The valvular lesions consisted of endothelial proliferation, round-cell infiltration, and edema of the valve (Fig. 1). The histologic characteristics of the valvular lesions were quite uniform, without variations that could be attributed either to age at the time of inoculation or to the time between inoculation and death. No histologic evidence of mural or valvular endocarditis was found in any of the control animals.

Coxsackie virus B_4 was recovered from the hearts of the infected animals as late as 8 days after inoculation. Viral antigen was identified in the valves and mural endocardium by immunofluorescent techniques.

We have shown that Coxsackie virus B_4 produces acute valvulitis in mice. Apparently such lesions have been overlooked previously because of lack of interest in the endocardium (*8*). It remains to be seen whether Coxsackie virus can produce chronic valvulitis, with scarring and calcification.

Endocarditis is not considered a complication of viral disease in man (*9*). Nevertheless, clinicians are well aware that many patients with acute and chronic valvulitis have no history of rheumatic fever, bacterial endocarditis, or syphilis. Because group-B Coxsackie viruses commonly infect man, are highly cardiotropic, and produce acute valvulitis in other mammals, it is important to determine whether they produce lesions in man similar to those we describe in mice.

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13 October 1965

Atlantic Deep-Sea Stratigraphy: Extension of Absolute Chronology to 320,000 Years

Abstract. *Thorium-230 measurements on a core of globigerina ooze from the Caribbean Sea substantiate the prediction of Ericson* et al. *that the paleontological boundary U-V (Sangamon-Illinoian boundary in their scheme) in the Atlantic sediments has an age of close to 320,000 years. As the ages derived by Ericson* et al. *were based on extrapolations of mean sedimentation rates established by carbon-14 and protactinium-231 dating of the upper sections of this and other cores, this result confirms the assumption that sedimentation rates in the Caribbean Sea have not changed significantly during the past several hundred thousand years. The uranium content of the ocean as indicated by the deposition rate of thorium-230 was no more than 30 percent higher during glacial than during interglacial periods.*

Study of the planktonic foraminiferans in the Atlantic deep-sea sediment has provided stratigraphic markers as well as evidence of climatic changes in the past (*1–5*). Two methods of study have been extensively explored: Ericson *et al.* (*3, 4*) use the absolute abundance of *Globorotalia menardii* as an indicator of the surface temperature of the ocean, and Emiliani (*2, 5*) uses primarily data on oxygen isotopes and relative species abundances. Although the climatic curves constructed by the two approaches agree only down to the bottom of the W zone of Ericson *et al.* (*5, 6*), and their interpretations in terms of continental glacial sequences await clarification (*6, 7*), the specific and isotopic changes observed in a sizable number of cores taken from the Atlantic Ocean and connected seas are internally consistent and correlatable from core to core. Hence, the establishment of radiometric ages for any one core provides an absolute chronology which can be extended throughout the Atlantic Ocean. Paleontological zones have been designated in

