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Author(s): S. J. Mazzullo, K. E. Anderson-Underwood, C. D. Burke, W. D. Bischoff
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Holocene Coral Patch Reef Ecology and Sedimentary Architecture, Northern Belize, Central America

S. J. MAZZULLO, K. E. ANDERSON-UNDERWOOD,1 C. D. BURKE, and W. D. BISCHOFF

Department of Geology, Wichita State University, Wichita, KS 67260

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The biotic composition, growth and relationship to sea level history, and diagenetic attributes of a representative Holocene patch reef (“Elmer Reef”) in the Mexico Rocks complex in northern Belize are described, and compared to those of Holocene patch reefs in southern Belize. Elmer Reef has accumulated in shallow (2.5 m) water over the last 420 yr, under static sea level conditions. Rate of vertical construction is 0.3–0.5 m/100 yr, comparable to that of patch reefs in southern Belize. A pronounced coral zonation exists across Elmer Reef, with Montastrea annularis dominating on its crest and Acropora cervicornis occurring on its windward and leeward flanks. The dominance of Montastrea on Elmer Reef is unlike that of patch reefs in southern Belize, in which this coral assumes only a subordinate role in reef growth relative to that of Acropora palmata. Elmer Reef locally is extensively biodegraded and marine, fibrous aragonite and some bladed high-magnesium calcite cements occur throughout the reef section, partially occluding corallites and interparticle pores in associated sands.

Patch reefs in southern Belize have developed as catch-up and keep-up reefs in a transgressive setting. In contrast, the dominant mode of growth of Elmer Reef, and perhaps other patch reefs in Mexico Rocks, appears to be one of lateral rather than vertical accretion. This style of growth occurs in a static sea level setting where there is only limited accommodation space because of the shallowness of the water, and such reefs are referred to as "expansion reefs".

INTRODUCTION

Coral patch reefs are major components of Holocene platform carbonate facies systems in tropical and subtropical areas (James, 1983). Many studies have been published on such reefs, and have focused on aspects of their environmental setting and morphology, biotic compositions and zonations, rates of growth, and synsedimentary diagenesis (reviews in James, 1983, 1984; James and Macintyre, 1985; Schroeder and Purser, 1986b; Fagerstrom, 1987; and papers in Frost et al., 1977 and Schroeder and Purser, 1986a). Similar studies of Holocene and Pleistocene patch reefs in Belize have also been done, and they have dealt exclusively with those on the southern shelf (Wantland and Pusey, 1971; York, 1971; Purdy, 1974a, b; York and Wantland, 1975; Halley et al., 1977; Miller and Macintyre, 1977; Shinn et al., 1979; James and Ginsburg, 1979; Choi, 1981; Choi and Ginsburg, 1982; Westphall and Ginsburg, 1984; Westphall, 1986) or on large atolls seaward of the continental margin (Wallace and Schaferman, 1977; James and Ginsburg, 1979). In contrast, there is no published information on patch reefs in northern Belize despite their abundance and importance to carbonate sedimentation here. Preliminary study (Anderson, 1990) has suggested some fundamental differences between Holocene patch reefs in northern and southern Belize in terms of depositional settings, ages, and biota. Furthermore, this study suggests that patch reef growth, and relationship to sea level history, are distinctly different in northern and southern Belize. However, the extent of these differences and their effects on reef development remain to be evaluated.

This paper presents the results of a detailed study of a single Holocene coral patch reef on the northern Belize shelf, one that is representative of the many such patch reefs that occur in this area. The age and geologic setting, relationship to Holocene sea level history, types of biota and associated sediments, rates of reef construction, and synsedimentary diagenetic attributes of this patch reef are described. This patch reef is compared to published descriptions of some Holocene patch reefs in southern Belize, and interpretations therefrom provide information critical to interpreting patch reef development in other areas of the world.
LOCATION AND METHODS OF STUDY

The study area is within the Mexico Rocks complex, seaward of Ambergris Cay in northern Belize (Fig. 1). Mexico Rocks covers approximately 1.5 km² on the shallow, outer-shelf lagoon to the lee of the Belize barrier coral reef, and includes scores of coral patch reefs (Fig. 2A). Moderate physical energy levels of the Mexico Rocks area result from wind-driven waves and deep-ocean swells which enter the lagoon through passes on the barrier reef (Fig. 1). Current and sediment transport directions here are to the northwest, and semi-diurnal tidal range is less than 0.3 m. Distribution of Holocene facies in the area is shown in Figure 1B. Holocene sediments are deposited on Pleistocene limestone bedrock (Ebanks, 1975; Pusey, 1975) dated at 125 Ka old (Lighty and Russell, 1985).

