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The Rock Art of Bahamian Caves: Multi-Scalar Distribution Patterns and Preservation Management

Michael J. Lace,
Coastal Cave Survey, West Branch, IA, USA
michael-lace@uiowa.edu (corresponding author)

John E. Mylroie,
Dept. of Geosciences, Mississippi State University, Starkville, MS, USA
mylroie@geosci.msstate.edu

Joan R. Mylroie,
Dept. of Geosciences, Mississippi State University, Starkville, MS, USA
joanmylroie@gmail.com

Nancy A. Albury,
National Museum of The Bahamas/ Antiquities, Monuments and Museum Corporation, Marsh Harbour, Abaco, Bahamas
nancyalbury@gmail.com

Recent field research in the Bahamian Archipelago has focused on building a more comprehensive karst and cultural site inventory in order to more effectively model the distinctive rock art distribution patterns of the region. We documented cave rock art occurrences across six islands, expanding the geographical distribution in the Archipelago by including previously unreported sites. Detailed cultural resource inventories and cave maps were generated for each of the eleven Bahamian sites and one from the Turks & Caicos islands, some mapped for the first time, to define comparative motif distributions as a function of overall site geomorphology. We defined the spatial context of cave rock art sites in the region, examining their multi-scalar distribution patterns, associated landscape uses, and apparent site selection criteria. The comparative distributional analysis clearly indicates that site selection and rock art panel surface utilization criteria were restrictive, deterministic and dependent on the cave geomorphologies specific to a limited number of islands in the Bahamian Archipelago. We further assessed other indigenous and Euro-colonial uses associated with each site as well as their current and long-term preservation status as fragile cultural remnants unique to the region.

Investigaciones de campo recientes en el archipiélago de las Bahamas se han enfocado en la construcción de un inventario de sitios kársticos y culturales más abarcador con el fin de modelar con mayor eficacia los patrones distintivos de distribución del arte rupestre de la región. Documentamos las ocurrencias del arte rupestre de cuevas en seis islas, ampliando la distribución geográfica en el archipiélago al incluir sitios previamente no documentados. Se generaron inventarios detallados de recursos culturales y mapas de cuevas para cada uno de los once sitios bahameños y una de las islas Turcas y Caicos, algunos cartografiados por primera vez, para definir distribuciones de motivos comparativos en función de la geomorfología general del sitio. Definimos el contexto espacial de los sitios de arte rupestre en la región, examinando sus patrones de distribución multi-escalar, usos asociados del paisaje y criterios aparentes de selección del sitio. El análisis distributivo comparativo indica claramente que la selección del sitio y los criterios de utilización de la superficie del panel de arte rupestre fueron restrictivos, deterministas y dependientes de las geomorfologías de cavernas específicas de un número limitado de islas en el archipiélago de las Bahamas. También evaluamos otros usos indígenas y euro-coloniales asociados con cada sitio, así como su estado de conservación actual y de largo plazo como restos culturales frágiles únicos de la región.

Des recherches récentes sur le terrain dans l'archipel des Bahamas ont mis l'accent sur la construction d'un inventaire plus exhaustif du karst et des sites culturels afin de modéliser plus efficacement les modèles distinctifs de distribution de l'art rupestre de la région. Nous avons documenté des occurrences d'art rupestre des cavernes dans six îles, élargissant la distribution géographique dans l'archipel en incluant des sites précédemment non signalés. Des inventaires détaillés des ressources culturelles et des cartes des grottes ont été créés pour chacun des onze sites des Bahamas et un des îles des Turques et Caïques, certaines cartographiées pour la première fois, pour définir des distributions de motifs comparatifs en fonction de la géomorphologie globale du site. Nous avons défini le contexte spatial des sites d'art rupestre des grottes de la région, en examinant leurs schémas de distribution multi-scalaires, les utilisations du paysage associées et les critères de sélection du site. L'analyse comparative distributionnelle indique clairement que les critères de sélection des sites et d'utilisation de la surface des panneaux d'art rupestre étaient restrictifs, déterministes et dépendaient des géomorphologies des grottes spécifiques à un nombre limité d'îles de l'archipel des Bahamas. Nous avons ensuite évalué d'autres utilisations indigènes et euro-coloniales associées à chaque site ainsi que leur statut de conservation actuel et à long terme en tant que vestiges culturels fragiles propres à la région.

Introduction

Geographic and geologic settings.

The Bahamas consist of 29 islands, 661 cays and over 2300 smaller structures with an emergent landmass exceeding 11,000 km^2. The Turks & Caicos Islands (TCI), a geologic and geographic extension of the Bahamian Archipelago, consist of eight principal islands and numerous smaller cays (Fig. 1). All of the islands within the Archipelago are formed within a system of shallow submerged carbonate banks that span an area of 134, 447 km^2 (Meyerhoff and Hatten, 1974). In contrast to the nearby island arcs, such as the Antilles, the majority of the Bahamian islands lie within a comparatively stable tectonic environment. Pleistocene-aged dune ridges are predominant landscape features on many of the larger islands and cays and the majority of documented caves are formed within such comparatively young carbonate dune structures (Carew and Mylroie, 1997). A significant portion of recorded caves are *flank margin caves* that formed by dissolution processes in the margin of the fresh-water lens during past glacioeustatic sea-level highstands and which are dry at today's sea-level position (Mylroie and Mylroie, 2013a). *Banana holes* are a cave type common in the Archipelago. They are also dissolutional voids (i.e., a variety of flank margin cave) specifically formed within a prograding strandplain by a rapidly migrating freshwater lens [See Mylroie and Mylroie (2013) for a more in depth discussion of the mechanism]. Other cave types are also present in The Bahamas, including *littoral caves* (i.e., sea caves) formed by sea erosion of rocky island margins; *tafoni* formed by salt air weathering; *talus caves* which are cavities formed by dislocated blocks precipitated by cliff retreat; *pit caves* which consist of comparatively simple vertical shafts with limited lateral passage development; and finally numerous oceanic and inland *blue holes* which are inundated structures, including some of the most extensive conduit cave systems in The Bahamas. For a discussion of blue hole identification and their geologic origins, see Mylroie et al. (1995).

The Turks & Caicos Islands encompass the southeastern extension of the Bahamian Archipelago, consisting of shallow carbonate banks fringed by benthic waters. Geologically, the islands feature similar coastal landform development patterns and a predominant expression of flank margin caves, as noted in The Bahamas. The Turks & Caicos Islands, however, occupy a comparatively intermediate tectonic environment where physical expressions of their proximity to the Caribbean and North American plate boundary transform fault zone are apparent in surface and subsurface geomorphologies. In contrast to the majority of the Bahamian cave inventory, TCI cave morphologies indicate a limited but apparent degree of tectonic uplift due to their proximity to complex fault systems in the Greater Antilles.

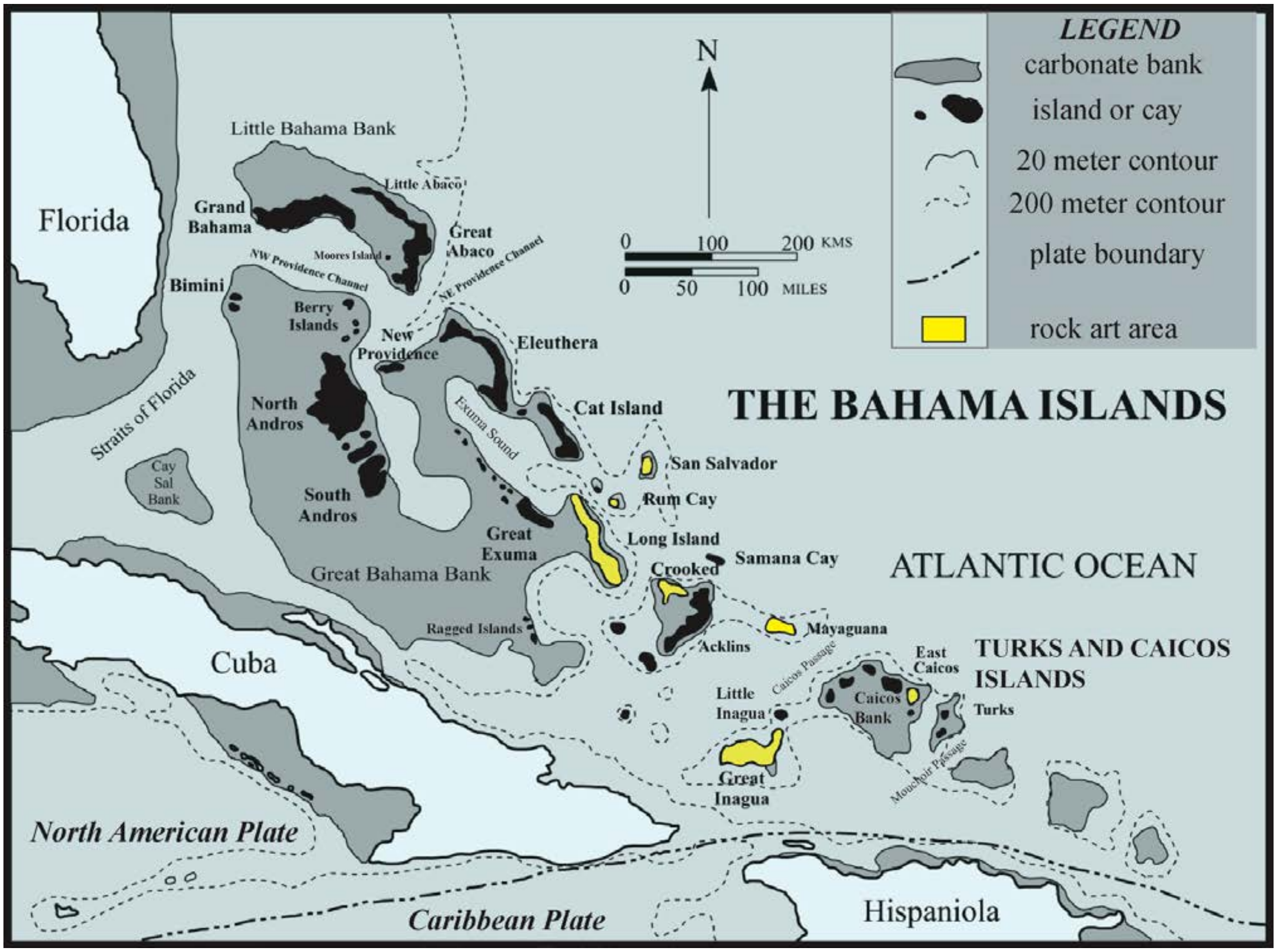


Figure 1. Regional rock art distribution map of The Bahamas and Turks & Caicos Islands. Islands with recorded rock art sites are shown in yellow.

Cultural setting.

As The Bahamas and Turk and Caicos Islands are generally considered an archipelago unit, so too can they be defined as a contiguous pre-Columbian cultural landscape on a regional scale. Coastal settlement and subsistence patterns have been strongly influenced by the dynamic nature of receding and prograding coastal landscapes in the Bahamian Archipelago (Hoffman, 1967; Keegan, 1992a; Scudder, 2001), not unlike the insular coastlines of the adjacent Caribbean region (Doerr, 1960). While surficial deposits have been subjected to long-term episodic redistribution by natural processes, caves have served as comparatively more stable repositories of cultural materials, as noted in many coastal settings (Lace and Mylroie, 2013a). Anthropogenic modification of both surficial and cave sediments, however, has compromised the Bahamian archaeological record to a comparable degree.

History of Cave Archaeology in the Bahamian Archipelago

The Bahamian Archipelago was the focus of several 19th and early 20th century descriptive expeditions, some of which noted cultural vestiges in a select few caves, from the first human remains identified in a Bahamian cave by Brooks (1888) to early cave reconnaissance by De Booy (1912, 1913) and Krieger (1937). In the 1950s, Granberry (1956) noted over 60 prehistoric sites in The Bahamas, with caves forming the majority of this number but the absence of any complete site inventory for the broader archipelago at that time supported only generalized site and artifact distribution trends: "… Furthermore, the southern and central islands are characterized by the presence of cave petroglyphs, monolithic axes, duhos, and a great many zemis, which are relatively infrequent farther north." [1956:131].

Granberry utilized these general distribution patterns to propose a spatial model composed of three distinct geocultural subareas within The Bahamas (i.e., northern, central and southern islands), based primarily on evident distributions of ceramic, wood, lithic and shell materials as well as petroglyph occurrences (Fig. 1). Coincidentally, these arbitrary regional delineations approximated subsequent generalized models of Bahamian paleoclimatic zones (Sears and Sullivan, 1978). Consistent with cultural sequence models of the period, migration into the region was defined primarily by ceramic seriation, placing human occupation beginning in the so-called "late-prehistoric" (period IV), as per Rouse (1992). Later models drew on advancements in surface site excavations and a more modern review of cultural uses within a limited number of cave sites (Carr, et al. 2012). To date, no Pre-ceramic sites have been identified in The Bahamas, consistent with the current spatiotemporal models of pre-Columbian migration through the region (Berman, 2015; Berman and Gnivecki, 1995; Keegan, 1992b).

A number of surface sites have been identified in recent years while the identification of archaeologically significant cave sites has been sporadic. Recent exploration of inundated cave structures in The Bahamas have proven particularly productive on multidisciplinary levels, however, the geographic coverage of these efforts is far from complete with many blue holes yet to be examined in detail (Steadman, et al. 2007; Swart, et al. 2010). No rock art has been identified within or proximal to these structures.

In comparison, the Turks & Caicos Islands display an even more limited rock art distribution pattern with no recorded surface rock art sites and only a single cave site initially recorded on East Caicos (De Booy, 1912). Field studies have demonstrated an archaeologically significant human presence on several islands in the chain associated with surface and/or cave sites (Franz, et al. 2001; O'Day, 2002). Many of these sites date back to the late Ceramic period while the oldest pre-Lucayan settlement in the entire Archipelago identified to date lies on Grand Turk (i.e., GT-3, Coralie Site, A.D. 700 (Keegan, 1992b; Scudder, 2001). The physical proximity of the Turks & Caicos to Hispaniola and Cuba and the similarity of a range of cultural materials have so far supported their theoretical position in models of pre-Columbian migration, settlement and trade in the Bahamian Archipelago (Berman, 2013, 2015).

