extensive attention from several researchers, including Froidevaux (1920), Bouge (1982), Dubelaar (1995), Monney (2022 [2008]) and Delpuech (2021). Geographically, the park is set in a natural amphitheater bordered by a 30-meter-high cliff on the north side, gradually sloping towards the coast. A small stream, Petite Rivière, flows through the park, contributing to the dynamic landscape (Delannoy et al., 2022, p. 5). Archaeologists have focused on locations within the park where rocks such as *"La Tortue", "Le Cacique"* and *"Des Capitaines"* can be found. These names, translated as the tortoise, chief and captains, owe them to the engravings on them. For example, an engraving on *"La Tortue"* resembles a turtle and *"Des Capitaines"* was so named by Merwart in the late 19th century because of the distinctive features of the engravings on the rock (Delpuech, 2021, p. 12).

Figure 3.2.1.1. View through to the rock with petroglyph titled *"Le Cacique".* Le Parc Archéologique des Roches Gravées is landscaped with footpaths and is very well maintained by the park caretakers. The rock visible in the image accommodates *"Le Cacique",* one of the most interesting petroglyphs in the park (Photograph: A. Dekker).

The center area contains most of the petroglyphs, making it ideal for studying the spatial organization and artistic diversity of the engravings (Delannoy et al., 2022, p. 5). Each rock in the park has unique characteristics; for example, for example, *"La Tortue"* features various geometric patterns and depictions of people and animals (Delpuech, 2021, p. 12)(see frontpage figure). A notable finding is that several rocks with petroglyphs, including *"La Tortue", "Le Cacique"* and *"Des Capitaines",* have fallen or cracked. According to Delannoy et al. (2022, p. 13) the rock of *"La Tortue"* was intact at the time the engravings were applied. Figure 3.2.1.1 shows *"Le Cacique",* where it is immediately visible that there is a large cut in the rock, presumably caused by natural processes. The crack is also clearly visible at *"Des Capitaines"* (see Figure 3.2.1.2), because one panel of this rock (called B2 by Delpuech, 2021, p. 12) is no longer in situ. Although it is not known whether the rock was intact at the time the petroglyphs were made, Geusde (2019 [1814-1867], p. 170) observed that this rock was already broken and overgrown with mosses before his

expedition in 1864. Dubelaar (1995, p. 202) attempted to reconstruct what the rock looked like when the petroglyphs were made (see Figure 3.2.1.3).

Figure 3.2.1.2. Present appearance of rock of *"Des Capitaines"* in Le Parc Archéologique des Roches Gravées. Delpuech (2021, p. 12) divides the rock into three panels, B1, B2 and B3. Panel B2 (upper right) has been removed and is on display at the American Museum of Natural History in New York. (Photograph: A. Dekker).

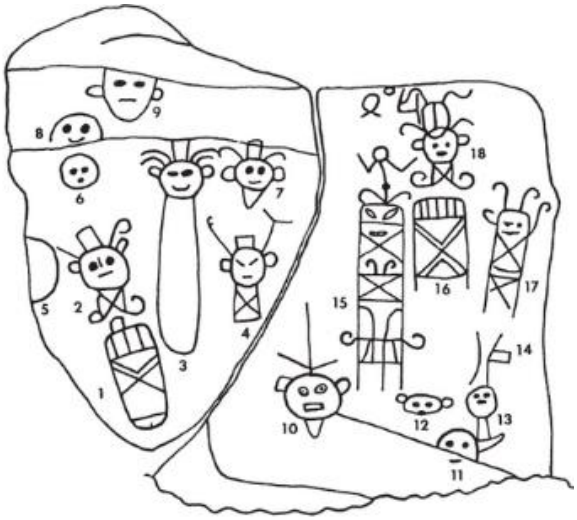

Figure 3.2.1.3. Drawing of rock *"Des Capitaines"* restored to its original state. The drawing depicts *"Des Capitaines"* in its present state, including the removed B2 panel. (Drawing: C. N. Dubelaar, 1995, p. 202).

In addition to engravings, archaeological research in 2006 revealed other artifacts such as a wheel, postholes, ceramics, and shards dated from 859 to 1015 AD through charcoal analysis, extending to the colonial period (Bonnissent, 2022 [2008], p. 2).

Since its classification as a historic monument in 1974 and its subsequent opening to the public in 1975, the park has played a central role in the preservation of the region's rock art heritage (Richard, 2009, p. 146). In its first year, the park attracted 17,000 visitors, including 1,000 schoolchildren (Renard, 1977, p. 159). In 1981, the then owner of the park decided to handed over the management to the Conseil Général, which has been responsible for the exploitation ever since.

The park is located close to the coast and easily accessible by car with plenty of parking space. Although it is currently closed to the public due to archaeological excavations (2024), the park usually offers organized tours when open. These tours allow visitors to admire the engravings and understand their significance while protecting the petroglyphs by ensuring supervised visits. The park features well-constructed walkways and footbridges, maintained

public gardens, and paths that keep visitors at a safe distance from the petroglyphs, although some paths allow a closer look. There are no information boards near the rocks, so visitors rely on the guided tour for explanations and visual representations of petroglyphs no longer visible.

3.2.2 Anse des Galets

Geographic location: 15° 58 '21.4 "N, 61°37 '34.1" W

Anse des Galets is an archaeological site located at the mouth of the Petit Carbet River, in the municipality of Trois-Riviéres on Basse-Terre in Guadeloupe. The site was discovered by Basette after heavy flooding caused by a cyclone in 1995. The first rock with engravings was discovered immediately after the cyclone and a second one was found a year later (Mazière & Mazière, 2022 [1998], p. 1) while Pélissier was making a cast of the first rock (Delpuech, 2022 [1996], p. 1).

The site, which consists of stacked volcanic rocks located above a small spring (Richard, 2009, p. 140), has largely been buried under vegetation. After clearance work in 1998, only these first two of all discovered rocks were found to be in a good state of preservation, while the others were cracked by root growth and had suffered damage from storms and water erosion (Mazière & Mazière, 2022 [1998], p. 1).

Due to a total of nine rocks with engravings from which at least 20 figures can be interpreted, Anse de Galets is an important archaeological site in Guadeloupe (Richard, 2009, p. 140). The engravings range from simple inscriptions to bas-reliefs. Bas-relief is a sculptural technique in which images and figures emerge from a flat surface, but only to a limited extent. In this technique, images are carved or cut into the rock, with some parts of the image protruding more than others, creating a three-dimensional effect. At Anse des Galets, some of these bas-reliefs make use of the natural shapes and textures of the rock to add depth and detail to the engravings (Mazière & Mazière, 2022 [1998], p. 2).

The most prominent engraving, named *"Homme des Galets"* or *"Pebble Man",* depicts a schematic human figure with features similar to engravings from South America. This name was given by Bassette in 1995 when this rock was found (2022 [1995], p. 2). On an adjacent rock, there is an engraving known as *"Femme des Galets"* or *"Pebble Woman",* named by Pélissier in 1996. This figure displays characteristics indicative of a female form, including breasts, two heads (one of which is inverted), and a headdress similar to *"Le Cacique"* found in Le Parc Archéologique des Roches Gravées (see Figure 3.2.1.1). Delpuech (2022 [1996], p. 1) states that the depicted man appears to be 'looking' at the woman from the other side of the spring. The woman is portrayed as a frog, which holds mythological significance (see supra § 2.4). Several archaeologists, including Mazière & Mazière (2022 [1998], p. 3) and Petitjean Roget (2009, p. 485), interpret the scene as

depicting childbirth, possibly symbolizing fertility. The rock with this petroglyph is situated in a spring, leading it to be submerged at high tide. This is also evident from the nearby grinding stone which holds water.

Figure 3.2.2.1. Rock with petroglyph called "*Femme des Galets*". Rock located in the water with a petroglyph depicting a woman twofold. To the left of the petroglyph a grinding stone has been cut out, in which there is a layer of water meaning that the water can reach the top of the rock (Photograph: G. Richard).

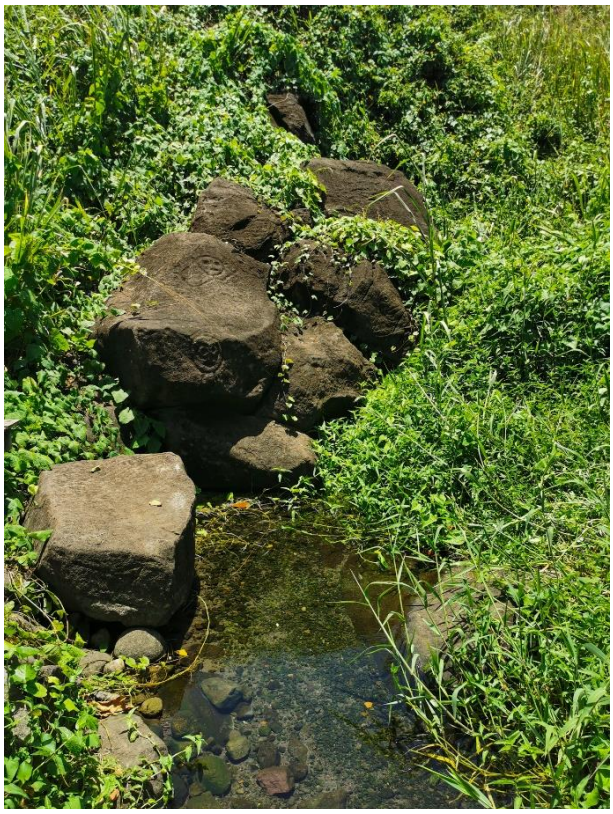

Figure 3.2.2.2. Rock cluster of Anse des Galets. The rocks with engravings are in a warm, tropical area where vegetation grows wild. On the right, buried under the vegetation, is the rock with "*Femme des Galets*" (see Figure 3.2.1.1.) (Photograph: A. Dekker).