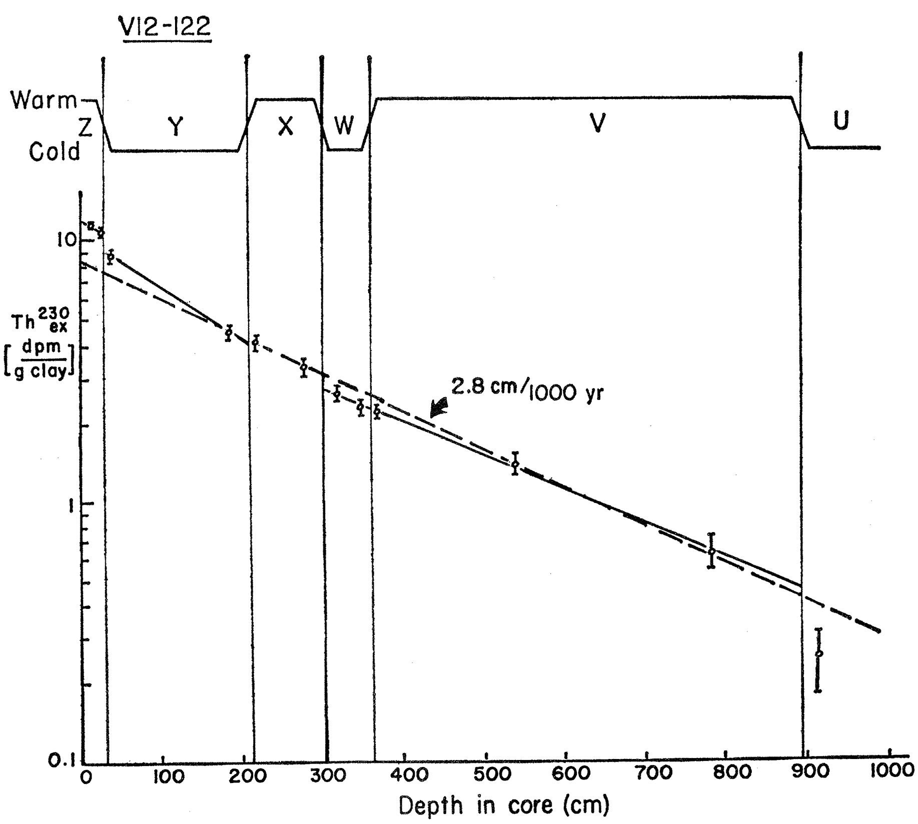

Fig. 1. Activities of unsupported Th^{230} on a basis of unit weight of noncarbonate material as a function of depth. Analytical errors are represented by vertical bars. Zonal divisions are the work of Ericson *et al.* (*4*). In the calculation of the rate, a half-life of 75,200 years for Th^{230} is used (*19*).

Atlantic Ocean globigerina ooze sediments based on the presence or absence of the species *Globorotalia menardii* (*3*). Ericson *et al.* have designated the zones by an inverse alphabetic sequence. The *G. menardii*–rich zone at the top of the cores is designated Z; the *G. menardii*–free zone underlying it, Y; and so forth. Ericson *et al.* interpret the *G. menardii*–rich zones as periods of interglacial climate, and those free of *G. menardii* as glacial. The age of the midpoint of the transition from the last cold oceanic climate (Y) to the present warm climate has been reliably established at 11,000 years by carbon-14 dating. The ages of the other boundaries, Y-X, X-W, and W-V, have been established independently at about 68,000, 100,000 and 120,000 years, respectively, either by extrapolating sedimentation rates obtained in the upper portion of the core by C^{14} (*2, 8–10*) or by Pa^{231}/Th^{230} measurements (*11, 12*). The reliability of these ages has been discussed by Broecker (*6*). The age of the boundary U-V, however, has been estimated only by extrapolation of sedimentation rates (*4*, fig. 5; *6*, fig. 2). Since the reliability of such extrapolation is open to question, establishment of the age of this boundary by direct radiometric measurement is desirable.

V12-122 is one of the 26 cores selected by Ericson *et al.* in their compilation of the complete Pleistocene record. It is 1095 cm long and was raised by Lamont's R.V. *Vema* from a depth of 2800 m in the Caribbean (17°00′N, 74°24′W). Ericson *et al.* (*4*) show that the core contains a complete climatic record extending from the present (Z zone) back to the U zone (Illinoian stage of Ericson *et al.*). Using the protactinium method, Sackett (*4, 13*) has obtained a set of dates for this core (see Fig. 2). Unsupported Pa^{231} activities were detected by him down to the depth of 360 cm.

