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SALINITY HISTORY OF A COASTAL SALINA, WEST CAICOS, BRITISH WEST INDIES

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ABSTRACT

East Salina, 0.4 km wide and 3 km long, lies within a shallow depression behind a 400 m wide Holocene dune system along the windward side of West Caicos Island, BWI. Holocene deposits from the salina exhibit two restrictive-upward carbonate cycles, the uppermost of which is capped by an evaporitic gypsum "mush". The entire sequence rests unconformably upon Pleistocene limestone. Within the carbonate interval five distinct units are recognized in ascending order: (Unit I) basal Burrowed Molluscan Wackestone-Packstone; (Unit II) Laminated Wackestone; (Unit III) Burrowed Molluscan Wackestone; (Unit IV) Peneroplid Packstone; (Unit V) Laminated Mudstone-Wackestone. A low diversity restricted-marine molluscan assemblage characterizes units (I), (III), and (IV), whereas units (II) and (V) are devoid of molluscs, as is the overlying gypsum interval (unit VI).

Ostracodes preserved in the carbonate interval represent three assemblages: (1) Lacustrine assemblage of four species characteristic of enclosed bodies of water having salinities ranging from brackish to hypersaline; (2) Transitional assemblage of at least three species found elsewhere in saline lakes and on open carbonate platforms, typically in waters of normal marine salinity but tolerant of some salinity fluctuation; (3) Marine assemblage, a diverse fauna typical of unrestricted carbonate platforms with normal marine salinity. Initial Holocene deposition (Unit I) is dominated by marine ostracodes followed by a lacustrine assemblage (Unit II) in which salinities were probably hypersaline. During deposition of Unit III the marine assemblage dominates. A lacustrine fauna prevails throughout the remainder of the carbonate interval (Units IV and V), suggesting a return to hypersaline conditions. Above the carbonate interval, extreme hypersaline conditions resulted in the precipitation of gypsum and proved too harsh for ostracodes and other calcifying fauna. The two restrictive upward cycles represented by basal Unit I through Unit II, and Unit III through Unit VI likely reflect periodic breaching and closing of the Holocene dune system separating the salina and the carbonate platform.

INTRODUCTION

The purpose of this paper is to report on the salinity history of an intra-island basin known as East Salina located on West Caicos Island in the British West Indies (Figs. 1 and 2).

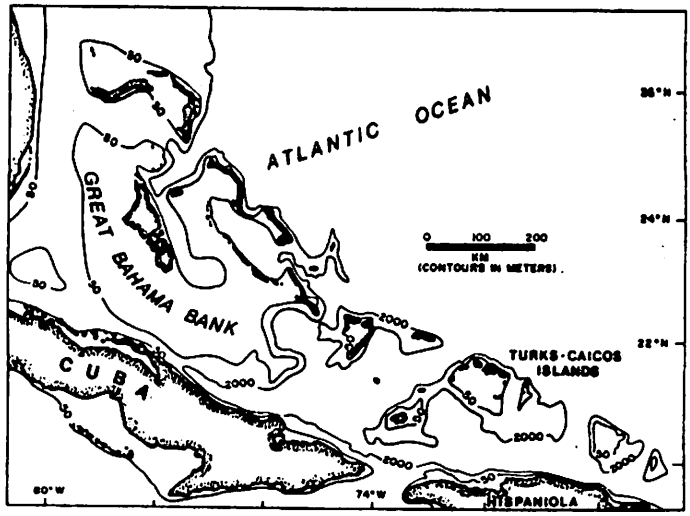


Fig. 1. Regional setting of Turks and Caicos Islands, British West Indies (figure courtesy of R.D. Perkins).

