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**Cover Photo: Outcrop showing Pleistocene soil profile,
caliche crust, and rhizcretions,
San Salvador, Bahamas.
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SEDIMENTOLOGY AND TAPHONOMY OF A HOLOCENE CARBONATE LAGOON PIGEON CREEK, SAN SALVADOR, BAHAMAS

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INTRODUCTION

In part, sedimentology and paleontology have a similar goal, i.e. to determine the causes and environmental history at the time of sediment accumulation. While their methods differ, both paleontologists and sedimentologists contribute to an understanding of sediment accumulation. A major tenet of carbonate sedimentology is that sediment accumulation is largely derived from *in situ* production. To this end, sedimentologists have compared biogenic production to accumulation and have attempted to evaluate sedimentation rates, transport (export and import), abrasion, pellet and aggregate formation, and skeletal breakdown (Bathurst, 1971; Scoffin, 1988).

In addition to evaluating sedimentary parameters of accumulation, fuller understanding of carbonate accumulation should include a paleontologic perspective. In particular, it is critically important to establish the degree to which the fossil assemblage as seen in the rocks is an accurate reflection of the original biologic community. Promising techniques in determining the environment of deposition have been the utilization of species composition, numerical abundance, preserved biomass, and taphonomic signatures.

We used sedimentological and paleontological techniques to describe the environments of deposition within the very dynamic Pigeon Creek system. What follows is a description of these findings.

THE PIGEON CREEK SYSTEM

Pigeon Creek is a tidally influenced carbonate lagoon covering approximately six square kilometers near the southeastern corner of San Salvador, Bahamas (Figure 1). Here, 34

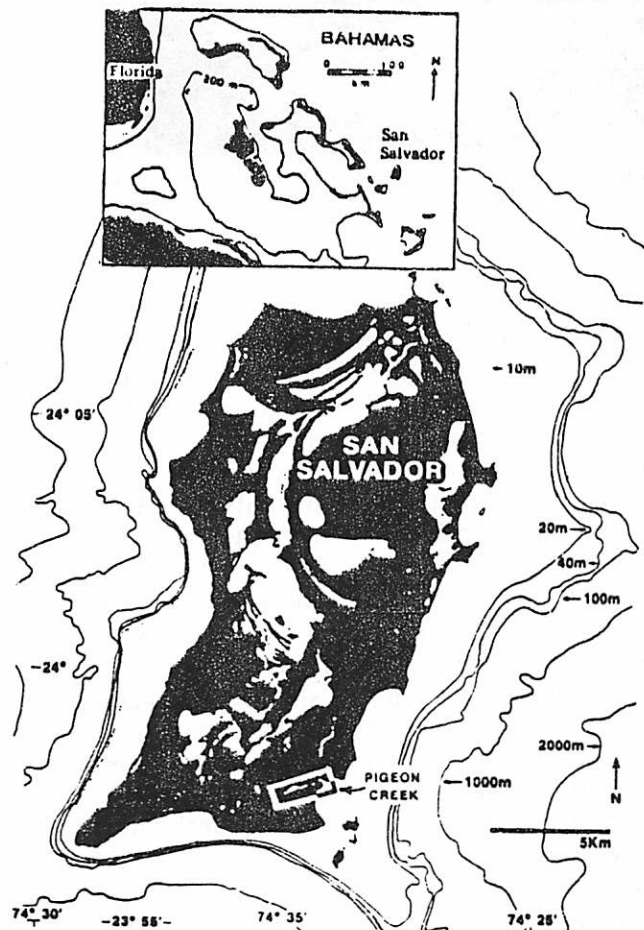


Figure 1: Location map of Pigeon Creek, San Salvador, Bahamas.

shallow-core samples were taken from a wide spectrum of physical environments ranging from the restricted upper reaches of the inlet to high velocity tidal channels and then beyond the ebb-tidal delta (Figure 2). Pigeon Creek is

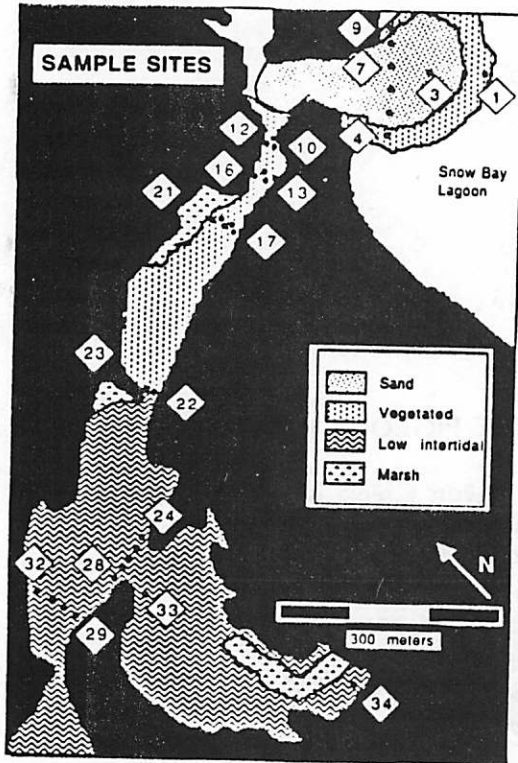


Figure 2: Pigeon Creek study area showing the location of sample sites and major subtidal environments.

the name given to two elongate, narrow arms of a lagoon located in the southeast corner of San Salvador. Within the Pigeon Creek system, there are distinctive sub-environments including: grassbeds (dense, normal, and sparse), sandy bottoms, exposed mud flats at low tide, a tidal delta, and scour pits. The two arms (or branches) are oriented north-south and east-west and are approximately 30 m wide and 2 km long. The arms are connected at the southeast corner where the lagoon is in contact with the more open lagoon, Snow Bay. Portions of the lagoon are shallow subtidal, and other areas are intertidal. Each branch of the lagoon contains a central channel 1 to 3 m deep and is lined by mangroves. Arms of the lagoon are not connected to a continuous source of fresh water (i.e., they are not elongate estuaries). Salinity is generally highest at the enclosed ends and lowest (normal marine) at the connection with Snow Bay (Figure 3). Tidal fluctuations alternately fill

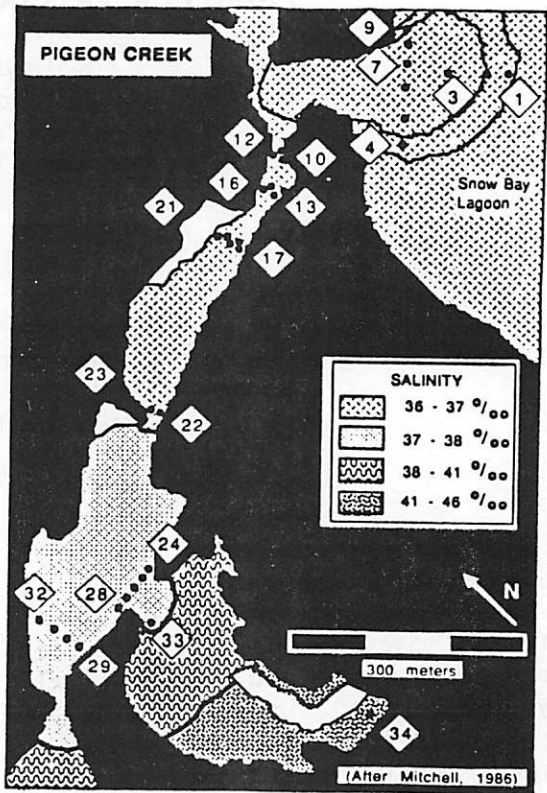


Figure 3: Salinity distributions within Pigeon Creek. Numbers refer to sampling locations.

and empty the lagoon, and tidal currents are very strong. The two branches converge at a narrow inlet, and the resulting tidal currents attain speeds of >70 cm/s (1.5 knots) (Figure 4). These high currents are responsible for

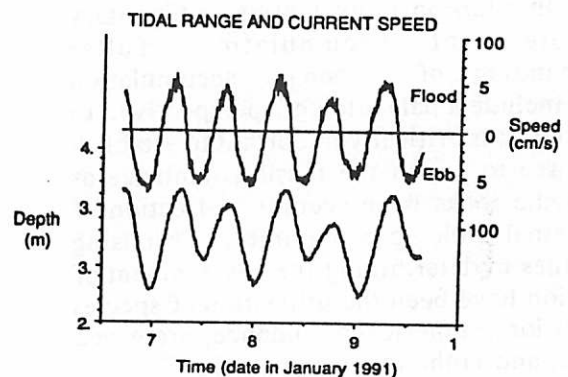


Figure 4: Tidal range and current speed at the throat of the inlet connecting the western arm of Pigeon Creek with the more open lagoon of Snow Bay. Current speeds are clearly related to tidal fluctuation and attain maximum velocities of >70cm/s. There is very little time when currents are not strong at Pigeon Creek

creating and maintaining the deep scour pits seen in the channel throat and the sandy ebb-tidal delta located seaward of the throat.

