RECOGNIZING TILEFISH MOUNDS IN THE ROCK RECORD: LESSONS FROM MODERN TILEFISH MOUNDS OF ISLA COZUMEL, MEXICO

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INTRODUCTION

The sand tilefish, *Malacanthus plumieri*, are important geologic agents in shallow waters of the Caribbean (Fig. 1). The fish make a depression in the sand and then collect pebble- and cobble-size clasts from the surrounding area to construct a mound over and around the depression, thus concentrating clasts into protective mounds. If alarmed, the fish will dive head first into its burrow, turn around, and face outward.

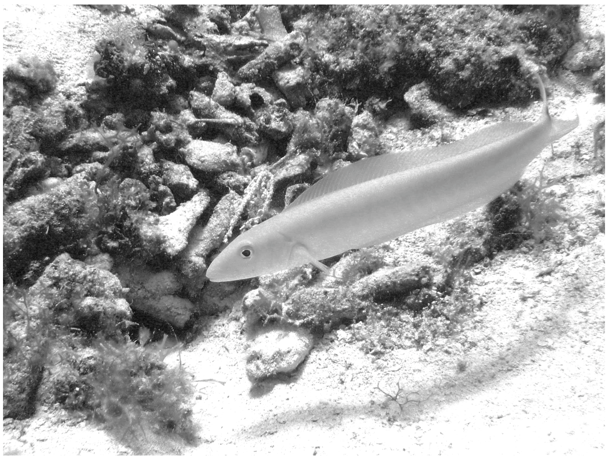

Figure 1. Tilefish alongside its mound.

Several researchers have studied the behavior of *M. plumieri* (e.g., Baird, 1988; Clark et al., 1988; Baird and Baird, 1992), but few have concentrated on the fish as a geologic agent. Clifton and Hunter (1972) first noted the importance of this fish's mound building; they investigated mound structure and distribution in the Virgin Islands where mound concentrations reach one per 10 m^2. Büttner (1996) reported on *M. plumieri* mound composition off the coast of Colombia. All of these studies, whether biological or geological in approach, attest to the abundance of this tilefish in shallow Caribbean waters. To our knowledge, however, no mounds have been described from the rock record. One of our goals, therefore, was to build on the work of Clifton and Hunter (1972) and Büttner (1996) by more thoroughly describing tilefish mounds to facilitate their recognition and differentiation from physical accumulations of clasts in the rock record. A second goal was to evaluate mounds as possible environmental indicators to facilitate paleoenvironmental analysis.

We investigated characteristics of mounds on a 10-km stretch of the leeward shelf of Isla Cozumel, Mexico, which lies 18 km east of the Yucatan Peninsula (Fig. 2). Geologically, the island is a tilted fault block that probably separated from the mainland in the Late Jurassic. The surface rocks result from late Pleistocene bank deposition (Spaw, 1977, 1978).

The leeward shelf of Cozumel is narrow and consists of three sand-covered terraces formed during Holocene sea-level rise (Muckelbauer, 1990) (Fig. 3). Steps between terraces can be distinct (common in the southern part of our study area) to gradual. Coral reefs develop near the edge and seaward face of the steps (Muckelbauer, 1990). The tilefish mounds that we studied occur in water depths of 7 to 17 m. Thus, our sampling was restricted to the equivalent of Terrace 2 and the most landward part of Terrace 3. We observed tilefish and mounds, however, to depths greater than 27 m, indicating that they occur throughout Terrace-3 depths.

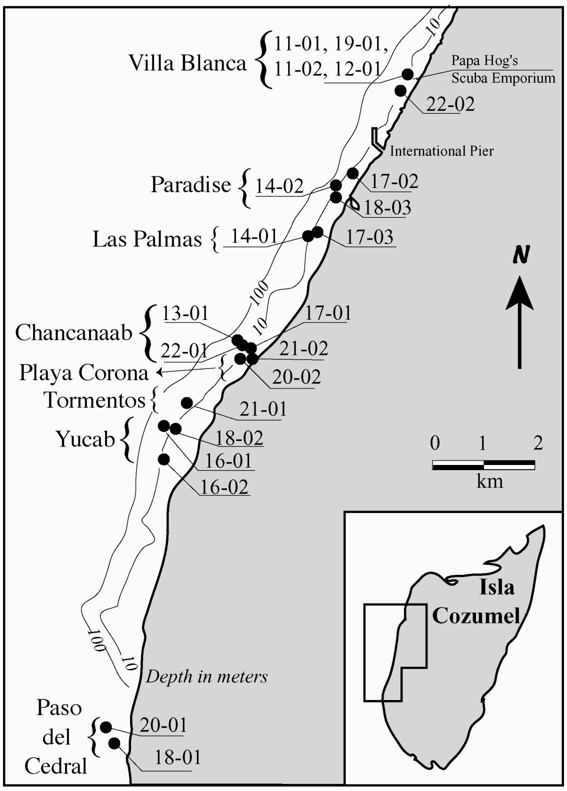

Figure 2. Isla Cozumel (inset) showing field area on its west-central coast. Locations of individual mounds are plotted and dive-site names are noted.