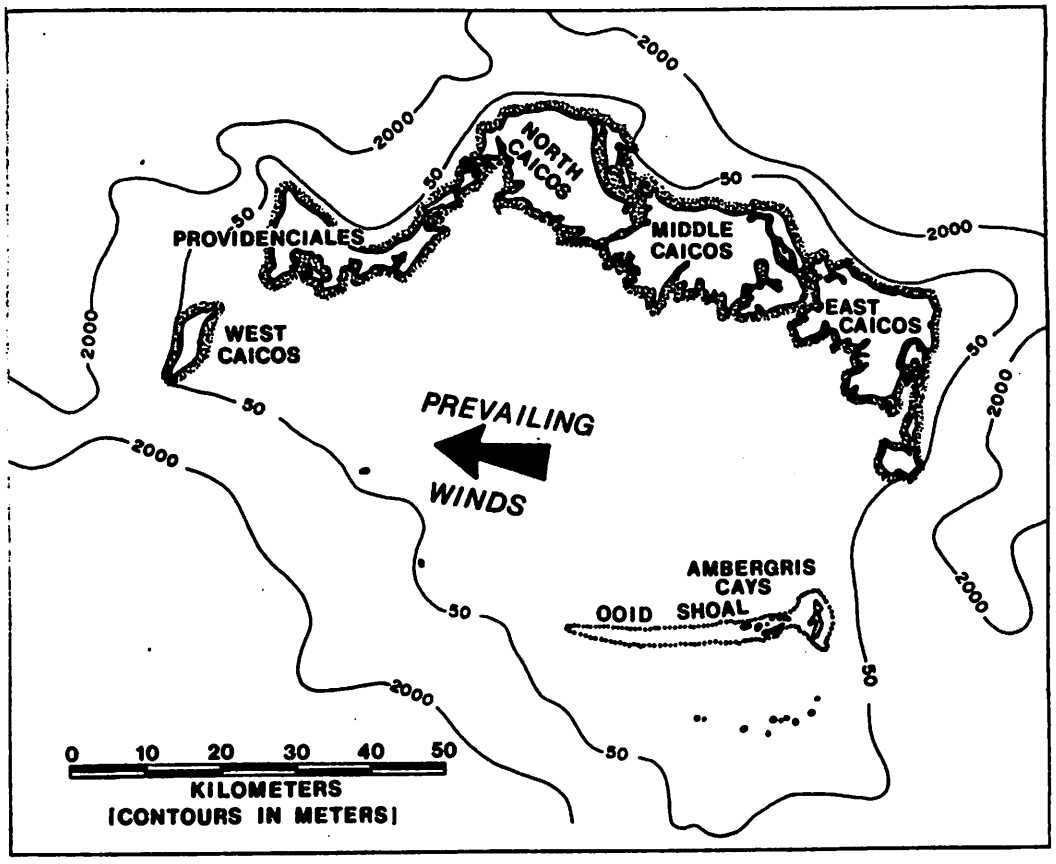


Fig. 2. Index map of Caicos Platform. East Salina is located along the windward side of West Caicos Island (after Lloyd *et al*, 1987).

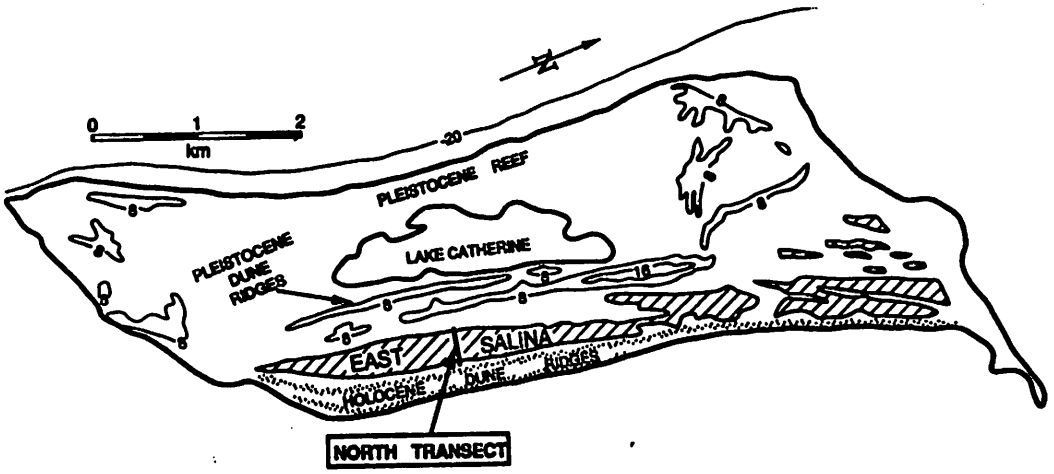


Fig. 3. Index map of West Caicos Island. East Salina is the largest of a string of salinas on the eastern side of the island. Sediment cores for this paper were collected along North Transect. Results from analysis of sediment cores collected along a "South Transect" (350 m south) are not discussed herein since they are similar to those of the North Transect. Contours in meters.

East Salina lies along the eastern side of West Caicos Island in an elongate depression behind a sparsely cemented Holocene oolitic dune/beach system (Lloyd *et al*, 1987) (Fig. 3). Pleistocene eolianite ridges bound the salina to the west. Within East Salina, unconsolidated Holocene carbonate and evaporite sediments have accumulated unconformably upon Pleistocene limestone in an eastward thickening wedge, attaining a maximum thickness of 2.2 meters before merging with the Holocene dune/beach system. The essentially flat salina surface lies approximately 0.4 m below mean tide, is covered by a blistered gypsum-encrusted algal mat, and remains dry throughout most of the year. Seawater saturates the salina sediments from below and becomes increasingly hypersaline toward the surface and westward primarily due to evaporation (Rosoff, 1990).

