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REFINEMENT AND TIMING OF SALINITY FLUCTUATIONS IN WATLING'S BLUE HOLE, SAN SALVADOR ISLAND, BAHAMAS

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ABSTRACT

Previous study of the Holocene of Watling's Blue Hole has revealed the presence of four ostracode assemblages: 1. *Cyprideis americana* Zone; 2. Pitted *C. americana* Zone; 3. *Hemicyprideis setipunctata* Zone; and 4. *Perissocytheridea bicelliforma* Zone in ascending order. Each assemblage reflects a prevailing salinity based on the observed salinity range of each zone's dominant species. Other lakes on San Salvador reveal similar, parallel salinity trends through the Holocene.

There are problems in the above application of taxonomic uniformitarianism. Three of the four common lacustrine ostracode species have broad overlapping salinity tolerances. Also, in the Holocene of Salt Pond the dominant ostracode is the brackish species *P. bicelliforma*, although there is good reason to believe that this lake has been hypersaline during much of its history.

An alternative method of paleosalinity interpretation is minor element chemistry of ostracode shells. Because of its wide salinity tolerance (10.8-98.5 ppt), *C. americana* was chosen. In this species, magnesium exhibits an inverse relationship with salinity. Overall, the paleosalinities based on assemblages and magnesium concentrations are similar for Watling's Blue Hole with two differences. In the latter method, each zone exhibits a range in salinity and a salinity minimum occurs at the boundary between each of the four zones. Similar salinity minima have also been observed in Salt Pond. Salinity fluctuations may be in response to variation in sea level or climate.

Accelerator mass spectrometry radiocarbon dates on molluscs at the boundaries between the four zones are 2680±80, 1900±80, and 1360±90 RCYBP. The earliest salinity minimum (2680±80 RCYBP) coincides with a lower stand of sea level. At this time sea level on San Salvador stood between 2.7 and 3.2 m below present. The cause of the salinity minima at 1900±80 and 1360±90 RCYBP is uncertain.

The time frame established by the youngest date and the lack of any younger obvious sedimentologic or paleontologic evidence indicating increased erosion rates during colonial times suggests that pre-colonial soils were neither thicker nor more extensive than present.

INTRODUCTION

The saline lakes of San Salvador Island have supported a low diversity collection of ostracode species throughout the Holocene. These species occur in distinct assemblages representing fresh water, marine and lacustrine environments. The lacustrine assemblage is by far the most common and occurs primarily in brackish and hypersaline conditions.

Crotty and Teeter (1984) recognized four ostracode zones, based mainly on changing abundances of lacustrine species, throughout the Holocene of Watling's Blue Hole. The four zones in ascending order are: 1. *Cyprideis americana* Zone; 2. Pitted *C. americana* Zone; 3. *Hemicyprideis setipunctata* Zone; 4. *Perissocytheridea bicelliforma* Zone. The *C. americana* Zone was interpreted to have a prevailing salinity of approximately 25 ppt whereas the Pitted *C. americana* experienced decreased salinity, probably in the low to mid teens. The ostracode assemblage of the *H. setipunctata* Zone reflects the highest prevailing Holocene salinity, probably between 25 and 35 ppt. The youngest interval, the *P. bicelliforma* Zone, experienced decreased salinity, possibly in the high teens. In their interpretation, Crotty and Teeter (1984) diagrammed the salinity as being relatively constant within each zone. However, in view of observations on salinity of the saline lakes of San Salvador during the past decade it is likely that fluctuation has occurred over prolonged intervals during the Holocene.

Little Lake (Sanger and Teeter, 1982) and Reckley Hill Pond (Luginbill, 1983) also exhibit successive Holocene ostracode assemblages which reflect salinity changes parallel to those interpreted from Watling's Blue Hole.

