Holocene Core Logs and Site Statistics for Modern Patch-Reef Cores: Biscayne National Park, Florida

Open-File Report 2009–1246

U.S. Department of the Interior
U.S. Geological Survey

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By Christopher D. Reich, T. Don Hickey, Kristine L. DeLong, Richard Z. Poore, and John C. Brock

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All photographs are from U.S. Geological Survey files.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	2.590	square kilometer (km^2)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	centimeter (cm)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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Introduction

The bedrock in Biscayne National Park (BNP), a 1,730-square kilometer (km^2) region off southeast Florida, consists of Pleistocene (1.8 million years ago (Ma) to 10,000 years ago (ka)) and Holocene (10 ka to present) carbonate rocks (Enos and Perkins, 1977; Halley and others, 1997; Multer and others, 2002). Most of the surficial limestone in BNP, including the islands of the Florida Keys, was formed at ~125 ka during the highstand of marine oxygen-isotope substage 5e, when sea level was approximately 6 meters (m) higher than today (Chappell and Shackleton, 1986; Multer and others, 2002; Lidz and others, 2003; Siddall and others, 2003; Balsillie and Donoghue, 2004). During the substage-5e regression, the entire Florida Platform became exposed. Subaerial exposure lasted for approximately 115,000 years (kyr), which resulted in erosion and enhancement of karst-like features (Lidz and others, 2006). As the Holocene transgression began to flood the Florida shelf ~7 to 6 ka, the bedrock depression under Biscayne Bay began to flood, and Holocene coral and reef debris laid the foundation for the present reef system (Enos and Perkins, 1977; Lighty and others, 1982; Toscano and Macintyre, 2003; Lidz and others, 2006).

More than 3,000 patch reefs exist within the BNP boundary. Most contain hermatypic corals of various species such as those belonging to *Montastrea*, *Diploria*, *Siderastrea*, *Porites*, *Acropora*, and *Agaricia*. Patch reefs within BNP have two morphologies: pinnacle and flat top. Experimental Advanced Airborne Research Lidar (EAARL) data collected along the offshore BNP coral reef tract show that these two morphologies are clearly defined both in the high-resolution bathymetry maps produced by the Lidar data and by statistical analyses of the Lidar dataset (Brock and others, 2008). Brock and others (2008) also show that the pinnacle patch reefs are deeper than the more shallow, broad, and flat patch reefs. The control for these two patch-reef morphologies is unclear; however, their shapes may be due to a slightly lowered sea level or a stillstand in the middle-Holocene around 4 ka that caused erosion of the shallower reefs and allowed the deeper reefs to remain unaffected. Lidz and others (2006) have suggested a stillstand around 4 ka that carved a 2.5-kilometer (km)-wide nearshore rock ledge into the seaward side of every island in the Florida Keys.

The objectives of this study were to sample living corals to understand the more recent (<200 years) changes in climate and environmental conditions of the area and to investigate the Holocene (in this case, <8,000 years in the Florida Keys) depositional history at progressively deeper patch-reef sites. This report provides statistics for the cores and core sites and a basic lithologic description of these Holocene cores.

Methods

Coring

Core samples were obtained from the carbonate platform and head corals in BNP using the U.S. Geological Survey (USGS) rotary hydraulic coring system (Macintyre, 1975; Shinn and others, 1994; Reich and others, 2006). Holocene wireline (WL) cores were collected at four locations, and head coral (HC) samples were collected at three locations (figs. 1 and 2; tables 1 and 2). Drilling equipment consisted of a hydraulic-powered submersible drill, a 4-inch (in.)-diameter by 24-in.-long core barrel with surface-set diamond bit, and a hydraulic-power unit operated from the surface supply boat. A tripod was used in the shallow water to suspend the hydraulic drill and to help maintain vertical position during coring (fig. 3). Corals were drilled where the growth axis was presumed to be vertical. In many cases, the core barrel had to be inserted multiple times to collect the full length of coral growth on top of bedrock. After core extraction from the coral, the cores were placed on an onboard drying table prior to being wrapped in plastic and secured for travel. Coral cores were then placed in wood boxes and archived at the USGS-St. Petersburg, FL, facility. A pre-cast concrete plug was inserted into the 4-in. open hole left in the head coral. The plug provides a substratum that will be overgrown by the coral.