Detailed analysis of plastic-impregnated polished slabs prepared from 25 East Salina sediment cores indicates the presence of 6 stratigraphic units within the Holocene sediment wedge. The textural and mineralogical character of these units, and the sequence in which they occur suggests that deposition in East Salina has occurred in 2 restrictive upward carbonate cycles, the uppermost of which is capped by gypsum mush. To determine the paleosalinity conditions of each stratigraphic unit, a core containing the six unit succession was subsampled for faunal analysis. The diversity and relative abundance of Mollusca and Foraminifera were qualitatively examined since they are found in only 3 of the 6 units. Ostracodes, on the other hand, are much more vertically ubiquitous, occurring in 5 of the 6 stratigraphic units. Their use in paleosalinity reconstructions in other Bahamian intra-island basins is well documented (Teeter, 1989 and references therein). Therefore, our quantitative faunal analysis efforts focused on the ostracodes.

The results of the faunal analyses combined with the textural and mineralogical character of each stratigraphic unit are the basis for our interpretation of the salinity history of East Salina.

SALINA STRATIGRAPHY AND SEDIMENTOLOGY

A vertical succession of 6 discrete stratigraphic units occurs within the Holocene salina sediments and is shown as an ideal sequence in Figure 4. Descriptions of the textural and mineralogical character of each unit are displayed along the right side of the figure with average thickness of each unit. Dunham's (1962) carbonate rock classification system is used, although these deposits are primarily unconsolidated.

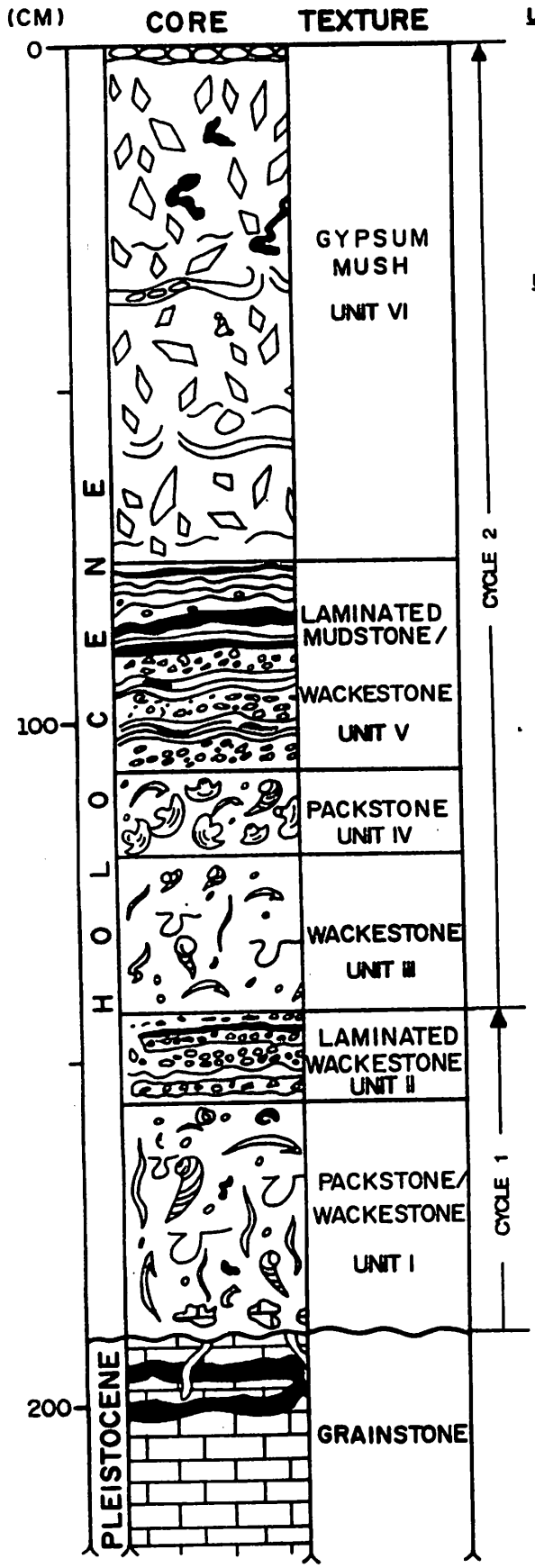
The salina sequence is interpreted as two restrictive-upward cycles with the mollusc and foram rich units (I, III, and IV) representing moderately restricted marine conditions and the algal laminated units (II and V) and gypsum mush (Unit VI) reflecting deposition under highly restricted conditions. The highly restricted carbonate units lack marine indicators such as molluscs and forams, are well laminated, and contain lithified micritic grains and layers (crusts) composed of aragonite and/or high magnesium calcite. These lithified carbonates commonly display gypsum crystal molds and apparently precipitated under hypersaline conditions. Similar precipitates have been observed in the shallow hypersaline ponds (salinity=62-140 o/oo; Rosoff, 1990) present on the salina surface and in other modern hypersaline peritidal settings such as Lake MacLeod, Australia (Logan, 1987), the northwestern Bahamas (Dakoski and Bain, 1984; Mitchell, 1987; Neumann, *et al*, 1989), and Belize (Ebanks, 1975). Units I and III contain vertical root sheaths interpreted as remnants of saline-water grasses, and are replete with burrows. These factors suggest less restricted conditions than during deposition of Units II, V, and VI.

