



Nova Southeastern University
NSUWorks

Oceanography Faculty Proceedings, Presentations, Speeches, Lectures, Department of Marine and Environmental Sciences

5-1977


Climatic Implications of Barbados Coral Growth

Richard E. Dodge
Yale University, dodge@nova.edu

Karl K. Turekian
Yale University

J. Rimas Vaisnys
Yale University

Follow this and additional works at: http://nsuworks.nova.edu/occ_facpresentations

 Part of the [Marine Biology Commons](#), and the [Oceanography and Atmospheric Sciences and Meteorology Commons](#)

NSUWorks Citation

Dodge, Richard E.; Turekian, Karl K.; and Vaisnys, J. Rimas, "Climatic Implications of Barbados Coral Growth" (1977). *Oceanography Faculty Proceedings, Presentations, Speeches, Lectures*. Paper 6.
http://nsuworks.nova.edu/occ_facpresentations/6

This Conference Proceeding is brought to you for free and open access by the Department of Marine and Environmental Sciences at NSUWorks. It has been accepted for inclusion in Oceanography Faculty Proceedings, Presentations, Speeches, Lectures by an authorized administrator of NSUWorks. For more information, please contact nsuworks@nova.edu.

Proceedings, Third International Coral Reef Symposium
Rosenstiel School of Marine and Atmospheric Science
University of Miami
Miami, Florida 33149, U.S.A.
May 1977

CLIMATIC IMPLICATIONS OF BARBADOS CORAL GROWTH

Richard E. Dodge, Karl K. Turekian, and J. Rimas Vaišnys
Department of Geology and Geophysics
Yale University
New Haven, Connecticut 06520

ABSTRACT

Results from a coral growth band analysis utilizing samples of *M. annularis* from the Recent Barbados reef and from three fossil raised reefs (Barbados I, II, and III dated at 82,000, 105,000, and 125,000 yrs. B.P.) indicate that in the Barbados II collection both average band width and variability were lower than in the other samples. We suggest the climate during formation of the 105,000 yrs. B.P. reef was significantly different than that of the present.

KEY WORDS: Coral Growth Band Analysis, Climate, Fossil, Reefs

CLIMATIC IMPLICATIONS OF BARBADOS CORAL GROWTH

Richard E. Dodge, Karl K. Turekian, and J. Rimas Vaišnys

Introduction

This paper presents the results of a coral growth band analysis and these results suggest that the climate during the time of formation of the 105,000 yrs. B.P. raised reef in Barbados was significantly different from that of the present. Coral skeletons have been demonstrated to record a variety of information about the environment in which they are growing (1), (2), (3), (4), (5), (6), (7), (8), (9). The major controls of coral growth are light intensity, ambient temperature, nutrient supply, and the effect of toxic substances or excess detritus. In some cases the record of such controls are being unravelled from the study of living corals (7), (8), (10), (11), (12). There are risks in proceeding from the comparative *terra cognita* of the recent past to the great unknown of the glacial ages, but it is in just such extensions that environmental controls over time on the Earth's surface can be understood. In this spirit we have undertaken a study of the growth bands of fossil corals from Barbados where three major high sea stands with attendant coral reef development have been recognized and dated (13), (14). We ask the question: how different were the various warm periods of the past in their influences on the growth history of corals in the reef complexes of that time?

The approach to the question was motivated by the following considerations. The development of climate with time may be described at the most detailed level by equations governing the behavior of meteorological variables as functions of space and time; less detailed descriptions could be obtained by various degrees of spatial averaging; for the description of climate, rather than weather, it makes sense to do time averaging as well. The resulting equations involve not only mean values of the variables, but higher moments of various distributions. Thus it appears both worthwhile and reasonable to attempt not only an assessment of the averages but also of the fluctuations in climatic variables as well.

Collection procedure

Recent living specimens of *Montastrea annularis* (all columnar type growth form) were collected in less than 4 meters of water from the reef off Bellairs Institute, Holetown, Barbados in July, 1974. Specimens of fossil *M. annularis* were collected from localities in each of three raised reefs on the coral cap of Barbados (Barbados I, II, and III) dated at approximately 82,000, 105,000 and 125,000 yrs. B.P. (13), (14).

This paper will only deal with fossils having the same general reef crest zone. The one exception is that while corals from the Barbados III terrace (125,000 yrs. B.P.) were unquestionably columnar in form, their zone of collection was in the *M. annularis* head or buttress region (below *Acropora palmata* and *A. cervicornis* zones) and consequently were probably not reef crest or near reef crest residents, as were the corals from the other collections. Until the influence of depth on growth rate is fully understood, results from this sample should be interpreted cautiously.