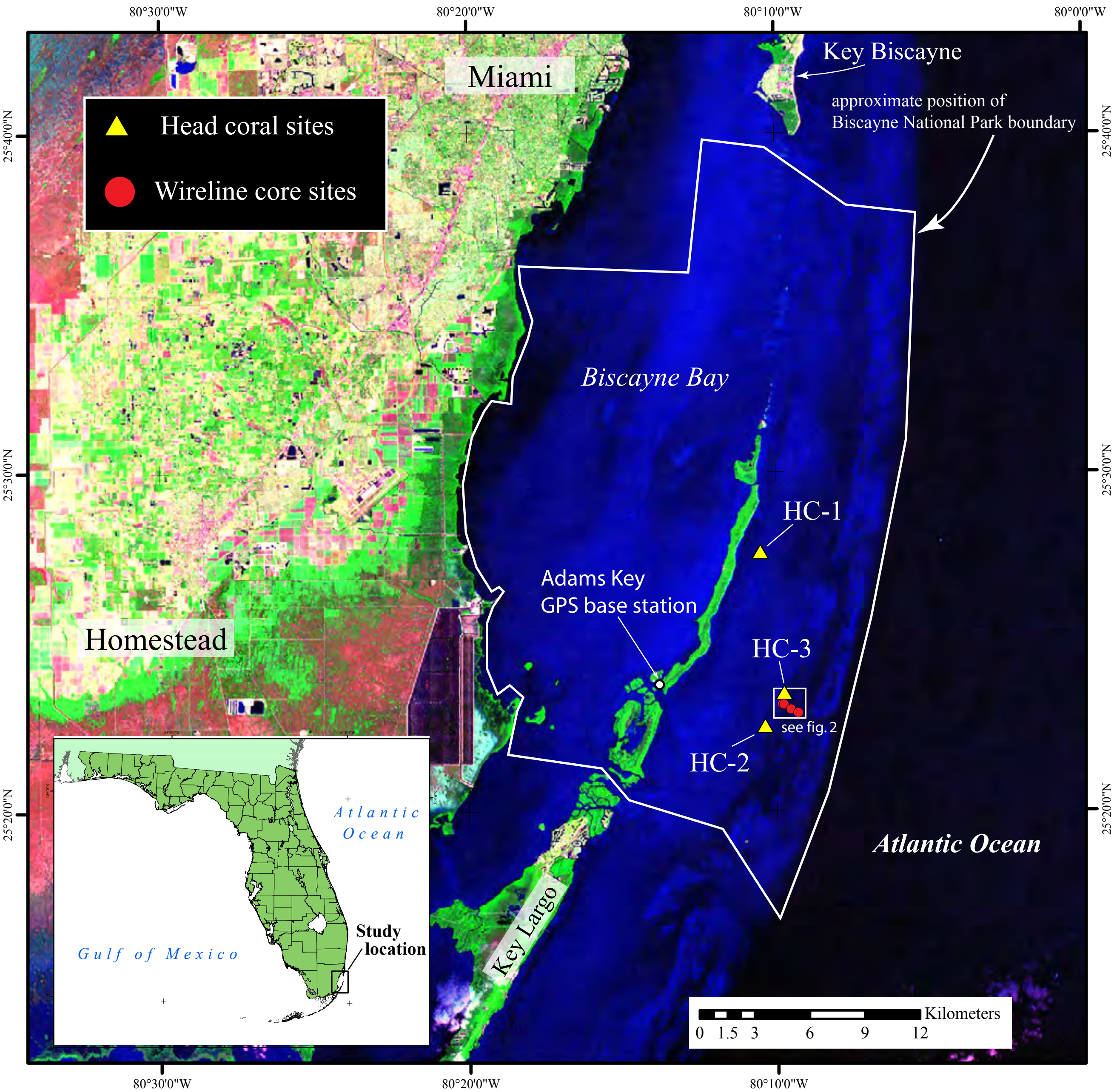

Figure 1. Annotated Landsat 7 false-color thematic mapper (1999) image denoting wireline (WL; circle) and head-coral (HC; triangle) coring locations in Florida. Inset shows Biscayne National Park (BNP) study area.

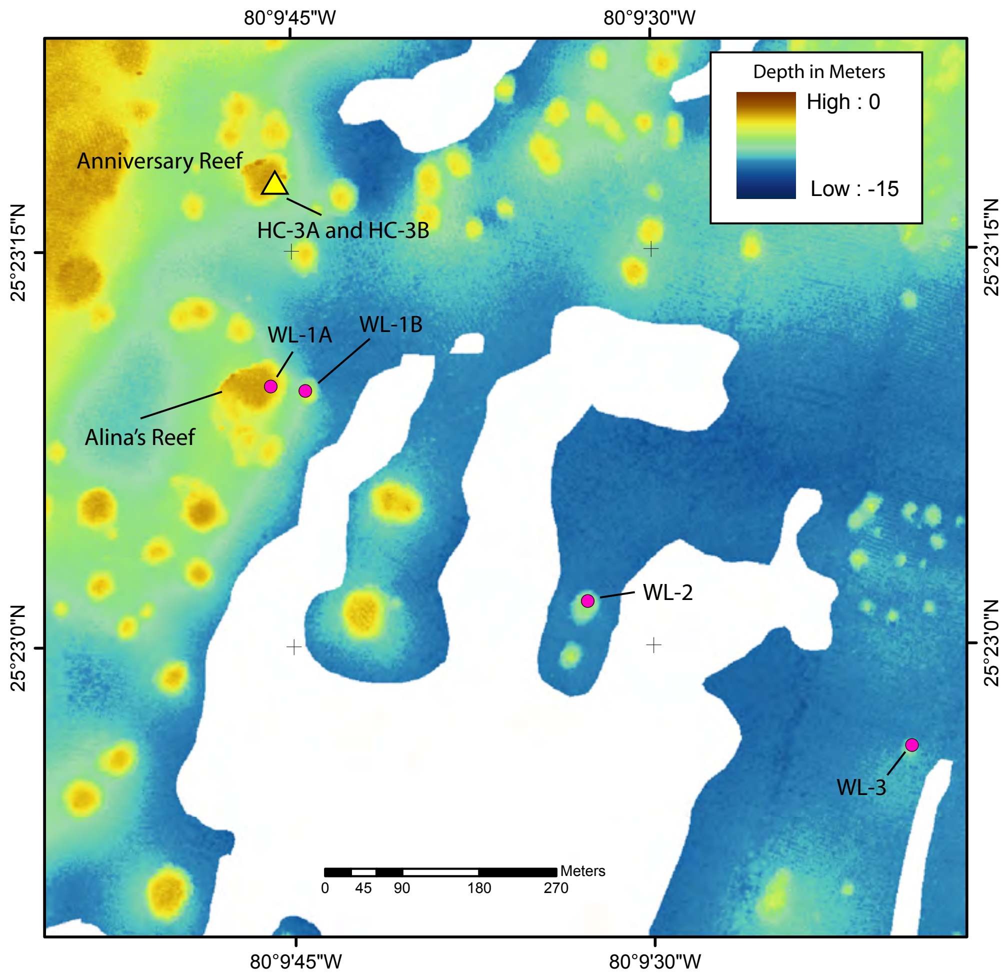

Figure 2. High-resolution Lidar bathymetry and location of sites drilled near Alina's Reef. Circles represent wireline (WL) core sites that were drilled to the top of the Pleistocene surface. Triangle at Anniversary Reef is the site where *Diploria strigosa* and *Montastrea faveolata* head corals (HC-3A and HC-3B, respectively) were cored. White area indicates that no Lidar data are available. Note that shallow sites near Alina's Reef and Anniversary Reef are broad and flat, and sites farther offshore are pinnacle shaped. See appendix B for cores and core logs from Sites WL-1A, WL-1B, WL-2, and WL-3.

Table 1. Information on head coral (HC) cores collected in Biscayne National Park (BNP) in May 2008.

Date collected	Site name	Latitude (N.)	Longitude (W.)	Core length (centimeters)	Water depth (meters)	Coral species	Notes
May 2, 2008	HC-1A	25.47097	–80.17342	38	~3	*Siderastrea siderea*	
May 2, 2008	HC-1B	25.47097	–80.17342	51	~3	*Montastrea faveolata*	
May 4, 2008	HC-2	25.35806	–80.19036	47	~2.5	*Montastrea faveolata*	Used tripod to suspend drill head
May 5, 2008	HC-3A	25.38832	–80.16266	43 (section 1)	~2.5	*Diploria strigosa*	Used tripod to suspend drill head
	HC-3A	25.38832	–80.16266	18 (section 2)	~2.5	*Diploria strigosa*	
May 5, 2008	HC-3B	25.38832	–80.16266	43 (section 1)	~2.5	*Montastrea faveolata*	Cored completely through to bedrock
	HC-3B	25.38832	–80.16266	47 (section 2)	~2.5	*Montastrea faveolata*	
	HC-3B	25.38832	–80.16266	17 (section 3)	~2.5	*Montastrea faveolata*	

Table 2. Information on Holocene wireline (WL) cores collected in Biscayne National Park (BNP) in May 2008.