The other rocks at the site also show engravings, but many are faded or damaged. There are additionally several other types of depictions, including two heads with eyes and mouths in circles, two heads with eyes on either side of a corner, and three anthropomorphic figures (Mazière & Mazière, 2022 [1998], p. 5). A total of two grinding stones have been documented at this site (Richard, 2009, p. 140). Petitjean Roget (2009, p. 485) states that researchers have largely overlooked the frequent association between grinding stones and rock engravings. He explains that the close proximity of a female engraving, a male engraving, and grinding stones at the Anse

des Galets site is deliberate. This arrangement is thought to symbolize sexual activity and the perpetuation of humanity through reproduction.

The archaeological site is located in a tropical environment with rich vegetation, which means that the rocks with petroglyphs are not always clearly visible. During the visit in the summer of 2023, the *"Femme des Galets"* was overgrown. Most of the other rocks were easily admirable despite the vegetation present, with the exception of the higher rock outcrop (see Figure 3.2.1.2). Because of its location, it is only possible to reach the site by foot. To allow visitors to view the engravings up close, a platform has been constructed over the spring. Once you stand on the platform, the petroglyphs are within easy reach, which immediately poses one of the risks. In addition, information about the site and the engravings is available in the form of an information board situated near the petroglyphs. This archaeological site is classified as a historical monument in 2012 (Monumentum, 2024).

3.2.3 Capesterre Petit-Pérou

Geographic location: 16° 03' 09.7" N, 61° 33' 29.0" W

Figure 3.2.3.1. Overview of the petroglyphs in Capesterre Petit-Pérou. The rocks face each other forming a natural walkway (Photograph: A. Dekker).

Petit-Pérou is an archaeological site situated in the municipality of Capesterre-Belle-Eau near the Pérou River, from which this site takes its name. This site was first mentioned by Father Breton in the chronicles he wrote in 1640, highlighting its historical significance (Petitjean Roget, 2009, p. 476). Breton described the engravings as distinct from those at Le Parc Archéologique des Roches Gravées and Anse des Galets, noting differences in style, form, and technique (Richard, 2009, p. 138) (see Figure 3.2.3.1). In 1887, the petroglyphs were rediscovered by Guédet, after which they again fell into obscurity. In 1990, however, they were again rediscovered by a Capesterre resident. The site remained the only known petroglyph location in Capesterre until the mid-1980s when additional sites were discovered (Richard, 2009, p. 138). From 1972 to 1989, several researchers visited the site to locate the rocks but did not find them. Beaugendre finally confirmed its existence in 1990 (Dubelaar, 1995, p. 331). The importance of the site was highlighted when it was established as a historical monument in 2015 (Ministère de la Culture, 2022).

Figure 3.2.3.2. Front of the rock on the left side of the trail in Capesterre Petit-Pérou. The rock shows human like graphic engravings, with the engraving of the mask shown off well by the deep grooves and more defined contours. (Photograph: A. Dekker).

Figure 3.2.3.3. Front of the rock on the right side of the path in Capesterre Petit-Pérou. The rock shows a central engraving of an isolated figure resembling a man with a beard. (Photograph: A. Dekker).

Petit-Pérou contains two engraved rocks with a total of 24 engravings positioned opposite each other on a rock plateau, forming a walkway (see Figure 3.2.3.1). As Breton noted (Richard, 2009, p. 138), the engravings are different in style and form compared to the engravings in Trois Rivieres, due to the more deep grooves, more defined contours. The depiction of human figures is also distinct, such as the large isolated figure on the rock on the right side of the pathway. According to my interpretation, this is a large man with a beard and headgear or big ears, big eyes and an open mouth. The figure is centrally placed on the rock, possibly indicating its significance

(see Figure 3.2.3.3). The rock on the opposite side features different kind of figures, such as a mask in the shape of a diamond with eyes, a mouth, two hair tufts on the head, and two lines curling outward from the head, possibly representing ears or additional hair. Another rounded face appears to be sticking out its tongue, accompanied by more graphic elements including lines and curves. Despite the figures being clear and detailed, it is primarily the mask that is clearly recognizable in Figure 3.2.3.2. So far, the engravings in Petit-Pérou have not been given a name.

A few meters away from the rocks, an information board under a canopy provides explanations about the petroglyphs, although it was vandalized during my visit in 2023, making the information difficult to read.

3.3 Threats and potential threats that could damage petroglyphs

To apply targeted sustainable strategies, threats to archaeological sites must be identified. Therefore, existing threats have been classified as natural threats and human-caused threats. These threats pose a risk to petroglyphs because they can cause damage to both the rock itself, and the environment in which they are. This may result in this cultural heritage eventually becoming invisible to future generations. Some threats have not caused actual damage so far, while others have already caused damage to petroglyphs. The overview of natural and human-caused threats lists the threats. It then highlights the damage present at each site as a result. An overview with descriptive terms and classification by stage for each petroglyph per site can be found in Table X.1, X.2 and X.3 in the Appendix. The damage present was identified based on Dubelaar's (1995) inventory, the studies from Delannoy et al. (2022), Delpuech (2021), Mazière and Mazière (2022 [1998]), Petitjean- Roget and Richard (2006), Rad et al. (2013), my own observations in the park and photographs taken of it during the field visit.

3.3.1 Overview of natural threats

The petroglyphs at Le Parc Archéologique des Roches Gravées, Anse des Galets, and Capesterre Petit-Pérou face various natural threats that jeopardize their preservation. According to Agnew et al. (2015, p. 20), these threats can be categorized into six groups: 1) rock weathering, 2) water, 3) chemical processes, 4) biological weathering, 5) influences by animals, and 6) major environmental events. Since erosion is also a natural threat, I add it as category 7) erosion. These threats often interact and compound one another, as the occurrence of one can trigger or exacerbate the effects of another.

1) Rock weathering

A major threat is rock weathering, which includes both mechanical and chemical processes. Petroglyphs are located primarily on volcanic rock surfaces, which are naturally susceptible to weathering. This weathering includes physical degradation such as cracking, flaking, weakening of internal rock structure and even collapse of rock surfaces, leading to deformation or loss of petroglyphs. The tropical climate accelerates these processes through frequent alternations of wet and dry periods, causing expansion and contraction of the rock (Rad et al., 2013, p. 333). In addition, the water on Guadeloupe contains dissolved volcanic substances, resulting in an acidic composition of the water. These acids, which include carbonic, sulfuric and hydrochloric acids, accelerate rock weathering (Rad et al., 2013, p. 334).

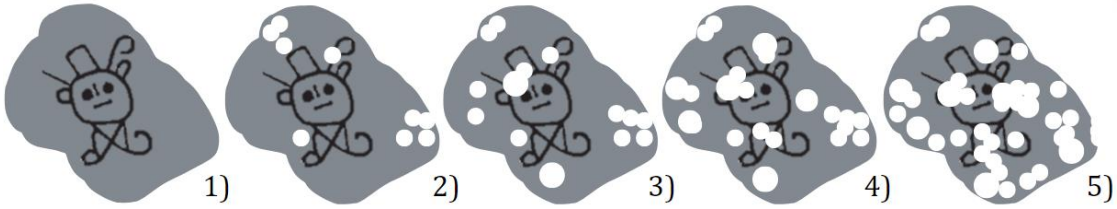

Figure 3.3.1.1. Stages of visibility reduction of petroglyphs due to natural and/or chemical weathering[1]. Visibility categories of petroglyphs after exposure to natural and/or chemical weathering: 1) The petroglyph is fully visible, 2) Slight weathering is noticeable, 3) Weathering is significantly present, 4) Weathering significantly affects the visibility of the petroglyph, 5) The petroglyph is barely or no longer visible. (A. Dekker).

Analysis shows that 16 out of 17[2] petroglyphs in Le Parc Archéologique des Roches Gravées have been affected by weathering processes. The damage appears to be the result of a suspected natural reaction that causes staining throughout the stone. These stains reduce or completely obscure the engravings. Based on my own analysis, the degrees of weathering have been divided into five stages, as illustrated in Figure 3.3.1.1, which provides a standardized numerical assessment of impact. Five petroglyphs are classified as stage 5, meaning that the petroglyphs here are almost completely invisible. In addition, six petroglyphs in the Parc Archéologique des Roches Gravées show signs of fragmentation and cracks in the rock. This causes the engravings to fall apart and lose their original

[2] The engraved rocks in Le Parc Archéologique des Roches Gravées have been classified by Dubelaar (1995, p. 168) into five different groups, with group 1B encompassing the rocks located within the park's boundaries. The inventory of group 1B includes 15 petroglyphs. During my research, I noticed two additional petroglyphs in the park that were not described by Dubelaar. These findings, designated as numbers 31 and 32 in Table X.1, bring the total number of petroglyphs to 17.

positions, making them difficult to interpret. An example of this is at the *"Des Capitaines"* rock where fragments have fragmented and become scattered. According to Delannoy et al. (2022, p. 13), the engravings were made after the rock became fragmented. The *"La Tortue"* rock has also become detached and appears to have slid down along the surface (see Figure 3.3.1.2). The geomorphologic analysis by Delannoy et al. (2022, p. 13) shows that this occurred before the engravings were placed on this part of the rock. At Capesterre Petit-Pérou, observations show different degrees of rock weathering. On the right side, the rock is intact, classified as weathering stage 3. On the left side, the rock is also intact but is at a slightly lower stage 2 (See Figure 3.2.3.2 and Figure 3.2.3.3). However, the rocks appear completely intact, with no signs of fragmentation or cracks. In contrast, at Anse des Galets there are no visible signs of rock weathering. But, according to Mazière and Mazière (2022 [1998], p. 2), the rock known as *"Homme des Galets"* did break after the two heads on the sides had engraved on it. The fragments on which, according to Mazière and Mazière (2022 [1998], p. 2), there should be busts or limbs are not present (visibly) at the site. Because of the high visibility of the petroglyphs at Anse des Galets, I classified them as stage 1. This suggests that the petroglyphs at this location were either less exposed to weathering agents or benefited from environmental conditions that minimize such processes.

Figure 3.3.1.2. View of rock 23 *"La Tortue"* in Le Parc Archéologique des Roches Gravées. The rock fractured and the marked fragment fell down by gravity. On the fragment are engravings which, according to the geomorphologic study by Delannoy et al. (2022, p. 13), were made after this event occurred (Delannoy et al., 2022, p. 14).