METHODS

Molluscs

Thirty-four box core samples, 176 cm² x 17 cm deep, were taken from a spectrum of environments in Pigeon Creek. The samples were sieved in the field using a 2 mm screen and preserved in buffered formalin. Samples were transported to Miami University in Oxford, Ohio for analysis. Because many box cores contained over 2000 individuals, a subsampling strategy was employed to facilitate analysis. All molluscs were identified, categorized as right or left valve, whole shell or fragment, and measured (maximum anterior-posterior lengths for bivalves and maximum apex-aperture length and maximum width for gastropods). For taxonomic characterization of the death assemblage, a total of 300 whole shells, when available, were randomly subsampled from each box core. Rarefaction curves, the number of new species collected versus shell count, were generated to verify that 300 shells were enough to adequately sample the number of species in each box core. In the majority of cases, the new species versus shell count plateau was reached after identifying 200 shells. In the 34 box core samples, 9881 molluscs were identified (Table 1).

Taxonomic identification followed Warmke and Abbott (1962), Abbott (1974), Morris (1975), and the West Indies Laboratory, St. Croix, United States Virgin Islands. Biomass, species richness, equitability, the ratios of gastropods: bivalves and infauna:epifauna were also used to characterize the molluscan facies in Pigeon creek (Medahl and Flessa, 1990; Dodd and Stanton, 1990).

Relative Abundance and Biomass Determinations

Relative abundance and biomass were calculated for the top fifteen species from each molluscan facies. The Spearman rank test was used to compare the rank-order of numerical abundance and biomass within each sedimentary facies to compare the preserved

species abundance with biomass. Biomass estimates were calculated from the relation between biomass and shell dimensions (Powell and Stanton, 1985). For bivalves, the equation is: $\text{Log}_{10} \text{Biomass (gm)} = 0.9576 \text{ Log}_{10} L^3 - 4.8939$ where L is the maximum anterior-posterior length in mm. For gastropods, the equation is $\text{Log}_{10} \text{Biomass (gm)} = 0.7708 \text{ Log}_{10} V - 3.2421$ where V is the operational equivalent of shell volume derived, in most cases, from the equation for the volume of a cone, $V = 1/3\pi(W/2)^2L$, where W (mm) is the maximum width and L (mm) is the maximum length. For a complete discussion of the determination of biomass from shell volume and its paleontological significance, refer to Powell and Stanton (1985) and Staff et al. (1985).

Species Richness

Species richness was calculated using the Margalef's index of species richness which minimizes the effect of sample size bias (Odum, 1971; Dodd and Stanton, 1990) using the formula: $D = S - 1 \div \ln N$ where D = species richness value, S = number of species, and N = number of individuals collected.

Gastropod: Bivalve and Infaunal:Epifaunal Ratios

The ratio of gastropods to bivalves and infauna to epifauna may be useful in recognizing molluscan facies, particularly if gastropods and bivalves tend to be more abundant in distinctive environments. For instance, high gastropod:bivalve and low infauna:epifauna ratios may be more common in vegetated areas. The ratios of gastropods to bivalves and infauna to epifauna were calculated using the abundances of individuals encountered. For instance, a sample containing 200 *Cerithium eburneum*, a gastropod, and 100 *Codakia orbiculata*, a bivalve, would have a ratio of 2 gastropods:1 bivalve and 2:1 epifauna:infauna.

Vegetation

Seagrass density was determined by counting the number of seagrass blades within a 23 cm x 23 cm quadrat randomly placed three times at each sampling location. The dominant species were *Thalassia testudinum*,

Species	Numerical Abundance	Relative Abundance (%)
<i>Cerithium eburneum</i> Bruguière, 1792	2525	25.60
<i>Codakia orbiculata</i> (Linné, 1778)	1029	10.41
<i>Cerithium variable</i> C.B. Adams, 1845	785	7.94
<i>Tellina</i> sp. Blainville, 1814	662	6.70
<i>Divaricella quadrisulcata</i> (Orbigny, 1842)	505	5.10
<i>Cerithium literatum</i> (Born, 1778)	465	4.71
<i>Trigoniocardia antillarum</i> (Orbigny, 1842)	441	4.60
<i>Lucina pensylvanica</i> (Linné, 1758)	405	4.10
<i>Modulus carchedonius</i> (Lamarck, 1822)	395	4.00
<i>Bàlla striata</i> Bruguière, 1792	356	3.60
<i>Acmaea pustulata</i> (Helbling, 1779)	281	2.84
<i>Tegula fasciata</i> (Born, 1778)	167	1.69
<i>Semele nuculoides</i> (Conrad, 1841)	151	1.53
<i>Tricolia affinis</i> (C.B. Adams, 1850)	147	1.49
<i>Chione cancellata</i> (Linné, 1767)	131	1.33
<i>Cerithidea scalariformis</i> (Say, 1825)	115	1.16
<i>Anomalocardia brasiliiana</i> (Gmelin, 1791)	112	1.13
<i>Rissoina cancellata</i> Philippi, 1847	103	1.04
<i>Nassarius albus</i> (Say, 1826)	91	0.92
<i>Smaragdia viridis viridemaris</i> Maury, 1917	86	0.87
<i>Turbo castaneus</i> Gmelin, 1791	86	0.87
<i>Polinices lacteus</i> (Guilding, 1834)	86	0.87
<i>Anachis sparsa</i> (Reeve, 1859)	75	0.76
<i>Codakia orbicularis</i> (Linné, 1758)	71	0.72
<i>Brachidontes exustus</i> (Linné, 1758)	58	0.59
<i>Bailya parva</i> (C. B. Adams, 1850)	57	0.58
<i>Olivella floralia</i> (Duclos, 1853)	44	0.45
<i>Vermicularia spirata</i> (Philippi, 1836)	35	0.35
<i>Barbatia cancellaria</i> (Lamarck, 1819)	33	0.33
<i>Crenella divaricata</i> (Orbigny, 1845)	31	0.31
<i>Retusa sulcata</i> (Orbigny, 1842)	29	0.29
<i>Haminoea succinea</i> (Conrad, 1846)	20	0.21
<i>Pinctada radiata</i> (Leach, 1814)	21	0.21
<i>Dentalium</i> sp. Linné, 1758	18	0.18
<i>Arcopsis adamsi</i> (Dall, 1886)	18	0.18
<i>Columbella mercatoria</i> (Linné, 1758)	17	0.17

Table 1: Species listing of the top 36 species found at Pigeon Creek. These species represent 9649 individuals and 97.8% of the molluscs collected in the study.

Syringodium filiforme, and *Halodule wrightii*. Seagrass cover was quantified by converting blade counts to a seagrass coefficient designed to account for the varying surface area of the three species of seagrass. Estimates of surface area were based upon calculations by Miller (1988): .0025 cm² for *Halodule*. The seagrass coefficient, modified from Miller (1988) was then calculated for each sampling station where: $V = (T \cdot .0025) + (S \cdot .0007) + (H \cdot .0002)$, where T, S, and H are the densities per m² of *Thalassia*, *Syringodium* and *Halodule*. The distribution of seagrass density is shown in

Figure 5 and Table 2. The densest grass is found seaward of the ebb-tidal delta.

