

LARGE SERPULID WORM TUBE AGGREGATES INDICATE AN ABRUPT MID-HOLOCENE TRANSITION FROM MARINE TO RESTRICTED HYPOSALINE CONDITIONS

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INTRODUCTION

Large aggregates of calcareous serpulid worm tubes recorded paleoclimate conditions as they colonized the mid to late Holocene Enriquillo embayment. Serpulid worms flourished in the Enriquillo embayment following the demise of the coral reef complex at 5 ka. While serpulid tubes are found in thin layers and as single tubes encrusting corals in normal marine deposits around the lake, they dominated the later environment in a unique aggregate form. Large monospecific mounds up to 2.8 m in height cap the reef sequence and mark the extent of different paleoshorelines around the periphery of the valley. These serpulid mounds are thought to represent the period of transition between open marine conditions and a hyposaline lagunal environment (Guerard et al, 2004).

Serpulids are sessile, polychaete annelids that protrude from their tubes in order to filter feed. Present-day serpulid species are known to exist in mound form but rarely do they attain the size of those at Lago Enriquillo. Observation of modern serpulid reefs in Baffin Bay, Texas suggests serpulids are a euryhaline animal, able to withstand variable environmental conditions (Glumac et al, 2004). Tubes can grow to ~2 cm in length, and form bell-shaped accretionary ridges. In Baffin Bay, these filter-feeding worms colonize waters from 0.5 to 2.5 m depth, and are generally not exposed at high tide (Andrews, 1964).

A thick tufa rind coats the exterior of mounds at many locales around the lake. This well-indurated outer layer is comprised of mainly low-magnesium calcite (Mann et al, 1984). Photomicrographs show a porous, micritic, microsparitic, and peloidal carbonate cement surrounding the elliptical serpulid tubes (Glumac et al, 2004). Similarity between the composition of the serpulid tubes and the tufa suggests contemporaneous deposition (Glumac et al, 2004). By looking at high and low resolution stable isotope data and age dating, we can gain a better understanding of the environments that generated these mounds.

METHODS

Field

A laterally continuous, 58.5 m profile was constructed, beginning with low elevation island mound to a capping fourth tier mound. Geographic (GPS) coordinates were obtained at all mound terrace and contacts. Samples were collected from both mounds and their coral substrates, and sampling sites were marked on the profile. Samples were collected from the Cañada Honda (18°32.020" N, 71°37.202" W) and Abuela Grande (18°24.462" N, 71°36.707" W) locales.

Laboratory

Samples for age dating were chosen after examination under a binocular microscope

and using dental picks. Detrital material was removed using an ultrasonic cleaner, and samples were subsequently powdered. Tubes were removed from both aggregate samples as well as from pieces of coral collected at the stratigraphic contacts between mounds.

Stable isotope data was obtained on powdered calcite extracted from serpulid tubes at high resolution along the length of each tube and as a bulk sample. These two sampling strategies were necessary given that the high resolution sampling transect targets environmental changes that may have occurred during the life span of the individual and the bulk samples provide average environmental conditions.

Whole tubes were crushed by mortar and pestle to obtain the bulk samples. Tubes selected for high-resolution sampling were handpicked from a piece of mound, sonicated until clean, and drilled using a Merchantek Micromill. This computer-directed drilling device enabled recovery of powder from consecutive segments of the tube.

RESULTS

Field Mapping

Mound morphology varies with elevation and location. Mounds closest to the present-

day lake shore are isolated “island” mounds colonizing massive *Montastraea annularis* coral colonies. These single-tiered structures are low relief, lobate serpulid aggregates ringing the patch reefs (Figure 1A) with more developed growth on the leeward side. Four levels of laterally extensive mound terraces on a steeper gradient exist upslope from the sporadic island mounds. Unlike the generally formless mounds of the lowest elevations, the terraced mounds have a hemispherical shape with a distinctive organ-pipe structure (Figure 1B). The lowest level consists of small, squat, “muffin” shaped formations. The second tier displays better developed mounds that colonized *A. cervicornis* rubble. This coral pavement is well cemented. Pieces of packed coral also serve as substratum for the third tier, though a recent road cut reveals a cross-section of fairly pristine *A. cervicornis* directly underneath third tier mounds. The third and fourth tiers contain the largest mounds, with a maximum measured circumference of 12.9 m. The uppermost mounds sit directly atop the third terrace (Figure 1B). Two coalesced mound tiers rim the paleoshorline along the rocky northern cliffs of the valley.