Just as the unique island genesis within the Bahamian Archipelago places temporal constraints on cave development on a geologic timescale, the current model of pre-Columbian migration and cultural progression in The Bahamas also places narrower temporal constraints on the provenance of Bahamian rock art. This stands in contrast to the Greater and Lesser Antilles where several "Archaic" sites have been recently identified or reevaluated within the context of modern models of pre-Columbian migration patterns as well as practical and ritual landscape uses (Fitzpatrick, 2011; Keegan, 1997; Rodriguez Ramos, et al. 2018).

Practical and ritual cave site usage.

Caves have long served as storm shelters to the Lucayans, European colonists and modern inhabitants in the Bahamian Archipelago. A continuum of cultural as well as utilitarian cave uses in The Bahamas has also been defined (Berman, 2011; Carr, et al.

2012; Keegan, 1982), spanning the early settlement of the Archipelago through post contact periods and into the late 19th century when commercial excavation of guano-rich sediments dominated human interaction with Bahamian and TCI caves (Fig. 2). These commercial-scale excavations, in which cave sediments were typically removed down to the underlying bedrock floor, have undoubtedly destroyed cultural deposits at numerous sites. Figure 2A, for example, illustrates an obvious former guano level indicating the removal of more than one meter of floor sediments. It also illustrates the characteristic morphology indicative of flank margin cave development within an eolianite dune – a common coastal structure strongly associated with karst development patterns in the region.

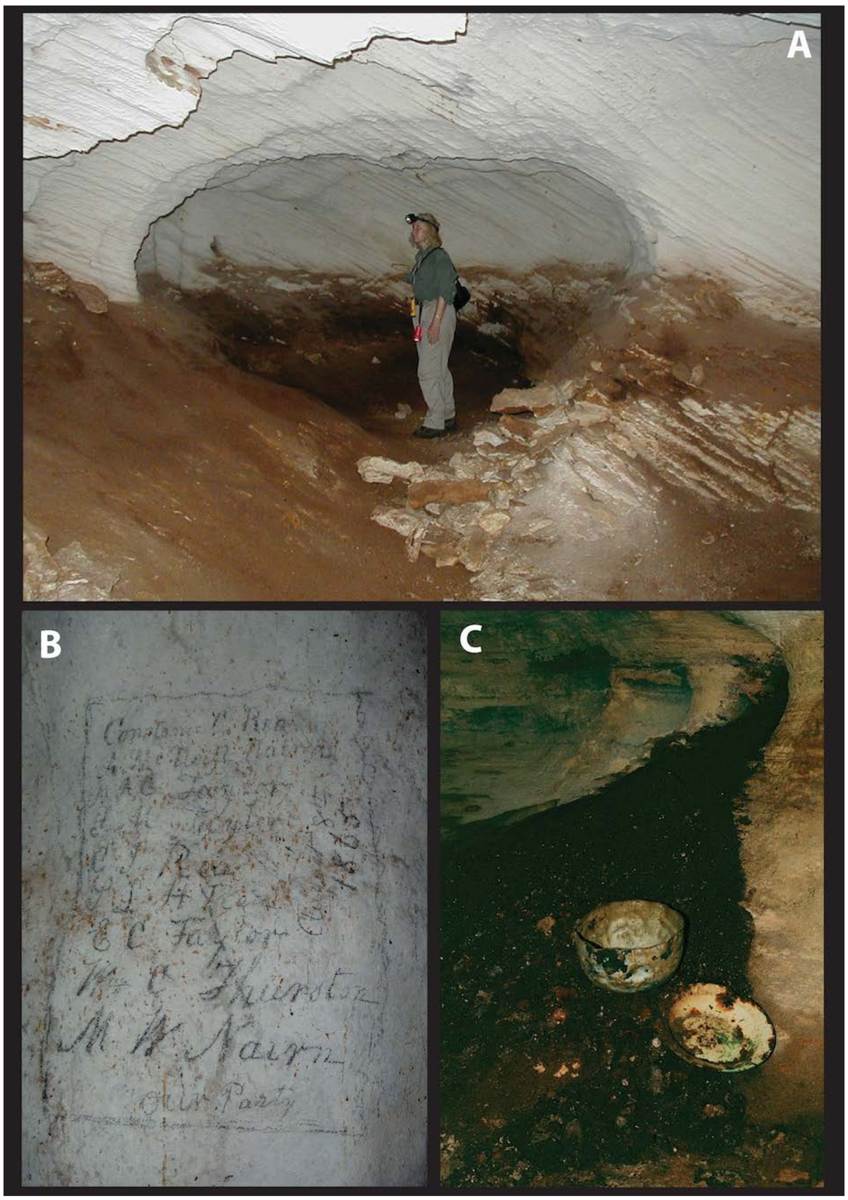


Figure 2. A) Guano-excavated cave chamber, illustrating dipping foreset calcarenite beds within a coastal dune (note former level of floor sediments removed during historic commercial guano mining). B) Example of historic signatures in Hamilton's Cave (Long Island). C) Typical small-scale commercial guano mining evidence.

Many of the cave sites associated with rock art were also associated with other apparent practical and ritual uses from potential water and marine resource utilization to ceremonial activities, including numerous human burials (Keegan, 1982; Schaffer et al. 2012). The cadaster of latter examples, assembled by Pateman (2007), comprises one of the most complete inventories of mortuary cave sites identified in The Bahamas so far. In addition to temporal variations between pre-Columbian migration and settlement patterns, divergent cultural arcs through the Historic period further set the islands within the Bahamian Archipelago apart from those in the Antillean island arc, manifesting itself on many levels of cultural expression and landscape uses.

Ship graffiti within the Bahamian Archipelago, for example, is primarily associated with parietal surfaces of specific colonial era structures (Baxter, 2011; Keith, 2016; Turner, 2006). Identifiable images of historic period sailing vessels were predominantly engraved into the plastered limestone wall surfaces. Only one cave harbors this manifestation of historic period site use in the Bahamian Archipelago and from a comparative perspective stands in stark contrast to other island settings, such as Isla de Mona (Puerto Rico), where it occurs solely within caves as one of many manifestations of an extensive and complex colonial presence (Samson and Cooper, 2015). Systematic documentation of historic period signatures and graphic imagery within caves and other coastal settings in The Bahamas is also currently in progress.

The challenges to rock art research in caves of the Bahamian Archipelago are significant. Anthropogenic and natural effects have significantly altered cave environments, masking or obliterating evidence of past cultural uses. The difficult terrain featured on many of the islands has also made the thorough exploration and study of Bahamian cave sites challenging to researchers past and present. Recent systematic exploration of cave sites across the Archipelago demonstrates that patterns of ritual cave uses in The Bahamas still remain incompletely defined. As in other settings, the principal limitation in developing a more comprehensive understanding of such patterns rests with the compilation of a more complete cave inventory. Similar to studies in other coastal landscapes (Bradley, et al. 1994; Kourampas, et al. 2015), we have applied a multi-disciplinary approach that integrates the distinctive coastal geomorphologies and pre-Columbian rock art distribution as a measure of cultural use patterns within the karst landscapes of the Bahamian Archipelago.

Methods

Non-destructive data collection was systematically applied to all sites, particularly where cave structures were instrument surveyed, photodocumented and inventoried as per Lace (2012), with detailed maps generated for each site. No physical samples of any kind were collected in any surficial or subterranean setting for this study. We utilized a quantitative and qualitative set of criteria to identify the speleogenetic origin of each structure, including correct assessment of site geomorphologies consistent with modern theories of coastal cave development that had either been incorrectly interpreted, incomplete or altogether absent in previous studies in The Bahamas and Turks & Caicos. An in-depth familiarity with the complex coastal processes acting on rock surfaces associated with rock art panels proved indispensable in both identifying new sites and redefining known ones. Further, a rock art stability index (RASI) was determined for a majority of the cave sites. The RASI utilizes visual identification of multi-scalar attributes to compile a composite numerical rating of the overall rock art panel stability potential. The RASI score is based on six general categories containing a total of 43 specific criteria defining the geomorphology and associated anthropogenic, biological and climatic factors that positively or negatively influence the structural integrity of each rock art panel, as per Dorn, et al. (2008). Site number designations are derived from a broader interregional Coastal Cave Survey (CCS) database that comprehensively records all cave sites, including those of cultural, biological and geological significance, in support of wide-ranging multidisciplinary research efforts. Alternate site codes from the Antiquities, Monuments and Museums Corporation (AMMC) Master Register of Historic Resources are listed parenthetically.

Results

Regional Rock Art Site Inventory

Rock art sites were surveyed on six islands in the Bahamian Archipelago, namely, San Salvador, Rum Cay, Crooked Island, Long Island, Mayaguana and East Caicos. The following examples from these islands are described in detail to illustrate the range of site uses and accompanying geophysical attributes, as compiled in Table 1.

Hartford Cave (Rum Cay), CCS Site RU01 (AMMC: RC-001). The flank margin cave is a remote but historically well-known site initially described by Nelson (1853), Maynard (1890) and Mallery (1893), located less than 10 meters from the modern shoreline (Fig. 3). A single 13-meter wide entrance extends 30 meters into a large chamber with a total 65 petroglyphs (Fig. 4 and 5A), including geometric and anthropomorphic motifs (Winter, 1991; 2009) and one pictograph reported by Núñez Jiménez (1997). The petroglyphs cluster in five panels that form a discontinuous arc along the cave's interior perimeter and, as in all cave sites examined, located within the photic zone (Fig. 5A). It is the highest rock art density site reported in The Bahamas to date.

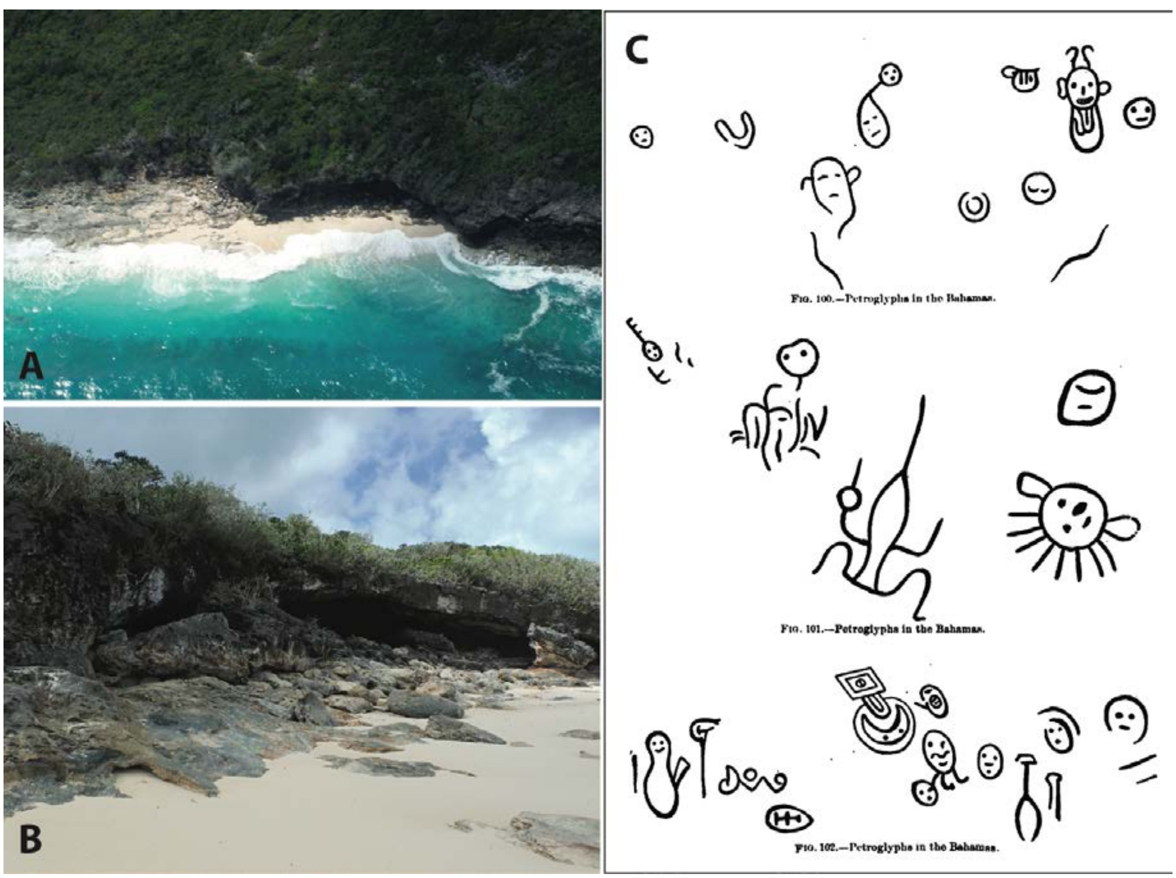


Figure 3. Hartford Cave, Rum Cay. A) Aerial view of coastal setting. B) Cave entrance. C) Historic sketches of petroglyphs in Hartford Cave (from Mallery 1893).