Taphonomic Signatures

Taphonomic signatures were determined on 20 shells of the bivalve *Codakia* sp. and 20 of the gastropod *Cerithium* sp. These genera were abundant in the majority of the thirty-four samples taken from the four sedimentary facies.

Each shell was measured and taphonomically "scored" under a binocular

Sedimentological Determinations

Standard wet sieve analysis was used for sediment texture determination. All samples were soaked in 50% Clorox solution and rinsed to remove organics prior to sieving. Pipette analysis was performed to determine the <63, <16, and <4 micron size fractions.

To determine sediment composition, at least 300 sediment grains in the 1-2mm size fraction were identified from each sample. This size fraction was chosen because it provided the greatest number of readily identifiable grains. Compositional categories included *Halimeda*, bivalves, gastropods, foraminifera, aggregates, abraded grains, and other skeletal components (including crab fragments, bryozoans and echinoderms).

Cluster Analysis

To determine the sedimentary and molluscan biofacies in Pigeon Creek, Q- and R-mode cluster analysis were employed (Dodd and Stanton, 1990). While recognizing the limitations of this technique (Miller and Cummins, 1990), cluster analysis is useful in recognizing natural groupings of sedimentary environments and organisms that reflect the physical and biological structure of the Pigeon Creek ecosystem.

Sedimentological Facies Determination

Grain compositional variables along with percent mud were analyzed by cluster analysis to compare the sedimentological characteristics among samples. The program CLAP (written by Sepkoski and Sharry (1976) and modified for microcomputer by Miller (1988)) was used to perform Q- and R-mode analyses using Unweighted Pair-Group Method with Arithmetic Averaging (UPGMA). Analyses were accomplished using the mean character distance coefficient on standardized data. A combination of Q- and R-mode analyses provided a two way cluster analysis from which sedimentary facies were derived.

Four major groupings of sedimentary parameters were identified by cluster analysis (Figure 6). These groups are considered to be sedimentary facies and have been assigned textural names based upon the most abundant and diagnostic allochem within each cluster group (Table 1). The four facies are: 1)

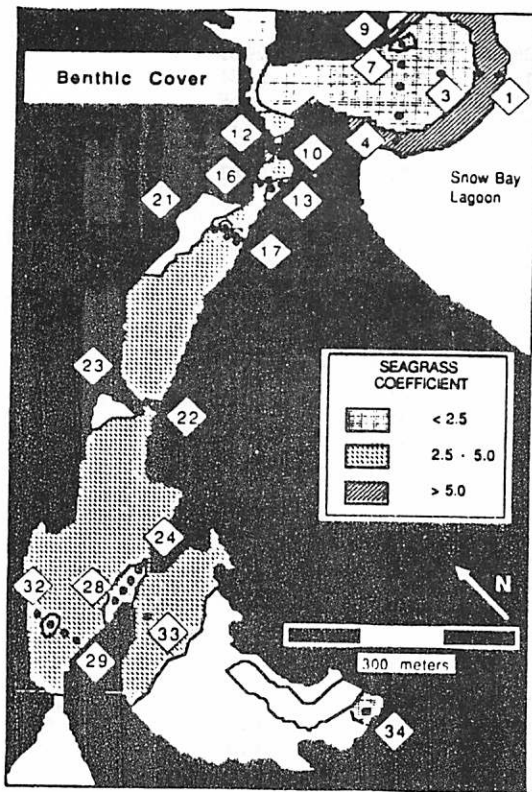


Figure 5: Distribution of seagrass within Pigeon Creek. Seagrass cover was quantified by using a "seagrass coefficient" with >5 representing dense cover, 2.5-5 moderate cover, and <2.5 sparse cover. Numbers refer to sampling locations.

microscope at 10X (see Speyer and Brett, 1986; Parsons, 1989; and Davies et al., 1990). The preservational quality was assessed by comparing shells to a reference standard. Taphonomic features analyzed included: a) breakage (whole shells scored a "0", major fragments consisting of 20% of the long axis receiving a "1", and small fragments given a "2"); b) color loss (0-3, with "0" considered pristine); c) dissolution or chalkiness (0-2, with a "2" representing maximum chalkiness); d) abrasion (0-3, with a "3" representing a highest amount of abrasion); e) rounding (0-2, with a "2" being the most rounded); f) encrustation (0-5, with a "5" corresponding to the highest percent coverage); and g) presence/absence data on predational borings, root etchings, and accretion.

Facies/Sample	Species Richness	Gastropod/Bivalve ratio	Infauna/Epifauna ratio	Seagrass Coefficient	% Mud
High-Density Grassbed					
1	5.26	4.26	0.28	5.92	29.01
2	3.98	6.88	0.16	9.04	38.84
4	5.79	2.9	0.41	5.06	18.69
9	5.79	3.11	0.7	6.88	18.11
Mean	5.21	4.29	0.39	6.73	26.16
St. Deviation	0.85	1.83	0.23	1.71	9.82
Sand Bottom					
3	5.61	0.39	6.11	0.3	0.42
5	5.44	0.6	4.22	0.11	0.81
6	4.96	0.42	4.21	0.02	0.26
7	5.69	0.35	5.18	0	0.26
11	3.16	0.36	80.33	0	4.18
18	5.44	0.53	8.07	0.43	2.75
20	4.46	0.64	12.4	0.11	3.84
Mean	4.97	0.47	17.22	0.14	1.79
St. Deviation	0.90	0.12	27.98	0.17	1.75
Channel-Grass Mix					
15	4.93	6.46	0.44	3.54	14.87
22	5.96	3.84	0.63	0	5.62
Mean	5.45	5.15	0.54	1.77	10.25
St. Deviation	0.73	1.85	0.13	2.50	6.54
Normal Grassbed					
8	6.31	1.56	2.81	3.28	5.27
10	6.31	0.86	3.96	3.98	4.82
12	5.79	2.26	1.23	5.36	4.28
13	4.73	1.88	1.52	0.65	5.82
14	4.73	3.35	0.72	1.61	11
16	4.03	1.56	3.41	3.04	5.28
17	4.56	1.03	4.02	2.86	16.97
19	5.26	1.11	2.34	3.44	12.79
21	3.33	4.77	4.06	3.93	14.28
23	4.56	1.42	1.96	4.2	8.11
24	3.51	1.8	4.1	3.34	24.01
25	4.21	2.3	3.58	0.73	19.09
26	4.73	1.42	4.44	2.02	11.09
27	2.98	1.59	6.57	1.21	13.32
28	3.33	1.42	3.97	0.17	9.16
29	2.98	3.05	2.00	3.28	28.35
30	2.46	3.05	2.07	3.97	26.98
31	2.98	4.41	2.02	1.72	31.4
32	2.63	3.76	2.00	2.54	26.59
33	2.6	3.41	10.13	2.72	19.59
Mean	4.11	2.30	3.35	2.70	14.91
St. Deviation	1.21	1.16	2.11	1.36	8.77
Other					
34	2.28	7.33	-	-	9.22

Table 2: A listing of species richness, gastropod/bivalve ratio, infauna/epifauna ratio, seagrass coefficient, and percent mud among molluscan facies. Names of each facies were determined by the dominant sediment type within each cluster group (shown in bold).

