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## Evaluation of Grenada's "Carib Stones" via the Rock Art Stability Index

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## ABSTRACT

While not well-known or well-studied, Grenada's (Caribbean) Carib Stones host over 100 individual petroglyphs (rock engravings) representing some of the Caribbean's best examples. Two sites were assessed for this study: Duquesne Bay along the northwest Caribbean coast and Mt. Rich in the northern tropical rainforest. Their importance notwithstanding, little has been done to manage or assess the Stones other than basic glyph recording. This study employed the Rock Art Stability Index (RASI) to assess and document each panel's overall geologic stability. Using more than three-dozen rock decay elements, RASI represents an efficient and rapid tool to assess petroglyphs and pictographs, assigning an "Excellent -Good-Problems-Urgent Danger-Great Danger-Severe Danger" ranking based on a quantitative score. Overall, 13 panels were assessed individually, with a few exhibiting "Good" status, two in "Great Danger", and the remaining exhibiting "Problems". Analyses show the Duquesne Bay site remains at the behest of its proximity to water, such as stagnating puddles, waves, or storm and household runoff. In contrast, the Mt. Rich site receives substantial rainfall and remains under rainforest canopy, yet is significantly more stable. This research demonstrates the need for further monitoring efforts and lays the groundwork for continued study and assessment of the Carib Stones, while at the same time raising their profile to the international stage in hopes of securing greater recognition ultimately leading to better management practices.

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## Introduction

As a first step toward a potential cultural heritage management strategy for Grenada's Carib Stones, and to demonstrate the need for further investigation and monitoring, we employed Rock Art Stability Index (RASI, Dorn et al., 2008) to assess and document the panels' geologic stability. The RASI was devised to provide a rapid, efficient, non-invasive, and cost-effective scientific assessment of rock art usable by non-rock decay specialists (Dorn et al., 2008). While not designed to preserve or protect rock art specifically, the RASI represents a tool for land/site managers to help make informed and educated decisions. Once initial assessment is completed via RASI, it is hoped that land/site managers will use the analyses to determine which sites are most at risk and spend their funding on more expensive, time-consuming, extensive, and invasive techniques, such as those outlined by Viles et al. (1997) and Fitzner (2002). This study builds on previous successful RASI assessments to evaluate overall site conditions in Petrified Forest National Park, Arizona (USA) (Allen, Cutrell, Cerveny, & Theurer, 2011) and the Phoenix, Arizona (USA) metropolitan area (Allen & Lukinbeal, 2011). To that end, after a brief introduction of the study's location and significance, we present a concise overview of the RASI and its parameters. Then, we present an in-depth analysis of each site, including detailed RASI element analyses of each petroglyph-containing panel individually. Finally, once the analyses have been laid forth, potential implications for the sites are presented.

## Site setting and significance

Though a rather small island ( $\sim$  19 × 34 km), Grenada's climate varies from tropical rainforest interior to drier cactus-growing southern peninsulas. Straddling 12 degrees north latitude with the Atlantic Ocean on its east and the Caribbean Sea on its west, the prominent Northeast Trade Winds drive most of the weather. Air masses collide with the Island on its Atlantic (eastern) side, oro-graphically lifted over the 800 m-high mountains, and carried





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across to the Island's Caribbean (western) side. This pattern generates an average of 350 cm rainfall on the windward side and interior and 150 cm in the southern lowlands.

Geologically, Grenada lies on the southern edge of the Lesser Antilles Island Arc, and is entirely volcanic except for the off-coast coral reefs and resulting white sand beaches. The overarching rock type is basalt, though smaller smoothed and rounded granite stones can be found all around the island, and in particularly high concentrations at archeological sites. Since granite is not found naturally on Grenada, archeologists surmise that these were brought to the island or traded between islands and perhaps used in the Carib Stones' creation (Hayward, Atkinson, & Cinquino, 2009; Marquet, 2009).

Representing one of the largest concentrations of West Indian rock art, Grenada's Carib Stones contain more than 100 individual petroglyphs, carved into basalt. Depending on sources, there are five (Marquet, 2006) or six (Dubelaar, 1995) petroglyph sites, though the two most visited sites represent this study's focus: Duquesne Bay (also seen as *Duchesne*) on the Island's northwestern coast and Mt. Rich in the north-central rainforest (Fig. 1). Rock art itself is categorized into four overarching types: petroglyphs, or images pecked into the rock; pictographs, or painted images; geoglyphs, or rock alignments; intaglios, desert pavement scraped away to reveal non-varnished surfaces beneath (Whitley, 2005).

Dubelaar (1995) notes the Carib Stones' patterns and engravings are representative of rock art found throughout the Greater and Lesser Antilles that span the Pre-Contact era (900–1100 CE), suggesting creation by common inhabitants. Although individual petroglyphs and motifs of Grenadian rock art have been documented by outside parties periodically since the early 20th century (cf., Dubelaar, 1995; Hayward et al., 2009; A. Cody in Hedges, Cover, & San Diego Museum of Man, 1990; Huckerby, 1921; Marquet, 2002, 2006, 2009), any analyses of their physical conditions or geologic stability have been sorely neglected. To date, the Carib Stones' petroglyphs have also never been dated scientifically, with ages derived solely from archeological evidence found throughout the West Indies. Formal dating of the petroglyphs would add a new dimension to the sites' context.