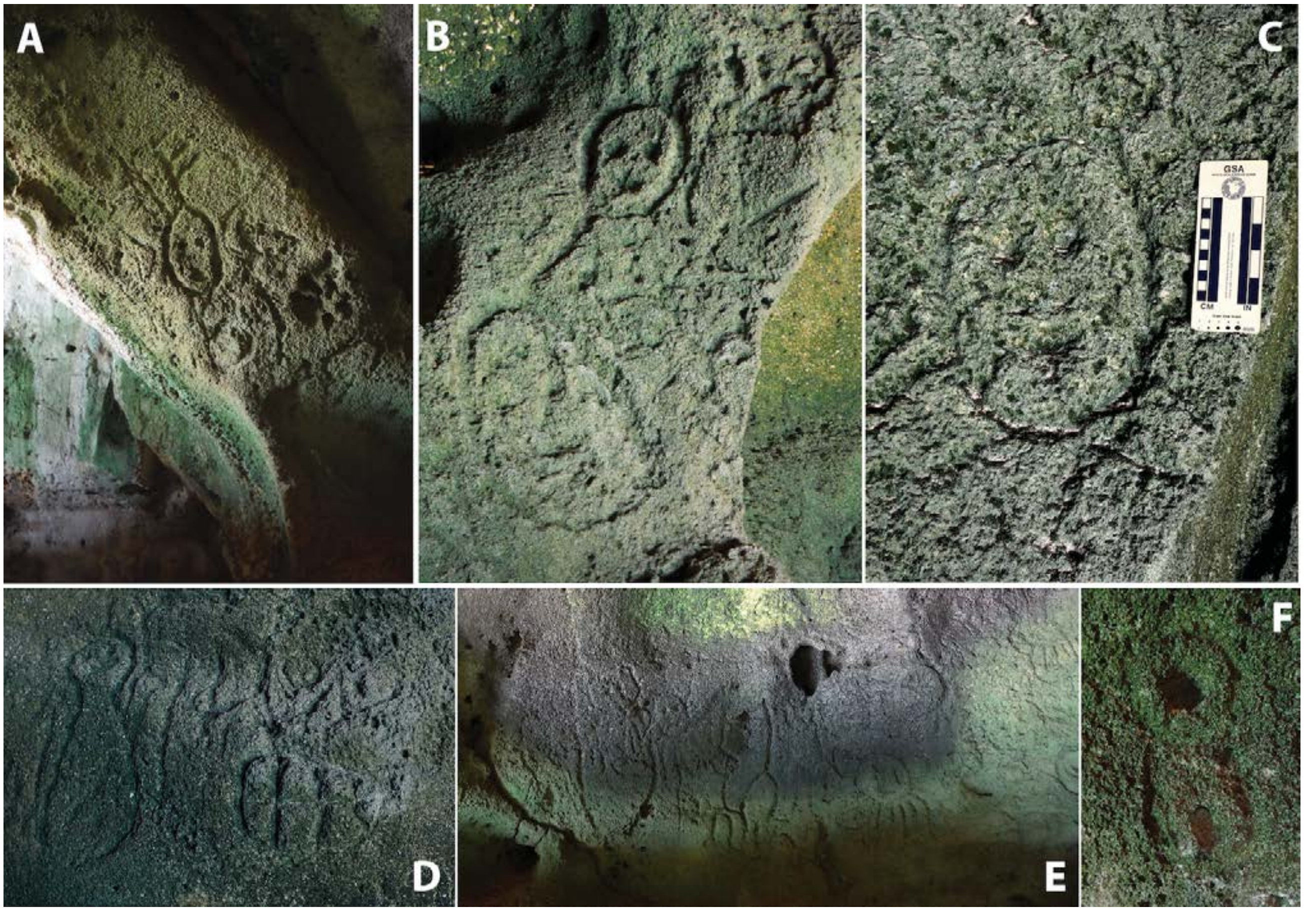
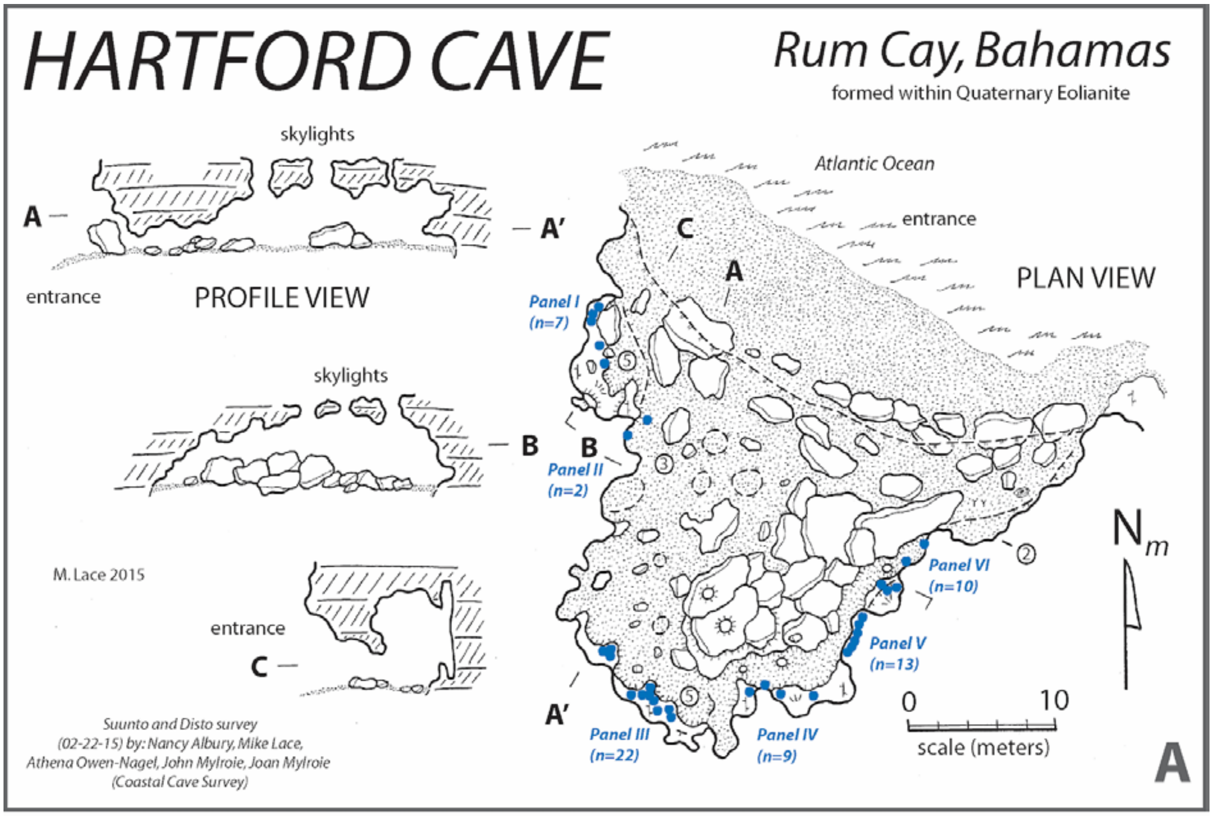


Figure 4. A-F) Representative petroglyph panels carved into the walls of Hartford Cave.

As a function of historical sampling methods, a petroglyph spanning a significant segment of panel III was removed from the cave (date unknown) and subsequently placed in the University of The Bahamas Gerace Research Centre Museum Repository on San Salvador, where it currently resides in storage (Fig. 6A-B). The excision and removal of an already naturally undercut surface represents a potentially synergistic structural destabilization of the panel with significant negative consequences to its long-term preservation (Table I). The site is also exposed to natural weathering and abrasion effects as the main entrance lies within an active supratidal zone and subject to concomitant episodic sand infill/removal events and progressive littoral weathering processes (Fig. 6C).



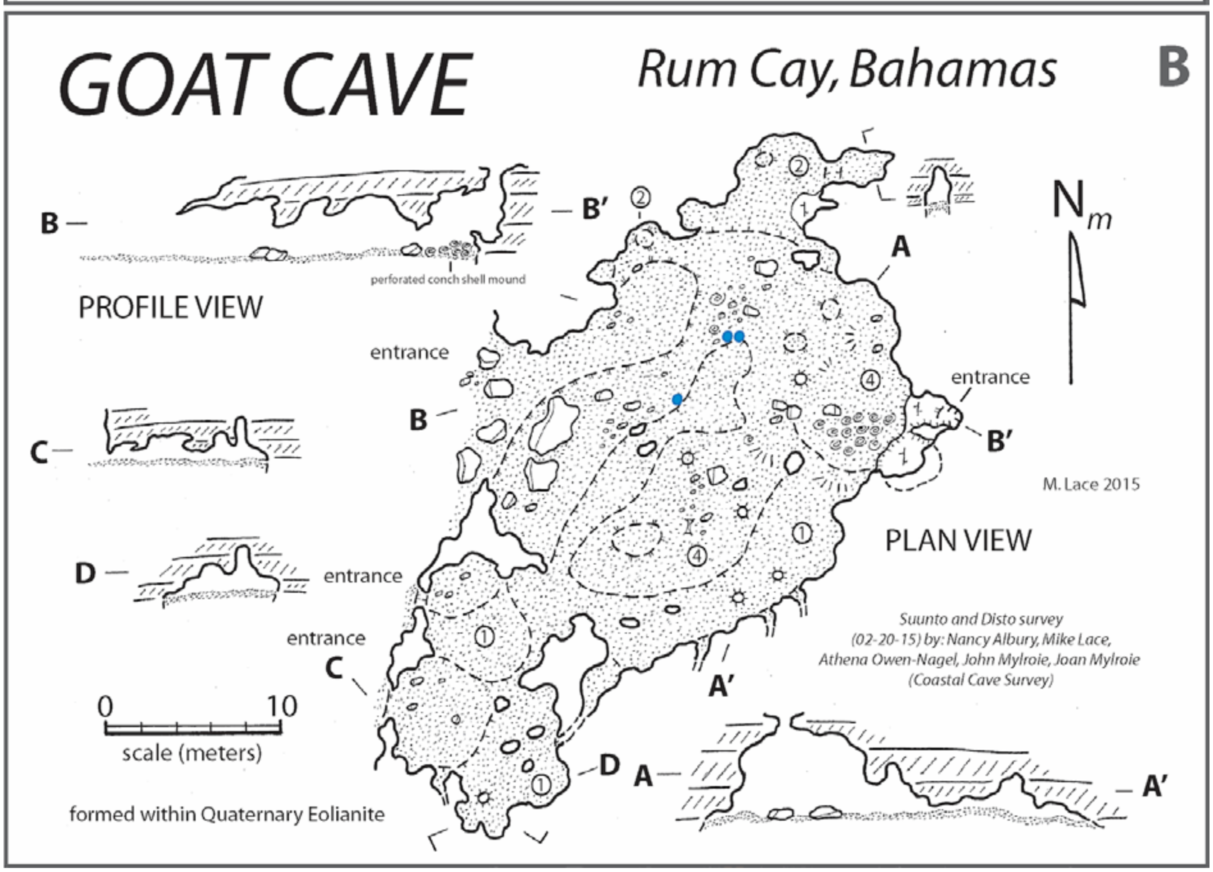


Figure 5. Rock art distribution patterns on Rum Cay. A) Map of Hartford Cave. B) Map of Goat Cave.

Figure 6. A) Petroglyph historically removed from Hartford Cave and B) currently housed at the Gerace Research Centre Museum Repository. C) Example of rock art panel exposure to littoral weathering processes in Hartford Cave.

Goat Cave (Rum Cay), CCS Site RU06 (AMMC: RC-013). The structure forms part of a multi-cave complex located on an interior flank of a dune ridge at the east end of the island. One large, walk-in main entrance and several small entrances (Fig. 7A and Fig. 5B) lead into cave with 70 perforated *Lobatus gigas* (Fig. 7E-F) and one anthropomorphic petroglyph previously reported by Winter (2009) (Fig. 7B). The current site survey confirmed these previous findings and identified a previously unreported single panel composed of six geometric charcoal glyphs partially encrusted with a calcitic deposit (Fig. 7C-D). While it is likely these previously unreported pictographs are of Lucayan origin, the proximity of the cave to colonial era salt works and a historic period origin cannot be discounted at this point. No dating of the overlying coating to define a minimum age date or the underlying charcoal has so far been performed in this or any other Bahamian cave to quantitatively determine temporal provenance of these images.

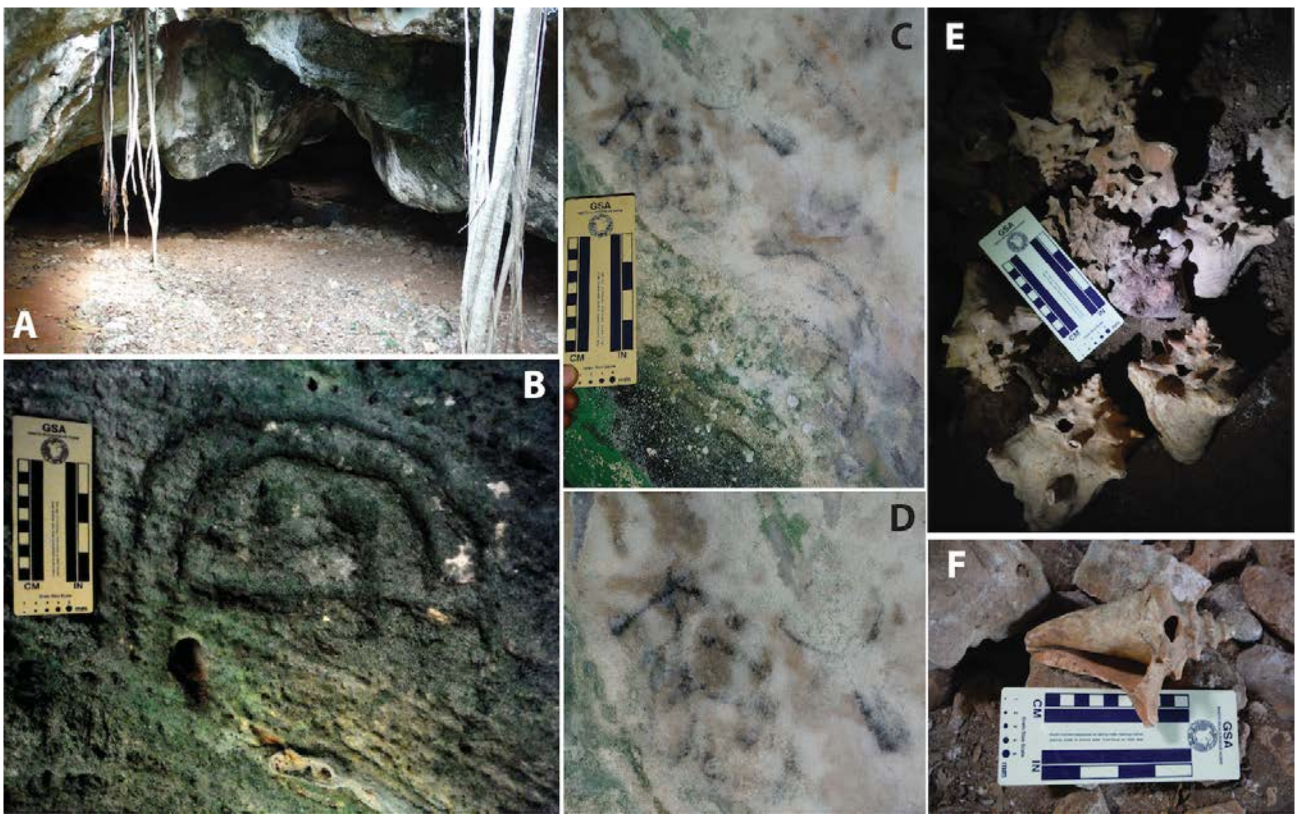


Figure 7. Main entrance to Goat Cave, Rum Cay. B) Solitary anthropomorphic petroglyph and B-C) additional charcoal forms in Goat Cave (note 10-cm scale and depositional calcite overgrowth). E-F) Perforated *Lobatus gigas* assemblage (note 10-cm scale).

