Estuarine, Coastal and Shelf Science 151 (2014) 78–87

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Geochemical study of coral skeletons from the Puerto Morelos Reef, southeastern Mexico

Juan J. Kasper-Zubillaga*, John S. Armstrong-Altrin, Leticia Rosales-Hoz

Instituto de Ciencias del Mar y Limnología, Unidad de Procesos Oceánicos y Costeros, Universidad Nacional Autónoma de México, Circuito Exterior s/n, 04510 México D.F., Mexico

A R T I C L E I N F O

Article history:
Received 20 May 2014
Accepted 28 September 2014
Available online 7 October 2014

Keywords:
corals
geochemistry
Puerto Morelos
Yucatan
Mexico

A B S T R A C T

Geochemical analyses in coral skeletons have been used as a proxy of marine environmental conditions and to understand the mechanisms of adsorption of chemical elements into the coral skeletons and growth forms. However, little attention has been given to show the possible differences in the growth rates of corals based upon major, trace, rare earth element and microprobe analyses to examine the physical-chemical conditions influencing those differences. Our goal is to show how branch and fan corals incorporate elements into their skeletons comparing them with their coral growth rates. We determine the development of the skeletons of two branching (*Acropora palmata*, *Acropora cervicornis*) and one fan shaped (*Gorgonia ventalina*) colonies in the Puerto Morelos Reef, southeastern Mexico based upon geochemical data and the influence of terrigenous input into the species.

Mg and Sr concentrations were the most statistically significant elements among the species studied suggesting that Mg concentration in *Gorgonia ventalina* is probably not linked to its growth rate. Mn content in the sea water is adsorbed by the three corals during past growth rates during high rainfall events. Sr concentration may be associated with the growth rate of *Acropora palmata.* Little differences in the growth rate in *Acropora palmata* may be associated with low rates of calcitization, negligible changes in the Sr concentration and little influence of temperature and water depth in its growth. Trace elements like Cr, Co, Ni and V adsorbed by the corals are influenced by natural concentration of these elements in the sea-water.

Rare earth elements in the corals studied suggests abundant inorganic ions CO_3^{2-} with variable pH in modern shallow well-oxygenated sea water. Lack of terrigenous input seawards is supported by geochemical, geomorphological and biological evidences. This study is an example of how geochemical data are useful to observe the differences in environmental conditions related to coral skeleton growth rates and morphology.

1. Introduction

Corals are colonial organisms belonging to the class Anthozoa and phylum Cnidaria. They are sensitive to suspended sediment input, water depth and physicochemical characteristics of the water (temperature, salinity, and pH) (Linn et al., 1990; Johannesson et al., 2006; Lewis et al., 2007). The major, trace and rare earth elements in corals have proved to be an useful tool to determine water masses movement, past and actual physico-chemical conditions of sea water (i.e. salinity, pH, metals, etc.) in which the corals have developed (Delaney et al., 1993; Readman et al., 1996; McCulloch et al., 2003; Wyndham et al., 2004). We examine the physical and chemical conditions of two branching and one fan specie *Acropora palmata*, *Acropora cervicornis* and *Gorgonia ventalina* in the Puerto Morelos Reef, southeastern Mexico. Differences in the incorporation of major, trace, and rare earth elements into their skeletons were evaluated and used to infer the environmental conditions. We compare the degree in which branch and fan-type coral species concentrate major, trace and rare earth elements into their skeletons in relation to their growth. The growth rates were obtained from published data, because only one specimen of each specie was collected due to restrictions in sampling, hence growth rate measurements *in situ* of our samples could not be established.

Acropora palmata is present in shallow waters between 0.1 and 17 m depth. Their branches are oriented parallel to the current flow. It has a large growth rate that varies from 47.3 ± 4.1 to 99.3 ± 6.9 mm/year depending on probably rainfall, muddy waters

* Corresponding author.
E-mail address: kasper@cmarl.unam.mx (J.J. Kasper-Zubillaga).

http://dx.doi.org/10.1016/j.ecss.2014.09.023
0272-7714/

caused by storms, water temperature and reef zone (Gladfelter et al., 1978; García et al., 1995; Alibert et al., 2003). *Acropora cervicornis* is observed in sheltered waters at 10 m depth in areas where inner lagoons are developed between the open-sea and landward oriented part of the reef (Roos, 1971; Gladfelter et al., 1978). Its average growth rate is 71 ± 6.5 mm/year associated with the geographic area but with highly variable growth rates being the most rapidly linear growing coral in the world (Chalker, 1977; Chalker and Taylor, 1978; Gladfelter et al., 1978).

Gorgonia ventalina grows in near-shore areas with heavy wave action and also on deeper reefs (depths greater than 15 m) (Colin, 1978). Its growth rate is 81 ± 0.9 mm/year height and 83 ± 0.9 mm/year width although it has been observed maximum growth rates of 12.8 ± 1.5 mm/year and minimum of 4.7 ± 1.9 mm/year depending on the geographical area.

2. Study area and its environmental conditions

The coral reef system of Puerto Morelos is in the Yucatan Peninsula, southeastern Mexico (21°00′00″ – 20°48′33″N and 86°53′14.40″ – 86°46′38.94″W) (Fig. 1). The reef is composed of the fore reef that descends to 20–25 m into a large sand platform facing the open sea, the reef crest and the back reef that is oriented landwards of a 3–4 m reef lagoon composed of calcareous sands and sea grass meadows (Rodriguez-Martínez et al., 2010). A high coral cover on the crest and rear reef zone of the Puerto Morelos Reef is observed. The fore reef zone is of low relief, smooth slope, and colonized by assemblages of scleractinian, sponges and hydroids with gorgonian populations (Jordán-Dahlgren and Rodríguez-Martínez, 2003).