The lateral distribution of the 6 stratigraphic units is depicted in an east-west cross-section in Figure 5. Location of this ("North") transect is indicated on Figure 3. As shown, the salina sequence is abbreviated over Pleistocene bedrock highs reflecting non-deposition of older units. Carbon-14 dates from Unit I (well-preserved molluscan material) and Unit IV (well-preserved peneroplids) are 4,840 $\pm$170 YBP and 3,210 $\pm$110 YBP respectively, though these dates may be erroneously old due to "dead" carbon contributed by Pleistocene limestone (Neumann personal communication; Teeter, 1989).

FAUNAL ANALYSIS

Sediment core 16 contains the entire stratigraphic sequence and was selected for

IDEAL SALINA SEQUENCE



UNIT VI Gypsum Mush (60 cm)

Unit VI is a gypsum mush made up of randomly oriented lenticular gypsum crystals averaging 0.75 mm in diameter. This unit is 90 to 95% gypsum, with carbonate material such as windblown ooids and precipitated micritic aggregates making up the remaining 5 to 10%. These carbonates often occur in layers adjacent to algal and remnant-algal laminations. Algal laminations are often deformed, indicating displacive gypsum precipitation and/or previous intense blistering and dessication as observed on the present salina surface. Calcifying fauna are not present in Unit VI probably due to the high salinities necessary to precipitate gypsum.

UNIT V Laminated Mudstone - Wackestone (30 cm)

Unit V is dominated by cm-scale laminations of micritic carbonate primarily composed of aragonite. Magnesium calcite (8-9 mol% $MgCO_3$), and protodolomite are major and minor components, respectively (Rosoff, 1990). As in Unit II, ostracodes are the only preserved calcifying fauna present in Unit V. Preserved algal mat laminations are abundant. Cm-scale layers of intraclastic packstones and grainstones are common.

UNIT IV Peneroplid Packstone (9 cm)

Unit IV is a packstone dominated by the larger foraminifer *Peneropils proteus*. A low diversity molluscan assemblage, miliolid forams, and ostracodes are also present.

UNIT III Burrowed Molluscan Wackestone (15 cm)

Unit III is very similar in character to Unit I, although it contains more mud and lacks lithoclasts of Pleistocene limestone except where it contacts bedrock in the western portion of the salina.

UNIT II Laminated Wackestone (10 cm)

Unit II is dominated by laminations of intraclast-pelletoid wackestones and occasional packstones. Centimeter thick lithified crusts are common and often contain molds of gypsum crystals. These crusts are dominantly aragonite and rarely high magnesium calcite (13 mol% $MgCO_3$). Protodolomite is a major component of Unit II comprising 5 to 25 % of the bulk mineralogy. Black algal laminations are common. Calcifying macrofauna are absent and microfauna are dominated by ostracodes.

UNIT I Burrowed Molluscan Wackestone - Packstone (30 cm)

Unit I is dominated by burrowed aragonite mud with vertical root sheaths (salt grasses?). Non-skeletal grains include black and white Pleistocene lithoclasts which increase in size and abundance toward the base, and pelletoids which are randomly distributed. Ooids occasionally are encountered increasing in abundance eastward, apparently transported in from adjacent dune/beach sands.

A low-diversity, molluscan assemblage dominates the skeletal material in Unit I, along with miliolid forams and ostracodes. Well worn fragments of *Halimeda* plates are a rare occurrence.

The top of Unit I is commonly lithified and rich in calcian protodolomite which has apparently replaced aragonitic muds; while aragonitic shells have undergone partial to total dissolution resulting in shell moldic porosity.