The patch reef examined in this study (“Elmer Reef”) is located near the northeastern tip of Mexico Rocks (Figs. 1, 2). It was chosen for study because it appeared to be representative of the many patch reefs here in terms of geometry and biota. Elmer Reef is 16 m in length and a maximum of 8 m in width. Its thickness and height above the sea floor vary from 1.6–2.2 m, although deep crevasses are present locally (Fig. 2B). Water depths around Elmer Reef and throughout the Mexico Rocks area average 2.5 m, and the top surfaces of most of the patch reefs, including Elmer Reef, are within 0.3 m of mean sea level.

Identification of the invertebrate biota living on and around Elmer Reef was done during snorkel and SCUBA surveys. Determination of biotic distribution patterns was done by counting the number of different species present within each square (0.3 m²) on grids placed across the reef. Because extensive coring and underwater excavations of reefs are not permitted in Belize, we were able to take only one core through Elmer Reef, at a locality near its seaward side (Fig. 2B). Samples recovered from this core were examined by thin section petrography and scanning electron microscopy. A sample from an unaltered (aragonitic) coral from near the base of the core was sent to Geochron Laboratories (Cambridge, Mass.) for radiocarbon dating.

Thickness of modern sediments and subsea depth to the top of the Pleistocene limestone were measured in Mexico Rocks, and specifically along two traverses around Elmer Reef (Fig. 1B), by probing to bedrock with a steel rebar (reinforcement bar). Twelve surface sediment samples were collected along the two traverses, within 20 m of the reef (Fig. 1B), in order to evaluate sediment budget in the immediate area. One additional sample was collected for comparison from the sand flat behind the barrier reef (Fig. 1B).

PATCH REEF ARCHITECTURE

Reef Foundation

Thickness of unconsolidated, Holocene marine sediments in the study area varies from about 370 cm along the coast of Ambergris Cay, 440 cm in the sand flat immediately behind the barrier reef, to only 10–20 cm around Elmer Reef (Fig. 3A). Sediment thickness in the study area is the inverse of topography on the underlying Pleistocene limestone, and the entire Mexico Rocks complex has formed on a NE-trending bedrock ridge of considerable areal extent (Fig. 3). Elmer Reef is situated on a 0.35 m high bump on this larger bedrock ridge (Fig. 4).
Extant Reef Biota and Ecology

*Montastrea annularis* is the principal framebuilder on the living surface of Elmer Reef, composing approximately 70% of the total biota (Table 1). Other corals living on the reef include *Diploria sp.*, *Agaricia agaricites*, *A. purpurea*, *Porites furcata*, *P. porites*, various octacorals (*Plexaura sp.*, *Plexaurella sp.*, and *Gorgonia sp.*), and rarely, *FIGURE 3—A) Thickness of Holocene sediment in study area (CI = 20 cm around Elmer Reef and changes to 100 cm away from it). B) Depth to top of Pleistocene limestone, datum mean sea level (CI = 0.5 m).
Millepora sp. (Table 1). Montastrea dominates on the eastern (windward) half of the patch reef proper, where it comprises nearly 90% of the total biota. In contrast, Montastrea makes up about 50% of the total biota on the western (leeward) side of the reef proper, and is associated with a more diverse assemblage of other corals which altogether compose 77% of the total biota (Fig. 4 and Table 1). Agaricia occurs mainly on the undersides of and between larger coral heads on the patch reef. Isolated stands of Acropora palmata are found on some patch reefs in the Mexico Rocks complex, but do not occur in Elmer Reef. Encrusting foraminifera (Homotrema rubrum) and coralline algae (Lithothamnion) are found locally on the corals. Calcareous algae (Halimeda incrassata, Penicillus capitatus, Udotea flabellum, and locally Padina sp.), anemones, fan worms and featherworms, sponges (Callyspongia sp. and Verongia sp.), echinoderms (Diadema sp.), and various molluscs inhabit sheltered areas between corals and crevasses within the reef. Coral growth at Elmer Reef has resulted in a steep-walled accumulation that is a maximum of 2.2 m high (Fig. 2B). Our observations suggest that such a geometry is characteristic of most of the patch reefs in Mexico Rocks.

