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MODERN SEDIMENTARY ENVIRONMENTS, TWIN CAYS, BELIZE, CENTRAL AMERICA

BY

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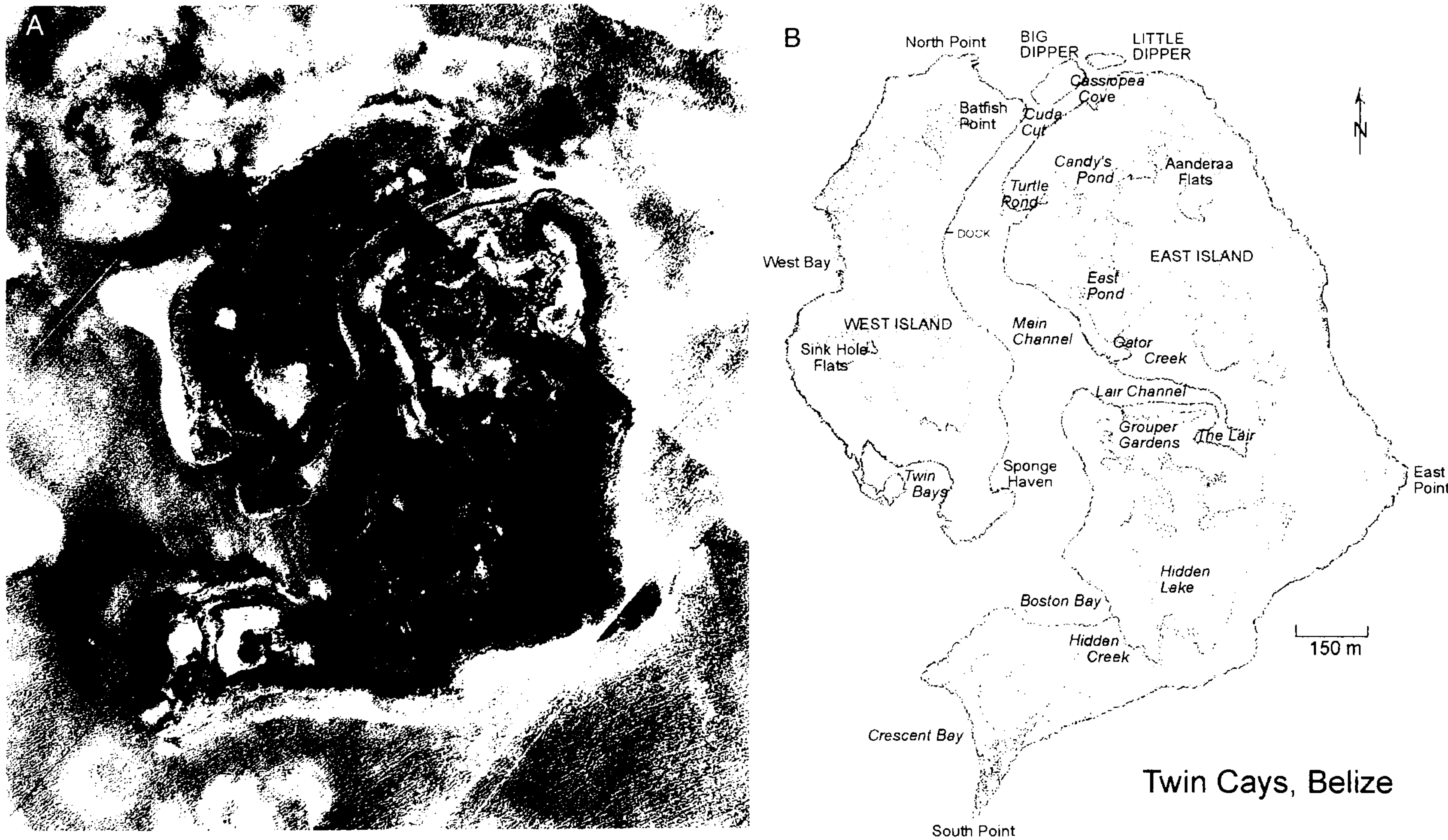

Figure 1. Twin Cays, Belize. A) Aerial photograph montage assembled from photographs supplied by David R. Stoddart in 1979. B) Map with place names introduced in the 1982 survey and by later workers.

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IAN G. MACINTYRE[1], MARGUERITE A. TOSCANO[1], AND GREGOR B. BOND[2]

ABSTRACT

The mapping of environmental settings on and around Twin Cays was completed in 1982 with the aid of aerial photographs. A total of three mangrove-island and five marine depositional environments were identified. Size analyses of surface samples collected from 120 marine sites indicate that the higher percentages of mud are found mostly in protected areas between the two islands and in deeper locations. In contrast, the very sandy sites were found in nearshore shallow flats and isolated offshore shoals where winnowing action has removed the finer fraction. *Halimeda* and molluscs dominate the sand-size fraction.

