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Holocene Core Logs and Site Methods for Modern Reef and Head-Coral Cores: Dry Tortugas National Park, Florida

By Todd D. Hickey, Christopher D. Reich, Kristine L. Delong, Richard Z. Poore, and John C. Brock

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8
Horizontal coordinate information is referenced to North American Datum of 1983 (NAVD 83).

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Introduction

The Dry Tortugas are a series of islands, banks, and channels on a carbonate platform off the west end of the Florida Keys. Antecedent topography of the Dry Tortugas reflects carbonate accumulations of the last interglacial (marine isotope substage 5e, ~ 125,000 years ago, ka) when sea level was ~ 6 to 7 meters (m) higher than present (Schrag and others, 2002). The substage 5e surface was subsequently lithified and modified during subaerial exposure associated with lower sea level from ~ 120 ka to 8 ka. The lithified late Pleistocene carbonates are known as the Key Largo Limestone, a coral reef (Hoffmeister and Multer, 1964; Multer and others, 2002), and the Miami Limestone, a tidal-bar oolite (Sanford, 1909; Hoffmeister, 1974). The Holocene and modern sediments and reefs of the Dry Tortugas then accreted during the rise of sea level associated with the end of the last glacial and the start of the current interglacial (marine isotope Stage 1).

With the exception of a half dozen or so islands, the Dry Tortugas region has been submerged for approximately 8,000 years, allowing conditions suitable for coral reef formation once again. The Holocene reef accumulation varies in thickness due to the antecedent topography. The reefs are composed of massive head corals such as species of *Montastraea*, *Siderastrea*, and *Diploria* (Swart and others, 1996; Cohen and McConnaughey, 2003) and rest atop the Pleistocene Key Largo Limestone high (Shinn and others, 1977). The coral reefs within the Dry Tortugas represent a windward reef margin relative to dominant wind and wave energies (Hine and Mullins, 1983; Mallinson and others, 1997; Mallinson and others, 2003).

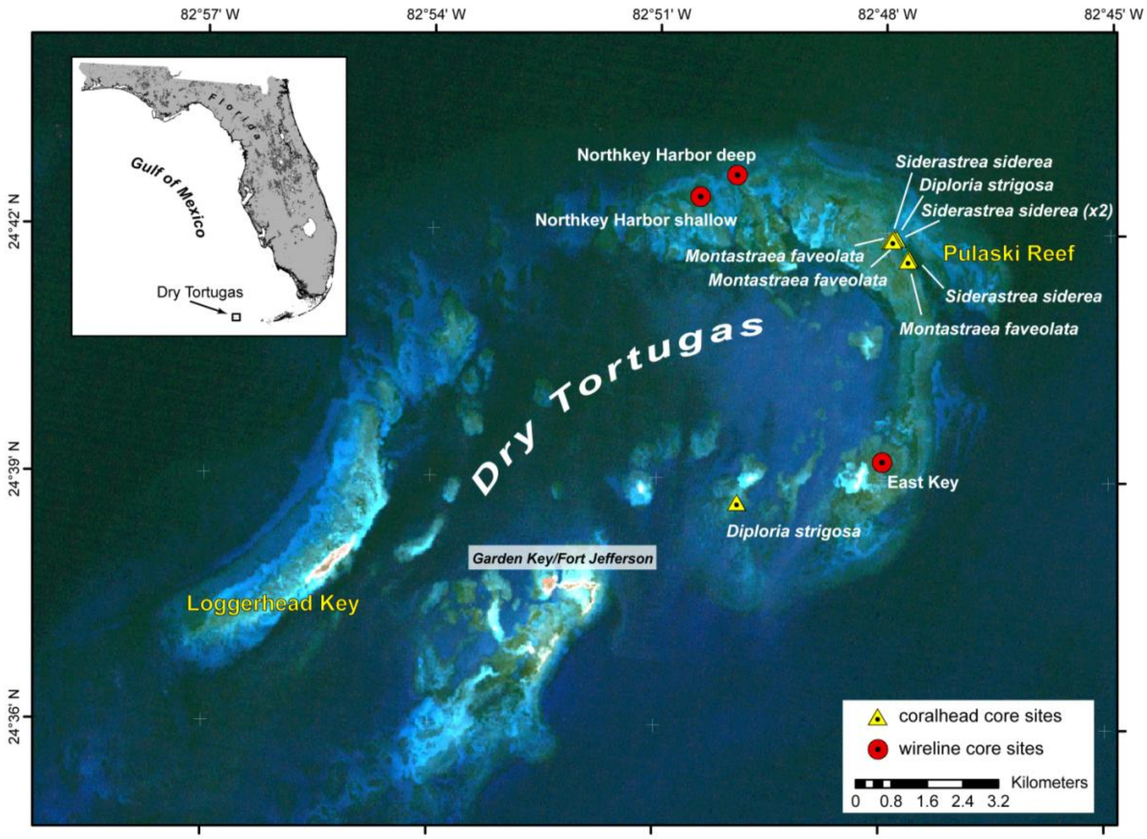

Figure 1. Landsat image with wireline and coral coring locations. Inset shows Dry Tortugas National Park study site in Florida.

Dry Tortugas National Park, established in 1992, occupies an area of approximately 259 square kilometers (km^2) and is located 110 kilometers (km) west of Key West, Fla. The isolation and relatively low anthropogenic impacts make the Dry Tortugas an ideal area from which to collect Holocene and modern coral cores to be used as a proxy for multidecadal paleoclimate reconstructions. This report summarizes the 2008 Dry Tortugas core-collection project and provides information on the methods used.

Methods

Coring

Northkey Harbor and East Key were core drilled with the U.S. Geological Survey (USGS) portable hydraulic drill to recover lithologic samples spanning the Holocene back into the late Pleistocene. Reich and others (2009) provide a complete description of the coring method. Three Holocene cores were recovered one from East Key and two from Northkey Harbor (fig. 1, table 1). The hydraulic drill was powered by an 18-horsepower (hp) Briggs and Stratton engine. Another 18-hp Briggs and Stratton engine was used to hydraulically power a water pump that forced water down the annulus of the drill stem to lubricate and clean the predominantly carbonate cuttings from the drill-stem annulus. The core barrel was a Longyear NQ2 wireline system (fig. 2).

Table 1. Holocene core information from Dry Tortugas National Park, Florida.

Date Collected	Site Name	Reef Name	Latitude (°N)	Longitude (°W)	Water Depth (meters)	Core Length (meters)
8/10/08	EK shallow	East Key	24.65372	-82.79980	5.3	18.3
8/11/08	NKH shallow	Northkey Harbor	24.70702	-82.84075	3.9	12.2
8/12/08	NKH deep	Northkey Harbor	24.71143	-82.83265	6.7	10.7

This system retrieved a 2-inch (in.)-diameter rock core and left a 3-in. open hole when the drilling was complete. Each piece of drill pipe was 5 feet (ft) long. Therefore, at each 5-ft depth interval, the drilling stopped and the inner barrel was retrieved. The drill head was removed, and the overshot (an inner barrel retrieval device) attached with line was sent down inside the drill string to engage and lock on the inner barrel. The inner barrel assembly consisted of two stainless-steel split barrels that were held together by a core catcher on the bottom end and a device referred to as the spearhead, which forms the contact at the upper end. Next, the overshot was connected to the spearhead, and the inner barrel was raised out of the drill stem. To keep the operation running smoothly, two inner barrels were used so the one removed could be replaced right away. Once the overshot and the full inner barrel were removed from inside the drill stem, the second inner barrel was immediately attached to the overshot and placed within the drill stem. The empty inner barrel was then lowered to the base of the drill stem, and a device called the messenger was sent down the line to disengage the overshot from the spearhead. After pulling the overshot out of the drill stem, another 5-ft section of drill pipe was added, and the drill head was screwed back onto the drill string. This process was repeated until the desired depth of penetration was acquired, which, in this case, was indicated by recovery of the Pleistocene Key Largo Limestone at ~ 35 ft below the core top at the ground surface.