McKay Bluff Cave (Crooked Island), CCS Site CI04 (AMMC: CR-005). McKay Bluff Cave [aka. Kelly Cave (Winter, 1991)] is a small single chamber (Fig. 8) that harbors anthropomorphic, zoomorphic (e.g., tortoise) and geometric petroglyphs. Hoffman (1973) reported a total of six petroglyphs. Recent survey of the site, however, revealed a total of 15 petroglyphs within a near continuous panel, six meters in length. The site previously yielded ceramic and bone fragments consistent with Lucayan uses (Winter, 1991). Recent investigation of the site confirmed mortuary use as well as the presence of hutia bone in dated assemblages ranging from A.D. 1450 to 1620 (Steadman, et al. 2017). The provenance of the lightly incised petroglyphs on the aeolianite wall remains undefined but the images suggest a possible post contact origin (Fig. 9); if correct, this would be the only known cave site in the Archipelago featuring identifiable contact period rock art.

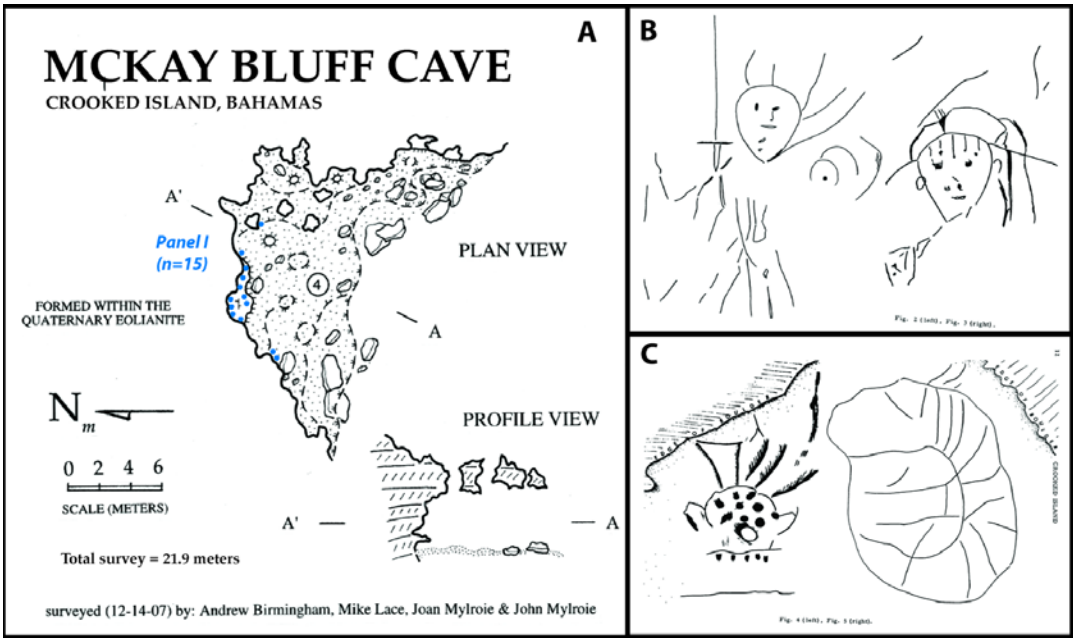


Figure 8. A) Distribution map of McKay Bluff Cave, Crooked Island and B-C) sketches of petroglyphs within McKay Bluff Cave (from Hoffman 1973).

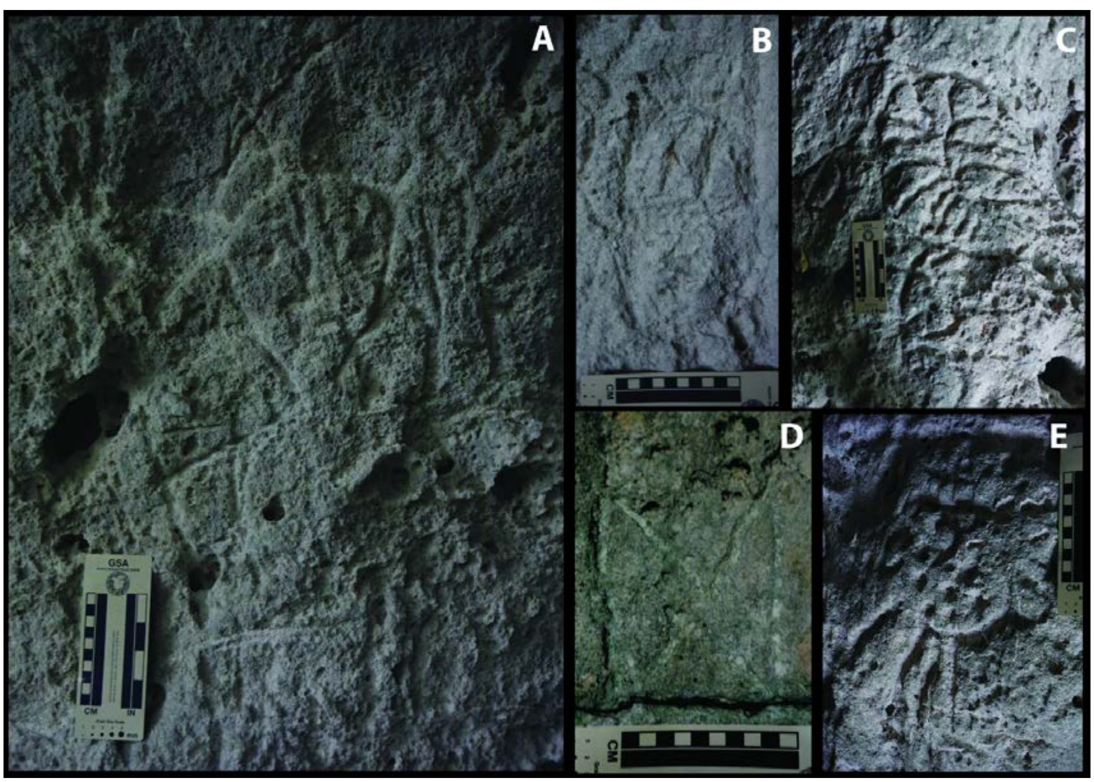


Figure 9. Anthropomorphic, geometric, and zoomorphic petroglyphs within McKay Bluff Cave (note 10-cm scale).

Temple of Athena (Crooked Island). Also known as McKay Cave (Winter, 1991), the site consists of a large single cave chamber formed within the seaward flank of the enclosing eolianite dune (Fig. 11B). This flank margin cave was revealed by progressive lateral breach of the dune by littoral erosion and continues to be exposed to storm surges within the supratidal margin. It harbors some of the most elaborate petroglyphs documented in The Bahamas to date, with a total of 11 examples of distinctive and complex anthropomorphic, zoomorphic (avian) and geometric petroglyphs. The cave also has one of the highest rock art densities in the Archipelago (Fig. 10 and Table 1). Materials excavated from the site yielded a radiocarbon date of A.D. 1240 (Winter, 1991). A recently completed cave inventory by the authors indicates that Crooked Island harbors only two rock art sites out of a total of 31 surveyed caves.

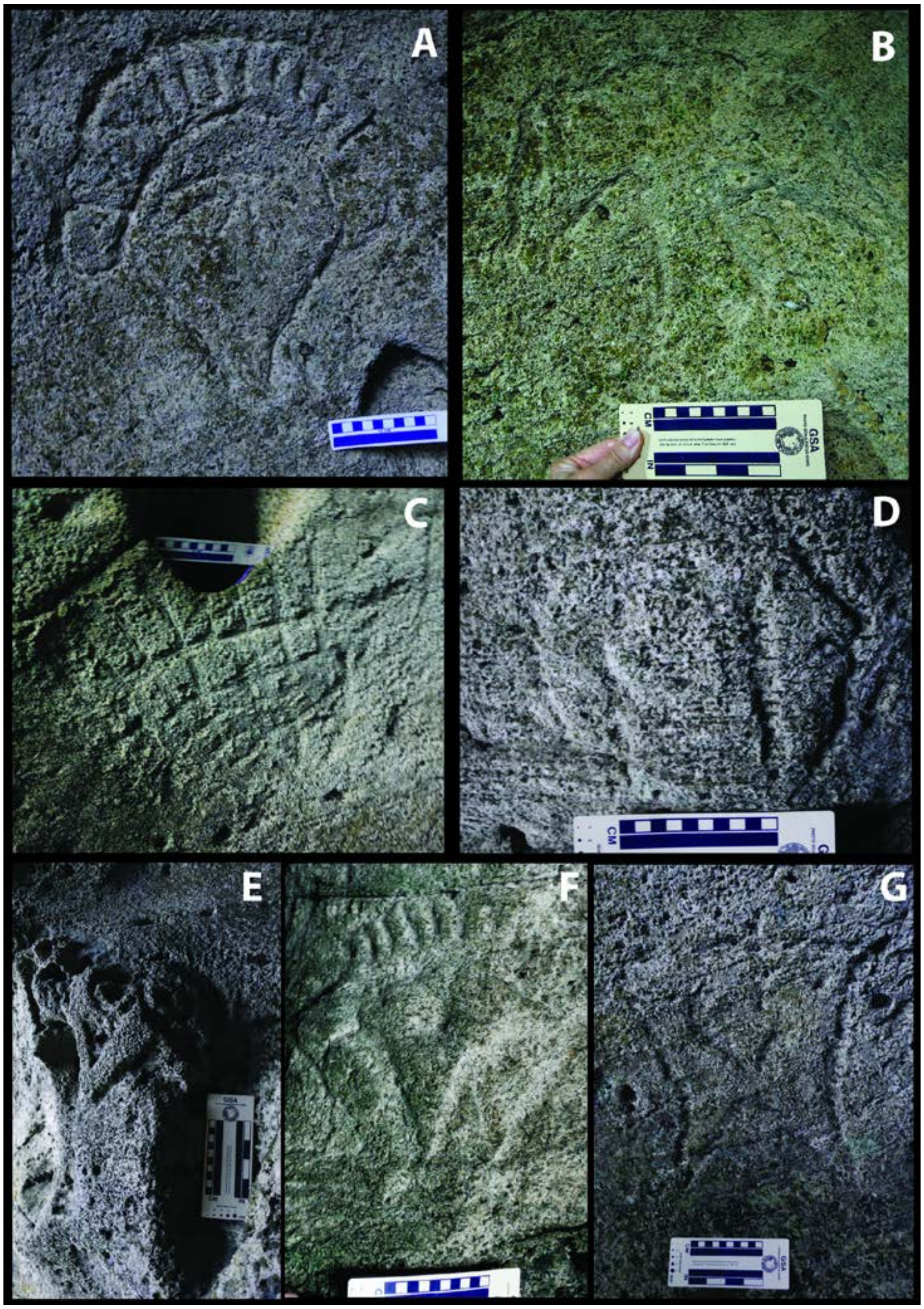
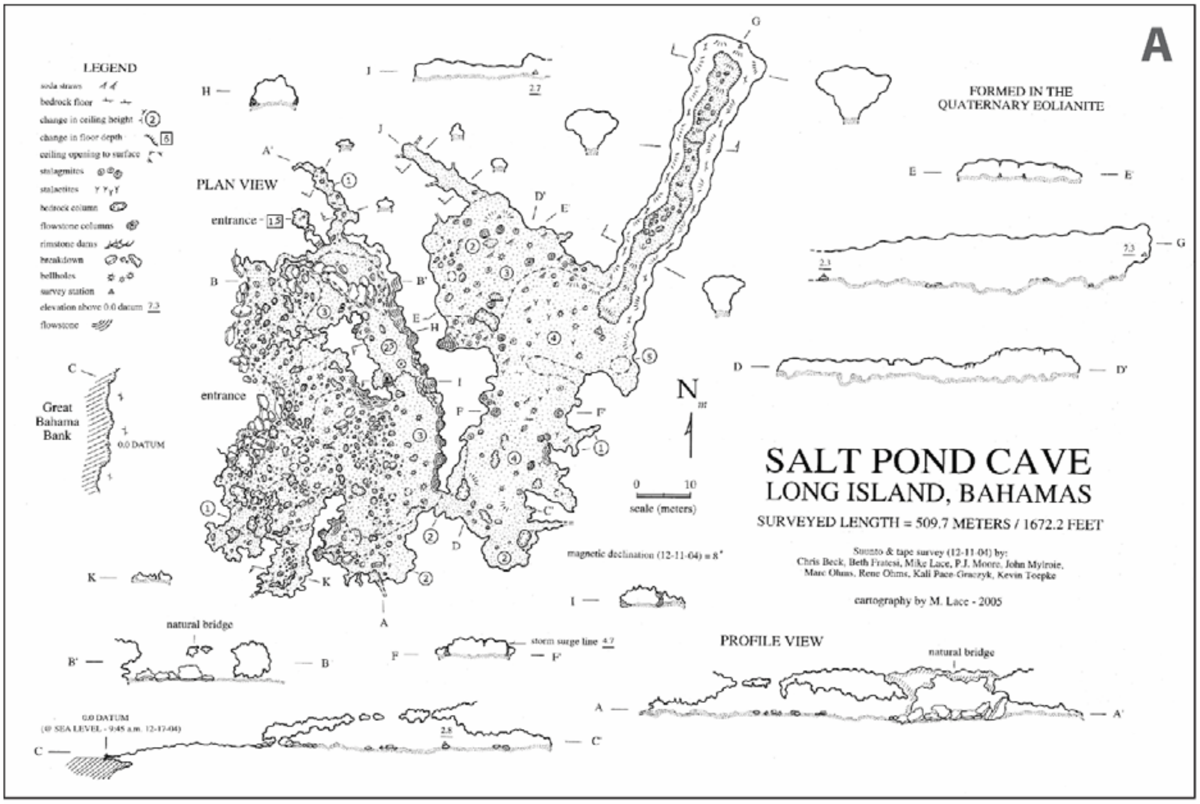


Figure 10. Range of petroglyph types within Temple of Athena, Crooked Island (note 10-cm scale).