INTRODUCTION

The continental shelf off Belize is about 250 km long and 15-50 km wide (Purdy et al., 1975). It consists of an Outer Barrier Platform that supports a variety of patch reefs and mangrove islands and is bordered along its eastern edge by a fringing reef off Ambergris Cay that extends southward into the longest Caribbean barrier reef (Smith, 1971). Shoreward, this shallow platform gives way to the Shelf Lagoon that to the north is 20-25 km wide and less than 15 m deep but deepens to the south to more than 15 m and reaches widths of more than 40 m before expanding into the Gulf of Honduras (Rützler and Macintyre, 1982).

Our study site at Twin Cays is located in the Central Province (Burke, 1982) which extends from Gallows Point Reef to Gladen Spit (Purdy et al., 1975). This province is characterized by long sections of uninterrupted barrier reef behind which numerous patch reefs and mangrove islands occur on the shallow platform lagoon.

In the Central Province, terrigenous sediments occur in the Shelf Lagoon and are dominantly quartz sand and terrigenous clay. This is in marked contrast to the carbonate sands and muds that characterized the Outer Barrier Platform (Purdy et al., 1975). Purdy et al. (1975) included the Twin Cays site in their carbonate *"Halimeda"* facies (p.25).

The purpose of this study is to provide a more detailed understanding of the distribution patterns of sediments surrounding Twin Cays and in the channel that separates the two islands.

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METHODS

In 1982, I. G. Macintyre and W. T. Boykins mapped the major marine and subaerial surface depositional environments for Twin Cays and the surrounding area with the aid of aerial photographs (Fig. 1). During this mapping, a total of 120 surface sediment samples were collected (Fig. 2) from the marine environments. Size analyses were carried out in all but the very organic-rich samples collected in the channel areas. Samples were wet-sieved at the Texas A&M Geosciences laboratory (mesh sizes 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, and <0.063 mm) (Bond, 1988). The mud fractions were then sent to the Sedimentology Laboratory at Smithsonian Institution and separated into silt (63 mm - 4μ) and clay (<4μ) size fractions by decantation. Percentages for each size fraction were calculated for all samples (Table 1). Samples estimated to be composed of >50% organics were not sieved. These have been omitted from Table 1.

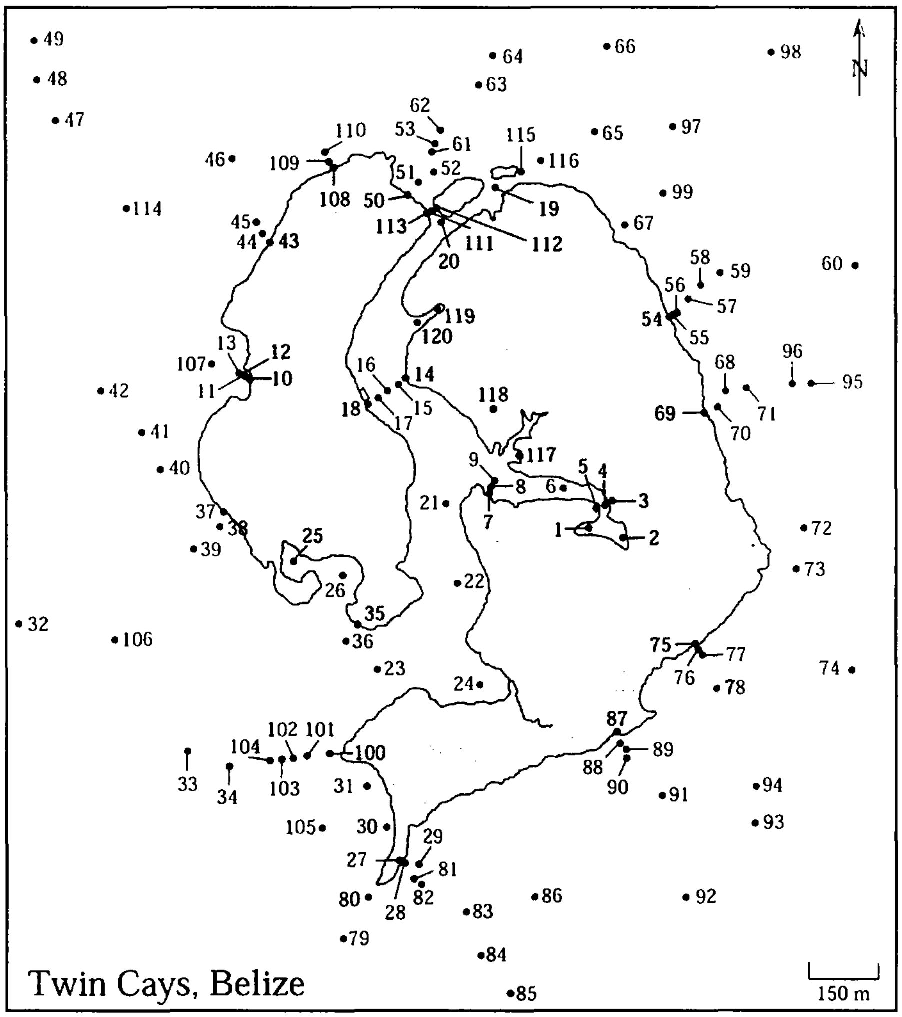

Figure 2. Map of Twin Cays with numbered sediment sample locations.

