

**PRELIMINARY STUDIES OF THE FATE OF SHALLOW-WATER
DETRITUS IN THE BASIN NORTH OF ST. CROIX, U.S.V.I.**

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ABSTRACT

Three dives were made in the DSRV ALVIN to investigate the quantity and distribution of shallow-water sediments and biological debris in the 4500 m deep basin north of St. Croix, U.S.V.I. The percent of shallow-water derived sediments decreased from 93% to 7% in a downslope direction. Grass was distributed more evenly, with concentrations typically in the range of 0.1-6 blades per m².

Despite the surprisingly high nutrient values (NH₃-N = 4.48 - 49.41 μM; NO₂ + NO₃-N = 0.34 - 36.27; DON > 30 μM N), organic carbon levels within the sediment were consistently low (0.1-0.8%). The low carbon values are related to the highly oxidative conditions (Eh = 200-400 Mv) and recycling by aerobic heterotrophs.

INTRODUCTION

Previous studies indicate that substantial quantities of carbonate sediments (5-10 Kg/m² yr: Hubbard et al. 1981) and seagrass (500-1000 gC/m² yr: Zieman and Wetzel 1980) are produced on the insular shelf of St. Croix. These are moved off the shelf, primarily during storms, and introduced into the adjacent basins (Hubbard et al. this symp.). The main objective of this project was to determine the fate of these materials in the deep (4500 m) basin north of St. Croix (Fig. 1). Specifically, we were interested in determining how much and what kinds of shallow water sediments ultimately reached the basin, and what depositional patterns resulted. We were also concerned with how much seagrass reached the basin, how it was utilized or decomposed, and how much was ultimately incorporated in the sediments as organic carbon.

STUDY AREA

St. Croix is located in the Caribbean Sea, 100 km southeast of Puerto Rico (Fig. 1). The island is composed primarily of uplifted Cretaceous, basinal deposits (Whetten 1966) of the Caledonia Formation. Miocene-Pliocene strata which occupy the central portion of the island were deposited in a basin or "seaway" similar to, but shallower than the one presently north of St. Croix. The present basin is a 4500-m deep reentrant from the larger basin to the south. High-resolution seismic profiles across the basin show large aprons of sediment along the basin margins (Fred Bowles, written comm.). Sand-body geometry suggests the introduction of shelf-derived sediments from St. Croix, and to an even greater extent from St. Thomas to the north.

METHODS

Three dives were made in the basin north of St. Croix (Fig. 2), using the DSRV ALVIN. The dive sites were chosen to represent an area associated with the larger Christiansted canyon/fan system (DIVE 1101), an area near a minor canyon system that could not be traced into the basin (1102) and an area off an open shelf (1103). Each dive was made in a different depth range to examine up-slope variability. While this approach posed potential interpretive problems by mixing environmental and depth variables, we felt that it would potentially provide the most information from the few dives available.

On the bottom, sediment samples were collected in 35 cm-long core tubes using ALVIN's manipulator. In areas where the sediments contained large quantities of coarse gravel, or were underlain by lithified pavement, grab samples were taken with canvas bag samplers (note: some mud was lost by this method). In addition, a number of live holothurians and urchins were collected for gut-content analysis. One species of holothurian which covered itself with *Thalassia*, apparently as a tactile defense mechanism, was collected at several sites to recover the grass. Seagrass distribution was estimated visually on all three dives. In addition, the external Benthos camera was cycled at 4-6 sec intervals along several transects on each dive. Later, concentrations of *Syringodium filiforme* and *Thalassia testudinum* were determined within calibrated counting fields on color photographs using an ocular micrometer under a dissecting scope.

