DATING AND STABLE ISOTOPE ANALYSES OF *ACROPORA CERVICORNIS* GROWTH IN THE ENRIQUILLO VALLEY, DOMINICAN REPUBLIC

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INTRODUCTION

Towards the end of the last glacial period, as global sea level rose, the Caribbean Sea flooded the Enriquillo Valley, Dominican Republic, producing a seaway in which fringing reefs developed (~9-5 ky BP). Over 3,500 years, ~11 m of *Acropora cervicornis* accumulated as the dominant reef species. Today, *A. cervicornis* is experiencing a significant die off in the Caribbean and Atlantic oceans. This study characterizes the climate changes associated with the mid-Holocene die off to better understand the causes of modern decline in *A. cervicornis*.

The Enriquillo Valley exhibits an exposed mid-Holocene *A. cervicornis* reef. This study focuses on *A. cervicornis* samples, collected from the Las Clavellinas arroyo, on the north shore of Lago Enriquillo, to gain a better understanding of climate and environmental changes at different time scales using stable and radiogenic isotopes. The high resolution dating analysis yields detailed information on the growth pattern and accumulation rate of *A. cervicornis*.

METHODS

Sample Collection and Preparation

Samples were recovered from a vertical section at 100 cm intervals in 2000 by Lisa Greer, 10 cm intervals in 2004, and 2 cm intervals in 2005. The lower two meters of the 2004 sample section correspond to the 2005 transect. All samples were cleaned with a toothbrush and sonicated in De-Ionized water to remove dirt and organic material. X-ray diffraction analyses were performed on all clean samples to determine percentage aragonite. Analysis was performed on a DIANO 2100*E X-ray diffraction machine as a step scan on a 2-theta range of 24.00° to 31.00°.

Stable Isotope Mass Spectrometry

Powdered carbonate samples were generated using a computer controlled micromill. The 10 cm samples were drilled along the axial corallite at ~1000 μm intervals with a Merchantek micromill. The 2 cm samples were drilled using the Saskatchewan Micromill at the University of Saskatchewan, Canada. The powdered carbonate samples were collected at 250 μm intervals along both the axial corallite and a corresponding lateral corallite. Each coral sample was drilled from oldest to youngest growth.

Stable carbon and oxygen isotope mass spectrometry analyses were performed on the powdered carbonate samples. Stable isotope analyses were completed at the Lamont-Doherty Earth Observatory, Palisades, New Jersey on a MICROMASS Optima Mass Spectrometer. At the University of Saskatchewan, Saskatoon, Canada, analysis was performed using a Finnigan Kiel-III carbonate preparation device directly coupled to a Finnigan MAT 253 isotope ratio mass spectrometer.

Age Dating

Five *A. cervicornis* samples, from the 100 cm sampling interval, were dated via $^{234}U/^{230}Th$ dating analysis on a PLASMA 54 magnetic sector multicollector ICP-MS at Lamont-Doherty Earth Observatory. Radiocarbon dating analyses were performed on samples collected at 10 cm intervals as well as on the samples previously dated with $^{234}U/^{230}Th$ analysis. Radiocarbon dating was completed with a 10MV Tandem Van de Graaff Accelerator at the Center for Accelerated Mass Spectrometry at the Lawrence-Livermore National Laboratory.

RESULTS

Age Dating

Radiocarbon dates have been determined for 47 samples at 20 cm intervals up the outcrop. The conventional radiocarbon dates were corrected into calendar years before present using CALIB Radiocarbon Calibration 5.0.2.html (Stuiver et al., 2005). The average of the 1 Sigma Range was taken as the sample age.

The $^{234}U/^{230}Th$ dates are consistent with the ^{14}C dates. The youngest sample dated by both methods shows a 412.5 year difference between $^{234}U/^{230}Th$ age and ^{14}C age. The corrected ^{14}C data gives an older age for the coral than $^{234}U/^{230}Th$ data suggests. The other $^{234}U/^{230}Th$ data are more consistent with ^{14}C data as ^{14}C dates are only ~130 years older.

