RECOGNIZING TILEFISH MOUNDS IN THE ROCK RECORD: MOUND SIZE AND ENVIRONMENT ON THE WESTERN COAST OF COZUMEL, MEXICO

MARTIN BEVIS
Department of Geology, Whitman College
Faculty Sponsor: Pat Spencer
PETER DOUGLAS
Department of Geology, Pomona College
Faculty Sponsor: Linda Reinen
GENEVIVE MATHERS
Department of Geology, Macalester College
Faculty Sponsor: Karl Wirth

INTRODUCTION

Sand tilefish (*Malacanthus plumieri*) build mounds of sediment clasts on the ocean floor that serve as protection from predators. The mounds are significant sedimentary structures, averaging 0.1 m^3 in volume. These mounds have not been observed in the geologic record, possibly because no one has recognized them due to the lack of information about their composition and structure.

This project focuses on tilefish mounds along the western coast of Cozumel Island, Quintana Roo, Mexico (Figure1) at depths from eight to approximately seventeen meters. The purpose of this research is to characterize the sedimentary environments in which the mounds occur in terms of the density and type of available clasts, as well as the sand-size sediment surrounding the mounds. Ultimately, the goal of this research is to determine the characteristic features of modern tilefish mounds and their environments so that they might be recognized in the fossil record. A second objective is to determine if tilefish mounds might be useful paleoenvironmental indicators.

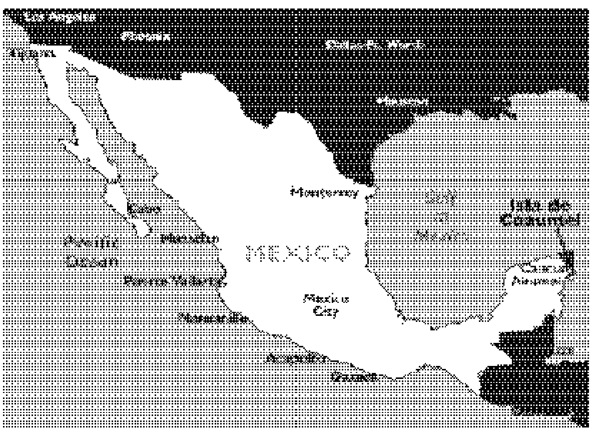

Figure 1. Location of the study area.

METHODS

Data were collected from 21 tilefish mounds and associated transects. At each site the height of a mound was estimated by placing a frame marked in 2 cm increments on its side next to the mound and sighting along it. The length and width of the mound were measured using tape measures in order to estimate the volume of the mound. In order to attain a random sampling of clasts in the mound, a 0.25 m^2 frame was partitioned into twenty-five 0.01 m^2 squared segments with string. The lengths of the long, intermediate and short axes and the type of each clast located at the intersection of two strings were recorded, resulting in between 25 and 100 clasts sampled at each mound.

Two 12-meter transects were constructed roughly north and south from the center of each mound along the contour of the ocean floor. Along the transects a 0.25 m^2 frame was used at 2.5, 5 and 12 meters to measure clasts. This frame was further divided into four equal quadrants of 0.063 m^2 . Each group recorded the long, intermediate, and short axes and type of each clast with a long axis exceeding 20 mm until at least 25 clasts were measured at each transect site.

Sediment samples were collected at 2.5, 5, and 12 meters on each side of the transect. About 75 cm^3 of sediment was collected using a 25 mm diameter core, and was transferred to a resealable plastic bag. The sediments were later sieved (phi sizes -2, -1, 0, 1, 2, 3, 4) dried, and weighed.

Photographs were taken of each mound and each frame along the transect using an underwater digital camera. Environmental observations, such as the general topography, distance from the nearest reef, and species of coral, algae, and plants present were also recorded at each mound site.

RESULTS

The mounds that were studied appear in a wide variety of ocean environments, including areas of various water depths, mean sediment grain size, and abundance of clasts along transects. These variables are not well correlated with mound size, indicating that these aspects of the physical environment have little influence on mound size. Specifically, there is a very low correlation between mound size and mean sediment grain size (Figure 2; $r^2 = 4 \times 10^{-7}$). Similarly, mound size is apparently not related to clast density, the mean number of clasts found per square meter of ocean floor along the transect. (Figure 3; $r^2 = 0.03$). Clast density should represent the availability of mound building materials as tilefish use clasts found on the ocean floor to build their mounds. There is also no correlation between clast density and sediment size along transects (Figure 4; $r^2 = 0.007$). The data suggest that the percentage of rhodoliths (reddish limestone concretions formed by algae), gastropod shells and non-branching coral on the transect increases with distance from the reef whereas the percentage of branched coral decreases (Figure 5). However these data are not statistically

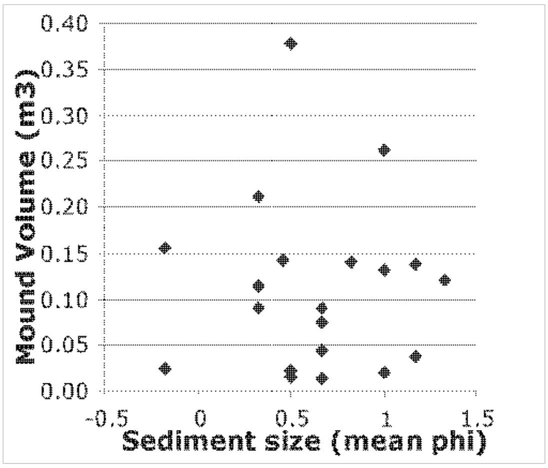

Figure 2. Relationship between sediment size and mound volume.

