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LAMONT RADIOCARBON MEASUREMENTS VIII

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Like Lamont VI (Broecker and Olson, 1959), this list contains only results on samples of known age (most of which formed during the past ten years). The measurements were made largely in order to gain an understanding of the distribution of radiocarbon within the dynamic carbon reservoir. Again, the data are not reported primarily with the idea of drawing new conclusions but rather to bring together in one place information which is presently scattered throughout the literature or which otherwise might remain unpublished.

Although the system of data presentation is essentially the same as that adopted in our previous paper, a change has been made in the normalization formula:

previous relationship (Lamont VI)

$$\Delta C^{14} = \delta C^{14} - 2\delta C^{13}\left(1 + \frac{\delta C^{14}}{1000}\right) - 50.0$$

revised relationship (as suggested by K. C. Munnich and J. C. Vogel, personal communication)

$$\Delta = \delta C^{14} - 2\delta C^{13}\left(1 + \frac{\delta C^{14}}{1000}\right) - 50.0\left(1 + \frac{\delta C^{14}}{1000}\right)$$

or

$$\Delta = \delta C^{14} - (2\delta C^{13} + 50)\left(1 + \frac{\delta C^{14}}{1000}\right)$$

The symbol Δ has been substituted for ΔC^{14} in the revised formula in order to eliminate confusion between the two modes of normalization. The $\left(1 + \frac{\delta C^{14}}{1000}\right)$ term replaces unity as a multiplier of the constant term, 50.0, in order to yield Δ values which reflect the exact per-millage change in the fractionation-normalized C^{14} concentrations. That this was not precisely the case with the previous system can be most easily demonstrated by considering an example. Two plant samples identical in C^{13}/C^{12} ratio ($\delta C^{13} = -25.0$) but differing by a factor of 1.200 in C^{14}/C^{12} ratio ($\delta C_1^{14} = 0$ and $\delta C_2^{14} = 200$) would have ΔC^{14} values of 0 and 210 per mil respectively and Δ values of 0 and 200 per mil. Thus, the old scale (ΔC^{14}) would unnecessarily introduce an additional 10 per mil difference, while the corrected scale (Δ) would give a difference consistent with the measured C^{14} activities.

The convenience provided by the Δ scale should more than compensate for any confusion resulting from the change. ΔC^{14} results can be easily converted to Δ results by the following relationship:

$$\Delta = \Delta C^{14} - \frac{\delta C^{14}}{20}$$

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It can be seen that the scale difference exceeds 5 per mil only for samples having C^{14} concentrations differing from 0.95 oxalic acid by more than 100 per mil.

The scale change in no way alters the method of computing δC^{13} and δC^{14} values or the use of .95 oxalic acid as a base for age calculations. One point concerning the use of the oxalic-acid standard warrants discussion, however. As shown by Craig (1961), considerable differences in δC^{13} value exist between gases prepared by different laboratories. These differences presumably result from isotope fractionation during chemical conversion of the oxalic acid to the compound used for the radioactivity assay. If corrections are not made, the activity of standards used by various laboratories (and even by the same laboratory at different times) will not be identical. To avoid this, it is proposed that all laboratories correct the activity of counting gas (or liquid) prepared from oxalic acid to the activity it would have had if its δC^{13} value were –19.0. Thus,

$$.95A_{ox} = .95A'_{ox}\left(1 - \frac{2(19.0 + \delta C^{13\prime}_{ox})}{1000}\right)$$

where A'_{ox} and $\delta C^{13\prime}_{ox}$ are based on the actual counting and mass-spectrometer measurement made on a gas prepared from the oxalic-acid standard. If a further chemical conversion is required in order to convert the compound used for the radio assay into the compound (usually CO_2 gas) used for mass analysis, this conversion, of course, must be carried out without any additional isotopic fractionation.

A recalibration of the mass-spectrometer used for C^{13} analyses at Lamont indicates that the previous calibration was in error over the entire range by 1.7 per mil. Thus a δC^{13} result given previously as –16.9 per mil would become –18.6. Although this change does not alter the relative values for any of the previously published Lamont results, it does introduce about a 3 per-mil error in comparing Lamont ΔC^{14} results with those from other laboratories. Because of this, Δ values in this paper are expressed in terms of the new calibration and should supersede results published elsewhere. In order to correct the results in Lamont VI, 1.7 per mil should be subtracted from each δC^{13} value and 3.4 $(1 + .001\ \delta C^{14})$ should be added to each ΔC^{14} value. Further conversion to the Δ scale requires the subtraction of $\frac{\delta C^{14}}{20}$ from each result. Thus the results on the oxalic-acid standard (previously given as $\delta C^{14} = 53$, $\delta C^{13} = -16.9$, and $\Delta C^{14} = 39\pm2$) become $\delta C^{14} = 53$, $\delta C^{13} = -18.6$, $\Delta C^{14} = 42\pm2$ and $\Delta = 39\pm2$. It should be noted that as the result of the change in calibration the δC^{13} for the Lamont oxalic-acid CO_2 agrees within experimental error with that of –19.0 obtained by Craig (1961) for the same gas.

The CO_2 method for measuring C^{14} activities was used in all cases. Details of the Lamont procedure have been published by Broecker, Tucek, and Olson (1959).

As the results on the samples in section IID have not been published elsewhere, a brief discussion of their significance is appropriate. Four types of information can be derived from these analyses; 1) the relationship between

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Δ for shells from open coastlines and Δ for surface water from the adjacent open ocean; 2) the magnitude of the Suess effect in the surface ocean; 3) the Δ value for areas of the surface ocean for which no direct measurements are available; 4) control values for age determinations on marine organisms.

The Δ values for coastal shells are compared with the average Δ values for the adjacent surface ocean in table 1. As would be expected, the agreement is satisfactory, the mean deviation (11 per mil) being only slightly greater than that expected from the experimental errors.

TABLE 1

Comparison of Δ values for coastal shells with those for the adjacent surface ocean

Lamont No.	Shell Location	Shell Collection Date	Δ Shell	Average Δ Adjacent Open Ocean*
L-576B	Bahamas	1950	−51 ± 5	−49
L-593C	Bahamas	1958	−25 ± 7†	−49
L-599A	Western France	1952	−58 ± 5	−49
L-576A	Jamaica	1930	−48 ± 5	−51
L-241A	Algeria	1954	−43 ± 10**	−49
L-576E	Tahiti	1957	−62 ± 5	−49
L-576C	Iceland	1946	−64 ± 6	−54***

* see Broecker and others, 1960.
** see Broecker and Olson, 1959.
*** based on the results of Fonselius and Östlund, 1959.
† the relatively high C^{14} concentration probably reflects the presence of bomb-produced C-14.