Methods

After collection, corals were sectioned with a diamond bit rock saw to obtain slabs containing the point of highest relief on the living or formerly living growth surface and the nearest approximation to the point of colony origin. These rough slabs were resectioned to uniform parallel sections approximately .5 cm in thickness, and X-radiographed on Kodak AA Industrial X-ray film. The X-radiograph negatives were printed onto photographic paper (Fig. 1) and band widths were measured along one

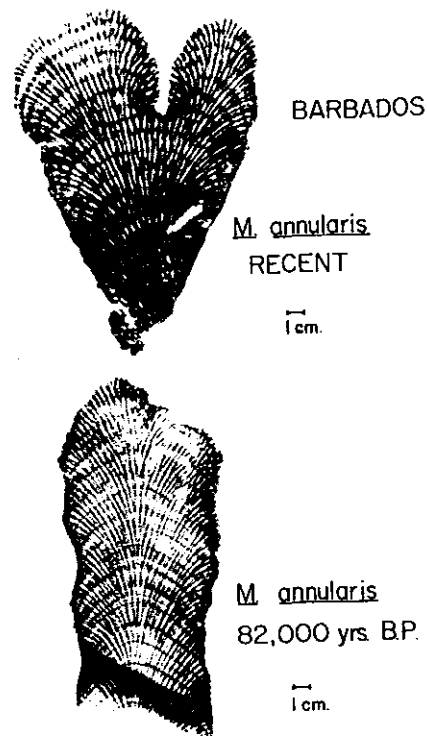


Figure 1 - X-radiograph positives of a recent and fossil *M. annularis*.

or two transect lines drawn normal to former growth surfaces, (approximately parallel to corallites) and along the estimated axis of maximum growth. The width of an annual cycle was determined as the linear distance between consecutive top edges of high density band portions. That certain hermatypic corals record annual density variations in their skeletons has been firmly established (1), (2), (12), (15), (16).

Results

The average band width (growth rate) for samples are plotted in the upper part of Fig. 2. "n" indicates the number of different band widths measured, each sample consisting of several corals. Length of the bar gives the 95% confidence limit under the assumption of normality to be discussed shortly. The average value of the growth rate was clearly lower in the 105,000 yrs. B.P. sample that at present (by t test (17) these two averages differ significantly at the .001 level), or for that matter than the other raised reef samples (significant by t test at least at the .01 level).

To assess variability, a root mean square variability, v , was defined by the equation:

$$v^2 = \frac{\sum_{i=1}^n (x_i - A)^2}{n}$$

where x_i is the i th band width and A is the average band width for the sample. Results for each sample are plotted in the lower part of Fig. 2. The sample size, n , is the same as for the upper graph and the lengths of the bars indicate the 95% confidence limits. As evident from the graph, the variability of the 105,000 yrs. B.P. sample was clearly lower than that of the Recent or other collections (by F test (18) at least at the .05 level). The same conclusions about change in variability with time are reached if index variability (i.e., variability normalized to the average band width of each coral in the sample) is used, or if individual coral records are filtered appropriately before computation.

To demonstrate in more detail the differences between samples of the Recent and the 105,000 yrs. B.P. as well as to indicate the extent to which assumptions used in the significance tests are met, we present Fig. 3. This diagram shows a plot on probability paper of the cumulative frequency band width distribution for the Recent (small dots) and for the 105,000 yrs. B.P. (large dots) samples. The two distributions have different means and standard deviations and can be approximated by two different straight lines.

Discussion

Barbados is the "type section" of the record of several high sea stands in the pre-Wisconsin interglacial. Of the three such stands, marked by the coral terraces sampled and analyzed in

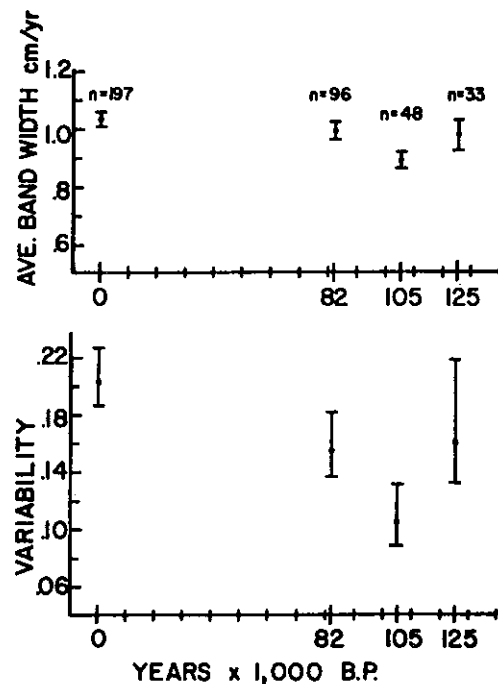


Figure 2 - Upper: Average band width of each sample; Lower: Variability of each sample as defined in the text. Length of the bars is the 95% confidence interval. "n" refers to sample size.

