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PHYSICAL AND GEOLOGICAL CHARACTERISTICS OF MERMAID POND, AN ANCHIALINE LAKE ON SAN SALVADOR ISLAND, BAHAMAS

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ABSTRACT

As part of a larger ecological investigation of Mermaid Pond, physical and geological characteristics were examined during the spring and summer of 2004 and 2005. GPS coordinate data indicated that the surface area of the pond measured approximately 15.5 ha. Average water depth was 2.5 m, with the greatest depth of 7.9 m recorded at one of two major conduit mouths. Sediments were predominantly carbonate shell hash with greatest sediment abundance and thickness restricted to the pond margins adjacent to Red mangrove (*Rhizophora mangle*) root systems. A thin veneer of fine sediments and organic flocculent material covered the majority of the lake bottom. Silts and clays (<63 μm) comprised less than 2% of all sediments sampled. Sediment organic carbon content ranged from 3.1 to 23.2%. Temperature, salinity, and dissolved oxygen data indicated that conduit flow was sufficient to maintain marine conditions throughout the pond. The connection of surface water from Mermaid Pond to the Stouts Lake system appeared to be dependent on seasonal tides with northward flow occurring only during extreme spring tides.

INTRODUCTION

San Salvador Island is composed of carbonate rock, which is soluble in rainwater. This characteristic has led to the formation of a landscape riddled with sinkholes, conduits and inland lakes (Mylroie, 1993). A prominent feature of the island is its numerous inland lakes. Many are seep-fed with high evaporation rates and exhibit hypersaline conditions. Others are termed anchialine (with no surface connection to the sea) and are conduit-fed and marine in nature (Davis & Johnson, 1989). Most inland ponds and lakes on San Salvador are nearly undisturbed ecosystems that have received little attention. These bodies of water form ecological "islands" within islands, each unique from all other ponds and lakes (Edwards, 1996).

Mermaid Pond is located in southeastern San Salvador, immediately south of the Stouts Lake system. Winter (1993) conducted the first survey of this pond and reported a conduit-fed system with marine conditions. He also reported that Mermaid Pond is connected to Stouts Lake to the north via a shallow mudflat and that circulation between these bodies of water is limited to a northward flow from Mermaid Pond into the southern portion of Stouts Lake.

The objective of this study was to examine the physical and geological characteristics of Mermaid Pond and to ascertain the dynamics of the surface water connection to the Stouts Lake system.

MATERIALS AND METHODS

Fieldwork was conducted during May and June 2004 and again in May 2005. Dissolved oxygen and temperature were measured with an YSI-550 dissolved oxygen meter and salinity with a hand-held refractometer. Eighty-three soundings were randomly taken with a lead line marked at 1.0 m increments along a series of N-S and E-W transects. All depths were recorded to the nearest 0.5 m and corrected for tidal variation and lag time using NOAA tide tables. Latitude and longitude at all sites were recorded with a Garmin GPS-II.

Sediment samples were collected randomly at 15 sites throughout the pond using the scoop method. All samples were washed with deionized water, dried at 60°C, and subdivided by the cone and quarter method (Ingram, 1971). One subsample was analyzed for total organic carbon, carbon from carbonate, and insoluble minerals by methods presented in Dean (1974). Grain size fractions were determined by sieving a subsample through a graduated sieve set.

RESULTS AND DISCUSSION

Environmental Setting

Areal coverage via GPS data indicated that Mermaid Pond was approximately 15.5 ha in size. Unlike many other ponds and lakes on San Salvador, Mermaid Pond was completely encircled by thick stands of red mangrove (*Rhizophora mangle*) with no areas of exposed rocky shoreline. Salt-accumulating soil (salina) affected by tidal fluctuations comprised the landward margins of the pond. With increasing elevation, this salina intergraded into Pleistocene aeolian ridges (Mylroie, 1993). As a result, Mermaid Pond was located in a tidally influenced basin.

The fringing salina varied in width with the predominant terrestrial floral components, including Red mangrove (*R. mangle*), Black mangrove (*Avicennia germinans*), White mangrove (*Laguncularia racemosa*), and Buttonwood (*Conocarpus erectus*), all of which exhibited the monospecific zones typical of a basin mangrove forest (Odum *et al.*, 1982). Additional halophytic species present in this area included southern glasswort (*Salicornia perennis*) and seaside purslane (*Sesuvium portulacastrum*).