## Method

Separated into five general categories, RASI analyzes over threedozen different rock decay forms that, together, yield a finelydetailed snapshot of the current state, strength, and potential longevity of rock art panels, or rock faces. These overarching categories include: the setting, impending loss, incremental loss, large break-off events, and rock coatings. Researchers rate each type of rock decay on a scale of 0-3 in all four categories for every individual panel, resulting in six degrees of risk that coincide with specific scores (Table 1).

The setting assesses the boulder as a whole including factors such as the panel's aspect, stone hardness, fissures/cracks, and lithification (how the stone was formed). Impending (future) loss rates the possibility and prediction of decay in the near future. This could be in the form of nearby roots fracturing the rock, undercutting of the boulder's foundation, or the development of weathering rinds, among other elements. Incremental loss refers to the detachment of small pieces of rock or superficial issues such as chipping, granular disintegration, deteriorating rock coatings, and more than a dozen other elements. The fourth section, break-off, evaluates larger events, like fire damage, rock fall due to undercutting, and anthropogenic removal, plus several additional elements. Mostly observational in its deployment, the fifth section, rock coatings, centers on determining whether or not the coating strengthens or weakens the rock. The RASI also contains a sixth,



Fig. 1. The tri-island nation of Grenada, West Indies and the two study site locations.

## Table 1

The final score ranges for a RASI assessment providing broad view of a panel's overall geologic stability. The final score together with a fifth, qualitative category, allows site managers to see a generalized picture of the panel in question, while still being rigorous enough to help determine specific concerns that may need further management. To help visualize the RASI's rock decay parameters, an online atlas is available: http://alliance.la.asu.edu/rockart/stabilityindex/RASIAtlas.html.

Score range	Meaning	Associated Color Code
≤20	Excellent condition	Blue
20-29	Good status	Green
30-39	Problem(s) that could cause erosion	Brown
40-49	Urgent possibility of erosion	Yellow
50-59	Great danger of erosion	Orange
60+	Severe danger of erosion	Red

qualitative category of elements allowing researchers to catalog basic observations that a site manager might use in their overall site assessment (highlighting vandalism and other issues).

## Results

## Duquesne Bay analysis

The petroglyphs at Duquesne Bay, located on the northwestern coast within feet of the Caribbean Sea, are hosted on three panels, numbered from north to south (Fig. 2). Although some of the host boulders can often have a thin dust coating of sand and salt, this is generally washed away with each (numerous) precipitation event. Consequently, no evidence of salt accumulation that would lead to potential salt weathering as might be seen along desert coasts is found at Duquesne Bay. This location also hosts six boulders containing multiple cupules (cup-shaped, pecked pits on a rock surface) ranging from two to twenty-two that were recorded and mapped, but not evaluated as part of this study. The site is so close to the water, that several of the cupules remain partially submerged-some covered entirely during high tide-and consequently highly eroded or covered with barnacles and other crustaceans. Local "guides" note that more boulders were once here, but have since been covered with sand.

Potential now-covered petroglyphs notwithstanding, the two main rock art panels rest on a boulder *below* the sand level. In a previous attempt to protect the petroglyphs, all the sand surrounding the boulder was excavated during the 1990s and cement retaining walls erected. Despite the good intentions, however, the walls collect (waste)water and runoff from nearby homes and ridgeline, as well as rain and storm water during the wet season. This has caused severe damage to these petroglyphs, especially those located at the base of the boulder, reflective in this site's final RASI scores. The third panel, located on the now-bottom side of a boulder that has since fallen from the ridgeline, hangs precariously *above* the ocean, away from the two larger panels. This panel is unique among Grenada's Carib Stones because it is carved *around* the corner of a large, rectangular boulder.

## Panel One

Representing by far the most well-known, and easiest to find, Panel One depicts what many believe to be male and female humanoid gods (Dubelaar, 1995; Hayward et al., 2009; Marquet, 2009) along with very large, and extremely faint, concentric circles reaching up to six feet in diameter, covering the entire rock face (Fig. 3). The primary concerns with this panel revolve around the amount of stagnant water found around the boulder's base and subsequent significant lithobiont activity and potential for scaling.

Lithobionts—organisms like mosses and lichens that can *live* on rock (Viles, 1995; Viles, Naylor, Carter, & Chaput, 2008)—are capable of not only decaying rock minerals, but when they die and detach, they often take the now-weakened rock grains with them, leaving a pitted surface. This process, known as lithobiont pitting, is destructive in several ways (Danin, 1985; Danin & Caneva, 1990; Garty, 1999). In the case of Grenada's Carib Stones, firstly, bits of rock itself are being lost, and secondly, the process also leaves behind mineral-deprived stone surfaces more susceptible to other forms of decay. In the case of Panel One, where pitting started, other structural and superficial issues such as abrasion, flaking of the surface, and the presence of other organisms, like lizards and spiders inhabiting fissures (and sometimes inside the lithobionts' pits).