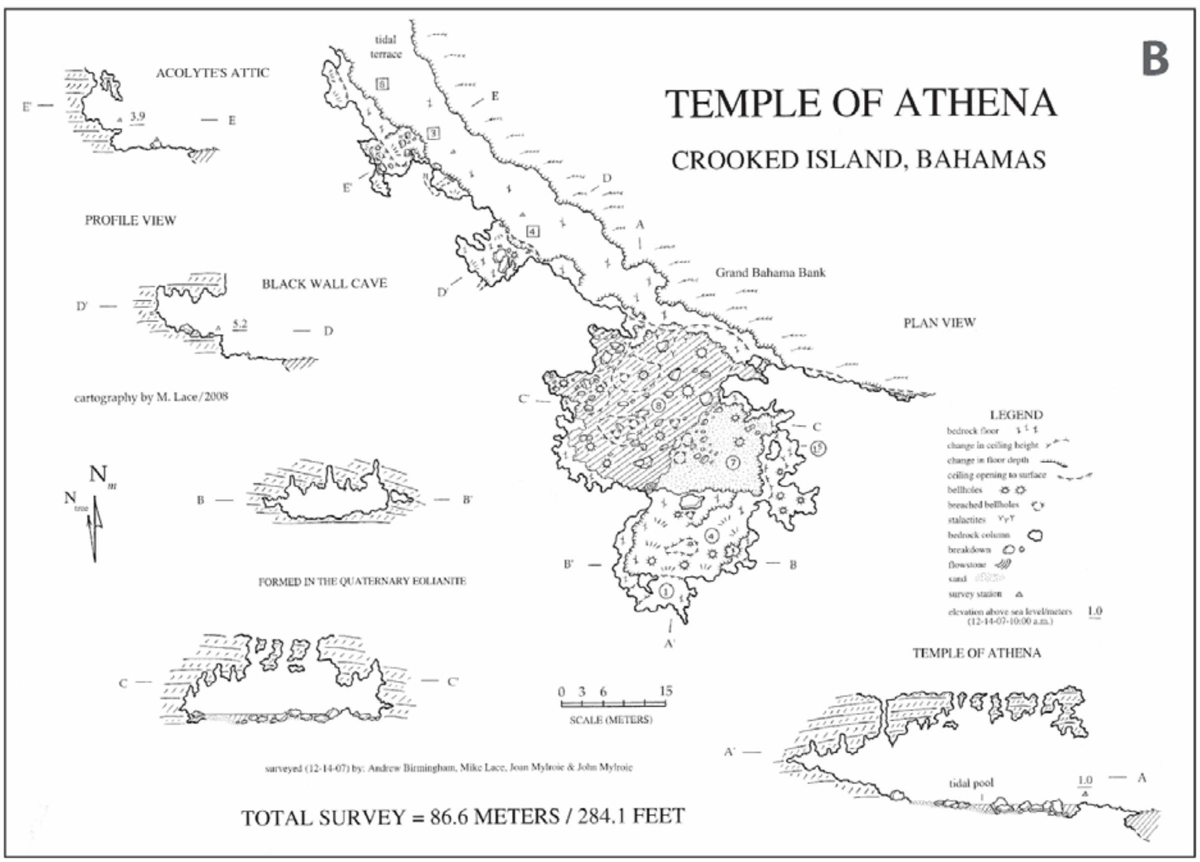


Figure 11. A) Map of Salt Pond Cave, Long Island. B) Map of Temple of Athena (aka McKay Cave), Crooked Island.

Salt Pond Cave (Long Island), CCS Site L07 (AMMC: LN-104). This large flank margin cave has served as a seminal example in the geoscience literature of what is arguably the most common type of cave formed in littoral settings worldwide (Fig. 11A). Previously undocumented as a rock art site, this flank margin cave features a single anthropomorphic petroglyph (10 x 12 cm) identified in 2015 (Fig. 12) in one of the collapse chambers near its littoral flank. As noted in RASI analysis in Table I, the site has been exposed to energetic storm activity over many years with clear implications to its current and long-term preservation status. Evidence of modern storm surges greater than four meters above modern sea level has been recorded >50 meters inside the interior chamber, suggesting its long-term use as a shelter may have been impractical. The cave was also mined for guano on a limited commercial scale and features a number of historical graffiti panels, most commonly composed of handprints made from the excavated guano-laden sediments, as noted in several other Bahamian caves.

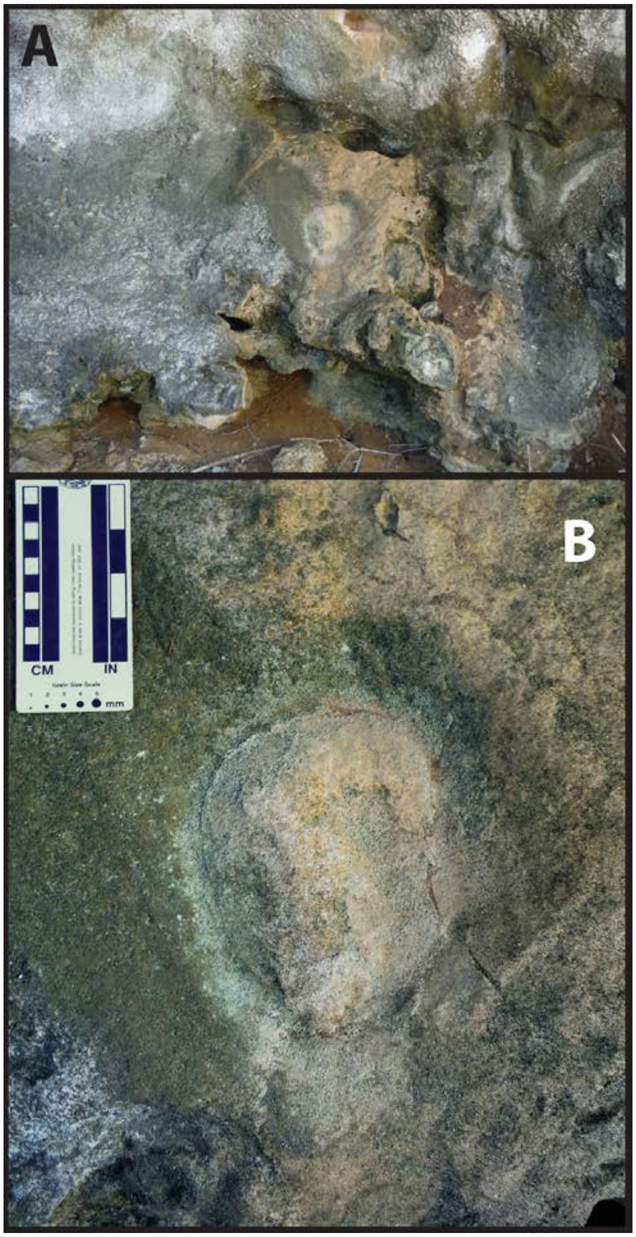


Figure 12. Salt Pond Cave rock art. A) Panel morphology and B) anthropomorphic petroglyph weathering rind (note 10-cm scale).

Hamilton's Cave (Long Island), CCS Site L04 (AMMC: LN-067). The site is one of the largest flank margin caves in The Bahamas. Palmetto ware fragments were collected from within the cave by Krieger (1937). The extensive flank margin cave was heavily mined for guano in the historic period and still retains a number of historic signatures with periodic modern tourist visitation. The cave is reported to harbor pictographs (Winter, 1991) but this could not be confirmed during a recent site inventory. The cave has been significantly impacted by historic mining and modern vandalism.

Beach Cave (San Salvador Island), CCS Site SS010 (AMMC: SS-073). This large, remote flank margin cave (Figs. 13A and 14A) is formed within eolianite (Hagey and Mylroie, 1995). The site harbors a single anthropomorphic petroglyph (Winter, 1991). More than 39 prehistoric settlement sites have been documented on the surface of San Salvador, displaying a wide distribution strongly associated with its 68 km of coastline. Of the two known rock art caves on San Salvador, however, one is located within a coastal plain and one located in the island interior. A total of 22 of the 39 open air sites previously examined on the island are located within 1500 meters of a cave (Hopkin, et al. 2011).

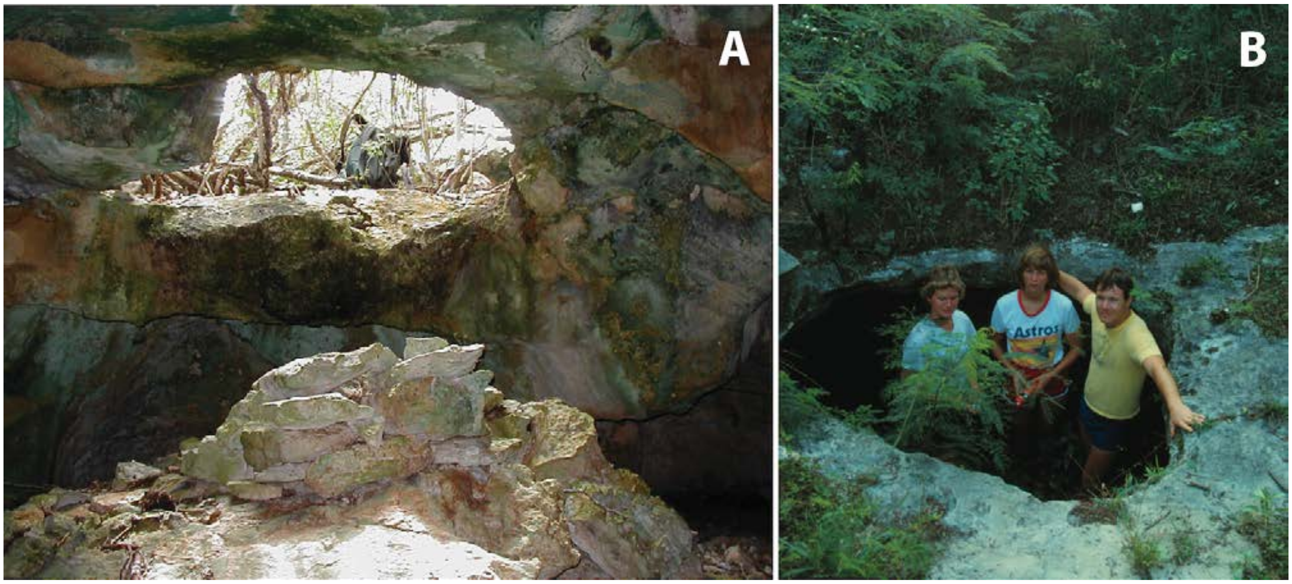


Figure 13. Entrance photos of A) Big Well and B) Beach Cave, San Salvador.

Big Well Cave (San Salvador Island), CCS Site SS011 (AMMC: SS-025)**.** The small single chamber is a banana hole - a specific form of flank margin cave - and the only such cave type known to be associated with rock art in The Bahamas (Fig. 13B and 14B). The site is reported to harbor a single petroglyph on an exfoliated parietal calcarenite slab (Winter, 1991) but a recent survey of the site revealed no trace of it.

Salt Pond Hill Cave (Great Inagua), CCS Site GI01 (AMMC: IN-019). Ceramics consistent with thin-walled red ware from other Bahamian islands were collected by Krieger (1937) at the cave site, as well as additional shell and ceramic materials from surface sites (Keegan, 1993). This large flank margin cave (Fig. 14C) is reported to harbor two anthropomorphic petroglyphs (Winter, 1991) but a modern inventory and preservation status assessment of this site, and others on the island, has not yet been performed.