Figure 2. Underwater photograph of tripod and wireline coring system.

Coral coring methods were less labor intensive. The drill head was a DL07652 Stanley hydraulic drill with a 4-in.-diameter core barrel 24 in. in length attached to the drill (fig. 3). A small hole was made in the coral surface with a ¼-in. starting bit to prevent the 4-in. drill bit from “walking” across the top of the head coral. To collect full coral cores, extension pieces were added after the coral core was recovered from the diamond-studded core barrel. This process was repeated until the base of the coral was penetrated.

Figure 3. Diver operating the hand-held drill while coring a *Montastraea faveolata* coral at site C2.

Core-site Elevation Survey

Proper elevation control for each Holocene core was necessary for correlating the recovered cores. Elevations were acquired using a kinematic global positioning system (GPS) system at the wireline coring sites. Ashtech high-precision, dual-frequency GPS receivers coupled with Thales chokering antennas were used for this survey. Seco GPS poles were used to mount the antenna to the drilling tripod and were leveled using a hand level. A base station was set up on top of the Civil War-era Fort Jefferson over a previously established benchmark. Minimal time (30 minutes) was needed to obtain the core-site elevation (sessions) due to the < 15-km distance between coring and base-station locations. Sessions were processed using the NovAtel GrafNet program.

Results and Summary

Coral-core Description

Three different coral genera were selected for coring: *Montastraea*, *Siderastrea*, and *Diploria*. Coral cores were recovered near Middle Key and on Pulaski Reef (fig. 1). Photographs of the cored heads are presented in appendix 1. Nine coral cores were recovered (table 2).

Wireline Core Description

One objective of this study was to recover complete Holocene cores in the Dry Tortugas to facilitate and expand paleoclimate studies within the USGS. Previous USGS drilling expeditions in the Dry Tortugas (1976, 1997, and 2004) provided valuable information about the depth of penetration for complete recovery of the Holocene section. Three long cores were attempted in this study with varying degrees of success. Core logs were generated using LogPlot99 and Adobe Illustrator software. The logs (accompanied with Holocene and Pleistocene core photographs) are shown in appendix 2. The core logs include depth of recovery, sedimentary structure, lithologic description, core-recovery percentages, location coordinates, site elevation, and other pertinent observations.

Table 2. Coral core information from Dry Tortugas National Park, Florida.

Date Collected	Site Name	Photo ID	Reef Name	Coral Species	Latitude (N°)	Longitude (W°)	Water Depth (meters)	Core Length (centimeters)
8/6/08	08MK-A1	A1	Middle Key	*Diploria strigosa*	24.64530	-82.83205	3.4	23
8/6/08	08PS-A1	A2	Pulaski	*Siderastrea siderea*	24.69883	-82.79745	4.3	113
8/6/08	08PS-A2	A3	Pulaski	*Siderastrea siderea*	24.69883	-82.79745	4.3	83
8/7/08	08PS-B1	B1	Pulaski	*Siderastrea siderea*	24.69887	-82.79810	3.4	46
8/7/08	08PS-C1	B2	Pulaski	*Diploria strigosa*	24.69887	-82.79810	3.4	60
8/7/08	08PS-B3	B3	Pulaski	*Montastraea faveolata*	24.69857	-82.79862	3.4	142
8/7/08	08PS-B4	B4	Pulaski	*Montastraea faveolata*	24.69847	-82.79835	3.4	110
8/8/08	08PS-F1	C1	Pulaski	*Siderastrea siderea*	24.69495	-82.79465	3.7	64
8/8/08	08PS-C2	C2	Pulaski	*Montastraea faveolata*	24.69460	-82.79490	3.7	156

Previous work has indicated the Holocene accretion is approximately 15 m thick regionally (Hoffmeister and Multer, 1964; Multer and others, 2002). This study is in agreement. Evidence is observed in the shallow Northkey Harbor site where a subaerial unconformity is found 35 ft below the seafloor. The three Holocene cores provided similarities and differences with respect to lithologies down core. Carbonate muds were prevalent near East Key and were reduced at the shallow Northkey Harbor site. All three sites included boulder corals as the main reef builders throughout the region, with little or no presence of branching or finger corals. The cores show that reefs of the Dry Tortugas have geologically evolved through predominantly boulder/massive head-coral accretion and not as much due to branching or finger corals. Other lithologic matrices observed include mudstones, packstones, and grainstones, but are few and far between in relation to the head-coral assemblages. Some of the common biogenic participants observed in all the cores include coralline algae, calcareous worm tubes, bioeroders, and bivalves.

Acknowledgments

We thank P.J. Walker of Everglades National Park for permission and access to Dry Tortugas National Park. Captains Clay Douglass, Janie Douglass, and John Spade of Dry Tortugas National Park provided logistical support above and beyond that necessary to help make the coring a success, and for that, we are most appreciative. Thanks are extended to Jordan Sanford and B.J. Reynolds of the USGS and Michèle LaVigne of Rutgers University for assistance in the collection of the cores. The USGS Coastal and Marine Program funded the project.