TABLE 2

Estimates of the Suess effect in the surface ocean

Location	Lamont No.	Collection Date	Δ	Estimated Suess Effect in 1955
Jamaica	L-576F	1884	−43 ± 5	13 ± 17
	L-576A	1930	−48 ± 5	
Bahamas	L-576G	1885	−55 ± 7	⩽ 8
	L-576B	1950	−51 ± 5	
Iceland	L-576I	1840	−72 ± 6	
	L-576H	1900	−69 ± 6	⩽ 8
	L-576C	1946	−64 ± 6	
Tahiti	L-576K	1885	−58 ± 5	⩽ 15
	L-576E	1957	−62 ± 5	

The magnitude of the Suess effect in the surface oceans has been estimated in four different localities by measuring pairs of gastropod shells collected at different times from each locality. The results as summarized in table 2 suggest that the decrease in Δ has been less than 10 per mil between 1880

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and 1955. Since the atmosphere showed a decrease in Δ of about 25 per mil over the same time interval, the rate of vertical mixing in the oceans must be quite rapid. This is in agreement with the vertical distribution of Sr^{90} in the oceans as observed by Bowen and Sugihara (1960). Rapid vertical mixing is also consistent with the fact that the observed atmospheric Suess effect is only a small fraction of what it would be if a major portion of combustion CO_2 were not being taken into the ocean. A quantitative treatment of this problem will be published separately.

Very few surface-water samples were collected for radiocarbon analysis from the North Pacific prior to 1957. Because results on samples collected since that time are influenced by the presence of bomb-produced C^{14}, measurements on shells grown before bomb-testing will perhaps be the only way to establish the steady-state Δ for these waters. Three of the samples reported here provide estimates of this value; Oahu, Hawaii (L-576J) $\Delta = -62\pm6$; Eniwetok Atoll (L-584A) $\Delta = -76\pm5$; and Vancouver Island (L-595) $\Delta = -55\pm5$. Certainly many more such analyses are needed before any conclusions can be formulated.

The selection of a proper contemporary standard for radiocarbon dating of marine shells has always presented a serious problem. The results of this study suggest the following generalizations.

1) For age determinations on shells which formed on open-ocean coast lines in the latitude range from 40°N to 40°S, a control value of $\Delta = -55\pm10$ should be used. Since the C^{14} activity corresponding to this Δ value is almost the same as that of the usual standard for age determination of terrestrial organic materials (.95 oxalic acid), use of the latter standard seems justified for these shells. The additional error resulting from uncertainty in the initial C^{14}/C^{12} ratio of mid-latitude shells will probably not increase the total error for such samples beyond that for terrestrial organic materials.

2) Because C^{14}-deficient deep-water horizons outcrop at high latitude, age determination on samples formed there presents greater difficulty. This is particularly true in the Antarctic. As demonstrated by the measurement on the living seal from McMurdo Sound (L-570, this date list), marine organisms in this region form with an abnormally low C^{14} concentration, so that at death they appear to have ages as great as 1200 yr. Low values of C^{14} concentration are also found for surface water samples from the Antarctic. On the other hand, the effect in the northern North Atlantic should be much smaller, perhaps equivalent to an "initial age" below 200 yr. There are three reasons why this is so: a) the deep waters of the North Atlantic have relatively high Δ values (approximating—100 per mil), b) the Gulf Stream is a significant contributor to North Atlantic waters, and c) Atlantic circulation may be cyclic (Broecker and others, 1960).

3) The most difficult problem is the evaluation of results on samples from lagoons, estuaries and other restricted parts of the ocean. In these cases the contribution of limestone-derived carbon from terrestrial drainage may cause a significant depression in the initial Δ. Whether this is the explanation for the low value of the Pearl Harbor sample (L-576D, this date list) is not certain; more probably, the result implies a finite age of the sample at the time of col-

lection. More work is needed before the magnitude of these local effects can be evaluated.

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SAMPLE DESCRIPTIONS

I. SAMPLES UTILIZING ATMOSPHERIC CO_2

A. Samples Defining the Atmospheric C^{14}/C^{12} Ratio Before 1900

	δC^{14}	δC^{13}	Δ
L-549A. Tokyo, Japan	**−1±5**	**−25.8**	**1±5**

Wood from the 1849 to 1853 growth rings of a Quercus Glandulifera tree growing in a forest near Iwaizumi (Akita-Ken) Japan (39° 48′ N Lat, 141° 48′ E Long). Coll. by K. Kigoshi, Gakushuin Univ., Tokyo.

L-549B. Stockholm, Sweden	**9±6**	**−26.3**	**12±6**

Wood from the 1844 to 1856 growth rings of an oak tree from a resort area near Stockholm (59° 20′ N Lat, 18° 08′ E Long). This wood has been used as a radiocarbon standard by the Stockholm Laboratory which obtained a Δ value of 6±5 per mil. Subm. by G. Östlund for purposes of interlaboratory calibration.

B. Samples Defining the Atmospheric C^{14}/C^{12} Ratio During the Time of the Suess Effect (1900-1952)

L-458. Lower Hutt, New Zealand	**−18±6**	**−25.4**	**−17±6**

Wood from pine lumber used by New Zealand Laboratory as a standard (exact age unknown but cut prior to 1950). Subm. by T. Rafter and G. Fergusson for purposes of an interlaboratory calibration. New Zealand Laboratory obtains a Δ value of −18±4 per mil.

L-539B. Palisades, New York	**2±6**	**−23.7**	**−1±6**

Wood from the 1952 growth ring of an oak tree cut April 19, 1959 on the grounds of Lamont Geol. Observatory (41° 00′ N Lat, 73° 55′ W Long). Sample was run to determine whether it contained carbon photosynthesized subsequent to formation of the ring. The Δ value is 25±10 per

	δC^{14}	δC^{13}	Δ

mil greater than that for similar age rings from trees cut prior to 1954, suggesting that a small amount of bomb-produced C^{14} was incorporated into the ring subsequent to its formation. Also compare Δ for this sample with –41 ± 15 for twigs coll. on Lamont grounds in 1952 (see L-184E, Broecker and Olson, 1959). The bulk sample was combusted without pretreatment. Coll. by the authors.

C. Samples Defining the Atmospheric C^{14}/C^{12} Ratio Since Large-scale Bomb-testing Began (1952-1960)

L-453. Stratosphere **225±6** **–7.2** **181±6**

Composite of several CO_2 samples separated from stratospheric air, distributed by L. Machta, U. S. Weather Bureau, for purposes of intercalibration between the various laboratories interested in bomb-produced C^{14}. Result obtained agrees well with those of the other participating laboratories.