Three thin sections, in the coarse, medium, and fine sand ranges, were made from a sediment sample representing each major marine depositional environments as determined in the field from aerial and boat-based reconnaissance. Thin sections were point-counted to a minimum of 320 points per slide. Loose grains of the very coarse sand and granule size distributions were also counted for these samples, with either the entire set of grains being counted or a subsample if more than 600 grains were present.

RESULTS

Three emergent and five submerged surficial sedimentary environments were characterized based on field and aerial reconnaissance of sediments and vegetation cover (Fig. 3).

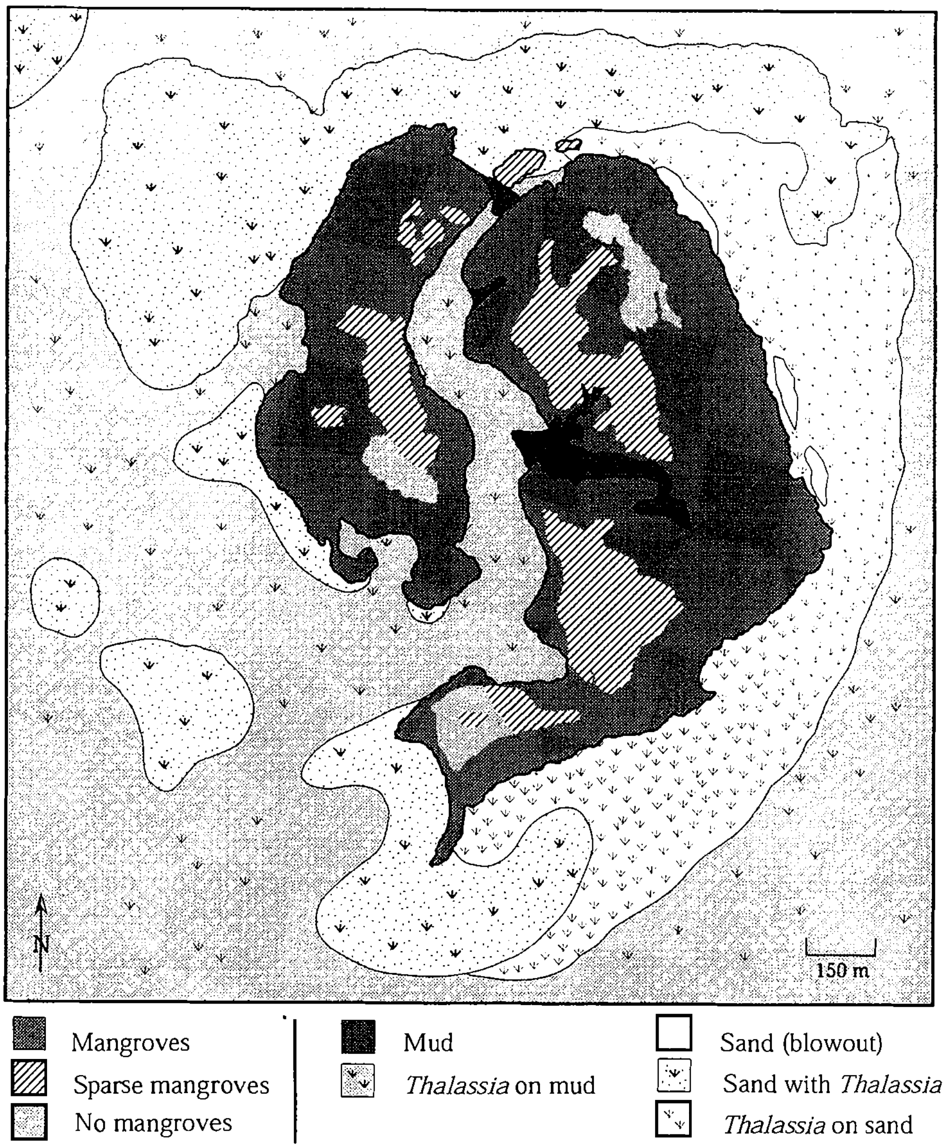

Figure 3. Depositional environments map of Twin Cays based on 1982 field observations.

Emergent Environments

Mangrove cover consists of thick-to-moderate density of either mixed red and black mangroves or monospecific red mangroves along the outer margins of the islands, closest to water. Mangroves create an *in situ* peat substrate with leaf mats, which intertongue with carbonate sands at the shoreline.