Salinity interpretations are most easily accomplished when stenohaline fresh water and marine assemblages are present. The much more frequently encountered lacustrine assemblage consists of four species. *Perissocytheridea bicelliforma* is apparently restricted to brackish water whereas the remaining three species, *Cyprideis americana*, *Hemicyprideis setipunctata* and *Dolerocypria inopinata* range from brackish to hypersaline conditions. Although each of the latter three species has a salinity range where it dominates, their overlapping tolerances make it difficult to interpret paleosalinities using taxonomic uniformitarianism.

A related problem was demonstrated in Salt Pond by Teeter et al (1987). The Holocene record here is dominated by the brackish water ostracode *P. bicelliforma* although the current salinity of approximately 300 ppt. and the presence of gypsum beds suggest hypersaline conditions. Clearly, an independent method of paleosalinity determination would help to resolve the above problems.

PALEOSALINITY REFINEMENT USING MAGNESIUM-SALINITY RELATIONSHIP IN *Cyprideis americana*

Because of its broad salinity tolerance (10.8 - 98.5 ppt.) *C. americana* was selected to determine whether any relationship existed between the magnesium content of its low magnesian calcite shell and salinity. Teeter (1988) reported on the inverse relationship between magnesium content, determined by electron microprobing, and the salinity of the water in which individuals of this species were living.

Five adult ostracode valves were selected from each of 23 intervals throughout a 1.98 m core from Watling's Blue Hole. Polished thin sections of these specimens were prepared for WDX electron microprobing. Instrument conditions were as follows: 15 KV; $.5 \times 10^{-5}$ma; beam diameter of approximately 10 microns. Each specimen was probed at 3 points midway through the shell thickness. The results of the analyses are recorded in Figure 1. Figure 2A, a spline curve constructed throughout the mean values of Figure 1, clearly illustrates fluctuating paleosalinity during the Holocene of Watling's Blue Hole. Figure 2B represents paleosalinity interpreted from ostracode assemblages. For direct comparison this latter figure has been modified from Crotty and Teeter (1984) to the same paleosalinity scale as Figure 2A.

At first glance the pronounced fluctuations in the spline curve make it appear distinctly different from the curve based on assemblage data. The fluctuations undoubtedly represent a more realistic situation. If the paleosalinities, determined on weight per cent magnesium oxide, are averaged for the intervals within each of the four zones and compared with those determined from ostracode assemblages the results are quite similar (Table 1). Thus paleosalinity determined from magnesium concentrations in *Cyprideis americana* has independently confirmed the previous interpretation (Crotty and Teeter, 1984) based on ostracode assemblages.

The remarkable feature about the salinity fluctuations (Figure 2A) is the occurrence of distinct salinity minima at the three zone boundaries established by ostracode assemblages. Two similar paleosalinity minima were observed by Teeter et al (1987) in Salt Pond. The zone between these two minima was correlated 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). The presence of the upper two paleosalinity minima in Watling's Blue Hole supports this correlation.

In Little Lake the lower two Holocene zones (lower *Xestoleberis* and *Cyprideis "ovata"* zones) are correlated with the *Cyprideis americana* and Pitted *C. americana* zones respectively in Watling's Blue Hole. In one of the cores from Little Lake the boundary between the two lower zones is marked by a fresh water ostracode assemblage, indicating a salinity minimum (Sanger and Teeter, 1982). This correlates nicely with the oldest salinity minimum in Watling's Blue Hole.

Varying salinity events may have been caused by change in climate, in sea level or interaction between the two (Crotty and Teeter, 1984). Increased precipitation or lowered temperature causing decreased evaporation would produce a lower salinity event. Lowering sea level acts to reduce salinity. As sea level drops, so does the water level in the saline lakes. With shrinking

