STABLE ISOTOPES IN EARLY-HOLOCENE ACROPORA CERVICORNIS CORALS FROM THE ENRIQUILLO VALLEY, DOMINICAN REPUBLIC

LIDA TENEVA
Franklin and Marshall College
Sponsor: Carol de Wet

INTRODUCTION

The Enriquillo Valley, Dominican Republic, exhibits subaerially exposed and well preserved early- to mid-Holocene coral reefs. This valley (Fig.1) is an excellent locality to investigate the coral-climate connection because elsewhere in the world reefs of such age are usually still submerged beneath living reefs.

The most widely used carbonate material used for tropical climate studies up to now has been microfossils, such as foraminifera or ostracodes, although massive corals, such as *Montastrea annularis* and *Siderastrea radians* are more frequently the focus of contemporary research. Such carbonates are abundant in the Enriquillo reef exposures. However, the branching coral *Acropora cervicornis* is a dominant species in the Las Clavellinas region of the Enriquillo Valley, and the thick accumulation of this coral may provide a record of paleoenvironmental conditions in the Enriquillo embayment.

This study focuses on high-resolution sampling for stable isotope values of well-dated *Acropora cervicornis*. Geochemical patterns in these corals have significant implications to the understanding of the stratigraphic, tectonic, and climatic evolution of the Enriquillo embayment. Specifically, isotope geochemistry provides insight into whether the embayment corals were more sensitive to regional Caribbean climatic changes, or reflect local hydrography and tectonic factors.

Climate setting

Located at about 19°00' N, the Dominican Republic today is characterized by a primarily tropical climate with little seasonal temperature variation, but significant seasonal variability in the amount of rainfall. The average annual temperature is 25°C, and the average rainfall is 150 cm (Library of Congress, Federal Research Division 1988).

In terms of the ancient Caribbean climate, Mayewski et al (2004) provide strong evidence that the period of 9,000 to 8,000 yrs BP was characterized as an episode of widespread tropical aridity in the midst of a long humid period that began in the early Holocene.

METHODS

The study site is in an erosional gully through a ~9-meter monospecific deposit of *Acropora cervicornis*. Coral samples were collected from a 2-m vertical transect at 2-cm intervals. Ten specimens were evaluated using X-ray diffraction to ascertain original aragonite mineralogy. The specimens were then microdrilled along discrete linear transects up the axial corallite and the time-equivalent lateral corallite using a Merchantek microdrill. The samples were subsequently analyzed on a MAT 253 dual inlet mass spectrometer directly coupled to a Kiel-III carbonate preparation device at the Saskatchewan Stable Isotope Laboratory in the University of Saskatchewan.

Statistical software JMP IN was used to analyze significance of variability in the isotope data. Three samples were selected (A1-3, E1-6, and J2-6 from heights of 4 cm, 87 cm, and 188 cm in the section, respectively) to be dated by radiocarbon dating at the Center for Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory at the University of California.

In order to be able to reconstruct seasonal climate variations from the coral isotopic record, sampling had to be done at subannual intervals. However, studies have shown that the growth rate of *Acropora cervicornis* can vary from ~71 mm/yr to as much ~260 mm/yr (Shinn 1966; Lewis et al. 1968; Gladfelter et al. 1978). We sampled ~12 samples along the whole length of the lateral corallite in each specimen (the diameter of the chosen specimens was between 10-15 mm, and the length of the lateral corallite was ~6-7 mm; hence, sampling interval was ~500μm), and then, sampled identically along the adjacent axial corallite (Fig.1).

The purpose of this strategy was three-fold: 1) to contribute to a clearer understanding of the growth rate of lateral corallites and the axial corallite in this species; 2) to examine the isotopic signatures of the two different skeletal fabrics; and 3) to observe any potential seasonal variation that may be observed as cyclicity in the $\delta^{18}O$ and $\delta^{13}C$ values, taking into account that problems may arise from seasonal variations in growth rate. (see discussion section)

RESULTS

Radiocarbon dating of specimens from heights of 4 cm, 87 cm, and 188 cm in the section yielded ages of 9362, 8475, and 8325 calendar years B.P., respectively, each with a 35-year margin of error. Two different accumulation rates were calculated based on those three dates (Fig.2), and ages of other specimens in the section were estimated based on their height above base and the calculated accumulation rate.