Abraded grain "grainstone" corresponding with samples in the tidal delta (samples 3, 5, 6, 7); 2) Foraminifera-rich "grainstone" corresponding with scour pits and sandy bottom lagoonal locations (samples 8, 10, 11, 12, 16, 18, 20); 3) Mollusc-rich "packstone" found within the more sparsely vegetated areas

within the upper reaches of Pigeon Creek (samples 24, 25, 26, 27, 28, 33); and 4) *Halimeda*-rich "packstone" common within vegetated areas (samples 1, 2, 4, 9, 13, 14, 15, 17, 19, 22, 23, 29, 30, 31, 32). The lateral distribution of sedimentological facies is

PIGEON CREEK SEDIMENTOLOGICAL CLUSTER

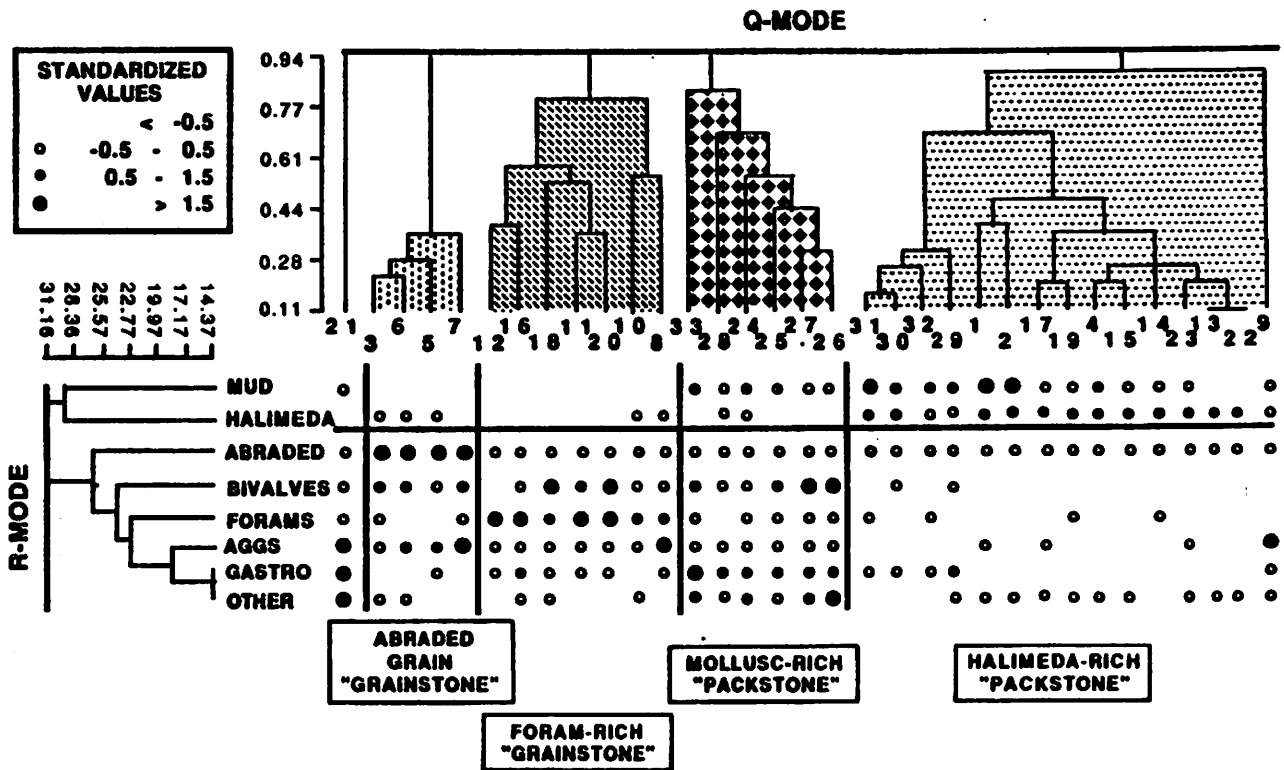


Figure 6: Two-way cluster analysis of Pigeon Creek sedimentological variables. Filled circles depict sedimentary variables well above standardized mean, open circles depict variables near the mean, and no circle indicates variables well below the standardized mean.

shown in Figure 7.

Molluscan Facies Determination

Seventy-four species of molluscs were identified within the death assemblage of Pigeon Creek (Table 1). The 33 most abundant species in the death assemblage were used in the cluster analysis and four major groupings of molluscs were found (see Figure 8 for the cluster diagram). The four molluscan facies are: 1) High-density grassbed fauna found in samples 1, 2, 4, and 9); 2) Sandy bottom fauna found in samples 3, 5, 6, 7, 11, 18, and 20; 3) Channel-grass mix fauna found in samples 15 and 22; and 4) Normal grassbed fauna found in samples 8, 10, 12, 13, 14, 16, 17, 19, 21, and 23 through 33).

Sample 34 does not fall into any of the above facies. It is located (see Figure 2) in the extreme upper-reaches of Pigeon Creek. The physical environment is extreme; with high salinities and turbidity, and hot temperatures. It's fauna is so unique that it did not cluster into any of the other groups. The dominant

species (*Anomalocardia brasilina*, *Cerithidea scalariformis*, and *Cerithium variable*) overwhelm all other taxa. *Anomalocardia* is a genus known to thrive in stressful environments (Parker, 1959; Stanley, 1970) and has been found in other studies in salinities as high as 79 ppm. This site is also characterized by its low species richness (Table 3).

Relative abundance and biomass dominants within each molluscan facies are shown in Figures 9 and 10.

Percent-transformed data were compared in the Q-mode analysis using the quantified Dice Similarity (S_D) (also referred to as Czekanowski's or Sorensen's Coefficient in Sepkoski, 1974). Percent transformation of the data converts the raw abundances of each molluscan species into percentages of the total number of specimens within the sample as defined by the equation:

$$X_{1j} = (X_{1j} / P_{\sum j=1} X_{1j}) * 100$$

thus lessening the effect of differences in sample size (Miller, 1988). The Q-mode cophenetic correlation coefficient was .8389,

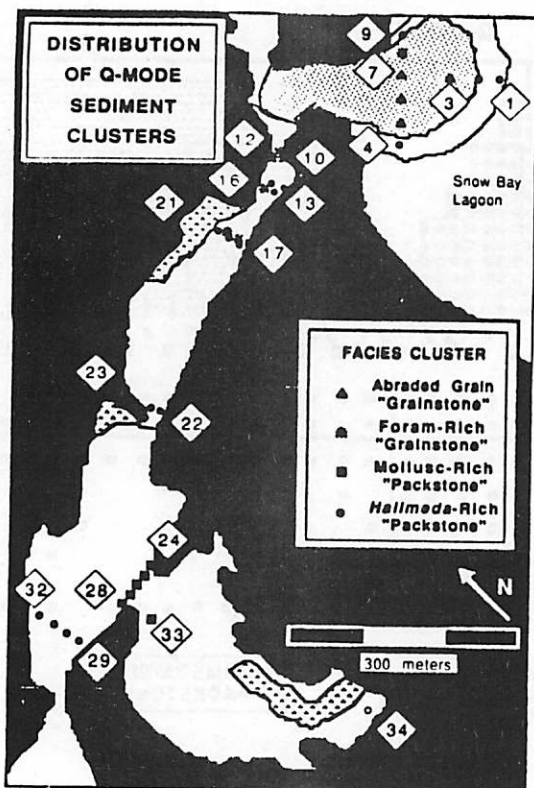


Figure 7: The lateral distribution of sedimentary facies within Pigeon Creek. Numbers refer to sampling locations.

R-mode=.7735.

RESULTS AND DISCUSSION

Numerical Abundance and Biomass

Numerical abundance of species is a frequently used parameter in ecological and paleontological analyses. This technique is powerful when comparing shelled fauna (Kidwell and Bosence, 1991). However, rarely does the relative abundance of the life assemblage equal that of the death assemblage, when soft-bodied organisms are also considered, because in many marine communities, the vast majority of benthic organisms are soft-bodied and are not preserved. Because of the uncertainty inherent in interpreting relative abundance data when most of the original community is not preserved, some researchers (Powell and Stanton, 1985) have suggested that biomass can be a more important paleontological measurement than relative abundance. Molluscs are frequently the biomass dominants

of benthic communities and biomass, as estimated by the volume of skeletal remains, is less affected by taphonomic loss than is numerical abundance (Staff et al., 1985, 1986; see Kidwell and Bosence, 1991).