Sparse mangrove cover is found in shallow ponds and other interior portions of the islands. Scattered red mangrove development occurs in the ponds, while a mixture of red and black mangroves grows around the ponds and extends into interior regions. Sediment on pond bottoms consists of flocculated mud cover on a thick peat base, with scattered *Halimeda* sp. and *Thalassia testudinum*. The forest mat is a peat base with leaf litter layers and a mixture of remains of other succulent plants.

Mangroveless environments occur near the large shallow pond in the interior of the island. The bottom is covered with a thin layer of flocculated mud over a peat base. Scattered molluscs occur as well as rare dwarf red mangrove trees.

Submerged Environments

The ***"Mud bottom"*** environment occurs in both the interior channels of Twin Cays and in the protected leeward lagoon near the island. Mud is described as "thixotropic" and/or flocculent. Patchy *Thalassia testudinum*, *Halimeda* and *Penicillus* occur on the mud bottom. Callianassid shrimp burrows and the upside-down jellyfish, *Cassiopeia xamachana,* are common (Fig. 4). Along channel shorelines, the mud bottom is replaced by a *Halimeda* sand bottom adjacent to mangrove prop roots surrounded by *Halimeda* mats. The oyster *Crassotrea rhizophorae* also commonly encrusts prop roots, giving rise to adjacent shell hash. Mangrove leaf mats cover some muddy areas. In the extremely restricted Lair Channel the mud bottom is very rich in organic content (Fig. 5).

The ***"Thalassia on Mud"*** bottom environments consist of muddy or soft sand-mud bottoms with either a patchy or extensive *Thalassia testudinum* cover, both in open deeper (~>3m) areas and in channels (Fig. 6). The *Thalassia* has longer blades, typical for deeper areas. Scattered *Halimeda* and *Penicillus* grow within the *Thalassia* areas. *Caulerpa* sp., *Diadema* and Callianassid shrimp burrows are common. This depositional environment has a wide depth range (0.5 - 7.5 m; avg. 3.5 m).

The ***"Thalassia on Sand"*** *environment* occurs on the windward side of Twin Cays and is characterized by a compact sandy or sandy mud bottom densely covered by *Thalassia testudinum,* with *Syringodium filiforme*, *Penicillus* sp., *Halimeda opuntia* (forming large mounds), *Diadema*, other echinoids, *Porites furcata* and Callianassid shrimp mounds (Fig. 7). The sediments in some places contain shell hash layers or overlie a peat base. Sand blowouts are sandy depressions in these *Thalassia* beds that have been eroded during severe storm activity. Water depths range from 0.0 to 2.5 m (avg. 1.2 m).

The "***Sand with Thalassia***" bottom is generally a shallow water (0.1 - 3.9 m; avg. 1.7 m) environment (Fig. 8) trending E-W across the northern coast of Twin Cays. Smaller areas occur at South Point and in small shallow patches within the deeper "***Thalassia***

***on Mud*"** environment on the leeward western side of the islands (Fig. 3). The bottom consists predominantly of hard, compact, rippled sand. Varying densities of the seagrasses *Thalassia, Syringodium*, and *Halodule* occur with the algae *Halimeda opuntia, Penicillus, Laurencia* and branching *Neogoniolithon strictum*. Corals include *Manicina areolata, Porites divaricata, Porites furcata, Porites astreoides, Siderastrea radians*, branching *Cladocora arbuscula*, and rare occurrences of *Acropora cervicornis*. *Diadema* are numerous as are Callianassid shrimp burrows. Other echinoids occur, as do gorgonians.

Figure 4. "Mud bottom" depositional environment in north end of the channel separating the West and East Islands. Note scattered *Halimeda* and the upside-down jellyfish *Cassiopeia xamachana* (arrow).

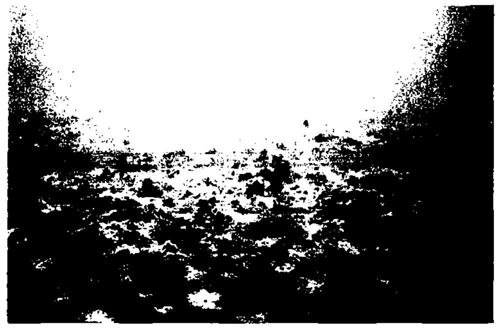

Figure 5. Organic-rich mud bottom of the Lair Channel.

Figure 6. "*Thalassia* on Mud" depositional environment along the leeward (western) lagoonal side of West Island, Twin Cays. Note long *Thalassia* blades and Callianassid shrimp burrows (arrows).

Figure 7. "*Thalassia* on Sand" depositional environment along the windward (eastern) shoreline of East Island, Twin Cays.