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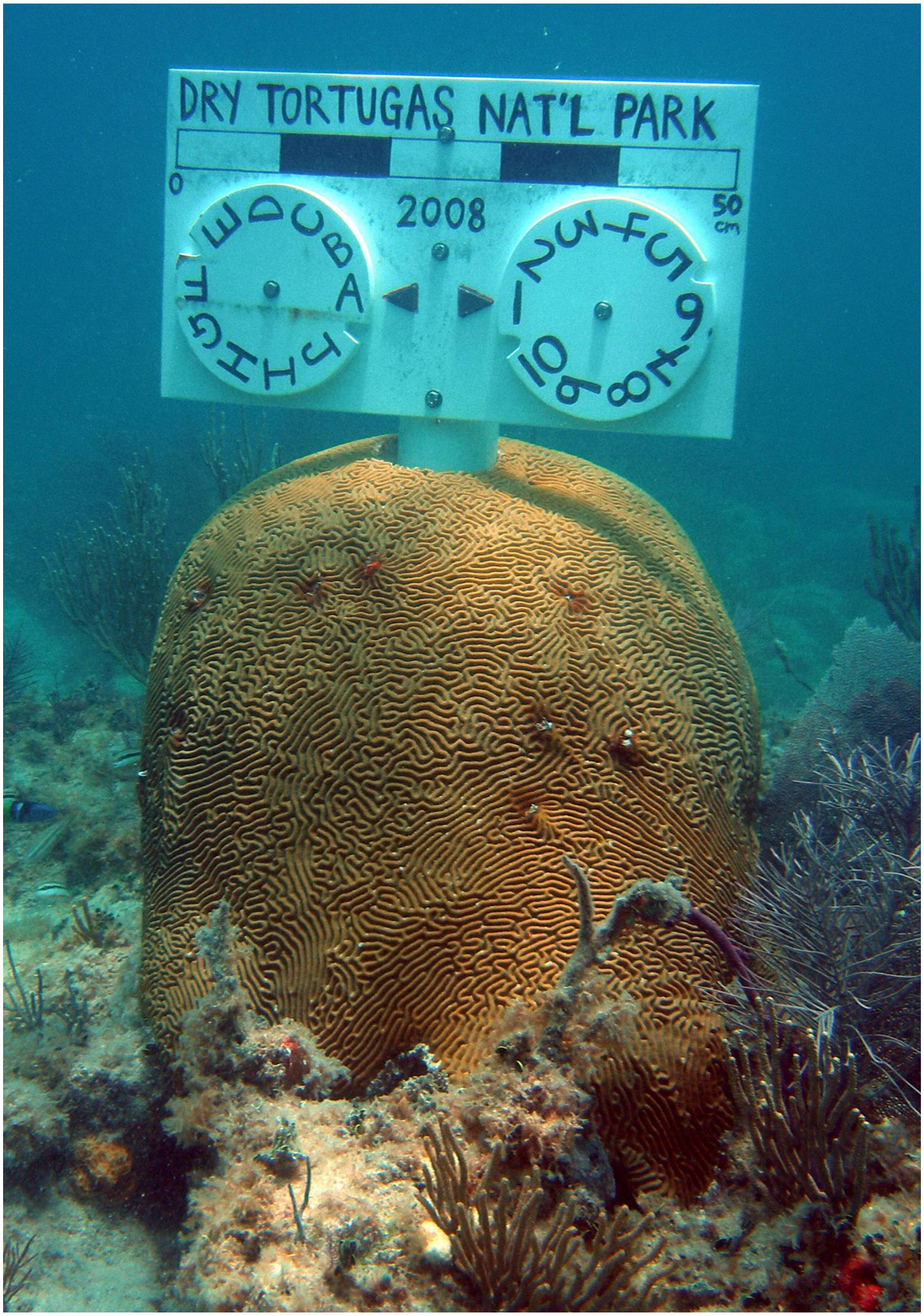
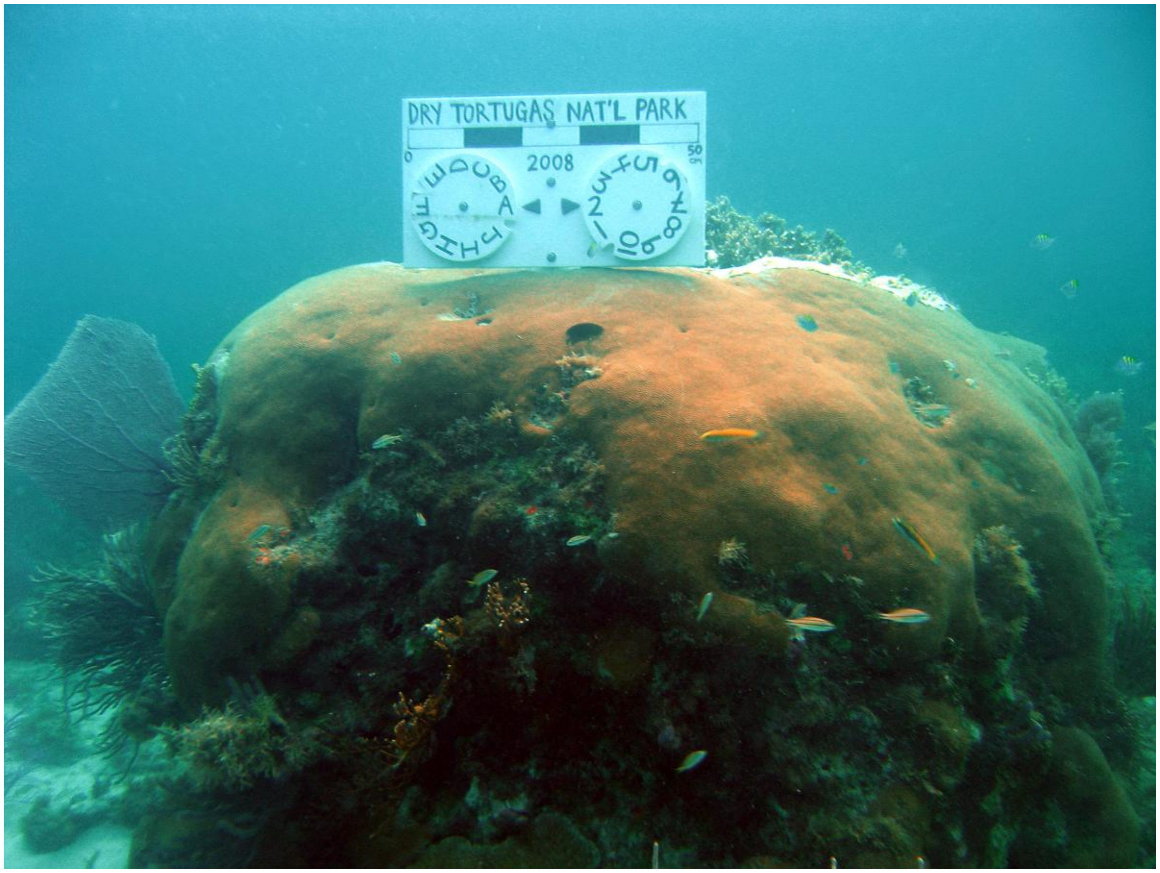
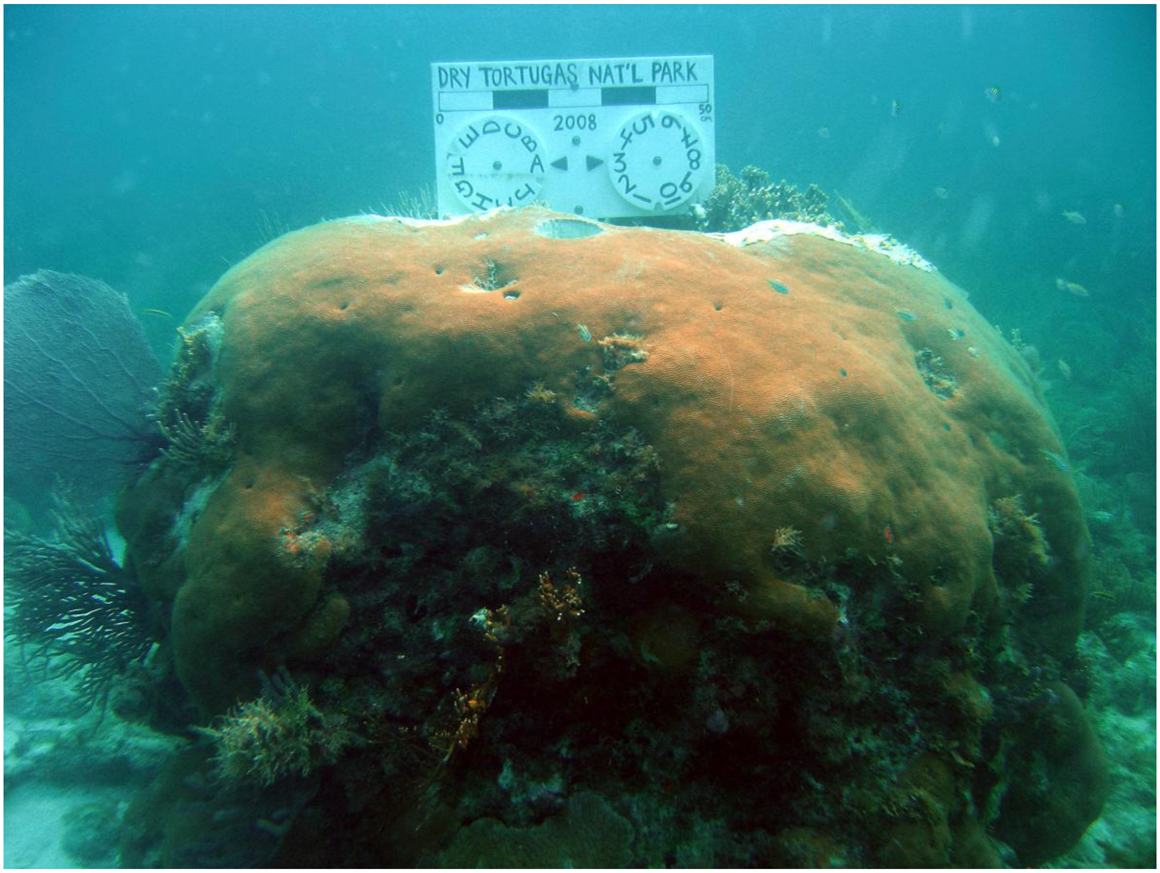
Appendix 1. Photographs of cored corals, Dry Tortugas National Park, Florida