We compared numerical abundance and biomass of the top 15 molluscan species within each molluscan facies to see how numerical abundance and biomass would compare (see Figures 9 and 10). Would the top 15 species be equivalent? Or, would there be little similarity between biomass and relative abundance? In freshwater communities, Cummins (1994) found, using the spearman rank test, that the preservable species live/dead rank-order of numerical abundance and biomass was similar ($P < 0.10$) in undisturbed environment. Also, species that were numerically dominant in the death assemblage were also the death assemblage biomass dominants.

Marine systems are more diverse and physically more complex than freshwater systems--taphonomic processes may be much different among marine and freshwater environments. At Pigeon Creek, the biomass and relative abundance rank-order comparisons are independent of one another ($P > 0.10$) within each facies (Table 4). That is, the rank-order of biomass dominants are distinctive from the numerical rank-order dominants in each molluscan facies. This is mostly the result of the effect size has on biomass (biomass increases with the cube of the length of the mollusc shell). A few larger shells, while not numerically important, are more immune to taphonomic destruction than are smaller shells. Thus, they can make significant contributions to community biomass.

Which measure is most useful in community reconstruction? Both have utility and provide distinctive information on past community structure.

Taphonomic Signatures

As Davies et al. (1990) so aptly put it, "All dead things are not created equal." Once a potentially preservable organism dies, its skeletal remains are subject to the destructive effects present in its environment of deposition -- taphonomic alteration may vary in a predictable way with environmental setting (Brett and Baird, 1986; Speyer and Brett, 1986; Davies et al., 1989). Molluscan

PIGEON CREEK SPECIES TWO-WAY CLUSTER ANALYSIS

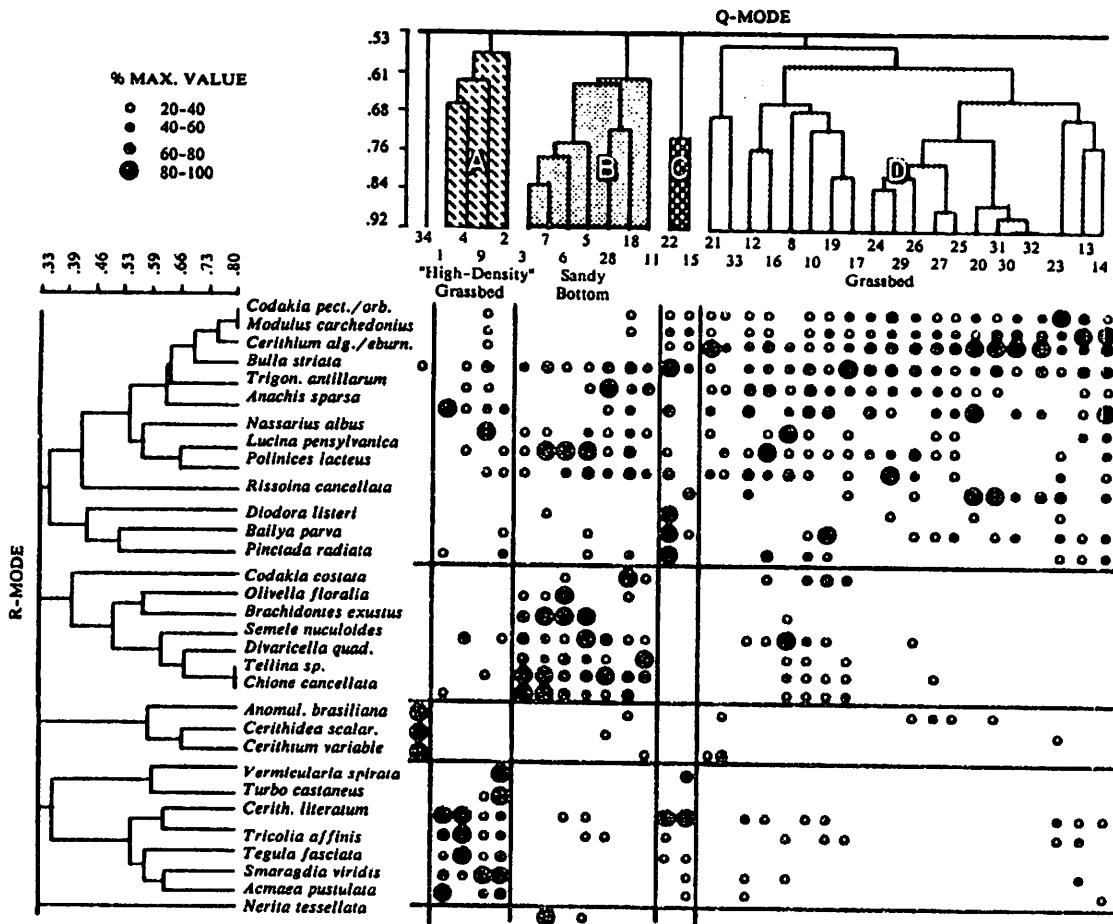


Figure 8: Two-way cluster analysis of molluscan skeletal remains. Circles were placed on the grid wherever a sample contained a percent maximum-transformed value of at least 20% for that species. The sizes of the dots reflect relative values of those abundances.

shells, for instance, behave like other particles in the sediment and are subject to unique types of alteration which varies from one depositional environment to the next. Taphonomic characteristics such as shell breakage, roundness of shells, abrasion, dissolution, size frequency as well as sedimentologic parameters have been used as indicators or "signatures" of the environment of deposition. The use of taphonomic signatures as a tool to better recognize environments of deposition, when coupled with other sedimentary data, shows great promise in paleocommunity reconstruction.

In Pigeon Creek, we describe four sedimentary facies. Using taphonomic signatures, we examined how taphonomic signatures vary across these four facies and

whether there are distinctive signatures among these sedimentary environments. To address these questions, we used *Cerithium* sp., an epifaunal gastropod, and *Codakia* sp., an infaunal bivalve. Both genera were common at the majority of our sampling sites and because of their unique modes of life, we were also able to compare the taphonomic signatures of an epifaunal gastropod with an infaunal bivalve.

Cerithium and *Codakia* show many generalized visual similarities in their taphonomic signatures among facies. The most obvious trend is increased abrasion, breakage, and rounding in the abraded grain facies and reduced levels of encrustation (Figures 11 and 12) for both the epifaunal gastropod *Cerithium*

Pigeon Creek Sedimentary Facies

Sedimentary Parameter	Abraded Grain "Grainstone"	Foram-Rich "Grainstone"	Mollusc-Rich "Packstone"	<i>Halimeda</i> -Rich "Packstone"
Mud	0.44+/-0.26	4.35+/-0.89	16.04+/-5.74	19.54+/-10.17
<i>Halimeda</i>	38.33+/-4.26	23.92+/-19.79	29.06+/-16.85	81.27+/-12.57
Abraded Grains	16.33+/-1.15	1.58+/-1.51	0.39+/-0.80	0.46+/-0.73
Bivalves	22.55+/-2.80	18.52+/-12.39	23.80+/-8.10	3.61+/-2.86
Forams	6.11+/-3.18	36.52+/-11.21	11.08+/-5.65	3.66+/-3.45
Aggregates	11.31+/-4.33	7.50+/-4.63	5.58+/-1.64	2.84+/-6.87
Gastropods	5.11+/-3.48	11.36+/-5.69	28.12+/-13.64	7.71+/-7.09
Other	0.29+/-0.33	0.60+/-0.43	1.98+/-1.07	0.47+/-0.37

Table 3: Means and standard deviations of the sedimentary particles found within each facies. Names of each facies were determined by the dominant sediment type within each cluster group (shown in bold).