Mermaid Pond seemed to be unique among ponds on San Salvador Island in that it was not missing any of the mono-specific mangrove zones. Of all the ponds described by Edwards (2001), every pond was lacking at least one mangrove zone. Studies of Moon Rock Pond, Pain Pond, Crescent Pond, Oyster Pond, and Osprey Pond observed that Oyster Pond was the only brackish or marine site to be ringed by red mangroves. Other sites, like Osprey Pond, were lacking black mangroves.

Physical Parameters

Previous studies have reported that large lakes on San Salvador, such as Storrs, Granny, and Great Lake, are large in areal coverage but have little or no conduit flow, and therefore are hypersaline in nature (Edwards *et al.*, 1990; Mylroie, 1993). These lakes generally maintain salinities ranging from 55-85 ppt because their water levels are controlled by evaporation and precipitation, as opposed to conduit-supplied tidal exchange. Even some smaller lakes, such as Little Lake, Six Pack, and Reckley Hill Pond, have active conduits but are not able to sustain marine conditions because the conduits are barely tidal (Edwards *et al.*, 1990). Other smaller lakes and ponds that have tidally active conduits, such as No Name, Pain, Moon Rock, Wild Dilly, Crescent, and Oyster Pond, are able to maintain marine conditions with salinities ranging from 36-38 ppt. Edwards and others have concluded that large lakes experience less tidal exchange and greater evaporation rates than smaller lakes, whether a conduit system is present or not, causing larger lakes to exhibit more hypersaline conditions (Edwards *et al.*, 1990; Whitelaw, 2001).

Small lakes and ponds with a good exchange of seawater exhibit salinities that are close to marine (Edwards *et al.*, 1990). Indeed, ermaid Pond had normal marine conditions, with an average salinity of 35.7 ppt (31.5-38.5 ppt). The average temperature recorded in May and June was 31.3°C (30.9-31.7°C), with average dissolved oxygen of 5.24 mg/l (4.52-5.60 mg/l).

Our data, along with that of Winter (1993), indicated that conduit flow was sufficient to maintain marine conditions throughout Mermaid Pond. Davis and Johnson (1989) observed that conduits were always found associated with lakes that exhibited normal marine salinities and temperatures.

Bathymetry

The average depth of Mermaid Pond was 2.5 m, with the greatest depth of 7.9 m recorded in the southwestern corner (Figure 1). Winter (1993) described two solution hole conduits at depths of approximately 4.5 m along with a lateral crack in the rock bottom. Our data indicated two major conduits located at the northern and southwestern regions of the pond, at depths of 7.1 and 7.9 m, respectively. Additionally, two minor conduit features at depths of 4.3 and 4.4 m were recorded in the central portion of the pond.

Sediments

Sediments in many ponds on San Salvador have been described as beds of molluscan shell fragments in soft carbonate mud (Edwards, 2001). One pond, Crescent Pond, contains shell hash mounds at all conduit exits except near the smallest conduit (Whitelaw, 2001). Whitelaw suggested that shell mound formation results from the forceful flow of water from the conduit, which pushes sediments away from the conduit mouth. Other ponds, such as Oyster Pond, have rocky vertical sides and a bottom layer of coarse shell hash up to 2.5 m thick (Edwards *et al.*, 1990).

The sediments in Mermaid Pond were predominantly carbonate shell hash, with the thickest layers restricted to the pond margins. Whole and large shell fragments of mollusks dominated fractions >500 μm. A thin veneer of mixed sediments and flocculent material covered the majority of the bedrock pond bottom.

Overall, sediments were poorly sorted, with silts and clays (<63 μm) comprising less than 2% of all sediments sampled (Figure 2). The fine grain sediments were restricted to the pond margins and were probably derived from the soil that comprises the salinas. This suggests that Mermaid Pond is a low energy system, with minimal disturbance around the margins from the circulation of the conduit.