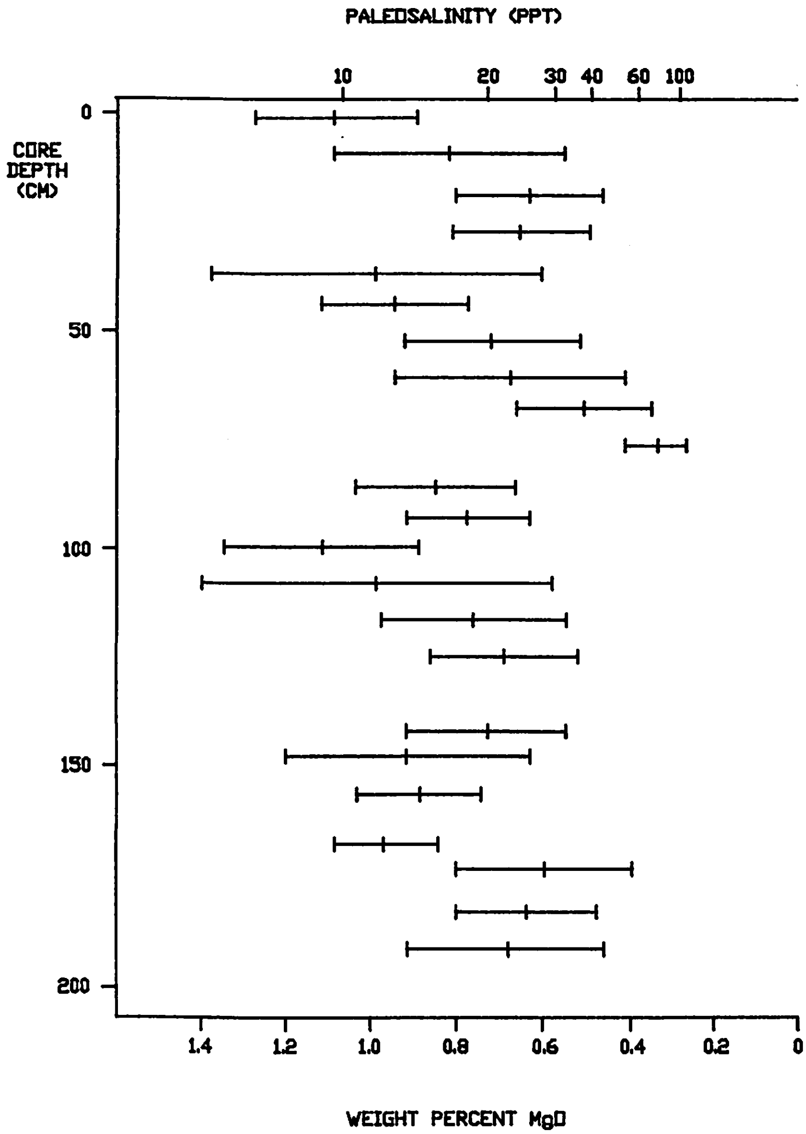

Fig. 1. Distribution of weight percent MgO in C. americana *and correlative paleosalinity, core 2, (Crotty and Teeter, 1984) Watling's Blue Hole. Mean and standard deviation indicated.*

volumes of saline water in the lake basins, precipitation and fresh ground water seepage exert an increasing control on salinity. If sea level should fall below the floor of a lake basin and if that basin were underlain by relatively impermeable materials a fresh water lake would result.

TIMING OF SALINITY-MINIMUM EVENTS

Accelerator mass spectrometry radiocarbon dates (RCYBP) on molluscs at the boundaries between the four ostracode zones are 2680±80, 1900±80 and 1360±90 RCYBP (Figure 2). The youngest two dates were obtained on the pelecypod *Polymesoda maritima* and the oldest date on a collection of Rissoacean gastropods. A live specimen of *Polymesoda maritima* was also dated in order to determine the influence of incorporation of "dead" carbon from the limestone bedrock. This factor was applied to the carbon dates from the core to produce the corrected values above.

DePratter and Howard (1981) presented evidence for a sea level lowstand between 3000 and 2400 years B.P. on the Georgia and adjacent South Carolina coasts. They state that sea level fell to at least 3 to 4 m below present mean sea level. Martin, Suguio and Flexor (1986) record a lowstand of sea level at approximately 2700 years B.P. from the Salvador region of coastal Brazil. Although they do not indicate the precise amount of sea level lowering their figure suggests approximately 1 m.