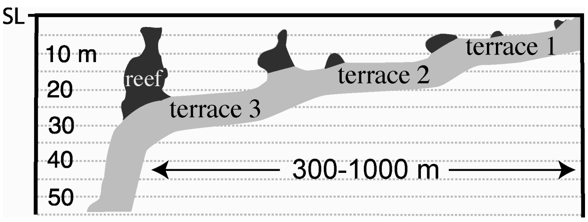

Figure 3. Schematic profile of the western (leeward) shelf of Isla Cozumel (after Muckelbauer (1990)).

METHODS

We described and measured the first tilefish mound encountered on each of 21 SCUBA dives as follows (see Fig. 4). Mounds studied showed evidence of recent occupation by a tilefish (e.g., well maintained burrow entrance).

We measured the length, width, and height of the mound and set up a 24-m-long transect by stretching out two tapes from the center of the mound approximately along a contour (oriented about N-S in the area of Cozumel).

Two pairs of researchers focused on each mound. Surface mound clasts were sampled using a 0.5 x 0.5 m PVC-pipe frame strung at 10-cm intervals. Each clast directly under string intersections was classified as to type (rhodolith (i.e., red-algal nodules), branching coral, columnar coral, rose coral, bivalve shell, gastropod shell, or unknown), measured with calipers (long, intermediate, and short axes), and returned to its original place on the mound. The grid was flipped (indicated by dashed frames in Fig. 4) until the entire mound was sampled.

Two pairs of researchers measured and described clasts at 2.5, 5, and 12 m along the transect to the north and south of the mound using a 0.5 x 0.5 m PVC frame quartered with string. All clasts within a quarter were typed and sized. If fewer than 25 clasts occurred in a quarter, the next quarter was sampled until at least 25 clasts were measured at each of the six sampling distances. Figure 5 shows teams of students measuring and describing clasts along transects and at the mound.

At 2.5, 5, and 12 m north and south of the mound, we collected about 75 cm of sediment using a 25-mm-diameter core. The sediment was emptied into a resealable plastic bag. Onshore, samples were sieved (phi sizes of -2, -1, 0, 1, 2, 3, 4), air dried, and weighed.

We photographed each mound and each frame along the transect using an underwater digital camera. We recorded environmental information (including depth, distance from reef, percent cover, and types of algae and invertebrate animals) on mylar sheets. Onshore, data were entered into computer databases.

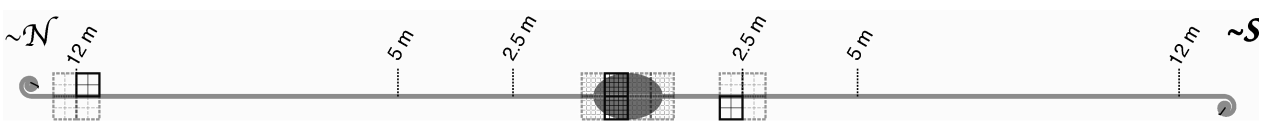

Figure 4. Schematic showing methods for sampling mound (center) and at six areas along a transect (2.5, 5, and 12 m north and south of the mound).

Figure 5. Students working along the northern transect (foreground), mound (center), and southern transect (upper left).

RESULTS

Throughout the project, we worked as a group to measure and describe 21 mounds, enter data, process sediment samples, and catalog photographs. During the final week in the field, students chose an area of research on which to focus. Four students chose to focus on detailed characterization of the mounds and clasts available in the area for mound building. Chelsea Leven and Alice Waldron focused on the mounds themselves, and John Patrick Diggins and Drew Feucht compared clast sizes and types found along the transect to those on the mound surface. The other four students investigated the role of mounds as environmental indicators. Martin Bevis, Peter Douglas, and Genevive Mathers studied mounds in relation to physical and biological parameters such as depth, percent cover, and reef facies. Veronica Poteat focused on characteristics of the sediment throughout the field area. See each student paper for results.

HOW CAN WE RECOGNIZE TILEFISH MOUNDS IN THE ROCK RECORD?

Today, tilefish have a broad distribution, predominantly in tropical and subtropical waters worldwide (Dooley, 1978; Froese and Pauly, 2003). All tilefish construct burrows in sand or mud (Froese and Pauly, 2003); most members of the family Malacanthidae, the family in which *M. plumieri* is classified, build mounds.