2) Water

Precipitation contributes to the physical breakdown of rock surfaces, leading to the gradual loss of petroglyphs. During rainfall, water seeps into the porous rocks, resulting in expansion, shrinkage, cracking and flaking. The permeable soil causes water to quickly soak into the ground after heavy rainfall, leading to soil saturation and increased risk of erosion (Delannoy et al., 2022, p. 38; Rad et al., 2013, p. 333). These processes are further amplified by the location of Basse-Terre, an island with steep slopes and high rainfall, which causes rapid water runoff (Delpuech, 2007, p. 12).

> Analysis shows that in the Parc Archéologique des Roches Gravées, water affects rock art through processes of erosion and sedimentation. An example of this can be seen at *"Des Capitaines"* rock. Water erosion has caused an accumulation of sediments around the base of the rock, creating a layer almost a meter deep that partially covers the engravings. The sediment layers have a dual role here: on the one hand, they act as a protective barrier, but on the other, they obstruct the visibility and accessibility of the engravings (Delannoy et al., 2022, p. 11). In contrast, at Anse des Galets we see that water is a threat due to the location of the rocks in the stream, but no damage has been observed as a result. However, at Capesterre Petit-Pérou there are also no visible signs of water damage to the naked eye, but according to Petitjean Roget (1990, cited in Dubelaar, 1995, p. 331), the rock on the left side was pushed over by a spring tide. This made the underside, which has a flat surface, visible. Thus, the water did not cause visible damage at this site, but rather created a place where petroglyphs could be applied and are easily visible.

3) Chemical processes

Petroglyphs in Le Parc Archéologique des Roches Gravées face significant risks due to chemical processes. Dust and mineral deposits, such as salts and minerals, accumulate on the rocks during dry periods when there is no precipitation to wash them clean (Rad et al., 2013, p. 338). These accumulations can damage the rocks by promoting chemical reactions that weaken the stone structure. Efflorescence, a process in which salts migrate from the interior of the rock to the surface and crystallize, is particularly detrimental. As the salts crystallize, they expand and exert pressure on the rock, causing it to crack and flake, which can render the petroglyphs unrecognizable (Rad et al., 2013, p. 334).

> In Le Parc Archéologique des Roches Gravées, observations show damage from efflorescence on rock number 31. Figure 3.3.1.3 illustrates the impact of efflorescence on this rock, with the petroglyph rendered unrecognizable by salt deposits. At Anse des Galets, the petroglyphs, including *"Femme des Galets",* are at risk for chemical processes

due to their location in the water (see Figure 3.2.2.1), which promotes salt accumulation and subsequent efflorescence. Vegetation growth can also trigger this process. Despite no direct visible damage at Anse des Galets and Capesterre Petit-Pérou, these sites are at increased risk because of their location.

Figure 3.3.1.3. Efflorescence on rock with petroglyph. Due to the chemical process, the petroglyph on this rock in Le Parc Archéologique des Roches Gravées is no longer recognizable. Therefore, the original drawing is shown in orange in the upper left (Photograph and drawing: A. Dekker).

4) *Biological weathering*

Guadeloupe's tropical climate promotes the growth of various biological organisms, such as algae, lichens and mosses which colonize the rock surfaces. Algae thrive in moist and shady environments, forming a thin layer on the rock surface and producing acids that can chemically weather the rock. Lichens are a symbiotic association between fungi and algae that adhere firmly to rock surfaces and penetrate deep into microcracks and pores of the rock (Chen at al., 2000, p. 122). The acids produced by lichens dissolve the minerals in the rock, resulting in accelerated chemical weathering (Chen at al., 2000, p. 124). Mosses retain moisture and create a microenvironment that promotes chemical weathering of the rock. Rocks in shady and moist areas are more susceptible to biological weathering, while rocks in drier and sunnier locations are less affected (Dubelaar, 1993, p. 47). Furthermore, minerals such as calcium, magnesium and iron in the rock can promote the growth of these organisms (Rad et al., 2013, p. 334). In addition to biological-chemical weathering by microorganisms, phytomechanical processes also pose a threat; the growth of roots and trees in the vicinity of petroglyphs can lead to stresses in the rock,

with roots penetrating cracks and joints and further fragmenting and displacing the rock (Delannoy et al., 2022, p. 13).

A clear example of the impact of biological weathering in Le Parc Archéologique des Roches Gravées can be seen on rock number 32, where petroglyphs are located on the western side of the rock. Due to the shady and moist environment, this side of the rock is prone to weathering by shade-loving organisms such as mosses and algae. Figure 3.3.1.4 shows how the petroglyphs have become invisible due to this form of biological weathering. Another rock that has been damaged by biological weathering is the *"Le Tortue"* rock. These engravings on this rock have been affected by phytomechanical processes due to the growth of trees and roots that have worked their way through cracks and joints in this rock (Delannoy et al., 2022, p. 13). This has caused the rock to break down and move, resulting in (partial) loss of the original context of the petroglyphs. At Anse des Galets and Capesterre Petit-Pérou, no visible damage caused by biological weathering was found. However, the petroglyphs at both sites have an increased risk due to wild vegetation growth there (see Figure 3.2.2.2 for Anse des Galets and Figure 3.2.3.1 for Capesterre Petit-Pérou).

Figure 3.3.1.4. Due to this form of biological weathering, the petroglyphs on rock 30, which are engraved on the western side of the rock, are no longer visible. Because this side of the rock is often in the shade, it is more susceptible to biological weathering by shade-loving organisms such as mosses and algae. (Photograph: A. Dekker).

5) Influences by animals

Rock art can be threatened by various animals. Insects such as wasps and termites can damage rock surfaces by building nests or digging out the rock. In addition, mammals living near rock art may dig or rub against the rocks, leading to physical damage to the engravings (Agnew et al., 2015, p. 20). No evidence of effects on animals was found in the literature or physically at one of the three sites.

6) Major environmental events

The islands of the Lesser Antilles are subject to natural hazards such as earthquakes, volcanic eruptions, floods, hurricanes and fire (Petitjean Roget & Richard, 2005, p. 60). These events can cause direct damage to rock surfaces and alter the landscape. Climate change further exacerbates these risks through increased frequency and intensity of storms, changes in precipitation patterns and rising temperature (Agnew et al., 2015, p. 18).

> From the Ceramic Age onward (see supra § 2.2), the island has experienced several environmental events. Hurricanes, such as Hugo in 1989, Ivan in 2004 and Maria in 2017[3], have caused heavy rainfall, strong winds and storm surges which caused destruction on the island (López-Marrero et al., 2013, p. 90). Another example is Hurricane Luis, which in 1995 exposed the Anse des Galets archaeological site and made some petroglyphs visible (Mazière & Mazière, 2022 [1998], p. 1), a rare positive consequence of a natural hazard. The formation of volcano La Grande Soufrière around 1440±40 AD is the cause of volcanic eruptions on the island, the last of which occurred in 1956 and 1976-1977 (Zlotnicki et al., 1992, p. 91). In addition, Guadeloupe suffers from earthquakes, such as the devastating 1843 earthquake (Feuillet et al., 2011, p. 3). This earthquake may have caused impact at Le Parc Archéologique des Roches Gravées. Delannoy et al, (2022, p. 11) notes that rock 23 *"Figuier"* collapsed due to a succession of seismic activities that periodically affect the region, such as the 1843 earthquake, and other seismic events in 1851, 1897 and 2004 (see Figure 3.3.1.5). Although there is no direct evidence that environmental events caused damage to the petroglyphs in Anse des Galets and Capesterre Petit-Pérou, it cannot be ruled out based on the published literature. According to Hofman et al. (2021, p. 15), climate change in the Lesser Antilles is likely to increase the frequency and intensity of these events through more extreme weather events.

[3] Hurricane Maria caused rocks at the Dérussy archaeological site, located near the Petit Carbet river, to suffer numerous damages due to uprooting of trees and crushing of rocks (Delannoy et al., 2022, p. 13). This emphasizes that petroglyphs could also have been moved naturally from their discovery.

Figure 3.3.1.5. View of rock 23 *"Figuier"* in Le Parc Archéologique des Roches Gravées. This rock collapsed, according to Delannoy et al. (2022, p. 9), due to successive seismic activity in 1843, 1851, 1897 and/or 2004. (Photograph: A. Dekker).

7) Erosion

Erosion is a natural process in which rocks and soil are gradually degraded and displaced by natural forces such as water and wind. Dragged along particles, sometimes millimeters small, gradually wear down porous rock surfaces (Delannoy et al., 2022, p. 39; Rad et al., 2013, p. 340).

Analysis shows that erosion has significantly affected at least one petroglyph. This concerns rock 28 in Le Parc Archéologique des Roches Gravées. According to Dubelaar (1995, p. 219), this rock has eroded so much that the engravings are barely visible. This implies that the drawings of the petroglyph, made during the inventory, do not contain the full context and that the exact engravings have been lost[4]. At Anse des Galets, there is another threat due to its location near the Carbet River, where waterfalls and steep slopes indicate an increased erosion risk that undermines the stability of the surrounding land (Rad et al., 2013, p. 340). Erosion in which petroglyphs have not yet been fully affected is often not readily visible to the naked eye. With further research, such as measuring the depth of the engravings and comparisons over a longer period of time, it can be better

[4] provided archaeologists elsewhere have preserved drawings of the petroglyph on rock 28.

concluded whether impairment has occurred at the petroglyphs present, both in Le Parc Archéologique des Roches Gravées and at Anse des Galets and Capesterre Petit-Perou.

3.3.2 Overview of human-caused threats

In addition to natural threats, there are also human-caused threats to petroglyphs. These can often be catastrophic. The value humans give to the petroglyphs art declined after contact with Europeans as traditional beliefs weakened. As a result, people may make different choices toward it. If there is financial or political gain, decisions may be made to remove or overbuild the rock art, such as by building roads or bridges. Another potential is the ignorance and lack of interest that results in residents and/or visitors not knowing (properly) the value of the rock art and destroying it or taking it as a souvenir (Clottes, 2008, p. 10).