Fig. 2. Location of Duquesne Bay study site (inset) and corresponding petroglyph panel locations.



Fig. 3. Duquesne Bay, Panels One and Two. Note the cement (right) and rock-and-mortar (left) retaining walls. While originally erected as a protective measure, they allow storm water and household runoff to collect at the boulder's base, destabilizing it. Note also the extreme discoloration and heavy rock coatings on both panels, including algae and lithobiont coatings.

Additionally, due to fissures, scaling (spalling) has already occurred on one of the Panel's main engravings, and future scaling is likely to continue in this region, eventually degrading the other main engraving. Dust and particulates trapped in the fissures can expand and contract with wetting and drying, forcing apart grains and eventually larger areas of the rock. In the case of Panel One, because this process is occurring *on* the motifs themselves, it is highly detrimental to the stability. Since the main engravings are near the rock's base, they are in greater danger of being lost.

Despite this intensive surface decay, however, the two humanoid petroglyphs are still very clearly seen, a testament to the incredible depth their creators carved into the rather hard basalt. Yet in light of these findings, Panel One remains in *Great Danger of Erosion*, and will require significant conservation efforts for longterm preservation.

## Panel Two

Located on the opposing face of the same boulder as Panel One, Panel Two has similar concerns and is in a slightly worse condition (Fig. 3). The engravings on this section are smaller and closer to ground level, resting in an area where water pools regularly, leading to abrasion events as water recedes. Drainage from nearby homes has also left heavy chemical deposits (efflorescence) on the entire face, raising questions of future abrasion and overall surface stability. Panel Two has also experienced a lot more granular disintegration than Panel One, severely compromising the surface. This could be due to mineral degradation, dissolution due to the efflorescence, or capillary action of evaporites, but also, like Panel One, there are signs of lithobiont pitting. While fissures cover the surface, they are mostly superficial (<a few centimeters deep), posing no structural threat. Given these RASI characteristics, Panel Two was rated as being in Great Danger of Erosion, and requires similar precautions to Panel One.

## Panel Three

Positioned on a boulder that has obviously fallen after the creation of the petroglyph, and found several meters south of the main Panels One and Two, Panel Three, a lone human face, is unique in its carving over two facets: one facing out toward the beach and the other downturned (Fig. 4). The boulder itself remains elevated about a meter above the high tide mark, with the bottom still visible. The underside, with less sun exposure but more water, has developed moss and algae, which could be a concern. The outer face is in better condition, aside from light chemical coatings (from chalking and painting-a common practice among some archeologists to "bring out" a petroglyph's form) and bird droppings. This panel is significantly closer to the sea so there is potential risk of wave damage, particularly underneath, but only during storms. Very thin dust coatings were also observed though, like salts, most likely get washed off after each precipitation event. Unlike the other two panels at this site, however, Panel Three has a thicker rock coating (a layer of hardened minerals that reinforces the surface, see Dorn, 1998) that usually stabilizes petroglyphs (Dorn et al., 2008), helping the panel earn a rating of Good Status despite its precarious position.

## Mt. Rich analysis

Situated at a higher elevation than Duquesne Bay, and in a tropical jungle environment, the Mt. Rich site consists of ten panels on three boulders and six cupules on two boulders at the bottom of a 10-m high ravine along the St. Patrick River (Fig. 5). Being so far inland and experiencing a tropical rainforest climate, there is no accumulation of salt decay patterns at this site, presumably because they are washed away with each precipitation event. Local "caretakers" claim the boulders were part of the ravine's ridge and fell into the gulch after the petroglyphs had been engraved, though exact timeframes vary depending on local sources. Topographical features and locational evidence (i.e., how the boulders "landed" in the riverbed) suggests the boulders *slid* rather than tumbled, leaving the many petroglyphs intact and near their original orientation. Misalignments and impossible angles of some panels support this assertion, though petroglyphs being added once the boulder settled in the riverbed should not be dismissed. Scientific dating of petroglyphs from each panel would help in establishing a clearer creation timeframe.



Fig. 4. Duquesne Bay, Panel Three. This boulder fell from the ridgeline long ago, and has rested in its present spot a meter above high tide for many years, according to the local "guides". It is unique as a petroglyph, as the maker used the boulder's corner to create their motif.



Fig. 5. Location of Mt. Rich study site (inset) and corresponding petroglyph panel locations.

While all boulders are currently situated in the active streambed, only the two small boulders, both cupule-bearing boulders, and part of the large boulder are inundated during floods. Most of the panels on the large boulder remain outside of a flood event's path. There is also the added element of thick vegetation and biota where, for example, several trees overhang the ravine and panels, at times having direct contact with the glyphs, and providing daylong shade which inhibits the rocks' drving capability leading to higher-than-normal lithobiont activity. The majority of panels at this site are found on a single massive boulder approximately  $5 \times 3 \times 4$  m in size, though Panels Two and Three are located on the same boulder, but different aspects, so they were analyzed separately. Likewise, remaining panels, numbered four through ten, rest on multiple facets of a single, large boulder (Fig. 5). Because differential exposure, alignment, lithification, and aspects play vital roles in the stability of rock art panels, each was evaluated individually.