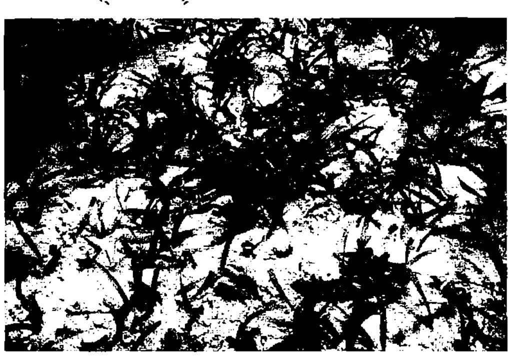

Figure 8. "Sand with *Thalassia*" depositional environment along the northern side of Twin Cays (also near South Point). Note the *Porites furcata* coral colony and black *Diadema* urchin in the center of the

Surface Samples

A plot of the sediment size analyses (Table 1) on a triangular size/nomenclature diagram (Folk, 1961) was placed on a map (Fig. 9) to define three basic sediment grain-size categories: sand (>90 %), dominantly sand (50-89%) with some silt and clay, and finally silt and clay size with sand (<50%).

Table 1. Sediment size analysis (wet sieved) from data of Bond (1988). S = Sand, Z = silt, M = mud, C = clay. sM = sandy Mud, zM = silty Mud, mS = muddy Sand, sC = sandy Clay, zC = silty Clay, etc. *Th* = *Thalassia.*

Sample No.	Depth (m)	%Sand	%Silt	%Clay	Sediment	Environment
7	1.0	96.1	2.0	2.0	S	Mud
8	1.5	40.5	40.0	20.0	sM	*Th* on Mud
11	0.5	93.0	3.0	5.0	S	Mud
13	0.9	40.4	40.0	20.0	sM	*Th* on Mud
15	0.5	16.3	69.0	15.0	sM	*Th* on Mud
16	1.2	20.3	29.0	51.0	sM	*Th* on Mud
17	2.9	25.2	27.0	48.0	sM	*Th* on Mud
19	2.6	84.0	9.0	7.0	mS	Sand w/ *Th*
20	3.2	64.0	14.0	22.0	mS	*Th* on Mud
21	4.3	29.2	23.0	48.0	sC	*Th* on Mud
22	4.5	28.1	24.0	48.0	sC	*Th* on Mud
23	5.2	34.1	21.0	45.0	sC	*Th* on Mud
25	1.0	41.3	18.0	41.0	sC	*Th* on Mud
26	1.9	67.0	10.0	23.0	mS	*Th* on Mud
27	0.0	100.0	0.1	0.1	S	*Th* on Sand
28	0.0	100.2	0.1	0.1	S	*Th* on Sand
29	0.5	98.0	0.1	0.1	S	*Th* on Sand
30	1.0	97.0	2.0	1.0	S	Sand w/ *Th*
31	1.6	88.0	1.0	1.0	S	Sand w/ *Th*
32	2.2	95.0	3.0	2.0	S	Sand w/ *Th*
33	1.8	99.0	0.1	1.0	S	Sand w/ *Th*
34	7.0	55.0	15.0	30.0	cS	*Th* on Mud
35	0.7	89.0	3.0	8.0	(m)S	Sand w/ *Th*
36	2.4	76.0	19.0	5.0	zS	Sand w/ *Th*
37	0.1	91.3	2.0	7.0	S	Sand w/ *Th*
38	1.0	98.0	1.0	1.0	S	Sand w/ *Th*
39	2.8	58.0	11.0	31.0	cS	*Th* on Mud
40	1.7	96.0	2.0	2.0	S	Sand w/ *Th*
41	2.9	59.1	15.0	26.0	cS	*Th* on Mud
42	1.8	98.0	1.0	1.0	S	Sand w/ *Th*
44	1.3	98.0	1.0	1.0	S	Sand w/ *Th*
45	1.7	96.0	2.0	2.0	S	Sand w/ *Th*
46	2.5	96.0	2.0	2.0	S	Sand w/ *Th*
47	2.6	94.0	3.0	3.0	S	Sand w/ *Th*
48	7.5	45.0	12.0	43.0	cS	*Th* on Mud
49	2.8	92.0	5.0	3.0	S	Sand w/ *Th*
51	0.9	94.0	5.0	1.0	S	Sand w/ *Th*
52	2.8	83.0	8.0	9.0	mS	Sand w/ *Th*
53	1.1	94.0	6.0	0.1	S	Sand w/ *Th*
54	0.35	96.0	3.0	1.0	S	*Th* on Sand
55	1.0	94.0	3.0	3.0	S	*Th* on Sand
56	0.9	64.0	22.0	14.0	mS	*Th* on Sand
57	0.7	81.0	12.0	7.0	mS	*Th* on Sand
58	0.9	92.0	4.0	4.0	S	*Th* on Sand
59	1.4	88.0	8.0	4.0	(m)S	*Th* on Sand