Stable Isotopes

Stable isotope values of coral samples, collected at 100 cm intervals, display sub-annual fluctuations, as seen in Figure 1. The oldest sample displays an average $\delta^{18}O$ value of -2.2‰ and an average $\delta^{13}C$ value of -4.8‰. A sample from 200 to 300 cm above the base of the outcrop displays an average $\delta^{18}O$ value of -2.4‰ and an average $\delta^{13}C$ of -3.9‰. A sample from 600 to 700 cm above the base displays an average $\delta^{18}O$ value of -3.6‰ and an average $\delta^{13}C$ value of -2.3‰. The stable isotopic values are reported relative to the Vienna Peedee belemnite (VPDB) standard.

High resolution stable isotope data (Fig.2.) for *A. cervicornis* samples collected at 2 cm intervals also reflect the general trend in $\delta^{18}O$ and $\delta^{13}C$ values . Stable isotope data, along the axial corallite and a lateral corallite, were determined for a coral from the bottom, middle, and top of the section. Slight variation exists between the stable isotope values for the axial corallite and corresponding lateral

^{14}C Dates							
Distance Above Base(cm)	Age in Calendar Years (BP)	Distance Above Base(cm)	Age in Calendar Years (BP)	Distance Above Base(cm)	Age in Calendar Years (BP)	Distance Above Base(cm)	Age in Calendar Years (BP)
0	9377	280	8511	620	7660	790	7471
10	9305.5	300	8730.5	640	7726.5	810	7481.5
30	9341.5	320	8625.5	660	7700.5	830	7440.5
40	9328.5	330	8746.5	680	7675	870	7316
70	9282.5	350	8421.5	700	7633	890	7348.5
80	9166.5	370	8406	720	7612	910	7381
90	8926	400	8421.5	740	7625	920	7435
100	9007.5	430	8245	760	7539		
120	9049	450	8178.5				
140	8736.5	470	8252.5				
160	8646	490	8186.5				
170	9033	510	8091.5				
180	8457	540	8092.5				
210	8521.5	550	8071.5				
240	8660	580	7762.5				
260	8630.5	600	7800.5				

$^{234}U/^{230}Th$ Age yBP	cm Above Base	14C Age yBP
9445	0-100	n/a
8662	400-500	8792.5
7588	600-700	7711.5
6916	800-900	7328.5
6060	1000-1100	n/a

Table 1. Calibrated ^{14}C dates for samples collected at 10 cm intervals were calculated with CALIB 5.0.2.html. $^{234}U/^{230}Th$ and ^{14}C dating analyses were performed on samples collected at 100 cm samples.

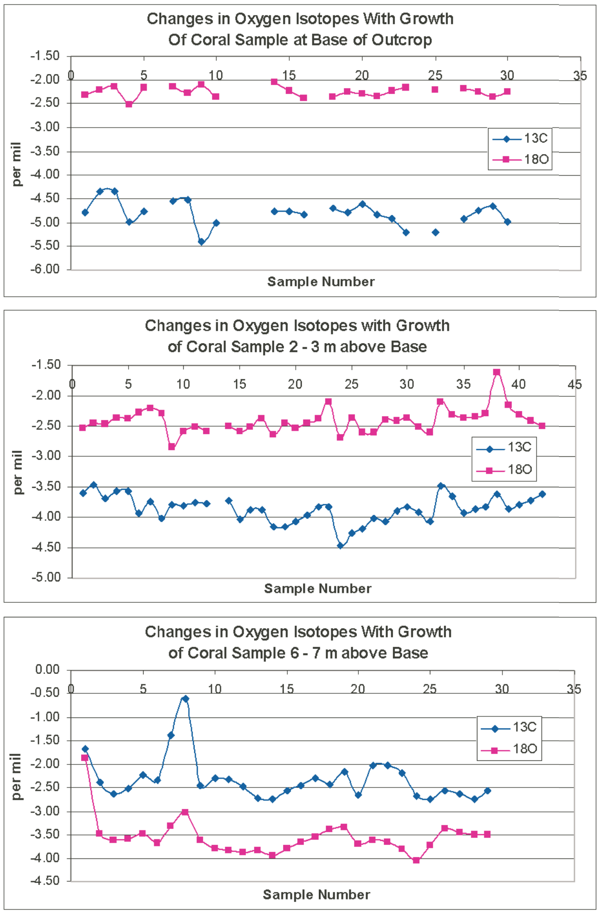
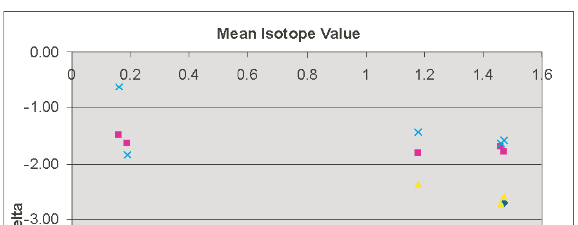