## Panel One

Resting on top of a low-lying flat boulder partially submerged in the stream, Panel One contains a singular face glyph (Fig. 6). On the panel itself, small grooves that parallel stream flow suggest the movement of debris and other objects over the surface during rain and flood events. This causes extreme abrasion and loss of rock coating that, with additional issues stemming from overhanging trees and branches that scratch the panel, destabilizes the rock's surface as a whole. While the glyph itself has been so smoothed it is barely detectable, the panel has a strong stability overall (*Problems That Could Cause Erosion*). Also noted on Panel One is the presence of a suspected cupule adjacent to the petroglyph—though it is not as deep or clear as others found at this site, the distinctive circular pattern can be seen.

## Panel Two

Consisting of two anthropomorph engravings, Panel Two sits on the downstream edge of the boulder (Fig. 7). There are obvious high water marks where abrasion has removed much of the rock's protective coating, leaving the surface susceptible to other forms of surficial decay and blurring of the petroglyph edges. The petroglyphs, however, are still clearly visible and the panel itself is relatively secure, so it received a lower RASI ranking. Being in considerably better condition than one would suspect for petroglyphs in a streambed (*Problems That Could Cause Erosion*), speculation can be made that the downstream aspect preserves the panel by reducing the risk of impact or other damage during possible flood events, though close proximity to the ravine wall leaves the boulder in danger of being covered by even a small mass-wasting event.

#### Panel Three

Resting on top of a boulder, Panel Three contains a single anthropomorphic face (Fig. 7). Much like Mt. Rich's Panel One, it has several branches and vines abrading the surface. But a more serious factor is the irregular formation of the rock itself. Dissimilar to the other boulders found at this site, Panel Three is sporadically fractured, uneven, and has fascinating microtopography, including multiple ridges and textural anomalies, that lead to different decay rates that, in this case, remain a major destabilizing agent. The surface stability has been greatly compromised as evinced by the deterioration of the whole rock face due to expansive alveolization (honeycombing) and granular disintegration. The boulder's location next to the ravine wall serves to lessen the risk of flooding, but increases potential loss from soil erosion and landslides. Like Panel Two, Panel Three's petroglyph is within inches of the heavilyvegetated ridge and even a minor mass-wasting event could completely bury the panel. Considering the combination of current decay characteristics with impending deterioration, Panel Three is at a considerably higher risk of destabilizing (Urgent Possibility of Erosion) than its neighbor, Panel Two.

## Panel Four

This large boulder's downstream face covers such an extensive surface area that it required a two-part assessment (*Upper Four* and



**Fig. 6.** Mt. Rich, Panel One. This large boulder, containing only one engraving, shows evidence of being abraded during flood events ("Linear Abrasion"), as well as significant lithobiont (lichen) growth. Notice also the small cavities ("Textural Anomolies"), potentially from ballistic impact during flood events, and the leaf litter that can secrete chemicals that affect rock stability.



Fig. 7. Mt. Rich, Panels Two and Three. Split essentially in half by a large fissure, the boulder hosting Panels Two (boulder's right-side) and Three (upper left) shows evidence of abrasion from high water events and vegetation, as well as surficial water runoff that comes from the unstable slope (left side).

*Lower Four*) providing greater attention to detail, and then a rejoining of the parts for the final panel analysis. Lower Four consisted of several anthropomorph and complex geometric engravings, while Upper Four contained only a few faint humanoid faces. The panel overall has major concerns with undercutting and lithobiont activity, both of which can be attributed to its downstream location and south-facing aspect. During floods, water removes nearly all the sediment that once supported this section of the boulder, and abrasion, which would be expected during peak discharges, is non-existent. Without direct contact from flood sediments, the river lacks the required force to dislodge any lichen from the boulder's surface. This allows a lithobiont lifespan long enough to decay the rock minerals, die, and take weakened rock grains with them. This is both a current and future concern as the panel is covered with pitting and still-living lithobionts (lichen and algae).

Upper Four contains the majority of the panels' fissures, with several running the entire panel length. Surficial water runoff, undercutting, and a large textural anomaly along the main fissure, also raise concerns about Upper Four's structural integrity. Some textural anomalies have also lead to slight differential and cavernous decay, which only encourage the habitation of small organisms in the cracks, increasing stresses on the rock. With these elements then, Panel Lower Four, with the majority of lithobionts, is in significantly more danger of erosion, while Upper Four displays problems leading to erosion. The disparity could be due to the lower half's closer proximity to the point of impact and/or greater flood damage and higher humidity rates being closer to the water source, though averaging the two panels' scores results in an *Urgent Possibility of Erosion* classification (Fig. 8).