There are 26 scleractinian corals in the fore reef with *Montastraea cavernosa*, *Dichocoenia stokesii* and *Meandrina meandrites* being the most abundant species (Jordán-Dahlgren, 1979; Rodriguez-Martínez et al., 2010).

2.1. Physical oceanography

Circulation in the reef lagoon is parallel to the coast although there is a change in speed and direction due to several factors such as the influence of the Yucatan current, winds and the location of surge channels among others (Ruíz-Rentería et al., 1998). Waves in the reef lagoon are of 0.14 m (Merino and Otero, 1991).

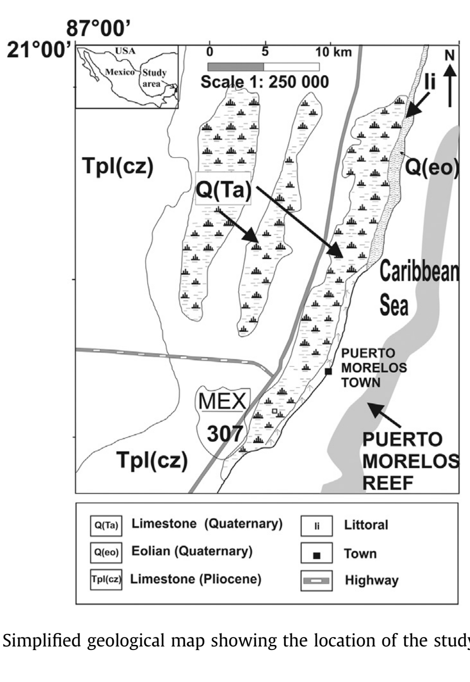

Fig. 1. Simplified geological map showing the location of the study area.

2.2. Climate, precipitation and physical-chemical water conditions

The climate in the southeastern coast of Mexico is tropical wet and dry savanna climate (Aw) with average maximum temperature of 30 °C and minimum temperature of 19 °C (Kottek et al., 2006). In general, hurricanes occur from June to November (Rodríguez-Martínez et al., 2010). Average maximum water temperature surrounding the reef during 2004 was 31.8 °C (august) and the lowest 24.1 °C (february) (Álvarez-Cadena et al., 2008). Average air and surface water temperatures (°C) near and at the Puerto Morelos Reef are shown in Fig. 2A and B (http://www.weather.com; Álvarez-Cadena et al., 2008). From 1993 to 2004 the average rainfall was 1060.6 mm/year (~171.4) (Rodríguez-Martínez et al., 2010). Average monthly precipitation (mm) in Puerto Morelos is presented in Fig. 2C (http://www.weather and climate.com). The average water salinity is 35.7‰ (Merino and Otero, 1991).

2.3. Geology and physiography of the southeastern coast

The Yucatán Peninsula located in the southeastern area of Mexico is composed of a limestone platform (Ward and Weidie,

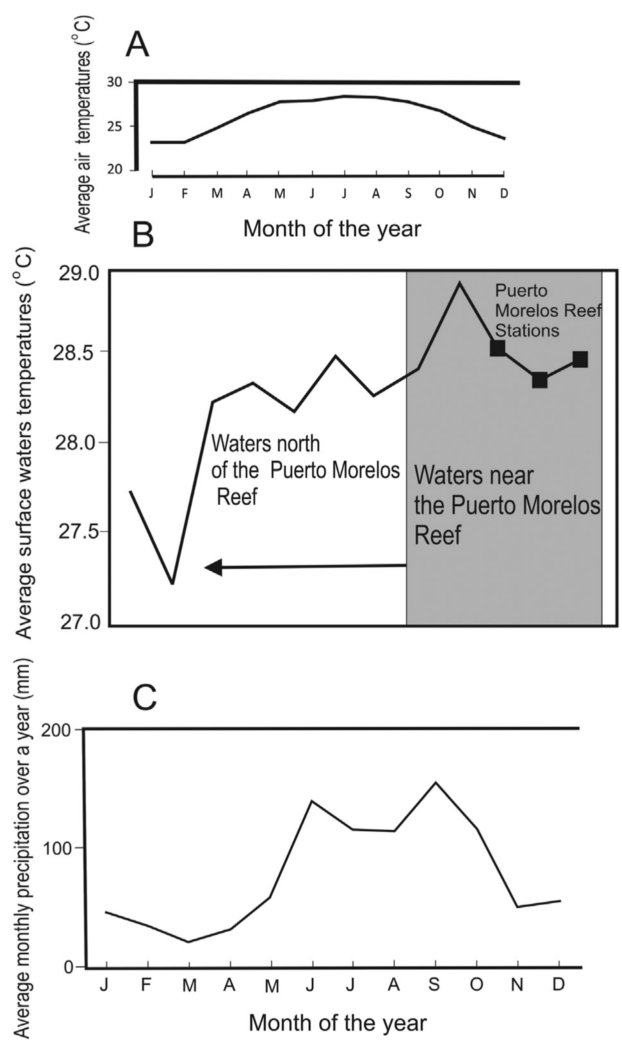

Fig. 2. A) Average air B) surface water temperatures (°C) and C) average monthly precipitation (mm) near and at the Puerto Morelos Reef.