Figure 1. Stable isotope data for 100 cm samples; each sample was drilled at ~1000 μm intervals.

corallite, but the data reveal an isotopic trend similar to that shown by the 100 cm samples. Going up the section, $\delta^{18}O$ values decrease continually while $\delta^{13}C$ values increase.



Thecal Wall			Corallite	
avg. d13C	avg. d18O	sample	avg. d13C	avg. d18O
-5.01	-1.50	A_1	-4.04	-0.62
-4.90	-1.63	A_2	-4.61	-1.84
-3.47	-1.81	F	-2.37	-1.44
-3.20	-1.70	H3B_1	-2.72	-1.63
-2.71	-1.78	H3B_2	-2.59	-1.59

Figure 2. Average stable isotope value of ~20 samples for each coral. A samples are 20 cm above base, F is ~120 cm above base, and H3B samples are ~150 cm above the base.

Two samples were analyzed for $^{87}Sr/^{86}Sr$, one from the base and one from the top of the outcrop. The sample from the base of the outcrop has an $^{87}Sr/^{86}Sr$ value of 0.709053 while the top of the outcrop has a $^{87}Sr/^{86}Sr$ value of 0.709134. Both isotope values are close to normal seawater.

INTERPRETATION

The calibrated ^{14}C dates (9.377 to 7.435 ky BP) and $^{234}U/^{230}Th$ dates yield evidence for continuous accumulation of *A. cervicornis* in correct stratigraphic order at Las Clavellinas between 9.45 and 6.06 ky BP. Deposition was primarily in situ with possible mixing at ~185 cm and ~330 cm above the base of the outcrop, suggestive of a large storm event at ~8.4 ky BP.

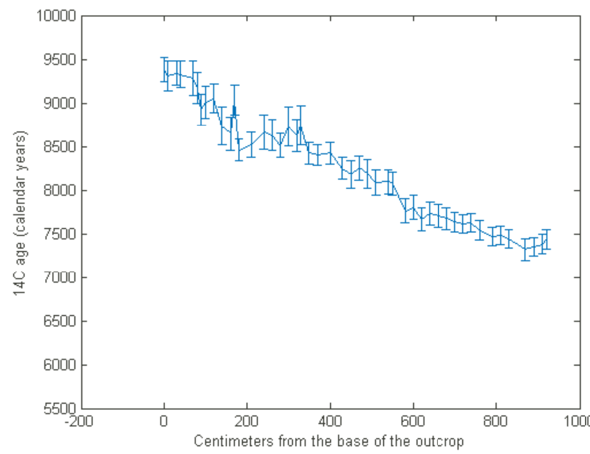


Figure 3. Calibrated ^{14}C ages with error bars showing the 1 Sigma range.

The stable isotope data for both the 2 cm and 10 cm resolutions show an isotopic trend similar to the bulk isotope data for the outcrop (Greer, unpublished). Figure 4 shows the change in *A. cervicornis* isotope values between 9.5 and 6 ky BP. $\delta^{18}O$ values decrease by 1.3‰ while $\delta^{13}C$ increases by 3.1‰. For the three analyzed 10 cm resolution samples, $\delta^{18}O$ values decrease by ~1.3‰ while $\delta^{13}C$ values increase by ~2.5‰ over ~1.9 ky. The high resolution, 2 cm, stable isotope data also reveals a similar trend: $\delta^{18}O$