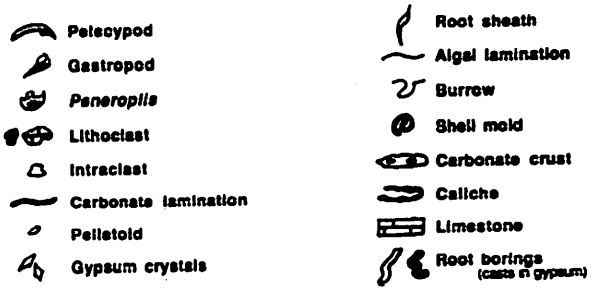


Fig. 4. Ideal salina stratigraphic sequence. Dunham's carbonate rock classification system is used although the Holocene deposits are primarily unconsolidated. The underlying Pleistocene limestone is a well lithified ooid/skeletal fragment grainstone.

faunal analysis. The >150 micron fraction from sixteen 1.5 cm subsamples was examined for type, abundance, and diversity of calcifying faunal constituents. Samples from the carbonate units (I - V) contain varying assemblages of molluscs, foraminifers, and ostracodes. Samples from the gypsum unit (VI) are barren of calcifying fauna, except at the contact with the underlying carbonates.

Mollusca

Vokes and Vokes (1983) was used to identify the molluscs.A depauperate,low - diversity molluscan assemblage is present in Units I, III, and IV, whereas Units II and V are devoid of molluscs. The assemblage is dominated by pelecypods *Anomalocardia, Parastarte*, and *Chione*, and gastropods *Cerithidea, Cerithium, Odostomia*, and *Ultriculastrata*. These genera are characteristic of restricted shallow marine environments (Ebanks, 1975; Vokes and Vokes, 1983; Schreiber, 1988; Teeter, 1989). The total number of molluscan genera (diversity) present in core 16 subsamples is displayed in Figure 6. Diversity peaks occur in the central portion of Unit I and at the top of Unit III, indicating that conditions

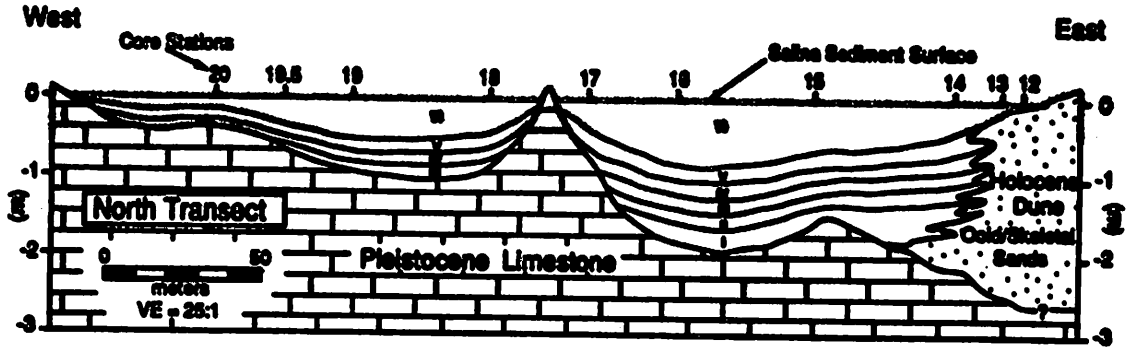


Fig. 5. Salina stratigraphic cross section constructed from North Transect sediment cores. Datum is the present salina sediment surface which is approximately 40 cm below mean tide (levelling survey and tide monitoring, May 1989).