L-493L. South Atlantic Ocean **118±5** **–7.4** **79±5**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (35° S Lat, 24° E Long). Coll. April 15 to 18, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-493M. South Atlantic Ocean **125±6** **–7.1** **85±6**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (27° S Lat, 46° E Long). Coll. April 28 to May 2, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-493N. South Atlantic Ocean **120±5** **–5.3** **76±5**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (13° S Lat, 65° E Long). Coll. May 13 to 17, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-4930. Mediterranean Sea **214±8** **–6.8** **170±8**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (36° N Lat, 7° E Long). Coll. August 8 to 10, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

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		δC^{14}	δC^{13}	Δ
L-493P.	**North Atlantic Ocean**	**200±8**	**–7.5**	**158±8**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (39° N Lat, 30° W Long). Coll. August 15 to 19, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-487M.	**Santa Barbara, California**	**109±6**	**–25.6**	**110±6**

Sycamore leaves from grounds of Santa Barbara Museum of Natural History (34° 31′ N Lat, 119° 41′ W Long). Coll. September 9, 1958 by P. Orr.

L-529A.	**North Atlantic Ocean**	**197±5**	**–6.8**	**153±5**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (33° N Lat, 76° W Long). Coll. October 22 to 24, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-529M.	**North Atlantic Ocean**	**193±8**	**–8.3**	**153±8**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (11° N Lat, 76° W Long). Coll. November 8 to 10, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-537A.	**Equatorial Pacific Ocean**	**176±9**	**–7.8**	**136±9**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (1° N Lat, 84° W Long). Coll. December 1 to 4, 1958 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-528C.	**Palisades, New York**	**264±7**	**–18.6**	**248±7**

Atmospheric CO_2 coll. statically in KOH exposed 3 ft above ground in dense forest on the grounds of the Lamont Geol. Observatory (41° 00′ N Lat, 73° 55′ W Long). Coll. by W. S. Broecker (Broecker and Olson, 1960).

L-516E.	**Carson City, Nevada**	**249±8**	**–25.5**	**250±8**

Willow leaves from tree growing W of town (39° 07′ N Lat, 119° 53′ W Long). Coll. June 5, 1959 by J. Calhoun, Nevada State Museum (Broecker and Olson, 1960).

	δC^{14}	δC^{13}	Δ
L-528F. Rockleigh, New Jersey	**232±8**	**–27.5**	**238±8**

Black-cherry leaves from tree growing on a golf course (41° 00′ N Lat, 73° 58′ W Long). Coll. June 9, 1959 by W. S. Broecker (Broecker and Olson, 1960).

L-537L. South Pacific Ocean	**144±7**	**–8.9**	**107±7**

Atmospheric CO_2 coll. on Columbia Univ. research vessel *Vema* by pulling air through CO_2-free KOH (49° S Lat, 75° W Long). Coll. January 28, 1959 by R. Gerard, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-519B. Lima, Peru	**135±7**	**–11.8**	**105±7**

Grass cut (12° S Lat, 77° W Long) March 6, 1959 by O. C. Johnson, U. S. Atomic Energy Commission (Broecker and Olson, 1960. Note: the ΔC^{14} given in this publication was incorrect).

L-523. Tucson, Arizona	**193±9**	**–22.4**	**187±8**

Leaves from tree growing in residential area on outskirts of Tucson (32° N Lat, 111° W Long). Coll. April 4, 1959 by W. S. Broecker (Broecker and Olson, 1960).

L-528A. Palisades, New York	**178±6**	**–27.6**	**183±6**

Maple leaves from the grounds of Lamont Geol. Observatory (41° 00′ N Lat, 73° 55′ W Long). Coll. May 16, 1959 by W. S. Broecker (Broecker and Olson, 1960).

L-528B. Alpine, New Jersey	**251±6**	**–20.6**	**240±6**

Atmospheric CO_2 coll. statically in KOH on top of a 400-ft radio tower (40° 57′ N Lat, 73° 55′ W Long). Coll. May 16, to June 7, 1959 by the authors (Broecker and Olson, 1960).

L-528E. Palisades, New York	**198±7**	**–27.9**	**205±7**

Maple leaves from the grounds of Lamont Geol. Observatory (41° 00′ N Lat, 73° 55′ W Long). Coll. June 7, 1959 by W. S. Broecker (Broecker and Olson, 1960).

L-547A. Alpine, New Jersey	**236±6**	**–25.7**	**238±6**

Atmospheric CO_2 coll. statically in KOH on top of a 400-ft radio tower (40° 57′ N Lat, 73° 55′ W Long). Coll. October 12 to 18, 1959 by the authors.

	δC^{14}	δC^{13}	Δ
L-547C. Alpine, New Jersey	**220±6**	**–26.0**	**222±6**

Atmospheric CO_2 coll. statically in KOH on top of a 400-ft radio tower (40° 57′ N Lat, 73° 55′ W Long). Coll. October 25 to 28, 1959 by the authors.

L-547F. Alpine, New Jersey	**202±7**	**–26.5**	**206±7**

Atmospheric CO_2 coll. statically in KOH on top of a 400-ft radio tower (40° 57′ N Lat, 73° 55′ W Long). Coll. November 25 to 28, 1959 by the authors.

D. Samples Defining the Amount of Bomb-produced C^{14} in Humans

L-371A. New York, New York	**61±10**	**–16.4**	**43±10**

Human-lung tissue and associated blood from autopsy performed June 1958; subm. by A. Schulert.

L-505A. Rockland County, New York	**106±8**	**–23.5**	**103±8**

Respiratory CO_2 from a local resident, coll. January 1, 1959 by respiration into CO_2-free KOH (Broecker, Olson and Schulert, 1959).

L-505B. Rockland County, New York	**115±8**	**–18.2**	**100±8**

Blood from same person as L-505A; also coll. January 1, 1959.

L-516A. Carson City, Nevada	**118±7**	**–18.1**	**103±7**

Blood from a local resident, coll. March 4, 1959; subm. by J. Calhoun, Nevada State Museum. (Broecker and Olson, 1960).

L-519A. Lima, Peru	**70±6**	**–18.9**	**57±6**

Blood from a local resident, coll. March 6, 1959; subm. by O. C. Johnson (Broecker and Olson, 1960).

L-516C. Ushuaia, Argentina	**33±8**	**–20.9**	**25±8**

Blood from a local resident, coll. March 15, 1959 by M. Ewing, Lamont Geol. Observatory (Broecker and Olson, 1960).

L-516D. Carson City, Nevada	**135±6**	**–19.7**	**123±6**

Blood from same person as L-516A, coll. June 1, 1959; subm. by J. Calhoun (Broecker and Olson, 1960).