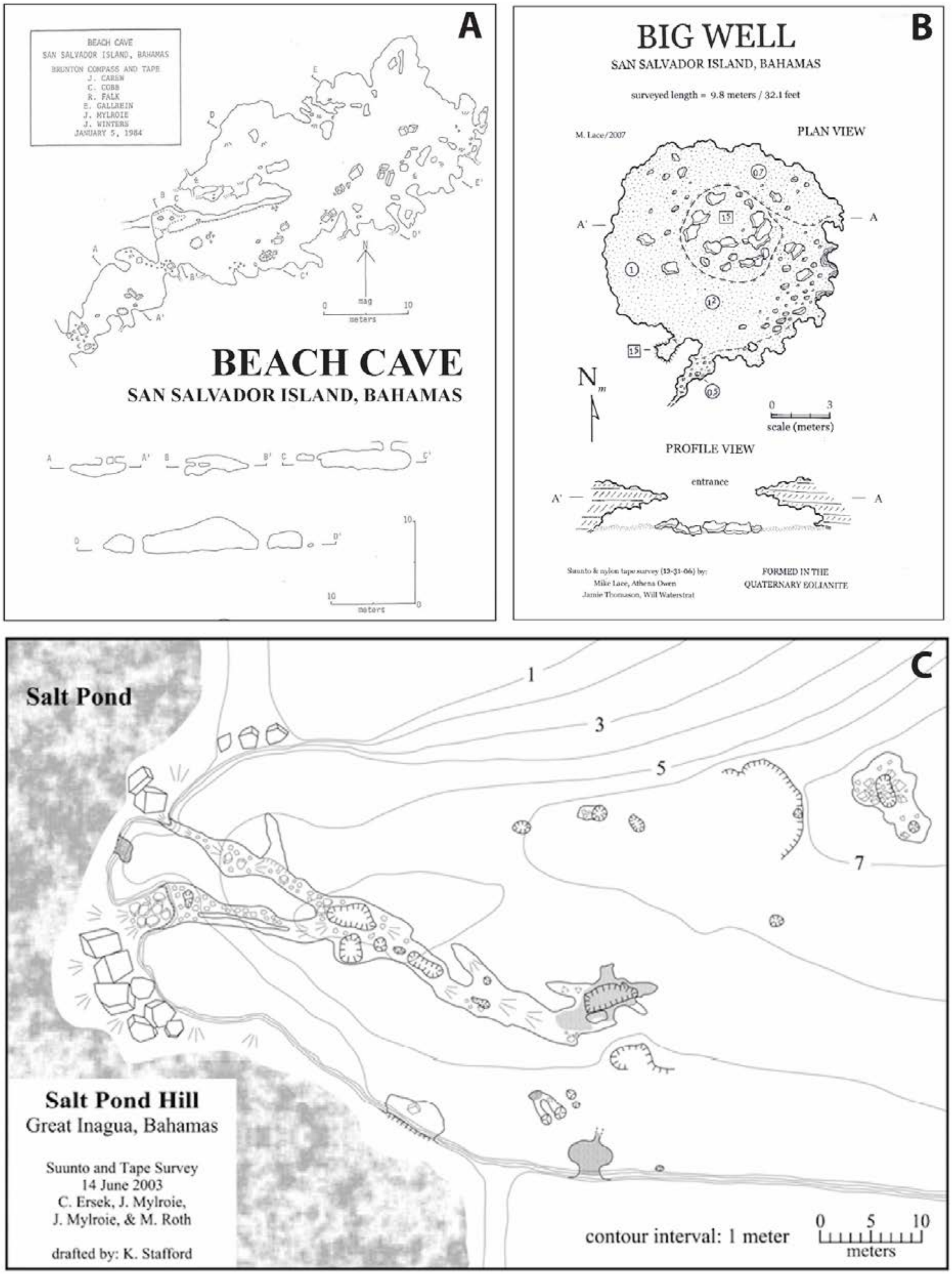


Figure 14. Maps of A) Beach Cave, San Salvador; B) Big Well Cave, San Salvador; and C) Salt Pond Hill Cave, Great Inagua.

Abraham's Bay Cave No.1 (Mayaguana), CCS Site MA001 (AMMC: MY-019). The island is one of the more remote locales in The Bahamas with significant portions currently uninhabited and effectively inaccessible. We noted only one cave site harboring evidence of potential Lucayan activity. The site is a large inland flank margin cave with a complex maze of interconnected chambers and crawlways that were heavily mined for their extensive guano deposits (Fig. 15). A single previously undocumented pictograph was identified. The anthropomorphic image (33 x 25 cm) is partially occluded with calcite overgrowth, which offers an additional opportunity for direct dating in future studies (Fig. 16). Though statistically rare as a pictograph in the regional database dominated by petroglyphs, its placement within the photic zone is entirely consistent with the overall data set. Compared to other islands in the Archipelago, Mayaguana has seen limited attention from multiple disciplines with field research primarily associated with its coastal areas (De Booy, 1913; Keegan, 1983b). While only ten cave sites are currently known on the island, significant expanses of its rugged interior remain unexplored.

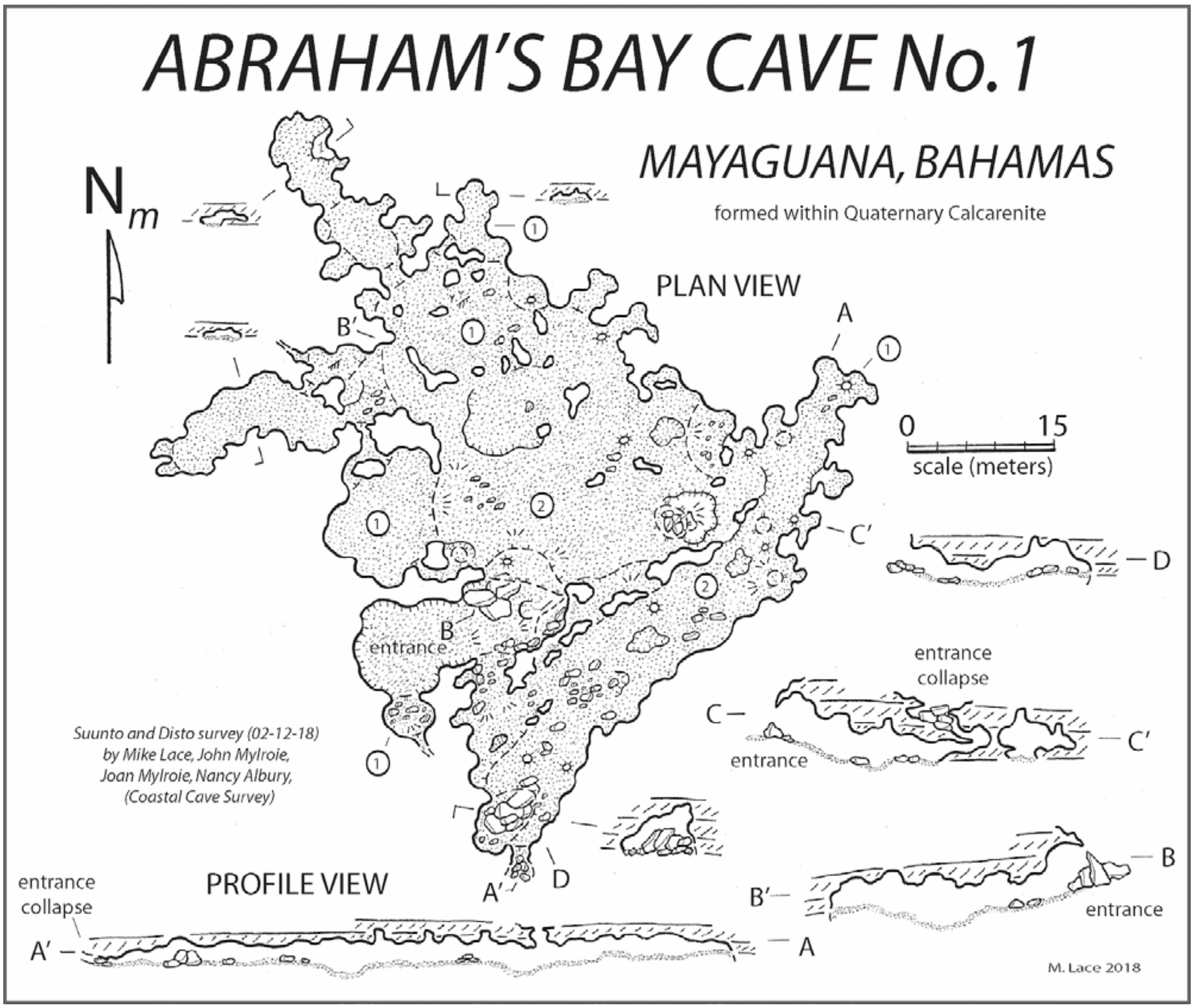


Figure 15. A) Map of Abraham's Bay Cave No. 1, Mayaguana.

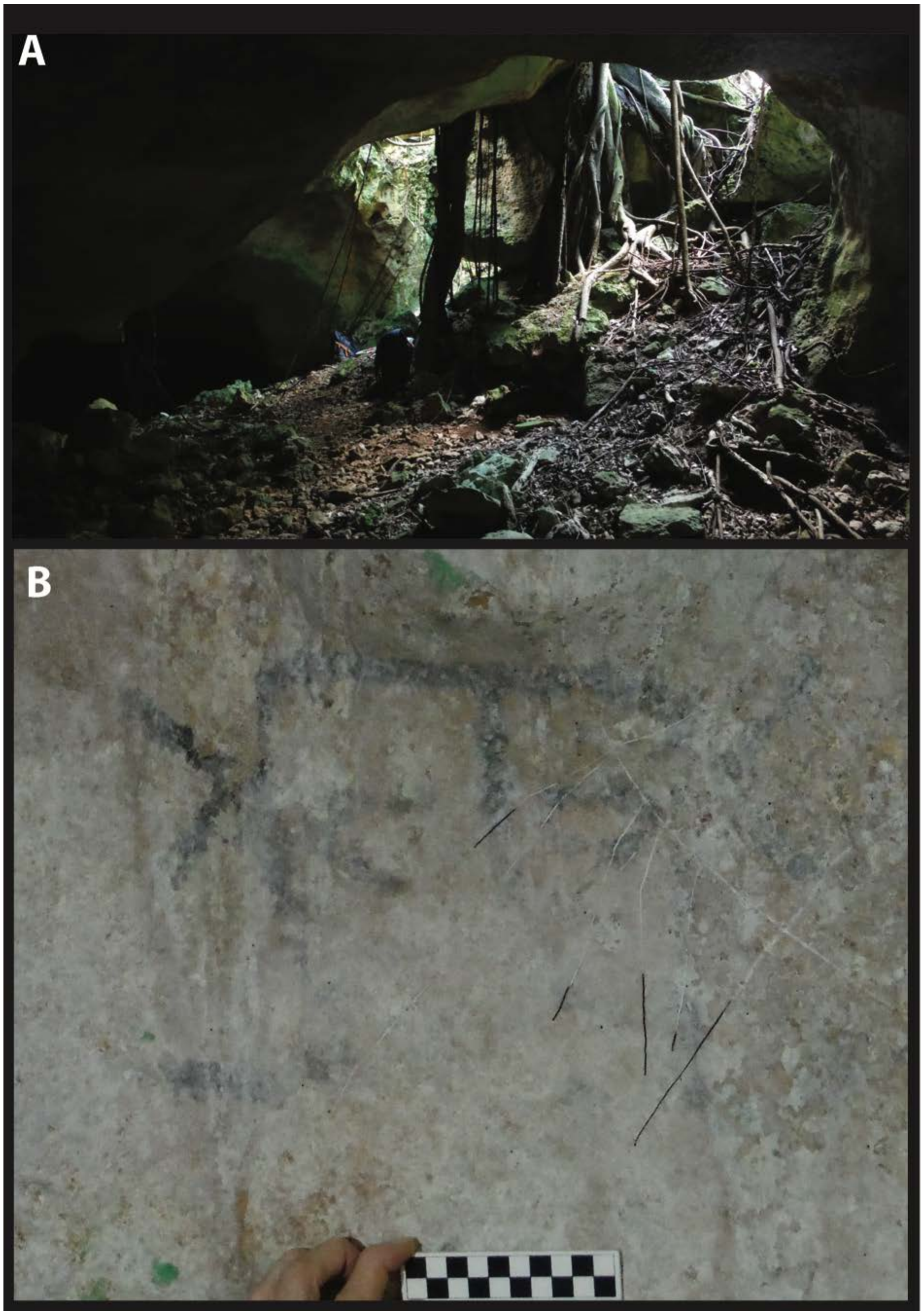


Figure 16. Main entrance of Abraham's Bay Cave No. 1, Mayaguana. B) Solitary anthropomorphic pictograph (note 10-cm scale and calcite overgrowth).

Preacher's Cave (Eleuthera Island), CCS Site EL02 (AMMC: EL-018). The site harbors evidence of significant Lucayan mortuary use and early colonial habitation and modification as a singular landmark for initial colonization of the islands by Europeans (Shaffer, et al. 2012). A single crude, heavily-eroded pictograph had been reported on the surface of the dune ridge harboring the cave (Carr, et al. 2006) but careful examination during a recent survey of the site revealed no trace of it. In the context of the current data set, its statistically anomalous placement as the sole surface rock art site in the region is problematic in its interpretation as Lucayan in origin and thus remains to be verified.

In addition to Preacher's Cave, other caves in The Bahamas also feature evidence of early colonial activity, such as 1702 Cave (Crooked Island) where colonial period use of the landscape followed Lucayan mortuary use of select caves formed within the same coastal ridge (Granberry, 1978; Steadman, et al. 2017).

Jacksonville Cave No.1 (East Caicos), CCS Site TCI300E. Located on the now uninhabited island of East Caicos, Jacksonville Cave No.1 (aka. Stubb's Guano Cave) is one of the most extensive caves in the Turks & Caicos Islands, second only to Conch Bar Cave (Middle Caicos) (Smart, et al. 2008). The site had been previously noted by De Booy in 1912 but the cave had never been surveyed. Currently, several hundred meters of interconnected cave chambers have been mapped of its projected 1 km total (Table I). A total of 13 petroglyphs were documented in a single internal chamber, placed in an arcuate arrangement (Fig. 17B) centered by a vertical collapse entrance that illuminates the panels with abundant daylight (Fig. 17A). The inventory includes a range of simple to elaborate anthropomorphic and geometric forms (Fig. 18). Both the cave and surface areas were heavily disturbed by large-scale excavations and coastal landscape alterations during the guano mining period of the mid-1800s. Similar alterations are evident within the chambers of Conch Bar Cave. Jacksonville Cave No.1 represents the sole rock art site recorded in the TCI to date. Examination of over 20 cave sites located on Providenciales, Middle Caicos and East Caicos has yielded no additional rock art, though the survey of the remaining islands and cays within the TCI group remains incomplete.