Pigeon Creek Relative Abundance By Molluscan Facies

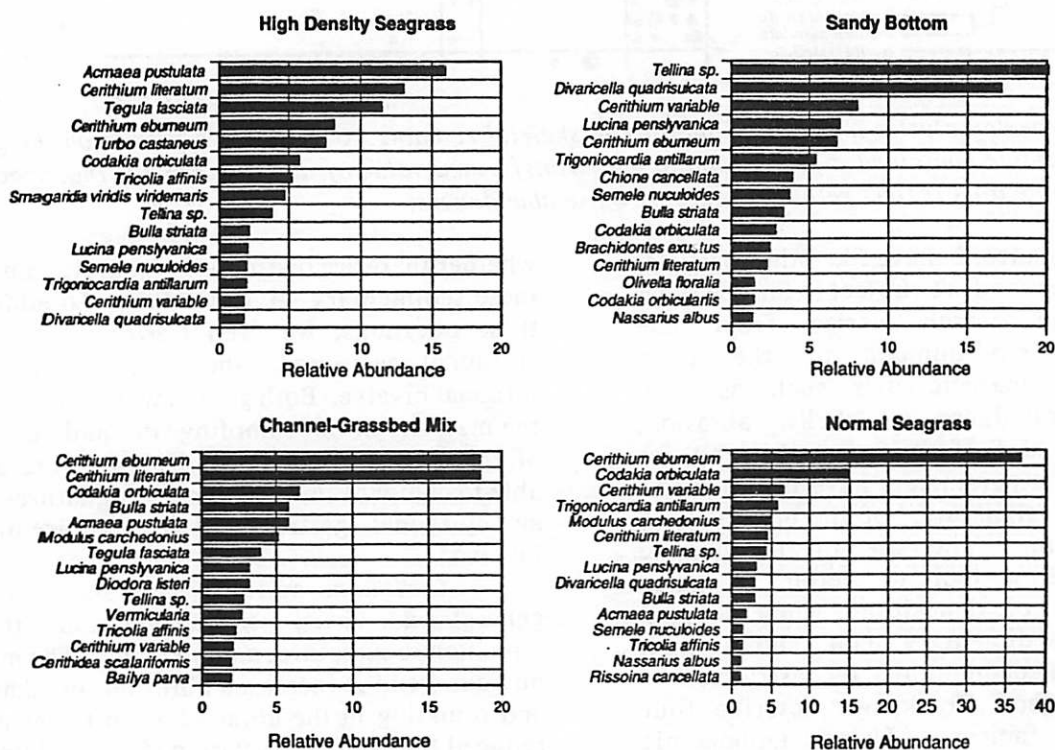


Figure 9: Pigeon Creek relative abundances for the top fifteen molluscan species among the four molluscan facies.

Pigeon Creek Biomass Dominants By Molluscan Facies

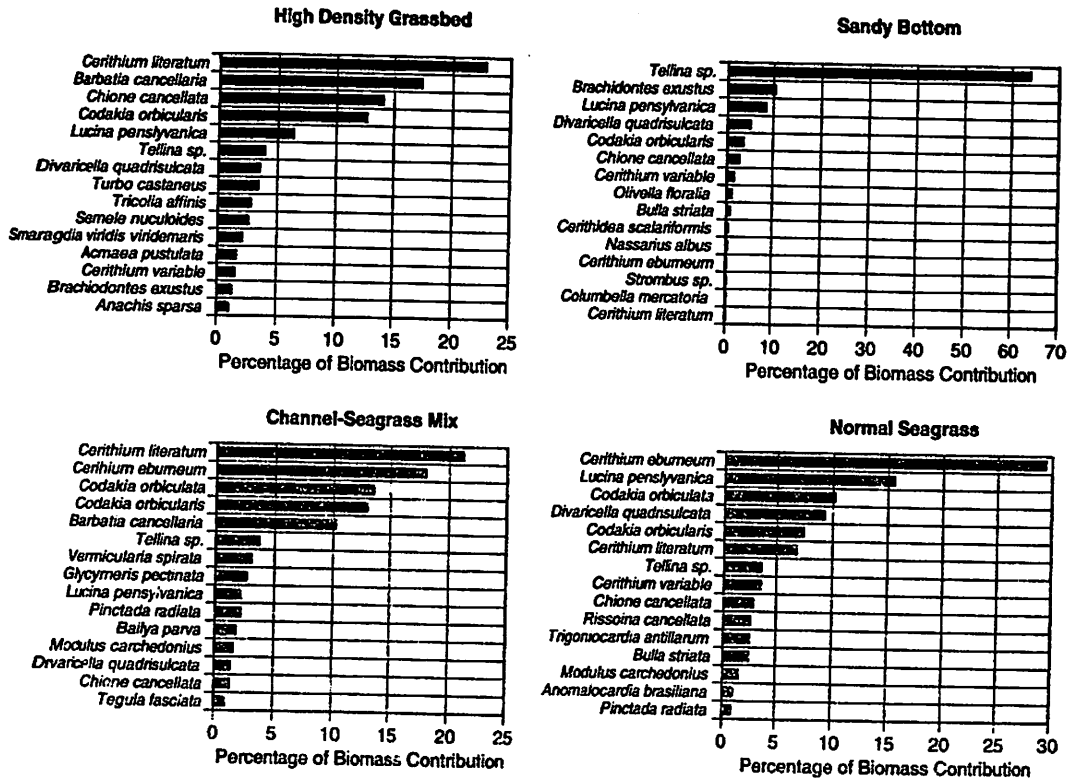


Figure 10: Pigeon Creek biomass dominants for the top fifteen molluscan species among the four molluscan facies.

Spearman rank comparisons of top 15 molluscan species biomass (B) and top 15 molluscan abundance (A) for each molluscan? facies

	Dense Seagrass (B)	Sandy Bottom(B)	Seagrass/Sand Mix(B)	Normal Seagrass(B)
Dense Seagrass (A)	-0.24			
Sandy Bottom (A)		.18		
Seagrass/Sand Mix (A)			.16	
Normal Seagrass (A)				.14

*No Significant Results

Table 4: Spearman rank comparisons of the top fifteen molluscan species biomass (B) and top fifteen molluscan numerical abundance (A) within each molluscan facies. There were no significant results ($P < 0.10$).

and infaunal bivalve *Codakia*. While these similarities for abrasion are significantly different ($P < 0.05$) among sedimentary facies (Table 5), the general trend is that there is more abrasion in high energy environments regardless of the taxa being examined. One might expect there to be more abrasion, breakage, and rounding in a deltaic environment dominated by strong currents -- we have measured flows as high as 1 m/sec during incoming and outgoing tidal flow --

and large volumes of sediment movement. Levels of encrustation would also be reduced in this physically reworked setting.

In the *Halimeda*-rich facies, encrustation values are at their highest levels for both *Cerithium* and *Codakia*. *Cerithium* shows high levels of breakage in the *Halimeda*-rich facies, particularly as compared with *Codakia* (Figures 11 and 12). Perhaps because *Codakia* is an infaunal bivalve, it is more protected from mechanical destruction --