Agnew et al. (2015, p. 20) categorize these risks into six groups: 1) impacts from economic development, 2) graffiti, vandalism, looting and theft, 3) other visitor impacts, 4) damage from wildlife, pets and plants, 5) social impacts on rock art managers, and 6) poorly conducted surveys, site protection and conservation. Although Agnew et al. (2015, p. 15) categorizes damage from wildlife, pets and plants under human-caused threats, my understanding is that this is a natural risk which is why it is covered in 3.3.1 Overview or natural threats.

1) Impacts from economic development

The expansion of urban and agricultural areas poses a significant threat to petroglyphs. Construction activities can result in the destruction or burial of petroglyphs and the use of heavy machinery and earth moving can directly damage rock art. For example, the construction of new roads may result in the removal or displacement of petroglyphs. Moreover, pollution from nearby urban areas may contribute to chemical weathering of the rock surfaces, exacerbating natural deterioration processes (Delpuech, 2021, p. 34). Haviser and Strecker (2006, p. 52) emphasize that economic development without adequate management plans can result in the destruction of these sites. But according to Ruig (2022 [2000], p. 2), it is sometimes difficult to know if petroglyphs are present in an area and thus to take them into account, especially if they have not yet been discovered[5].

[5] Despite the fact that agricultural activities can be detrimental to the context of petroglyphs, there is an example of a site near the Petit Carbet River where this type of work led to the discovery of petroglyphs. As a result, an archaeological survey took place in 2014-2015, identifying 89 new petroglyphs. This shows that agricultural activities in locations without known archaeological sites, if carried out with caution, can also contribute to the discovery of petroglyphs (Monney, 2022 [2014], pp. 1-3).

Tourist development at Le Parc Archéologique des Roches Gravées led to the installation of a footbridge, which necessitated the relocation of some rocks (Delannoy et al., 2022, p. 16). In addition, Delpuech (2021, p. 34) can tell us that in the nearby area, region of Trois-Rivières, petroglyphs have been destroyed by the construction of roads and urban development. Exactly which petroglyphs this concerns is not made clear.

2) Graffiti, vandalism, looting and theft

One of the most immediate human threats is vandalism, although this threat varies by site. Unauthorized persons can damage the petroglyphs by carving their own markings over the engravings or applying graffiti. This may be a greater threat at Anse des Galets and Capesterre Petit-Pérou than at Le Parc Archéologique des Roches Gravées, due to the free accessibility of the sites. Nevertheless, Petitjean Roget and Richard (2006, p. 74) noted that no irreparable acts of vandalism were reported until 2006. However, examples have been documented where petroglyphs have been taken from Le Parc Archéologique des Roches Gravées[6].

At least one rock fragment has been removed from Le Parc Archéologique des Roches Gravées[7]. This is rock 18 *"Des Capitaines"* where the rock was split into three panels in 1901 and the upper right part was sold to the American Museum of Natural History in New York (Delpuech, 2021, p. 30). Another rock called *"Louis Guesde"* was sold and sent to the Museum für Völkerkunde in Berlin in 1902. It is known that this rock came from Trois-Rivieres, but its exact original location is unknown. This pulls through to its location today, which is also unknown. According to Delpuech (2021, p. 27), it presumably disappeared during World War II because it cannot be found in German collections. Furthermore, the known damage from vandalism is limited to the information board at Capesterre Petit-Pérou, which has been destroyed and part of the information on it is no longer fully visible.

Other visitor impacts

Access by tourists without supervision can lead to unintended damage from foot traffic, touching and leaving litter on the site. Again, this is a greater risk at Anse des Galets and Capesterre Petit-Pérou because there is no supervision here. Without proper explanation of the vulnerability of the petroglyphs, visitors will be less aware and underestimate their historical value (Delpuech, 2021, p. 32). An example of this type of threat can be seen in photos of visitors touching the petroglyphs

[6] As discussed in § 2.3, Ruig (2022 [2000], p. 5) noted that 47 more petroglyphs were documented than found in the Trois-Rivieres municipality. It is unknown if these were not found or if the rocks were moved or taken away.

[7] Also known to have been moved is a petroglyph from the Petit Carbet series, named *"Derussy"*. It was exhibited in Guadeloupe in 1916 and 1935 and in Paris in 1939. Since 1982, the petroglyph has been back in Guadeloupe, where it is exhibited today at the entrance to the Edgar Clerc archaeological museum in Le Moule (Delpuech, 2021, p. 32; Dubelaar, 1995, p. 269).

at Capesterre Petit-Pérou (Aince, 2016), which can cause the engravings to be damaged by the natural oils and greases of human hands. This changes the chemical composition of the petroglyphs and accelerates weathering. In addition to touching, some visitors step on the rocks, presumably out of ignorance or invisibility of the engravings. This can cause the petroglyphs to break off or accelerate the erosion process, which will cause the engravings to fade.

4) Damage from wildlife, pets and plants – Is discussed in § 3.3.1 Overview or natural threats.

5) Social impacts on rock art managers

Whenever rock art managers (both communities and municipalities) are under pressure, this can lead to the inability to properly manage an archaeological site. This can occur, for example, because of social and economic pressures that shift attention to other priorities (Delpuech, 2021, p. 34). No evidence of social impacts on rock art managers was found in the literature or physically at one of the three sites.

6) Poorly conducted surveys, site protection and conservation

Inadequately documented and poorly executed research and conservation efforts can do more harm than good. For example, without adequate protection and documentation, rocks may be moved or removed from their original context, reducing their scientific and cultural value (Delpuech, 2021, p. 30). Ultimately, it is important that the information about archaeological sites be available to anyone who needs it, but this again creates a risk for people who would want to do harm and steal or destroy petroglyphs. Therefore, it is important to offer adequate protection at the sites themselves as well. Le Parc Archéologique des Roches Gravées has a fence and a gateway that makes it impossible to view the petroglyphs without permission. At Anse des Galets and Capesterre Petit-Pérou this is different. The sites are not fenced and anyone who knows where these sites suffered can visit at any time of the day. This risk will be taken into account in the proposed sustainable strategies (see infra § 4.3).

In addition to the conservation of the petroglyphs, removing moss and algae growth from the rocks to improve the visibility of the drawings should be done with care. Cleaning too often or improperly can have negative effects on both the drawings and the rocks themselves. Repeated scrubbing or use of harsh cleaning agents can damage the physical structure of the rock drawings. Improper cleaning methods can also corrode pigments and other materials on the petroglyphs, causing them to fade over time. In addition, too aggressive cleaning can result in the removal of the natural material on which the drawings are placed, which can reduce the integrity of the site. Although this practice is no longer carried out at Le Parc Archéologique des Roches Gravées (S. Guimarães, personal communication, June 28 2023), it remains an important example of how well-intentioned maintenance activities can be harmful (Delpuech, 2021, p. 30). Maintaining the

landscape in which the rocks stand, such as cutting grass or trimming vegetation, also pose a risk. These activities can inadvertently damage the rocks and expose the engravings to further erosion. Delpuech (2021, p. 34) emphasizes the importance of careful management to minimize these risks and ensure the integrity of the sites. Nevertheless, it is important to recognize that rock cleaning and vegetation removal can also have positive effects on petroglyphs. Rinsing rocks clean with water removes the minerals that have accumulated on the rock. Maintaining vegetation keeps the rock art visible, preventing it from falling into oblivion. In addition, cutting vegetation can reduce phytomechanical processes near the petroglyphs, which can be a natural threat (Delannoy et al., 2022, p. 13) . To make the right decision in the management strategy being implemented, the pros and cons should always be considered.

3.4 Current conservation strategies for sustainable management

Current conservation strategies for the sustainable conservation of petroglyphs include both on-site and off-site measures aimed at limiting damage from natural and human-caused threats. Measures vary from site to site depending on specific needs and circumstances. At Le Parc Archéologique des Roches Gravées, the most measures have been applied, followed by Anse des Galets and Capesterre Petit-Pérou.

On-site measures taken include access management, educational methods, maintenance and monitoring. To give an example, the infrastructure at Le Parc Archéologique des Roches Gravées was constructed as if to function as a tourist attraction. Footpaths and walkways regulate the flow of visitors and limit direct interaction with the petroglyphs. The park is demarcated and can only be entered when accompanied by a guide who provides supervision and educational information about the petroglyphs, the flora and fauna, and the indigenous inhabitants of Guadeloupe. This approach provides dual protection in that the presence of a guide both influences visitor behavior and promotes education. To make Le Parc Archéologique des Roches Gravées even more accessible through the renovation of the entrance building and adaptations for people with limited mobility, the park is currently closed indefinitely (since 2023).

At Anse des Galets, a platform has been placed next to the rock formation from which the petroglyphs can be closely observed. Although this platform is intended as an aid to visitors, it also serves as a stepping stone to the petroglyphs themselves, making it easy to touch the petroglyphs or climb the rock formation. It is therefore debatable to what extent this platform actually provides protection. However, an information board has been placed several meters away informing visitors of the presence of the petroglyphs. The same is true of Capesterre Petit-Pérou. At this site, at a short distance from the petroglyphs, there is an information board explaining their

discovery. In addition, no specific physical protection measures have been taken. The information boards provide protection based on awareness, which reduces the likelihood of causing damage.

Another type of physical protection is the maintenance that is carried out. At Le Parc Archéologique des Roches Gravées, maintenance is performed by gardeners who are active in the vegetation management of the site. The grass is cut, fast-growing plants are pruned and invasive species are removed. In addition to maintenance, global monitoring is carried out on this site by the structural presence of employees. Although Anse des Galets and Capesterre Petit-Pérou are under the same ownership as the park, vegetation management at these sites is organized differently. The sites are not continuously monitored so the managers are less likely to notice when maintenance is needed. As a result, maintenance takes place with a lower frequency than in Le Parc Archéologique des Roches Gravées (Guimaraes, personal information, 2023). Monitoring of these sites is also at a lower level. Nonetheless, at both Le Parc Archéologique des Roches Gravées and Anse des Galets and Capesterre Petit-Pérou, scientific investigations are taking place in which the petroglyphs are examined more closely. The methods and purposes of these investigations vary from study to study.