Therefore, the salinity minimum at 2680±80 RCYBP appears to represent a sea level lowstand. In core 2 from Watling's Blue Hole this horizon

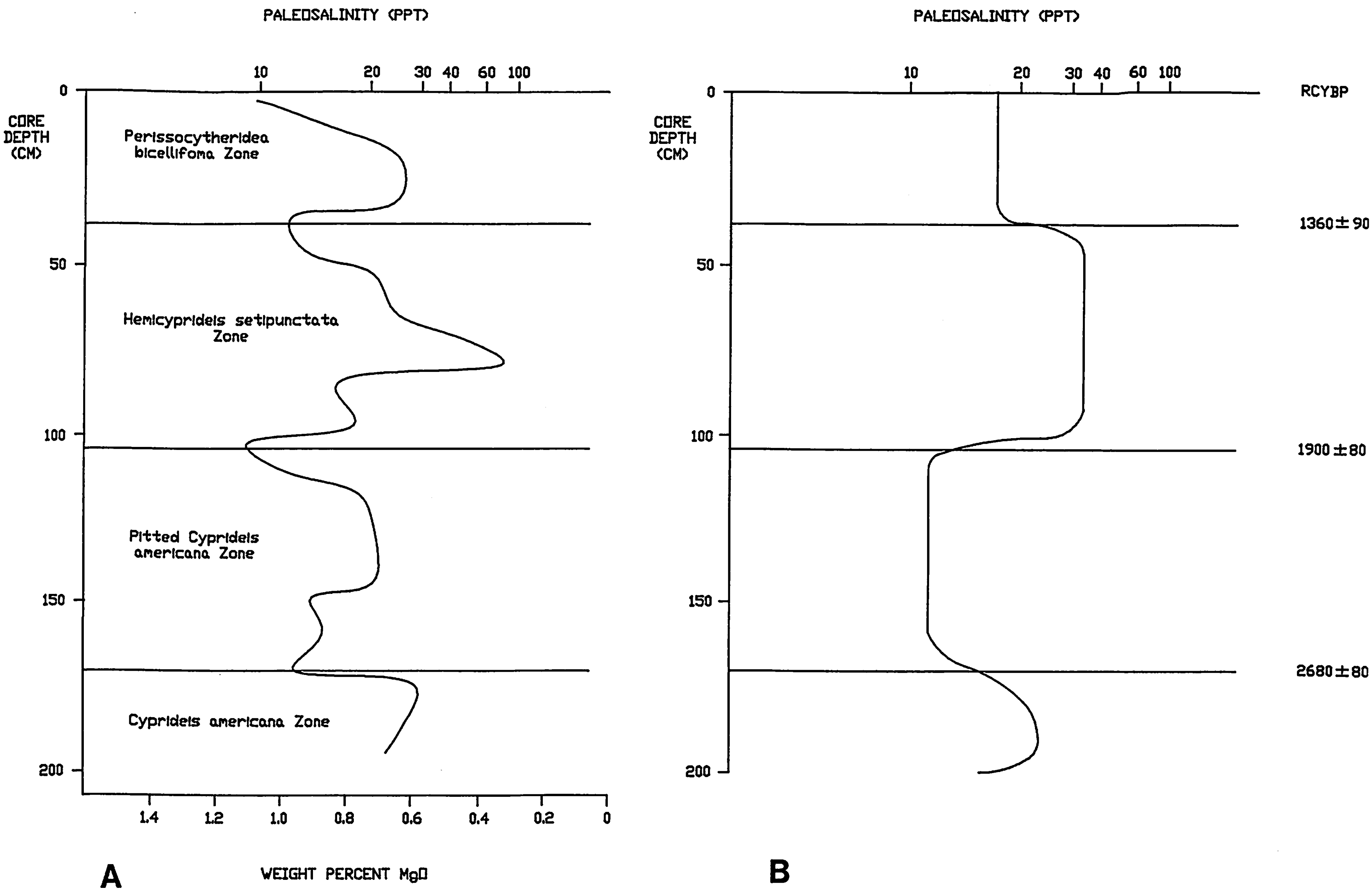

Fig. 2. Paleosalinity interpretations of the Holocene of Watling's Blue Hole. Horizontal lines at approximately 168, 104 and 38 cm represent the boundaries between the four ostracode zones and are dated at 2680±80, 1900±80 and 1360±90 RCYBP respectively. A. Spline curve based on means of weight percent MgO in C. americana. *B. Curve based on ostracode assemblages (modified from Crotty and Teeter, 1984).*

ZONE	PALEOSALINITY (ppt) FROM Mg CONTENT	FROM OSTRACODE ASSEMBLAGES
Perissocytheridea bicelliforma	18	high teens
Hemicyprideis setipunctata	28	25-35
Pitted *Cyprideis americana*	16	low to mid teens
Cyprideis americana	27	approximately 25

Table 1. Comparison of paleosalinities based on magnesium content of *Cyprideis americana* and ostracode assemblages

lies approximately 3.2 m below M.S.L. The brackish water ostracode assemblage here indicates that this elevation lay at or slightly below sea level at this time. In core 9 from Little Lake (Sanger and Teeter, 1982) the correlative horizon lies approximately 2.7 m below lake level which presently lies at or very close to M.S.L. The fresh water ostracode assemblage at this horizon indicates that this part of the lake lay above sea level at that time. Thus, at approximately 2700 years B.P. sea level on San Salvador lay between approximately 2.7 and 3.2 m below present sea level.

The cause of the salinity minima at 1900±80 and 1360±90 RCYBP is uncertain. If these were caused by lowered sea level the absence of any fresh water ostracode assemblages at correlative horizons in other lakes indicates that sea level lowering was less than 2.5 m and 1.9 m respectively.

ADVENT OF SLASH AND BURN AGRICULTURE

The colonization of the Bahamas by British loyalists in the late 1700's brought the introduction of clear cutting and slash and burn agriculture. It has been assumed that such practice would have greatly increased the rate of erosion, flushing soils into the lakes and surrounding marine environments.