Acropora cervicornis is the dominant coral flanking Elmer Reef. It is more abundant on the somewhat protected, lower-energy western (leeward) flank of the reef than on its eastern (windward) flank, composing 75% versus 50% of total biota, respectively (Table 1). Diploria, Gorgonia, Agaricia, Porites, octacorals, and some M. annularis also occur in these areas, together with the same taxa of calcareous algae, sponges, molluscs, and echinoderms as are found on the reef (Fig. 4 and Table 1). Large blocks of M. annularis dislodged from the Elmer Reef proper occur locally in areas flanking it.

The activities of parrot fish, clinoid and siphonodictid sponges, echinoids, boring pelecypods, rasping gastropods, and endolithic algae have resulted in locally extensive degradation of the reef. Bioerosion, likely along with periodic physical erosion, produce sediments which are deposited within crevasses and growth-framework voids, and partially cover eroded areas on Elmer Reef. These sediments are similar compositionally to sediments around the reef (discussed below).

Sediments Around Elmer Reef

Sediments around the reef (samples 1–12) consist of unconsolidated, poorly sorted, gravelly sands and slightly gravelly sands composed mainly of Halimeda and coral fragments, with lesser amounts of miliolid and rotaliid foraminifer, molluscs, H. rubrum, ostracodes, sponge spicules, and echinoderm fragments (Table 2). Peloids appear to be mostly micritized coral and Halimeda fragments. Sediments from the sand flat behind the barrier reef (sample 13) are similar compositionally to those around Elmer Reef (Table 2). Therefore, it is not possible to discern how much of the sediment surrounding Elmer Reef is actually derived from it versus having been transported there by currents from the sand flat.

Internal Structure and Composition

The top 0.19 m of Elmer Reef was not cored so as to avoid damage to living corals. Instead, the core was spud-
TABLE 1—Estimated average percentages of biota living on and surrounding Elmer Reef. “VB” refers to mostly vagrant benthos for which percentages were not tabulated.

<table>
<thead>
<tr>
<th>Biota</th>
<th>Elmer Reef</th>
<th>Off-reef (within 5 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East side</td>
<td>West side</td>
</tr>
<tr>
<td>Corals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agaricia agaricites</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>A. purpurea</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Acropora cervicornis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Diploria sp.</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Gorgonia sp.</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Montastrea annularis</td>
<td>89.5</td>
<td>50</td>
</tr>
<tr>
<td>Plexaura sp.</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Plexaurella sp.</td>
<td>0.5</td>
<td>4</td>
</tr>
<tr>
<td>Porites furcata</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>P. porites</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Algae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithothamnion sp.</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Halimeda incrassata</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Penicillus capitatus</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Udotea flabellum</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Worms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fanworms (Sabella sp.)</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Featherworms (Spirobranchus sp.)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sponges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Callyspongia sp., Verongia sp.</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Various molluscs (pelecypods, gastropods)</td>
<td>VB</td>
<td>VB</td>
</tr>
<tr>
<td>Echinoderms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diadema sp.</td>
<td>VB</td>
<td>VB</td>
</tr>
<tr>
<td>Totals</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

ded in a void between growing coral heads, and penetrated 1.41 m of Holocene section overlying Pleistocene limestone (Fig. 5). The upper few centimeters of Pleistocene limestone recovered at the base of the core consist of well indurated coralgal sands of low-magnesium calcite composition. Based on limited core recovery in the Pleistocene limestone section, it is not presently possible to determine if Elmer Reef developed on an older patch reef. Although the Pleistocene was exposed subaerially prior to Holocene submergence (Ebanks, 1975; Pusey, 1975), any physical evidence of exposure that may have been present has been obliterated by bioerosion.

In addition to coral growth-frameworks, Holocene samples in the core mainly included fragments of partially lithified sediments, and most of the unconsolidated sediments in the section were flushed from the core barrel during drilling. However, some of these sediments were collected (Fig. 5) when rates of drilling could be reduced. Numerous cavities were encountered in the section (Fig. 5) as indicated by the unimpeded drop of the core barrel during drilling.

The cored section above the Pleistocene limestone consists entirely of layers with in situ growth-framework corals, dominated by M. annularis and minor recognizable Diploria, admixed and interbedded with lenses and layers of gravelly sands (Fig. 5). Thickness of fossil coral colonies on the core varies from 0.025 m to 0.1 m, and like their living counterparts, the corals are encrusted locally by Homotrema rubrum and Lithothamnion, and are biocrititized. An unaltered (aragonitic) sample of M. annularis collected from the stratigraphically lowest recognized in situ coral colony at 0.19 m above the base of the core (Fig. 5) yielded a radiocarbon date of 420 ± 130 BP.