Other conservation strategies do not provide immediate protection but are effective in the longer term for the preservation of the petroglyphs. The petroglyphs are under state protection and are classified as Historical Monuments, which means strict legal protection. Work near these sites requires permission from competent authorities such as the Regional Directorate of Cultural Affairs (DRAC). All archaeological excavations and associated investigations must, by law, take place under state supervision, which requires a permit (Kayser, 2005, p. 86) .In this way, petroglyphs are protected from uncontrolled research.

Second, a database has been established in which petroglyphs have been systematically recorded over the years. The database contains site, rock, bibliographic and photographic descriptions of petroglyphs in Guadeloupe. In addition, the database also secures recording forms, descriptions of rock art entities and GPS coordinates and Geographic Information Systems (GIS), which are made accessible to researchers and other stakeholders (Monney, 2022 [2008], p. 4). For example, this enables the government to take into account the exact locations of petroglyphs when planning urban and agricultural expansion and helps researchers of locating the archaeological sites and reevaluating them based on the previously measured information.

Last of all, Richard and Petitjean Roget describe in a 2006 ICOMOS report (p. 75) that there are educational programs aimed at increasing awareness and appreciation of rock art. These programs include education in schools in the region, joint visits to the sites and the use of media to explain the importance of and promote respect for the engraved rocks. However, the specific

strategies and current status of implementation of these programs have not been documented, so it is unclear whether these initiatives are currently ongoing.

3.5 Conclusion

In this chapter, the petroglyph sites Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou in Guadeloupe have been analyzed in depth, with a focus on the threats to their physical integrity. Both natural influences and human activities were identified as major factors contributing to the degradation of rock art. Natural threats such as rock weathering, water erosion, chemical processes, biological weathering, major environmental incidents and erosion play a risk one for the degradation of petroglyphs. Examples include the fragmentation and cracks in the rocks at Le Parc Archéologique des Roches Gravées, forces of water at Capesterre Petit-Pérou and the particular location in the water of the archaeologists' most interesting petroglyph at Anse des Galets. Human-caused activities are another type of threat, where economic development and uncontrolled tourism can lead to direct and reversible damage to the petroglyphs. Since Anse des Galets and Capesterre Petit-Pérou do not have permanent surveillance, visitors may intentionally or unintentionally cause damage. An example of this is visitors touching the petroglyphs or standing on the rocks, which will accelerate the process of deterioration. The interconnectedness of various threats complicates conservation efforts, as addressing a single threat by itself is often insufficient to preserve petroglyphs. Conservation strategies such as footpaths and walkways at Le Parc Archéologique des Roches Gravées help mitigate these threats at this site. Informational signs at Anse des Galets and Capesterre Petit-Pérou inform visitors in the effort to better understand the value of the petroglyphs.

In conclusion, petroglyph sites in Guadeloupe are threatened by a combination of natural and human factors. Effective sustainable management strategies are necessary to both preserve the cultural integrity of these petroglyphs and ensure their accessibility to future generations. This will be discussed further in chapter four.

4. Sustainable Management Strategies

4.1 Introduction

This chapter describes the most effective conservation methods for the petroglyphs at Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou in Guadeloupe. These sites are endangered by several (potential) threats, as discussed in Chapter 3. To reduce risks and ensure the long-term preservation of this cultural heritage, effective sustainable management strategies must be implemented. By placing the risk assessments alongside strategies implemented in other regions, such as the Dendora Valley in Arizona (Wright, 2018), the Caguana site in Puerto Rico (Landon & Brent Seales, 2009) and in a number of other case studies (Bracciale et al, 2022; Chauk & AL-Amiri, 2023; Clottes, 2008; Delannoy et al, 2022; Ershad-Langroudi, 2022; Lenoble et al, 2013; Smith et al., 2021) I propose sustainable management strategies for the three sites. This includes a focus on further investigation of the physical condition of the petroglyphs, as this assessment cannot be determined with my visual exploration. Because of their unique characteristics and challenges, the strategies focus on both common and site-specific threats. This approach ensures that conservation measures are accurately tailored to the actual needs and risks of each individual site.

4.2 Lessons from other petroglyph sites in the Americas

In this section, I give a description of two examples of other petroglyph sites int the Americas where sustainable strategies are already being implemented and a brief comparative analysis on those case studies.

4.2.1 Case study: Dendora Valley in Arizona, USA

The case study "A site condition assessment of the Painted Rock Petroglyph Site, southwestern Arizona" by Wright (2018, pp. 1-115) examines the condition of the Painted Rock Petroglyph Site, located in Arizona's Dendora Valley. Wright (2018, p. iii) set the goal of creating an inventory of cultural heritage objects for this never before fully documented site, determining their condition and making recommendations for improving management.

The Painted Rock Petroglyph Site contains several cultural heritage objects, including petroglyphs, grinding stones, a historic wagon road and various types of artifacts. The most prominent feature of the site are the petroglyphs, of which at least 3,803 have been identified, scattered over 644 boulders and rock outcrops (2018, p. 9). These petroglyphs face threats from

both natural processes and human activities. First, the petroglyphs are exposed to erosion and climatic influences such as rain and temperature changes, which contribute to the decay of the rocks (Wright, 2018, p. 26). In addition, tourist visits result in physical damage to the petroglyphs, including wear and tear from foot traffic and vandalism, including in the form of graffiti (Wright, 2018, p. 9). To manage visitor impacts, petroglyphs at the site are monitored by volunteers (Wright, 2018, p. 5), however, this proves insufficient.

Wright (2018) provides recommendations that can be implemented to further protect the site, including removing shrubs that have grown over the rocks causing the petroglyphs to fade, (p. 37), installing and walkway with a railing to minimize visitor impacts from the ground of nearby petroglyphs (p. 34), moving the current path further away from the petroglyphs and demarcating it with bollards to keep visitors at bay (p. 35), a system for digital, continuous remote monitoring (p. 36) and as a deterrent to vandalism (p. 35).

4.2.2 Case study: Caguana in Utado, Puerto Rico

In this case study, Landon and Brent Seales (2009, pp. 188-197) focused on capturing, preserving and visualizing petroglyphs from Plaza A at the Caguana site in Utado, Puerto Rico. They developed and implemented a laser-based scanner to create three-dimensional (3D) models of the engraved surfaces. In this way, Landon and Brent Seales (2009, p. 194) were able to create accurate digital representations of the petroglyphs.

As with the previous case study and petroglyph sites in Guadeloupe, the greatest threats to the petroglyphs in Caguana are the natural elements and human activities that can lead to degradation and loss of detail. Traditional methods such as tracing and photography have their limitations, such as physical contact requirements and the loss of information when taking two-dimensional photographs (Landon & Brent Seales, 2009, p. 188).Conservation strategies have been employed to combat degradation. These included the development and use of a laser-based scanner to create high-resolution scans of the petroglyphs. This scanner could capture accurate 3D models and textures without the need for physical contact with the petroglyphs (Landon & Brent Seales, 2009, p. 190). It should be kept in mind that the use of this electronic tool is still very complicated at remote archaeological sites (Landon & Brent Seales, 2009, p. 192). Another aspect of the preservation strategy was the use of digital technologies to make the models accessible to researchers around the world through networks such as the Internet. This increases research and educational opportunities without the need for physical access to the sites (Landon & Brent Seales, p. 193). The conservation strategies employed proved highly effective. The high-resolution 3D models allowed detailed study of the petroglyphs, including interactive illumination and annotation, which traditional methods cannot provide (Landon & Brent Seales, 2008, p. 195. The

ability to make digital copies and share them through online platforms greatly enhanced access to and collaboration about the petroglyphs (Landon & Brent Seales, 2009, p. 196).

4.2.3 Comparative Analysis

The case studies on the Painted Rock Petroglyph Site at Dendora Valley in Arizona (Wright, 2018, pp. 1-115) and the Plaza A Petroglyphs at Caguana (Landon and Brent Seales, 2009, pp. 188-197) both focus on monitoring and protecting the petroglyphs at the site in question. Although both studies recommend advanced technology for documentation and preservation, the methods differ considerably. The Painted Rock Petroglyph Site relies primarily on traditional methods, supported by volunteers, and proposes physical structural changes, such as installing railings and moving paths. This contrasts with the Caguana Site, where a laser-based scanner is used to create detailed 3-D models of the petroglyphs. Volunteer involvement at the Painted Rock Petroglyph Site promotes local engagement, but protection remains limited by financial and physical vulnerabilities. At the Caguana site, costly technology poses challenges, especially in remote areas where using solid equipment is very complicated.

4.3 Proposed sustainable management strategies

The recommendations presented in this chapter represent a comprehensive list of possible measures to protect petroglyphs from the identified threats. A successful strategy requires that several of these recommendations be implemented. The proposed measures focus on determining the physical condition of the petroglyphs, implementing monitoring techniques, and applying physical protection measures at the sites themselves. However, further investigation is needed for elements that could not be determined during my visual study in order to actually decide which recommendations should be adopted.

4.3.1 Common strategies

The proposed common strategies for sustainable management of the petroglyphs of Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou are listed in Table 4.3.1 (p. 48).

4.3.2 Site-specific strategies

The proposed site-specific strategies for sustainable management of the petroglyphs of Le Parc Archéologique des Roches Gravées are shown in Table 4.3.2.1 (p. 50). Table 4.3.2.2 shows the proposed site-specific strategies of Anse des Galets (p. 51) and Table 4.3.2.3 shows the proposed strategies for Capesterre Petit-Pérou (p. 52).