On the surface, cores were sealed and packed in ice to return their temperatures to the 4° C in situ level measured on the bottom (core temperature could

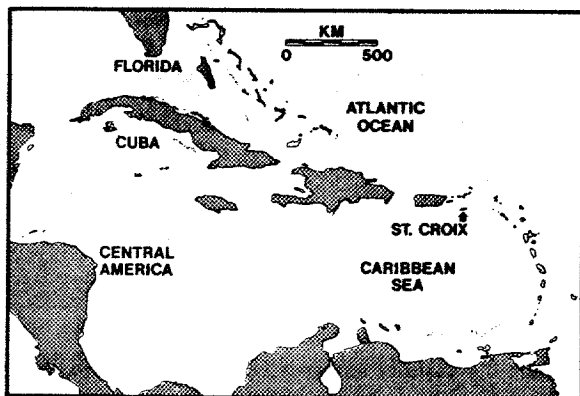


Figure 1. Map showing the location of St. Croix.

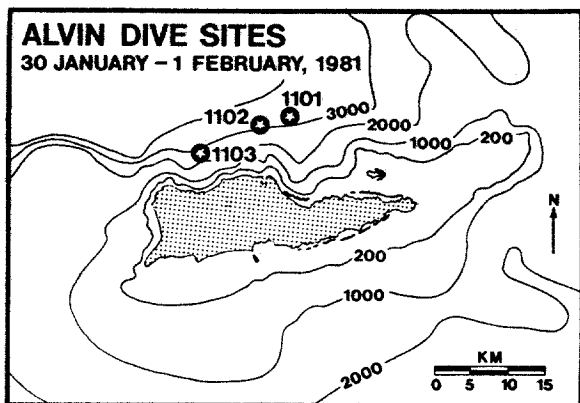


Figure 2. Map showing ALVIN dive sites.

have risen up to 20° on ascent). The core tubes were drilled at 5-cm intervals, and Eh/pH readings were taken using an Orion 399A Ionalyzer in a N₂ environment. The pH probe was calibrated against 7.00 and 4.01 buffers cooled to core temperature. Eh was read after 1 min: readings drifted only 10 mv after 30 sec and were very stable. Platinum electrode readings were corrected for the reference electrode to obtain the Eh value. All cores were then frozen for several days until after the dive series was completed.

Within each frozen core, 4-6 g of sediment were taken at 1-cm intervals for carbon analysis. The remainder of the cores were split into 4-5 cm intervals and centrifuged to remove pore waters. Leftover sediment was retained for grain-size and constituent analyses.

Pore waters were analyzed for ammonia (Koroleff 1970) and NO₂ + NO₃ (Strickland and Parsons 1965). Dissolved organic Nitrogen (DON) was determined by UV-oxidation. Organic carbon samples were dried at 40-60° C and ground with a mortar and pes-

tle. This material was analyzed using the procedure of Gaudette et al. (1974), which utilizes wet oxidation by acid dichromate. The resulting values should be interpreted as "chromate oxidation" values. However, this method has proved to be an accurate measure of organic carbon to 0.1% in varied sediment types (Gaudette et al. 1974, Gill unpubl. data).

Sediment samples were wet-sieved through a 62 μM screen. The mud fraction was split down, and a representative 15 g sample was pipetted according to Folk (1974). The sand and gravel fractions were sieved at 1/4-ϕ intervals, and pebbles were individually measured and weighed. Sedimentary constituents larger than 2.5 ϕ (0.18 mm) were visually examined and characterized by origin (deep-water vs. shallow-water). SEM Analysis of the finer material is underway.

RESULTS

SEDIMENT DISTRIBUTION

Our major concern was documenting the importance of shallow-water sediments in the basin. The data indicate that sandy sediment from the shelf occurs in all portions of the basin (Fig. 3). At 3500-4000 m off Christiansted canyon, grain size varied between 4.0 ϕ (0.06 mm) and 6.0 ϕ (0.02 mm), generally decreasing in size toward the basin. Sediments off the Salt River and Cane Bay areas were coarser (Mz up to -2.5 ϕ, or 6 mm), and had a noticeable gravel component, comprised of coarse coral rubble and rounded terrigenous clastic pebbles probably derived from the Caledonia formation on St. Croix. Sediments were typically very poorly sorted (o₁ = 2-3 ϕ) at all sites. Deep-water sedimentary components were primarily planktonic foraminifera (*Globigerina* and *Orbulina*) and pteropods. Shallow-water constituents included coral and coralline algal fragments, ostracods, benthic forams, molluscs and rounded lithic fragments.