60	2.6	98.0	1.0	1.0	S	*Th* on Sand
61	0.9	79.0	14.0	7.0	mS	Sand w/ *Th*
62	1.4	100.0	0.1	0.1	S	Sand w/ *Th*
63	2.8	86.0	9.0	5.0	mS	Sand w/ *Th*
64	6.3	34.0	49.0	18.0	sZ	*Th* on Mud
65	0.8	94.0	4.0	2.0	S	Sand w/ *Th*
66	3.0	93.0	3.0	4.0	S	Sand w/ *Th*
67	2.0	73.0	20.0	7.0	zS	*Th* on Sand
68	1.4	92.0	5.0	3.0	S	*Th* on Sand
69	0.25	80.0	16.0	4.0	zS	*Th* on Sand
70	1.0	94.0	4.0	2.0	S	*Th* on Sand
71	1.5	39.0	41.0	20.0	sZ	*Th* on Sand
72	2.5	97.0	2.0	1.0	S	*Th* on Sand
73	0.9	92.0	6.0	4.0	S	*Th* on Sand
74	1.8	83.0	11.0	6.0	zS	*Th* on Mud
75	0.4	98.0	1.0	1.0	S	*Th* on Sand
76	1.4	86.0	10.0	4.0	mS	*Th* on Sand
77	1.7	94.0	4.0	2.0	S	*Th* on Sand
78	1.05	82.0	10.0	8.0	mS	*Th* on Sand
79	1.8	91.0	5.0	4.0	S	Sand w/ *Th*
80	0.9	84.0	9.0	7.0	mS	Sand w/ *Th*
81	1.4	79.0	10.0	11.0	mS	*Th* on Sand
82	1.7	73.0	16.0	11.0	mS	*Th* on Sand
83	1.5	90.0	6.0	5.0	S	Sand w/ *Th*
84	2.9	80.0	13.0	8.0	mS	Sand w/ *Th*
85	7.0	77.1	19.0	4.0	zS	*Th* on Mud
86	2.0	92.0	4.0	4.0	S	Sand w/ *Th*
87	0.3	100.1	0.1	0.1	S	*Th* on Sand
88	1.8	94.0	3.0	3.0	S	*Th* on Sand
89	1.5	60.0	19.0	21.0	mS	*Th* on Sand
90	0.75	82.0	10.0	8.0	mS	*Th* on Sand
91	2.1	80.0	11.0	9.0	mS	*Th* on Sand
92	5.5	63.0	23.0	14.0	mS	*Th* on Mud
93	5.5	42.0	42.0	16.0	sZ	*Th* on Mud
94	2.3	87.0	6.0	7.0	mS	*Th* on Mud
95	1.7	96.0	2.0	2.0	S	*Th* on Sand
96	1.5	82.0	11.0	7.0	mS	*Th* on Sand
97	1.85	99.0	0.1	1.0	S	*Th* on Sand
98	4.0	77.0	14.0	9.0	mS	*Th* on Mud
99	1.05	95.0	4.0	1.0	S	*Th* on Sand
100	0.75	93.0	4.0	3.0	S	Sand w/ *Th*
101	0.9	96.0	2.0	2.0	S	Sand w/ *Th*
102	1.4	91.0	5.0	4.0	S	Sand w/ *Th*
103	1.75	98.0	1.0	1.0	S	Sand w/ *Th*
104	2.35	83.0	7.0	10.0	mS	Sand w/ *Th*
105	3.2	53.0	21.0	26.0	mS	*Th* on Mud
106	5.5	40.0	39.0	20.0	zS	*Th* on Mud
107	2.1	61.0	31.0	8.0	zS	*Th* on Mud
108	0.2	101.2	0.1	0.1	S	Sand w/ *Th*
109	0.65	92.0	3.0	2.0	S	Sand w/ *Th*
110	1.15	87.0	8.0	6.0	mS	Sand w/ *Th*
111	3.9	87.0	7.0	6.0	mS	Sand w/ *Th*
112	2.5	43.0	25.0	32.0	sM	*Th* on Mud
113	3.2	87.0	5.0	8.0	mS	Sand w/ *Th*
114	2.4	95.0	2.0	2.0	S	Sand w/ *Th*
115	1.35	96.0	2.0	2.0	S	*Th* on Sand
116	0.7	98.0	1.0	1.0	S	*Th* on Sand
120	2.0	17.2	53.0	30.0	sM	Mud