Table 4.3.1. Proposed common strategies for Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou

Diagnosis	To identify the vulnerability of the petroglyphs, the recommendation is to apply a combination of advanced diagnostic techniques. This can be either chemical analysis (Smith et al., 2021, p. 215) or through the application of infrared thermography and ultrasonic testing (Chabuk & AL-Amiri, 2023, p. 133). Chemical analyses can determine the impact of chemical weathering by identifying specific contaminants and their effects. In addition, infrared thermography and ultrasonic testing can help detect internal damage and structural weaknesses in the rocks on which petroglyphs have been deposited.
Digital documentation assurance	To ensure accurate documentation of petroglyphs, the use of laser scanning and photogrammetry is recommended (Chabuk & AL-Amiri, 2023, p. 133). These methods can create accurate 3D models of the petroglyphs. Laser scanning offers high resolution and accuracy, allowing even the smallest details of the petroglyphs to be captured. Photogrammetry complements this by converting photographs into 3D models, making it possible to examine petroglyphs online. Once petroglyphs are further damaged or lost, this way they are not completely lost.
Systematic monitoring of petroglyphs	To quickly detect changes in the state of petroglyphs, the recommendation is to implement monitoring techniques. This can include the implementation of digital systems using high-resolution cameras and environmental sensors (Landon & Brent Seales, 2009, p. 109). Continuous monitoring with these technologies allows for timely detection of changes in petroglyphs, making it possible to act more quickly when the status changes. In addition, a long-term photographic program is recommended, in which photographs are taken regularly and compared with older photographs to identify changes in petroglyphs (Smith et al., 2021, p. 217). In addition, the use of LiDAR (Chabuk & AL-Amiri, 2023, p. 133) and 3D mapping can accurately track changes in the landscape and identify potential threats early (Delannoy et al., 2022).
Monitoring of environmental conditions	To control the influence of environmental factors on the petroglyphs, the recommendation is to install sensors for continuous monitoring of temperature, humidity, and chemical composition of the air and precipitation water in the vicinity of the petroglyphs (Lenoble et al., 2013, p. 656). Changes in these parameters may contribute to the accelerated weathering of the petroglyphs, and by monitoring these factors, specific measures can be taken on time.
Updating the database	Based on the above recommendations, much new data is collected. The advice is to continuously upload the database with newly woven data so that analyses can be performed based on data from different periods. This will allow a better understanding of trends and changes in the

	state of petroglyphs. In addition, new finds should be added immediately so that stakeholders can be informed of them and make possible connections between previous findings and these new ones.
Management of environmental influences	To protect petroglyphs from environmental influences, a combination of planting vegetation and soil stabilization is recommended. A natural barrier against (the erosion caused by) wind and rain is vegetation. Planting vegetation additionally helps stabilize the soil. Along with this goes the management of vegetation, taking into account the negative effects of vegetation, including moisture retention and shade creation (see infra Management of vegetation in Table 4.3.2.2).
Covering petroglyphs	A recommended strategy for petroglyphs where the engravings have been damaged by natural influences is to apply protective coatings. The use of nanocomposite coatings (Ershad-Langroudi, 2022, p. 192) and/or ETFE films (Bracciale et al., 2022, p. 14) offers opportunities because of their protective properties against damaging effects of weathering, such as direct exposure to rain, wind, UV radiation, and other factors that contribute to rock weathering and erosion. These coatings can improve the mechanical strength of the rock and provide protection against environmental factors such as acid rain and salt weathering. To apply this strategy, the thorough preliminary research should be done to test the suitability of these coatings or whether they would still be readily visible afterwards and whether the coating is removable if necessary without causing damage.
Develop cleaning methods	To preserve petroglyphs, the recommendation is to develop cleaning methods that use gentle, non-invasive methods. These protocols are designed to remove biological growth and sediments without damaging the rock surfaces. Effective cleaning improves the visibility of petroglyphs for future generations and scientific research. However, previous cleaning techniques have caused damage due to abrasive action. For this reason, petroglyphs can only be cleaned again with proper methods.
Collaboration with local communities	The advice is to work intensively with local communities. Involving local people in the management and conservation of petroglyphs can result in better compliance with conservation measures and a deeper appreciation of cultural heritage. This can be done through the organization of community archaeology, where archaeological research or renovation work is carried out together with local people. This increases their involvement in the project and strengthens their connection to the rock art. By training local people and making them "ambassadors" of the petroglyphs, they will feel responsible for its preservation (Clottes, 2008, p. 12).

International collaboration	To ensure the sustainability of petroglyph conservation in Guadeloupe, it is recommended that international cooperation be promoted. By participating in international cooperation projects and establishing a long-term rock art conservation management plan, knowledge and experiences from other regions, such as rock art sites in the Lesser Antilles and Greater Antilles, can be further shared and applied. In addition, this creates an opportunity to receive financial support.
UNESCO World Heritage Site Status	Efforts have already been made to become a UNESCO World Heritage Site, including the systematic classification of sites as Historical Monuments. This process must continue in order to reap the benefits of World Heritage status, including the implementation of more stringent protection measures. With official recognition, managers receive financial, scientific and legal assistance in creating and implementing management strategies (UNESCO, 1972, p. 3).

Table 4.3.2.1. Proposed site-specific strategies for Le Parc Archéologique des Roches Gravées

Stabilization	Because of the fragmentation of some important petroglyphs, the advice is to take stabilization measures. One way to carry this out is by placing support frames near rocks that are fragile to prevent further fragmentation. These frames can be made of stainless steel or another durable material that will not have damaging effects on the rocks. In addition, it is recommended that further research be conducted into methods of reinforcing existing cracks so that further cracking is less likely.
Provision of information	Even though a visit is always accompanied by a guided tour, the advice is to optimize the provision of information in the park. In this way, visitors who have not heard the full story or do not speak the guide's language can still learn about the petroglyphs. Good provision of information improves understanding and reduces risks of vandalism. The advice is to place information signs near the petroglyphs, to give a flyer during the tour so that it can be referred to during and after the visit, or by using digital solutions, for example by scanning a QR code with a smartphone so that information about the petroglyphs is within reach.

Table 4.3.2.2. Proposed site-specific strategies for Anse des Galets

Water-level management	To protect the flooded engraving *"Femme des Galets"* from water erosion, it is recommended that a water level management system be implemented. This system may include the use of pumps to control water flow during high water periods. By actively monitoring and regulating water levels, petroglyphs can be prevented from being submerged for long periods of time, threatening their integrity by erosive forces.
Management of vegetation	To preserve the petroglyphs, the recommendation is to apply frequent vegetation management. This includes regular pruning of trees and shrubs and removal of invasive species to prevent roots from destabilizing rocks or causing root penetration and rock fragmentation. Excessive vegetation can retain moisture and create shade, which promotes erosion and biological weathering and affects the integrity of petroglyphs. However, it should be considered that only trained individuals perform this type of maintenance. People trained in the specific requirements of the sites where the rocks are located and the care required when using modern pruning equipment should perform these tasks. This is because there is a risk that careless use of such equipment can damage the rocks, increasing the damage rather than reducing it.
Accessibility and barriers	To minimize direct human impact on the petroglyphs at Anse des Galets, it is recommended that the barrier present in the form of a platform be optimized. Currently, visitors can use the platform as a stepping stone to the petroglyphs. To keep visitors at a safe distance, additional barriers including bollards or a glass plate can be placed to make it more difficult to approach the engravings directly. If there is a desire to attract more visitors to the site, access paths to the site should be implemented with visible indication of the route. This should be done with a clear strategy to control human-caused threats. Without proper control, uncontrolled visitors and lack of awareness can lead to physical damage and vandalism of the petroglyphs.
Provision of information in combination with media use	The recommendation is to use media as a means of providing an interactive and educational experience without physically disturbing the petroglyphs. This can be accomplished by using augmented reality and/or giving explanations through an audio tour. Virtual tours can inform visitors without the need for a guide. These technologies are easy for visitors to use, as almost everyone carries a smartphone these days. By simply scanning a QR code, visitors can receive information about the site in their own language on their phones. This makes the educational experience accessible and contributes to a better understanding of the value of rock art with which it may prevent vandalism and theft.

Table 4.3.2.3. Proposed site-specific strategies for Capesterre Petit-Pérou

Management of vegetation	Same proposal as for Anse des Galets (see Table 4.3.2.2).
Infrastructure	To protect the petroglyphs at Capesterre Petit-Pérou from direct physical impact, the recommendation is to provide clear footpaths that guide visitors and ensure that the petroglyphs cannot be approached directly. Well-designed paths guide visitor behavior by allowing their brain to understand that the designated route is the most accessible way to experience the site. As a result, visitors will be less likely to deviate from the paths and the direct physical impact on the petroglyphs will be reduced. A similar approach has proven effective in other petroglyph sites, such as Dendora Valley (Wright, 2018, p. 34).
Hiring nearby residents as supervisors	It is recommended that, given the proximity of some properties to these petroglyphs, residents be appointed as supervisors. These neighbors should be financially compensated for their services. Through effective communication arrangements between residents and managers, the conservator will be more quickly informed of events at the site and appropriate action can be taken.
Accessibility	If there is a desire to attract more visitors to the site, access paths to the site should be implemented with visible indication of the route. This should be done with a clear strategy to control human-caused threats. Without proper control, uncontrolled visitors and lack of awareness can lead to physical damage and vandalism of the petroglyphs.
Provision of information in combination with media use	Same proposal as for Anse des Galets (see Table 4.3.2.2).

5. Discussion

5.1 Discussion and reflection

This research has aimed to develop sustainable management strategies that both preserve the cultural integrity of petroglyphs and ensure their accessibility to future generations. This goal has been mostly achieved. Risks were determined after a meticulous investigation that examined a visit, photograph-analysis and literature-based analyses. After identifying all the risks and examining the damage already occurred, recommendations were made for a sustainable management strategy for in Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou. Those recommendations were in line with my expectations.

The study's primary conclusion is that Guadeloupe's petroglyphs are vulnerable to a range of challenges, both man-made and natural. Unexpectedly, natural hazards occur more frequently than those brought on by humans. Surprisingly, natural risks are more frequent than human-caused threats. This contrasts with my initial expectation that human activities, such as theft and tourism impacts, would be the largest threat. Natural threats such as erosion, chemical processes and biological weathering already seem to have caused more damage. During the research, I faced threats that were unknown to me, including rainfall and minerals that can cause damage if left on the rock surface, which raises the possibility that the rock could fragment. Although human hazards have currently caused less damage, they are expected to increase as awareness and visitor numbers to rock sites grow, especially given the current management and protection of Anse des Galets and Capesterre Petit-Pérou.