The lithified, gravelly, skeletal sand layers in the core vary in thickness from 0.25 m to nearly 0.5 m (Fig. 5). These deposits, as well as samples of unlithified sediments that were collected, consist of particles of the same biotic types as are found living on the modern reef surface and
TABLE 2—Particle composition in different size fractions of Holocene sediments versus distance from Elmer Reef, given in averages for respective sample suites (see Fig. 1B for locations of samples).

<table>
<thead>
<tr>
<th>Particle types</th>
<th>Immediately surrounding the reef (5.0 m): samples 3, 4, 7, 10</th>
<th>Distal from the reef (20 m): samples 1, 6, 9, 12, 13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gravel Medium to very coarse sands</td>
<td>Medium to very coarse sands</td>
</tr>
<tr>
<td>Corals</td>
<td>21.5</td>
<td>12.2</td>
</tr>
<tr>
<td>Halimeda</td>
<td>62</td>
<td>63.6</td>
</tr>
<tr>
<td>Miliolids and</td>
<td>6.5</td>
<td>11.9</td>
</tr>
<tr>
<td>Rotaliids</td>
<td>5.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Molluscs</td>
<td>3.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Homotrema rubrum</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Ostracodes</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>1.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Echinoids</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Peloids</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

around it. Coarse sand and gravel size fragments of M. annularis and Halimeda dominate in these sediments.

**Interpretation of Core**

We interpret the cored section as being of patch reef origin based on the abundance of coral framestones and associated coralgal sand and gravel. Reefs and patch reefs typically consist of abundant rubble together with in situ reef framework (Friedman, 1970; James, 1983). Cavities in this section are interpreted as being large growth-framework voids which are common in modern and ancient reefs (James, 1983).

**Diagenesis**

All skeletal components on and around the reef and in the core are composed of either aragonite or high-magnesium calcite, the exception being ostracodes which are primary low-Mg calcite. Aside from biodegradation, the most conspicuous diagenetic aspect of Elmer Reef is the presence throughout the core (Fig. 5) of syndepositional marine cements and internal sediments. Internal sediments occur within corals, and consist of pockets of crystal silt and micrite that locally are graded and laminated (Fig. 6A).

Marine cements occlude from 10–15% of primary porosity in the core. The most abundant cement mineralogy encountered is aragonite, as confirmed by XRD and the occurrence of prominent Sr peaks on EDAX scans. The abundance of aragonite cement in Elmer Reef contrasts with the overall dominance of high-magnesium calcite cements in reef and fore-reef settings in southern Belize (James and Ginsburg, 1979; Shinn et al., 1982). Aragonite cements occur most commonly as isopachous druses of needles and square-tipped fibers 100 to 500 μm long and 3 μm wide (Fig. 6B). Crystals typically have nucleated syntaxially on corallite walls, and also occur in interparticle pores in partially lithified sediments. Also present, but less abundant, are isopachous druses of acicular aragonite crystals 15 to 20 μm in length and 3 μm in width (Fig. 6C). These crystals are commonly found in small corallites where they also have precipitated syntaxially on skeletal aragonite substrate, and also in interparticle pores in associated sands and internal sediments. These arago-
Syndepositional diagenetic fabrics are similar to those described in Holocene and Pleistocene reefs by many workers (Friedman, 1974; Macintyre, 1977; James and Ginsburg, 1979; Bathurst, 1983).

Large (60–75 μm), bladed cement crystals occur rarely within some corallites, where they have precipitated on substrate of acicular aragonite cement (Fig. 6D). A magnesian calcite mineralogy of these cements is suggested by the presence of subdued Mg peaks and corresponding absence of Sr peaks on EDAX spectrum scans. The MgCO₃ concentrations of these cements could not be determined by this technique with available equipment, or by other techniques, because of inadequate supplies of samples. However, they resemble marine, bladed HMC cements described by several workers from Holocene and Pleistocene reefs (Schroeder, 1973; James et al., 1976; Bathurst, 1983; Pierson and Shinn, 1985). Equivocal examples of micritic HMC cements were not found in any of the samples examined.