Site 08MK-A1, *Diploria strigosa*.

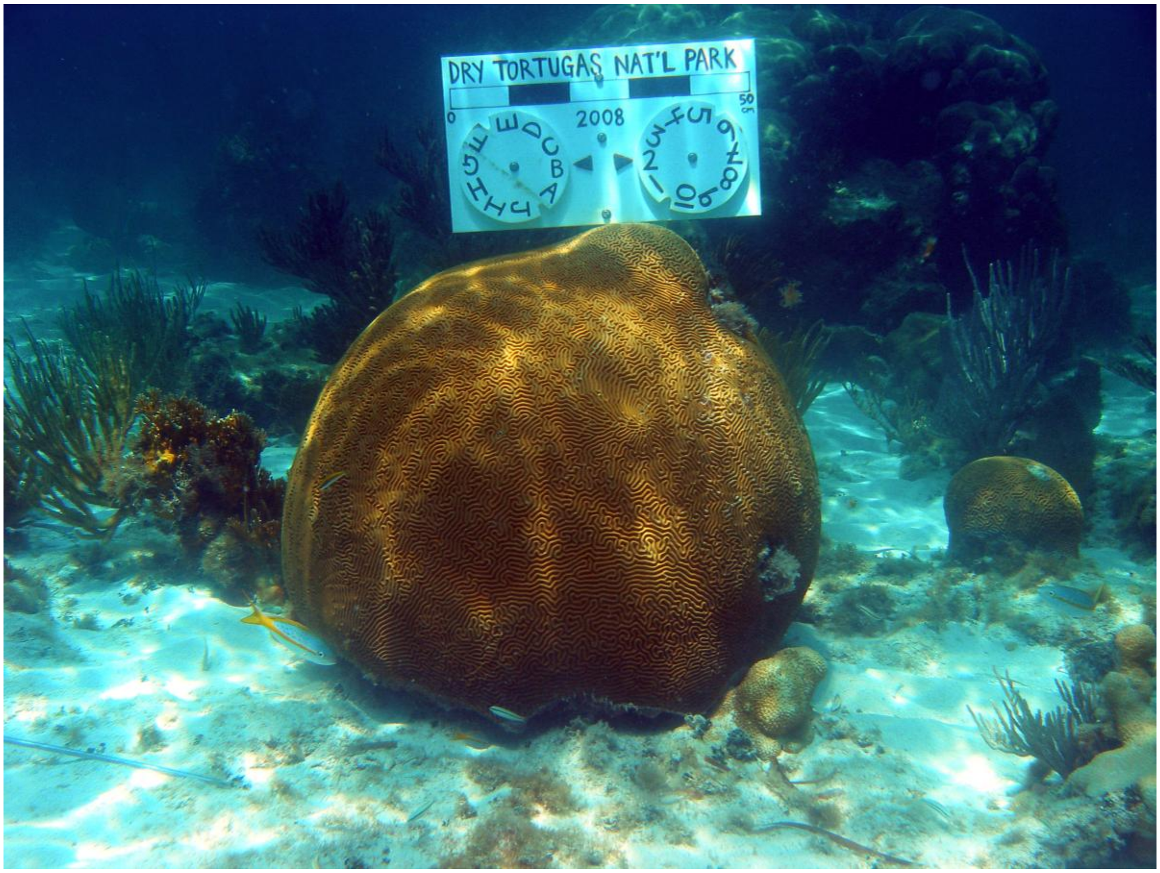


Site 08PS-A1, *Siderastrea siderea.*

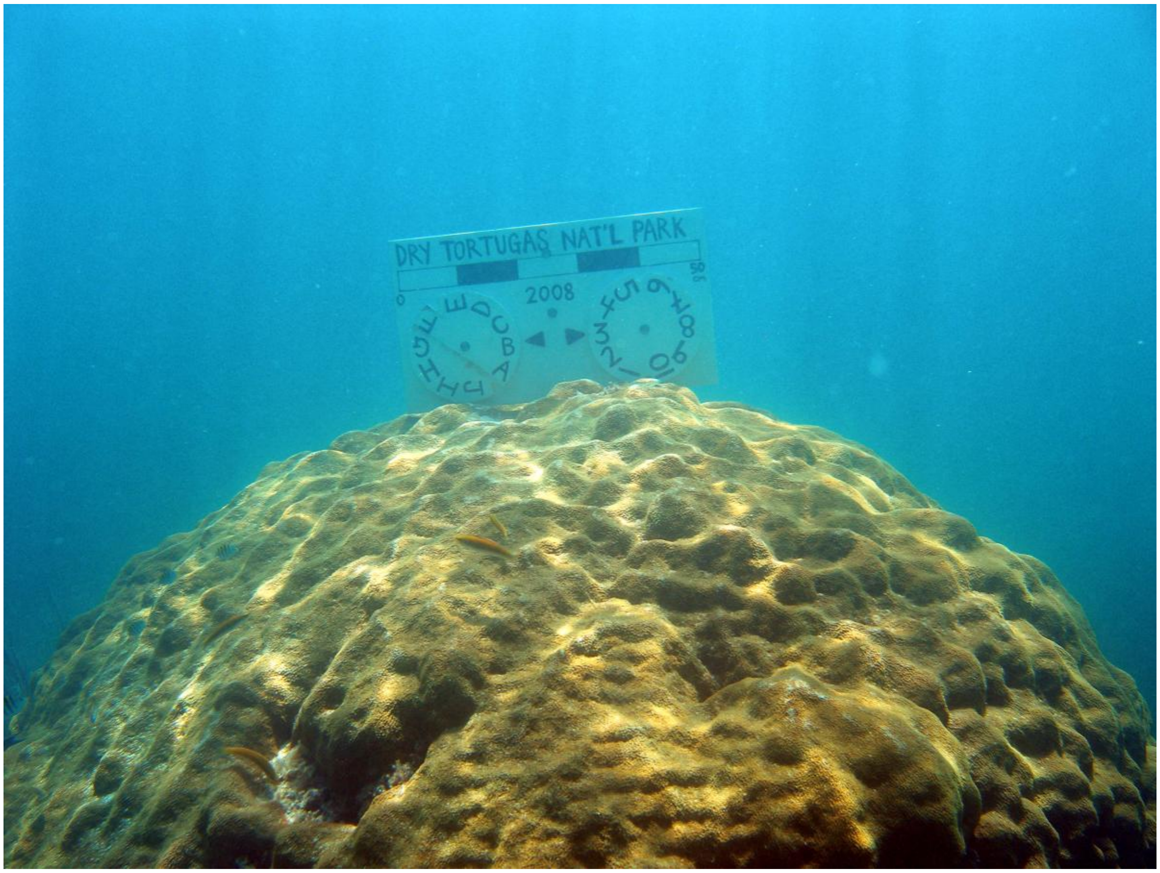