[NAVD 88, North American Vertical Datum of 1988]

Date collected	Site name	Latitude (N.)	Longitude (W.)	Total depth drilled (feet)	Approximate water depth (meters)	Seafloor elevation (meters NAVD 88)
May 5–6, 2008	WL-1A	25.38617	–80.16299	14.0	2.5	–2.837*
May 6–7, 2008	WL-1B	25.38603	–80.16235	30.0	4.0	–4.321
May 7–8, 2008	WL-2	25.38380	–80.15910	26.5	5.5	–5.680
May 9, 2008	WL-3	25.38226	–80.15535	30.0	6.5	–6.479

*Approximate depth, located near pre-existing site (see Reich and others, 2006).

Figure 3. A SCUBA diver using the underwater coral coring drill.

Coring the Holocene seafloor was accomplished using an NQ-2 wireline system (Boart Longyear), a high-speed and low-torque hydraulic motor, and a gear pump that circulated water as drilling fluid (fig. 4). The NQ-2 wireline system contains an inner barrel that retains a 2-in.-diameter core and is extracted at 5-foot (ft) intervals by using an overshot tool attached to a rope (or wire) that runs through a pulley to a capstan mounted on the tripod. Core barrels are 5 ft long; core extraction was made at those intervals. After extraction, the core barrel with core was taken to the boat, where the core was removed, placed in a wood box, and allowed to air dry before being placed in a cardboard core box for archiving. All cores were eventually archived at the USGS-St. Petersburg facility.

Core Location Elevation Survey

Proper elevation control for each core was critical for allowing accurate cross-borehole core correlations. To maintain comparable elevations (bathymetry) for the top of each core, a kinematic Global Positioning System (GPS) was used at each site where wireline cores were collected. Ashtech high-precision, dual-frequency GPS receivers coupled with Thales choke-ring antennas were used for this survey. The antenna was mounted to the coring tripod using SECO GPS poles and leveled using a hand level. A base station was established on Adams Key (south end of Elliott Key) over a previously established benchmark (fig. 1). In order to keep GPS errors to a minimum, each site only needed to be occupied for 30 minutes because core locations were less than 15 km from the base station. All reported root-mean-square errors in position (horizontal and vertical) were less than 3 centimeters (cm). The elevations were corrected to the GEOID03, and results are provided in the North American Vertical Datum of 1988 (NAVD 88) datum (table 2). Sample collection period data were processed using the Novatel GrafNet program.

Figure 4. Tripod and underwater wireline coring system. In this photograph, SCUBA divers are extracting the inner barrel that contains the core.

Results and Summary

Coral Cores

Coral core data are presented with limited interpretive information because coral samples can be used for paleo-oceanographic/paleo-climatic analyses yet to be conducted. Studies utilizing BNP coral cores can include coral-growth (extension rates) based on X-radiographs. Subannual to monthly ocean temperature and salinity variability can be determined with trace metal (strontium-to-calcium ratios) and oxygen-isotope ($\delta^{18}O$) analyses of coral powders

Table 1 includes general information on the head coral cores collected for this study, including GPS coordinates, core length, water depth, and coral species. Three coral species were sampled: *Siderastrea siderea*, *Montastrea faveolata*, and *Diploria strigosa*. Photographs of the coral heads after drilling are shown in appendix A.

Wireline Cores

Wireline cores were described according to the classification of Dunham (1962). Appendix B contains core logs and photographs of the cores at each location. The core logs contain information on texture, fossil remnants, color, sedimentary structures, and core recovery. The core descriptions in appendix B were constructed using RockWare® LogPlot and Adobe® Illustrator® software.

The objective of this part of the study was to collect the Holocene section from a progressively deepening patch-reef transect in BNP. Alina’s Reef was selected as the starting point of the coring because of the vast number of research studies conducted at or near that site. Reich and others (2006) core-drilled the reef to install monitoring wells for a water-quality study and provided background data on the geology of the patch reef. The target depth of drilling was the top of the Pleistocene surface, which is identified by a laminated caliche (subaerial-exposure surface). An example of the laminated caliche can be seen just above the 30-ft mark in the core photograph from WL-2 (appendix figure B7). The Holocene sections from each of the patch reefs cored are very similar and consist of massive head corals, cemented reefal debris (grainstone and packstone lithology), and numerous fossils (bryozoa, coralline algae, serpulid worm tubes, molluscan shells, and foraminifera).

X-Ray Diffraction and Carbon-14 Analyses

Samples from the wireline cores were prepared for X-ray diffraction (XRD) and accelerated mass spectrometry radiocarbon dating (AMS). Samples chosen for XRD and AMS age dating were composed of visually unaltered coral material. Thirteen samples were collected from the four coring sites (table 2), cleaned using an ultra-sonicator in a deionized (DI) water bath, and air dried. A portion of the sample (~8–10 grams) was placed in a plastic zipper bag for ^{14}C analyses, and another portion (~2 grams) was ground into a powder with a corundum mortar and pestle. Prior to dating, each powder sample was run on a Bruker D4 X-ray diffractometer to verify that the samples were unaltered aragonite (fig. 5). This verification process is necessary prior to submission of carbonate samples for ^{14}C age dating because the presence of calcite can result in ambiguities and introduce noise in the precision of age dating using ^{14}C analytical methods. The coral samples were shipped to the USGS radiocarbon dating laboratory in Reston, VA. Age dates and depths from the radiocarbon analyses are presented in table 3. Ages were determined at the Center for Accelerator Mass Spectrometry (CAMS), Lawrence Livermore National Laboratory, Livermore, CA.