DISCUSSION
Rates of Construction

Elmer Reef is 1.6 m thick at the locality where the core was taken (Fig. 2B), and the coral that was dated at 420 ± 130 BP was from 0.19 m above the top of the Pleistocene limestone (Fig. 5). Hence, average rate of vertical construction (total mass balance between coral growth and destruction: Schlager, 1981) of the upper 1.41 m of the reef here is approximately 0.5 m/100 yr. The maximum thickness of the patch reef is 2.2 m. Assuming that the 0.19 m of unrecovered sediment section in the core beneath the dated coral (Fig. 5) is also about 420 yr old, a maximum rate of...
vertical construction of 0.5 m/100 yr is indicated for Elmer Reef. These construction rates (0.3–0.5 m/100 yr) are within the range of values reported for patch reefs on the southern Belize shelf, which are generally lower than those of Holocene platform margin reefs (Fig. 7). We cannot estimate rates of lateral accretion of the reef because we were able to take only one core through it. However, work in progress on other reefs in Mexico Rocks is attempting to resolve this matter.

Rate of accumulation of sediment surrounding Elmer Reef, based on a maximum thickness of 20 cm, is 0.05 m/100 yr, and is comparable to that reported by Halley et al. (1977) for sediments surrounding Boo Bee patch reef in southern Belize (0.4–0.5 m/100 yr). The order of magnitude difference between accumulation rates of patch reef and off-reef deposits in the study area is similar to that of platform reef and lagoonal accumulation rates in Holocene sediments in Belize (Purdy, 1974a).

Relationship to Sea Level and Mode of Growth

Sea level on the northern Belize shelf stood about 4.9 m below present stand at 6100 yr BP (Pusey, 1975), and reached present stand about 1000 yr BP (Fig. 8). There is no evidence on the northern Belize shelf of sea levels lower or higher than present in the last 1000 yr. Hence, Elmer Reef has developed a shallow water (2.5 m) during the last 420 yr or so, in a static sea level setting, during which time the reef grew rapidly to near sea level. The undated 0.19 m-thick sediment section beneath the dated coral in the reef grew rapidly to near sea level. The undated 0.19 m-thick section beneath the dated coral in the reef grew rapidly to near sea level. The undated 0.19 m-thick section beneath the dated coral in the reef grew rapidly to near sea level. The undated 0.19 m-thick section beneath the dated coral in the reef grew rapidly to near sea level.

![FIGURE 7—Growth rates of patch reefs in the study and in southern Belize, and comparative data for Belize barrier reefs and typical Holocene, shallow-water reefs.](image)

![FIGURE 8—Sea level curve for northern Belize during the last 6100 yr, based on uncalibrated radiocarbon dates of buried mangrove peats (new data and data from Pusey, 1975), and shallow-buried dolomite crusts on peritidal flats on Ambergris Cay (from Mazzullo et al., 1987).](image)
Purdy (1974a, b) provided little information on growth modes of the large patch reefs in southern Belize which he studied. According to him, however, these reefs began to grow 4000-6700 yr ago, and at least one of them (Laughing Bird Cay) appears to be a catch-up reef (see descriptions of facies in cores through this cay in Wantland and Pusey, 1971, p. 74–75). Despite different environmental settings and modes of origin (e.g., relationship to sea level), there is no apparent difference in rates of construction between keep-up, catch-up, and expansion type patch reefs in northern and southern Belize (Fig. 7). However, patch reefs in the latter area are thicker and areally more extensive than in northern Belize because: 1) they have been growing for a longer period of time, generally on antecedent topographic highs of larger dimension than in the study area, and; 2) many started in relatively deep water, and hence there was greater accommodation for vertical growth than on the northern shelf. The net result is that southern patch reefs have either caught up or kept up with a sea level rise of as much as 15 m in the last 8000 yr (Halley et al., 1977).

According to Neumann and Macintyre (1985), an internal facies architecture composed of shallow water, frame-building biota and associated sediments characterizes keep-up reefs which, in turn, indicates deposition in transgressive settings. The stratigraphy of the core taken through Elmer Reef (Fig. 5), however, indicates that its facies architecture is similar to that of many keep-up reefs, for example, Boo Bee patch reef in southern Belize (Halley et al., 1977). Hence, a facies stratigraphy composed entirely of framebuilding corals and associated sediments cannot be used in ancient reefs to imply the existence of keep-up reefs deposited in transgressive settings.