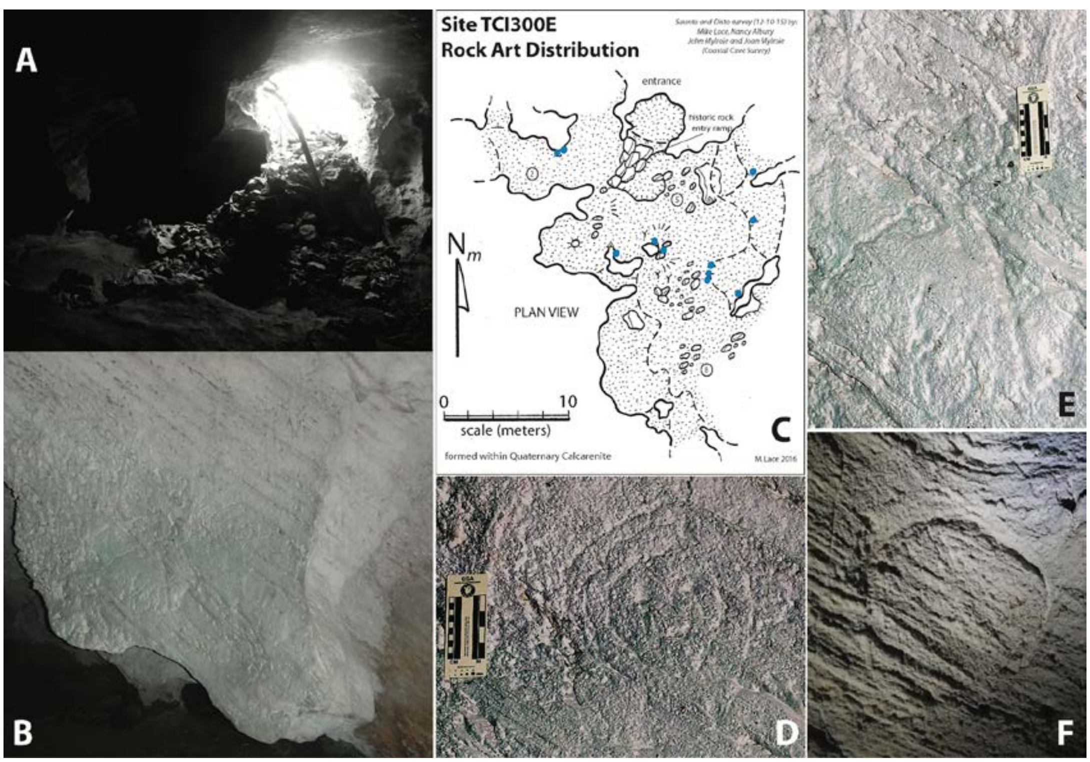


Figure 17. A) Entrance and B) representative rock art panel morphology (1 x 0.9 meter). C) Partial rock art distribution map of Jacksonville Cave No. 1, East Caicos, TCI. D) Petroglyph example (note 10-cm scale). E) Eoloanite surface contours and associated petroglyph incision (10-cm diameter glyph).

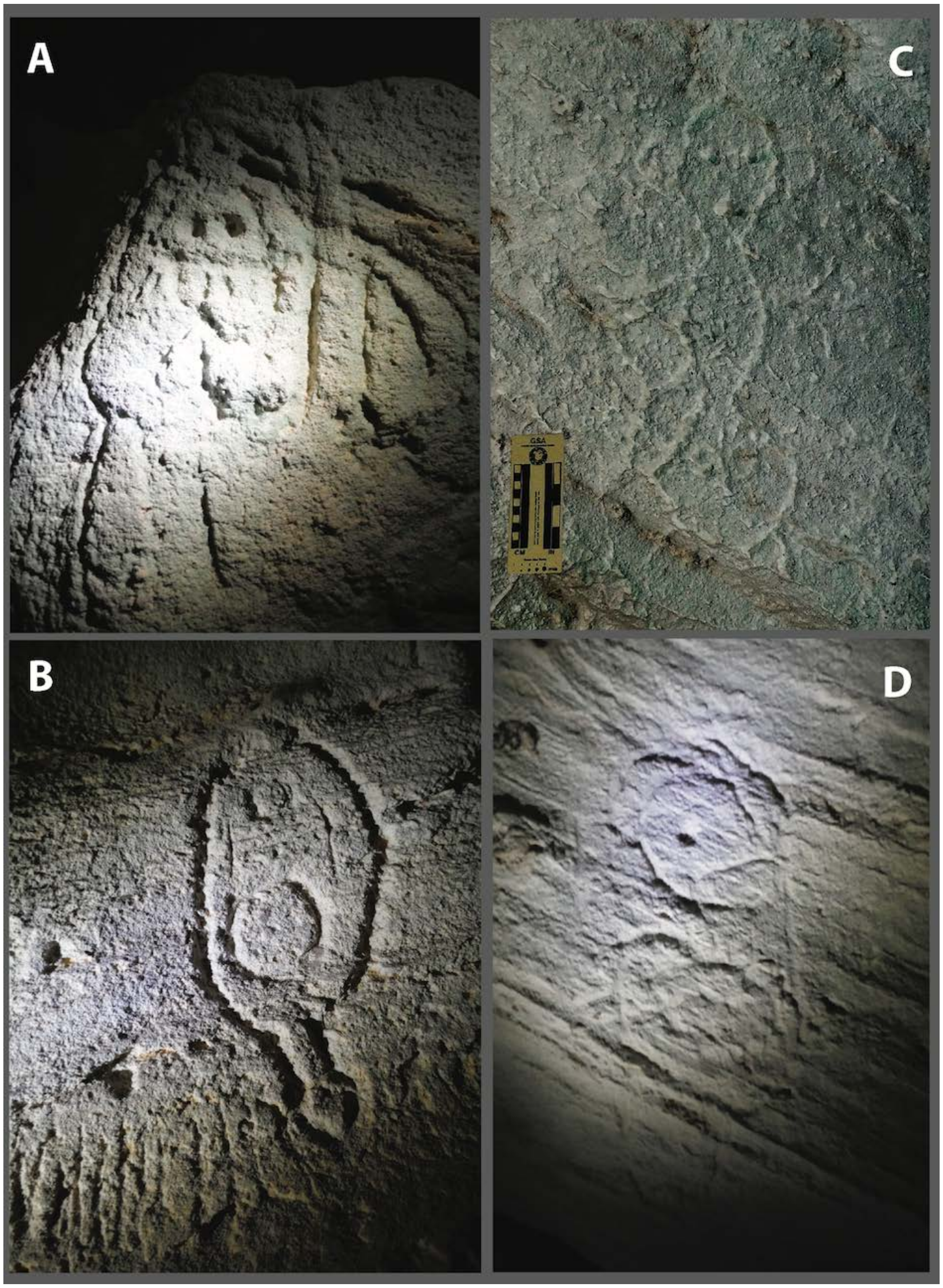


Figure 18. Anthropomorphic and geometric examples within Jacksonville Cave No. 1, East Caicos, Turks & Caicos Islands.

Rock art distribution analysis.

A total of 113 rock art examples have been recorded at 12 cave sites distributed across 7 islands in the Bahamian Archipelago to date. Rock art occurrences documented across the Archipelago revealed distinctive patterns of site uses, from regional scale attributes to specific rock art panel locations and image composition. Table 1 illustrates the apparent placement schemes and comparative rock art densities at each cave site as well as the accompanying geomorphology and preservational status.

Table 1. Summary distribution profile of Bahamian rock art sites.

Site	Island	[1]Cave aerial footprint m(2)	Rock Art Types	[2]Rock art density (recorded images)	Surface utilized	[3]RASI score average
Hartford Cave	Rum Cay	567	pictograph petroglyphs	63	Parietal Eolianite	23
Goat Cave	Rum Cay	530	Pictographs petroglyhs	5	Parietal Eolianite	27.5
Salt Pond Cave	Long Island	4167	petroglyph	1	Parietal Eolianite	32
Hamilton's Cave	Long Island	7432	pictographs	Nd	Nd	Nd
McKay Hill Cave	Crooked Island	120	petroglyphs	15	Parietal Eolianite	47
Temple of Athena	Crooked Island	953	petroglyphs	11	Parietal Eolianite	38
Beach Cave	San Salvador	642	petroglyph	1*	Parietal Eolianite	Nd
Big Well	San Salvador	109	petroglyph	1	calcarenite facies	Nd
Salt Pond Hill Cave	Great Inagua	216	petroglyphs	2*	Parietal Eolianite	Nd
Abraham's Bay Cave No.1	Mayaguana	2127	pictograph	1	Parietal Eolianite	36
Jacksonville Cave No.1	East Caicos, (TCI)	>1000**	petroglyphs	13	Parietal Eolianite	44
				(Total=113)		

[1] Cave areas quantitatively determined from completed cave maps (generated from instrument surveys) using Image J software (www.NIH.gov). [2]Rock art density is expressed as the total number of recorded images at each site. [3]RASI = rock art stability index (Dorn, 2008) where an increasing RASI score inversely correlates with decreasing projected panel stability, expressed as an average for multiple panels at a given site where appropriate.*as reported by Winter (2009) ** indicates cave survey incomplete.

A) General Criteria. We identified baseline features of rock art distribution in the Bahamian Archipelago: (1) No surface (i.e., open air) rock art sites have been confirmed in Bahamas or the Turks & Caicos Islands to date. The only documented rock art occurs in caves. No confirmed rock art has been documented in the caves located on northern tier of islands in the Bahamian Archipelago, with San Salvador and Great Inagua forming the northern and southern limits of recorded sites, respectively. (2) All rock art surfaces are composed of comparatively young coastal carbonates (Quaternary-aged) – a function of the inherent regional geology and includes subtidal and eolianitic calcarenites which are not uniformly expressed or utilized in other coastal settings in adjacent regions. (3) No examples of aphotic (i.e., dark zone) placement have been found to date with all rock art panels restricted to photic zones within each cave site.

B) Range of rock art forms utilized. The majority of recorded rock art examples are petroglyphs. Williams (1978) first defined the predominantly anthropomorphic form as the Timehri type, a definition later invoked by Winter (1991) to frame a broader inventory of Bahamian sites into a single stylistic category. While representations of simple human faces predominate, the imagery recorded on the cave walls across the Archipelago appears to be more complex, with forms ranging from simple to moderately elaborate anthropogenic and zoomorphic figures to simple geometric patterns (Table 1).

C) Rock art panel surface utilization. Though multiple cave types are expressed in The Bahamas, all rock art sites examined were located within flank margin caves (i.e., caves formed by dissolutional processes associated with past freshwater lenses). No rock art has been recorded in pit caves, talus caves, sea caves, tafoni or blue holes to date. No positive apparent correlation between cave size (as defined by mapped aerial footprint) and rock art density was observed (Table 1).

Pleistocene-aged carbonate eolianite surfaces (i.e., fossil dune facies) are predominantly expressed within flank margin caves of the Bahamian Archipelago. While eolianites are widely distributed across island and continental coastal areas on a global scale (Brooke, 2001), they form a dominant available substrate for parietal rock art placement in The Bahamas due to the inherent island cave geomorphology (Fig. 17D). Other Caribbean islands, for example, Aruba, Curacao, Bonaire, Isla de Mona, Barbados or the Cayman Island group are uplifted islands, and the flank margin caves are developed within reef facies, typically of Mio-Pliocene to Pleistocene age.

Rock art surveys were not limited to islands with recorded cave rock art sites, as additional Bahamian islands were also examined. For example, a recent expedition surveyed 34 cave sites on Cat Island with no evidence of rock art but the caveat remains that not all cave sites on the island have been examined, as the remote interior is extremely difficult to access. Similar negative data sets have been collected on other islands and cays in the Archipelago, such as the Abacos, including Little Abaco, Great Abaco, Moores Island and two offshore cays, Lubber's Quarters and Sugar Loaf Rock Cay, where 35 caves have so far been surveyed but no rock art detected. To date, over 850 caves in the Bahamian Archipelago are known but the detailed survey of cave and karst resources on many of The Bahamas and Turks & Caicos Islands is ongoing. Nevertheless, the substantial negative data set so far compiled further supports the strikingly limited statistical occurrence (i.e., 1.4%) and geographic distribution of rock art sites in the region.

Rock art stability index (RASI) analysis

All sites were evaluated for long and short-term preservation potential based on detailed criteria defining the effects of a range of natural and anthropogenic factors. The Rock Art Stability Index (RASI) rating (Dorn, et al. 2008) of each panel within each cave site revealed a range of impacts from coastal processes and inherent site geomorphologies as well as varying degrees of anthropogenic site modification (Table 1). An increased RASI score correlates with an increased panel instability and concomitant decrease in preservation potential, where a score of 0 indicates perfect panel stability and a score of 100 indicates maximal instability and poor preservation potential. While an individual data point derived from a single panel or site offers limited insight into the overall status of rock art preservation (similar to limitations of any case study), an array of RASI data from multiple sites on a regional scale provides a useful measure of cultural resource vulnerability that would otherwise remain unclear and offer a baseline from which one can monitor long term changes in the status of such resources, as demonstrated in other settings displaying diverse geomorphologies (Cerveny, et al. 2016; Groom, 2016).

Hartford Cave (Rum Cay, RASI=23), for example, exhibits an average stable rock art panel preservation potential and moderate vulnerability to predictable cave microclimate effects, corrosional pitting and littoral erosion due to continual exposure to lithobionts, sea spray and storm surge events given its proximity to the intertidal zone and the degree of chamber exposure due to progressive dune breach, as illustrated by the site map (Fig. 5A). Examination of the RASI for each of the five panels within Hartford Cave, reveals a greater variation in apparent stabilities and incumbent projected preservation potential, partly based on the influence of anthropogenic effects, as previously discussed in the site description (Fig. 6).