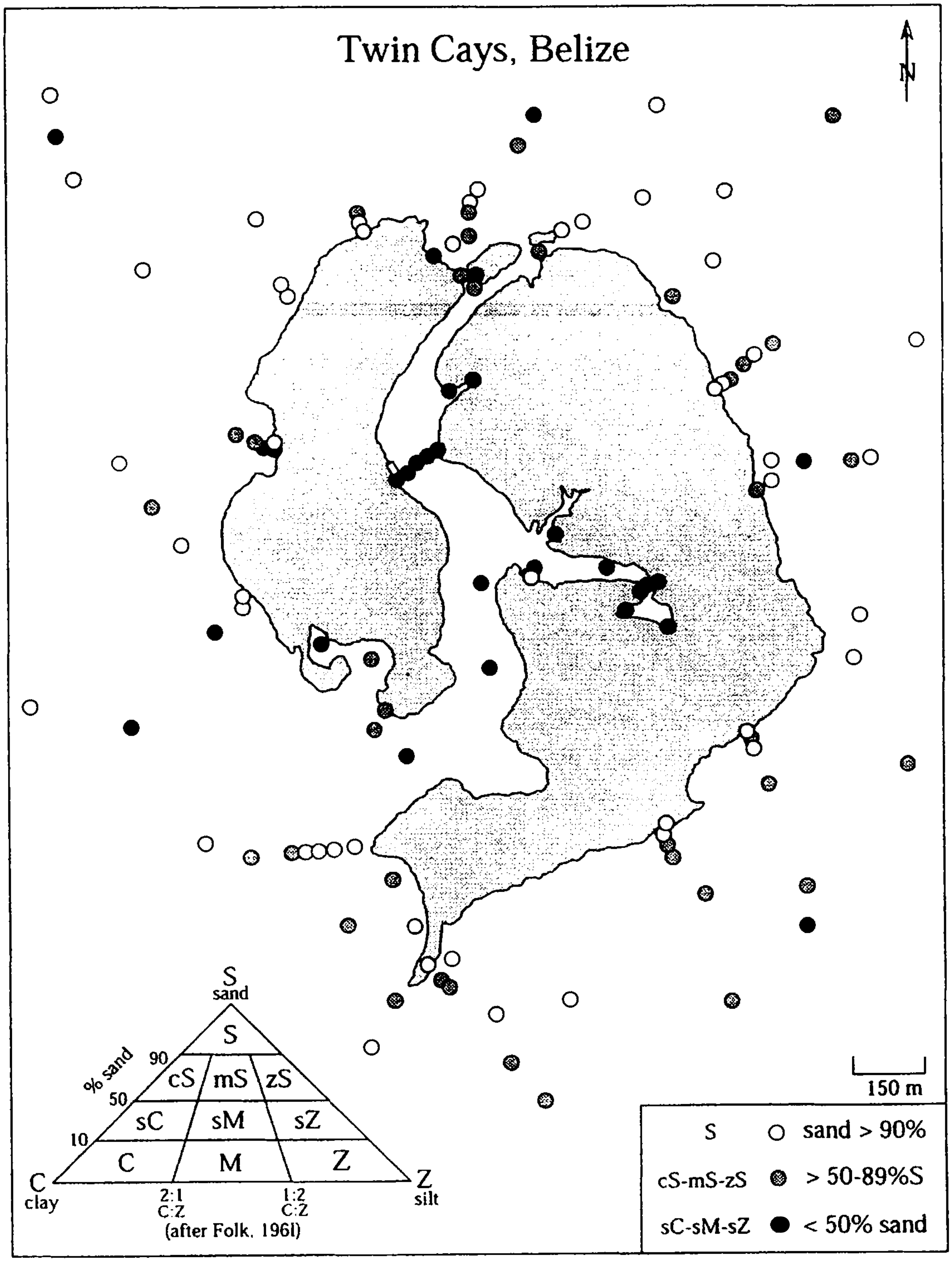

Figure 9. Map showing the sediment grain-size size characteristics at each location based on Folk's (1961) nomenclature illustrating the percentage of sand for each sample. Compare to depositional environment map (Figure 3).

Thin Sections

Particle types that were point-counted included: *Halimeda* plates, bivalves, gastropods, miliolid foraminifera, soritid foraminifera, rotilid foraminifera, echinoderm fragments, coral fragments, coralline algae, crustacean fragments, tunicate spicules, alyconarian spicules, diatoms, fish teeth and quartz grains (Bond, 1988). Point count data (percentages of various grain types) of samples (33, 34, 48, 63, 72, 94, 96, 113) representing the depositional environments (Table 2) indicate that *Halimeda* is the dominant skeletal component in the thin sections forming the primary skeletal grain in the sand size range and in the granule class. Both bivalve and gastropod shell fragments are the next most abundant grain type, followed by foraminifera. The combined compositional percentages of *Halimeda* and molluscs correlate closely to the percent sand in the samples, except in two mud-dominated samples. Other constituent grains include, in the coarsest size fractions, molluscs, miliolid foraminifers and echinoderm fragments, with bivalves in certain cases being locally dominant. Foraminifera tend to be miliolids in the sand size fractions and in the finer grained fractions rotilid and soritid foraminifera become increasingly abundant. Echinoderm fragments form no more than three percent of any thin section point count.