Site 08PS-A2, *Siderastrea siderea.*

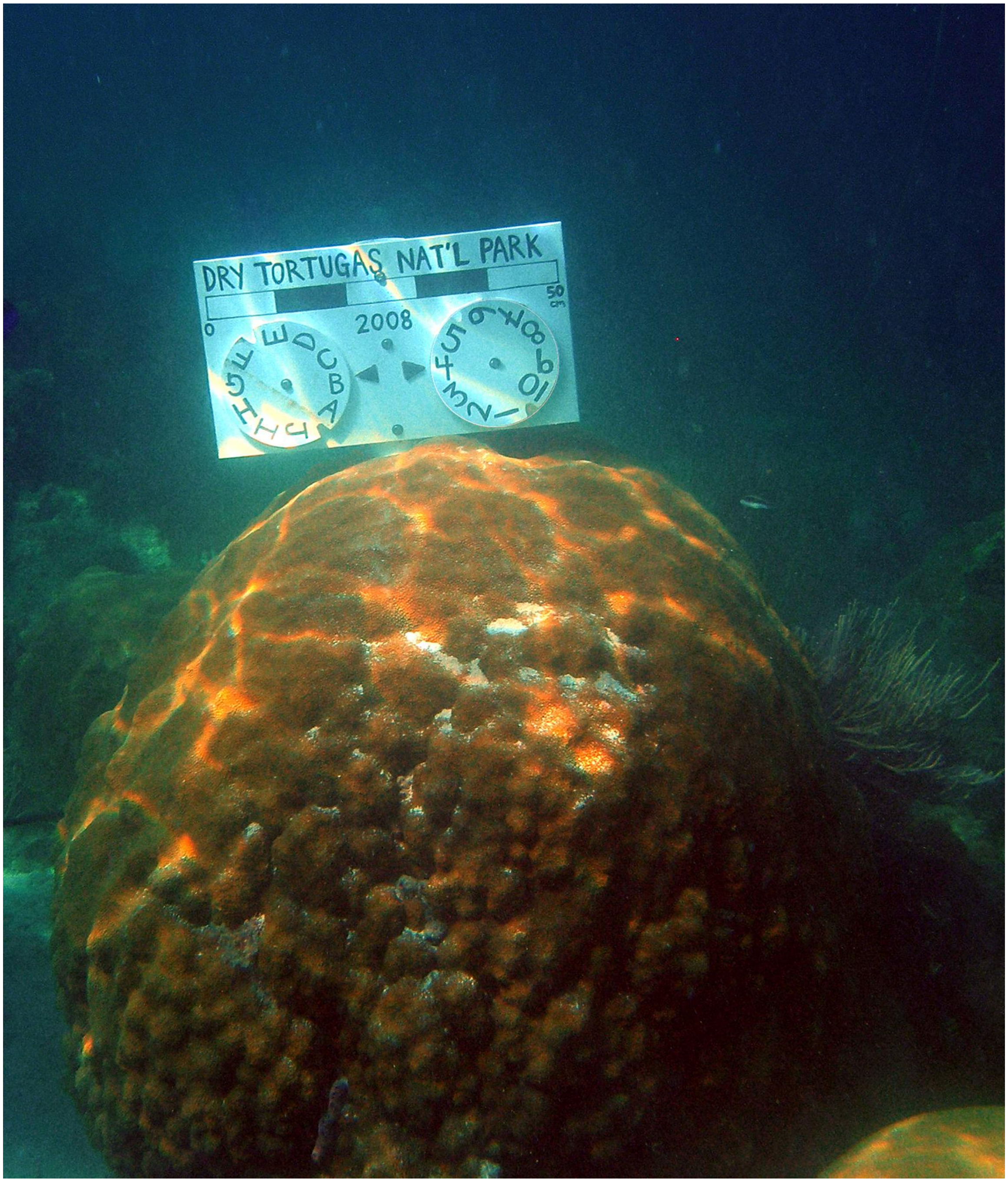
Site 08PS-B1, *Siderastrea siderea*.