There are many other rock art sites worldwide that face similar natural and human threats as the sites in Guadeloupe. Experiences at other rock art sites were used to validate the research. The case studies have highlighted interesting sustainable management strategies that could be implemented in Guadeloupe. These include the use of technology, such as at the Caguana site in Puerto Rico, which offers a potential solution for continuous monitoring and documenting significant visual changes found on the petroglyphs. The case study of the Painted Rock Petroglyph Site in Arizona emphasizes the importance of physical protection measures, such as building footpaths and using barriers to minimize direct human interaction. Because of the natural threats that have already caused damage and the possible future increase in visitors to rock sites, it is wise to implement these two reliable strategies immediately.

In addition, the study has produced several other important findings. A start has been made on identifying the damage occurred, but this is limited to what is visible to the naked eye.

Due to the high number of natural threats, it is likely that there are petroglyphs that have been damaged without being visible. This constitutes a major limitation of this study. The analysis depended on photographs and a one-time visit to the sites. The limited number of photographs and suboptimal angles provide an incomplete picture of the condition of the petroglyphs. Photographs from Dubelaar's (1995) inventory were also often difficult to interpret due to their quality. Moreover, this photo analysis provides only snapshots from a couple of moments, which can vary depending on vegetation and seasonal changes. The lack of detailed material examination means that the physical condition of petroglyphs has not been fully recorded. These limitations affect the validity and reliability of the study. Additional fieldwork would significantly improve the results, highlighting the urgency for further research.

5.2 Future research

Future research should focus on using more advanced diagnostic techniques, such as chemical analysis and non-destructive testing methods, to get a more complete view of the physical condition of petroglyphs. It is important to understand what minerals are present on the surfaces of the petroglyphs and how they respond to natural influences. This research provides more accurate insights into the severity of erosion and other degradation processes. In addition, longitudinal studies, with repeated visits over longer periods of time, would be useful to better understand changes in the condition of the petroglyphs and to evaluate the effectiveness of the management strategies implemented. Once it appears that many other petroglyphs are also affected by one or more of the natural threats, new recommendations should be proposed based this new findings. Second, future research should also focus on testing different protection strategies, including coating and developing reining methods. It should be understood which ways are effective to use in Guadeloupe's climate and volcanic rock to prevent further damage to the petroglyphs.

6. Conclusion

The objective of this study aimed to develop effective management strategies for the protection of petroglyphs made by the indigenous people of Guadeloupe. In doing so, the focus has been on three specific petroglyph sites: Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou. The research has focused on formulating sustainable management strategies that both preserve the cultural integrity of these petroglyphs and ensure their accessibility for future generations.

The central research question this study answers is: *How to effectively manage human and natural hazards that threaten petroglyphs created by the indigenous people of Guadeloupe in Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou be effectively managed to ensure both their protection and sustainable management for future generations?* This central question was further subdivided into several sub questions, each answering part of the research question.

First, *What natural influences and human activities affect the physical integrity of petroglyphs in Guadeloupe?*

The study shows that several natural and human factors threaten the physical integrity of petroglyphs in Guadeloupe. Because of location and situation, the level of threat for each site is not completely equal to each other. This can be recognized by the degree to which the petroglyphs at the sites are affected based on that risk.

The main natural threats to petroglyphs are rock weathering and water erosion. These threats cause physical degradation such as cracking, flaking and weakening of the rock's internal structure. Chemical processes, such as the migration of salts to the surface of the rock and crystallization, cause further damage by exerting pressure that leads to cracking and exfoliation. Biological weathering due to the growth of algae, lichens and mosses on the rock surfaces also accelerates chemical weathering and contributes to the deterioration of the petroglyphs. These three forms of weathering have all been observed at the sites and have caused damage that cannot be repaired. Another more obvious threat is from major environmental events. Hurricanes and earthquakes leave significant damage when they hit petroglyph sites. In addition, they can alter the natural environment to the point where erosion occurs here and other threats are exacerbated. Human activities also pose a substantial threat to petroglyphs. Economic developments such as urban and agricultural expansion can lead to the destruction or

disappearance of petroglyphs. Uncontrolled visits can lead to physical damage if visitors are not properly informed. Foot traffic and touch can already endanger the integrity of petroglyphs. The risk of vandalism and theft is also present. Le Parc Archéologique des Roches Gravées is gated and accessible only during opening hours and under the supervision of a guide, while the petroglyphs at Anse des Galets and Capesterre Petit-Pérou are freely accessible. No supervision increases the risk of vandalism and theft. Inadequate management and poorly executed conservation efforts can cause unintended damage, while a lack of awareness and education among visitors and locals contributes to the problem.

Ale mentioned factors can cause significant damage to petroglyphs that is irreversible. Risks for this reason were examined individually upon which matching recommendations for sustainable management strategies were presented.

Second, *How have successful conservation strategies for rock art been applied across the Americas?*

Examining case studies of other petroglyph sites in the Americas provided valuable insights into effective conservation strategies, especially because of the similar issues experienced by these rock sites. In the case study of the Painted Rock Petroglyph Site in Arizona, physical barriers, monitoring systems and volunteer efforts proved to be effective measures to manage visitor impacts and natural threats. These physical protection measures rely on a more traditional approach to managing archaeological sites. For the Caguana site in Puerto Rico, the use of laser scanning and photogrammetry was recommended for digital documentation and remote monitoring. These modern technologies made it possible to create detailed 3-D models of the petroglyphs. These models are then shared on an online platform, after which researchers can use this data to conduct analyses. This approach provides an innovative way to accurately map and monitor petroglyphs without the need for physical presence, minimizing the risk of damage.

Despite both case studies having different conservation strategies, it seems necessary to combine both traditional and modern approaches for best results. Physical barriers and monitoring systems provide immediate and tangible protection from human and natural threats, while digital documentation and remote monitoring provide a sustainable and detailed method of continuously evaluating the state of petroglyphs. By integrating these methods, archaeological sites can be effectively protected and preserved while remaining accessible for research and education.

Last, *Which conservation methods are most effective for petroglyph sites in Guadeloupe, considering (potential) threats and strategies already implemented?*

Several sustainable management strategies have been proposed for the three petroglyph sites in Guadeloupe. These recommendations were arrived at after examining all the threats to which the petroglyphs are exposed (see first sub-question) and based on the strategies already implemented at the individual sites. There is a clear difference in the way the sites are managed, despite the fact that management is in the same hands. Inspiration for effective recommendations was drawn from analyzed case studies in the Americas (see second question) and worldwide, where similar issues were identified. The strategies are composed of common proposals and site-specific recommendations, based on the current situation of the site and the implementations already applied. In addition, the strategies are preventive in nature and are not intended to repair existing damage. Based on this research, certain strategies can be implemented immediately or scheduled later. Each carefully implemented strategy contributes to the integrity of the petroglyphs and their accessibility to future generations.

Consideration should be given to any additional research that must take place to implement actual recommendations. The application of a coating should always be tested beforehand on a rock of the same material without petroglyphs to determine that this right will not cause additional damage.

Le Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou

- Implement advanced diagnostic techniques such as chemical analysis, infrared thermography and ultrasonic testing that can detect internal damage and structural weaknesses in the rock.
- Implement laser scanning and/or photogrammetry which allows for accurate 3D modeling of petroglyphs. This is a strategy that matches the positive effect of long-term monitoring and being able to quickly detect changes in the condition of petroglyphs.
- Install high-resolution cameras that allow the condition of petroglyphs and visitor activity to be monitored at all times and responded to appropriately if the condition of a petroglyph has suddenly changed or a visitor engages in inappropriate behavior.
- Install environmental sensors that can take measurements for pollutants in the air and/or in the water that allow action to be taken based on sudden changes before it is too late and it causes irreparable damage.
- Update the database based on any new information obtained and ensure that the database is accessible to anyone who needs it, but keep in mind access for unauthorized persons who may want to do harm with it.

- Manage the environment including planting vegetation to create shade which reduces the rate of biological weathering.
- Stabilize soil near petroglyphs to reduce threats from rain and wind.
- Apply protective coatings to damaged petroglyphs can also help protect them from further damage from natural influences.
- Develop cleaning protocols that both clean the rock from (biological) weathering that can be polished away without these cleaning techniques harming the rock itself.
- Involve local communities in petroglyph management and conservation which can result in better compliance with conservation measures and a deeper understanding of cultural heritage. Organizing community archaeology, where local people are trained and involved in archaeological research, can increase their involvement and create ownership.
- Engage in international collaborations, such as participation in regional or global projects and the pursuit of UNESCO World Heritage status. This can provide financial, scientific and legal support in creating and implementing management strategies.

Le Parc Archéologique des Roches Gravées

- Improve the provision of information for visitors so that they do not only depend on the information told to them by the guide, but they can consult it during the tour itself. In this way, you ensure a better understanding of the value of the petroglyphs which may help at a later date with word-of-mouth advertising about the fun experience in the park. In addition, a good experience can prevent destruction at a later date because its value to the visitor has also increased.
- Stabilize fragile rocks through the use of frames so that they are virtually assured during the next environmental event

Anse des Galets

- Manage water levels to prevent the most important petroglyph on the site from being lost or damaged by erosive forces.
- Place barriers that make it not possible (anymore) to touch the engravings or step on the rocks. This should take into account the environment and that it will not be affected by the installation of the barrier.

Anse des Galets and Capesterre Petit-Pérou

- Improve the current vegetation policy due to inadequate management. This employee should be trained enough explanation that they know exactly where the rocks are and cannot be accidentally bumped into them.

Capesterre Petit-Pérou

- Build footpaths for visitors as a natural boundary to protect the petroglyphs from touch and foot traffic
- Work with neighbors of the petroglyphs in exchange for a fee to make arrangements for supervision that can be performed when the site is visited

Together, these recommendations form a comprehensive and integrated conservation plan to protect and sustainably manage the petroglyphs of Guadeloupe.

