

Surficial and Shallow Subsurface Geology of the Northern and Central Exuma Cays, The Bahamas

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Abstract—The surface and subsurface geology of the Exuma Cays in the central Bahama Islands records sea-level cyclicity that extends back to the Jurassic, however the focus of this paper is the Plio-Pleistocene, since approximately 1–3 million years ago. During the 1990s, the first author surveyed a large number of the islands by boat, mapped the geology on 1:25,000 topographic maps with the aid of air photos, and more recently complemented these mapping studies using Google Earth Pro. In 1994, two 33 m cores were extracted from Norman’s Pond Cay and Lee Stocking Island in the southern group of the Exuma Cays. The outcropping rocks throughout the Cays are characterized by a mix of nearly pure bioclastic and oolitic sediments and limestone units. Generally, the highstand limestone deposits are capped with lowstand *terra rossa* paleosols, red-stained micritic limestone, calcrete, or karst surfaces. From surface and subsurface geology, a minimum of seven stratigraphic units are recorded, yet many cycles are obviously missing. Three broad eustatic intervals are evident from the $\delta^{18}\text{O}$ record. These are associated with the Pliocene-early Pleistocene (“PP” >1.2 Ma), Mid-Pleistocene Transition (“MPT” ~1.2–0.7 Ma), and the mid-late Pleistocene (“MLP” ~0.7 Ma to present). A combination of physical stratigraphy, geomorphology, paleomagnetism, and amino acid racemization (AAR) provide a general age framework for these deposits. Pliocene beds at -25 m in only one core appear to indicate slow subsidence of the Bahama Banks. An interval of prolonged bank marginal or lower sea stands of the MPT are indicated by a cluster of dense, clayey red paleosols. Many MLP rocks on the islands and in the cores retain sufficient amino acids to establish a relative chronology for the MLP. The geomorphic and stratigraphic succession from the Exumas shows very rapid progradation of the over-steepened bank margin toward Exuma Sound by several km since the Plio-Pleistocene. The purpose of this paper is to: 1) characterize the geology of the existing Exuma rocks and cays; 2) demonstrate the shallow-subsurface stratigraphy in two 33-m long cores; and 3) provide some examples of how the Exuma Cays and their margins have evolved over the past 1–3 million years.

The past three decades have seen a revolution in the study of the geology and science in the Bahama Islands (e.g., Garrett and Gould 1984; Carew and Mylroie 1987; Hearty and Kaufman 2000, Kerans et al. 2019; Vimpere et al. 2019). The number of scientific publications dealing with the Bahama “Banks” and islands has increased exponentially, stimulated by the potential information provided about past climate and sea-level changes, as well as the recent new applications of dating techniques. This cumulative research has increased the importance of the region for understanding depositional processes, island evolution, and climate change. Growth of the islands and platforms is a sedimentary response to cycles of sea-level change over millions of years; however, only the past few hundred thousand

years are represented in the surface rocks forming the islands today.

The Exuma Cays (spoken like “keys”) in the central Bahamas archipelago consist of nearly 300 islands extending over 200 km from Ship Channel Cay in the north to Barre Terre on the northern end of Great Exuma Island (Fig. 1), which is not included in this study. In the study area, nearly 30 larger islands greater than 2 km in length are surrounded by hundreds of smaller rocks and cays.

The deep-sea oxygen isotope record (“ $\delta^{18}\text{O}$ ”; Lisiecki and Raymo 2005) provides a template for global ice and sea-level cycles and limestone depositional events during the Quaternary (Fig. 2). With the redefinition of the Pliocene-Pleistocene boundary from 1.88 Ma to

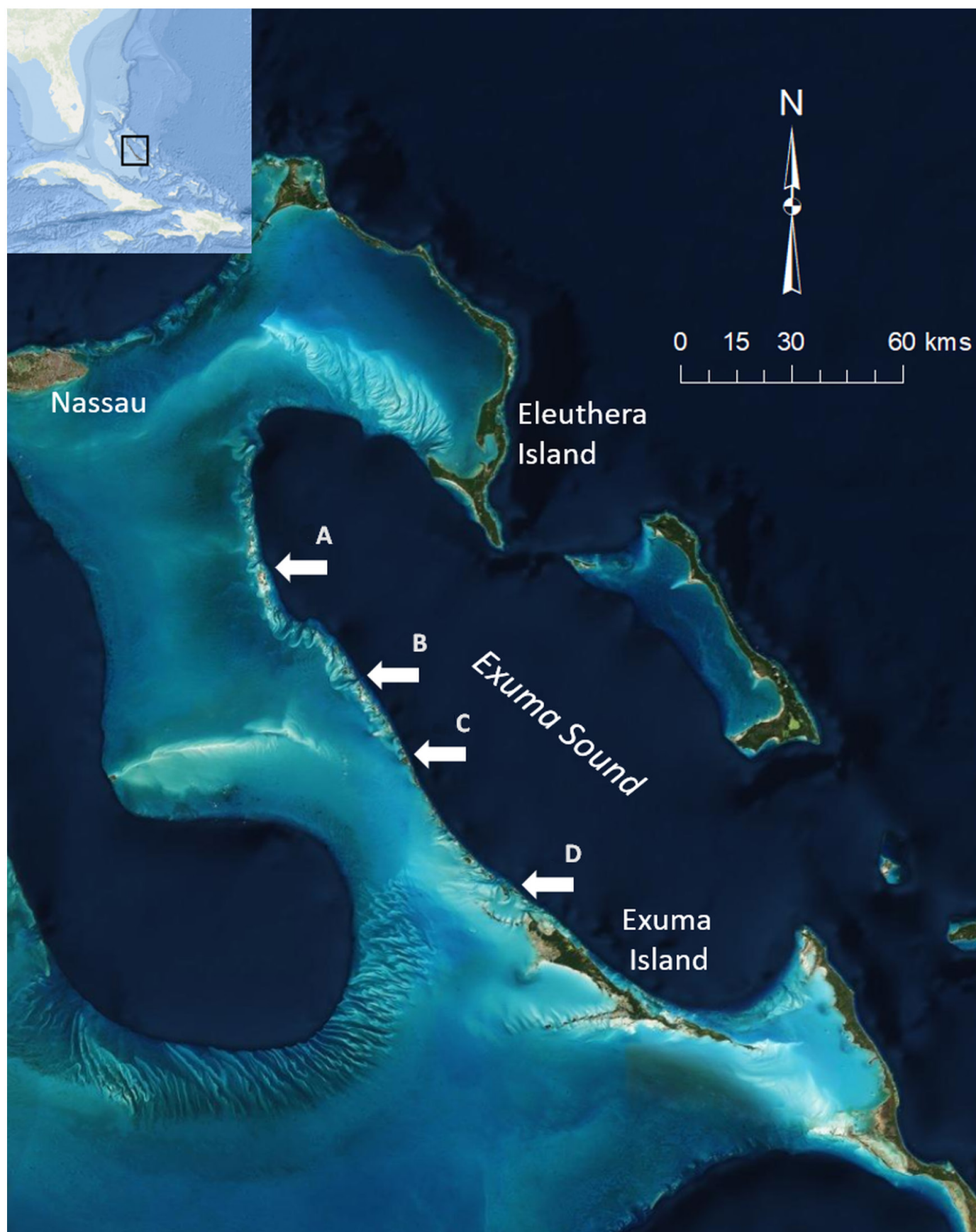


FIG. 1. Google Earth image of the central Bahamas and Exuma Cays. The main islands and figure locations (arrows) correspond from north to south, to Figure 5A–D. The master geological map can be accessed at: <https://arcg.is/1akbf0>

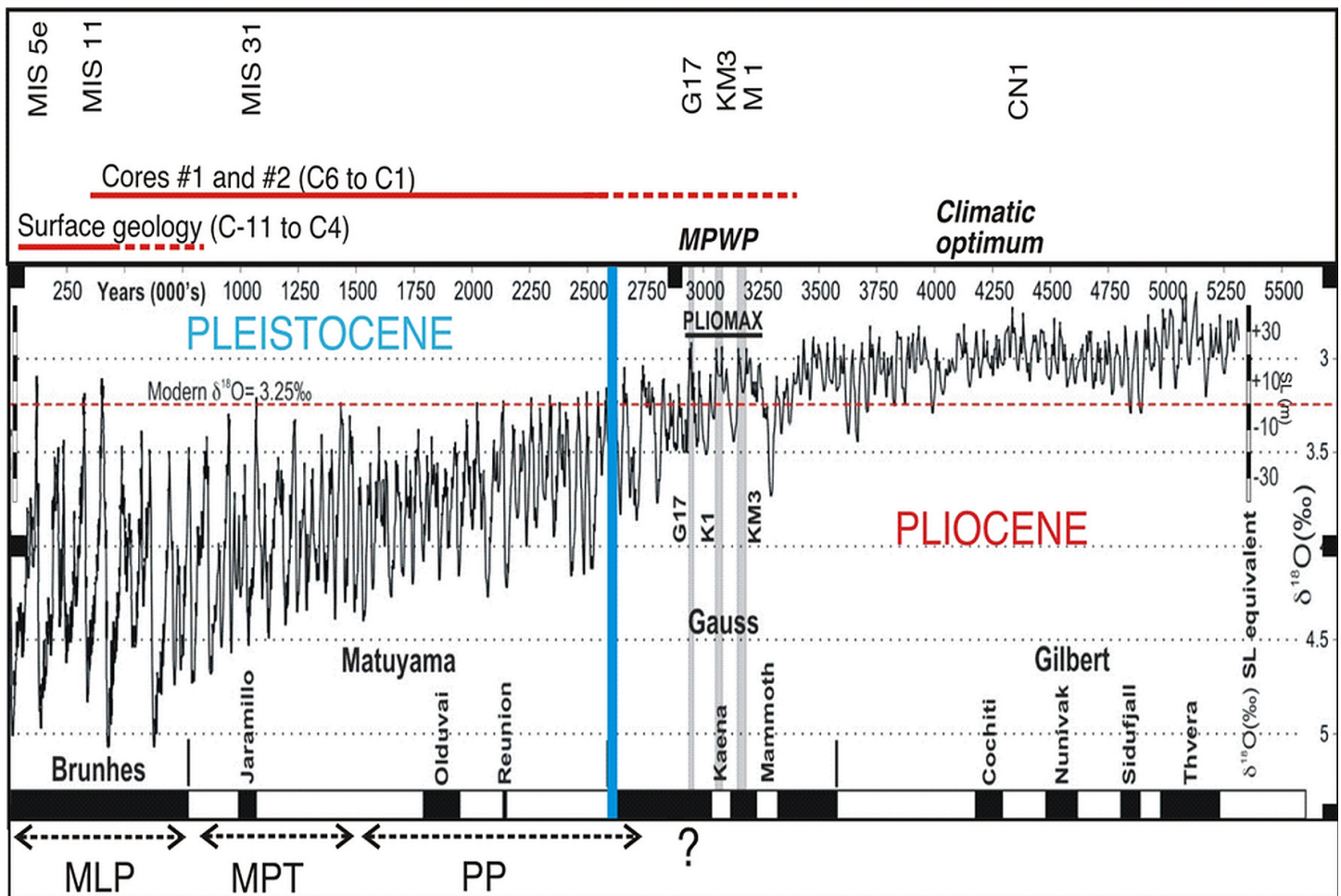


FIG. 2. The $\delta^{18}\text{O}$ record (Lisiecki and Raymo 2005) generally represents ice volume and sea-level changes over the past 3.5 Ma. Depositional intervals of both surface and subsurface (core) geology are graphically indicated at the top of the figure. Of course, the records are far from complete due to shifting depo-centers and erosion. The broad highstand intervals: the Mid-Late Pleistocene (MLP), Middle Pleistocene Transition (MPT), and Plio-Pleistocene (PP), are indicated in the lower portion of the figure. The vertical blue line marks the Plio-Pleistocene boundary (2.58 Ma). C unit in figure represents stratigraphic units.