	δC^{14}	δC^{13}	Δ
L-516G. Carson City, Nevada	**183±6**	**–19.5**	**170±6**

Blood from same person as L-516A, coll. December 17, 1959; subm. by J. Calhoun (Broecker and Olson, 1960).

L-569B. Rockland County, New York	**213±6**	**–19.9**	**201±6**

Respiratory CO_2 from a local resident, coll. January 13, 1960 by breathing into large plastic bag (Broecker and Olson, 1960).

L-569A. Rockland County, New York	**194±6**	**–18.4**	**178±6**

Blood from same person as L-569B, coll. January 19, 1960 (Broecker and Olson, 1960).

L-583A. New York, New York	**156±10**	**–17.9**	**140±10**

Composite of blood-free muscle tissue coll. during an autopsy on February 8, 1960; subm. by P. Hudson, Columbia Univ. (Broecker and Olson, 1960).

E. Samples Defining the C^{14} Concentration in Soil-Organic Materials

L-528D. Palisades, New York	**106±7**	**–24.9**	**106±7**

CO_2 given off by soil in dense forest on the grounds of Lamont Geol. Observatory (41° 00′ N Lat, 73° 55′ W Long). Coll. continuously from May 16 to June 7, 1959 by exposing a tray of CO_2-free KOH within an inverted barrel driven several in. into the soil. Total CO_2 obtained indicated that 1.7 moles of CO_2 were being given off per week from each square m of soil surface (Broecker and Olson, 1960).

L-528K. Palisades, New York	**–1±7**	**–26.1**	**1±7**

Coarse organic material from composite sample of soil (0 to 21 in.) coll. June 8, 1960 from same locality as L-528D. Sample, consisting of leaves, twigs, rootlets, etc., was obtained by sieving the soil through a window screen. Amount of material obtained corresponds to 4±2 gm of carbon per kg of soil (Broecker and Olson, 1960).

L-528L. Palisades, New York	**–123±9**	**–24.7**	**–124±9**

Fine organic material from same soil as L-528K. A representative sample of that portion of the soil passing through the 40-mesh screen was combusted. Amount of CO_2 obtained corresponds to 10±2 gm of carbon per kg of soil (Broecker and Olson, 1960).

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	δC^{14}	δC^{13}	Δ
L-528G. Palisades, New York	**−25±7**	**−25.9**	**−23±7**

Humic acid extracted from fine fraction of soil (L-528L) by boiling it in 2% NaOH. Ca. 35% of the organics was dissolved by this treatment (Broecker and Olson, 1960).

L-528P. Palisades, New York **−218±9 (−24.7) (−218±9)**

Residual organics after treatment with NaOH. Ca. 55% of the organic material appeared in this fraction (Broecker and Olson, 1960).

L-528R. Palisades, New York **−83±20 (−24.7) (−82±20)**

Acid-soluble humic material from sample L-528L. That portion of the NaOH-soluble organics which was not precipitated upon acidification of the NaOH with HCl. Ca. 10% of the carbon in the fine fraction appeared in this fraction (Broecker and Olson, 1960).

II. SAMPLES UTILIZING CO_2 DISSOLVED IN SEA WATER

A. CO_2 obtained from acidified samples of sea water from Atlantic Ocean and adjacent seas. All samples in this group were coll. by the scientific staff of Columbia Univ. research vessel *Vema*, under direction of M. Ewing, R. Gerard, and B. Heezen. The techniques used in collecting and measuring samples have been published by Broecker, Tucek, and Olson (1959). The implications of the results have been discussed by Broecker, Gerard, Ewing, and Heezen (1960). The rather large variations in the δC^{13} ratios are the result of isotope fractionation during the processing of the sample and do not represent real variations within the ocean. The numbers in parentheses beside each laboratory number are the index numbers used by Broecker and others (1960). δC^{13} values in parenthises are estimated rather than measured. The corresponding Δ values are based on these estimates.

1) *Surface water 0 to 50 m*

L-326A. (1) Gulf Stream **−9±7** **0.1** **−59±7**

Coll. October 30, 1955; 38° 22′ N Lat, 71° 32′ W Long; 1 m depth.

L-287E. (2) North Atlantic Current **12±8 (−3.7) (−31±10)**

Coll. July 19, 1955; 37° 58′ N Lat, 50° 53′ W Long; 1 m depth.

L-326B. (3) Sargasso Sea **−5±6** **−2.8** **−49±6**

Coll. November 1, 1955; 36° 06′ N Lat, 66° 06′ W Long; 1 m depth.

L-538P. Gulf Stream **28±8** **−1.0** **−21±8**

Coll. July 10, 1959; 35° 20′ N Lat, 74° 40′ W Long; 1 m depth.

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δC^{14} δC^{13} Δ

L-326C. (4) Sargasso Sea **4±6 (3.3) (–53±8)**
Coll. November 3, 1955; 34° 06′ N Lat, 65° 06′ W Long; 1 m depth.

L-465Z. (5) Sargasso Sea **–1±5 –0.2 –51±5**
Coll. November 13, 1957; 34° 05′ N Lat, 65° 00′ W Long; 1 m depth.

L-367I. (6) Sargasso Sea **–5±5 0.5 –56±5**
Coll. June 2, 1956; 33° 50′ N Lat, 66° 18′ W Long; 1 m depth.

L-367K. (7) Sargasso Sea **–6±6 –1.0 –55±6**
Coll. June 7, 1956; 33° 00′ N Lat, 49° 48′ W Long; 1 m depth.

L-367J. (8) Sargasso Sea **9±6 –0.3 –41±6**
Coll. June 5, 1956; 32° 38′ N Lat, 57° 55′ W Long; 1 m depth.

L-367L. (9) Sargasso Sea **–13±7 (–0.7) (–62±10)**
Coll. June 12, 1956; 31° 45′ N Lat, 34° 38′ W Long; 1 m depth.

L-464B. (10) Sargasso Sea **26±5 (3.3) (–32±8)**
Coll. November 16, 1957; 29° 57′ N Lat, 61° 41′ W Long; 1 m depth.

L-464D. (11) Sargasso Sea **13±6 –3.5 31±6**
Coll. November 17, 1957; 29° 13′ N Lat, 60° 30′ W Long; 46 m depth.

L-326D. (12) Antilles Current **5±6 3.2 –51±6**
Coll. November 5, 1955; 27° 05′ N Lat, 73° 32′ W Long; 1 m depth.

L-416A. (13) Florida Current **–2±7 0.6 –49±7**
Coll. June 24, 1957; 25° 42′ N Lat, 79° 23′ W Long; 1 m depth.