To answer the central research question; *How to effectively manage human and natural hazards that threaten petroglyphs created by the indigenous people of Guadeloupe in Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou be effectively managed to ensure both their protection and sustainable management for future generations?*

To formulate an effective management strategy, comprehensive information is needed on various aspects that affect petroglyphs. This includes research on the natural and human threats, the damage these threats have caused, successful conservation strategies implemented elsewhere, and the effectiveness of strategies already implemented that may not yet have produced the desired results. The sustainable management plan was reasoned through these components creating a recommendation combining traditional and modern management strategies. By carefully implementing these recommendations and conducting further research where necessary, it will be possible to both protect and sustainably manage petroglyphs, preserving their cultural integrity and keeping them accessible to future generations.

Abstract

English

This thesis examines the most appropriate sustainable management strategy for petroglyphs created by the indigenous people of Guadeloupe, with a focus on the petroglyphs at Parc Archéologique des Roches Gravées, Anse des Galets and Capesterre Petit-Pérou. Through visual inspection, literature review and analysis of case studies of other petroglyph sites, the natural and human threats to which petroglyph sites are exposed were identified. The main natural threats to the petroglyphs at the sites are natural, biological and chemical weathering and erosion caused by water and wind. This has caused significant damage to several petroglyphs. Petroglyphs also become invisible due to the growth of mosses and algae. In addition, human activities such as economic development, tourist impact and vandalism and theft pose significant risks. To implement sustainable management, recommendations have been made that involve a combination of advanced diagnostic techniques, digital documentation, systematic monitoring, environmental management, and community and international cooperation. These recommendations provide an effective management strategy that both preserves the cultural integrity of petroglyphs and ensures their accessibility for future generations. Due to the limitations of the visual aspect of this study, future research is recommended that recommends applying advanced diagnostic methods and long-term monitoring, as well as developing specific protection strategies such as coatings and cleaning methods adapted to the specific conditions of the petroglyphs in Guadeloupe.

Français

Cette thèse examine la stratégie de gestion durable la plus appropriée pour les pétroglyphes créés par les peuples indigènes de la Guadeloupe, en se concentrant sur les pétroglyphes du Parc archéologique des Roches Gravées, de l'Anse des Galets et de Capesterre Petit-Pérou. L'inspection visuelle, l'examen de la littérature et l'analyse des études de cas d'autres sites de pétroglyphes ont permis d'identifier les menaces naturelles et humaines auxquelles les sites de pétroglyphes sont exposés. Les principales menaces naturelles qui pèsent sur les pétroglyphes des sites sont l'altération naturelle, biologique et chimique et l'érosion causée par l'eau et le vent. Plusieurs pétroglyphes ont ainsi subi des dommages importants. Les pétroglyphes deviennent également invisibles en raison de la croissance des mousses et des algues. En outre, les activités humaines telles que le développement économique, l'impact touristique, le vandalisme et le vol posent des risques importants. Pour mettre en œuvre une gestion durable, des recommandations ont été formulées qui combinent des techniques de diagnostic avancées, la documentation numérique, la

surveillance systématique, la gestion de l'environnement et la coopération communautaire et internationale. En raison des limites de l'aspect visuel de cette étude, des recherches futures sont recommandées, dans lesquelles il est conseillé d'appliquer des méthodes de diagnostic avancées et un suivi à long terme, ainsi que de développer des stratégies de protection spécifiques telles que des revêtements et des méthodes de nettoyage adaptées aux conditions spécifiques des pétroglyphes de Guadeloupe.

Nederlands

Deze scriptie onderzoekt de meest geschikte duurzame beheerstrategie voor de petroglyfen die gecreëerd door de inheemse bevolking van Guadeloupe, met een focus op de petrogliefen in Parc Archéologique des Roches Gravées, Anse des Galets en Capesterre Petit-Pérou. Door middel van visuele inspectie, literatuuronderzoek en analyse van casestudies van andere petroglyfensites zijn de natuurlijke en menselijke bedreigingen waar de petroglyfensites aan blootgesteld worden in kaart gebracht. De belangrijkste natuurlijke bedreigingen voor de petrogliefen op de sites zijn natuurlijke, biologische en chemische verwering en erosie die ontstaat door water en wind. Dit heeft bij meedere petrogliefen voor aanzienlijke schade gericht. Ook raken petrogliefen onzichtbaar door de groei van mossen en algen. Daarnaast vormen menselijke activiteiten zoals economische ontwikkeling, toeristische impact en vandalism en diefstal significante risico's. Om een duurzaam beheer te implementeren, zijn er aanbevelingen gedaan die bestaan uit een combinatie van geavanceerde diagnostische technieken, digitale documentatie, systematische monitoring, milieubeheer en gemeenschaps- en internationale samenwerking. Deze aanbevelingen bieden een effectieve beheerstrategie die zowel de culturele integriteit van de petroglyfen bewaart als hun toegankelijkheid voor toekomstige generaties waarborgt. Vanwege de beperkingen van het visuele aspect van dit onderzoek, wordt toekomstig onderzoek aanbevolen waarbij geadviseerd wordt om geavanceerde diagnostische methoden en langdurige monitoring toe te passen, evenals het ontwikkelen van specifieke beschermingsstrategieën zoals coatings en reinigingsmethoden, aangepast aan de specifieke condities van de petroglyfen in Guadeloupe.

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Appendix

Table X.1. Rock damage in Le Parc Archéologique des Roches Gravées. The table shows damage to rocks with petroglyphs on it in Le Parc Archéologique des Roches Gravées and categorizes them according to the natural and human-caused threats (see supra § 3.3.1 & 3.3.2). The numbering of the rocks is taken from Dubelaar's inventory (1995, p. 174).

** The abbreviations N and H stand for natural (N) and human-caused (H) threats.*

Rock number and *name*	**Damage description**	**N / H***
16 *"La Tortue"*	Rock is split forming three panels. Both in panel 2 and 3 deep cracks, Part of rock slipped from base, it now lies in front of it on the ground, weathering stage 3. Weathering has increased by one stage compared to image from inventory Dubelaar (1995, p. 195)	N
17	Crack with possibility for water to come through (Dubelaar, 1995, p. 201), weathering stage not assessable	N
18 *"Des Capitaines"*	Rock is split to form three panels. Two present in park, left horizontal shallow crack, one moved to New York in 1902 (Delpuech, 2021, p. 11), weathering stage 1.	N & H
19	Rock intact, weathering stage 1 (Dubelaar, 1995, p. 204)	N/A
20	Rock intact, weathering stage 2 (Dubelaar, 1995, p. 206)	N
21 *"Duhoux"*	Rock intact, weathering stage 5. Petroglyph not visible at a glance	N
22 *"Le Cacique"*	Rock completely split in two, weathering stage 4	N
23 *"Figuier"*	Rock collapsed due to seismic activity, weathering stage 3, moss growth on the top of the rock (Dubelaar, 1995, p. 212; Delannoy et al., 2022, p. 9)	N
24	Rock intact, weathering stage 3 (Dubelaar, 1995, p. 213)	N
25 *"Grotte"*	Rock intact, weathering stage 2 (Dubelaar, 1995, p. 216)	N
26	Rock intact, weathering stage 3 (Dubelaar, 1995, p. 217)	N
27	Deep crack in rock, weathering stage 5 (Dubelaar, 1995, p. 218)	N
28	Very eroded, stage 5 (Dubelaar, 1995, p. 219)	N
29 *"Jean Bernard b"*	Crack in rock at top, weathering stage 2 (Dubelaar, 1995, p. 222)	N
30 *"Jean Bernard a"*	Rock intact, weathering stage 2 (Dubelaar, 223, p. 216)	N
31 *unknown by Dubelaar*	Rock intact, weathering stage 5. Petroglyph not visible at a glance	N
32 *unknown by Dubelaar*	Rock intact, biological weathering stage 5. Petroglyph not visible at a glance	N

Table X.2. Rock damage in Anse des Galets. The table shows damage to rocks with petroglyphs on it in Anse des Galets and categorizes them according to the natural and human-caused threats (see supra § 3.3.1 & 3.3.2). The numbering of the rocks is taken from Mazière & Mazière's study (2022 [1998]).

** The abbreviations N and H stand for natural (N) and human-caused (H) threats.*

Rock number and *name*	**Damage description**	**N / H***
a) *"Homme des Galets"*	Rock is split forming ? panels (Mazière & Mazière, 2022 [1998], p. 2), no weathering, stage 1	N
b) *"Femme des Galets"*	Risk due to vegetation growth, is completely in the water at high tide, completely invisible during visit (2023), no weathering, stage 1	N
c)	Risk because of vegetation growth, no weathering, stage 1	N
d)	Risk due to vegetation growth, completely invisible during visit (2023), no weathering, stage 1	N
e)	Risk due to vegetation growth, as a visitor you can easily touch the petroglyph, no weathering, stage 1	N
f)	Risk because of vegetation growth, location in the water, as a visitor you can easily step on the petroglyph, no weathering, stage 1	N & H
g)	Risk due to vegetation growth, location on water, no weathering, stage 1	N
h)	Risk due to vegetation growth, completely invisible during visit (2023), no weathering, stage 1	N
i)	Risk because of vegetation growth, location in the water, as a visitor you can easily step on the petroglyph, no weathering, stage 1	N

Table 3.3.3.3. Rock damage in Capesterre Petit-Pérou. The table shows damage to rocks with petroglyphs on it in Capesterre Petit-Pérou and categorizes them according to the natural and human-caused threats (see supra § 3.3.1 & 3.3.2). The numbering of the rocks has been assigned by me.

** The abbreviations N and H stand for natural (N) and human-caused (H) threats.*

Rock number and *name*	**Damage description**	**N / H***
1 *right side*	Rock intact, weathering stage 3, High risk of overgrowth due to wilderness vegetation. No unfencing present. Rock easy to climb	N & H
2 *left side*	Rock intact, weathering stage 2, High risk of overgrowth due to wilderness vegetation. No unfencing present. Rock easy to climb	N & H