## Panel Five

Illustrative of a panel with *Good Status*, and located on the northwestern tip of the large boulder, Panel Five houses one intricate anthropomorph and one geometric engraving. Primary concerns for Panel Five include fissures and lithobiont activity. Continuing in a curvilinear pattern around the rock from Panel Four, one fissure runs directly through Panel Five's geometric. This is a major concern in tropical environments because the abundant dust, soil, plant matter, evaporites, and tiny organisms lodge in the cracks, contracting and expanding in conjunction with moisture differences. This generally accepted rock decay process exerts pressure on the fractures and breaks down the stone structure (Birkeland, 1974; Büdel, 1999; Frazier & Graham, 2000; Rundel, 1978; Viles, 1995). The lithobionts on this panel are primarily mosses and algae, which are less destructive to the stability of the boulder initially, but grow faster in the damper climate and more shaded location, obstructing the petroglyphs themselves, rendering them lost. An interesting aspect to this particular panel is the anthropomorphic face inset *into* the rock approximately 5 cm, meaning the artist had to first carve out the indent—or enlarge an already-present vug—and then engrave the face on *that* surface. Regardless, this unusual petroglyph required significant work and patience as well as use of implements capable of engraving into the resilient basalt.

#### Panel Six

Found almost entirely on a pillow basalt inclusion, Panel Six on the western face contains several basic geometric designs. Pillow basalts, while less common on other parts of the island seem to be prevalent in the Mt. Rich area, and perhaps owing to pillow basalt's unique decay pattern, very few fissures were found on this panel, with the majority of its threats being non-structural, such as lithobiont pitting and rounding of petroglyph edges. Like the rest of the panels at this site, due to the higher humidity and shady locale, Panel Six exhibits significant lithobiont activity. This can lead to a higher degree of surficial damage and mineral depletion, as manifested by granular disintegration and a breakdown of the surface structure. For the most part, however, these are minor issues, nonthreatening to the petroglyphs themselves, as evinced by a *Good Status* on the RASI ranking scale.

## Panel Seven

Panel Seven, the large boulder's south-facing upper section, includes multiple anthropomorphic faces and a few geometrics, all of which are very faint, and some of which are nearly indistinguishable from general rock decay patterns. Although Panel Seven is several meters above the water, it sits barely a meter from a very steep hillside with small cocoa and gum trees next to it. Evidence of small mass-wasting and flood events exist in the form of multiple striations and abrasions. The added stress of previous lithobiont activity, coupled with being covered by a small leafy canopy, puts the panel even more at risk. With fewer minerals to strengthen the outer shell, debris impacts, or even falling rocks, have greater



**Fig. 8.** Mt. Rich Panels Four through Ten. This single large boulder contains the majority of petroglyphs at the Mt. Rich site. Note the ubiquitous lithobiont (lichen, moss, and algae) cover, indicating a perpetually stable and moist state. Panel Four contains the largest fissure of the boulder's fissures which bisects Panel Ten (top) and separates Panels Seven and Eight (backside of boulder). The small rock in the lower-left corner offers evidence that this boulder slid down the slope, rather than tumble, as petroglyphs from Panel Eight abut against it, making it impossible to create the engraving *in situ* (see Fig. 9).

influences on the stone surface. For Panel Seven, this deadly duet has taken its toll, and many of the petroglyphs are at risk of being lost entirely. Since RASI is designed to assess geologic stability of the rock as a whole and not the petroglyphs specifically however, Panel Seven is ranked as *Good Status*, even though there is significant surficial damage and many petroglyphs are fading due to loss of rock coatings.

#### Panel Eight

With a high concentration of heavily pecked petroglyphs representing an array of subjects, Panel Eight on the underside of the south aspect, contains particularly interesting glyphs: several large cat-like engravings (Fig. 9). What makes these zoomorphics so intriguing is the absolute absence of any large mammal-including any feline species except domestic cats first introduced during the Colonial Period-on the island. The largest mammal to inhabit Grenada is the >1 m in size Mona monkey, introduced (accidentally) in the early Colonial Period via a slave ship. Based on similar South American motifs (Whitley, 2001), this leads to the assertion that these particular petroglyphs serve as a type of "remembrance" from a previous location, most likely from Venezuela, based on the size and shape (David S. Whitley, W & S Consultants, 25 May 2012, e-mail). This hypothesis is further supported with archeological evidence that the Arawak and Carib Indians (the presumed "authors" of the Carib Stones) migrated from northern South America where large feline species are common (Hayward et al., 2009).

Considering the age, location, and mass-wasting event the entire boulder experienced, this panel is in remarkably good condition, especially for being in the direct flow of water during floods. The rock coating has long since eroded and there is a fairly large fissure running down the side, but the engravings are so deep, they remain incredibly clear. Much like the rest of the boulder, Panel Eight contains copious lithobiont pitting, but again, this is mainly confined to the surface, and does not yet threaten the deep carvings. Overall, this unique panel is experiencing *Problems That Could Cause Erosion*—a very good score for a panel resting in and near a stream for such a long time.

Panel Nine

Located on the boulder's top, but on a different aspect as Panel Ten, Panel Nine, on the eastern edge of the boulder, contains multiple anthropomorphs and the signature petroglyph for this site: a large and complex sun geometric. A small abandoned house at the ravine's top has been converted into an unofficial viewing platform for the boulder itself, and the sun glyph is the most easily recognized from that vantage point.