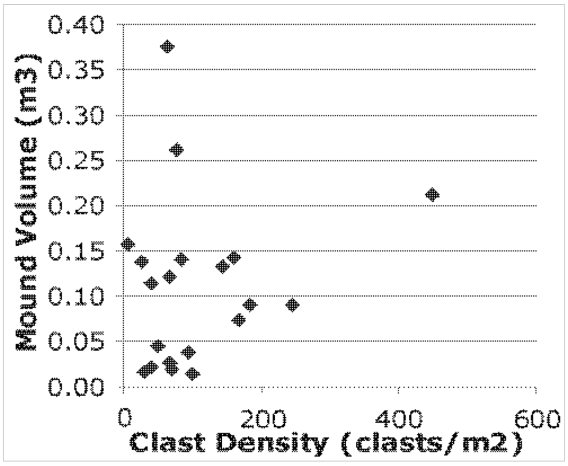

Figure 3. Relationship between the density of clasts and mound volume.

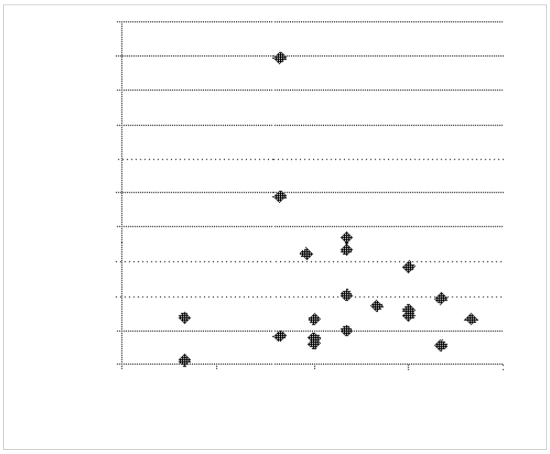

Figure 4. Relationship between clast density (clasts per m3, y axis) and sediment size (mean phi, x axis) along a single transect through the study area

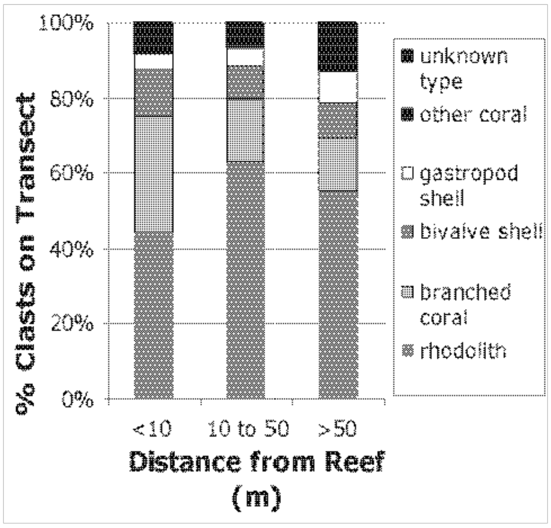

Figure 5. Distribution of clast types with increasing distance from the reef.

significant, so further verification is required. Mound volume shows little correlation with distance from a reef (Figure 6).

DISCUSSION

A previous study (Clarke et al., 1977) suggested that the density of modern tilefish mounds in an area is correlated with the abundance of clasts in that area. This led us to predict that the availability of building materials might also correlate with mound size, but analysis of mound volume and clast density along the transects suggests that these variables are not correlated (Figure 3). Thus, while Clarke's work suggests that clast density is correlated to mound density, our work indicates that there is no correlation with mound size.

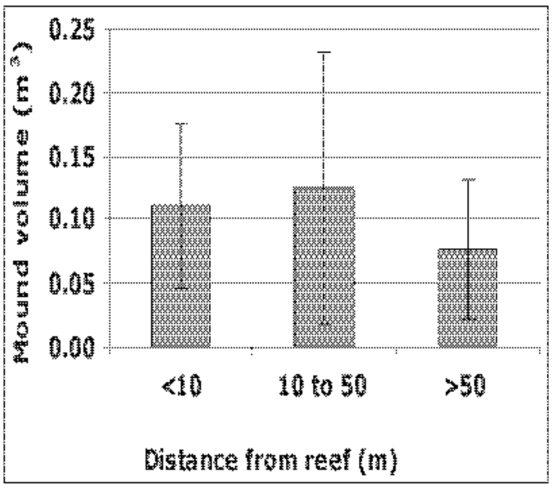

Figure 6. Changes in mound volume with increasing distance from the reef.