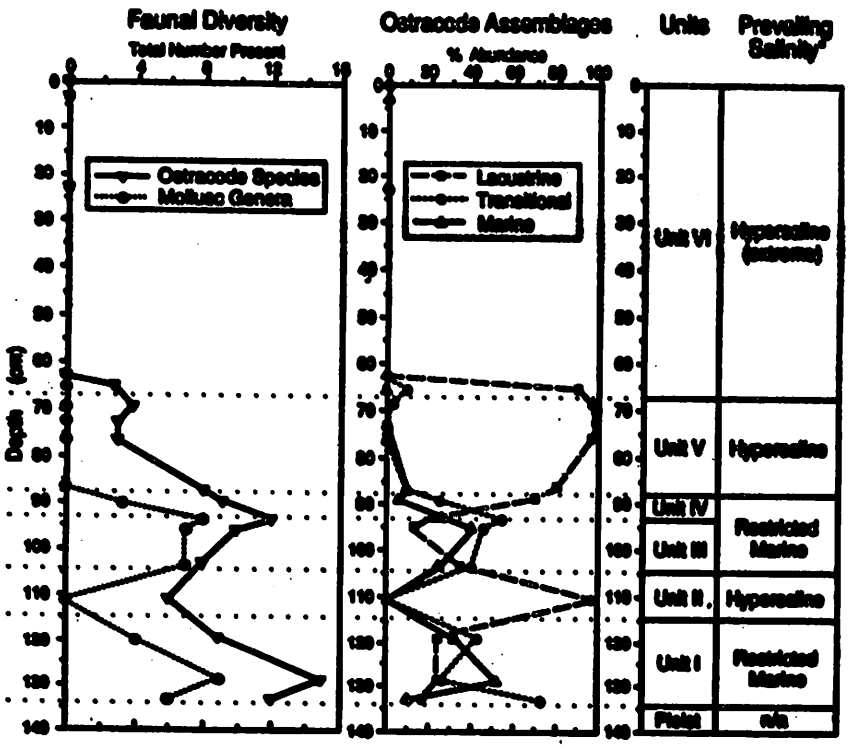


Fig. 6. Results of faunal analyses from sediment core 16. Stratigraphic units and interpreted prevailing salinity are shown on right. *See text for elaboration of salinity interpretation. Depths are shallower than in cross section due to uncorrected core compaction.