Samples were taken for Th^{230} measurement just above and just below each of Ericson's paleontological boundaries. This is done because deposition of carbonate, of noncarbonate, and of Th^{230} may change along with climate, as found by Broecker *et al.* (*9*) in a mid-equatorial Atlantic core. Such changes make Th^{230} results difficult to interpret. If this situation exists in the Caribbean, then the Th^{230} concentration in sediments

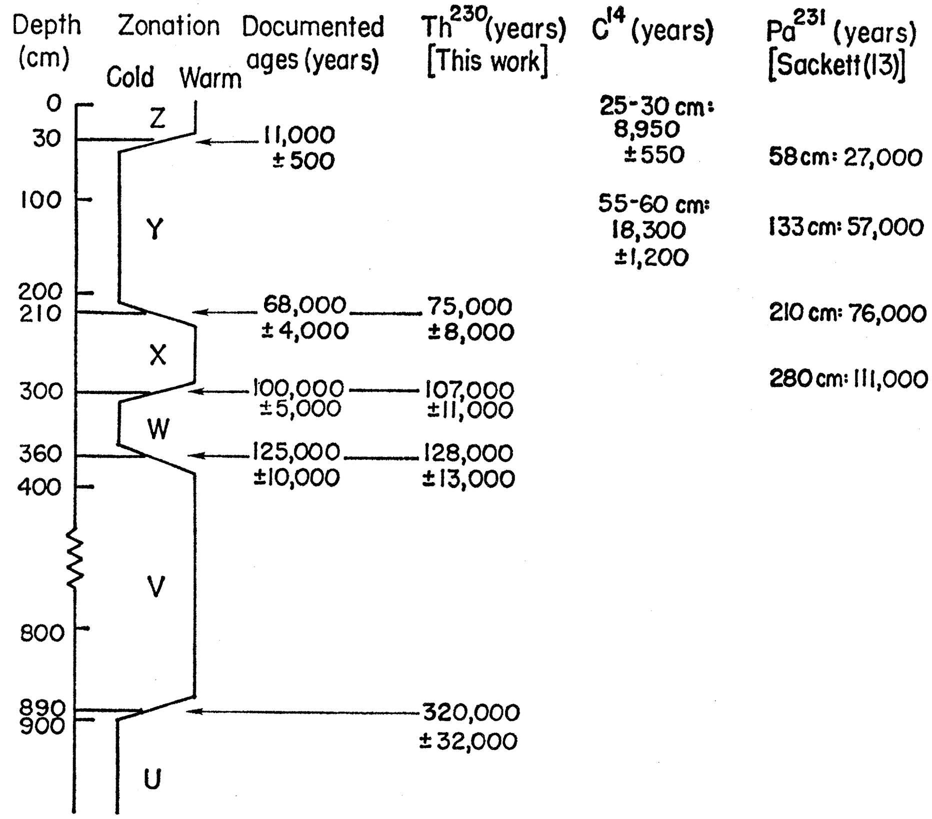

Fig. 2. Radiometric age data for V12-122. Documented ages were obtained by (i) C^{14} and extrapolation of sedimentation rates (*2, 8–10*), and (ii) Pa^{231}/Th^{230} (*11, 12*). Carbon-14 dates were determined by the Lamont C^{14} laboratory.

Table 1. Analytical data on core V12-122.