Cerithium Taphonomic Signatures by Sedimentary Facies

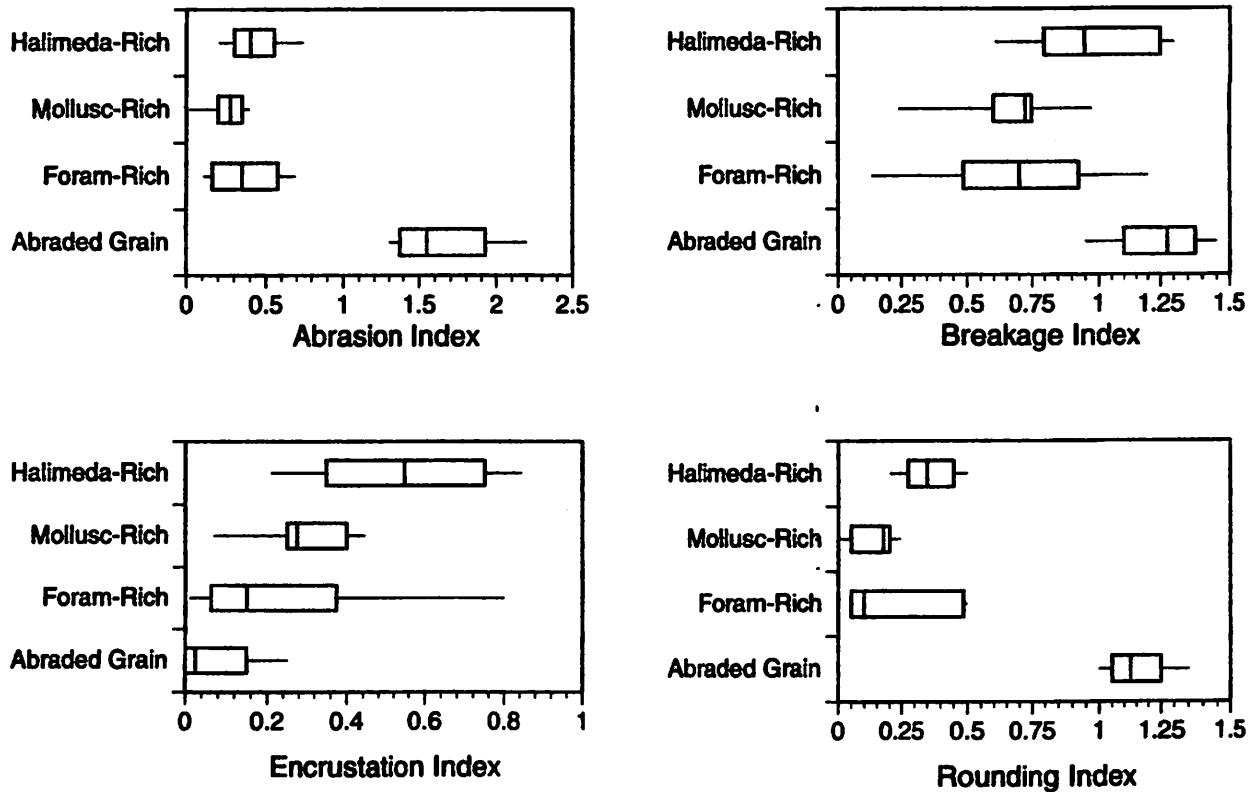


Figure 11: Selected taphonomic signatures of *Cerithium* among the sedimentary facies. Compare with *Codakia* in Figure 12.

when they die, they are more easily entombed by sediments than are the gastropods. *Cerithium*, which lived on and above the sediments in life, has shells which are more exposed to mechanical destruction for longer periods of time after death.

When we compare the taphonomic signatures of *Cerithium* and *Codakia* without regard to sedimentary facies, abrasion, breakage, dissolution, and the frequency of bore holes are significantly different between species ($P < 0.05$). Interestingly, taphonomic signatures for rounding and encrustation for *Cerithium* and *Codakia* are similar (Table 6).

It is clear that the use of taphonomic signatures has great utility in paleocommunity analysis. The signatures found on these shells are reflective of their environment of deposition, particularly when examining

specimens in the Abraded grain facies and *Halimeda*-rich facies.

Molluscan Facies

Figure 9 illustrates the relative abundance of the top 15 species in each molluscan facies. While these facies may appear to be distinctive in terms of species composition and rank-order of abundance, only the High Density Grassbed vs. the Sandy Bottom fauna and the Sandy Bottom vs. Channel-Grassbed Mix fauna have a rank order of abundance that is independent ($P > 0.10$) of one another. The rest of the facies comparisons, using the Spearman Rank-order of abundance test, do not have rank-orders of abundance that are independent of one another ($P < 0.10$). In short, the biggest distinction in

Codakia Taphonomic Signatures by Sedimentary Facies

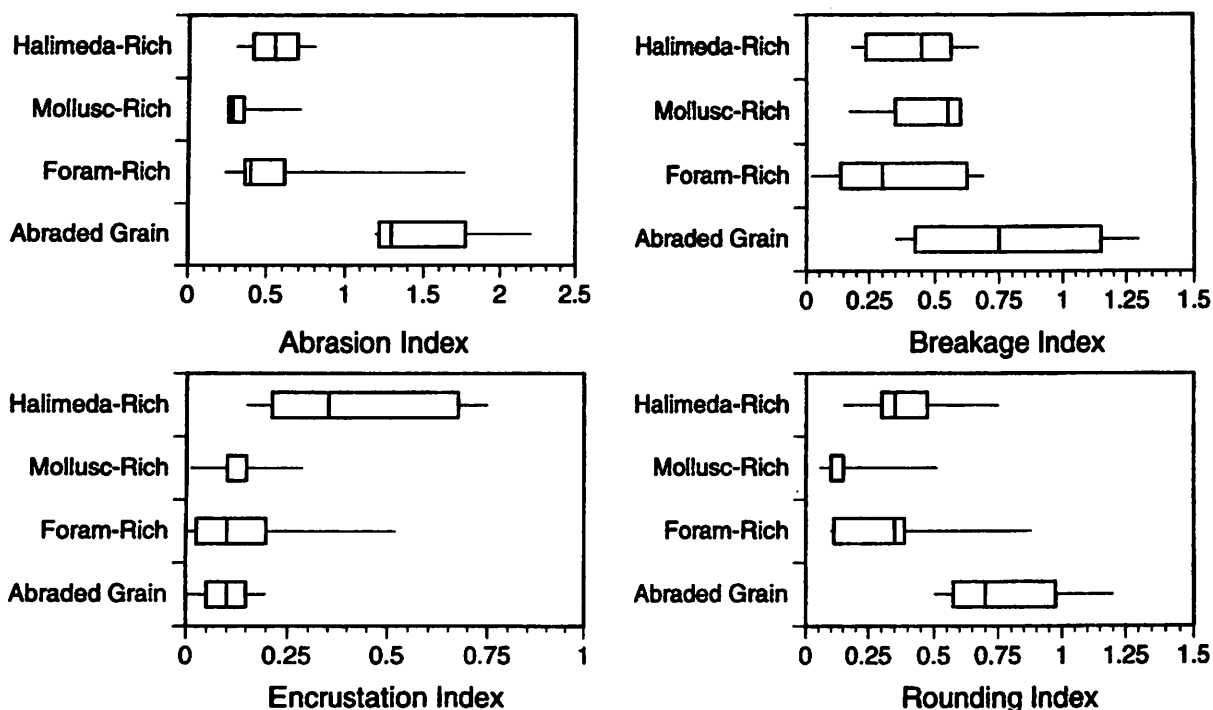


Figure 12: Selected taphonomic signatures of *Codakia* among sedimentary facies. Compare with *Cerithium* in Figure 11.

molluscan fauna is between grassbeds and sandy bottoms.

Gastropod:Bivalve and Infaunal:Epifaunal Ratios

Table 3 illustrates the differences among molluscan facies of gastropod:bivalve and infaunal:epifaunal ratios (for each sample and the mean score for each molluscan facies). These measurements may be useful in community reconstruction. We wanted to test whether or not the sediments preserve the communities' prevailing molluscan mode of life. Is the *in situ* death assemblage more indicative of a grassbed fauna or sandy community based not only on species composition but also on mode of life? Most gastropods are epifaunal in dense grassbeds and infauna tend to dominate on sandy bottoms. Are these community characteristics preserved in the sediments?