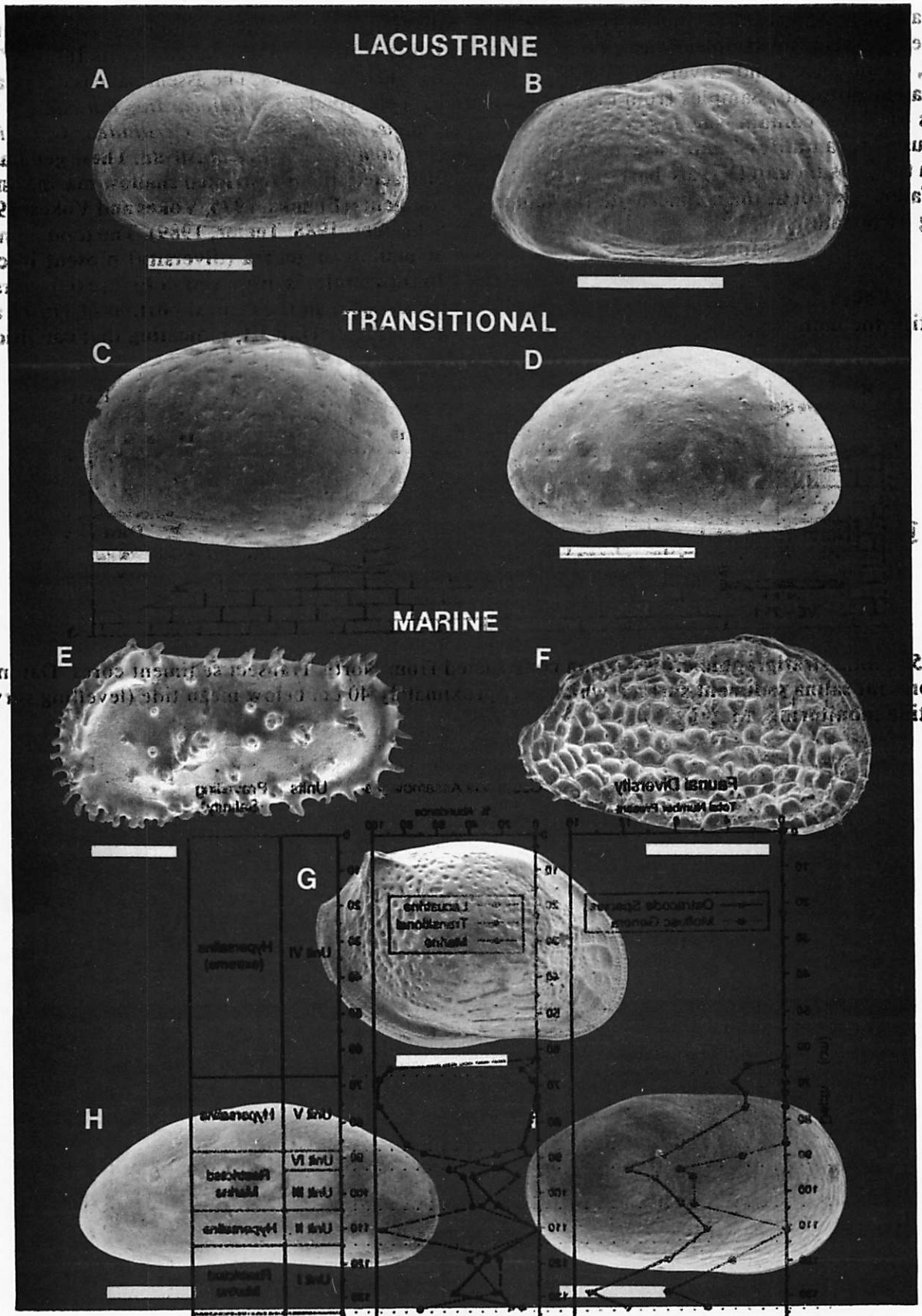


Fig. 7. Representative Holocene ostracodes from East Salina, West Caicos, B.W.I. Lacustrine species: A. *Cyprideis similis* (Brady), male, left valve. B. *Perissocytheridea bristoli formosa* Swain, female, right valve. Transitional species: C. *Hemicyprideis setipunctata* Brady, female, left valve. D. *Xestoleberis curassavica* Klie, male, left valve. Marine species: E. *Actinocythereis bahamensis* (Brady), male, left valve. F. *Aurila floridana* (Benson and Coleman), female, right valve. 6. *Loxoconcha postdorsoalata* Puri, female right valve. H. *Triangulocypris laeva* (Puri), right valve. I. *Cytherella arostrata* Kornicker, male, right valve. Bar scale equals 200 microns.

were least restricted during deposition of these intervals.

Foraminifera

Wantland (1975) was used to identify the foraminiferans. Much like the molluscs, benthic forams are abundant within carbonate units I, III, and IV, and are rare or totally absent from carbonate units II, and V, and the gypsum mush (unit VI). The foraminiferal assemblage is dominated by species of the miliolids *Quinqueloculina* and *Triloculina*, except in unit IV, which is dominated by *Peneroplis*. Accumulations of these forams have been observed in other shallow restricted-marine settings with salinities ranging from normal marine (35 o/oo) to hypersaline (70 o/oo) (Mitchell, 1987; Logan, 1987; Teeter, 1989).

Ostracoda

Ostracodes in core 16 may be divided into three assemblages, lacustrine, transitional, and marine, representative specimens of which are illustrated in Figure 7. Vertical distribution of the ostracode assemblages is recorded in Figure 6. Of the four species present in the lacustrine assemblage, *Perissocytheridea bicelliforma* typically occurs at salinities of 10 to 20 o/oo whereas the remaining three, *Dolerocypria inopinata*, *Cyprideis similis* and *C. americana*, range from brackish to hypersaline conditions. the latter species, so common throughout the Bahamas, is rare in East Salina.

Species of the transitional assemblage include *Hemicyprideis setipunctata*, which overwhelmingly predominates, *Xestoleberis curassavica* and *Loxoconcha purisubrhomboidea*. All three species exhibit a broad salinity tolerance but live most abundantly at approximately normal marine salinity.

The marine assemblage consists of 13 species all of which live in open marine conditions. In the intervals examined in core 16 no single species of this assemblage dominates the population.

The high diversity and dominance of the transitional and marine assemblages in units I and III suggest open interchange between the salina and the marine waters of the carbonate platform. Reduced diversity and dominance of the lacustrine assemblage in unit IV reflects increasing restriction and salinity within the salina.

Low diversity and dominance of the lacustrine assemblage in units II and V suggest complete restriction and hypersaline conditions. Although the dominant ostracode is the brackish water species *P. bicelliforma*, conditions were probably prevailingly hypersaline. The dominance of *P. bicelliforma* may reflect its presumed opportunistic nature - multiplying rapidly after salinities had been reduced, possibly following tropical storms - as suggested elsewhere (Teeter *et al*, 1987).

The extremely low numbers of *C. americana* throughout core 16 prevented using the Mg content of this species to determine paleosalinity (Teeter and Quick, 1990). However, the upper three intervals in unit II from neighboring core 15 produced enough specimens for Mg analysis. The results (Table 1) clearly show that Unit II was hypersaline and that approaching the contact with Unit III salinity decreases.

SUMMARY

Mineralogy, sediment textures and structures, and paleontology reveal two upwardly restrictive cycles within the Holocene deposits of East Salina. Each cycle begins with moderately restricted marine salinity and terminates with hypersaline conditions. Assigning an absolute

Interval (cms)	Average Weight Percent MgO	Paleosalinity (o/oo)
95.0-96.5	.39	67
96.5-98.0	.34	78
98.0-99.5	.27	94

Table 1. Paleosalinities derived from analysis of Mg content of the carapace of Cyprideis americana. Five fresh adult valves were selected from each of three intervals from uppermost Unit II, core 15. Each sectioned valve was microprobed medially at three separate points and the 15 analyses averaged for each interval.

paleosalinity to each stratigraphic unit is not possible. Instead, a salinity range for each unit should be considered. The restricted marine units (I, III and IV) had salinity which hovered around normal marine and probably ranged to moderately hypersaline (60 o/oo?). However, during deposition of units in which hypersaline conditions prevailed (II, V and VI), the salinity range was much greater, fluctuating from brackish to extremely hypersaline (> 150 o/oo necessary for gypsum precipitation).