The importance of shallow water material correlates well with grain size. Off Christiansted, shallow-water constituents varied between 7% and 43%, generally increasing toward the island. Off Salt River (1102) and Cane Bay (1103), sand and gravel formed a more significant portion of the sediments, and shallow water constituents were consistently more abundant (50-93% off Cane Bay; Fig. 3).

Perhaps the most impressive evidence of the shallow-water contribution to the basin are the cobbles and boulders comprised of "Caledonia"-like material and corals that littered the bottom on the latter two dive sites. In many cases, the coral calices were unmodified, and the corals could be identified as *Montastrea annularis* and *Acropora cervicornis*.

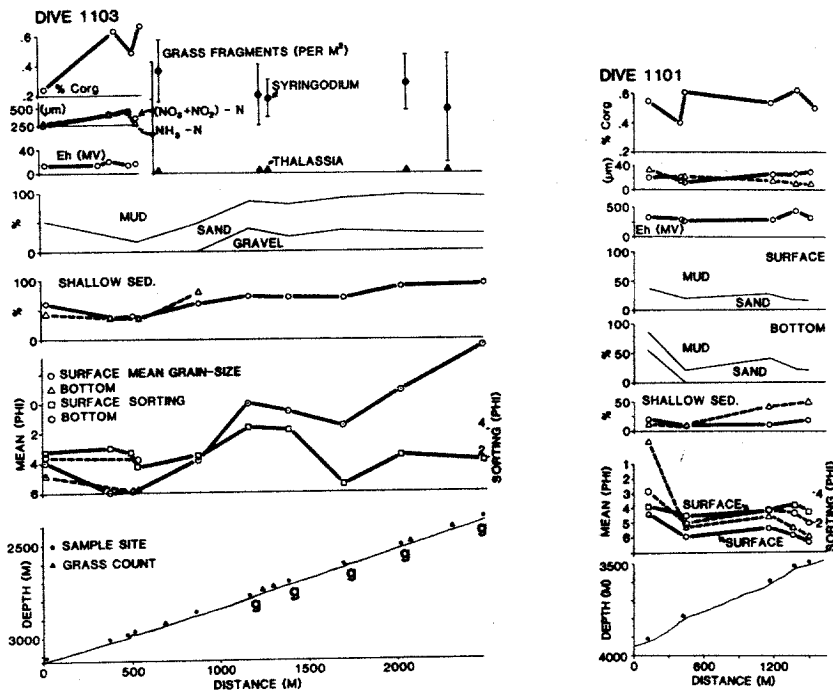


Figure 3. Variations in sample parameters with depth along profiles 1101 and 1103.

The coral blocks were not significantly buried, indicating either very slow depositional rates, recent emplacement of the blocks, or else, active transport which is preventing burial of the blocks.

A model to explain the sedimentary distribution in the basin is illustrated in Figure 4. Deepwater sediments are formed from settled planktonic forams. Shallow-water sands and gravels are introduced primarily as bedload during storms. The general mixture of shallow and deep sediments throughout the cores, and the lack of sedimentary structures revealed by X-ray, indicate continuous mixing of sediment. This reflects either constant reworking by bioturbation, or perhaps more or less continual introduction of shallow sediments by small storms. The latter is consistent with the findings of Hubbard et al. (this symp.) who found that periodic storm-related, off-shelf transport far outweighed that by sudden substrate failure. The cobbles and boulders were introduced either during major storms capable of moving large material to the shelf edge in 30 m of water, or else were moved off the shelf during the lower Pleistocene sea-level which would allow this material to be introduced directly into deep water.