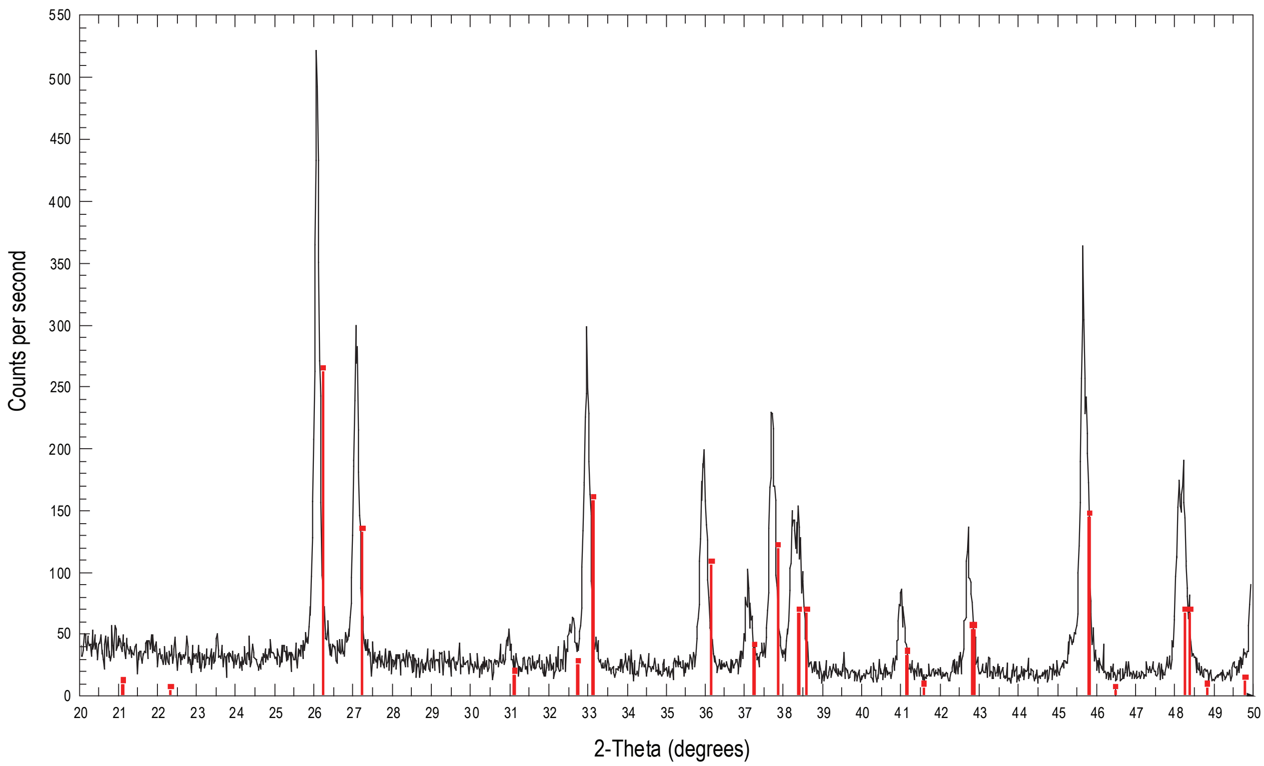

Figure 5. X-ray diffraction (XRD) plot showing results of coral powder (black line) from Holocene sample 08BNP-Site 2-LS1. Sample is nearly 100 percent aragonite, as shown by the red marker lines (aragonite standard peaks).

Table 3. Radiocarbon ages and corrected ^{14}C dates for Holocene wireline core samples from Biscayne National Park.

[In all cases, material dated was fossilized coral. Sample ID corresponds to site and sample number (for example, 08BNP-Site1A-LS1 represents site WL-1A and limestone sample number 1) and is also denoted in appendix B lithologic description logs. NAVD 88, North American Vertical Datum of 1988; ±, plus or minus; σ, 1 standard deviation]

Sample ID	Lab ID	Sample depth (feet below sea floor)	Depth (meters NAVD 88)	Radiocarbon age and error		Calibrated age (cal yr BP)†			
				^{14}C age	±	median	from	to	σ
08BNP-Site1A-LS1	WW7188	1	–3.142	4530	35	4736	4818	4624	54
08BNP-Site 1A-LS2	WW7189	4.5	–4.209	4890	35	5216	5294	5067	64
08BNP- Site 1A-LS3	WW7190	9	–5.580	5130	35	5504	5577	5434	41
08BNP- Site 1A-LS4	WW7191	11	–6.190	5185	35	5548	5602	5467	37
08BNP- Site 1B-LS1	WW7192	5	–5.845	4160	35	4225	4346	4126	56
08BNP- Site 1B-LS2	WW7193	10	–7.369	4285	30	4396	4490	4307	42
08BNP- Site 1B-LS3	WW7194	13	–8.283	5445	35	5816	5895	5731	45
08BNP- Site 1B-LS4	WW7195	19	–10.112	5440	35	5812	5890	5728	45
08BNP-Site2-LS1	WW7196	0.4	–5.802	4335	35	4459	4546	4380	41
08BNP-Site3-LS1	WW7197	0.1	–6.509	5140	35	5511	5577	5445	38
08BNP-Site3-LS2	WW7198	7	–8.613	5625	40	6010	6150	5915	57
08BNP-Site3-LS3	WW7199	12	–10.137	5975	35	6375	6455	6296	41
08BNP-Site3-LS4	WW7200	19.5	–12.423	6065	40	6478	6593	6391	51

†Calibrated ages obtained using OxCal v. 4.1 (Bronk, 1994) and marine reservoir correction value of 405+18 (cal yr BP=calibrated years before present (1950)).

Acknowledgments

We thank Richard Curry at Biscayne National Park for access to the park, permission to core, and on-site logistical support. Thanks to Jordan Sanford and B.J. Reynolds of the USGS and Michèle LaVigne of Rutgers University for assistance in the collection of core samples. Appreciation is extended to John Haines and the USGS Coastal and Marine Geology Program for continued funding support. We also thank John Lisle, Ilsa Kuffner, Barbara Lidz, and John Watson for their comments and reviews.

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Appendixes

Appendix A. Photographs of coral heads after drilling, Biscayne National Park.

Appendix B. Core logs and photographs of the cores at each location, Biscayne National Park.

Figure A1. Site HC-1A, *Siderastrea siderea*. Note cement plug in core hole in top of coral head.

Figure A2. Site HC-1B, *Montastrea faveolata*. Note cement plug in core hole in top of coral head.

Figure A3. Site HC-2, *Montastrea faveolata*. Note diver's hand for scale.