Average sediment organic carbon content was 8.95%, with a range of 3.1-23.2%

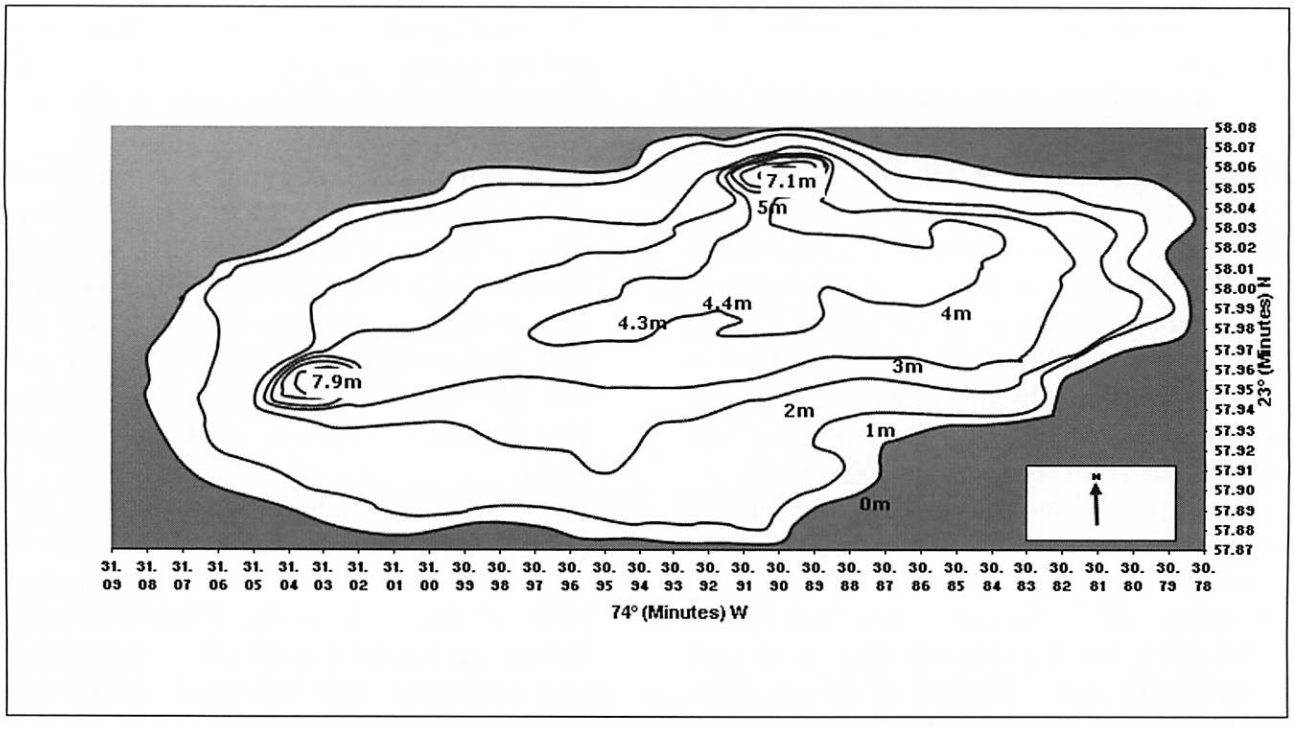

Figure 1. Bathymetric map of Mermaid Pond, showing depth contours (meters), major conduits (7.1 and 7.9 m), and minor conduits (4.3 and 4.4 m).