L-326E. (14) Antilles Current **6±5 –0.9 –42±5**
Coll. November 8, 1955; 25° 25′ N Lat, 75° 13′ W Long; 1 m depth.

L-326G. (15) Antilles Current **10±10 0.3 –41±10**
Coll. November 12, 1955; 20° 32′ N Lat, 68° 30′ W Long; 1 m depth.

L-326F. (16) Antilles Current **14±7 5:8 –48±7**
Coll. November 10, 1955; 19° 58′ N Lat, 70° 53′ W Long; 1 m depth.

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	δC^{14}	δC^{13}	Δ
L-326H. (17) Antilles Current Coll. November 14, 1955; 19° 07′ N Lat, 67° 07′ W Long; 1 m depth.	**8±5**	**0.4**	**–43±5**
L-529I. (165) West Caribbean Coll. November 6, 1958; 15° 51′ N Lat, 75° 11′ W Long; 1 m depth.	**20±7**	**2.1**	**–35±7**
L-4640. (18) North Equatorial Current Coll. November 26, 1957; 15° 03′ N Lat, 39° 48′ W Long; 1 m depth.	**1±8**	**–2.7**	**–44±8**
L-538I. (163) North Equatorial Current Coll. May 14, 1959; 10° 31′ N Lat, 45° 02′ W Long; 1 m depth.	**19±6**	**2.4**	**–37±6**
L-326R. (19) West Caribbean Coll. December 20, 1955; 19° 04′ N Lat, 80° 48′ W Long; 1 m depth.	**–1±7**	**(1.3)**	**(–52±9)**
L-326P. (20) West Caribbean Coll. December 10, 1955; 16° 17′ N Lat, 79° 14′ W Long; 1 m depth.	**–11±10**	**5.5**	**–71±10**
L-326Q. (21) West Caribbean Coll. December 16, 1955; 17° 39′ N Lat, 79° 04′ W Long; 1 m depth.	**–5±7**	**–2.8**	**–49±7**
L-326O. (22) East Caribbean Coll. December 8, 1955; 12° 27′ N Lat, 77° 25′ W Long; 1 m depth.	**9±6**	**0.6**	**–43±6**
L-326L. (23) East Caribbean Coll. November 25, 1955; 17° 05′ N Lat, 71° 36′ W Long; 1 m depth.	**9±7**	**3.8**	**–49±7**
L-326J. (24) East Caribbean Coll. November 19, 1955; 16° 43′ N Lat, 70° 38′ W Long; 1 m depth.	**4±7**	**2.9**	**–52±7**
L-326I. (25) East Caribbean Coll. November 17, 1955; 17° 11′ N Lat, 68° 55′ W Long; 1 m depth.	**–1±6**	**3.4**	**–58±6**
L-326K. (26) East Caribbean Coll. November 22, 1955; 17° 47′ N Lat, 68° 22′ W Long; 1 m depth.	**11±7**	**4.2**	**–48±7**
L-367Y. (27) East Mediterranean Coll. August 16, 1956; 34° 04′ N Lat, 26° 21′ E Long, 1 m depth.	**–4±7**	**2.5**	**–59±7**

	δC^{14}	δC^{13}	Δ
L-367R. (28) Gulf of Corinth	**−53±7**	**−4.0**	**−93±7**
Coll. July 24, 1956; 38° 06′ N Lat, 22° 54′ E Long; 1 m depth.			
L-464R. (29) South Equatorial Current	**−28±6**	**−2.8**	**−71±6**
Coll. December 5, 1957; 00° 51′ N Lat, 32° 52′ W Long; 49 m depth.			
L-334A. (30) South Equatorial Current	**−2±6**	**−0.3**	**−52±6**
Coll. February 15, 1956; 03° 06′ S Lat, 32° 26′ W Long; 1 m depth.			
L-334E. (31) South Equatorial Current	**−13±7**	**(−0.7)**	**(−61±10)**
Coll. February 17, 1956; 03° 34′ S Lat, 31° 22′ W Long; 1 m depth.			
L-410D. (32) South Equatorial Current	**−24±5**	**−2.1**	**−69±5**
Coll. January 9, 1957; 04° 29′ S Lat, 34° 54′ W Long; 1 m depth.			
L-419B. (33) North Benguela Current	**−24±7**	**−5.0**	**−63±7**
Coll. May 20, 1957; 05° 41′ S Lat, 10° 39′ E Long; 1 m depth.			
L-464T. (34) Brazil Current	**−8±7**	**(−2.7)**	**(−52±9)**
Coll. December 16, 1957; 09° 38′ S Lat, 34° 05′ W Long; 1 m depth.			
L-410E. (35) Brazil Current	**−11±7**	**−5.9**	**−49±7**
Coll. January 19, 1957; 10° 59′ S Lat, 32° 28′ W Long; 1 m depth.			
L-465D. (36) Brazil Current	**7±7**	**−3.8**	**36±7**
Coll. December 26, 1957; 23° 12′ S Lat, 37° 38′ W Long; 1 m depth.			
L-410JJ. (37) Central South Atlantic	**−10±15**	**(−2.7)**	**(−54±15)**
Coll. May 12, 1957; 14° 30′ S Lat, 07° 34′ E Long; 1 m depth.			
L-410DD. (39) Central South Atlantic	**−13±5**	**−3.0**	**−56±5**
Coll. May 3, 1957; 25° 31′ S Lat, 12° 26′ E Long; 1 m depth.			
L-410AA. (40) Central South Atlantic	**−2±7**	**−2.6**	**−47±7**
Coll. April 29, 1957; 32° 13′ S Lat, 16° 20′ E Long; 1 m depth.			
L-465X. (41) Central South Atlantic	**−8±6**	**−2.9**	**−52±6**
Coll. April 6, 1958; 34° 06′ S Lat, 18° 06′ E Long; 1 m depth.			