We found that in the High-Density Grassbed (characterized by high seagrass coefficients), death assemblage gastropod:bivalve ratios were the highest of all molluscan facies with a mean of 4.29. Infaunal:epifaunal ratios averaged 0.39, which was the lowest of all molluscan facies. The Sand Bottom molluscan facies had a gastropod:bivalve ratio of only 0.47, which was the lowest of all molluscan facies. The infauna:epifauna ratio was 17.22, by far the highest. This index is inflated because sample #11 had a ratio of 80.33 infauna:epifauna! If we throw this value out, the infauna:epifauna ratio drops to 6.70, which is still the highest of all molluscan facies. The Channel-Grass Mix is dominated by gastropods with a mean gastropod:bivalve ratio of 5.15 and an infauna:epifauna ratio of 0.54. This suggests that the station #22, with a sandy substrate, receives an abundance of dead gastropods from adjoining grassbeds. The

**Chi-Square Analyses among Sedimentary Facies Using Taphonomic Signatures
for *Cerithium* and *Codakia*, Pigeon Creek, Bahamas**

Taphonomic Signature	<i>Cerithium</i>	<i>Codakia</i>
Breakage	33.3***	12.8*
Abrasion	188.5***	124.1***
Dissolution	32.9***	54.4***
Rounding	103.3***	67.4***
Encrustation	40.2***	22.9***
Bore Holes	31.7***	22.5***
	P < 0.005*	
	P < 0.005**	
	P < 0.0005***	

Table 5: Chi-square analyses among sedimentary facies using taphonomic signatures. Chi-square values and significance levels are shown.

**Chi-Square Comparisons of *Cerithium* and *Codakia* Taphonomic Signatures,
Pigeon Creek, Bahamas**

Taphonomic Signature	<i>Cerithium</i> vs <i>Codakia</i>
Breakage	120.0***
Abrasion	8.5*
Dissolution	18.8***
Rounding	0.67
Encrustation	9.2
Bore Holes	16.3***
	P < 0.05*
	P < 0.005**
	P < 0.0005***

Table 6: Chi-square analyses of taphonomic signatures without regard for sedimentary facies. Chi-square values and significance levels are shown.

Normal Grassbed fauna have a mean gastropod:bivalve ratio of 2.30 and a mean infauna:epifauna ratio of 3.35. This is the only molluscan facies that shows mixed results -- perhaps this is due to a mixture of muddy- and sandy-substrates in this facies.

Gastropod:bivalve and infauna:epifaunal ratios are useful in linking the Pigeon Creek molluscan death assemblage to the physical and biotic environment of the once living community.

CONCLUSIONS

The blending of sedimentological analyses, taphonomic signatures and community attributes such as species composition, numerical abundance and

biomass can be used to further understand environments of deposition. Pigeon Creek has distinctive sedimentary environments, separated in space in some instances by only a few meters, which appear to be structured by water depth, seagrass cover, and current flow. Organismal distribution is also strongly affected by the same parameters. The good news is that the sediments seem to faithfully preserve these structural differences across the Pigeon Creek system despite some physical mixing of sediments, and associated death assemblages, due to strong currents. This is particularly apparent when contrasting seagrass zones with sandy areas.

Taphonomic signatures are very powerful in distinguishing the high energy portions of Pigeon Creek (sandy areas) from

grassbeds. This seems to hold true for epifaunal gastropods as well as infaunal bivalves. The use of biomass and numerical abundance in community reconstruction in Pigeon Creek yields marked distinctions in which species dominate within each molluscan facies. We suggest that both measurements be used to describe the time-averaged death assemblage recognizing that community biomass, as has been found in previous studies, is less altered by taphonomy than is numerical abundance.

Infaunal:epifaunal- and gastropod:bivalve- ratios appear to have great utility in community reconstruction. The time-averaged death assemblage seems to faithfully preserve the ratios present in the living community.

REFERENCES

- Abbot, R. T. 1974. American seashells. Van Nostrand Reinhold, New York, 663p.
- Bathurst, R. G. C. 1971. Carbonate sediments and their diagenesis, *Developments in Sedimentology* 12. Elsevier, New York, 658p.
- Boardman, M. R. and C. Carney, eds. 1992. The geology of Columbus' landfall: A field guide to the Holocene geology of San Salvador, Bahamas. Miscellaneous Report no. 2, Field trip 3 for the annual meeting of the Geological Society of America, Columbus, Ohio.
- Brett, C. E. and G. C. Baird. 1986. Comparative taphonomy: A key to paleo-environmental interpretation based on fossil preservation. *Palaios*, 1: 207-227.
- Cummins, R. H. 1994. Taphonomic processes in modern freshwater molluscan death assemblages: Implications for the freshwater fossil record. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 108: 55-73.
- Davies, D. J., E. N. Powell, R. J. Stanton, Jr. and G. Staff. 1989. Taphonomic signature as a function of environmental process: Shells and shell beds in a hurricane-influenced inlet on the Texas coast. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 72: 317-356.
- Davies, D. J., G. M. Staff, W. R. Callendar, and E. N. Powell. 1990. Description of a quantitative approach to taphonomy and taphofacies analysis: All dead things are not created equal, in Miller, W., III, ed., *Paleocommunity Temporal Dynamics: The long-term Development of Multispecies Assemblages*, The Paleontological Society, Special Publication No. 5: 328-350.
- Dodd, J. R., and R. J. Stanton, Jr. 1990. *Paleoecology, concepts and applications* (second edition). John Wiley and Sons, New York, 502p.
- Kidwell, S. M. and W. J. Bosence. 1991. Taphonomy and time-averaging of marine shelly faunas, in Allison, P. A. and D. E. G. Briggs, eds., *Taphonomy: Releasing the Data Locked in the Fossil Record*, Volume 9 of *Topics in Geobiology*. Plenum Press, New York, 115-209.
- Miller, A. I. 1988. Spatial resolution in subfossil molluscan remains: Implications for paleobiological analyses. *Paleobiology*, 14(1): 91-103.
- Miller, A. I. and H. Cummins. 1990. A numerical model for the formation of fossil assemblages: Estimating the amount of post-mortem transport along environmental gradients: *Palaios*, 5: 303-316.
- Morris, P. A. 1975. A field guide to shells: Atlantic and Gulf coasts and the West Indies. Houghton-Mifflin, Boston, 330p.
- Meldahl, K. H. and K. W. Flessa. 1990. Taphonomic pathways and comparative biofacies and taphofacies in a Recent/shallow shelf environment. *Lethaia*, 23: 43-60.
- Odum, E. P. 1971. *Fundamentals of ecology* (third edition). W. B. Sanders Publishing Co., Philadelphia, 574p.
- Parker, R. H. 1959. Macro-invertebrate assemblages of central Texas coastal bays and Laguna Madre. *Bulletin of American Association of Petroleum Geologists*. 43:

2100-2166.

- Parsons, K. M. 1989. Taphonomy as an indicator of environment: Smuggler's Cove, St. Croix, U.S.V.I., in Hubbard, D. K., ed., Terrestrial and marine geology of St. Croix, U.S.V.I.: Special Publication No. 8, West Indies Laboratory, Teague Bay, St. Croix, U.S.V.I., 135-143.
- Powell, E. N. and R. J. Stanton, Jr. 1985. Estimating biomass and energy flow of molluscs in paleo-communities. *Palaeontology* (London), 28: 1-35.
- Scoffin, T. P. 1988. An introduction to carbonate sediments and rocks. Blackie, New York. 274 p.
- Sepkoski, J. J. Jr. 1974. Quantified coefficients of association and measurement of similarity. *Mathematical Geology*, 6: 135-152.
- Speyer, S. E. and C. E. Brett. 1986. Trilobite taphonomy and Middle Devonian taphofacies. *Palaios*, 1: 312-327.
- Staff, G. M. R. J. Stanton, Jr., E. N. Powell, and H. Cummins. 1986. Time-averaging, taphonomy, and their impacts on paleocommunity reconstruction: Death assemblages in Texas bays. *Geological Society of America Bulletin*, 97: 428-443.
- Stanley, S. M. 1970. Shell form and life habits in the Bivalvia (Mollusca). *Geological Society of America Memoir* 125. 296p.
- Warmke, G. L. and R. T. Abbott, 1962. Caribbean seashells. Dever, New York. 348p.
- Wilson, V. H. 1988. Taphonomic processes: Information loss and information gain. *Geoscience Canada*, 15(2): 131-148.