Paralleling the river, there is an element of flood risk for Panel Nine. While the majority of the petroglyphs are on the upper half of the panel, evidence of previous flood damage (abrasion, impact marks, and loss of rock coating) overwhelms the lower portion. Several fissures along the surface, some within inches of the glyphs, also suggest an element of structural weakness, possibly from the initial fall/slide. Though little impending risk of the fissures completely dislodging this section of the boulder exists, their proximity to the glyphs is an immediate threat. Water flowing off the surface (i.e., rain events) tends to take the path of least resistance-in this case the fissures-and form mini channels. Unabated, this increases the quantity and velocity of potential surface water, and also the erosive ability, leaving the petroglyphs in a compromising position. The RASI's purpose, however, rests in establishing a rapid and encompassing assessment of a panel's current condition with only a few elements of future predictions. As the majority of concerns with Panel Nine are impending risks, it received a Good Status ranking.

## Panel Ten

The final panel at Mt. Rich consists of a few anthropomorphic faces, but the angle of the panel makes analysis difficult. Resting on the very top of the boulder, the panel could only be seen from two vantage points: a *very* unstable nearby slope near Panel Seven, or the make-shift ridge top view house. The detailed analysis was conducted for the few portions visible from the unstable slope, and the "big picture" issues and setting assessments were evaluated from the view house. The fairly consistent patterns of decay on this boulder made this normally unconventional method permissible, and Panel Ten's major concerns are fissures and lithobiont



Fig. 9. The "Big Cat" petroglyphs at Mt. Rich, Panel Eight. Unique among West Indian rock art, these "remembrance" etchings remain fairly stable from a rock decay standpoint. The inset image shows the impossible carving angle, supporting the notion that the large boulder came to rest against the smaller boulder during its presumed sliding down from the ravine's top.

activity—what would be expected for an upward-facing petroglyph panel in this environment.

## Panel Ten displays multiple shallow fissures across the surface, implying a low level of structural risk. The panel's orientation and overall stability, however, suggest these are the result of either textural anomalies or surficial water movement from precipitation events. Many of the fissures have filled with soil, dust, lithobionts (mostly lichen and algae), and presumably evaporites, introducing minor concerns for the development of fissuresols (or calcrete/soil wedging, see Villa, Dorn, & Clark, 1995). Additionally, while the lithobionts in the fissures present future issues, they have already done significant damage elsewhere on the panel. Through extensive pitting across much of the surface, rock coatings have been severely compromised, especially on the petroglyphs themselves. Rock coating removal can destabilize an entire panel and expose rock underneath to environmental pressures—increased in the harsh tropical climate.

A nearly-fluorescent orange "stripe" was found on Panel Ten, and could be an attempt to prevent the extreme pitting by a local "guide" (though its effectiveness is questionable), an amateur attempt at chalking, or just random graffiti. Regardless of its intent, the strip serves to destabilize the rock surface. Much like other panels on this boulder, however, Panel Ten exhibits a lot of potential for *future* complications, but as of now remains, structurally at least, fairly stable in *Good Status*. Another encouraging note on this panel is the presence of repatinated petroglyphs, or glyphs completely recoated in rock coating. While at first glance they were thought to be lithobiont (lichen) growth, upon closer inspection, the darkened surface are indeed a mineral coating. Rock coatings form very slowly and over long periods of time, leading to the inference that many of the petroglyphs have been consistently stable for an exceptionally long time.

#### **Discussion and conclusions**

In the interest of an informal and fledgling cultural heritage management endeavor, RASI was employed to assess the geologic structural stability and longevity of two well-known rock art sites on the island of Grenada: one on the Caribbean coast and the other in the rainforest. Extensive analyses showed both the Duquesne Bay and Mt. Rich sites to be at risk of decay, though on the whole, the coastal site (Duquesne Bay) remains in a considerably less stable condition than the rainforest (Mt. Rich) site.

Overall, the stability of the petroglyphs at Duquesne Bay depend almost entirely on their proximity to water: whether puddles stagnating behind the retaining walls, waves crashing during a storm, or residential runoff. Panel Three has the benefits of an elevated position and rock coatings. Ironically, the efforts made to protect Panels One and Two backfired and have severely compromised their stability. On the other hand, without the retaining walls, beach sand would completely bury the motifs on Panel One and all of the petroglyphs on Panel Two. In the end, it seems the retaining wall was put in place based on perceived necessity and infrastructure at the time, even though it is clearly a main contributor to the boulder's accelerated deterioration. Still, the RASI scores suggest very endangered petroglyphs for Panels One and Two and very stable ones for Panel 3 (Table 2).

Although the rock art site at Mt. Rich receives a considerable amount of precipitation, it remains shaded year round, is located in an active riverbed, and has significantly more impact from vegetation than Duquesne Bay. Yet the panels overall are much more stable (Table 2). Reasons for this may include: the lack of direct contact with salt water and accompanying evaporites, which can be extremely detrimental to rock stabilization; the remote location

Table 2	2
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Summary of Duquesne Bay (DB) and Mt. Rich (MR) RASI analyses.