Once the sediments leave the shelf, they are controlled primarily by gravitational processes on the steep island face. Shallow-water muds are carried far out into the basin, while sand, gravel and bould-

ers settle along the slope in a distribution that reflects their angle of repose. The sands and gravel are deposited on the upper apron (Fig. 4) at a point where slope decreases to less than 30°. The cobbles continue to roll and slide or else gradually creep downslope until the declivity lessens to approximately 10°-15°. The result is an increase in shallow-water cobbles and boulders downslope until a flatter bottom is encountered. Such slow and continual creep would also explain the boulders seemingly sitting on, rather than in, the surrounding sediments.

GRASS DISTRIBUTION

One of our original thoughts was that the distributions of seagrass and shallow-water sediments might generally follow each other, inasmuch as their modes of introduction to the basin were similar. Despite the systematic change in sediment character on the three dives, however, no similar grass distribution emerged. Apparently, in the absence of large turbidity events that might tend to extend this common control further into the basins, weak basinal currents that are incapable of resorting the sediments continue to further distribute the grasses in a seemingly homogenous pattern. Seagrasses were generally present in low abundance, with the exception of shallow depressions or down-slope

channels which held greater concentrations of seagrass detritus.

Syringodium was far more abundant than *Thalassia* on all 3 dives (Fig. 3). In general, *Syringodium* detritus increased upslope to about 6 blades/m² at 3000 m where a slight decrease occurred. Furthermore there was a change in the quality of the seagrass with depth. At the deepest depths (approx. 3900 m) the detrital seagrass was very brown, almost black, in color and light in weight, consisting of little more than the structural components. At shallower depths (2800-3000 m) some "fresher" green and greenish brown seagrass appeared. *Thalassia* was very widely scattered on all dives, never increasing above about 0.1 blades/m². These figures, based on the Benthos camera transects which had a limit of resolution for fragments greater than about 2 cm in length, was consistently lower than observer counts.

THE FATE OF THE GRASSES

Once seagrasses have reached the deep sea they may be involved in a number of important processes (Fig. 5). First, they may provide a substrate for epiphyte colonization, chiefly by bacteria which decompose the grass material and increase its nitrogen content, making the particulate material more nutritionally valuable to detritivores such as holothurians. Secondly, they may be directly consumed by grazers which break the seagrass into smaller fragments to be recolonized by bacteria. In the two urchins sampled, about 93% by volume of the stomach contents were *Syringodium*, followed by *Thalassia* and *Sargassum*. Preliminary findings of ongoing studies to compare δC^{13} values in the

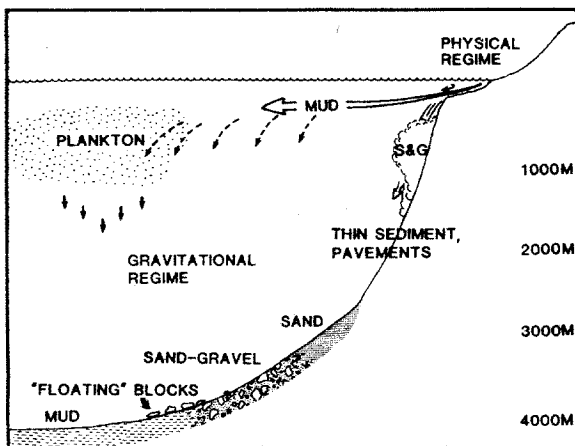


Figure 4. Diagram illustrating the mechanisms responsible for the sediment distribution observed from ALVIN.

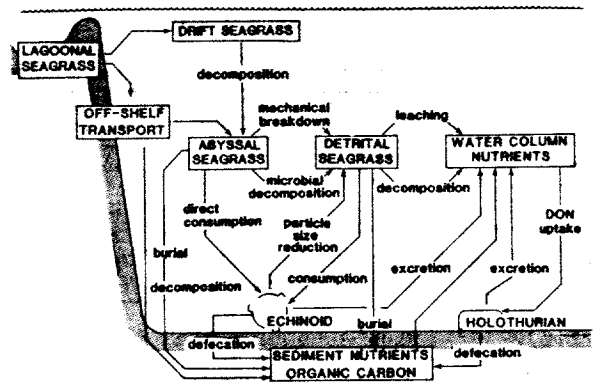


Figure 5. Diagram summarizing the cycling of shallow-water grasses in the basin north of St. Croix.

tissues of bottom dwellers to that of the surrounding grasses further support the precept of grass utilization by bottom dwellers (P. Parker, written commun.).