In contrast, Jacksonville Cave (East Caicos, RASI=47) harbors a single internal rock art chamber that is comparatively more protected from a range of active coastal processes and climatic effects but has been subjected to significant site impact due to historic guano mining. The site currently remains remote enough to limit progressive modern anthropogenic impacts but the convergence of cumulative natural and anthropogenic destabilization of the panel surfaces, overall morphology and structural integrity specific to the site impair its long-term preservation potential compared to other sites in the Archipelago.

Discussion

This study represents the most complete characterization of cave rock art sites in the Bahamian Archipelago to date, identifying previously unrecorded rock art caves while offering the first thorough modern analysis of rock art occurrence in other caves incompletely documented in historical narratives. We examined the potential role of the unique geomorphologies of Bahamian and Turks & Caicos caves may have played in site selection, the strikingly low observed rock art densities across the Archipelago compared to other settings and how these factors may influence future preservation efforts.

Comparative rock art density analyses.

Rock art distributions in other continental and island settings have been reported on varying geocultural scales (Atiles Bido, 2009; Dubelaar, 1995; Fiore and Campo, 2009; Manhire, et al. 1983). This report offers a quantitative assessment of rock art densities in the Bahamian region based on thorough surveys of all cave sites, both on island and archipelago-dependent scales, regardless of karst setting, cave type, or additional cultural significance.

While thorough documentation at any individual site forms a critical data set with which one can gauge the specific effects unique cave morphologies may have had on overall site selection and panel placement, it also provides an important baseline from which one can determine changing rock art panel conditions as a function of changing site conditions and in the context of long-term site preservation. Similarly, the compilation of cave rock art distribution data on a variety of scales can be integrated with geologic models ranging from island-specific to regional scales, potentially identifying broader cultural landscape trends that would otherwise remain obscure.

Regional distribution patterns of other cultural materials have proven productive in the Bahamian Archipelago, for example, the compilation of duho occurrences, compositional analyses and isotopic dating (Ostapkowicz, 2015). Currently, we find no apparent correlation between rock art distribution (Figure 1) and the distribution of wooden artifacts, such as Duho or Lucayan paddles, in cave sites so far recorded. Similarly, we find no apparent correlation of mortuary cave sites with rock art placement, as human internments are associated with a small subset of caves featuring rock art while the majority of mortuary cave sites have none. Yet, a statistical comparative analysis of multiple trends in cultural cave uses and associated materials requires a more complete cadaster of sites across the region. This study forms part of a baseline dataset that can be built upon to reveal such patterns in future regional and inter-regional comparative studies.

Multiscalar rock art distribution analysis as a function of associated cave geomorphologies.

Historically, designations of cave type have frequently been impaired by explorational bias and a lack of clearer models of coastal speleogenesis. For example, the term “cave shelter” has long been used to define a subset of archaeologically significant sites. However, this term merely describes the general physical appearance of the structure with no specific reference to the mechanism that formed it, as such, a void can be formed and subsequently modified by a number of karst and/or pseudokarst processes over time (Mylroie and Mylroie, 2013b). By applying modern tenets of coastal speleogenesis, we have constructed a clearer delineation of the origins of cave structures in this and other regions with consequences to modeling past site uses and future preservation strategies.

Cave geomorphology and Rock Art Site Selection.

All rock art caves in The Bahamas are phreatic in origin - dissolutional structures shaped within coastal landforms (i.e. “flank margin caves”) which is the predominant expression of cave development in The Bahamas and may be the most prevalent form of coastal cave development worldwide (Mylroie, 2013). Thus, cave type is essentially normalized in this context (similar to Isla de Mona, Puerto Rico, where rock art sites are also found predominantly within flank margin caves) and may indicate an opportunistic predominance of these caves compared to other structures, such as sea caves, tafoni or talus caves. Alternatively, this can be interpreted as a deterministic trend, representing a set of sites with specific structural characteristics consistent with applied rock art placement criteria. No speleothem surfaces were utilized as all sites featured rock wall, ledge or disarticulated blocks of Quaternary-aged calcarenite even though travertine, stalactite and stalagmite surfaces are common in Bahamian caves in general.

The limited numbers of confirmed rock art sites and accompanying rock art images in The Bahamas, however, exhibit a much more restricted regional distribution confined to a selection of central and southern islands. The reasons for this limited distribution remain unclear. Similarly, the Turks & Caicos chain of islands feature only a single documented rock art site to date. As the cave inventory in the TCI is formative, we cannot rule out the identification of additional sites in future surveys. In some Bahamian settings, local rumors indicating the presence of rock art caves persist, such as Cat Island where folklore tells of “rock paintings” (Palmer, et al. 1986) but its location is apparently lost to collective surviving memory. Similar local folklore has been noted on other Bahamian islands but detailed ethnographic surveys of cave and karst areas in the region have been sporadic. The limited range and size of the current inventory presents challenges to more rigorous statistical analyses, yet the comparative data set can currently support qualitative trends capable of defining otherwise overlooked patterns of cave utilization on multiple scales.

Rock art panel locations within the caves of the adjacent Greater Antilles exhibit a diverse range of photic and aphotic (i.e., dark zone) placement with sub-regional distribution patterns indicating preferential zone selection in some coastal cave settings (Lace, 2012). Without exception, all documented Bahamian cave rock art sites are located within segments featuring minimal to abundant daylight, either from large horizontal entrances or through vertical openings primarily the result of denuded bell holes (i.e., vertical cylindrical ceiling cavities breaching the enclosing dune surface). This stands in stark contrast to zonal rock art panel placement trends in the broader Caribbean and notably within island caves adjacent to The Bahamas, such as Cuba, Hispaniola and Puerto Rico (Flore and Ocampo, 2009; Núñez Jiménez, 1997).

The very composition of these eogenetic carbonate surfaces (e.g., rock porosity and accompanying structural integrity) potentially plays an important role in the long-term stability of rock art panels in the Bahamian Archipelago. This geomorphological profile is distinct from other nearby island settings (i.e., Greater and Lesser Antilles) where non-carbonate surfaces and a broader range of more mature carbonate deposits, such as limestones and dolomites of varying age, granitics and diorites, or more fragile corrosion residues and beachrock were used for rock art placement (Lace, and Mylroie, 2013a). As such, correct interpretation of site-specific geomorphologies is also a critical component in gauging the overall preservation of cultural cave resources.

For example, Isla de Mona (Puerto Rico) has one of the highest density cave rock art per island landmass in the Caribbean. The island features dense arrays of complex finger fluting ("Grabados digitales") or digital tracing in the soft residues, (composed of either mineral corrosion residues or potential biogenic films, that coat the walls and ceilings of caves (Samson et al. 2013). No such rock art form has been found in The Bahamas. The comparative lack of so-called corrosion residues in Bahamian caves may simply be a function of the underlying geomorphology of the younger Bahamian eolian calcarenites and mineral deposition patterns specific to caves within this locality. Once again, the geomorphologic profile of the coastal settings may play a key role in directing specific cultural uses; in this case, determining the essential structure of cave wall fabrics, or "palette", available for specific ritual expressions.

Lithologies specific to rock art panels in other areas has been associated with variation in rock art form use and image placement (Valle, 2015; Lace, 2012). Tafoni, for example, can form rapidly in comparison to caves formed by other mechanisms, as numerous examples of tafoni development can be found on colonial era calcarenite stone structures or modern road cut facies in the Bahamian Archipelago and elsewhere. The formation of such voids in relatively young, porous carbonates by this mechanism generates interior surfaces with a friable, granular composition destabilized by pitting at varying scales. In a modern context, such surfaces are transient and highly susceptible to short term degradation. In an archaeological context, such surfaces would have offered similar morphologies that would have proven unsuitable for durable placement and preservation of rock art imagery, which would explain the apparent absence of rock art in any Bahamian tafoni. In contrast, tafoni formed within dioritic rock, as on Aruba, form more durable surfaces which were used for the placement of distinctive polychrome rock art examples (Lace and Mylroie, 2013b). While the cave host rock in the Bahamian Archipelago is essentially uniform, the available surfaces within these structures is more complex and diverse, featuring dune facies, rhizomorphs, breccia facies, paleosols, protosols – all of which display varying stabilities over time. Thus, the principal geomorphological characteristics of such spaces, including the rock surfaces within, could have readily influenced rock art site selection in the Bahamian Archipelago.

The variation in rock art complexity and stylistic components has long proven to be a tempting platform from which broader significance in patterns of ritual landscape uses and cultural progression in the region have been postulated (Berman, 2013; De Hostos, 1923; Holmes, 1894; Olsen, 1973; Roe, 2009; Winter, 2009). However, many of these interpretive projections have proven speculative at best. For example, attempts to construct a durable cultural sequence based solely on stylistic comparisons and the seriation of rock art motifs remain controversial if not problematic, as illustrated in comparative design elements within rock art inventories from other regions (Hayward, et al. 2014; Wesley, et al. 2014). Such models have often incorporated weak correlations with associated dated materials tempered with exploration and sampling biases, and often with data sets too limited to support statistically robust projections of broader cultural patterns. For example, Mallery speculates on the origin of the limited Bahamian petroglyph distribution (restricted to a solitary known site at the time) in his 1893 report on Hartford Cave (Rum Cay):

> "Although we visited numerous caves in the various islands of The Bahamas, in no other did we find any appearance of markings or carvings on the walls, nor could we hear of any reported to have such markings. The absence of any traces of carvings in other caves whose situation was better adapted for the preservation of markings, had such ever existed, and the proof that their contents afforded that most of those caves had been known to the Lucayans and used by them as burying places or otherwise, and the close proximity of Hartford Cave to the sea, taken in connection with the great number of markings on its walls, led me to think that possibly this cave had been there sort of the marauding tribes whom the Lucayans gave Columbus to understand were their enemies, and who were in the habit of making war upon them; and if so, the Caribs, or whatever tribe it may have been, had left these rock markings as mementos of their various expeditions and guides to succeeding ones."[1893:138-139].

No evidence to support such a model has ever been produced. More importantly, it illustrates a common two-fold conceptual/statistical bias associated with constructing a broader model of cultural landscape uses based on single site attributes and narrow qualitative stylistic assessments. Though Mallery's observations are dated, they illustrate limitations that have persisted as a direct consequence of the lack of a correlative database of rock art sites and caves overall in The Bahamas. To avoid such pitfalls, we have utilized definitive coastal geomorphologies and quantitative site density criteria specific to the Bahamian Archipelago database in order to compare and contrast emerging patterns of ritual and utilitarian cave uses in this and other regions.

Rock Art Site Preservation

Defining rock art distribution patterns within coastal caves can be problematic as caves in coastal settings are often not immutable, unchanging structures but rather components of dynamic coastal landscapes, particularly within a geologic timeframe. Coastal cave walls and ceilings are complex surfaces derived from the interaction of a range of long-term processes that can progressively alter rock art panel integrity over time (Pope, et al. 2012). Caves in coastal settings are subject to landscape scale coastal instabilities while their interior surfaces are influenced by inherent coastal geomorphologies and cave microclimate effects, both natural and anthropogenic, that are expressed on a rock art panel scale (Dragovich, 1981; Vieten, et al. 2013). Thus, effective, long-term preservation of such structures must be rooted in a clear understanding of the unique site geomorphologies associated with dissolutional and erosional cavities formed within eogenetic (i.e., geologically immature) coastal limestones (Lace, et al. 2013c; Waters and Kuehn, 1996). Each of the sites examined displayed a significant but varying degree of risk to long-term preservation potential based on the convergent influences of multiple factors specific to each locality.

As Granberry noted a half a century ago: "Provided ample time did present itself and finances were forth-coming the task of conducting a survey would still be no simple one, for the majority of sites located so far have been in caves, with which most islands are literally riddled. Many of these caves have been dug for their rich deposits of cave-earth, used as fertilizer, making the chances of finding a rewarding site very slim indeed." [1956:128].

Granberry's concerns over the preservational integrity of cave sites and the scope of challenges facing systematic, multi-disciplinary cave research in The Bahamas remain no less true today. Current legal protections for Bahamian cultural sites are clear within a broader integrated coastal zone management (ICZM) framework implemented by numerous governmental and non-governmental agencies (Winter, 2009). The Antiquities, Monuments and Museums Corporation is one of the principal Bahamian agencies responsible for cultural and heritage preservation and administers a range of natural and cultural heritage sites, which includes cave and karst areas. Similarly, the National Trust of the Turks & Caicos Islands is charged with preservation of areas displaying natural and cultural significance. Yet, the widely dispersed and occasionally remote rock art sites located outside of designated protected areas remain at risk to modern human impacts that range from modern small scale mining of cave sediments, looting and vandalism to large scale site alterations from commercial coastline development.

As in other cultural resource areas in the Caribbean region, the implementation of protective measures remains just as problematic in the Bahamian Archipelago. While limited geo-tourism development of suitable cave sites can potentially offer a degree of protection in some cases, successful cave management/preservation strategies in this context require long-term, continual monitoring coupled with effective visitor and stakeholder education programs to further limit site degradation. Yet, many of the rock art sites are located on more remote islands with limited resources available to support long-term monitoring and active site protection.

Conclusions

Clearly, physical attributes unique to these cave sites inspired complex cultural uses, in part, implemented with a common suite of techniques associated with rock art application in the region. The majority of caves, however, harbor no evidence of rock art or traces of ritual uses even though they share a common speleogenetic origin and have been exposed to the same changing coastal environment. The distribution patterns indicate that while the cultural traditions of incorporating rock art to ritual spaces persisted in the Lucayan colonization of the Bahamian Archipelago, its application to caves took a markedly distinct form compared to those in the Greater and Lesser Antilles.

As in any comparative analysis of rock art distribution patterns, whether it be in the Bahamian Archipelago or many other settings, the cave data set still remains incomplete. More than 60 years after Granberry's distribution model, Lucayan rock art sites are still being discovered and this underscores the need for expanding systematic exploration and documentation efforts to construct a more comprehensive inventory of all cave sites in the region. Such a fundamental resource management tool can, in turn, support both a clearer understanding of their geological, biological and cultural significance and the design of sustainable preservation strategies.

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