Our results suggest that other environmental factors do not constrain mound size. Mound size does not correlate with mean sediment grain size (Figure 4), nor is mound size correlated with distance from reef (Figure 6). This suggests that mound size does not reflect local energy conditions as indicated by mean sediment grain size, that mean sediment grain size is not a good indicator of local energy conditions, or that there are biological factors influencing tilefish mound size that are unrelated to the characteristics of the physical environment that we examined.

Tilefish mounds are part of a complex ecosystem and the wide variance of mound sizes may reflect this complexity. Biological factors that could influence mound size may include the size and age of the tilefish, the gender of the tilefish, the social status of the tilefish, or the threat of predators within an area. In any case, the stage of construction of the mound, the ability of each individual tilefish to move clasts, and the role that other organisms play in moving the clasts both on the mound and the transect are all additional variables that cannot be accounted for quantitatively. Moreover, work was conducted in a complex sedimentary environment due to the biological production of sediment. One possible manifestation of this complexity is the poor correlation between clast density and sediment size (Figure 4), two variables that would be related in an environment dominated by physical sedimentary processes.

The distance from a reef may influence the types of clasts available for mound construction. The percentage of rhodoliths, gastropod shells, and non-branching corals as clasts on the transects increases with increasing distance from the reef, whereas the percentage of branching coral decreases (Figure 5). This suggests that with increasing distance from a reef the environment supports more rhodolith-producing algae, gastropods, and non-branching corals. These changes in clast type with distance from a reef might also be seen within the mound and would reflect changes in available materials (see Leven and Waldron, this volume). The correlation between distance from reef and clast types in the transect is suggested by our data, but not statistically significant. Additional research may confirm this apparent trend.

One direction for further research would be to study how mounds differ between defined sedimentary environments. All of the mounds that we studied are exclusively within the shallow carbonate shelf-edge reef system as defined by Leeder (1999). However, we observed several mounds outside the shelf edge reef environment (e.g. in the fore-reef environment along the San Francisco Wall west of our study area) that could be studied in the future. Muckelbauer (1990) defined multiple microenvironments in the shelf-edge reef environment on the basis of biological indicators, and many of these microenvironments are found in our study area. Although we collected data from many of these microenvironments, we don't have enough data from any particular microenvironment to notice trends in mound size. Further research could focus on mounds within specific microenvironments to see if mound size shows trends within these smaller environments. If so, this might indicate that within a broad depositional environment, such as the shelf edge reef, mound size is primarily influenced by small-scale biological environments rather than physical parameters.

The prevalence of mounds in modern facies suggests that fossil mounds should be found in similar Pleistocene facies. The shallow carbonate reef environment studied in this project most closely resembles the leeward coral facies identified by Spaw (1978) in his mapping study of the Pleistocene rock facies of Cozumel. Assuming that tilefish population levels and mound building behavior have not changed since the Pleistocene, the western part of Cozumel Island should have a high density of tilefish mounds in its rock record. The results of this study suggest that the size of fossilized mounds may not correlate with sediment size, clast density, or proximity to reefs within the geologic record. No fossil mounds were identified during a brief, informal reconnaissance study of outcrops along part of the coast, but future study is recommended.

CONCLUSION

We examined tilefish mounds throughout the study area in a shallow carbonate reef edge environment. The size of these mounds is apparently not well correlated with water depth, mean sediment grain size, availability of clast material, or proximity to reefs. Thus we found no physical parameter that correlates with mound size. As we found mounds of various sizes throughout our study area we expect that mounds widely ranging in size will be found in other shallow carbonate environments where tilefish live. We also expect that fossilized mounds will be found throughout a similar Pleistocene facies on the west side of Cozumel and elsewhere in the world.

ACKNOWLEDGEMENTS

We would like to thank Steve Ballou, Carol Mankiewicz, and Karl Wirth for their leadership, knowledge, guidance and wisdom; the crew of the Keck Cozumel 2003 project for collecting data and playing some great cribbage; Papa Hog's Scuba Emporium for taking care of us in Cozumel and for our first experience with the Federales; Beloit College Geology Department for the use of its facilities; and finally, the Keck Geology Consortium for the Benjamins.

REFERENCES CITED

Clarke, D.G., Crozier, G.F., Schroeder, W.W., 1977, Observations on the ecology and behavior of the sand tilefish, Malacanthus plumieri: Proceedings, Third International Coral Reef Symposium v.3. p. 579-583.

Leeder, M., 1999, Sedimentology and sedimentary basins: Oxford, Blackwell Science 430 p.

Muckelbauer, G., 1990, The shelf of Cozumel Mexico: topography and organisms: Facies, v. 23, p. 185-240.

Spaw, R.H., 1977, Late Pleistocene carbonate band deposition: Cozumel Island, Quintana Roo, Mexico: Gulf Coast Association Geological Societies Transactions, v.28, no. 2, p. 601-619.

White, R., and White, S., 2002, http://www.cozumelvillas.com/mexmap.html in Vacation villas and condos in Cozumel, Mexico: Tropical Island Connections. Accessed 2 July,