A total of 213 samples from ten specimens were analyzed for $\delta^{18}O$ and $\delta^{13}C$ values. Isotope values are reported in per mil V-PDB (‰) with

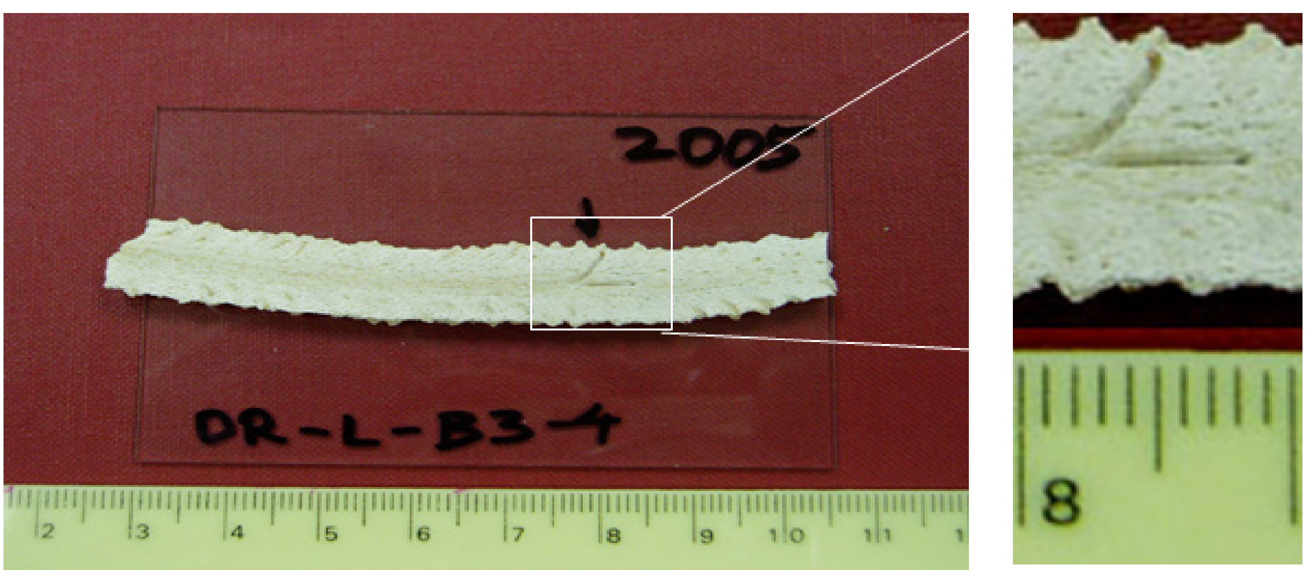

Figure 1. High-resolution micromilled linear transects along the axial corallite and lateral corallite.

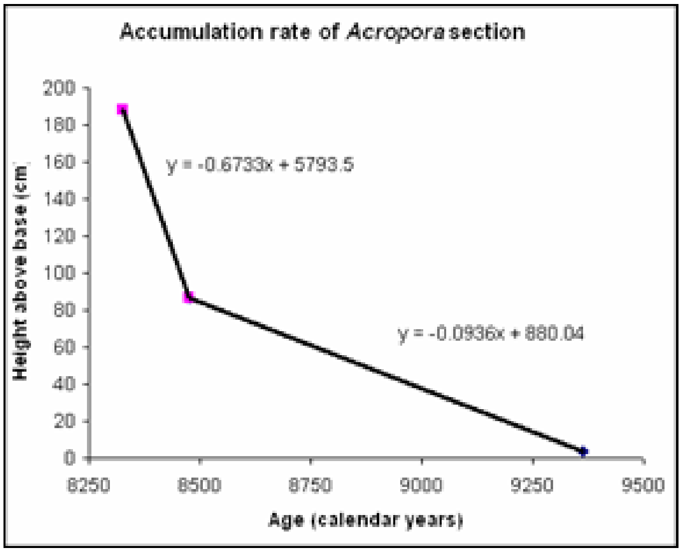

Figure 2. Two different accumulation rates for the section based on 3 ^{14}C dates. Reason for acceleration ~8500 yrs BP is unclear.

respect to modern ocean water (‰). High-resolution oxygen and carbon variability has been graphed for the two different skeletal elements (Fig.3). X-ray diffraction showed minimal calcite content.