Bowman and Teeter (1982) suggested that in Little Lake the advent of the Upper *Quinqueloculina bosciana* zone marked the beginning of slash and burn agriculture. However correlation with Watling's Blue Hole indicates that the Upper *Q. bosciana* zone began prior to 1360 RCYBP. In their study of Salt Pond, Teeter et al (1987) selected a horizon below the youngest salinity minimum as the possible initiation of slash and burn agriculture. This selection was based on increased insoluble inorganic residue and aluminum content.

Clearly both of the above events predate British colonization of the Bahamas by several hundred years. In the absence of any obvious younger sedimentologic or paleontologic evidence of increased erosion rates it is questionable whether the soils exposed by initial clear cutting were any more thick or extensive than present soils.

CONCLUSIONS

Paleosalinities determined by ostracode assemblage data and the application of the magnesium-salinity relationship in *Cyprideis americana* for each of the four ostracode zones in Watling's Blue Hole are closely similar. Fluctuation in paleosalinity, determined from magnesium concentration, is revealed in each of the four zones. Distinct salinity minima occur at each of the boundaries between the four zones. Accelerator mass spectrometry radiocarbon dates from each of the three boundaries are 2680±80, 1900±80 and 1360±90 RCYBP. The oldest boundary marks a lowstand of sea level between 2.7 m and 3.2 m below present. Cause of the younger two salinity minima is uncertain.

Previous speculation on the effect of clear cutting and slash and burn agriculture on erosion rates has been shown to be incorrect. In the absence of any clear sedimentologic or paleontologic evidence of increased erosion rates caused by colonization it is questionable whether soils were any thicker or more extensive than now.

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