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Cover photo: *Diploria strigosa*, the common brain coral, preserved in growth position at the Cockburn Town fossil coral reef site (Sangamon age) on San Salvador Island. Photo by Al Curran.

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HOLOCENE DEPOSITIONAL HISTORY OF SALT POND, SAN SALVADOR, BAHAMAS

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ABSTRACT

An 84 cm core was collected in Holocene sediments of Salt Pond and studied with respect to (1) distribution of ostracodes, (2) carbonate content, (3) non carbonate organic content, and (4) insoluble inorganic residue content. *Perissocytheridea bicelliforma* dominates throughout most of the core, especially at the bottom and top. Elsewhere, *Cyprideis americana* and to some extent, *Hemicyprideis setipunctata* approach codominance with *P. bicelliforma.*

Microprobe analysis of the magnesium content of *C. americana* throughout the core reveals a history of changing salinity. Prevailingly brackish salinities are suggested for the base and for approximately 10 to 22 cm from the top of the core. Above this latter interval, increasingly saline conditions are indicated. The salinity of Salt Pond at the time of coring was 283 ppt. The zone between the two brackish water events was prevailingly hypersaline. We correlate this hypersaline zone with the youngest marine event in Little Lake (Sanger and Teeter, 1982), Watling's Blue Hole (Crotty and Teeter, 1984) and Reckley Hill Pond (Luginbill, 1983).

Carbonate content throughout most of the core varies from 84 to 96% and non-carbonate organic content from 1 to 8%. The remaining insoluble inorganic residue typically varies from approximately 2 to 8%. X-ray analysis of this latter fraction indicates that quartz, chlorite, and illite are almost always present, whereas plagioclase and orthoclase are much less common. Two sampled intervals from the earlier hypersaline zone contain a large amount of gypsum.

A nine element microprobe analysis of the inorganic residue indicates a peak Al value at 28 cm from the top of the core. Consistently higher insoluble inorganic residue contents occur above 28 cm. Both presumably reflect increased influx of clays from soil erosion following clear cutting of the island by colonists.

INTRODUCTION

The previously unnamed lake, herein called Salt Pond, lies on the east coast of San Salvador approximately 300 m NNE of Holiday Track Settlement. Historically, this pond has been used for harvesting salt and hence its proposed name.

Salt Pond is separated from the Atlantic Ocean to the east by a low, narrow Pleistocene bedrock ridge capped by Holocene dune sands. A 30 m high bedrock ridge rises west of the pond. Maximum water depth at the time of coring (1/4/85) was approximately 20 cm although past higher stands of water level were indicated by a broad, barren shore zone surrounding the pond. No conduits connecting pond and ocean were observed. However, salt water does trickle slowly into the pond from bedrock exposures above the barren zone during high tide and is the apparent source of the saline water within the pond. The salinity at time of coring was 283 ppt. and, apart from aquatic insect larvae, no living organisms were observed.

OSTRACODE MICROFAUNA

Previous studies of lacustrine ostracode faunas from San Salvador (Sanger and Teeter, 1982; Luginbill, 1983; Crotty and Teeter, 1984) reveal the predominance of four species whose distribution is primarily controlled by salinity. Salinity ranges for these species are presented in Table 1.

Table 1. LACUSTRINE OSTRACODE SALINITY RANGES

SPECIES	SALINITY RANGE (ppt)	REMARKS
Perissocytheridea bicelliforma	8.1 - 27.1	Typically common at 10-20 ppt.
Cyprideis americana	10.8 - 98.5	Least abundant at 30-40 ppt.
Hemicyprideis setipunctata	11.3 - 60.9	Peak abundance at approximately 30-40 ppt.
Dolerocypria inopinata	10.0 - 76.0	

Based on Crotty and Teeter (1984), Garbett and Maddocks (1979), King and Kornicker (1970), Klie (1939 a,b), Krutak (1971), and continuing research.