2.58 Ma (Finney 2010; Gibbard and Head 2010) many strata previously associated with the Pliocene now fall into the early Pleistocene. It is well recognized that carbonate production and island growth is centered on interglacial highstand events and periplatform deposition (Reijmer et al. 1992; Schlager et al. 1994). The odd-numbered isotope stages noted in the $\delta^{18}\text{O}$ record represent interglacial stages 1, 3, 5, 7, 9, and 11. During sea-level lowstands, little or no carbonate is contributed to the islands. It is during the lowstand interval that carbonate diagenesis, dissolution (including cave formation), and paleosol development (with a significant aerosol fraction) are the dominant processes. Each stratigraphic unit may consist of multiple coastal facies including eolian, beach, subtidal, reef, etc., and may be capped by a weathering surface that may be composed of red or brown clayey soil, brown to reddish calcrete

lenses, solution holes, vugs, other karst features, or erosional surface. Obviously, multiple cycles are likely missing from the record due to erosion and/or periods of non-deposition as discussed below.

Bank marginal, bank top, and bypass highstands since the late Pliocene

Kindler and Hearty (1996) observed that the composition of limestone units could be explained in part by the position of sea level relative to the platform surface. Implied in such sea-level changes are concomitant changes in ocean currents, temperature, and chemistry. These important and fundamental relationships are played out in the sedimentary facies (shoreface, foreshore, back shore, dune) of carbonate deposits of various compositions (skeletal, oolitic, peloidal, etc.). Based on widespread geological surveys across the Ba-

hamas, it was established that three general categories (a, b, and c) of sea-level amplitude could be deciphered (Kindler and Hearty 1996):

- A) *Bank marginal flooding*: Shallow or bank-marginal flooding events typically generate largely coarse skeletal sediment composition. MIS 1, 5a, and 7 would be typical examples and perhaps the MPT. Such periods are characterized by reef and biologically dominated shallow coastal margins that generate abundant bioclastic sediments.
- B) *Bank top flooding*: Sedimentary structures were observed that indicate higher-than-present sea level (i.e., deeper flooding of the platform surface), which were consistently and regionally associated with finer-grained oolitic and peloidal limestone petrology.
- C) *Bypass flooding*: In particular cases, such as the MIS 11 highstand, flooding of the entire bank top occurred, leaving only sedimentary and geomorphic records on a few higher, older islands, or during regressions from the highest position of the sea. Extreme flooding events such as late MIS 5e and 11 (and most likely the Pliocene) that deeply flood the entire platform are among these exceptional events.

Parallel petro-stratigraphic sequences are documented in a survey of seven major islands in the northern Bahamas (Kindler and Hearty 1997) as well as in periplatform sediments (e.g., Boardman et al. 1986). Because sea level has affected a multitude of islands and periplatforms in similar ways over the course of several interglacial cycles, morphostratigraphic successions *generally* expose sequences of equal-age deposits with similar petrographic composition on different islands. These parallel rock successions demonstrate their common process of formation by sea-levels changes.

Fossil coral reefs from the last interglacial are the most effective source of chronologic control of island deposits, with U/Th dating providing a resolution of <5 ka typically. However, in-situ coral reef deposits are not abundant above sea level across the Bahama Banks. Banktop flooding during MIS 5e resulted in widespread and constantly-shifting oolitic-peloidal sediments to develop, and these sediments were deleterious to corals from finding stable substrates on which to colonize. As a result, coral reefs mainly occur in a very small

percentage of outcrops and primarily those of the MIS 5e, last interglacial age. This paucity of coral reefs in time and space challenged scientists to apply new geochronological methodologies to improve dating capabilities applicable to a broader age-range of deposits. With stratigraphic and geologic mapping of many additional islands and the availability and increased application of amino acid racemization (AAR) relative dating methods, it was discovered that an extensive record of middle and late Pleistocene interglacial deposits was present among the islands (Carew and Mylroie 1995; Hearty 1998; Kindler et al. 2010; Godefroid 2012; Godefroid and Kindler 2015; Jackson 2017; Kerans et al. 2019).

The use of whole-rock (WR) AAR (Hearty and Kaufman 2000) became particularly important as the majority of outcrops consist of bioclastic and oolitic grainstones with comparatively high amino acid content (Kindler and Hearty 1996) for which the dating method is well suited. Hearty and Kaufman (2000) established that an abundance of outcrops was present, representing marine isotope stages (MIS) 1, 5a, 5e, 7/9, 11, and possibly 13/15, but there was a decreasing occurrence of older outcrops with greater age. To our knowledge, there are no surficial exposures older than approximately 500 ka in the Exumas, but older subaerial rocks have been described on Mayaguana Island in the southern Bahamas (Kindler et al. 2011). The absence of early Pleistocene and older rocks in the Exumas suggests that either: 1) sea levels were substantially lower; 2) subsidence has lowered the deposits below present sea level; and/or 3) erosion has destroyed evidence of these events.

A recent unpublished PhD thesis by Jackson (2017; with D. McNeill as advisor) focused on the Exuma Cays and contributed a number of radiometric ages (^{14}C and U/Th), numerous additional A/I whole-rock samples, as well as other technical applications. Whole-rock samples from Jackson (2017) were analyzed at the AAGL in Flagstaff, Arizona following procedures outlined Hearty and Kaufman (2000), and yielded amino stratigraphic results consistent with our previous work. Jackson (2017) also conducted drone and ground geologic mapping of several Exuma cays that were mapped earlier by Hearty. Her geologic mapping results added considerable detail on several cays (e.g., Hawksbill, Shroud, Bitter Guana Cays, etc.) consistent with previous works.

Thus, the objectives of this paper are to:

- 1) describe the exposed surficial rocks of the Exuma Cays;
- 2) extend the rock record from the surface islands into the subsurface to include two 33-m cores (Figs. 3; 4F) (the core records extend into the early Pleistocene and late Pliocene, refer to Fig. 2);
- 3) provide explanations about the geomorphology, disposition, age and general evolution of the islands and platform margin. The geologic maps presented in this study offer a general picture of the geology of this idyllic island group in the central Bahamas, and
- 4) provide a detailed geologic map of the Exuma Cays. It is expected that some middle Pleistocene may be late Pleistocene, and some mid Holocene may be late Holocene (or vice versa). As further research and technology progresses, we expect these preliminary maps will be refined and improved.

MATERIALS AND METHODS

Core collection methods: Subsurface Cores to -33 m

The selected drill sites on Lee Stocking Island (LSI; Core #1) and Norman's Pond Cay (NPC; Core #2) in the southern Exuma Cays (Fig. 5D) were selected due to the geology and easy shore access by the barge-mounted diesel-powered SCARID coring equipment. In 1994, our group of scientists, technicians, and students extracted two 33 m cores from LSI and NPC with average 90% recovery (Hearty et al. 1996; McNeill and Hearty 2009). Core stratigraphy was initially recorded in the field as 3-m barrels were withdrawn, and again under close examination at the University of South Florida, St. Petersburg, at which time subsamples for AAR and paleomagnetic analysis were extracted (Fig. 3). One coral fragment obtained in Core #1 was analyzed for its U/Th, but yielded a chemically unreliable age of 257 ± 19 ka (Ken Ludwig, USGS, per comm.). The 25 mm diameter paleomagnetic "plugs" were analyzed by McNeill at RSMAS at U. of Miami (McNeill 1989; Hearty et al. 1996; McNeill and Hearty 2009; McNeill et al. 2012), yielding the results found here.

Surface mapping and sample collection

Extensive geological surveys and rock/sediment

sampling of islands in the northern and central Exuma Cays were conducted by boat and on land by the first author in the 1990s. Field geologic mapping was recorded on 1:25,000 Department of Lands and Surveys topographic maps (1968 series), with the additional aid of black and white air photos and Google Earth Pro®. The hand colored geology of the maps was compiled and digitized using ArcGIS originally by Lorscheid and subsequently refined by co-author Backstrom (Fig. 5A–D). Distribution and surface areas of each geologic unit were calculated using standard GIS methods. Relative sea level (RSL; see Rovere et al. 2016; Lorscheid et al. 2017) and outcrop elevations are indicated by a "+" (as in +12 m) for above the present datum (zero elevation), and with a "-" for subsurface depths in cores. Given the large number of islands included in this study, it was not practical or possible to label maps with all the localities mentioned or discussed in the manuscript. A master GIS geomap is provided at <https://arcg.is/1aKbf0>.

High-quality, low-elevation color aerial photographs (e.g. Figs. 6, 7) were taken from a high-wing sea plane at altitudes between 100 and 500 meters by the first author. Because vegetation communities respond to various soils, bedrock, and slope, these air images provided detailed coverage of the geology of the islands, particularly boundaries between units that are apparent from vegetation changes, and tested by extensive ground-truthing in the field. Representative samples were analyzed by hand lens and binocular microscope for general petrographic composition, diagenesis, and quality of WR AAR criteria (see Appendix 1).

Typical geomorphic features, such as marine terraces, eolian dunes, beach ridges, and berms were observed and recorded in the field. The morphostratigraphy typical of The Bahamas is characterized by on-lapping, stacked, and off-lapping eolian and marine sequences that are generally younger nearer the platform margins. Platform architecture is characterized by broad and relatively flat surfaces flanked by steep and very deep margins (e.g., Fig. 1). Various environments on the platform (e.g., Rankey and Reeder 2010) include tidal flats, inlets with flood and ebb tidal deltas, shallow shelf, and slope to the deep basins.