Panel #	RASI score	Notes
DB 1	52	In stagnant water with potential capillary action of
		evaporite minerals, lithobionts, abrasion, flaking, future scaling of engravings
DB 2	54	In stagnant water with potential capillary action of
		evaporite minerals, granular disintegration, chemical
DB 3	20	Face etched on two sides of boulder and fallen from
		ridgeline, algal growth, potential wave and
		salt/evaporite damage due to ocean proximity.
MR 1	39	Low-lying boulder partially submerged, glyph barely visible.
MR 2	34	Downstream side of boulder, glyph clearly visible;
	10	abrasion, loss of rock coating.
MR 3	46	Same boulder as Panel 2, but on boulder's top;
		alveolization, susceptible to mass-wasting event.
MR 4	45 (Lower)	Large downstream-facing panel, divided into upper
	35 (upper)	and lower sections. Lower: Undercutting, lithobiont
		activity; upper: long fissures, water runoff, offset lithification
MR 5	28	Large boulder's northwestern tip. Fissures and
		lithobionts.
MR 6	23	Large boulder's western face. Lithobionts, granular
MD 7	22	disinfegration.
IVIK /	22	Large bounder's south-facing upper section.
MR 8	32	Large boulder's underside south aspect. Deeply-etched
		large cat-like engravings unique to the West Indies and
		potentially "remembrance" glyphs (Whitley, 2012,
		personal e-mail communication). Rock coating loss,
		lithobiont pitting. See Fig. 4.
MR 9	27	Large boulder's top, eastern edge, viewable from
MD 10	20	above ravine. Fissures, surface water flow.
IVIR 10	26	Large boulder's top. Fissures and lithobiont activity

that discourages human contact and visitor impact; the inconsistent sunlight (from the heavy canopy) that may delay the development of some lithobionts while enhancing those that do take root. Any of these, or more likely some combination, have protected the Mt. Rich site and left it, as a whole, in remarkably good condition. Glyph repatination, coupled with the engravings' intense depth of carving, also stands as a testament to the durability and long-term resilience of these petroglyphs despite their arduous environment.

## Implications and recommendations

The Rock Art Stability Index (RASI, Dorn et al., 2008) lays the groundwork for future research, conservation, and management efforts that take into account Grenada's Carib Stones' geologic stability. With the lack of political stability that often comes with smaller governmental infrastructures, and the resultant deficiency of heritage management resources, the conservation options for Grenadian rock art remain extremely limited. Duquesne Bay hosts the most recognized Grenadian rock art site, and is the only site with any physical form of attempted preservation. Yet the location of this site near the ocean, coupled with high foot traffic and close proximity to housing, detrimentally impact the petroglyphs despite the efforts of local (unofficial) caretakers. Besides completely removing the boulders from the coast, a costly and ultimately pointless endeavor, there is very little possibility of prolonging these petroglyphs. In the long term, detailed records and photographs will potentially serve best to retain these priceless cultural heritage resources unless funding and continued infrastructure can be provided by outside aid. Regardless of national or international action taken, researchers trained in the RASI will continue to evaluate the sites annually, and any abrupt changes in overall stability will be brought to attention of the Minister of Tourism.

The panels at Mt. Rich have potentially better futures. Although flooding might be a major concern, this research was conducted during an unusually wet year and the stream levels remained fairly low. While no formal stream gauge is present and no official flood history is recorded for St. Patrick's river, extensive conversation with multiple locals reveal that it does not flood regularly, so the risk of inundation is lower than perhaps assumed. Additionally, discovering repatinated petroglyphs represents a substantial factor in assessing the lasting stability of the panels, even though the options for active preservation are still limited. The deep, steep, and slippery ravine naturally limits human contact and detailed motif recordings with digital photographs should be compiled and updated regularly to monitor any change in stability. In 2006, Mt. Rich was nominated to UNESCO and ICOMOS (Conseil International des Monuments et des Sites) as a potential World Heritage Site (Marquet, 2006) but as of writing-and even though Grenada boasts more total glyphs than the other Windward Islands-this endeavor has proved fruitless.

All too often, ill-informed attempts to preserve, conserve, and/or manage cultural heritage resources backfire with detrimental results. Several decades ago in the Petrified Forest National Park, Arizona for example, clear epoxy was applied to preserve petroglyphs. But desert conditions blackened and melted the sealant, requiring extensive efforts to remove it without damaging the panels. In other cases, large rock art panels have been removed from their initial locations and placed in museums for protection. While this may prolong the life of the panels, the petroglyphs are no longer considered archeologically valid without the locational context, and the original site is potentially left scarred with blast marks and construction debris, like those found in Sego Canyon, Utah when Archaic Period panels were removed and taken to the Smithsonian Institution in Washington, DC. Of course, these endeavors occurred with good intentions, but they lacked scientific background and structure. The RASI offers that foundation and with solid scientific understanding of all key elements at play more applicable and effective policies can be established. In the case of Grenada's Carib Stones, their removal for specimen collection, display, and study would be extremely expensive and difficult, as well as removing them from context, negating their archeological significance. Considering the retaining wall already erected at the Duquesne Bay site and the relative stable condition of the boulders at the Mt. Rich site, it is suggested they be left in their current location.