Salt Pond Holocene Ostracode Distribution

Eighteen 2 cm intervals were selected throughout the core and approximately 1 gm of sediment from each was processed using standard micropaleontological techniques. With one exception, a minimum of 300 ostracodes (adult through A-2 instars, right valves and complete carapaces) was counted in each interval. The distribution of the five ostracode species recovered is presented in Figure 1.

Of the five ostracode species observed in the core, *Perissocytheridea bicelliforma* dominates in all but two intervals and is especially abundant at the bottom and top of the section. *Cyprideis americana* is usually more abundant than *Hemicyprideis setipunctata.* The latter two species are least common at the bottom and top of the core and approach the abundance of *P. bicelliforma* throughout the rest of the core. *Dolerocypria inopinata* appears in minor abundance midway through the core, and the fresh water to mesohaline *Limnocythere floridensis* occurs in the uppermost part of the core.

The salinity interpretation of other saline lakes - Little Lake (Sanger and Teeter, 1982), Reckley Hill Pond (Luginbill, 1983), and Watling's Blue Hole (Crotty and Teeter, 1984) - has been facilitated by the occurrence of marked variations in species abundance and the periodic appearances of distinctly marine and, less commonly, fresh water ostracode assemblages. The Salt Pond assemblages show no such clear cut changes. The tentative interpretation, based on the changing abundances of the brackish (10-20 ppt.) *P. bicelliforma* and euryhaline *C. americana* and *H. setipunctata*, would be initial low salinity, followed by higher salinity throughout much of the core with a return to lower salinity near the top.

Magnesium-Salinity Relationship in *Cyprideis americana*

Since the early 1960's trace and minor element chemistry in calcareous shells has received increasing attention as a means of distinguishing environmental parameters such as salinity and temperature. As Dodd and Stanton (1981) indicate, the concentration of trace and minor elements is a function of the physical chemistry of the skeletal formation process, the physiology of the organism, environmental variables and, after death and burial, diagenesis. The most frequently studied organisms to date are molluscs but the results are often contradictory (Eisma and others, 1976). Part of this problem may result from the analysis of the total mollusc shell (Davies, 1972) as opposed to the separate treatment of calcitic and argonitic components (Dodd, 1965). Further, the physiological control differs between species so that no two molluscan species may respond in the same manner during skeletal secretion.

Calcite-shelled ostracodes eliminate the problem of minor element fractionation between different carbonate minerals. Growth in ostracodes proceeds by ecdysis followed by rapid calcification of the shell. As molt stages are relatively short, lasting several days for most species, shell trace and minor elements should reflect environmental conditions shortly following molting. Cadot and Kaesler (1977) demonstrated highest

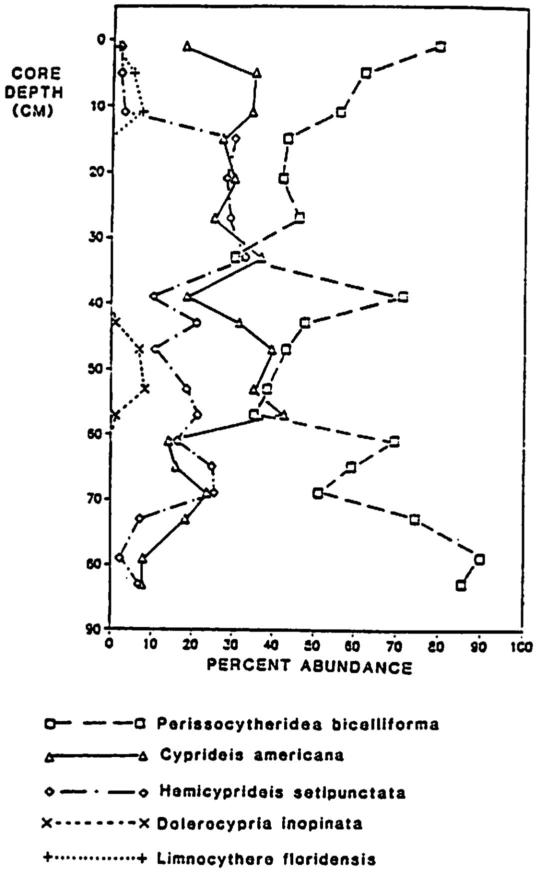

Fig. 1. Ostracode distributions within core from Salt Pond.