We do not know the distribution of ancient tilefish because fossils are rare. Arambourg (1927) reported a fossil tilefish of the family Branchiostedigae (today a non-mound-building family) from the Miocene of Algeria. Eagle (1997) reported a possible malacanthid from the Miocene of New Zealand. We know of no fossil mounds and only one report of fossil burrows that have been likened to those of tilefish; Snedden (1991) described Cretaceous-age burrows in Texas and suggested that they might have been constructed by "forerunners of the tilefish." Either geologists do not recognize cobble accumulations in the rock record as biological constructions or tilefish mounds do not occur in the rock record (i.e., mound-building behavior is recent). Assuming the former, how can we recognize biological mounds in the rock record? On the basis of results presented in this volume, in Mankiewicz et al. (2003), and in the literature, especially Clifton and Hunter (1972) and Büttner (1992), we suggest using the following criteria in support of a biological origin for cobble accumulations.

1. In sections parallel to bedding, the accumulation of clasts will appear circular to semi-circular in shape. The size can range from 0.25 to 2 m or more in diameter.

2. In cross-section, the accumulation will be lensoid in shape and up to 0.3 m high. The accumulation may be stratified. If stratified, irregular-shaped clasts will dominate in the lower part and will interlock; more regular shaped (ovoid) clasts will be on top. In addition, fine (muddy) sediment should occlude some of the pore spaces between the

larger clasts. Muds accumulate on modern mounds due to the baffling effect of the mound itself and that of organisms that encrust surface clasts, and, probably, due to in situ generation of feces and pseudofeces by the numerous organisms that inhabit the mounds. Sand too may occlude some porosity. Sand can be deposited from suspension or as migrating bedforms that impinge on the mounds. Thus, sand might drape over mound clasts or filter down between them. There should be some evidence of the former burrow. Look for (a) a void that might be about 10 cm+ high x 25 cm wide and some greater distance long; (b) evidence of collapse of the accumulation; (c) evidence of sediment fill (the sediment might be a different size than the surrounding sediment or may show some faint cross-strata that dip in towards the accumulation); or (d) any combination of a, b, and c.

3. The accumulation of clasts in the mound will be dominated by large pebbles to cobbles, possibly in the 40 to 90 mm size range. In Cozumel, the clasts in the area surrounding a mound are on average smaller by 20 to 40 mm, but this need not be the case in all environments; the size difference, in part, may reflect the submersed weight of the clast. (Larger sizes may be excluded by the fish because they are too large or heavy for the fish to handle. Smaller sizes might be excluded because they contribute less to the mound structure relative to the energy expended to collect and position them.) The size range of the clasts in the accumulation likely will be narrower than that in the surrounding area. The exclusion of smaller clasts relative to the surrounding area may be particularly helpful in differentiating the accumulation from one that was physically transported given that the flow competence determines the maximum size transported, not the minimum size.

4. In general, the types of clasts in the accumulation will reflect those found in the immediate area. This criterion will differentiate the deposit from a physical accumulation of clasts transported from another area.

Fossil tilefish mounds would most likely be found in Miocene to Holocene carbonate strata deposited in shallow water (less than 50-150 m depth) associated with tropical to sub-tropical reefs. The mounds might even serve as the base for patch reefs as suggested by Muckelbauer (1990). Largest mounds would probably be in reef flat facies; smaller mounds may be more common in shelf-edge facies. Many carbonate strata meet these criteria—even those on Isla Cozumel itself. We invite geologists to re-examine these units in search of tilefish mounds.

FUTURE STUDIES

Our results showed few simple relationships between mound characteristics and environmental indicators such as depth, sand-size distribution, algal cover, clast abundance, and distance from a reef. In part, the lack of strong correlation between parameters may reflect the broad reconnaissance approach in which we studied mounds along a 10-km stretch of the shelf. In a future study, we would refine and build on our earlier work, and more specifically study environmental parameters. Such a study would better address mounds as potential paleoenvironmental indicators.

We would choose two locations to study (one in the northern part and one in the southern part of our 2003 area) investigating mounds along a transect perpendicular to the coast. We would measure many of the same characteristics of mounds as in the 2003 study, but would devote more efforts to characterizing the environment. Ideally, we would make maps of mound locations, from which we could calculate mound density, and thereby better document the importance of tilefish as geologic agents. (We had originally planned to map in 2003, but strong currents that *can* occur in June *did* occur, forcing us to abort these plans.) Additionally, we would spend time studying outcrops of Pleistocene carbonates along the coast and in quarries; if we found fossil tilefish mounds, this portion of the project would be expanded.

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