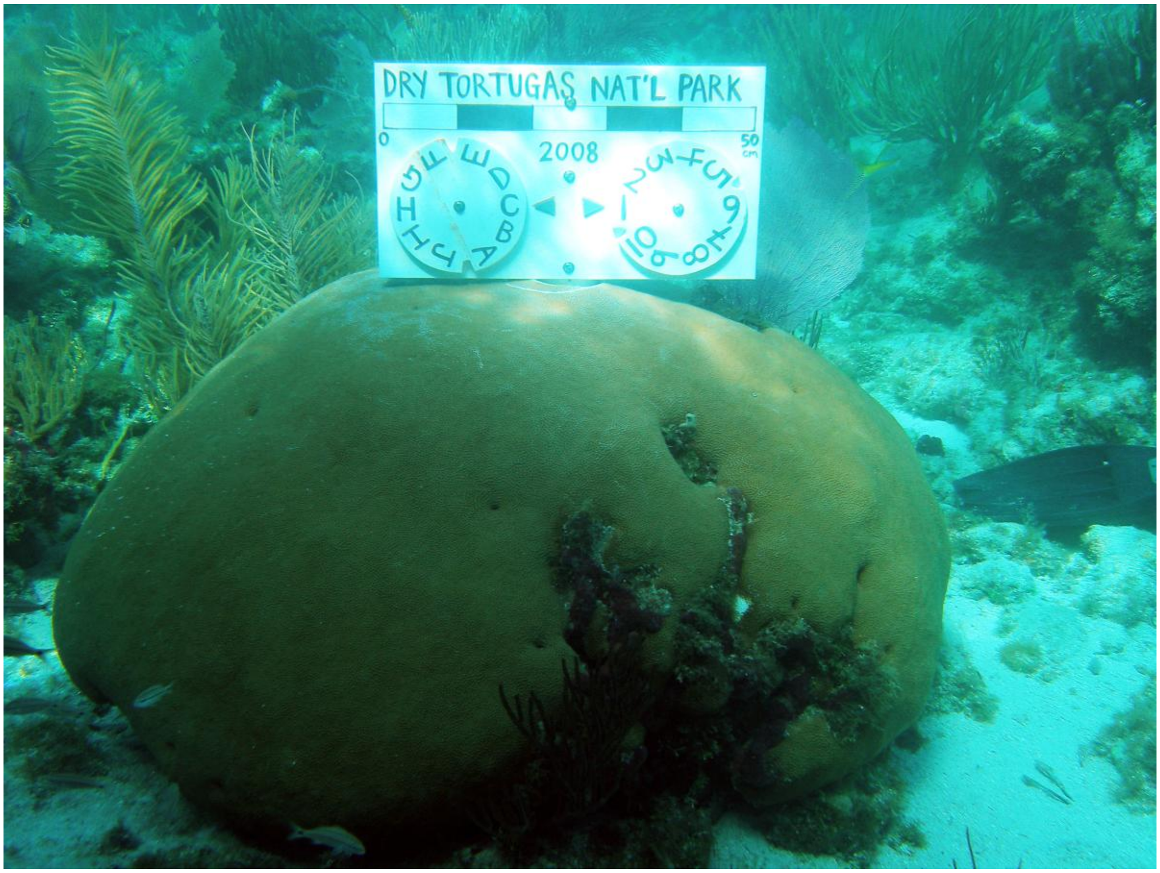
Site 08PS-C1, *Diploria strigosa.*



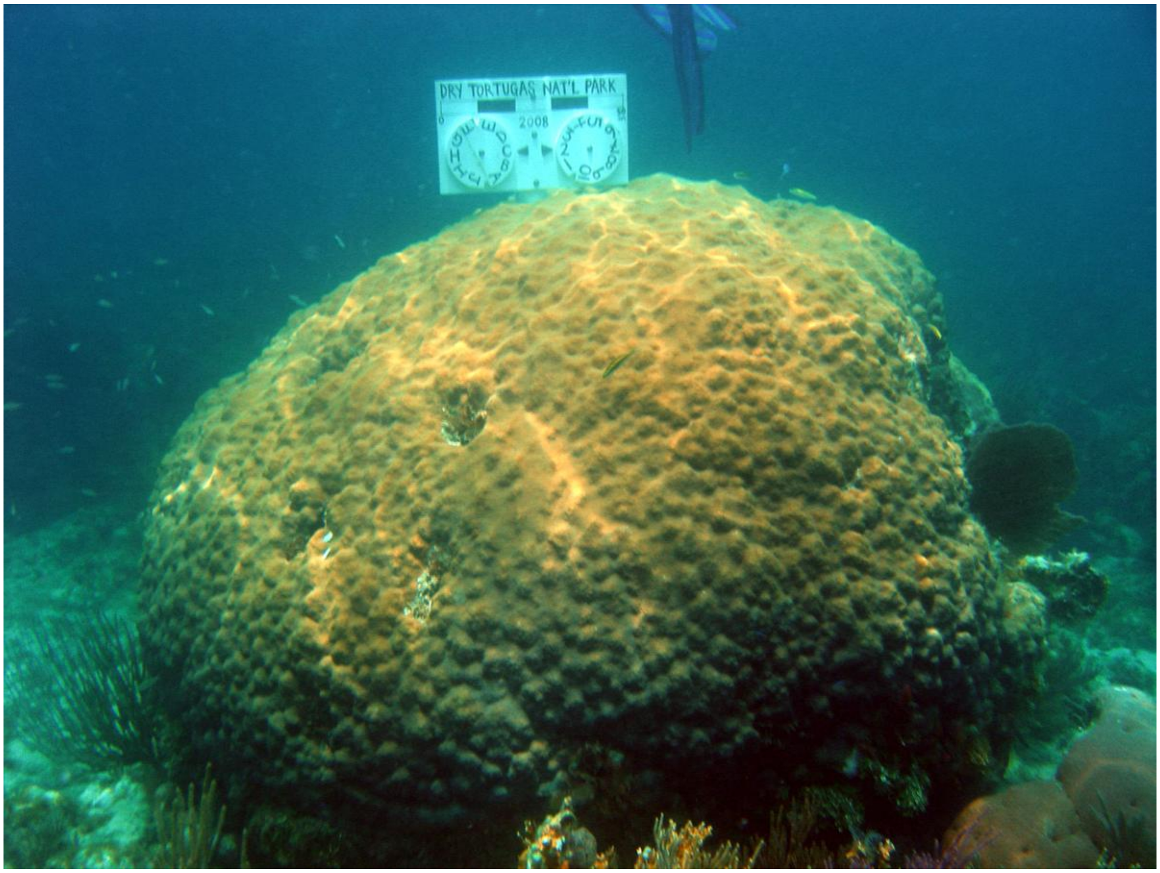
Site 08PS-B3, *Montastraea faveolata*.



Site 08PS-B4, *Montastraea faveolata*.



Site 08PS-F1, *Siderastrea siderea*.