Figure 1. (A) Lowermost “island” mound displaying low relief morphology and characteristic organ-pipe structure.



(B) Hemispherical fourth tier mound with a measured circumference of 10.6 m.

Geochemical Data

Radiocarbon age dating results are given in Table 1. The time interval between colonizing serpulid tubes and coral substrate ranges from 990 to 1120 years. The hiatus between tubes collected from the uppermost fourth tier and the lowermost island mounds is 335 yr. Of all the samples analyzed, the oldest were the *A. cervicornis* layer beneath tier three and the *M. annularis* colonies forming the substrate of the island mounds.

LOCATION	SPECIES	AGE (Ka)
Layer beneath Tier 3	<i>A. cervicornis</i>	5420
Tier 4 contact	<i>M. annularis</i>	5195
Tier 4 contact	<i>M. annularis</i>	5185
Lowermost Island	<i>M. annularis</i>	4990
Tier 3 contact	<i>A. cervicornis</i>	4355/5040
Tier 4 contact	Serpulid	4205
Lowermost Island	Serpulid	3870

Table 1. Ages of radiocarbon-dated samples. Both corals and serpulids were dated at several contacts to develop a time sequence of colonization.

Differences exist between the stable isotope values of the three sample populations: normal marine tubes, tubes from a period of trial mound colonization, and mound tubes (Figures 2 and 3).

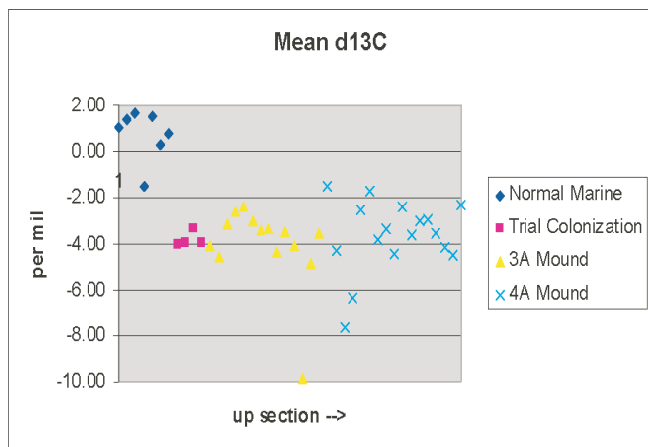


Figure 2. Plot of average $\delta^{13}\text{C}$ for four different locations of serpulid growth.

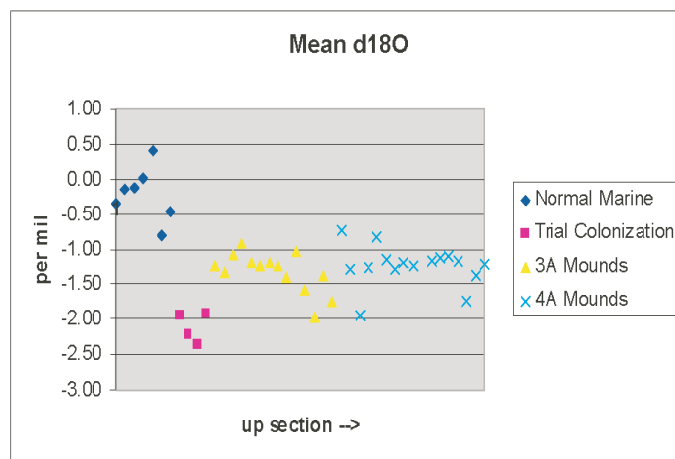


Figure 3. Plot of average $\delta^{18}\text{O}$ for four different locations of serpulid growth.