The two restrictive upward cycles observed in East Salina likely reflect periodic breaching and closing of the Holocene dune system separating the salina and the open marine platform.

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REFERENCES CITED

Dakoski, A.M., and Bain, R.J., 1984, Recent microbial mats and stromatolites of Granny Lake, San Salvador, Bahamas: in Teeter, J.W., ed., Proceedings of the Second Symposium on the Geology of the Bahamas, CCFL Bahamian Field Station, San Salvador, Bahamas, p. 17-26.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture: in Ham, W.E., ed., Classification of Carbonate Rocks, American Association of Petroleum Geologists Memoir 1, p. 108-121.

Ebanks, W.J., 1975, Holocene carbonate sedimentation and diagenesis, Ambergris Cay, Belize: in Wantland, K.F. and Pusey, W.C., eds., Belize shelf-carbonate sediments, clastic sediments, and ecology, American Association of Petroleum Geologists Studies in Geology, no. 2, Tulsa, Oklahoma, p. 234-296.

Lloyd, M., Kerr, S.D., Perkins, R.D., and Cole, S.A., 1983, Recent carbonate sedimentation seminar, Turks and Caicos Islands, British West Indies: 4th ed., Guidebook, Flamingo Associates Seminars Inc.

Lloyd, M., Perkins, R.D., and Kerr, S.D., 1987, Beach and shoreface ooid deposition on shallow interior banks, Turks and Caicos Islands, British West Indies: Journal of Sedimentary Petrology, v. 57, no. 6, p. 976-982.

Logan, B.W., 1987, The Macleod Evaporite Basin Western Australia: American Association of Petroleum Geologists Memoir 44, Tulsa, Oklahoma, 140p.

Mitchell, S.W., 1987, Sedimentology of Pigeon Creek, San Salvador Island, Bahamas: in Curran, H.A., ed., Proceedings of the Third Symposium on the Geology of the Bahamas, CCFL Bahamian Field Station, San Salvador, Bahamas, p. 215-230.

Neumann, A.C., Bebout, B.M., McNeese, L.R., Paull, C.K. and Paerl, H.A., 1989, Modern stromatolites and associated mats: San Salvador, Bahamas: in Mylroie, J.E., ed. Proceedings of the Fourth Symposium on the Geology of the Bahamas, Bahamian Field Station, San Salvador, Bahamas, p 235-252.

Rosoff, D.B., 1990, Sediment mineralogy, pore water geochemistry, groundwater hydrology, and hydrocarbon source potential of a Holocene salina, West Caicos, British West Indies: unpublished masters thesis, Duke University, 171 p.

Schreiber, B.C., 1988, Subaqueous evaporite deposition, in Schreiber, B.C., ed., Evaporites and Hydrocarbons, Columbia University Press, New York p. 182-255.

Teeter, J.W., 1989, Holocene salinity history of the saline lakes of San Salvador Island, Bahamas: in Curran, H.A., ed., Pleistocene and Holocene Carbonate Environ-

ments on San Salvador Island, Bahamas, 28th International Geological Congress Field Trip Guidebook T175, p. 35-39.

Teeter, J.W., and Quick, T.J., 1990, Magnesium-salinity relation in the saline lake ostracode *Cyprideis americana*: Geology, v. 18, p. 220-222.

Teeter, J.W., Beyke, R.J., Bray, T.F., Brocculeri, T.F., Bruno, P.W., Dremann, J.E.J., and Kendall, R.L., 1987, Holocene depositional history of Salt Pond, San Salvador, Bahamas: in Curran, H.A., ed., Proceedings of the Third Symposium on the Geology of the Bahamas, CCFL Bahamian Field Station, San Salvador, Bahamas, p. 145-150.

Vokes, H.E., and Vokes, E.H., 1983, Distribution of shallow-water marine Mollusca, Yucatan Peninsula, Mexico: Tulane University, New Orleans, 183 p.

Wantland, K.F., 1975, Distribution of Holocene benthonic Foraminifera from the Belize shelf: in Wantland, K.F. and Pusey, W.C., eds., Belize shelf-carbonate sediments, clastic sediments, and ecology, American Association of Petroleum Geologists Studies in Geology no. 2, Tulsa, Oklahoma p. 234-296.