Amino Acid Racemization (AAR) Geochronology—the Whole-Rock (WR) Method

WR samples were collected, prepared, and analyzed at the Amino Acid Geochronology Laboratory (AAGL;

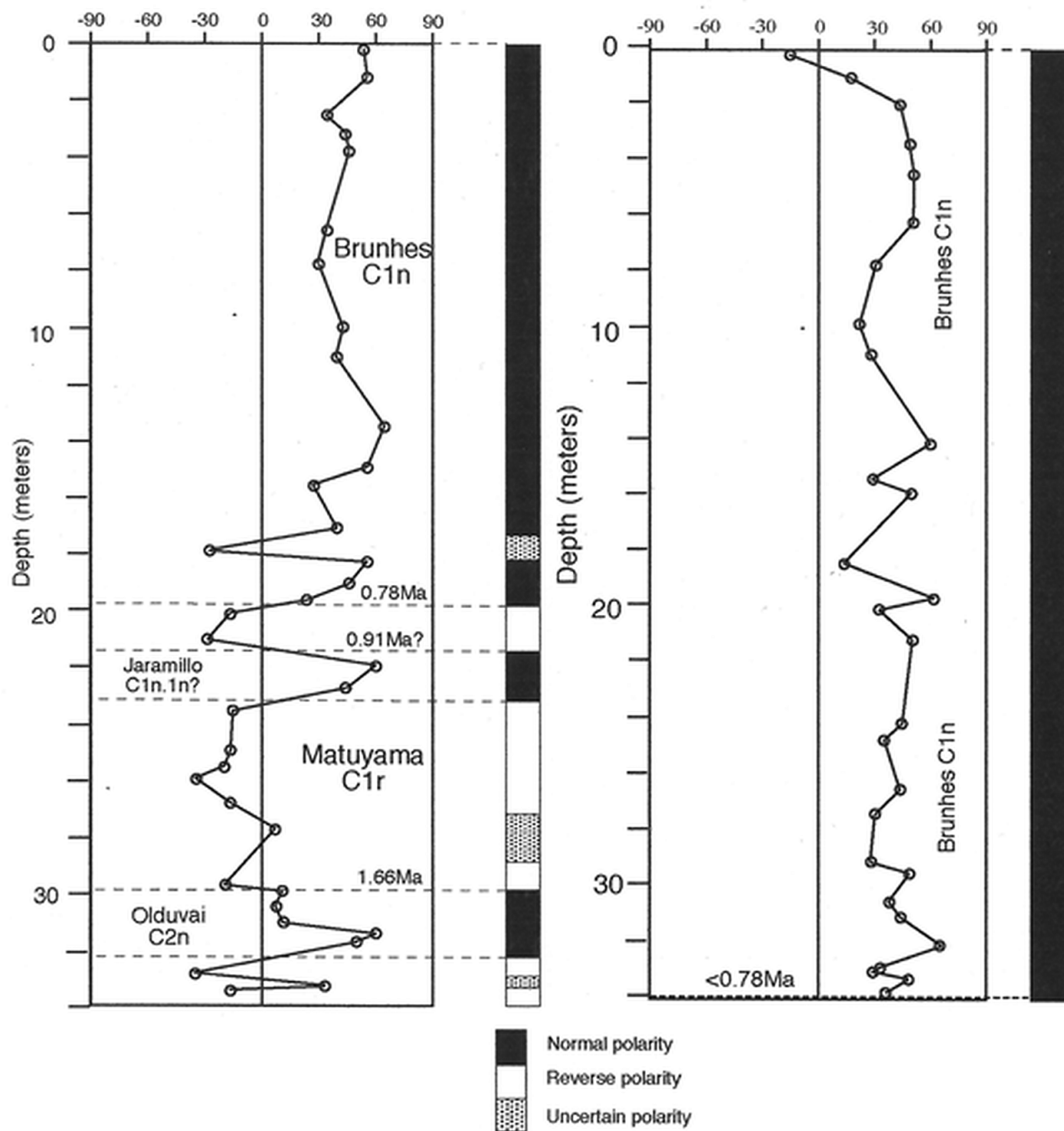


FIG. 3. Paleomagnetic polarity results of two 33-m cores from Normans Pond Cay (left; Core #2) and Lee Stocking Island (right; Core #1) (Hearty et al., 1996). Stratigraphy, facies, AAR and correlations are provided in the following figures. The upper horizontal axis is degrees of magnetic inclination.

Darrell Kaufman, Director) under protocols outlined for D-alloisoleucine/L-isoleucine (A/I) in Hearty and Kaufman (2000) and earlier papers. The AAR method utilizes organic carbonate of marine shells, land snails, or WR limestone for correlation and estimating the

ages of deposits. Mitterer (1968) showed that ooids, peloids, and aragonite muds contain concentrations of amino acids similar to those in mollusks and bioclastic limestones. These organic residues are present in appreciable quantities (Mitterer 1968), and reveal simi-



Fig. 4. A. Holocene strandplain at Cambridge Cay showing prograding beach ridges; B. White Horse Cay (North Point Member) showing a buildup of eolian cross-beds located near the bank margin; C. MIS 5a lunate ridge (top of photo) at Halls Pond Cay with extensive landward buildup of Holocene dunes; D. Massive MIS 5e dune at Old Land Rd, Great Exuma; E. Small middle Pleistocene island at Musha Cay with dense rhizomorphs and a ~2 m notch (formed early 5e?); F. Deeply karstified core section rock midway down Core #2 at -15 m depth, with section showing apparent paleosol with karst vugginess and reddening. A: Google Earth; B–F, P. Hearty.

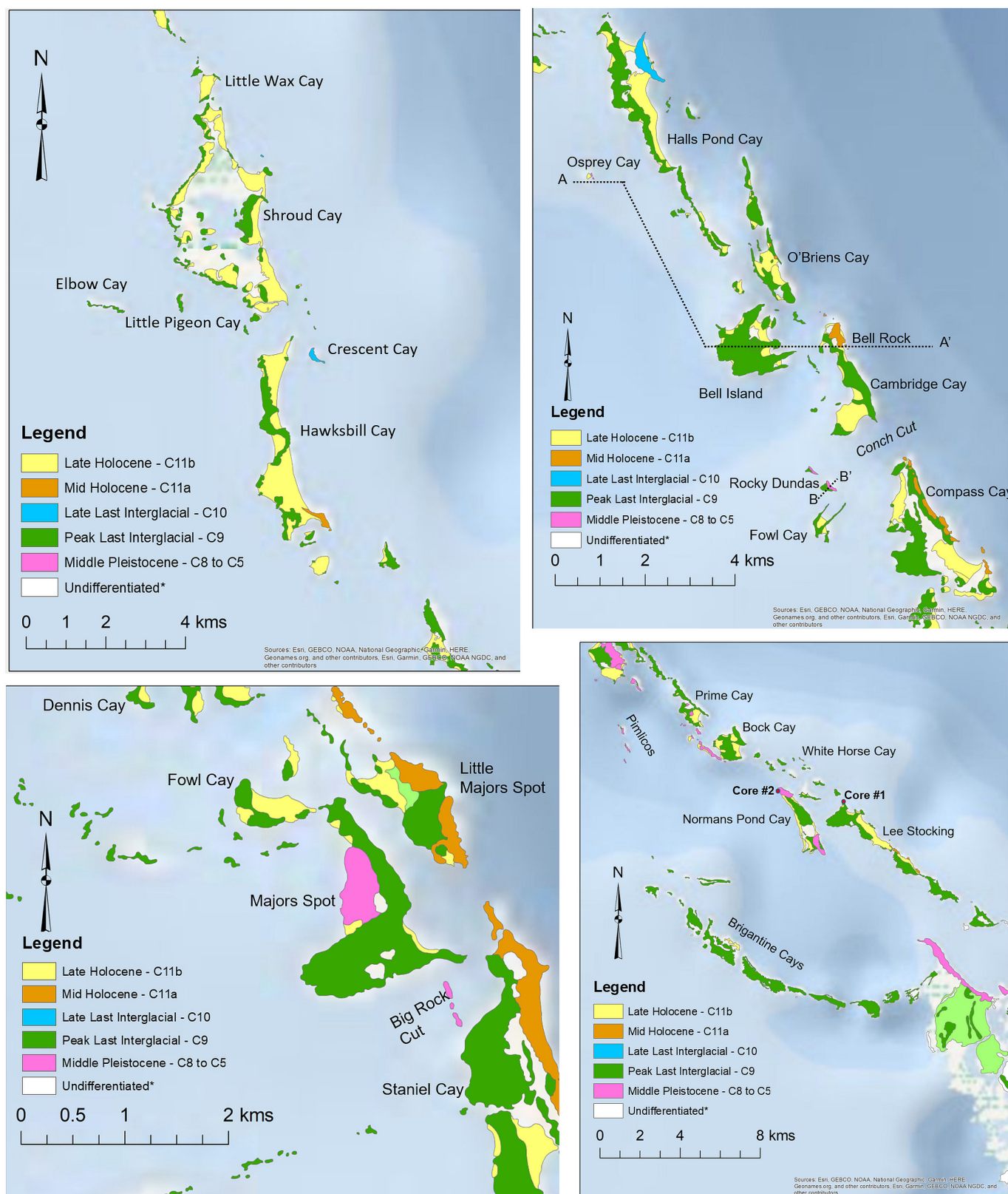


FIG. 5. Island geology of four selected areas of the Exuma Cays. Left to right, top to bottom: A. Shroud and Hawksbill Cays; B. Bell Island and adjacent cays (location of stratigraphic cross-sections A-A' and B-B' in Figure 9 identified); C. area around Staniel and Harvey Cays; and D: area around Lee Stocking and Normans Pond Cays (note location of Cores #1 and #2). *Undifferentiated would include unmapped areas as well and wetlands and salt ponds, which are common on most larger islands of the Exuma Chain. See text for details of each geological unit. Master geologic map can be accessed at: <https://arcg.is/1akbf0>