magnesium content at the inner margin and lowest values at the outer margin of the shell. They noted a positive correlation between magnesium and temperature at the superfamily level in their isohaline, essentially marine, ostracode assemblages. They also suggested that over a salinity range magnesium content might be expected to vary. Chivas and others (1983) demonstrated positive correlation between magnesium and temperature for a nonmarine ostracode at salinities of 3 ppt. and 9 ppt. More recently (1985) the same authors have shown that strontium content in 2 species of nonmarine ostracodes reflects the strontium content of the host water and suggest that this provides the basis for paleosalinity determination.

Since June, 1984 the senior author has carried out a continuing program of ostracode-bearing algae and sediment collection from lakes of different salinity on San Salvador. Although not measured, the overall temperature range is assumed to be small. Live adult individuals of *Cypridesis americana* have been selected and prepared for electron microprobing of magnesium content. Because of variation in magnesium content across the shell thickness (Cadot and Kaesler, 1977), for uniformity, only the middle of each section was probed. Preliminary results have clearly demonstrated the negative correlation of magnesium and salinity.

Five adult right valves of *C. americana* were selected from each of the 18 processed intervals of the core. Only individuals with transparent, unbored shells were chosen to eliminate, insofar as possible, any chance of diagenesis. Each individual was probed medially at three locations for magnesium content. The average magnesium content and standard deviation for each interval is plotted in Figure 2. Paleosalinity, interpreted from the magnesiun content of living *C. americana*, is also recorded.

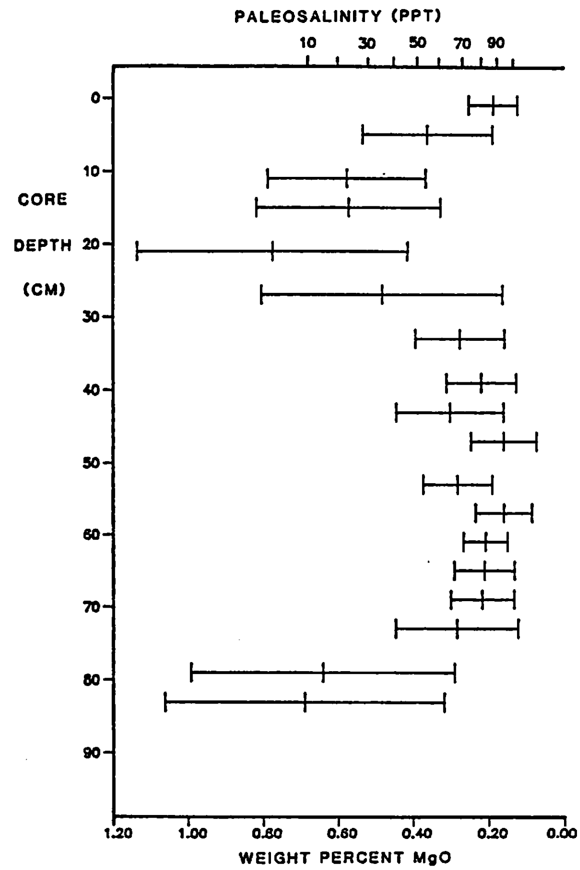

Fig. 2. Distribution of weight percent MgO (and correlative paleosalinity) in *Cyprideis americana* within core from Salt Pond.

The prediction, based on ostracode assemblages (Fig. 1), of low initial and higher subsequent salinity is at least partially confirmed as shown in Figure 2. The salinity minimum at approximately 20 cm and subsequent increase to the current high were not predicted. In fact, the low salinity interpreted at the top of the core using ostracode assemblages is clearly erroneous. The latter observation should not be particularly surprising in view of the salinity (283 ppt.) recorded at the time of core collection.