Depth in core (cm)	$CaCO_3$ (%)	U* (ppm)	Th* (ppm)	$\frac{U^{234}}{U^{238}}$	$\frac{Th^{230}}{U^{234}}$	$\frac{Th^{230}}{Th^{232}}$	$Th^{230}_{ex.}$ (dpm/g)	$Th^{230}_{ex.}$† (dpm/g clay)	$Th^{230}_{ex.}$‡ (dpm/g)	Zone
10 to 15	75.4	2.76	7.48	1.01 ± .04	6.62 ± .28	7.54 ± .41	2.84 ± .10	11.5 ± .5	2.96	Z
20 to 25	75.0	2.76	7.30	1.06 ± .04	6.00 ± .25	7.42 ± .21	2.70 ± .10	10.8 ± .5	2.91	Z
35 to 40	67.0	2.67	8.91	1.01 ± .04	5.38 ± .20	5.11 ± .12	2.91 ± .09	8.82 ± .38	3.28	Y
180 to 185	59.0	2.90	11.3	0.90 ± .03	3.32 ± .12	2.35 ± .09	1.83 ± .07	4.47 ± .21	3.34	Y
215 to 220	65.8	2.98	11.1	.96 ± .04	2.99 ± .15	2.35 ± .12	1.42 ± .09	4.04 ± .29	2.91	X
275 to 280	67.0	2.73	9.60	.92 ± .04	2.82 ± .15	2.23 ± .13	1.09 ± .08	3.30 ± .26	2.73	X
315 to 320	64.4	2.42	10.1	1.02 ± .04	2.43 ± .12	1.82 ± .09	0.91 ± .06	2.56 ± .19	2.60	W
345 to 350	53.0	2.62	12.5	0.98 ± .03	2.43 ± .11	1.38 ± .05	1.07 ± .07	2.28 ± .15	3.34	W
365 to 370	58.1	2.79	13.3	.90 ± .02	2.23 ± .06	1.28 ± .03	0.94 ± .04	2.24 ± .11	3.13	V
535 to 540	71.2	2.33	8.72	1.00 ± .04	1.82 ± .09	1.49 ± .07	.40 ± .04	1.39 ± .14	2.36	V
780 to 785	60.0	2.30	11.2	0.92 ± .03	1.43 ± .06	0.82 ± .04	.26 ± .04	0.65 ± .10	3.40	V
910 to 915	56.5	2.10	8.14	.90 ± .03	1.19 ± .05	.84 ± .03	.11 ± .03	.25 ± .07	2.20	U

* On a $CaCO_3$-free basis, the errors for U* are about ±4 percent (3 percent counting statistics and 3 percent $CaCO_3$ analyses); for Th* they are about ±6 percent (5 percent counting statistics and 3 percent $CaCO_3$ analyses). † $Th^{230}_{ex.}$ = dpm Th^{230} − dpm U^{234}; errors are the compound uncertainties of $Th^{230}_{ex.}$ (counting statistics) and $CaCO_3$ (±3 percent) measurements. ‡ Age-corrected value (the ages are estimated from the mean sedimentation rate of 2.8 cm/1000 years); this represents the initial excess Th^{230} present in the sediments. By taking the ratio of the average value for the warm period (zone Z + zone X, four sections) to that for the cold period (zone Y + zone W, four sections), we estimate the ratio of the uranium content in sea water during the glacial to that during the interglacial periods to be 1.1 ± .2.