Samples collected from the normal marine setting display the highest $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ (1.0 ‰ VPDB and 0.0 to 1.2 ‰ VPDB). Tubes taken from the short-lived trial colonization serpulid layer show little variation in $\delta^{13}\text{C}$ but are slightly more variable in $\delta^{18}\text{O}$. Mound tubes display the largest amount of variation in both proxies (-3.0 to -4.0 VPDB, and -0.8 to -1.4 ‰ VPDB), though the average $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values for this group and the trial colonization tubes are roughly the same.

Figure 4 compares plots of the results of high resolution sampling from these three tube settings. Each axis is plotted at the same scale in order to illustrate the disparity in both range and mean $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values. The tube that grew at the base of the fourth tier exhibits the most variability in both stable carbon and oxygen isotope composition. There seems to be little covariation between the two proxies.

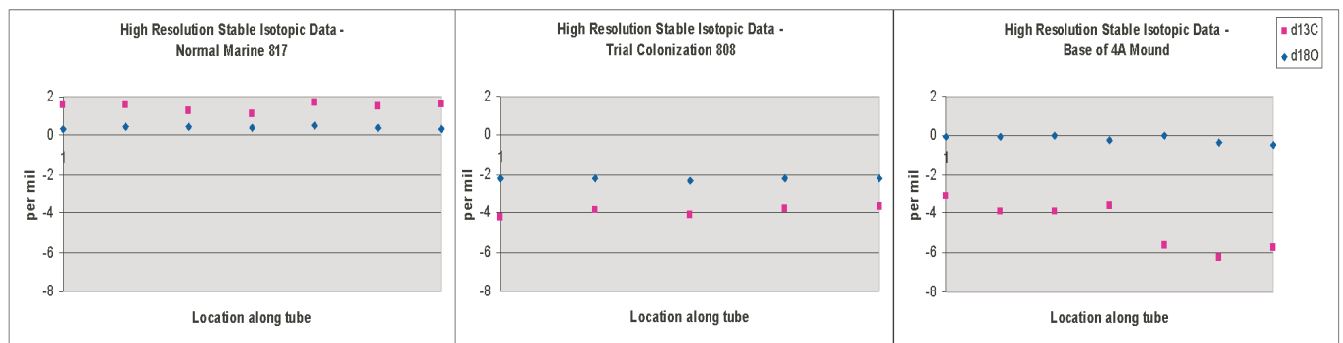


Figure 4. High resolution stable isotopic data of three serpulid tubes taken from a normal marine setting, a thin trial mound colonization layer, and a fully developed mound. Plots are scaled the same (-4 to 2 per mil) in order to highlight differences in range and mean composition.

DISCUSSION

There are three distinct settings of serpulid colonization, characterized by morphology and age. Individual tubes grew amongst healthy coral in the reefal facies, and were thus presumably living in normal marine waters. At the Abuela Grande locale, there is a thin yet stratigraphically distinct monospecific layer of serpulid tubes (Guerard et al, 2004) that overlies reef deposits and underlies the full-fledged mounds. This low diversity assemblage is therefore thought to represent a period of trial colonization. The large aggregates capping the sequence are not consistent with an embayment in open communication with the sea, and seem to have flourished in some sort of ephemeral transitional environment. There is no evidence of coral growth amongst the mounds, so there must have been a change from a normal marine environment.

Radiocarbon dates shed light on the order of formation of these different strata (Table 1) and provide information on the nature of the contact between mound and coral. Samples from the lowermost mounds record the youngest age indicating formation during a regression. The greater than 1,000 yr hiatus between coral termination and mound growth indicates that serpulids were not developing on live coral. The small age difference between tubes collected from the lowermost island mound and

the uppermost tier four contact suggests that these mounds may have been developing at the same time, and/or that growth was rapid.