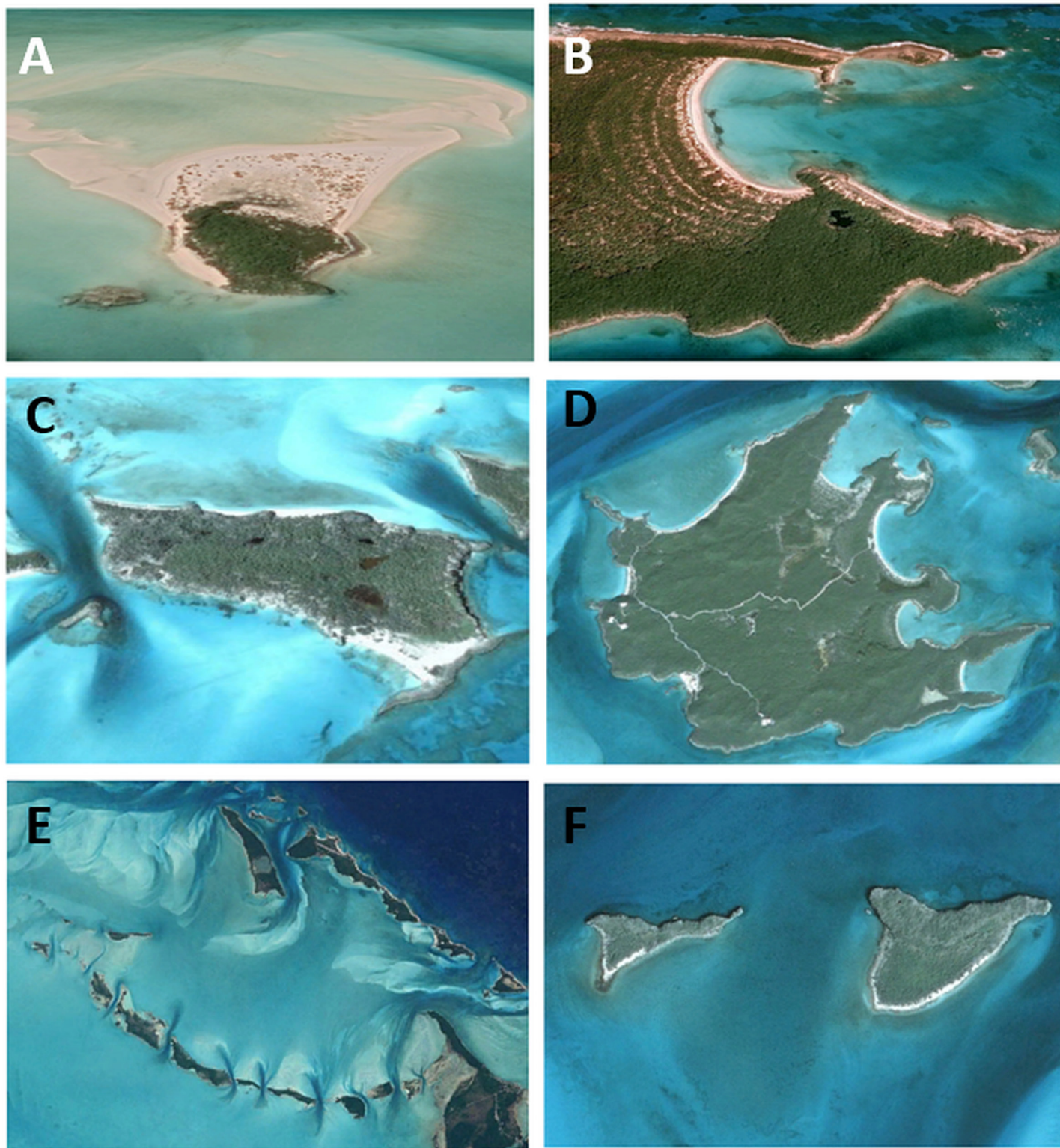


FIG. 6. Google Earth images of several Exuma Rocks and Cays. A. Osprey Cay (see transect in Fig. 9), recent sediments anchored on middle Pleistocene strata; B. Prime Cay showing a Holocene strandplain within Pleistocene ridges; C. Little Wax Cay just north of Shroud Cay (see Fig. 5A); D. Bell Island (see transect in Fig. 9); E. Area around Lee Stocking Island (Fig. 5D) and Brigantine Cays with floods of active recent sediments around older islands; F. Rocky Dundas (right) and neighboring unnamed rock (left) located in Conch Cut tidal pass along the Exuma Cays bank margin.



FIG. 7. Seaplane and pilot used to explore many of the islands of the Exuma Cays; photo by P. Hearty.

lar racemization/epimerization trends whether they are bioclastic or oolitic. Hearty expanded the WR AAR technology and protocols as demonstrated in several empirical whole-rock studies (Hearty and Kaufman 2000; Kerans et al. 2019, and refs therein). In several of these foundation studies, where a clear and unambiguous stratigraphic framework was present, whole-rock A/I ratios maintained stratigraphic order in over 90% of cases.

A newer set of A/I ratios were produced by Jackson (2017), and these generally agree with our *younger* defined aminozones. The calculation of individual numerical ages from the Hearty and Kaufman (2000) age model, as in table 3.2 of Jackson (2017), however should be conducted with caution, particularly with A/I values greater than 0.75. Jackson (2017) shows a large number (over 25%) of higher A/I values and numerical ages over 500 ka that do not accord with any published aminostratigraphic studies in the Bahamas. Due to decreasing concentrations and carbonate diagenesis, Hearty and Kaufman (2000; p. 169) clearly stated: "... the practical age limit of the whole-rock method in the Bahamas is approximately 450,000–500,000 yr (MIS 13)."

RESULTS

Identification of Physical Stratigraphic Units

Identification of stratigraphic units (youngest to oldest, in stratigraphic order) is based on some or all of the following distinguishing characteristics: a) the surface morphostratigraphic position of the ridge or observed vertical stratigraphic succession in the cores; b) the geomorphology of the deposits, including anchor-catenary ridge relationships (Garrett and Gould, 1984); c) the weathering, cementation, hardness, and diagenetic state of the limestone; d) petrographic composition of the units; e) extent of karst weathering; f) the color (Munsell, 2001) and clay content of the capping soils (Hearty 1998); and g) relative aminostratigraphic age (Appendix 1).

There are eleven identifiable units, most likely originating from a minimum of seven interglacial-glacial cycles (certainly many more not preserved) presented in this paper from cores and surface studies: Unit 11 (youngest) to Unit 1 (oldest) in the surface and subsurface geology of the Exuma Cays.

Unit 11b, MIS late 1 to modern (map color yellow)

Holocene beach and dune facies infill "energy

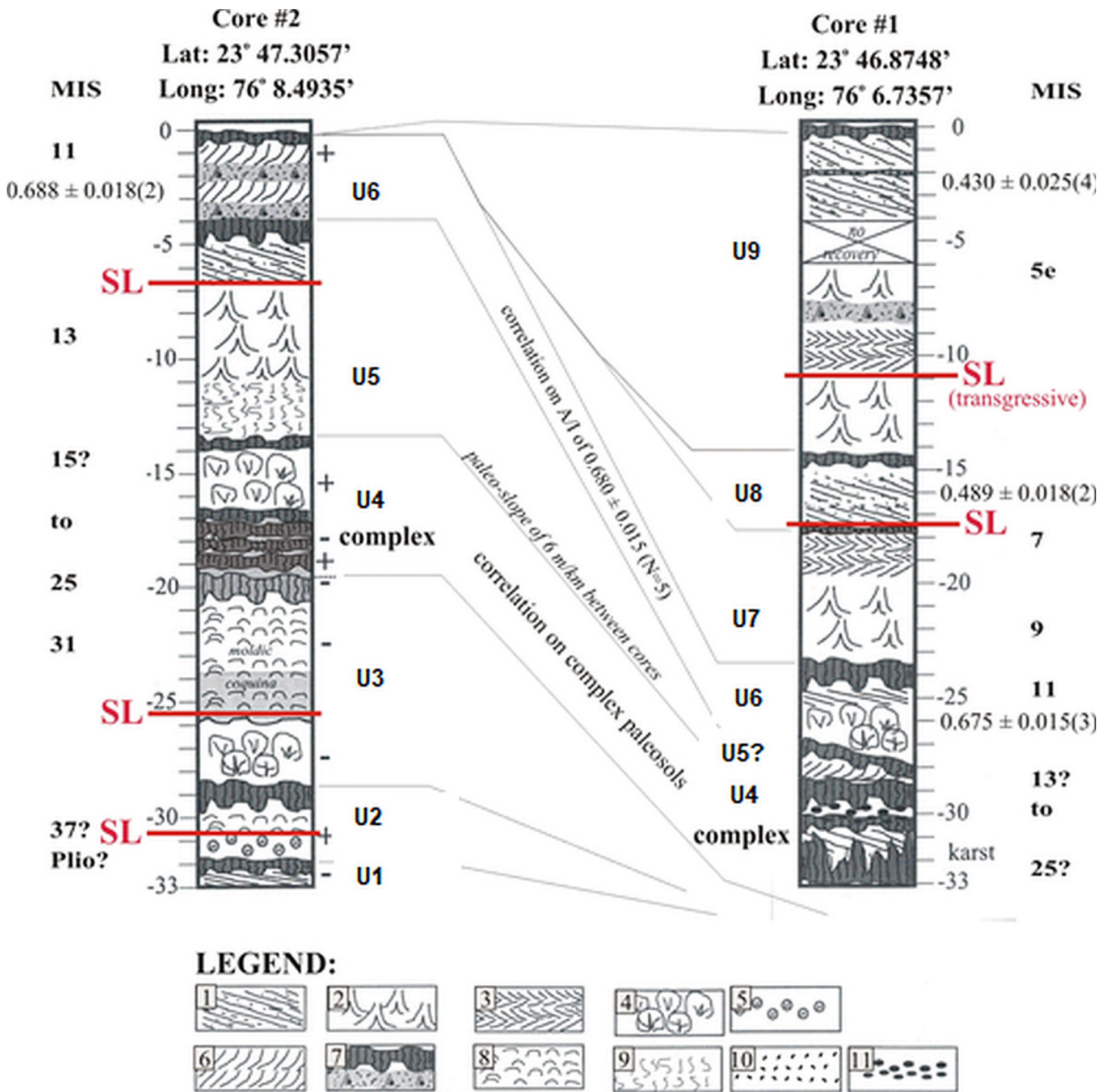


FIG. 8. Summary diagram and correlation based on several criteria of Core #2 (NPC) and Core #1 (LSI) and stratigraphy (top row then bottom row, left to right). Legend: (1) foreshore with fenestral porosity; (2) subtidal burrowed sand; (3) subtidal trough cross-stratification; (4) corals; (5) coral *Stylophera*; (6) eolian or subtidal bedforms and cross-beds; (7) paleosol (top) and protosol (bottom); (8) shell beds; (9) mottled, stained sands; (10) massive sands; (11) dissolution voids. Magnetic polarity indicated by (+) and (-) in Core #2. All of Core #1 is normal Brunhes polarity (<0.78 Ma). The C4 complex marks the approximate Brunhes/Matuyama Boundary in both cores. The “SL” notation indicates marine facies marking a subtidal/intertidal transition or boundary, and not necessarily the peak highstand of that stratigraphic interval.