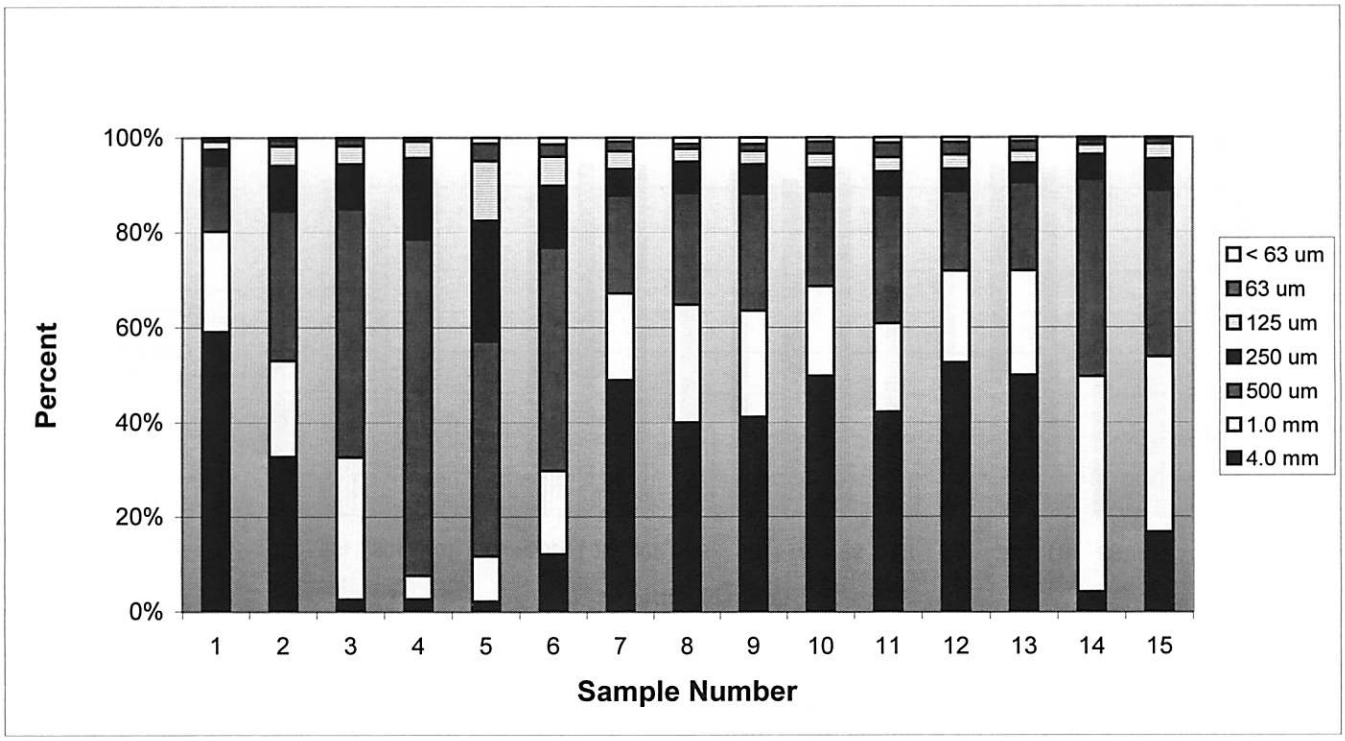

Figure 2. Grain size composition of Mermaid Pond sediment. Fractions >500 mm primarily consisted of mollusk shell fragments. Silt and clay fractions (<63um) comprised less than 2% of all sediments sampled.

(Figure 3). The source of organic material in the peripheral sediments appeared to be mangrove-derived detritus and debris entering as runoff from the pond perimeter. In comparison, sediments from Florida Bay, another shallow low-energy environment, have an organic carbon content of 7.6%, ranging from 1.43-18.05% (Scott *et al.*, 1997). Carbon from carbonate (primarily shell hash) averages 40.6%.

Although not examined in this study, the flocculent layer in Mermaid Pond presumably contains considerable amounts of organic material. Organic-rich flocculent material is common in most lakes on San Salvador (Edwards *et al.*, 1990). Edwards (1996) described the flocculent layer as a layer of microscopic organisms overlying the muddy pond substrate and suggested that these layers can only be found in low-energy systems that lack coastal ebb and flow.

Connection to Stouts Lake

The connection to Stouts Lake to the north is not readily visible from Mermaid Pond (Figure 4). Winter (1993) reported that the northward flow appears to be restricted to a shallow, surface water sheet that extends through a mud flat that connects both bodies of water. We observed the mud flat to be comprised of an algal mat that covers soft the bedrock bottom.

Our observations suggest that surface water flow may be highly variable and dependent upon seasonal high tides and prevailing wind direction (Figures 4 and 5). Low tides may provide limited northward flow, but leave most of the mudflat dry and exposed. However, the shallow nature, fetch, and spatial orientation of the mud flats may be strongly affected by seasonal winds, which may push surface water south against the northern tidal flow.