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	δC^{14}	δC^{13}	Δ
L-410Y. (42) West Benguela Coll. April 19, 1957; 34° 46′ S Lat, 06° 29′ E Long; 1 m depth.	**–2±7**	**–6.8**	**–38±7**
L-410S. (43) West Wind Drift Coll. April 6, 1957; 39° 03′ S Lat, 41° 48′ W Long; 1 m depth.	**–2±5**	**–0.7**	**–51±5**
L-410W. (44) West Wind Drift Coll. April 12, 1957; 40° 54′ S Lat, 20° 29′ W Long; 1 m depth.	**–21±7**	**–8.3**	**–54±7**
L-410X. (45) West Wind Drift Coll. April 15, 1957; 41° 15′ S Lat, 06° 10′ W Long; 1 m depth.	**–14±7**	**–3.9**	**–56±7**
L-410Q. (46) Falkland Current Coll. April 2, 1957; 40° 43′ S Lat, 56° 32′ W Long; 1 m depth.	**–27±5**	**–1.1**	**–74±5**
L-410R. (47) Falkland Current Coll. April 3, 1957; 41° 05′ S Lat, 51° 09′ W Long; 1 m depth.	**–27±7**	**–3.3**	**–69±7**
L-410P. (48) Falkland Current Coll. March 20, 1957; 45° 24′ S Lat, 59° 13′ W Long; 1 m depth.	**–27±6**	**–1.4**	**–73±6**
L-465S. (49) Antarctic Convergence Coll. March 24, 1958; 51° 27′ S Lat, 02° 38′ E Long, 1 m depth.	**–28±6**	**3.9**	**–84±6**
L-465M. (50) Drake Passage Coll. February 24, 1958; 55° 27′ S Lat, 57° 10′ W Long; 1 m depth.	**–69±7**	**–5.9**	**–105±7**
L-465R. (51) Antarctic Surface Water Coll. March 19, 1958; 57° 07′ S Lat, 07° 15′ W Long; 1 m depth.	**–79±5**	**–6.6**	**–113±5**

2) Subsurface water 200 to 400 m

	δC^{14}	δC^{13}	Δ
L-334U. (52) North Atlantic Central Water Coll. April 16, 1956; 25° 01′ N Lat, 59° 12′ W Long; 256 m depth.	**–11±7**	**1.2**	**–63±7**
L-367EE. (53) North Atlantic Central Water Coll. October 12, 1956; 23° 22′ N Lat, 27° 14′ W Long; 329 m depth.	**–15±5**	**2.5**	**–69±5**

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	δC^{14}	δC^{13}	Δ
L-334M. (54) North Atlantic Central Water	**−29±6**	**−4.3**	**−69±6**

Coll. April 11, 1956; 15° 49′ N Lat, 47° 12′ W Long; 229 m depth.

L-334K. (55) Transition NACW-SACW	**−49±9**	**−4.6**	**−88±9**

Coll. April 7, 1956; 08° 15′ N Lat, 37° 54′ W Long; 274 m depth.

L-464P. (56) Transition NACW-SACW	**−41±6**	**−2.6**	**−84±6**

Coll. December 3, 1957; 07° 22′ N Lat, 29° 59′ W Long; 240 m depth.

L-419G. (57) South Atlantic Central Water	**−18±7**	**−4.1**	**−59±7**

Coll. June 9, 1957; 00° 19′ S Lat, 24° 29′ W Long; 201 m depth.

L-334B. (58) South Atlantic Central Water	**−35±7**	**−2.1**	**−79±7**

Coll. February 16, 1956; 03° 17′ S Lat, 32° 14′ W Long; 274 m depth.

L-419A. (59) Lower SACW	**−38±7**	**−4.2**	**−78±7**

Coll. May 19, 1957; 06° 25′ S Lat, 11° 26′ W Long; 366 m depth.

L-464Y. (60) South Atlantic Central Water	**−8±5**	**−3.6**	**−50±5**

Coll. December 21, 1957; 14° 02′ S Lat, 37° 32′ W Long; 295 m depth.

L-464Z. (61) South Atlantic Central Water	**−4±6**	**−0.1**	**−54±6**

Coll. December 21, 1957; 14° 10′ S Lat, 37° 33′ W Long; 300 m depth.

L-410HH. (62) South Atlantic Central Water	**−13±7**	**−3.2**	**−56±7**

Coll. May 9, 1957; 21° 14′ S Lat, 03° 22′ E Long. 0-274 m depth.

L-410BB. (63) South Atlantic Central Water	**−4±7**	**−4.2**	**−45±7**

Coll. May 2, 1957; 28° 26′ S Lat, 08° 39′ E Long; 201 m depth.

3) *Subsurface water 500 to 1200 m*

L-287G. (64) Lower North Atlantic Central Water	**7±13**	**(−3.7)**	**(−35±13)**

Coll. July 19, 1955; 38° 00′ N Lat, 51° 37′ W Long; 732 m depth.

	δC^{14}	δC^{13}	Δ
L-367CC. (65) North Atlantic Undefined	**−41±10**	**6.8**	**−102±10**
Coll. October 11, 1956; 24° 23′ N Lat, 24° 03′ W Long; 1097 m depth.			
L-282M. (66) North Atlantic Undefined	**−50±13**	**(−3.7)**	**(−90±13)**
Coll. June 17, 1955; 23° 28′ N Lat, 65° 56′ W Long; 896 m depth.			
L-3340. (67) North Atlantic Undefined	**−49±6**	**(−3.7)**	**(−90±8)**
Coll. April 14, 1956; 22° 22′ N Lat, 54° 19′ W Long; 823 m depth.			
L-464H. (68) North Atlantic Undefined	**−57±6**	**−16.5**	**−73±6**
Coll. November 22, 1957; 20° 44′ N Lat, 49° 24′ W Long; 950 m depth.			
L-326U. (69) North Atlantic Undefined	**−43±7**	**−3.0**	**−85±7**
Coll. December 25, 1955; 19° 09′ N Lat, 76° 59′ W Long; 1097 m depth.			
L-334L. (70) North Atlantic Undefined	**−50±6**	**−1.7**	**−94±6**
Coll. April 11, 1956; 15° 49′ N Lat, 47° 12′ W Long; 823 m depth.			
L-464M. (71) North Atlantic Undefined	**−73±6**	**−8.8**	**−103±6**
Coll. November 26, 1957; 15° 29′ N Lat, 40° 30′ W Long; 823 m depth.			
L-334I. (72) North Atlantic Undefined	**−60±5**	**−1.8**	**−104±5**
Coll. April 7, 1956; 08° 14′ N Lat, 37° 48′ W Long; 823 m depth.			
L-464S. (73) Antarctic Intermediate Water	**−63±6**	**−3.0**	**−104±6**
Coll. December 5, 1957; 00° 51′ N Lat, 32° 52′ W Long; 799 m depth.			
L-334C. (74) Antarctic Intermediate Water	**−76±6**	**−1.9**	**−119±6**
Coll. February 16, 1956; 03° 22′ S Lat, 31° 50′ W Long; 732 m depth.			
L-419C. (75) Antarctic Intermediate Water	**−64±7**	**−14.4**	**−84±7**
Coll. May 26, 1957; 04° 47′ S Lat, 02° 40′ E Long; 732 m depth.			