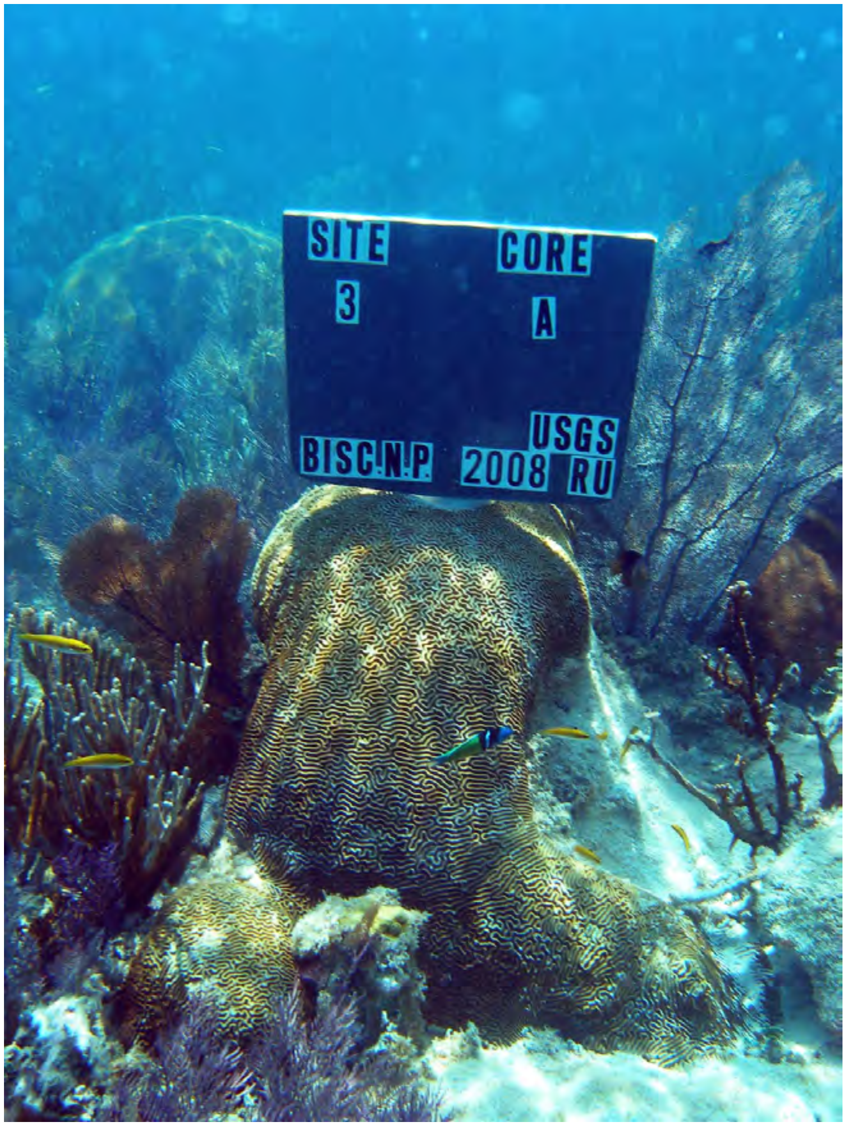

Figure A4. Site HC-3A, *Diploria strigosa*. Core hole beneath sign has been plugged with cement.

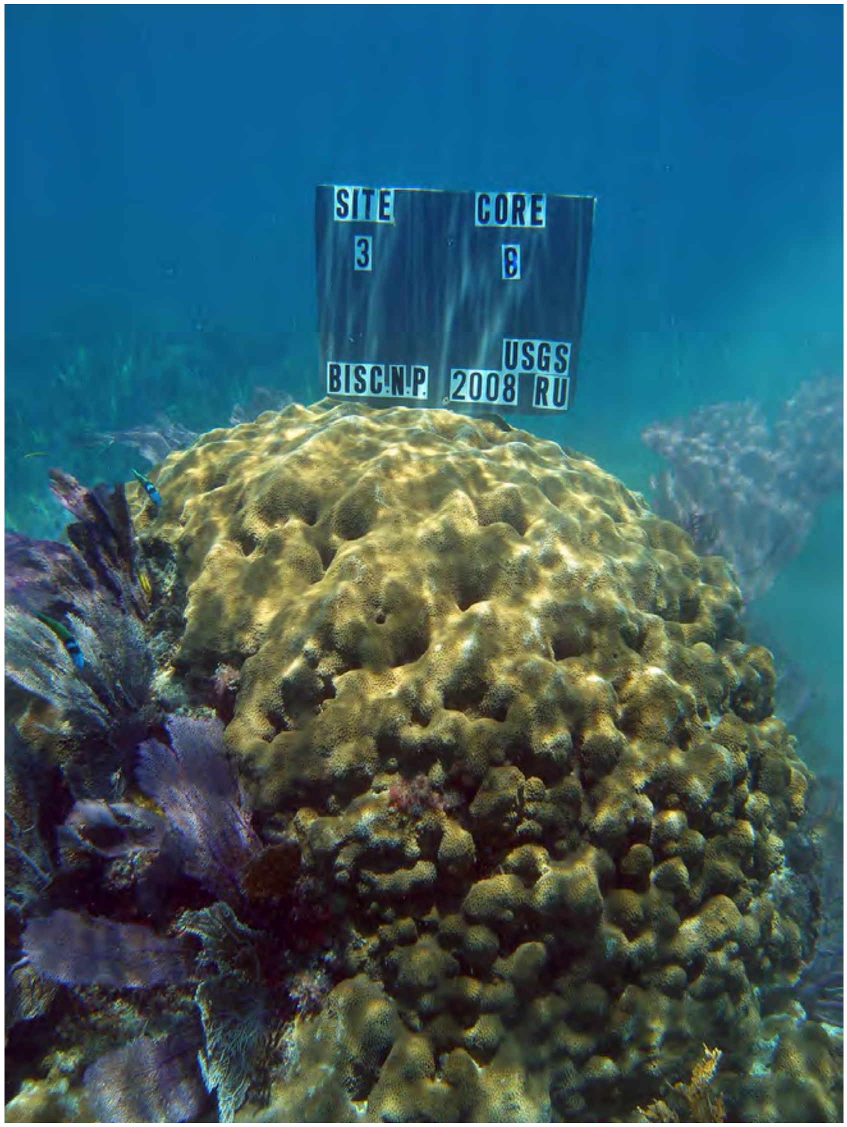

Figure A5. Site HC-3B *Montastrea faveolata*. Core hole beneath sign has been plugged with cement.