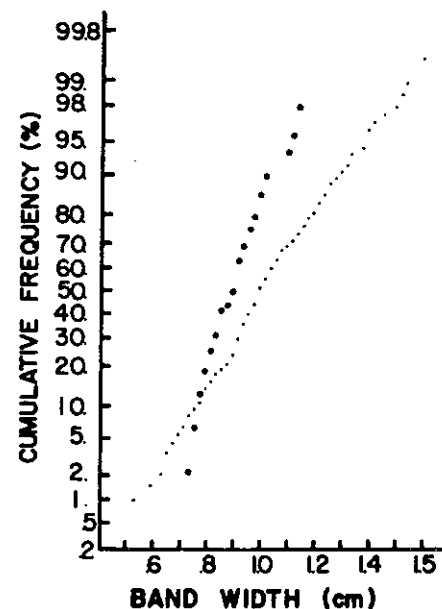


Figure 3 - Cumulative frequency band width distribution for samples from the recent (small dots) and 105,000 yrs. B.P. (large dots).

this study, the one with coral growth characteristics most clearly different from that of the contemporary high sea stand is the 105,000 yrs. B.P. terrace (Barbados II). The corals from this level indicate both a distinctly smaller variability and a thinner average band thickness than the present. Our assumed environmental model is that the environmental system responds on a time scale shorter than our sampling interval, so that each point is essentially an independent measure of the environment at the time indicated. The most important fact about Barbados II vis-à-vis the samples from the other stands is that the coral record implies both that the environment was less conducive to coral growth and that the environmental variability was smaller at that time.

As mentioned in the introduction, there are several primary controls of coral growth: light, water temperature, nutrition, and turbidity. The relative proportions of each, however, have yet to be identified directly in Barbados where we were further hampered by the unavailability of appropriate weather records. Nevertheless to the extent that one assumes Barbados coral response to the environment is analogous to that of previously reported corals (i.e., climatically controlled (10), (11), (12)), the results reported here can be given a more specific climatic interpretation.

We exclude the possibility of an increased sediment turbidity at Barbados II, as a cause, since all the corals are from the fore-reef, a zone fairly clear of resuspended sediment. We are thus left with the remaining three parameters known to influence coral growth: water temperature, light intensity, and nutrient supply.

Temperature does not appear to be the critical parameter. Comparison of oxygen isotope data on planktonic foraminifera for an equatorial Pacific core (V28-238(19)) with a Caribbean core (P6304-8(20)) show that both Barbados I and II were times of cooler surface water than either the present or Barbados III in the Caribbean region. Because samples from the Recent, Barbados I and III all show the same coral growth thickness and variability, it does not seem likely that ambient surface ocean temperature was a critical parameter in influencing the growth of the Barbados II corals. In addition, recorded time series of Barbados air temperature (admittedly a function of both sun intensity and water temperature due to the island effect on air temperature) revealed no significant correlation when compared to combined time series of annual band widths of the recent corals.

The role of light intensity as a critical parameter is less clear cut. If the Recent is assumed to be effectively a time of peak Northern Hemisphere summer insolation, as has been demonstrated for the times of Barbados I, II,

and III (13), (14), relative insolation peak heights and the coral data show similar trends. Lowest peak insolation was received during the 105,000 yrs. B.P. Barbados II time and it is this sample which shows lowest average band width and variability. On the other hand contemporary measurements of sunlight in Barbados (the significance of which must be qualified because of the considerable distance from recording station to collection site) show no correlation with contemporary coral band thickness variations from year to year in the sampled M. annularis. The interpretation is further complicated by local or global meteorological considerations (eg., cloud cover, wave strength, etc.) for which we lack data.