Table 1. Inferred correlation table of known stratigraphic units and key information described in this study. WPF: Whale Point Formation; NPI: New Providence Island; ELU: Eleuthera Island. The master geological map can be accessed at: <https://arcg.is/1aKbf0>

Unit # map color	Recognized Formations or Island Locations	Range in A/I values	Interpreted or known $\delta^{18}\text{O}$ Stage	Location
11b Yellow	Hanna Bay/Rice Bay Mbrs	0.04–0.09	MIS 1	Surface
11a Orange	North Point Mbr	0.09–0.12	MIS 1	Surface
10 Blue	Almgreen Cay Fm/WPF	0.28–0.32	MIS 5a	Surface
9 Light/Dark Green	Grotto Bay Fm	0.37–0.43	MIS 5e	Surface and Core #1
8 Pink	[NPI]	~0.50	MIS 7	Surface and Core #1
7 Pink	[NPI]	0.58–0.70	MIS 9	Surface and Core #1
6 Shades of Purple	[Goulding Cay, ELU]		MIS 11	Surface and Core #1 and #2
5 ?	[Goulding Cay, ELU]		MIS 13?	Cores #1 and #2
4 cmplx Red/White	[Goulding Cay, ELU]	NA	MIS 15–25?	Cores #1 and #2
3 Brown		NA	25, 31, or 37?	Core #2
2 Brown		NA	Pliocene? Olduvai >1.66 Ma	Core #2
1 Brown		NA	Pliocene?	Core #2

traps” on antecedent Pleistocene landscapes. Beach ridges often extend for some distance, suspended between older headlands of generally last interglacial age (Unit 9) (Fig. 8B). Accretionary strand plains and/or multiple beach ridges are also typical of this unit (Fig. 4A). The grains are generally skeletal but contain significant percentages of oolitic grains when located near tidal passes, in which ooids are now forming. The grains of Unit 11b retain their original mineralogy and are uncemented or loosely consolidated at depth. Capping soils are blond to tan, with some grays and brown in more organic-rich localities (Munsell 2001). A/I ratios range from near modern values (0.04) to about 0.09 (Appendix 1). This late oxygen isotope Stage 1 unit is correlated to the Hanna Bay Member of the Rice Bay Formation (Table 1; Carew and Mylroie 1985) and yields calibrated ^{14}C ages on skeletal grains and snails between 4–5 ka (Hearty and Schellenberg 2008).

Unit 11a, MIS mid 1 (map color orange; mid Holocene)

An eolianite of mid Holocene age occurs on many high energy (eastern) bank margins, lying more seaward than any other units as isolated islets or ridges in the Exuma Cays. This mid Holocene eolianite unit occurs more frequently in the southern part of the study area. Steep eolian foreset beds of gray to white color, dipping below present sea level, and sparse vegetation (Plate 1B) distinguish this unit from all others.

The grains are thinly-coated ooids (Kindler and Hearty 1996) and contain small percentages of skeletal grains and are generally diagenetically unaltered. Within the surf zone, the oolite can be strongly cemented, but is more friable at higher and more protected levels. In rare cases, Unit 11a is capped by brownish to pale orange sandy soils. A/I ratios are fairly consistent at 0.09 to 0.12, reflecting a distinct pulse of sediment formation as sea level breached the platform margin around 5–7 ka. Calibrated ^{14}C ages of the correlative North Point Member on San Salvador Island (Carew and Mylroie 1985) range from 6.5 to 6 ka (Hearty and Schellenberg 2008).

Unit 10, MIS 5a (late last interglacial)

Although common in the eastern, high-energy Atlantic-facing islands of the Bahamas (Hearty and Kindler 1993; Kindler and Hearty 1996; Kindler et al. 2010), Unit C10 only occurs in a few localities in the relatively protected embayment of Exuma Sound. It is distinguished from other units by its typical skeletal composition, lunate dune form (Plate 1C), seaward position relative to islands of LIG affinity, and displays eolian foreset beds which dip below the modern datum indicating deposition during a lower sea-level stand. Unit 10 is composed of a weakly to moderately cemented bioclastic limestone that retains its primary mineralogy (Kindler and Hearty 1996). Capping soils are brown

to reddish brown (Munsell 2001). A tight clustering of A/I ratios around 0.28–0.32 in the Bahamas (Kindler and Hearty 1996) indicate that Unit 10 is significantly younger than Unit 9, and most likely correlates with oxygen isotope Substage 5a around 85 ka. It is found as a small crescent-shaped unnamed island directly east of the northern tip of Hawksbill Cay (Fig. 5A), and on the northeastern margin of Hall's Pond Cay. Unit 10 is correlated with the Almgreen Cay Formation of San Salvador Island (Hearty and Kindler 1993; Table 1) and its correlative, the Whale Point Formation of North Eleuthera (Kindler and Hearty, in review).

Unit 9, MIS 5e (map color dark green; peak last interglacial)

A complex of MIS 5e oolitic-peloidal deposits are important stratigraphic landmarks in the Bahamas. In the Exuma Cays, this unit is represented as multiple

subparallel or parabolic dune and beach ridges with shoreface with beach to eolian facies (Vimpere et al. 2019). In many cases the most bankward ridges terminate in a meandering coastline of steep foresets that plunge below sea level. The seaward topset faces of some of these ridges are filled with beach fenestrae.

Unit 9 is easily recognized by several additional characteristics (Neumann and Moore 1975; Kindler and Hearty 1996; Neumann and Hearty 1996) including: 1) limestones composed of tangential-aragonitic ooids with thick cortices; 2) grains cemented by low-Mg calcite equant spar; 3) subtidal and beach facies exposed above present sea level; 4) a series of subparallel or V-shaped oolitic coastal ridges that form the highest and most conspicuous ridges (Plate 1D) on most islands including “chevron ridges” such a Harvey Cays (Fig. 5C) (Hearty et al. 1998); 5) rare coral reefs that rise

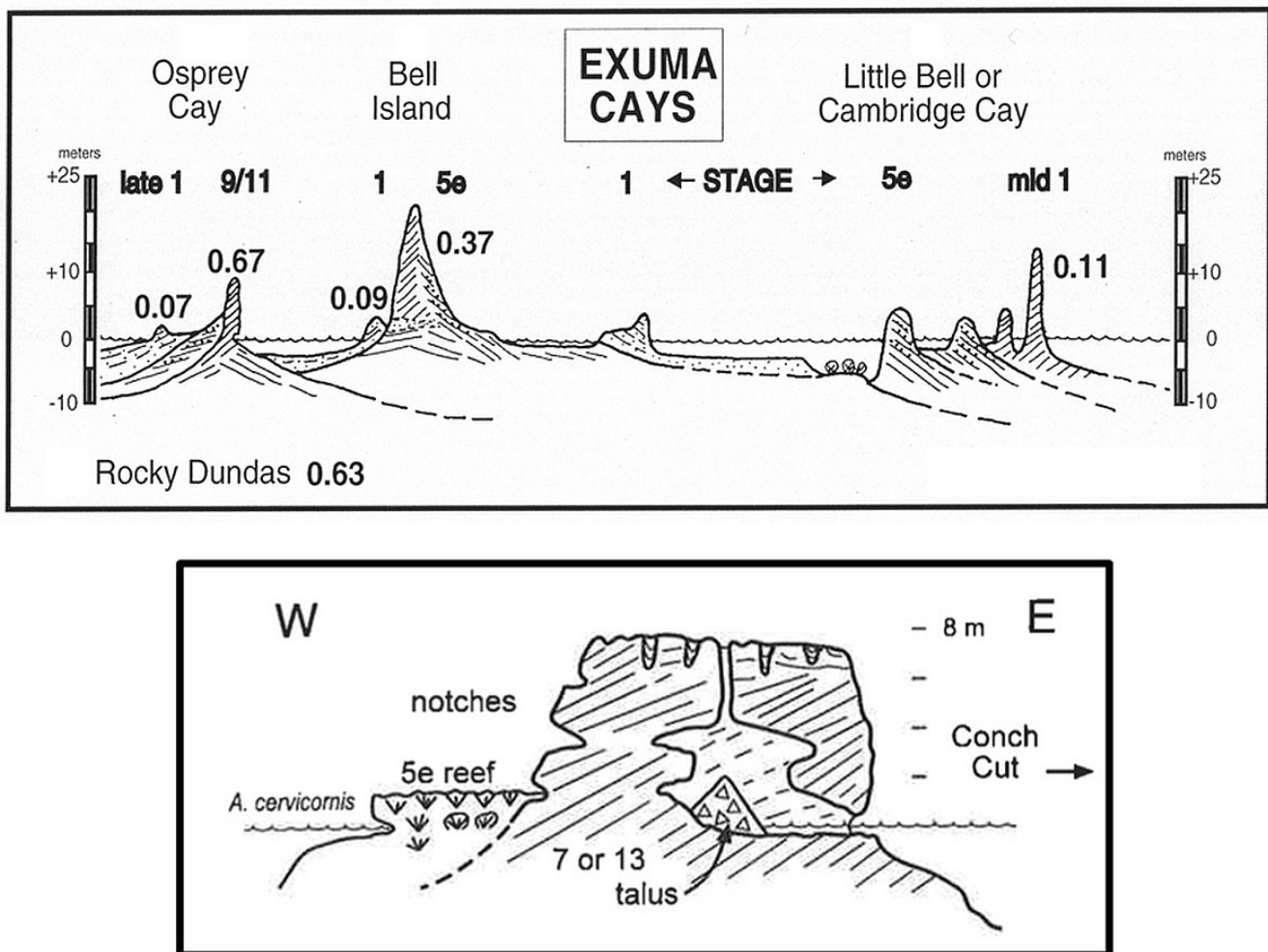


FIG. 9. Upper: A to A' - Morphostratigraphic and aminostratigraphic cross section from Osprey Cay to Cambridge Cay, to the margin of Exuma Sound. Lower: B to B' - Cross-section of Rocky Dundas Cay showing heavily karstified and notched mid Pleistocene rocks (MIS 11?) fringed on landward margin by a well-developed coral reef of MIS 5e age.