Classification of Carbonate Rocks According to Depositional Texture (after Dunham, 1962)

<table>
<tr><th colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</th><th rowspan="2">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE</th></tr>
<tr><td colspan="4">Original Components not Bound Together During Deposition</td><td rowspan="4">Original Components were bound together during deposition. . . as shown by intergrown skeletal matter, lamination contrary to gravity or sediment-floored cavities that are roofed over by organic matter and are too large to be interstices.</td></tr>
<tr><td colspan="3">Contains mud (particles of clay and fine silt size)</td><td rowspan="3">Lacks mud and is grain-supported</td><td rowspan="4">Crystalline Carbonate

(Subdivide according to classifications designed to bear on physical texture or diagenesis.)</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td></tr>
</table>

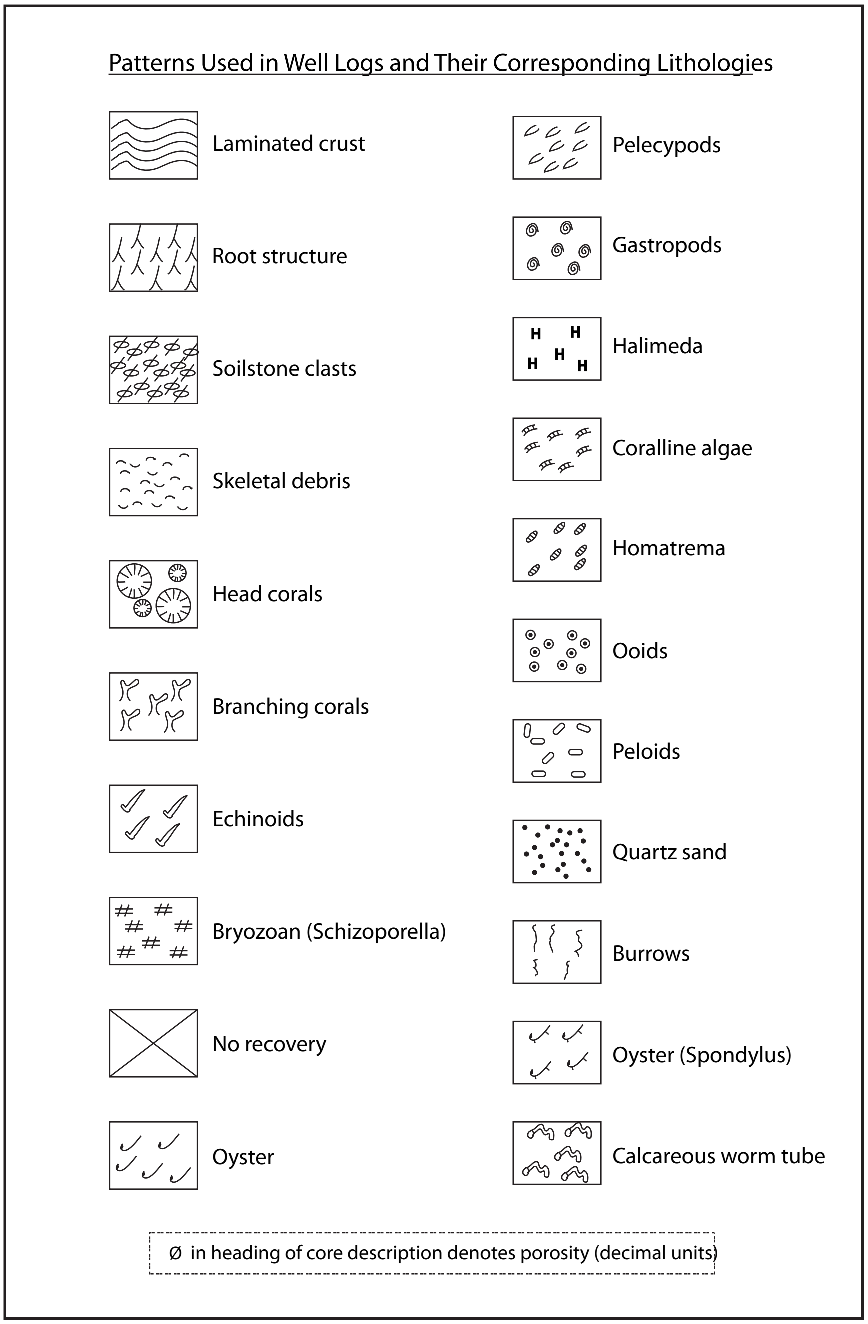

Figure B1. Log legend and lithologic patterns used in appendix B wireline core logs (modified from Dunham, 1962).