The association of the brackish *P. bicelliforma* in assemblages with *C. americana*, whose magnesium content indicates salinites of approximately 70-90 ppt., may seem enigmatic. However, it is unlikely that these two species coexisted, at least as adults. Because of the lake's shallow depth, seasonal rainfall may considerably reduce salinity permitting colonization by *P. bicelliforma* as well as euryhaline species. With the increasing salinity of the dry season *P. bicelliforma* perishes, other than in the egg stage perhaps, but *C. americana* survives to salinities approaching 100 ppt. The reason for the predominance of *P. bicelliforma* throughout most of the core is unknown. Possibly it is a more fecund species.

The salinity trend, based on magnesium content, closely resembles that of previously studied lakes, and we correlate the interval from approximately 25 to 70 cm with the *Hemicyprideis setipunctata* zone of Crotty and Teeter (1984), the upper *Xestoleberis* zone of Sanger and Teeter (1982), and the normal marine zone of Luginbill (1983).

LITHOLOGY

The Holocene sediment of Salt Pond is largely poorly sorted silt sized carbonate with some mud and sand sized material. Apart from the upper, more organic-rich 10 cm, which are black to dark gray, the core exhibits subtle, mainly gray color changes. Some of the sand sized fraction resembles beach ' sediment and may represent wind--blown or washover deposits from the nearby beach.

An approximately 1 gm split from each interval was leached in 10% hydrochloric acid, to determine the percent abundance of carbonate, then heated to 900°C in a muffle furnance to determine the percent abundance of organic matter. The fraction remaining is insoluble inorganic residue. The carbonate and insoluble organic residue content is plotted in Figure 3. The carbonate content typically varies from 84 to 96%. The organic content varies from a high of 8.1%, at the top of the core, to a low of 0.8%. The insoluble inorganic residue typically varies from 1.5 to 8.2%. The higher abundance of insoluble organic residue at interval 38-40 cm and especially 46-48 cm reflects the presence of gypsum which substantiates the hypersalinity indicated by the magnesium content of *C. americana* throughout this part of the core.

The insoluble inorganic residue from the 26-28 cm interval to the top of the core reveals consistently higher abundances (4.6 to 8.1%) than the rest of the core, possibly indicating increased soil erosion resulting from clear cutting by colonists. The insoluble inorganic residue was dissolved in molten lithium metaborate and the resultant glass beads were subsequently microprobed in a nine element analysis. The elements probed include Si, Al, Fe, Mg, Ca, Na, Sr, Ba, and

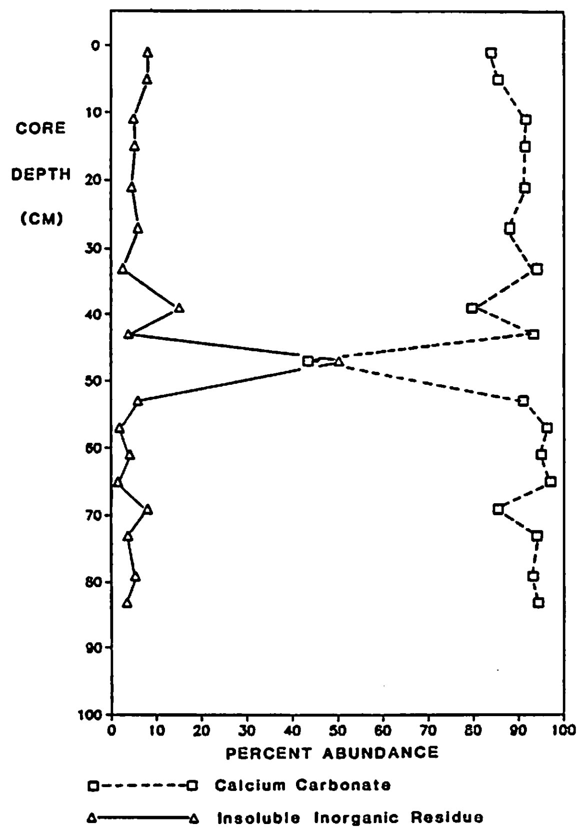

Fig. 3. Calcium carbonate and insoluble inorganic residue in Salt Pond core.