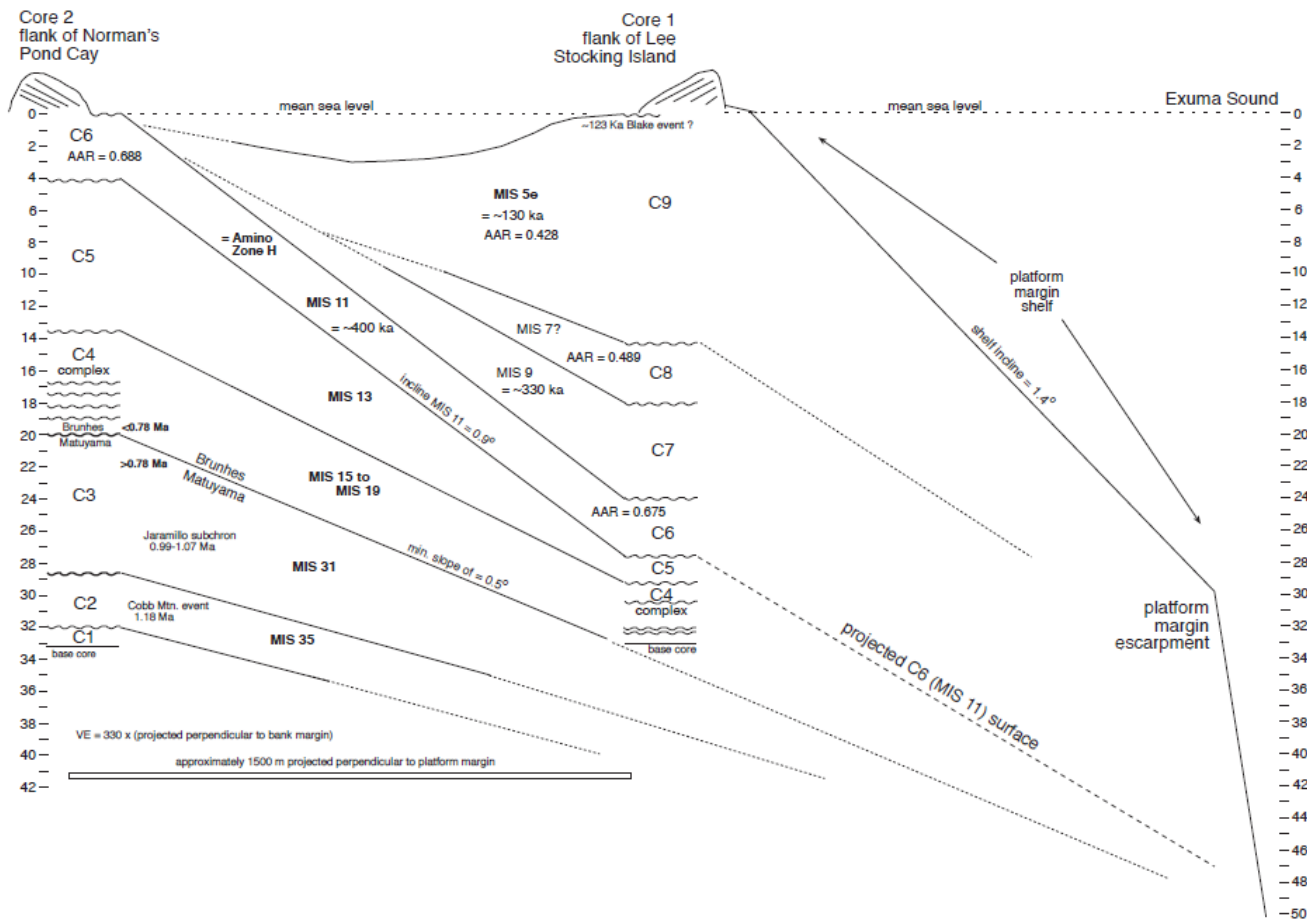


FIG. 10. Correlation of sea-level cycles in Cores #1 and #2 based on stratigraphy, aminostratigraphy, and magnetic polarity, with projected schematic of approximate slopes of the platform margin and escarpment into Exuma Sound. The cores reveal rapid basin-ward progradation of the limestone units over time scales of ~ 0.5 Ma (Hearty et al., 1996; McNeill and Hearty, 2009). C unit in figure represents stratigraphic units.

to about +2.5 m; and 6) deposits that produce concordant WR A/I ratios (0.37–0.43) across the region. The relatively uncommon MIS 5e coral reefs generally lie below +3 m, while sedimentary deposits and notches mark the higher stands of sea level.

On other islands of the Bahamas archipelago, such reefs have been dated between 132,000 and 119,000 yr old (Neumann and Moore 1975; Carew and Mylroie 1987; Chen et al. 1991; Thompson et al. 2011; Kerans et al. 2019). Typical examples of Unit 9 are present on Hawksbill Cay in the north, Bell Island (Figs. 5B, 6D), and Little Wax Cay (Fig. 6C). Figure 9 provides a morphostratigraphic and aminostratigraphic cross-section (A-A') from Osprey Cay, across Bell Islands and Cambridge Cay and Bell Rock, and further south across Rocky Dundas (B-B') in Conch Cut, which illustrate the complexity of some of the island chains.

Unit 8 to Unit 5, MIS 7-13?

In the Exuma Cays, middle Pleistocene rocks have distinctive characteristics, but only rarely are they found in stratigraphic context (i.e., multiple vertical, on or off-lapping rock units). From a geomorphological perspective, middle Pleistocene units are distinguished by highly weathered, craggy sub-vertical cliffs that are often deeply-incised by bioerosional notches at the modern tideline, and others at between +2 to +10 m (e.g., Figs. 4E, 6F). The multiple middle Pleistocene rock units are generally highly indurated oolitic/peloidal (typically MIS 11) and skeletal limestone (typically MIS 7 and >13), stained with clayey, reddish soil material, and partially to largely recrystallized. Paleosols are preserved mainly in solution pits and fissures. Typical localities include Osprey Cay (Figs. 5B, 6A); (west of Bell Island) and Rocky Dundas.

Subsurface Record from Cores #1 and #2 - (map color pink to purple: mid Pleistocene to Pliocene)

Details of Subsurface Physical Stratigraphy of Cores #1 and #2 (Figs. 8, 10):

Unit 9 (Core #1)

At the top of Core #1, unit Unit 9 yields a mean A/I of 0.428 ± 0.025 (N=4) if one value (0.32) is excluded, corresponding with the mean for “MIS 5e” in the central Bahamas (Hearty and Kaufman 2000) centered on 125 ka. Unit 9 is capped by reddish brown to red sandy (ridge crests) to clayey (near sea level) soils. Associated reefs of this age generally lie on the protected lee side of middle Pleistocene islands (e.g., Rocky Dundas; Figs. 5B, 9).

Unit 8/7

There are multiple levels that establish a correlation between, and the transition from, the surficial record to that of the cores in the subsurface. In Core #1, a fore-shore deposit at -17 m has been identified as Unit 8, producing a mean A/I of 0.489 ± 0.018 (N=2), values typical of MIS 7 (~200 ka). In the same core, Unit 7 yields distinctive intertidal and subtidal sedimentary facies, and is probably correlative with MIS 9 (~330 ka).

Unit 6 (Core #1)

Surface outcrops of middle Pleistocene eolianite at Osprey Cay and Rocky Dundas (Figs. 5B, 9) yield an aggregate mean of 0.658 ± 0.029 (N=3), corresponding precisely with the cores #2 and #1 samples (WR A/I: 0.687 ± 0.032 (N=2) and 0.675 ± 0.038 (N=3), respectively; Figures 8 and 10 from Unit 6, typical of Aminozone H, correlated with MIS 11 (Hearty and Kaufman 2000) around 400 ka. A major paleosol at -23.5 m is composed of pockets of red clay and reddened calcrete lenses 10–25 cm thick, overlying 50–80 cm of coarse skeletal grainstone. A deeper-water reef facies from -24.5 to -27.5 m with *Orbicella annularis* overlies an *Acropora cervicornis* (shallower water) reef in a matrix of coarse, skeletal, shelly limestone. A slightly altered specimen of *Orbicella* was sampled for U/Th dating, and the latter matrix sediment for AAR. Unfortunately, the U/Th sample was sufficiently altered to make the age unreliable. Core #1 is normal (Brunhes) polarity from top to bottom indicating an age of <0.78 Ma.

In Core #2, Unit 6 exposes moderately indurated eolian cross beds with intercalated protosols containing *Cerion* land snails between core top and -4 m. No marine facies of Unit 6 occur either in surface rocks or in

Core #2, which may be an indication of a much higher sea level that bypasses the margin and deeply flooded the entire platform. Presumably regressive eolian sands are deposited near sea level. This eolian unit is widely exposed and comprises the majority of the surface geology of NPC (Fig. 5D) as well as many of the bankward rocks and smaller islands of Exuma Cays.

Unit 5 (Core #1)

Thin clayey lenses and soil inclusions are interbedded with carbonate sand in high angle, possibly eolian or subtidal bedforms. A tentative correlation of this couplet is offered between cores only on the basis of its position below Unit 6 and above Unit 4. However, Core #2, Unit 5 exposes a shallowing-upward facies transition between deep subtidal burrowed sand, shallow subtidal burrows and cross beds, and beach in coarse skeletal sand indicating the precise position of relative sea level at -7 m.

Unit 4 – Paleosol complex - MIS 13-25?

The Unit 4 complex in Core #2 is exposed between -17 and -20 m and bears strikingly similar color and lithologic characteristics as the base of Core #1 (Fig. 8) at -31 m. At least five cycles of major dense calcrete paleosols alternating with decimetre thick lenses of deeply weathered, recrystallized shelly marine sands and calcarenite comprise the 3 m thick complex. In both cores, we interpret the Unit 4 complex as marking the average *maximum* upper reach highstands during a generally lower SL interval during the Middle Pleistocene Transition (MPT). We interpret this complex of paleosols (perhaps equating with the Big Red Soil “BRS” of Bermuda; Olson and Hearty, 2009) as perhaps ~0.5 Ma of non-deposition between 0.7 and 1.2 Ma (Fig. 2). The Unit 4 complex of couplets is similarly expressed in Core #1 by a number of paleosols within a 3 m zone below -15 m. A similar complex of paleosols is present at the base of Core #2.

Unit 3

A dense, Fe-stained pedogenic calcrete (lacking a paleosol) caps a thick (~9 m) shallowing-upward facies succession with platy corals on the older hardground (Unit 2) rising to an open matrix reef framework (*Acropora*?) between -27 and -25 m. Invertebrate borings occur on coral heads while brown calcite crystals fill in the vugs and voids (Plate 1F). Above the reef is a 1 m thick stratum of very dense, subtidal shelly marine

sand with abundant bryozoans capped by a low-angle bedded swash? beach sand indicating a relative sea-level position at c. -25 m. A clear facies transition occurs above this level in beds composed of dense, moldic coquina in a fine matrix apparently concentrated in a beach environment.