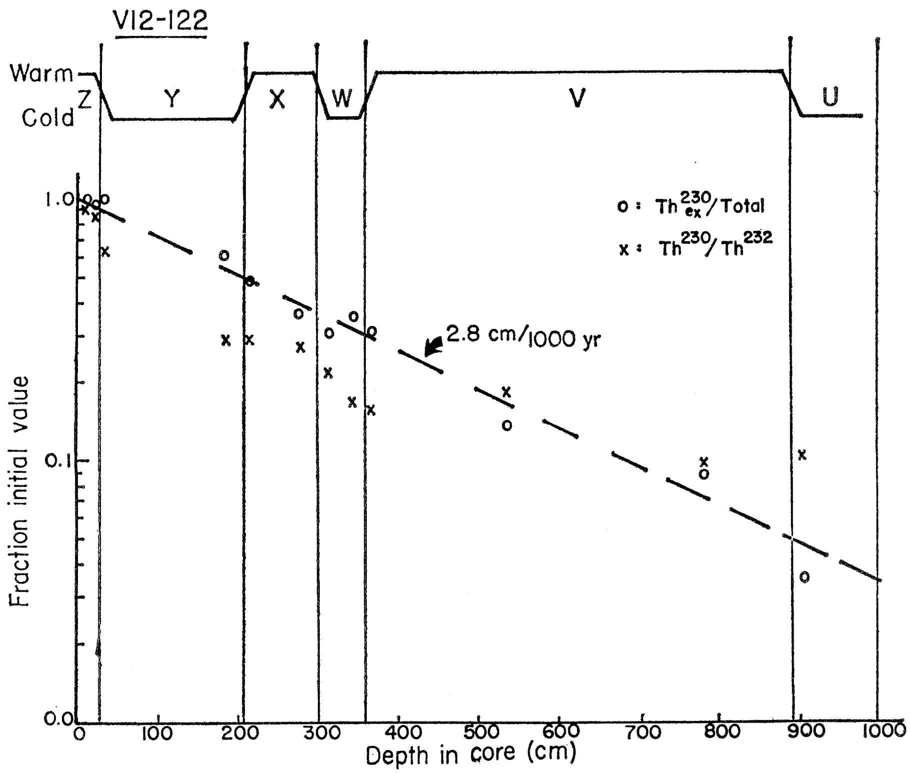

Fig. 3. Unsupported Th^{230} activities per unit weight of total sediments and activity ratio Th^{230}/Th^{232} as functions of depth. The Th^{230}/Th^{232} plot shows a much larger spread than does the excess Th^{230} plot.

should exhibit sharp fluctuations across the zonal transitions.

Uranium and thorium isotopic compositions were determined by alpha spectrometry. The sample treatment and analytical procedures have been described previously (*14*). Carbonate analyses were made by the method described by Turekian (*15*), with some modifications (*16*). Results are listed in Table 1. Errors here, unless otherwise indicated, represent the standard deviations for counting statistics.

In Fig. 1 the unsupported Th^{230} specific activities calculated on a carbonate-free basis are plotted against the depth. The paleontologic zones described for this core by Ericson *et al.* are also given. The Th^{230} exhibits a fairly regular logarithmic decrease, which indicates no major fluctuations in the ratio of the rate of noncarbonate material (that is, "clay") deposition to that of Th^{230} deposition at times of changing climate. Excess Th^{230} is still detectable at the U-V transition, the midpoint of which is located at about 890 cm. The average sedimentation rate estimated from the slope of the curve is 2.8 cm/1000 years. By using this rate and assigning zero age to the core top (age of the top of the core is less than the minimum C^{14} age; see Fig. 2), we estimate the age of the midpoint for the U-V boundary to be 320,000 ± 32,000 years. The error in this estimate arises largely from the uncertainty attached to the slope of the curve from which the average rate is derived. A comparison of the dates obtained in this core for other boundaries, that is, V-W, W-X, and X-Y, with their ages established by either extrapolation of C^{14} data or by the Pa^{231}/Th^{230} method from many other cores, indicates that where smooth exponential decreases are observed, the excess Th^{230} in a core provides valid absolute ages.

The age we obtained for the U-V boundary substantiates the estimate of Ericson *et al.* (*4, 6*) based on the extrapolation of sedimentation rates. Thus the assumption that deposition rates have, on the average, undergone no major changes during Pleistocene time has been confirmed for the past 300,000 years, at least for this portion of the Caribbean Sea.

The excess specific Th^{230} activities calculated on a carbonate-free "clay" basis show a more regular exponential decrease with the depth than does the curve of Th^{230}/Th^{232} (see Fig. 3). The points for excess Th^{230} per gram of total sediment show a smooth exponential decrease with a slope similar to that normalized to noncarbonate. This implies that whereas all three methods would give similar mean rates, those based on excess Th^{230} are subject to considerably smaller dispersion than that based on Th^{232}/Th^{230}.

Finally, the results of this work permit an estimation of the relative uranium concentrations in the oceans during glacial and interglacial times. By using the ratio of the glacial to the interglacial rates of Th^{230} influx into this core (over the Z through W interval), the ratio of the amount of uranium dissolved in the sea during glacial to that during interglacial times is estimated to be 1.1 ± 0.2, a value lower than that suggested by Koczy (*17, 18*).

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