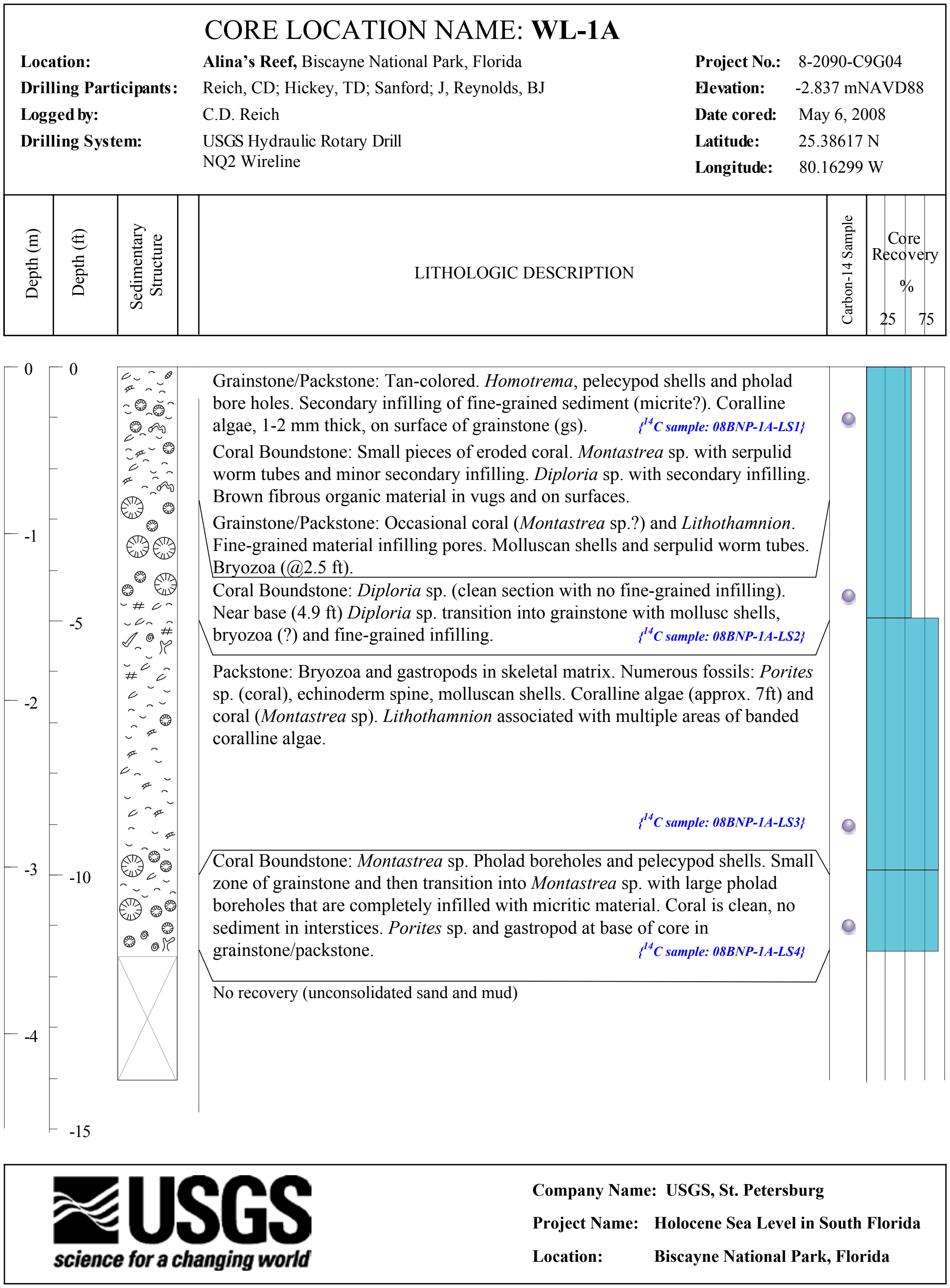

Figure B2. Core description for WL-1A.

Figure B3. Core collected at WL-1A (0 to 14 ft).

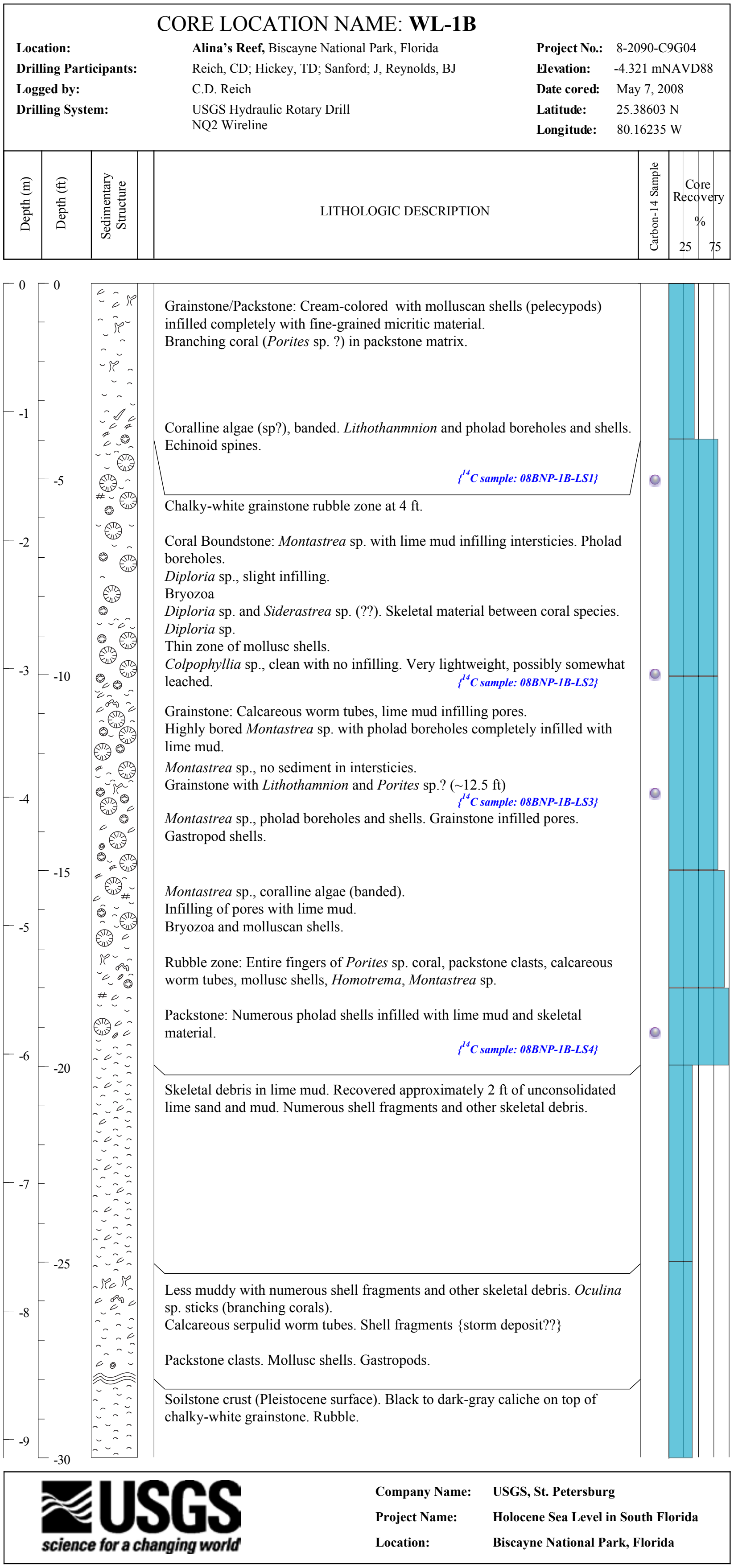

Figure B4. Core description for WL-1B.

Figure B5. Core (1 of 2) collected at WL-1B (0 to 15 ft).

Figure B6. Core (2 of 2) collected at WL-1B (15 to 30 ft).