Patch Reef Zonations and Biota

Coral zonation is a major attribute of many modern patch reefs (James, 1983), and Elmer Reef is no exception (Fig. 4). However, similarities as well as differences exist in the specific types of biota between Elmer Reef and some patch reefs on the southern Belize shelf because of their contrasting environmental settings. Wantland and Pusey (1971), York (1971), York and Wantland (1975), Halley et al. (1977), Westphall and Ginsburg (1984), and Westphall (1986) described important biotic attributes of patch reefs in central portions of the southern Belize shelf, discussed below.

Patch reefs in southern Belize are developed in a high-energy environment, and generally are surrounded by deep water. They contain a diverse coral community that is dominated by Acropora palmata and associated Montastrea annularis and Diploria on their windward sides, and locally on their tops (e.g., on Boo Bee reef: Halley et al., 1977), and also on their leeward sides when the reefs adjoin deep intra-shelf channels. Acropora cervicornis typically occurs in sheltered areas behind these reefs. Coral communities dominated by Porites, Montastrea, Diploria, and Manicina, associated with Neogoniolithon, occur in the interiors of many of these patch reefs (Westphall, 1986). In contrast, these biota are not the major reef builders on Elmer Reef, which instead, is dominated by Montastrea annularis. Except for several patch reefs on Glovers Atoll (Wallace and Schaefersman, 1977), the dominance of this coral as a major patch reef builder is unique in Belize. Wallace and Schaefersman (1977) suggested that the dominance of Montastrea in some patch reefs on Glovers Atoll is due to the fact that they represent a mature stage of recolonization following the catastrophic demise of coral communities dominated by Acropora. However, they did not provide any core data with which to substantiate this contention. The dominance of M. annularis on Elmer Reef clearly is not explained by the model proposed by Wallace and Schaefersman (1977) because this coral occurs throughout the core to the virtual exclusion of other coral genera. Instead, the dominance of Montastrea and the absence of A. palmata here likely reflects environmental controls on their distribution. In Holocene reefs in Belize and elsewhere, Montastrea is more common in somewhat less energetic environments, such as exist in the study area, than A. palmata which generally favors higher-energy environments along reef crests (Wantland and Pusey, 1971; Miller and Macintyre, 1977). In southern Belize, A. palmata is abundant in shelf patch reefs because high energy conditions prevail due to wind-generated currents across the wide platform and the presence of the deep Victoria Channel which funnels currents into adjoining shallower water areas (Wantland and Pusey, 1971; Miller and Macintyre, 1977). As noted above, however, A. palmata does occur on some patch reefs in Mexico Rocks, although its distribution and relative contribution to these reefs have yet to be studied. The occurrence of Acropora cervicornis-dominated communities along the shallow-water leeward and windward flanks of Elmer Reef is similar to their occurrence in protected environments around patch reefs in southern Belize.

CONCLUSIONS

Elmer Reef is a Holocene coral patch reef representative of the many patch reefs that occur in the Mexico Rocks complex in northern Belize. It was initiated on a topographic high on the underlying Pleistocene limestone bedrock, and has grown in a shallow water (2.5 m), moderate-energy environment during the last 420 yr, in a static sea level setting. Pronounced coral zonation is evident across Elmer Reef as it is across many patch reefs on the southern Belize shelf. However, some differences in specific coral taxa make this patch reef somewhat unique. Montastrea annularis dominates on Elmer Reef, in contrast to the Acropora palmata-Diploria-Montastrea-Porites-Manicina assemblage typical of southern shelf patch reefs. Associated biota on Elmer Reef include Diploria, Agaricia, Porites, octocorals, calcareous algae, Homotrema, Lithothamnion, sponges, and worms, and there is somewhat greater biotic diversity on its leeward side relative to its windward side. As in southern shelf patch reefs, Acropora cervicornis-dominated communities flank the
reef, although they are better developed along its leeward flanks in somewhat protected, lower-energy environments. The extant patch reef, as well as older Holocene patch reef facies identified in a core, are extensively biodegraded. Syndepositional marine cementation is dominantly by fibrous aragonite, with minor bladed high-magnesium calcite, that partially occludes primary porosity throughout the patch reef section.

Rates of vertical construction of Elmer Reef range from 0.3–0.5 m/100 yr, and are comparable to those of patch reefs on the southern Belize shelf. Dominant mode of growth of this northern shelf reef, however, appears to be one of lateral rather than vertical accretion because of its initial development in shallow water and growth in a static sea level setting. Internal facies architecture of Elmer Reef, composed of a section dominated by framebuilding corals and associated sediments, mimics that of keep-up reefs in southern Belize deposited in deeper water in a transgressive setting.

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