Ideally, although it would take much effort to implement, formal visitor regulations and monitoring should be instated at each site where resources allow—something with which UNESCO status could indeed help. Panel stability, as assessed using RASI, supports this notion, and we echo Marquet's (2006) sentiments in advocating for *at least* Mt. Rich to be included on the World Heritage site list. Establishing such a moniker would go a long way in terms of providing Grenada recognition for this example of truly outstanding cultural heritage significance, while simultaneously generating global and local awareness and respect for extremely fine examples of important past cultures that have all but disappeared.

#### References

- Allen, C. D., Cutrell, A. K., Cerveny, N. V., & Theurer, J. (2011). Advances in rock art research. *La Pintura*, 37(1), 4–6, 13.
- Allen, C. D., & Lukinbeal, C. (2011). Practicing physical geography: an actor-network view of physical geography exemplified by the rock art stability index. Progress in Physical Geography, 35(2), 227–248.

Birkeland, P. W. (1974). Pedology, weathering, and geomorphological research. New York: Oxford University Press.

- Büdel, B. (1999). Ecology and diversity of rock-inhabiting cyanobacteria in tropical regions. European Journal of Phycology, 34, 361–370.
- Danin, A. (1985). Palaeoclimates in Israel: evidence from weathering patterns of stones in and near archaeological sites. Bulletin of the American Schools of Oriental Research, 33–43.
- Danin, A., & Caneva, G. (1990). Deterioration of limestone walls in Jerusalem and marble monuments in Rome caused by cyanobacteria and cyanophilous lichens. *International Biodeterioration*, 26(6), 397–417.
- Dorn, R. I. (1998). Rock coatings (1st ed.). In Developments in earth surface processes, Vol. 6, Amsterdam, Netherlands: Elsevier.
- Dorn, R. I., Whitley, D. S., Cerveny, N. V., Gordon, S. J., Allen, C. D., & Gutbrod, E. (2008). The rock art stability index: a new strategy for maximizing the sustainability of rock art as a heritage resource. *Heritage Management*, 1(1), 37–70.
- Dubelaar, C. N. (1995). The petroglyphs of the Lesser Antilles, the Virgin Islands and Trinidad. Amsterdam: Foundation for Scientific Research in the Caribbean Region. Publication 135.
- Fitzner, B. (2002). Damage diagnosis on stone monuments in situ investigations and laboratory studies). Seoul: Stone Conservation Laboratory, Seoul National University.
- Frazier, C. S., & Graham, R. C. (2000). Pedogenic transformation of fractured granitic bedrock, southern California. Soil Science Society of America Journal, 64, 2057– 2069.
- Garty, J. (1999). Lithobionts in the eastern Mediterranean. In J. Seckbach (Ed.), Enigmatic microorganisms and life in extreme environments). Dordrecht: Kluwer Academic Publishers.
- Hayward, M. H., Atkinson, L-G., & Cinquino, M. A. (2009). Rock art of the Caribbean. University of Alabama Press.

- Hedges, K., Cover, D., & San Diego Museum of Man. (1990). Rock art papers. San Diego Museum of Man.
- Huckerby, T. (1921). Petroglyphs of Grenada and a recently discovered petroglyph in St. Vincent. Museum of the American Indian, Heye Foundation.
- Marquet, S. J. (2002). Les Pétroglyphes des Petites Antilles Méridionales. Contextes physique et culturel. Paris monographs in American archaeology 11 (BAR international series. 1051).
- Marquet, S. J. (2006). ICOMOS Caribbean rock art information request form submission for Grenada.
- Marquet, S. J. (2009). Contextual analysis of the Lesser Antillean Windward islands petroglyphs: methods and results. In M. H. Hayward, L.-G. Atkinson, & M. A. Cinquino (Eds.), Rock art of the Caribbean. University of Alabama Press.
- Rundel, P. W. (1978). The ecological role of secondary lichen substances. Biochemical Systematics and Ecology, 6, 157–170.
- Viles, H. A. (1995). Ecological perspectives on rock surface weathering: towards a conceptual model. *Geomorphology*, 13, 21–35.
- Viles, H. A., Camuffo, D., Fitz, S., Fitzner, B., Lindqvist, O., Livingston, R. A., et al. (1997). Group report: what is the state of our knowledge of the mechanisms of deterioration and how good are our estimations of rates of deterioration? London: Wiley.
- Viles, H. A., Naylor, L. A., Carter, N. E. A., & Chaput, D. (2008). Biogeomorphological disturbance regimes: progress in linking ecological and geomorphological systems. *Earth Surface Processes and Landforms*, 33, 1419–1435.
- Villa, N., Dorn, R. I., & Clark, J. (1995). Fine material in rock fractures: Aeolian dust or weathering? In V. Tchakerian (Ed.), *Desert Aeolian processes* London: Chapman & Hall.
- Whitley, D. S. (2001). Handbook of rock art research. Oxford: Altamira Press.
- Whitley, D. S. (2005). Introduction to rock art research. Walnut Creek, CA: Left Coast Press.