Winter (1993) reported salinities greater than 40 ppt. We recorded salinities between 60 and 70 ppt, with temperatures in excess of 35°C. These parameters strongly impact dissolved oxygen levels and, collectively, may act as a barrier for the exchange of faunal components between Mermaid Pond and Stouts Lake. During the seasonal low tides, we observed nothing

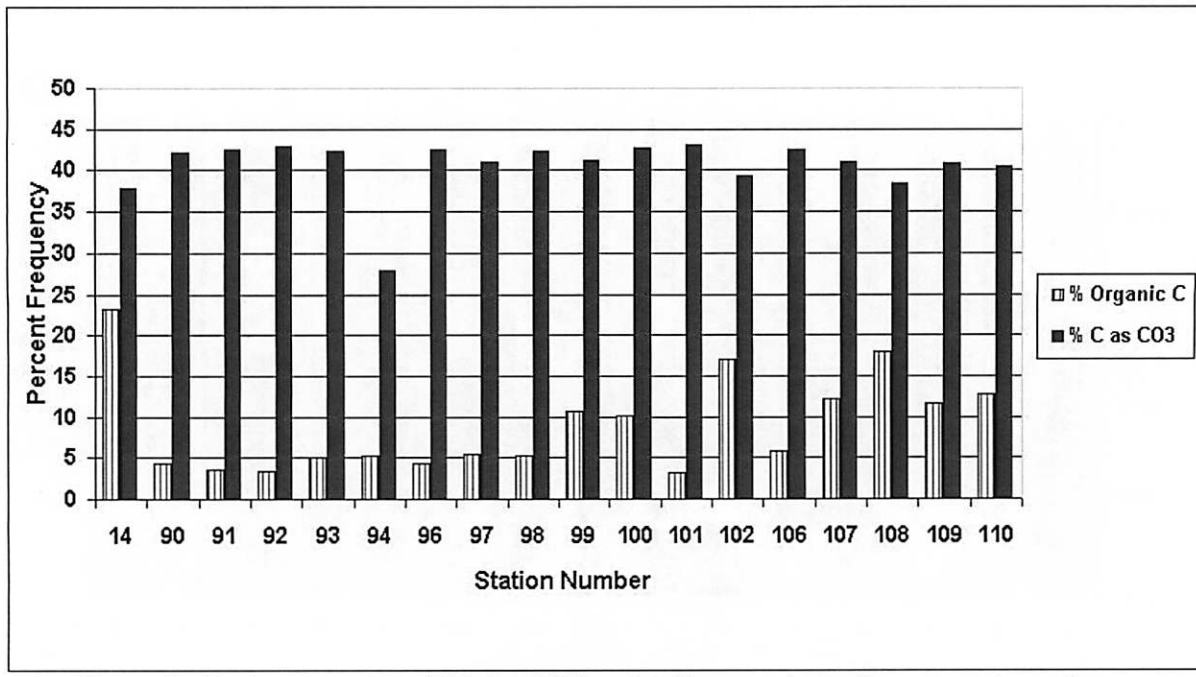

Figure 3. Carbon content of Mermaid Pond sediments, including organic carbon and carbon from carbonates.