Mn. The purpose of this analysis was to attempt to detect the influx of residual soil following clear cutting. The most likely mineral indicators of residual soils are quartz, clays, and ferric iron oxide, which produces the red pigment in the modern soils of San Salvador. However, the use of silica to indicate the presence of quartz and clays may be invalidated by the presence of biogenically precipitated opaline silica diatom frustules. Also under the reducing conditions within lake sediments, ferric iron oxide may be reduced to the more soluble ferrous state and thus leached from the system. Based on its relative immobility, it was decided to use aluminum whose principle source is the clay fraction of residual soils. Figure 4 indicates the distribution of aluminum expressed as mole percent of the nine oxides probed in the Salt Pond core. We suggest that the aluminum peak at 26-28 cm may indicate the advent of clear cutting and increased soil erosion. Comparable aluminum abundances at the bottom of the core may indicate higher rates of erosion caused by increased precipitation suggested by lowered salinities (Fig. 2).

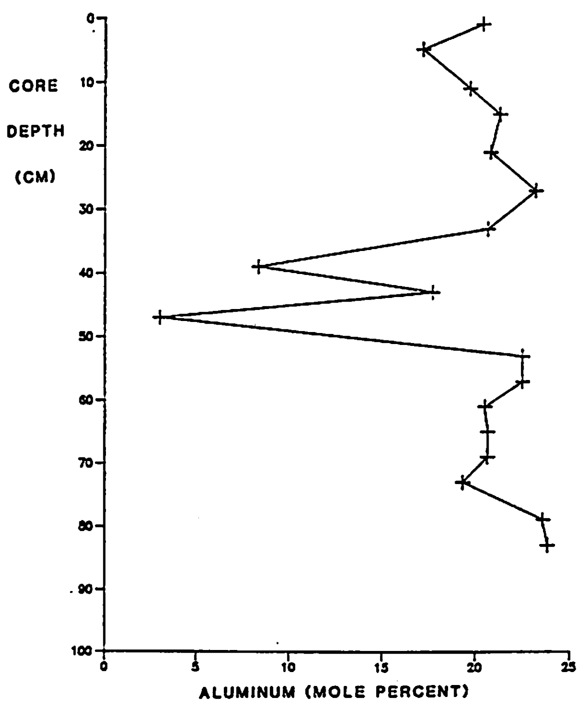

Fig. 4. Distribution of aluminum expressed as mole percent of the 9 oxides probed in the Salt Pond core.

Another split from each interval was leached in 10% hydrochloric acid to remove the carbonate and treated with Chlorox to remove organic matter. The residue was X-rayed to determine the minerals present. This analysis demonstrated the presence of quartz in all intervals, illite and chlorite in nearly all intervals, scattered ccurrences of plagioclase, a single occurrence of orthoclase and gypsum in the intervals at 38-40 and 46-48 cm. The ultimate source of the siliclastics is likely windblown materials from the Sahara (Glaccum and Prospero, 1980).

CONCLUSIONS

Based primarily on salinity controlled magnesium concentrations in *Cyprideis americana* and to some extent, ostracode assemblages, the following salinity history is interpreted (all distances measured from top of core):

4. Upper part of core increasingly saline with time.
3. At approximately 10 to 20 cm, prevailingly brackish.
2. From approximatley 25 to 70 cm, prevailingly hypersaline.
1. Lower part of core prevalingly brackish.

This salinity history parallels that of Little Lake, Watling's Blue Hole, and Reckley Hill Pond, reflecting a common control.

Consistently higher insoluble inorganic residues above 28 cm and the peak aluminum abundance at the same horizon may mark the beginning of clear cutting by colonists and increased soil erosion.

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