Statistical analysis showed: 1) the top of the section had on average $\delta^{18}O$ values that were more negative than those from the bottom of the section by 0.45 ‰, which in the context of this data set is statistically significant; 2) carbon values did not change significantly upsection; 3) oxygen and carbon isotope values from axial corallites were lower than the values from the time-equivalent lateral corallites by 0.15 and 0.27 ‰, respectively, which was statistically significant; 4) even though it may appear that the variability in isotope values increased through time, analysis shows that there was no statistically significant change in the variability through time, and the apparent increase in range towards the top of the transect is due to variable sample size from each interval.

DISCUSSION

A variety of factors influence stable isotope values preserved in coral skeletons. $\delta^{18}O$ values are greatly dependent on sea surface temperature (SST) and sea surface salinity (SSS) (Leder et al. 1996 and others). Multiple factors, such as solar insolation, photosynthesis/respiration ratio, calcification rate, growth rate, temperature, $\delta^{13}C$ value of DIC (dissolved inorganic carbon)

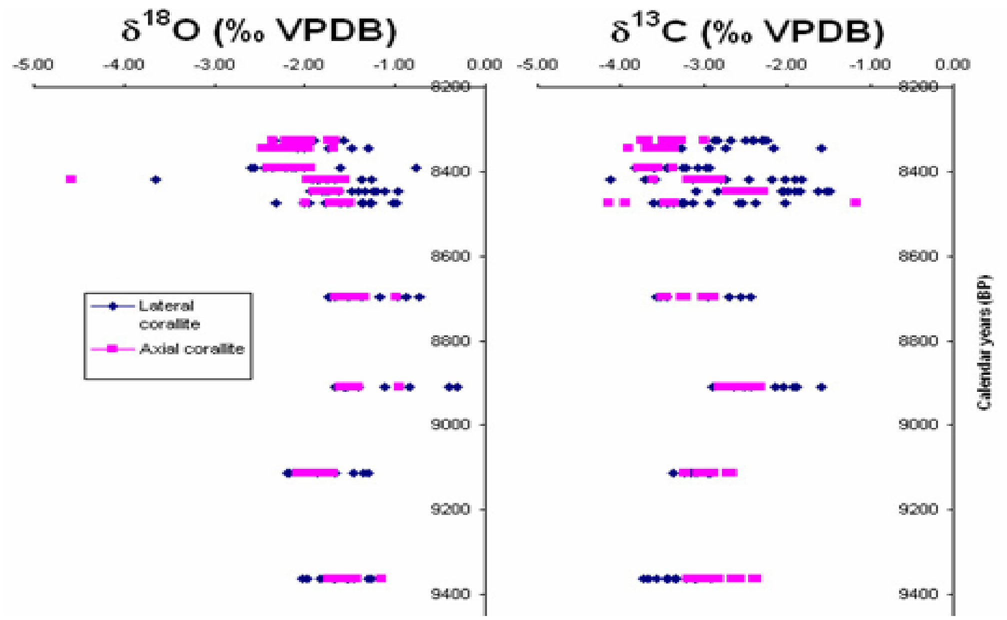

Figure 3. Oxygen and carbon isotope values from axial and lateral corallites for the period ~9300-8300 yrs BP. No statistically significant variability through time or within each specimen both imply lack of extraordinary seasonality associated with the ITCZ reaching Hispaniola in the early Holocene. Data confirms previous studies of an episode of tropical aridity elsewhere in the world ~9000-8000 yrs BP.

influence the $\delta^{13}C$ values (Swart et al. 1996). Both isotope values are also affected by the isotopic composition of ambient seawater. Deciphering original environmental conditions from isotope values may also be confounded 'vital effects'.

Diagenesis is not considered a major factor in this study because the calcite that was observed with X-ray diffraction is considered to be an artifact of laboratory drilling.

InterTropical Convergence Zone

In the time period ~9300-8300 yrs BP, our coral data shows a lack of statistically significant difference in the ranges of the oxygen isotope values through time. These data are in agreement with other studies (Mayewski et al 2004), which show that the period of 9,000 to 8,000 yr BP represented a time of bipolar cooling, which may have accounted for a compression of the low-latitude band of atmospheric circulation, and hence, an alteration of the distribution of moisture in the low-latitudes. Hence, this study confirms a short arid period on Hispaniola in the early Holocene, related to a compression of the InterTropical Convergence Zone, the presence of which induces isotope variability through enhanced seasonality.