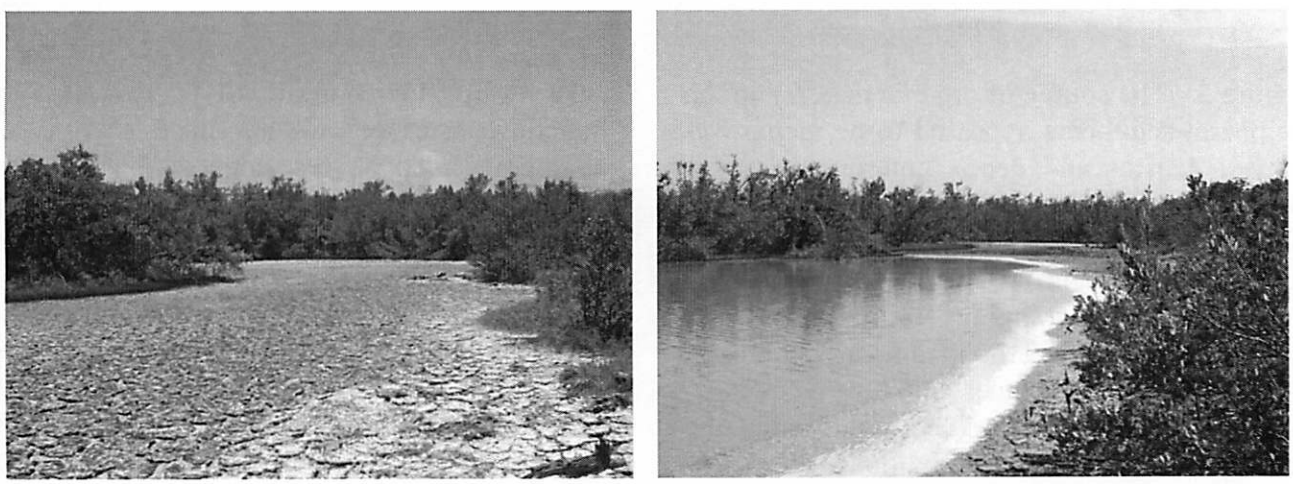

Figure 4. Surface water connection between Mermaid Pond and Stouts Lake, looking south toward Mermaid Pond during seasonal low tides in June 2004 (left) and seasonal high tides in May 2005 (right).

living in this area, but during seasonal high tides, small schools of mosquito fish (*Gambusia affinis*) were observed in the surface water connection.

CONCLUSIONS

Mermaid Pond is a salina-fringed, conduit-fed inland lake located in a tidally influenced basin. The average water depth of Mermaid Pond is 2.5 m, with the greatest depth of 7.9 m associated with one of two major conduits. Tidal exchange via these conduits is sufficient to maintain fully marine conditions. The sediments in the pond consist of poorly-sorted shell hash with silts and clays (< 63 μm), which comprise less than 2% of all sediments, restricted to the pond margins. Sediment organic

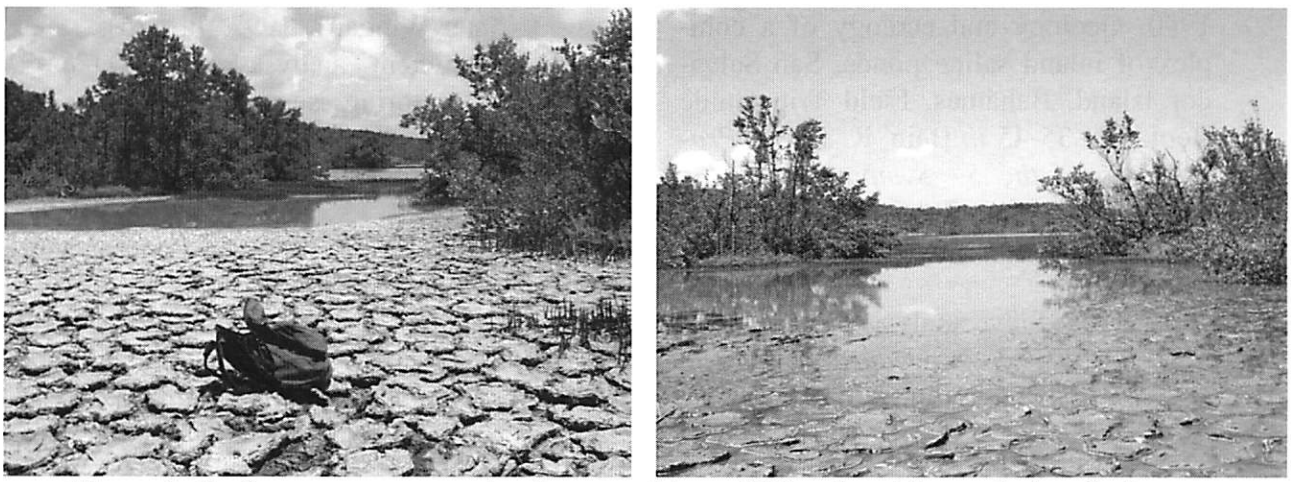

Figure 5. Surface water connection between Mermaid Pond and Stouts Lake. Sediments and algal mats are exposed during seasonal low tides in June 2004 (left) and submerged during seasonal high tides in May 2005 (right).

content averages 8.95%, with carbon from carbonate contributing 40.6%. The surface water connection from Mermaid Pond to the Stouts Lake system to the north appears to be dependent on seasonal tides and may be affected by prevailing winds.

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