Unit 2

This couplet is capped at -29 m by a thick, reddened pedogenic calcrete with angular dark limestone breccia displaying evidence of dissolution throughout. The lowest extent of the marine unit consists of coarse conglomerate at -32 m, rising to an *in situ* *Stylophera* reef of presumed Plio-Pliocene age (Budd et al. 1998; Klaus and Budd 2003) and burrowed, shelly marine sands. The upper facies transition indicates a relative sea-level position at -30.5 m.

Unit 1 (base of Core #2)

A dense, reddened paleosol hardground caps a ~1 m exposure of coarse-grained, burrowed, and cross-bedded *Peneroplis*-rich marine sands that we interpret as a shoaling shoreline at -31.5 m.

Geochronology and Paleomag Analyses

Core #1 from the north end of Lee Stocking Island contains a minimum of six full sea level cycles with a diversity of shoreline facies from subtidal burrows and coral reefs to supratidal dunes. The 33 m Core #1 reaches total depth within the paleosol complex of the C4 and is of normal polarity Brunhes interval throughout (Hearty et al. 1996; McNeill and Hearty 2009) (Figs. 3 and 8). Core #2 from the north end of Norman's Pond Cay was spudded in Unit 6 (MIS 11) and is correlated with Unit 6 in Core #1 at 25 m depth. Unit 6 in Cores #1 and #2 produced identical WR values of 0.675 ± 0.015 (N=3) and 0.688 ± 0.018 (N=2), establishing a near certain correlation with MIS 11. No other units below Unit 6 in Core #2 have provided reliable AAR values, but analyses have indicated numerous paleomagnetic reversals as shown in Figures 3, 8, and 10. Normal Brunhes paleomagnetic signature is found down to the base of Unit 4 paleosol complex (as in Core #1) at -20 m, a short reversal (-22 to -23.5 m; Jaramillo? 0.91 Ma) and deeper to -30 m normal (Matuyama to 1.0 to 1.66 Ma) polarity, and finally Core #2 is based in reverse (Olduvai or older than >1.66 Ma) polarity at -32 m. If indeed, Core #2 is over 2 My old, as we are confident it is, there are obviously many sedimentary cycles not represented

in the rocks, as the Unit 4 complex demonstrates. It is only possible to describe what is present, clearly acknowledging many units are missing from the record.

DISCUSSION: GEOLOGIC HISTORY OF THE EXUMA CAYS

Sea-Level Intervals Oxygen isotopes $\delta^{18}O$ (Figure 2)

In an overview of the stratigraphic record from the surface and subsurface geology of the Exuma Cays, three major intervals can be defined based on the overall trends of maximum sea-level highstands, and the resulting extent of bank top and/or marginal platform marine flooding. These sea-level intervals are generalized here as the Plio-Pleistocene (PP: >1.2 Ma), mid-Pleistocene Transition (MPT: ~0.7 to 1.2 Ma), and mid-late Pleistocene (MLP: ~0 to 0.7 Ma) (see Fig. 2).

Plio-Pleistocene (PP)

Recent well-constrained estimates of eustatic sea level during the Pliocene (4.6 Ma) and MPWP (3.0 Ma) converge on maximum values around 20–25 m above sea level (Hearty et al. 2020; Rovere et al. 2020). The highest Pliocene strata in Exuma cores is about -20 m, similar to depths found in cores from the northern Bahamas (Kievman 1998). There are possibly two known outcrops of Plio-Pliocene marine limestone in Mayaguana and Crooked Islands (Kindler et al. 2011; Godefroid and Kindler 2015) which may have experienced minor tectonic movement nearer to the plate boundary. Otherwise, the absence of Plio-Pliocene surface exposures in the central and northern Bahamas is presumably due to: 1) subsidence of the banks, or alternatively, 2) landscape reduction and removal by processes of karstification, bioerosion and dissolution.

Middle Pleistocene Transition (MPT)

The Unit 4 complex in Core #2 is exposed between -17 and -20 m and bears strikingly similar color and lithologic characteristics as in Core #1 below -28 m. This concentration of several paleosols almost certainly marks an interval of lower and unrecorded sea levels during the MPT between 1.25 and 0.7 Ma. Clark et al. (2006) suggested the “average ice volume gradually increased by 50 m sea-level equivalent.” A few outcrops and cores reveal a stratigraphic concentration of deep red clayey paleosols that apparently represent a sustained interval of lower sea levels during the MPT.

Mid-Late Pleistocene (MLP)

The oldest geological events recorded in the existing Exuma Cays and surface rocks appear to be

between 300 and 500 ka, which corresponds with the emplacement of what were probably extensive island chains of oolitic and skeletal sediments. Subsequently, these island masses were largely destroyed by physical and chemical erosion. Such island remnants provided nucleation points for deposition during the following, younger highstand cycles. This process can be viewed in the classic “anchor and catenary ridge” model (e.g., Fig. 5B) of Garrett and Gould (1984), subsequently elaborated by Kindler and Hearty (1996). Figure 6A provides an excellent example of a nucleation point of older rocks as an energy ‘magnet’ for younger mobile sediments.

Each of the 6–8 full cycles (MIS 15? to 1) and sub-cycles over the past 0.5–0.7 Ma flooded the platform to varying degrees, and those with the deepest flooding of the platform generally produced largely oolitic-peloidal sediments, while those more bank marginal, like MIS 7, 5a, and 1 produced predominantly skeletal bioclastic sediments. The underlying processes are further explained in Kindler and Hearty (1996).

Overview of Exuma Island stratigraphy

Middle Pleistocene deposits in the Exuma Cays

Whole-rock AAR values indicate that some of the oldest datable deposits (that still preserve indigenous amino acids) are most likely associated with MIS 11 or perhaps MIS 13 (400–500 ka). Unit 6 provides the clearest correlation between both cores and surface outcrops. Core #2 from the north end of Norman’s Pond Cay encountered early Pleistocene and Pliocene sediments midway through the core (Hearty et al. 1996; McNeill and Hearty 2009). This core demonstrates that sediments much older than MIS 9/11/13 (i.e., early Pleistocene and Pliocene) exist at very shallow depths (–15 to –20 m) in the Exuma Cays.

MIS 7

Sea level during MIS 7 appears to have been bank marginal, in a position most likely a few meters below present, throughout the cycle. In the rare occurrence of documented MIS 7 deposits in the Exumas, they occur exclusively as bioclastic eolianites with foreset beds dipping below the present datum. Effectively, this position of SL suggests that older MIS 9–15 “islands” underwent minimal direct impact from corrosion, bioerosion, or physical wave attack during MIS 7.

MIS 5e: The peak last interglacial highstands (MIS 5e)

As with other parts of the Bahamas, the last interglacial (Unit 9) was the most important period for construction of land masses above present sea level. This was due to several factors: 1) the duration of the interglacial (132,000 to 119,000 yr, Chen et al. 1991) which provided time to manufacture an enormous volume of sediments; 2) the height of sea level which reached between +2 and +10 m (Hearty et al. 2007), which could effectively distribute sediments across the platform banks; 3) vertical changes in sea level, which effectively produce and redistribute new sediments; and 4) wind and currents that shifted and transported sediments horizontally and vertically to form new islands. The highest elevations (~30–40 m) on most islands are in rocks of Unit 9 last interglacial age.

Antecedent topography plays a significant role in the configuration of the Unit 9 islands. Where older middle Pleistocene cays or rocks were present, they would form headlands or anchors upon which Substage 5e ridges were suspended. Unit 9 effectively infilled and back filled areas around the Units 7–5 remnants. The older rocks are clearly nucleation points that modified the sedimentary processes (by wave/energy refraction) during the younger events. On some more protected islands like New Providence (Nassau) (Hearty and Kindler 1997) and West Caicos (Kerans et al. 2019), MIS 5e is characterized by often three to as many as eight subparallel beach/dune ridges. Marking the close of Unit 9 was a massive buildup of dunes including chevron ridges, considered by Neumann and Hearty (1996) to be components of a “madhouse” event. These are regressive SL events, most likely punctuated by hurricanes or intense storms characteristic of a sea-level regression from warm interglacial to much colder global conditions at the onset of MIS 5d (ca. 115,000 yr).

Substage 5a

MIS 5a deposits might often be confused with MIS 7 deposits due to similar eolian appearance, location, and grain composition. MIS 5a deposits are always bank marginal, often protruding in crescent-shaped ridges attached to the eastern shore of the islands (Fig. 4C). Distinguishing MIS 5a from MIS 7 is generally based on diagenetic grade of the skeletal carbonate sediments and AAR ratios (Kindler and Hearty 1996). Unlike the coasts of northern Eleuthera (Hearty 1997), Substage 5a deposits are sparsely represented in the Exuma Cays with only a few sites now recognized (e.g., Hawksbill

Cay and Hall's Pond Cays; Figs. 5A, 5B). The paucity of these deposits could in part be explained by the lower energy conditions within Exuma Sound, compared to the open exposure of north Eleuthera to the Atlantic Ocean. From this small number of exposures, it is inferred that the event was brief and sea level probably did not rise above present for any sustained period.

MIS 1: Late Holocene Backfilling

After the apparently rapid emplacement of the bank marginal North Point Member oolitic eolianite (Unit 11a) midway through the present interglacial (5–6.5 ka), sea level rose and stabilized near the present level about 4–3 ka. It was at this time that a process of backfilling “energy traps” were created in areas bounded on two or more sides by older rocks. In some areas, extensive flatlands were filled with accretionary beach ridges (aka., strandplains) (Fig. 6B). In other islands more exposed to the higher energy conditions along Exuma Sound, large single beach and dune ridges were built up tens of meters high. During the past few decades, Holocene deposits along many coastlines have reversed positive sediment flux, and are now aggressively eroding, presumably due to sea-level rise and increased storminess.

Geologic age and distribution of the Exuma Cays

In general, in the existing Exuma Cays, older islands exist further bankward from west to east (<https://arcg.is/1aKbf0>; Figs. 5A–D) with the youngest Holocene deposits nearest the margin. However, there are numerous exceptions to this rule and those are most likely the result of margin bypass and bank marginal sea-level positions during each cycle or sub-cycle. Overall, the surficial and subsurface geology of the Exuma Cays reveals rapid eastward thickening and accretion of deposits toward the margin of Exuma Sound over the past several hundred thousand years.