Coral Sensitivity

Some may interpret the lack of statistically significant isotopic variability in this coral species as a sign that the corals were not sensitive enough to climatic changes in this period to record them in their skeletons. However, many previous studies (Hart and Cohen 1996; Reynaud et al. 2004; Swart and Grottoli 2003, etc.) have demonstrated that scleractinian corals and *Acropora*, in particular, are very sensitive to their environment and do not have high tolerance for significant temperature and salinity changes. Hence, these corals should be excellent recorders of changes in their surroundings.

Isotope Values of Seawater

Because the Enriquillo Seaway had a rather constricted connection to the Caribbean Sea, oxygen isotopic signatures in the corals are thought to represent mostly local temperature and salinity variability, rather than the global ocean water $\delta^{18}O$ value. We have not applied temperature transfer functions to the $\delta^{18}O$ values due to uncertainty regarding how much of the isotopic signal is influenced by temperature changes and how much of it reflects changes in influx of isotopically "heavy" freshwater.

The constricted nature of the paleoenvironment and the contribution of dissolved organic carbon from weathered Miocene limestones may also mean $\delta^{13}C$ values from the corals in the present study may not represent original seawater carbon isotopic signature.

Data Comparison

Comparison of data from this study with Enriquillo *Acropora cervicornis* coral data from Jackson (this volume) reveals several trends. The age ranges covered in the two transects are very similar, 9377-8522 yrs BP (Jackson, this volume) and 9362-8325 yrs BP (this study); yet, the accumulation rates are very different. Jackson's data shows a relatively constant accumulation rate throughout the whole time period, whereas the accumulation rate estimated in this study (Fig.2) seems to change abruptly towards the top of the section.

The oldest corals in both sections are considered to be some of the first corals to grow in the Enriquillo Seaway, in general. The bases of the two sections, however, differ by 6 m in elevation. The elevation difference can be due to either variable reef substrate morphology (as most of the precursor sediments were fluvial deposits and deltaic build-ups [McLaughlin et al 1991]) or due to movement along a fault in this tectonically active region.

If the elevations represent original differences in depth, the corals in Jackson's section must have been accumulating in slightly deeper waters than the corals in this study. For the period ~9300-8500 yrs BP, the corals in Jackson's section were accumulating faster (and in slightly deeper waters) than the corals in this study. Since this time period coincides with a relatively fast rise in sea level, corals growing in deeper waters, but accustomed to shallower water, may have been growing fast in order to keep up with the rising sea level. On the other hand, the corals in this study may have been growing more slowly because they were limited by accommodation space in shallower waters. The reason for the switch to a fast accumulation rate of the corals in this study between ~8500 and ~8300 yrs BP is unclear.

Comparison of isotope data from the oldest, time-equivalent corals from both sections shows slightly lower $\delta^{13}C$ and higher $\delta^{18}O$ values for the base of Jackson's section. The slight difference in the carbon values may be due to faster skeletal accumulation in deeper waters. The difference in oxygen values may be due to some freshwater influence due to greater proximity of this study's corals to a freshwater source.

Coral Skeletal Fabrics

Work on distinctive skeletal fabrics has also shown marked isotope heterogeneity between skeletal elements, which may have implications about extents of thermodynamic equilibrium with ambient seawater (Leder et al 1996). Coral skeletons precipitate with isotope values lower than predicted by thermodynamic equilibrium (Swart et al 1996).

Lower oxygen and carbon isotope values in the axial corallites may indicate either that the two different skeletal elements were precipitating in fluids of slightly different isotopic composition, or the axial corallites have been more susceptible to alteration than the lateral corallites. Preliminary trace element geochemical data may support the former.

Variable geochemical signatures in different skeletal elements need to be further investigated and may have considerable implications for the biomineralization mechanisms in *Acropora cervicornis*.

If indeed the environment of biomineralization for the axial corallite was a near-closed system of slightly modified seawater, then, perhaps future research in the usefulness of *Acropora cervicornis* for the reconstructions of paleoenvironments needs to focus on the lateral corallites, as their geochemical signatures may more accurately represent seawater.

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