Table 2. Thin section point count data – sedimentary constituents (after Bond 1988). % Sand is from Table 1. The % Sand correlates to the total of % *Halimeda* + % Molluscs in all cases except samples 34 and 48, which are located in muddy areas and have higher percentages of molluscs, foraminifera and other components. *Th* = *Thalassia.*

Sample No.	% *Halimeda*	% Molluscs	% Forams	% Other	% Sand	Environments
33	78.7	14.4	2.0	4.9	99.0	Sand w/ *Th*
34	41.2	25.4	14.9	18.5	55.0	*Th* on Mud
48	47.4	25.4	11.0	16.2	45.0	*Th* on Mud
63	67.4	21.7	5.2	5.7	86.0	Sand w/ *Th*
72	80.9	12.7	3.5	2.9	97.0	*Th* on Sand
94	78.4	10.3	5.8	5.5	87.0	*Th* on Sand
96	73.5	15.9	4.3	6.3	82.0	*Th* on Sand
113	60.9	26.7	3.1	9.3	87.0	Sand w/ *Th*

DISCUSSION AND CONCLUSIONS

A total of three emergent mangrove and five marine depositional environments occur on and around Twin Cays (Fig. 3). In marine depositional environments surrounding Twin Cays, sediment analyses (Table 1) and depositional environments mapped in Figure 3 indicate a generally sand-dominated series of bottom types distinguished by their windward or leeward locations, water depths, and the density of aquatic vegetation. An extensive study of the distribution of submerged macroalgae and seagrasses at Twin Cays was conducted by Littler et al. (1985). The sheltered channels of Twin Cays apparently contained lower species diversity (dominated by productive filamentous algae) and greater total cover than the more exposed bay community, where *Halimeda* and *Thalassia* provided the dominant cover. Lower levels of physical disturbance, lack of herbivory and greater availability of recycled nutrients in channels near mangroves account for the greater incidence of filamentous algae than in the wave-exposed bay environments (Littler et al., 1985). Nearshore windward depositional environments ("***Thalassia* on Sand**," Fig. 7) consist of sandier (*Halimeda*-rich) sediments with a denser cover of *Thalassia testudinum* than in leeward and offshore environments. The deeper windward offshore area is classified as "***Thalassia* on Mud**" (Fig. 6), a depositional environment that extends into the main channel between East and West Islands, as well as across much of the western (leeward) shelf. Areas of "**Sand with *Thalassia***" (Fig. 8) occur in patches on the western shelf, at South Point and along the northern edges of the islands. The "**Sand with *Thalassia***" depositional environment contains a lower density of *Thalassia* than the "***Thalassia* on Sand**" areas along the windward coast. The main muddy areas are limited to the W-E trending channel into the interior of East Island. Sediment samples 1-6 obtained from the inner reaches of this channel were judged to be too organic-rich for sediment analysis.

A comparison of the sediment grain-size patterns in Figure 8 with the marine depositional environments map in Figure 3 indicates that the mud-rich areas are mostly limited to the low-energy sites in the Twin Cays channels and to the deeper "***Thalassia* on Mud"** depositional environment. The muddy sands also tend to be found in more protected sites off the coasts and in the deeper "***Thalassia* on Sand"** areas. Finally, the very sandy samples are generally limited to the shallow well-winnowed and compact bottoms of the "**Sand with *Thalassia*"** environment.

The *Halimeda* sand-dominated sediments of the Twin Cays area are consistent with Purdy et al.'s (1975) designation of a large *Halimeda* facies for this area of the Barrier Reef Platform lagoon. Our sediment analyses allowed us to differentiate Purdy et al.'s (1975) general *Halimeda* facies into the three distinct environments described above based on the percentage of sand (Fig. 9). The dominance of mud-size sediment in the protected channel areas has persisted for thousands of years as illustrated in the Holocene cross-sections in Macintyre et al. (this volume).

The other muddy environment ("***Thalassia* on Mud"**), consisting of mud with a rich cover of *Thalassia,* occurs in the deeper (2-7 m) areas of the windward coast, all through the central channel between the Islands, continuing outward along the bay side (Fig. 3). The sandy areas ("**Sand with *Thalassia*;**" "***Thalassia* on Sand"**), directly adjacent to the shorelines, consist of shallow (0-4 m) flats of compact sand with scattered *Thalassia.* Again, the Holocene sections (Macintyre et al., this volume) indicate that over the 8,000 cal-year mangrove-peat history of Twin Cays, these lagoonal *Halimeda*-rich sands transgressed into the mangroves, sometimes for thousands of years. *Halimeda* dominated the sedimentation, while *Rhizopora mangle* formed peat and both maintained the buildup with sea-level rise over the Holocene.

Along the north coast of Twin Cays, the "**Sand with *Thalassia*"** depositional environment meets a shoreline of eroding peat and mangroves, similar to the north coast of nearby Tobacco Range (Macintyre et al., 1995). This erosion is likely due to the destructive N-NE winter wave climate. In contrast, the windward southern and eastern shores consist of mangroves that are prograding over lagoonal sediments, as reflected in the elongate shape of Eastern Island and the lobes of sandy deposits surrounding South Point.

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