The ultimate fate of detrital seagrass not consumed in the abyss is burial and further decomposition in the sediments, leading to mineralization of nutrients. During decomposition, soluble organic nutrients are leached from the plants and plant proteins are hydrolyzed, yielding ammonia (NH₃) which is then oxidized to NO₂ + NO₃. For detailed discussion, the reader is referred to Harrison and Mann (1975) and Klug (1980).

The biogeochemical regime of the sediments was very uniform over core depth, depth over one dive, and dive sites. Throughout a single core Eh varied by only 50-90 mv; pH typically varied 0.1-0.3 units; [NH₃] varied from 4-30 μM; [NO₂ + NO₃] varied from 2-17 μM. Over the depth transect of one dive, variation between cores taken at different depths was no more than that in any one core. Sediment pH values ranged from 6.9 to 7.5 and were up to 1 unit lower than those of overlying waters.

Pore water concentrations of NH₃ and NO₂ + NO₃ were consistently higher than we would have expected in this environment. NH₃-N ranged from 4.48-49.41 μM and NO₂ + NO₃-N from 0.34-36.27 μM. Sediment values were 6-30 times greater than overlying waters. Concentrations in the abyssal part of the water column were slightly higher than the low-nutrient surface waters which were below 0.1 μM NH₃. Except for 3 cores, [NO₂ + NO₃] was greater than [NH₃] which is to be expected in an oxidized environment. DON was fairly high, greater than 30 μM N. Pore water concentrations of NH₃ and NO₂ + NO₃ are in the range of shallow coral reef lagoon sediments where seagrasses have colonized, but have not yet formed mature beds. It was surprising to us that nutrient levels in the basin would fall within the range typical of the highly productive

shallow water grass beds. The fact that NH_3 is higher than trace amounts in highly oxidized sediments indicates that in terms of net processes, decomposition and/or animal excretion of reduced N is fast, or of a magnitude great enough to exceed the conversion of NH_3 to $\text{NO}_2 + \text{NO}_3$.

Any organic material not consumed in the above processes is stored in the sediments as organic carbon. Overall organic carbon content of the surface sediments falls in the range of 0.2 to 0.8% by weight (Fig. 3). These values correspond closely with other abyssal samples from the Caribbean area (Yemel-Yanov 1975), but fall below the generally-accepted value of 1.0-2.0% traditionally thought necessary to eventually produce a hydrocarbon deposit. Variation from core to core on dive 1101 appears to follow no significant trend. However, values from cores taken on dive 1103 tend to (1) be higher than those taken on dive 1101, and (2) increase upslope. Within individual cores, organic levels are typically highest in the first few centimeters, dropping 20-60% within 10 cm of the sediment-water interface. After this point, organic content decreases only slightly, to a maximum measured depth of 30 cm.

The structural homogeneity within the cores themselves decreases the likelihood of extensive reworking by bottom currents. The strong shallow water component within the sand fraction points to a mixed origin of the sediments, and quite likely applies to the organic material as well. The possibility exists for transported plant detritus to be contributing organic matter to abyssal sediments by in situ biological breakdown.

The lower carbon values are consistent with biological, sedimentological and geochemical data gathered on the dives. Eh values of both the interstitial and superstratal waters ranged between 200 and 400 mv (Fig. 3), indicating highly oxidized sediments. This, combined with unfertile surface waters, low sedimentation rates, and recycling by aerobic heterotrophs, does not favor hydrogenation of organic matter and subsequent preservation in the forms of petroleum hydrocarbons (Bordovskiy 1965, Tissot and Welte 1978).

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