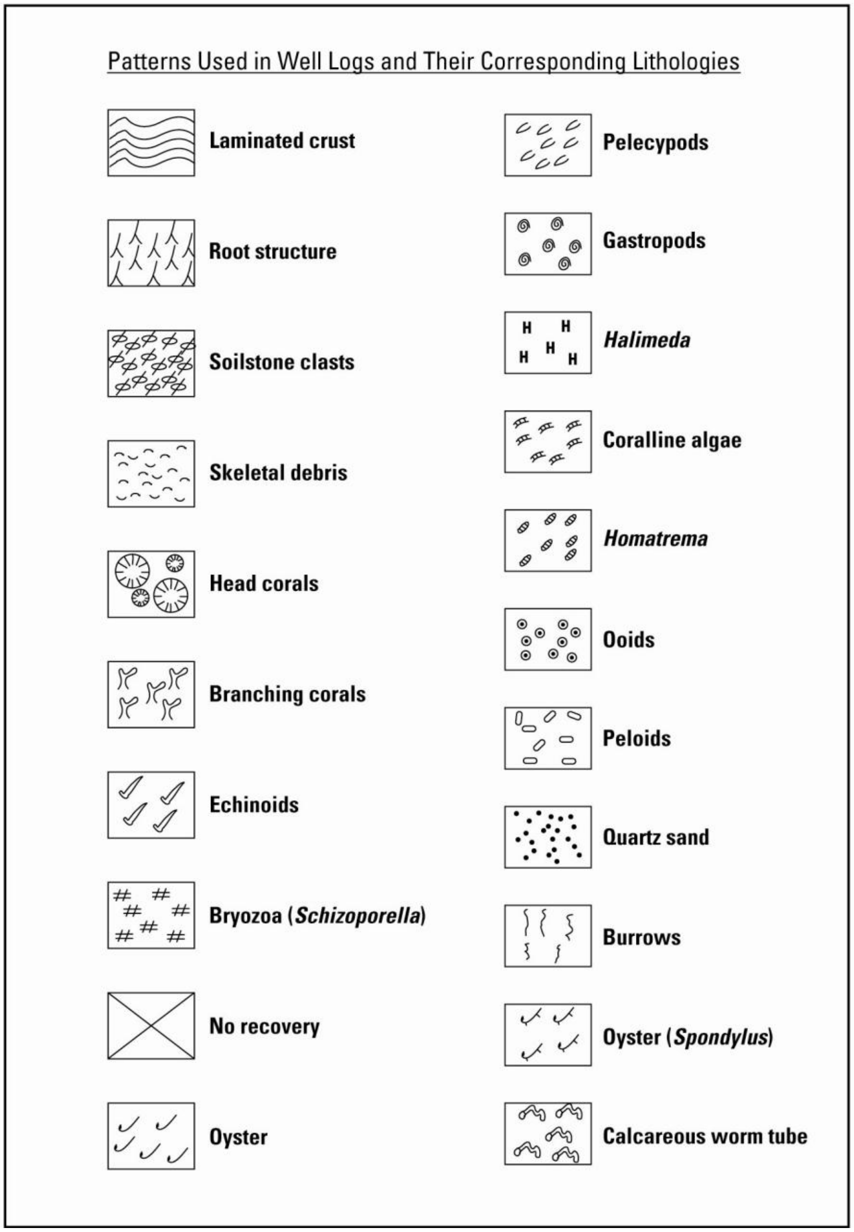


Site 08PS-C2, *Montastraea faveolata*.

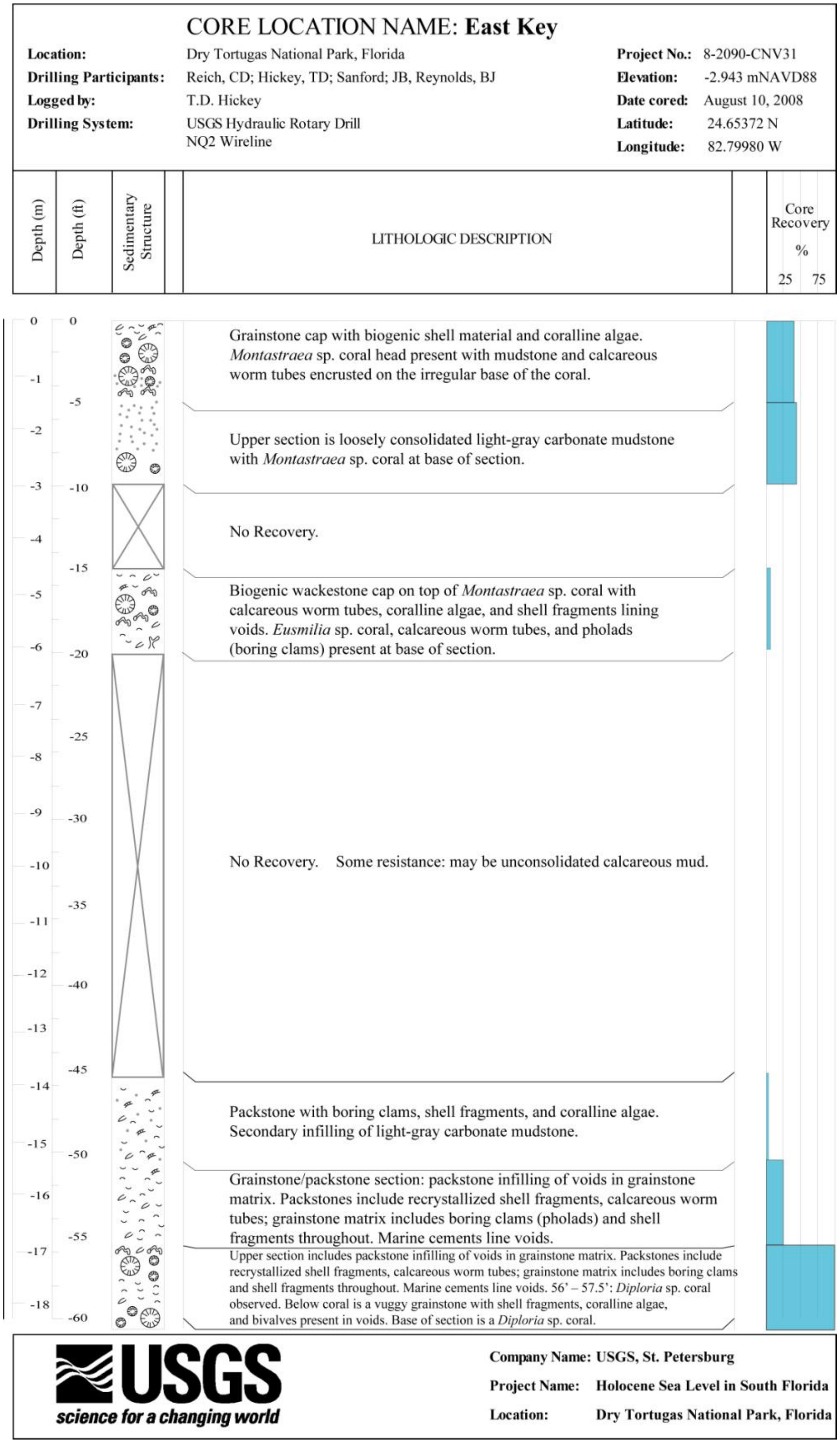
Appendix 2. Lithologic logs and core photographs, Dry Tortugas National Park, Florida

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

DEPOSITIONAL TEXTURE RECOGNIZABLE					DEPOSITIONAL TEXTURE NOT RECOGNIZABLE
Original Components not Bound Together During Deposition				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.	Crystalline Carbonate
Contains mud (particles of clay and fine silt size)			Lacks mud and is grain-supported		(Subdivide according to classifications designed to bear on physical texture or diagenesis.)
Mud-supported		Grain-supported			
Less than 10 percent grains	More than 10 percent grains				
Mudstone	Wackestone	Packstone	Grainstone	Boundstone	



Core log descriptions



Core log for East Key

East Key core.