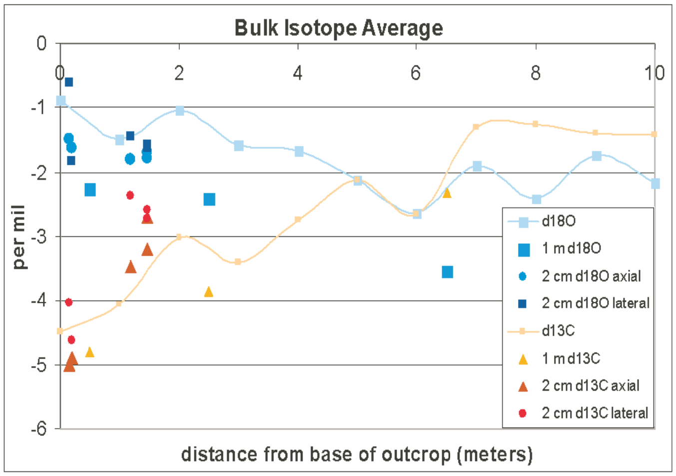


Figure 4. The average $\delta^{18}O$ and $\delta^{13}C$ values for samples collected at one meter intervals (Greer, unpublished).

values decrease by only ~0.6‰, and $\delta^{13}C$ values increase ~1.90‰ over ~0.7 ky. There is slight variation between the stable isotope values for the axial corallite and the lateral corallite of each coral sample.

Trends in $\delta^{18}O$ values and $\delta^{13}C$ values may be attributed to two possible climatic parameters: changing temperature and/or water budget. If the shift in the $\delta^{18}O$ value of the bulk isotope data is purely attributed to temperature, the shift would imply a 6°C increase in mean annual temperature in the Enriquillo Valley within a 3,500 year period, which is unlikely as it is not observed elsewhere (Greer, in press).

Because the shift in $\delta^{18}O$ is not a direct temperature effect, lower $\delta^{18}O$ values may imply an influx of water with lower $\delta^{18}O$ values throughout the Holocene. As the embayment closed, freshwater may have come to dominate the embayment's water budget, resulting in lower carbonate $\delta^{18}O$ values. Dissolved inorganic carbon, from weathering Miocene limestone, may have increased the carbonate $\delta^{13}C$ value. If these isotopic changes were related to the closing of the embayment, $^{87}Sr/^{86}Sr$ value should reflect the shift to a restricted environment. However, the $^{87}Sr/^{86}Sr$ values across the outcrop indicate that the embayment remained open to the ocean during the development of *A. cervicornis* reefs.

Lastly, the change in isotope values may be attributed to a shift of the Intertropical Convergence Zone (ITCZ) with the onset of the mid-Holocene Thermal Maximum. Multiple studies have shown evidence for a mid-Holocene Thermal Maximum between 10.5 to 5.4 ky BP (Haug et al., 2001; Davis et al., 2003; Curtis and Hodell, 1993; Demenocal et al., 2000). The thermal maximum, a result of increased insolation in the northern hemisphere, allowed for the northward migration of the ITCZ during the mid-Holocene (Greer, in press). As the ITCZ progressively moved north, precipitation in the Enriquillo Valley would have increased, decreasing the water $\delta^{18}O$ value of the embayment.

Stable isotope records from ostracods in Lake Miragoane, Haiti, the nearest Holocene proxy for the Enriquillo Valley, correlate well with the isotopic data for corals in this study. Curtis and Hodell (1993) have dated the climate shift to warmer and wetter conditions beginning ~10.0 to ~7.0 ky BP. During this period, decreasing $\delta^{18}O$ values and Sr/Ca ratios coupled with constant Mg/Ca ratios indicate increasing temperatures and rising lake levels. Minimum $\delta^{18}O$ values and Sr/Ca ratios for samples ~7.0 to ~5.3 ky BP imply low salinity of Lake Miragoane and moist conditions. After 5.3 ky BP, $\delta^{18}O$ values increased, marking an end to the moist period. The climate pattern recorded by Lake Miragoane sediment cores and by Enriquillo *A. cervicornis* strongly correlates with a northward shift of the ITCZ (Curtis and Hodell,1993; Greer, in press; Higuera-Gundy, et al., 1999; Hodell et al.,1991).

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