Given that both $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the normal marine tubes are significantly higher than the other two locales (Figs. 2 and 3), this sample suite likely formed in more saline conditions, with higher levels of organic marine productivity. $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of the trial colonization tubes are much lower suggesting warmer and/or lower salinity water. Low $\delta^{13}\text{C}$ values indicate potentially higher levels of terrestrial carbon, perhaps a result of increased runoff into the lake. This is consistent with a hyposaline scenario. As the embayment began to fill, Lago Enriqueillo became a giant “bowl,” filling up with rainwater and terrestrial runoff. The water level would also have risen if the restriction occurred too quickly for evaporation rates to catch up. This allows for the formation of serpulid mounds tens of meters above the current lake level.

Stable isotope data from tiers three and four of the mounds show a marked negative difference from that of the normal marine tubes (Figs. 2 and 3). The depleted carbon and oxygen isotopic values of both the mounds and the low diversity layer imply low salinity conditions.

In addition, samples taken from the contact between the third and fourth tiers vary widely in stable carbon and oxygen isotope

composition (Figs. 2 and 3). This may be a sign of disequilibrium in the environment between the termination of tier three and the development of tier four, such as a period of storm intensification.

Results from high resolution sampling of serpulid tubes corroborate the idea that mound architecture stems from environmental fluctuations. Rather than purely mechanical sea level change, the differences between tiers may be attributed to substantial oscillations in water temperature, salinity, and/or terrestrial input. A possible cause for these environmental changes could be periodic diversions of the Rio Yaque del Sur into the restricted embayment.

Ranges of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values within a single tube provide a “snapshot” of short-term environmental variability. The timescale represented is dependent upon tube growth rates. Growth rates of presumably closely related modern serpulids can be considered. Bosence (1979) determined a growth rate of 9mm in length over a one month period. Behrens (1968) gave a more complex formula of 1.5-2.5 mm/day for the first three days, followed by a decrease in rate of 0.8-1.3 mm/day for the next two to four weeks. After this, the rate decreases further to 0.1-0.2 mm/day. If the Behrens calculations are accurate, a maximum measured length of an individual tube of ~3cm could represent between 150-300 days growth. It may thus be assumed that the differences in isotopic composition of segments of individual tubes reflect annual seasonal variations in water temperature, salinity, and organic productivity (Glumac et. al., 2004).

CONCLUSION

Mean stable isotope values for the mound serpulids tubes are lower than serpulid values from older coral reef deposits. High resolution geochemical analyses indicate that sub-annual paleoenvironmental data may be extracted

from individual serpulid tubes, and seasonal paleoclimate variability is greater in mound tubes than in tubes formed under normal marine conditions. It is important to continue studying these unusually large serpulid tube mounds because shifting regional climate patterns may have contributed to final restriction of the Enriquillo embayment and termination of coral reef growth. Hopefully understanding this small piece of the puzzle will contribute to greater overall insight into Holocene climate change for the wider Caribbean region.

References Cited

- Andrews, P.B., 1964. Serpulid reefs, Baffin Bay, Southeast Texas. *Depositional Environments, South-Central Texas Coast: Field Trip Guidebook, October 30-31, Gulf Coast Association of Geological Societies, Annual Meeting in Corpus Christi*, p. 102-120.
- Behrens, E.W., 1968. Cyclic and current structures in a serpulid reef. *Contributions in Marine Science*, v. 13, p. 21-27.
- Glumac, B., Berrios, L., Greer, L., and Curran, H.A., 2004. Holocene tufa-coated serpulid mounds from the Dominican Republic: Depositional and diagenetic history, with comparison to modern serpulid aggregates from Baffin Bay, Texas. *Proceedings of the 11th Symposium on the Geology of the Bahamas and Other Carbonate Regions*: San Salvador, Gerace Research Center, p. 49-65.
- Guerard, G.M.M., Greer, L., Curran, H.A., 2004. Environmental indicator proxies from a mid-Holocene coral reef, Enriquillo Valley, Dominican Republic. *Proceedings of the 11th Symposium on the Geology of the Bahamas and Other Carbonate Regions*: San Salvador, Gerace Research Center, p. 35-48.
- Mann, P., Taylor, F.W., Burke, K., Kulstad, R., 1984. Subaerially exposed Holocene coral reef, Enriquillo Valley, Dominican Republic. *Geological Society of America Bulletin*, v. 95 p. 1084-1092.