CORE LOCATION NAME: **Northkey Harbor Shallow**

Location: Dry Tortugas National Park, Florida
Drilling Participants: Reich, CD; Hickey, TD; Sanford; JB, Reynolds, BJ
Logged by: T. D. Hickey
Drilling System: USGS Hydraulic Rotary Drill, NQ2 Wireline

Project No.: 8-2090-C9G04
Elevation: -3.689 mNAVD88
Date cored: August 11, 2008
Latitude: 24.70702 N
Longitude: 82.84075 W

Depth (m)	Depth (ft)	LITHOLOGIC DESCRIPTION
0 to -1.5	0 to -5	Thin coralline- algae cap with shell fragments on top of a *Montastraea* sp. coral. Coralline algae and calcareous worm tubes encrust voids. Majority of section is *Montastraea* sp. rubble with gray carbonate mud present at base.
-1.5 to -3	-5 to -10	*Montastraea* sp. rubble mixed with spiral gastropod and bivalve shells with carbonate mud present. Four-inch, bioeroded *Montastraea* sp. coral below rubble with calcareous worm tubes and coralline algae encrusting voids and irregularities of coral. Gray, unconsolidated mud present at base of section.
-3 to -4.5	-10 to -15	Top of section is *Montastraea* sp. coral rubble with coralline algae, calcareous worm tubes, and *Homatrema* encrusting rubble. Bioeroded *Diploria* sp. coral at base of section with coralline algae and calcareous worm tubes encrusting coral voids and irregularities.
-4.5 to -6	-15 to -20	Section top includes a bioeroded *Diploria* sp. coral with pholads present. Halfway through section, *Montastraea* sp. coral rubble encrusted with calcareous worm tubes and coralline algae is present. *Diploria* sp. coral is present at base of section with unconsolidated, calcareous mud on top of the coral, and calcareous worm tubes and coralline algae encrusting voids of the coral.
-6 to -7.5	-20 to -25	Top 2' of section is *Diploria* sp. coral. At base of coral are voids containing encrusting coralline algae, shell fragments, and calcareous worm tubes. Carbonate mud and boring clams are observed. Heavily bioeroded *Montastraea* sp. coral mid-section with encrusting coralline algae,shell fragments, and calcareous worm tubes lining voids. Boring-clam-filled *Diploria* sp. coral observed at base.
-7.5 to -9	-25 to -30	*Montastraea* sp. coral rubble with encrusting calcareous worm tubes, coralline algae, and unconsolidated, carbonate mud tops the section. Below is an irregular *Montastraea* sp. coral with bryozoans, shell fragments, calcareous worm tubes, and coralline algae encrusting walls of voids with carbonate mud and spiral gastropods present. Present at base of section is *Montastraea* sp. coral.
-9 to -10.5	-30 to -35	An abrupt surface tops the section. A heavily bioeroded (pholad) *Montastraea* sp. with shell fragments, calcareous worm tubes, and coralline algae encrusting and gray, carbonate mud present in voids. Grainstone rubble mixed with bryozoans and *Montastraea* sp. rubble and boring-clam shells. Bioeroded 2' section of *Montastraea* sp. follows down section to base with encrusting calcareous worm tubes, coralline algae, and unconsolidated, carbonate mud and shell fragments coating voids.
-10.5 to -12	-35 to -40	Soilstone crust observed on top of section. Heavily bioeroded (boring clam) *Montastraea* sp. is observed below the subaerial exposure with a low-porosity grainstone section following. Calcareous worm tubes, and coralline algae, encrust the voids with shell fragments and carbonate mud present. Near base of section is a highly porous grainstone and grainstone-rubble section. The base of the core is a mix of grainstone and *Montastraea* sp. rubble with a mixture of gastropods and bivalves.

Sedimentary Structure; Core Recovery % (25, 75)

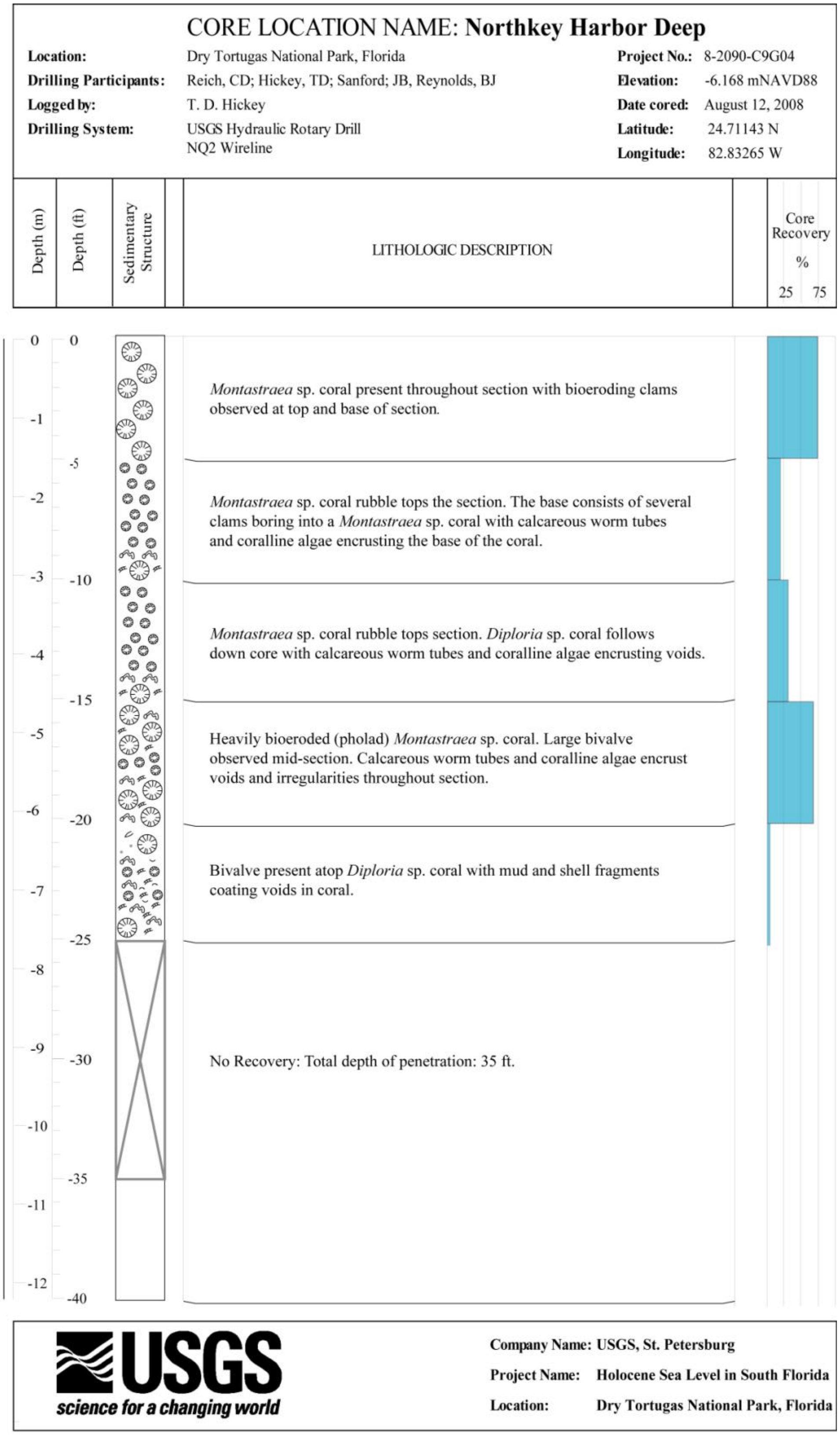
USGS science for a changing world

Company Name: USGS, St. Petersburg
Project Name: Holocene Sea Level in South Florida
Location: Dry Tortugas National Park, Florida

Core log for Northkey Harbor Shallow.

Northkey Harbor Shallow core, box 1 of 2.

Northkey Harbor Shallow core, box 2 of 2.



Core log for Northkey Harbor Deep.

Northkey Harbor Deep core.