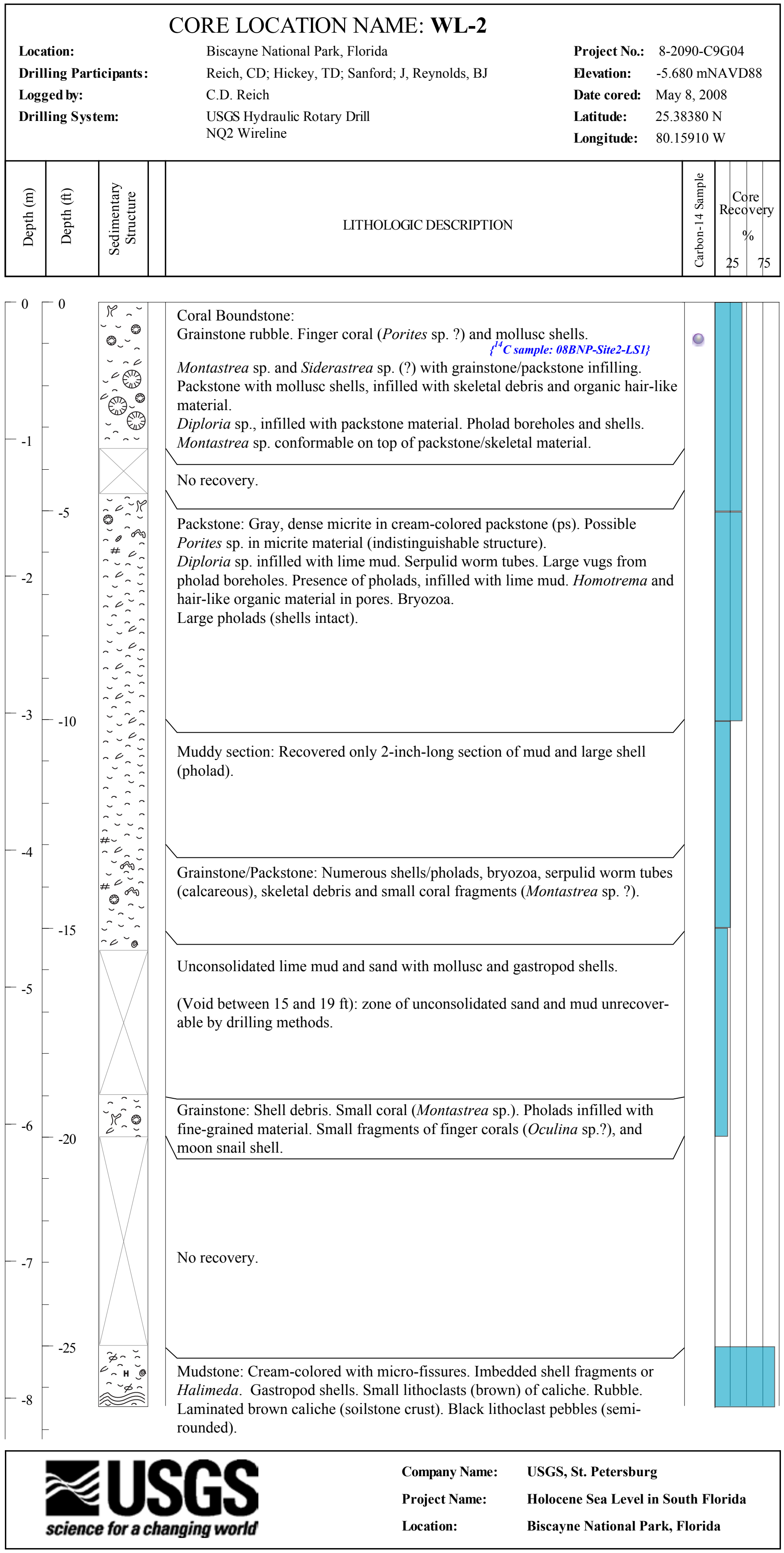

Figure B7. Core description for WL-2.

Figure B8. Core collected at WL-2 (0 to 30 ft).

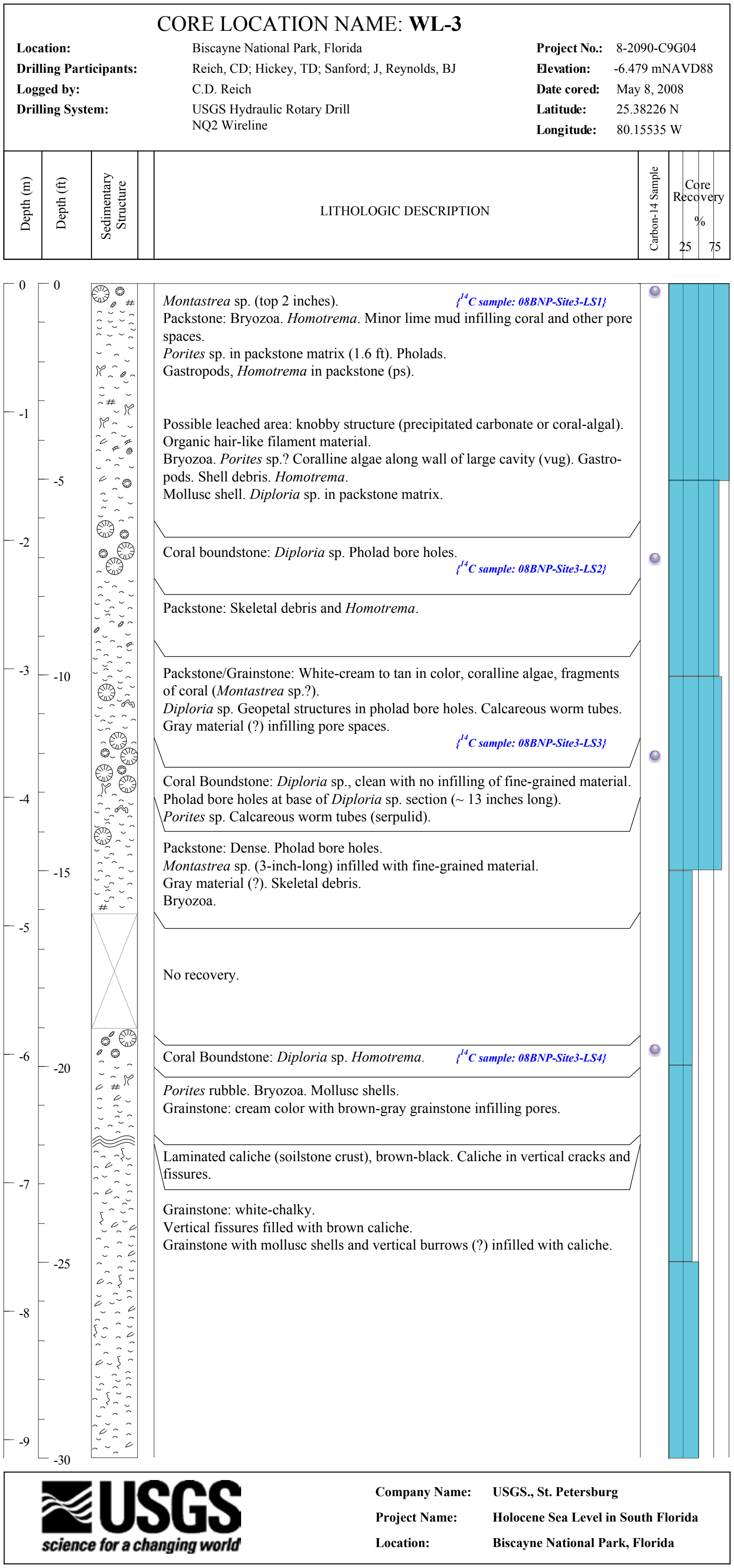

Figure B9. Core description for WL-3.

Figure B10. Core (1 of 3) collected at WL-3 (0 to 11.5 ft).

Figure B11. Core (2 of 3) collected at WL-3 (11.5 to 29 ft).

Figure B12. Core (3 of 3) collected at WL-3 (29 to 30 ft).

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