	δC^{14}	δC^{13}	Δ
L-464U. (76) Antarctic Intermediate Water	**−86±6**	**−2.4**	**−127±6**

Coll. December 16, 1957; 10° 04′ S Lat, 33° 52′ W Long; 914 m depth.

L-410II. (77) Upper Antarctic Intermediate Water **−67±7 −3.8 −107±9**

Coll. May 9, 1957; 21° 09′ S Lat, 03° 20′ E Long; 550 m depth.

L-410CC. (78) Lower Antarctic Intermediate Water **−92±7 −4.1 −130±7**

Coll. May 2, 1957; 28° 25′ S Lat, 08° 36′ E Long; 1189 m depth.

4) Subsurface samples 1200 to 2500 m

L-450E. (80) Upper North Atlantic Deep Water **−22±5 −3.9 −63±5**

Coll. October 31, 1957; 39° 16′ N Lat, 70° 46′ W Long; 2323 m depth.

L-287F. (81) Upper North Atlantic Deep Water **−19±7 (−3.7) (−62±13)**

Coll. July 19, 1955; 37° 58′ N Lat, 50° 53′ W Long; 1944 m depth.

L-464E. (82) Upper North Atlantic Deep Water **−32±10 (−4.7) (−74±10)**

Coll. November 17, 1957; 29° 13′ N Lat, 60° 31′ W Long; 1423 m depth.

L-282K. (83) Upper North Atlantic Deep Water **−20±13 −3.4 −62±13**

Coll. June 15, 1955; 25° 07′ N Lat, 69° 57′ W Long; 1829 m depth.

L-538M. (158) Upper North Atlantic Deep Water **−59±7 (−0.7) (−105±7)**

Coll. May 30, 1959; 21° 10′ N Lat, 66° 37′ W Long; 2520 m depth.

L-529C. (84) Upper North Atlantic Deep Water **−5±6 −4.4 −46±6**

Coll. November 4, 1957; 20° 31′ N Lat, 73° 22′ W Long; 1230 m depth.

L-529E. (152) Upper North Atlantic Deep Water **−9±7 0.3 −59±7**

Coll. November 4, 1958; 20° 31′ N Lat, 73° 22′ W Long; 1783 m depth.

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	δC^{14}	δC^{13}	Δ
L-529D. (154) Upper North Atlantic Deep Water	**−34±6**	**0.7**	**−84±6**

Coll. November 4, 1958; 20° 31′ N Lat, 73° 22′ W Long; 1863 m depth.

L-529F. (160) Upper North Atlantic Deep Water	**−32±6**	**−2.8**	**−75±6**

Coll. November 5, 1958; 19° 31′ N Lat, 74° 59′ W Long; 1290 m depth.

L-538L. (155) Upper North Atlantic Deep Water	**−30±6**	**0.2**	**−79±6**

Coll. May 25, 1959; 18° 58′ N Lat, 65° 38′ W Long; 1260 m depth.

L-419J. (87) Upper North Atlantic Deep Water	**−61±7**	**−14.7**	**−80±7**

Coll. July 4, 1957; 11° 12′ N Lat, 59° 19′ W Long; 2305 m depth.

L-419I. (88) Upper North Atlantic Deep Water	**−43±6**	**−7.3**	**−77±6**

Coll. July 4, 1957; 11° 12′ N Lat, 57° 16′ W Long; 1765 m depth.

L-419H. (89) Upper North Atlantic Deep Water	**−62±6**	**−17.6**	**−76±6**

Coll. July 3, 1957; 10° 49′ N Lat, 55° 41′ W Long; 1262 m depth.

L-367BB. (90) Upper North Atlantic Deep Water	**−56±5**	**−2.4**	**−99±5**

Coll. October 10, 1956; 25° 13′ N Lat, 21° 23′ W Long; 1463 m depth.

L-367AA. (91) Upper North Atlantic Deep Water	**−60±6**	**−1.4**	**−104±6**

Coll. September 10, 1956; 25° 13′ N Lat, 21° 23′ W Long; 1829 m depth.

L-334J. (92) Upper North Atlantic Deep Water	**−53±7**	**0.8**	**−102±7**

Coll. April 7, 1956; 08° 15′ N Lat, 37° 53′ W Long; 1463 m depth.

L-419D. (93) Upper North Atlantic Deep Water	**−47±6**	**−2.5**	**−90±6**

Coll. May 27, 1957; 04° 23′ S Lat, 00° 05′ W Long; 1829 m depth.

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δC14 δC13 Δ

L-464W (94) Upper North Atlantic Deep Water **−54±8 −2.6 −96±8**

Coll. December 16, 1957; 10° 06′ S Lat, 34° 54′ W Long; 1829 m depth.

L-464X (95) Upper North Atlantic Deep Water **−55±9 −8.3 −87±9**

Coll. December 17, 1957; 12° 37′ S Lat, 35° 00′ W Long; 1829 m depth.

L-465B (96) Upper North Atlantic Deep Water **−61±7 −1.3 −106±7**

Coll. December 22, 1957; 15° 17′ S Lat, 36° 00′ W Long; 4369 m depth.

L-410GG. (97) Antarctic Deep Water −80±10 −5.0 −117±10

Coll. May 8, 1957; 22° 40′ S Lat, 03° 16′ E Long; 1646 m depth.

L-410Z. (98) Antarctic Deep Water −71±10 −1.0 −116±10

Coll. April 2, 1957; 35° 20′ S Lat, 10° 42′ E Long; 2195 m depth.

L-410T. (99) Antarctic Deep Water −100±5 −6.0 −134±5

Coll. April 7, 1957; 38° 58′ S Lat, 40° 06′ W Long; 1829 m depth.

5) Subsurface samples 2500 to 4000 m

L-287N. (100) North Atlantic Deep Water **−43±10 (−3.7) (−84±10)**

Coll. July 27, 1955; 34° 55′ N Lat, 57° 11′ W Long; 3488 m depth.

L-334X. (101) North Atlantic Deep Water **−62±6 −0.8 −107±6**

Coll. April 18, 1956; 28° 41′ N Lat, 60° 19′ W Long; 2560 m depth.

L-367Z. (102) North Atlantic Deep Water **−62±8 −1.1 −107±8**

Coll. September 9, 1956; 26° 10′ N Lat, 18° 06′ W Long; 3503 m depth.

L-334S. (103) North Atlantic Deep Water −56±7 −0.8 −102±7

Coll. April 16, 1956; 25° 01′ N Lat, 59° 11′ W Long; 2560 m depth.

L-282R. (104) North Atlantic Deep Water **−50±7 (−3.7) (−90±9)**

Coll. June 22, 1955; 24° 26′ N Lat, 70° 23′ W Long; 2787 m depth.