Apparent subsidence rates of the Bahamas since the Pliocene

Neither the data or the dating are precise enough to accurately calculate the rate of subsidence, but some generalizations are possible given the absence of early Pleistocene and late Pliocene rocks among of the islands of the Exuma Cays. In Core #2, the Brunhes/Matuyama boundary (0.78 Ma) is encountered at -17 m depth, while the Plio-Pliocene (>1.8 Ma?) is encountered at -25 to -30 m (Figs. 3 and 7). Given recent constrained estimates of late Pliocene sea level of +20 to

+25 m (Rohling et al. 2014; Dumitru et al. 2019; Hearty et al. 2020; Rovere et al. 2020), this would imply total subsidence of 40–50 m has occurred over 2–3 Ma, giving broad subsidence rates of 1.5 to 2 m/100 ka. These rates accord well with Mullins and Lynts (1977) and Freeman-Lynde and Ryan (1985), who estimated rates from deep core data from Little Bahama Bank of ~1–2 m/100 ka over the past 30 Ma. McNeill (2005) also determined highly variable rates from several locations in the Bahamas.

CONCLUSIONS

1) From the geologic evidence provided, three sea-level intervals are defined and broadly bracketed chronologically as the Plio-Pleistocene (PP), the Middle Pleistocene Transition (MPT), and Mid-Late Pleistocene (LP) (Fig. 2). These broader sea-level intervals are generally associated with higher than present highstands (PP), lower than present highstands (MPT), and a mix of higher and lower peak highstands (MLP). The island geology of the modern Exuma Cays comprises primarily the latest MLP deposits.

2) The few island “relicts” of middle Pleistocene age (e.g., Rocky Dundas) illustrate the wholesale degradation of older limestone islands by physical and chemical processes. Some of these are generally small, vertically walled “castle-like” islands that stand out primarily on the western margin of the chain. They are distinguished on the basis of their morphology, extensive meteoric diagenetic overprint, and deep karst and pedogenic weathering (Fig. 6F).

3) The most significant island-building event (in terms of present island area and volume) occurred during multiple phases of the last interglacial MIS 5e when sea level was generally higher than present for over 10,000 years (Hearty et al. 2007). During the mid-Holocene, when post-glacial sea level was probably a few meters below present, large dune ridges composed of oolitic sediments were formed from the offshore shelf and blown into the stark formations seen today. These islands are most commonly observed along the shelf margin in the central part of the Exuma Cays. Subsequently, as sea level reached present, “Energy traps” created by older limestone “nucleation” ridges were progressively infilled over the past 2–6 ka with skeletal marine and eolian sediments, often forming extensive subparallel strandplains.

4) Several of the major units observed in the surface

geology MLP also occur in the upper parts of the 33 m cores. The Unit 4 paleosols, representing the MPT complex, implies that sea levels were generally lower than the platform shoaling surface and many marine units are obviously missing from the record. Deeper units in Core #1 reveal mid to early Pleistocene paleosol complexes, and Pliocene marine calcarenites and coral reefs representing both MPT and PP mega-cycles. The stratigraphic cross-section from the surface and cores shows rapid thickening and off-lapping of sedimentary sequences (Fig. 10) toward the bank margin since the Plio-Pleistocene. Because of this rapid seaward growth and subsequent steepening of the margin, there is presumably an increasing risk of bank margin collapse.

5) Given the emerging evidence of maximum sea levels during the Pliocene (5–3 Ma) above +20 to +25 m, it is apparent there has been a considerable amount of subsidence (~40–50 m) of the Bahama platform since that time, yielding approximate subsidence rates of 1.5–2.0 m/100 ka.

Acknowledgements—We would like to dedicate this paper to the memory of Dr. Robert Dill, who was key to organizing the team members for the initial coring project. Thanks also to D. McNeill, G. Shinn, B. Burke, K. Shapiro, SCARID, and the original funding from NOAA. The first author would like to express thanks to S. Anthony for lending a hand on LSI. We are particularly grateful to T. Lorscheid for initially digitizing Hearty's original 1:25,000 hand colored geological maps. Thanks to all those who facilitated the field survey by providing transport by boat and seaplane. Grateful to the former CMRC on Lee Stocking Island for coring, field logistics and accommodations.

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APPENDIX 1. A summary of whole-rock A/I ratios determined from sites in the Exuma Cays, Bahamas. Exclusions of sample data from calculation of group mean A/I values based on: (RC) Rejected on the basis of very low concentration of amino acids; (RS) Rejected due to proximity to soils or apparent leaching; (RU) Rejected for unknown reasons or conspicuously out of stratigraphic order. Exclusions of sample data from calculation of group mean A/I values based on: (RC) Rejected on the basis of very low concentration of amino acids; (RS) Rejected due to proximity to soils or apparent leaching; (RU) Rejected for unknown reasons or conspicuously out of stratigraphic order. Sk: Predominantly skeletal sediment; Oo: Predominantly oolitic sediment; AGE: Oxygen Isotope Stages

Site	Lab #	Field #	Locality	Petrology	AGE	A/I	SD	Exclusions
Exuma Cays								
1	1692B	XOS-1e	Osprey Cay	Oo	modern	0.044	± 0.002	
2	1789A	XNH-2a	Normans Cay	Oo	mid 1	0.092	± 0.009	
3	1689A	XBI-4e	Bell Island	Sk	mid 1	0.081	± 0.013	
3	1690A	XEB-1a	Bell Rock	Oo	mid 1	0.115	± 0.006	
4	1471A	XWH1c	White Horse	Oo	mid 1	0.103	± 0.000	
5	1787A	XHC-1a	Hawksbill Cay	Sk	5e	0.376	± 0.002	
6	1391A	XLS1a	Lee Stocking Island	Oo	5e	0.408	± 0.002	
2	1788A	XNH-1a	Normans Pond	Oo	5e	0.423	± 0.010	
3	1688A	XBI-3a	Bell Island	Oo	5e	0.371	± 0.015	
7	1472A	XWP3a	West Pimlico	Sk	7/13	0.427	± 0.003	RU
8	1474A	XPI1a	Pigeon Cay	Sk	7/13	0.372	± 0.005	RU
9	1475A	XSQ1a	Square Rock	Sk	7/13	0.396	± 0.007	RC
1	1691A	XOS-1a	Osprey Cay	Oo	9/11	0.655	± 0.018	
1	1692A	XOS-1a	Osprey Cay	Oo	9/11	0.688	± 0.032	
10	1790A	XRD-1a	Rocky Dundas	Oo	9/11	0.630	± 0.021	
Bell Island Core (~1 m increments downcore)								
3	1761A	XBI4-1	Bell Island	Oo	5e	0.377	± 0.002	
3	1762A	XBI4-2	Bell Island	Oo	5e	0.361	± 0.007	
3	1763A	XBI6-01	Bell Island	Oo	5e	0.385	± 0.009	
3	1764A	XBI6-02	Bell Island	Oo	5e	0.403	± 0.010	
3	1765A	XBI6-03	Bell Island	Oo	5e	0.260	± 0.007	RS
3	1766A	XBI6-04	Bell Island	Oo	5e	0.423	± 0.004	
3	1767A	XBI6-05	Bell Island	Oo	5e	0.428	± 0.004	
3	1768A	XBI6-06	Bell Island	Oo	5e	0.424	± 0.010	
3	1769A	XBI6-07	Bell Island	Oo	5e	0.349	± 0.005	
3	1770A	XBI6-08	Bell Island	Oo	5e	0.385	± 0.004	
3	1771A	XBI6-09	Bell Island	Oo	5e	0.367	± 0.010	
3	1772A	XBI6-10	Bell Island	Oo	5e	0.367	± 0.004	
3	1773A	XBI6-11	Bell Island	Oo	5e	0.394	± 0.002	
3	1774A	XBI6-12	Bell Island	Oo	5e	0.417	± 0.008	

3	1775A	XBI6-13	Bell Island	Oo	5e	0.313	± 0.004	RS
Lee Stocking Island (LSI) Core #1								
6	1394A	XC1-0-1	LSI	Oo	5e	0.438	± 0.013	
6	1394B	XC1-0-2	LSI	Oo	5e	0.426	± 0.010	
6	1394C	XC1-02-3	LSI	Oo	5e	0.395	± 0.006	
6	1394D	XC1-04-4	LSI	Oo	5e	0.454	± 0.009	
6	1394E	XC1-07-6	LSI	Oo	5e	0.315	± 0.007	RS
6	1394F	XC1-11-7	LSI	Sk	5e	0.476	± 0.014	
6	1394G	XC1-13-9	LSI	Sk	5e	0.502	± 0.010	
6	1394H	XC1-17-10	LSI	Oo	9/11	0.690	± 0.050	
6	1394I	XC1-17-11	LSI	Oo	9/11	0.675	± 0.016	
6	1394J	XC1-20-12	LSI	Oo	9/11	0.661	± 0.047	
6	1394K	XC1-21-13	LSI	Sk		0.401	± 0.063	RC
Norman's Pond Cay (NPC) Core #2								
6	1395A	XC2-00-1	NPC	Sk/Oo	9/11	0.673	± 0.027	
6	1395B	XC2-02-2	NPC	Sk/Oo	9/11	0.700	± 0.036	
6	1395C	XC2-03-3	NPC	Sk	>13	0.481	± 0.017	RC
6	1395D	XC2-04-4	NPC	Sk	>13	0.481	± 0.029	RC
6	1395eII	XC2-05-5	NPC	Sk	>13	0.522	± 0.025	RC
6	1395F	XC2-10-7	NPC	Oo	eP	0.581	± 0.048	RC
6	1395G	XC2-10-8	NPC	Oo	eP	0.583	± 0.032	RC
6	1395H	XC2-11-9	NPC	Oo	eP	0.523	± 0.028	RC
6	1395I	XC2-21-11	NPC	Sk	Plio	0.302	± 0.014	RC
Great Exuma Island (for comparison; not included in maps)								
11	1470A	XS1ab	Stocking Island	Sk	5a	0.307	± 0.003	
12	1390A	XOL1c	Old Land Road	Oo	5e	0.415	± 0.005	
12	1390B	XOL1a	Old Land Road	Oo	5e	0.428	± 0.008	
14	2536	XMT1a	Mt. Pleasant N	Oo	5e	0.424	± 0.001	
15	2537	XBB1a	Bahama Blvd.	Oo	5e	0.462	± 0.005	
16	2538	XFH1a	Farmer's Hill	Oo	5e	0.382	± 0.002	
13	1473A	XBB2a	Forrest Sett.	Sk	7	0.591	± 0.007	