Although we have no direct way of assessing nutrient supply rates in the past, it is possible that these were both more subdued and constant during Barbados II than during the other warm periods. A study of contemporary Bermuda coral bands (10), (11) indicated that as surface temperature decreases over the long run, the growth rate of corals increases. The decrease in temperature is ascribed to greater upwelling in the Sargasso Sea thus resulting in greater nutrient supply. In Bermuda, which is in a marginal coral growth latitude, this nutrient effect can be observed on a seasonal basis (21). In Barbados strong seasonal effects are lacking (22) but the possibility of small yearly changes in nutrient supply can not be excluded. If nutrient supply were to control Barbados coral growth, the coral patterns of Barbados II would imply a stable, stratified surface ocean persisting over considerable periods of time. This would probably have to be a local effect since if it were Caribbean-wide, it would have been reflected in warmer surface water in the planktonic foraminifera than is actually found.

The above discussion has attempted to associate coral growth rates with a single dominant variable. The possibility that several variables are about equally influential can not be analyzed because of limited data at this time. Clearly more research on the relation between coral growth and environmental influences in the recent and more extensive sampling in the fossil record will be necessary before reliable extrapolations to the past are to be made.

Acknowledgements

Support for this project came from NSF Grant #OCE75-17618, The Geological Society of America, The Woman's Seaman's Friend Society of Conn., Inc., and the Yale Department of Geology and Geophysics. We wish to thank R.K. Matthews of Brown University for discussion and help in the field.

References

- (1) W.S. Moore and S. Krishnaswami, 1974, Proc. Second Int. Coral Reef Symp., 2, A.M. Cameron et al. (eds.), The Great Barrier Reef Committee, Brisbane, Australia, 269-276.
- (2) I.G. Macintyre and S.V. Smith, 1974, Proc. Second Int. Coral Reef Symp., 2, A.M. Cameron et al. (eds.), The Great Barrier Reef Committee, Brisbane, Australia, 277-287.
- (3) R.W. Buddemeier, 1974, Proc. Second Int. Coral Reef Symp., 2, A.M. Cameron et al. (eds.), The Great Barrier Reef Committee, Brisbane, Australia, 259-267.
- (4) J.N. Weber, E.W. White, and P.H. Weber, 1975, Paleobiol., 1, 137-149.
- (5) R.E. Dodge, R.C. Aller and J. Thomson, 1974, Nat., 247, 574-577.
- (6) R.C. Aller and R.E. Dodge, 1974, Jour. of Mar. Res., 32, 209-232.
- (7) R.E. Dodge and J.R. Vaišnys, 1975, Geol. Soc. Am. Abst. with Prog., 7, 1055.
- (8) L.A. Barnard, I.G. Macintyre, and J.W. Pierce, 1974, Nat., 252, 219-220.
- (9) R.G. Fairbanks, and R.K. Matthews, 1976, Geol. Soc. Am. Abst. with Prog., 8, 859.
- (10) R.E. Dodge and J.R. Vaišnys, 1975, Nat., 258, 706-708.
- (11) R.E. Dodge and J.R. Vaišnys, 1976, Geol. Soc. Am. Abst. with Prog., 8, 838.
- (12) J.H. Hudson, E.A. Shinn, R.B. Halley, and B. Lidz, 1976, Geology, 4, 361-364.
- (13) W.S. Broecker, D.L. Thurber, J. Goddard, T.Ku, R.K. Matthews, and K.J. Mesolella, 1968, Sci., 159, 297-300.
- (14) K.J. Mesolella, R.K. Matthews, W.S. Broecker, and D.L. Thurber, 1969, Jour. Geol., 77, 250-274.
- (15) D.W. Knutson, R.W. Buddemeier, and S.V. Smith, 1972, Sci., 177, 270-272.
- (16) R.E. Dodge and J. Thomson, 1974, Earth Planet Sci. Lett., 23, 313-322.
- (17) J. Guttman and S.S. Wilks, 1965, Introductory Engineering Statistics, John Wiley & Sons, Inc., New York, N.Y., USA, 165-167.
- (18) A.M. Mood, F.A. Graybill, and D.C. Boes, 1963, Introduction to the Theory of Statistics, McGraw-Hill Book Co., New York, N.Y., USA, 438-440.
- (19) N.J. Shackleton and N.D. Opdyke, 1973, Quat. Res., 3, 39-55.
- (20) C. Emiliani, 1966, Sci., 154, 851-857.
- (21) D.W. Mensel and J.H. Ryther, 1961, Deep Sea Res., 7, 282-288.
- (22) E. Moore and F. Sander, 1976, Estuarine and Coastal Mar. Sci., 4, 589-607.