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	δC^{14}	δC^{13}	Δ
L-464G. (105) North Atlantic Deep Water Coll. November 21, 1957; 22° 03′ N Lat, 51° 27′ W Long; 2700 m depth.	**−53±6**	**−7.0**	**−87±6**
L-464I. (106) North Atlantic Deep Water Coll. November 22, 1957; 20° 43′ N Lat, 49° 26′ W Long; 2926 m depth.	**−62±6**	**−3.0**	**−103±6**
L-464L. (107) North Atlantic Deep Water Coll. November 25, 1957; 16° 44′ N Lat, 42° 38′ W Long; 3840 m depth.	**−69±7**	**−5.6**	**−105±7**
L-410A. (108) North Atlantic Deep Water Coll. December 31, 1956; 15° 52′ N Lat, 38° 03′ W Long; 3840 m depth.	**−53±5**	**−11.3**	**−79±5**
L-334N. (109) North Atlantic Deep Water Coll. April 11, 1956; 15° 49′ N Lat, 47° 12′ W Long; 2560 m depth.	**−74±7**	**1.4**	**−123±7**
L-334F. (110) North Atlantic Deep Water Coll. February 18, 1955; 03° 48′ S Lat, 30° 53′ W Long; 2560 m depth.	**−49±6**	**−2.7**	**−91±6**
L-419E. (111) North Atlantic Deep Water Coll. May 27, 1957; 04° 23′ S Lat, 00° 15′ W Long; 2743 m depth.	**−62±7**	**−3.0**	**−103±7**
L-410J. (112) North Atlantic Deep Water Coll. January 22, 1957; 17° 03′ S Lat, 28° 13′ W Long; 2807 m depth.	**−71±6**	**−10.0**	**−99±6**
L-410FF. (113) North Atlantic Deep Water Coll. May 8, 1957; 22° 56′ S Lat, 04° 52′ E Long; 2560 m depth.	**−63±7**	**−5.5**	**−98±7**
L-465H. (114) North Atlantic Deep Water Coll. January 18, 1958; 38° 25′ S Lat, 53° 11′ W Long; 2770 m depth.	**−57±6**	**−4.0**	**−96±6**

6) Subsurface samples greater than 4000 m

	δC^{14}	δC^{13}	Δ
L-287A. (115) North Atlantic Deep Water Coll. July 16, 1955; 39° 27′ N Lat, 56° 57′ W Long; 4345 m depth.	**−43±7**	**(−3.7)**	**(−84±9)**
L-287C. (116) North Atlantic Deep Water Coll. July 18, 1955; 39° 03′ N Lat, 53° 29′ W Long; 5281 m depth.	**−58±7**	**(−3.7)**	**(−98±9)**

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δC^{14} δC^{13} Δ

L-287H. (117) North Atlantic Deep Water
−40±13 (−3.7) (−81±13)

Coll. July 19, 1955; 38° 00′ N Lat, 51° 37′ W Long; 5369 m depth.

L-287L. (118) North Atlantic Deep Water
−73±13 (−3.7) (−112±13)

Coll. July 23, 1955; 37° 23′ N Lat, 53° 22′ W Long; 5368 m depth.

L-287M. (119) North Atlantic Deep Water
−53±7 (−3.7) (−93±9)

Coll. July 26, 1955; 35° 28′ N Lat, 55° 48′ W Long; 5416 m depth.

L-287K. (120) North Atlantic Deep Water
−58±5 (−3.7) (−98±9)

Coll. July 22, 1955; 35° 43′ N Lat, 53° 15′ W Long; 5454 m depth.

L-287I. (121) North Atlantic Deep Water
−76±13 (−3.7) (−115±13)

Coll. July 21, 1955; 34° 46′ N Lat, 52° 46′ W Long; 5481 m depth.

L-282Y. (122) North Atlantic Deep Water
−60±13 (−3.7) (−100±13)

Coll. June 27, 1955; 31° 47′ N Lat, 71° 13′ W Long; 5360 m depth.

L-282Z. (123) North Atlantic Deep Water
−56±7 (−3.7) (−96±9)

Coll. June 29, 1955; 31° 21′ N Lat, 66° 39′ W Long; 4893 m depth.

L-282X. (124) North Atlantic Deep Water
−52±9 (−3.7) (−92±10)

Coll. June 27, 1955; 31° 17′ N Lat, 71° 03′ W Long; 5367 m depth.

L-282W. (125) North Atlantic Deep Water
−33±13 (−3.7) (−74±13)

Coll. June 26, 1955; 29° 14′ N Lat, 69° 55′ W Long; 5400 m depth.

L-282L. (127) North Atlantic Deep Water
−53±20 (−3.7) (−93±20)

Coll. June 15, 1955; 25° 07′ N Lat, 69° 57′ W Long; 5508 m depth.

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		δC^{14}	δC^{13}	Δ
L-334T. (128)	**North Atlantic Deep Water**	**−88±6**	**−9.0**	**−117±6**

Coll. April 16, 1956; 25° 01′ N Lat, 59° 12′ W Long; 6035 m depth.

L-367DD. (129)	**North Atlantic Deep Water**	**−82±5**	**−0.2**	**−128±5**

Coll. October 11, 1956; 24° 23′ N Lat, 24° 03′ W Long; 4921 m depth.

L-282P. (130)	**North Atlantic Deep Water**	**−58±8**	**(−3.7)**	**(−98±8)**

Coll. June 20, 1955; 24° 05′ N Lat, 68° 23′ W Long; 5584 m depth.

L-282N. (131)	**North Atlantic Deep Water**	**−55±13**	**(−3.7)**	**(−95±13)**

Coll. June 17, 1955; 23° 28′ N Lat, 65° 56′ W Long; 5788 m depth.

L-334P. (132)	**North Atlantic Deep Water**	**−87±6**	**−8.3**	**−118±6**

Coll. April 14, 1956; 22° 22′ N Lat, 54° 19′ W Long; 5698 m depth.

L-410B. (133)	**North Atlantic Deep Water**	**−65±7**	**0.6**	**−113±7**

Coll. December 31, 1956; 15° 52′ N Lat, 38° 08′ W Long; 5264 m depth.

L-464N. (134)	**North Atlantic Deep Water**	**−83±9**	**−5.7**	**−118±9**

Coll. November 26, 1957; 15° 29′ N Lat, 40° 30′ W Long; 4147 m depth.

L-334D. (135)	**Antarctic Bottom Water**	**−99±7**	**−1.1**	**−142±7**

Coll. February 16, 1956; 03° 26′ S Lat, 31° 34′ W Long; 4389 m depth.

L-410H. (136)	**Antarctic Bottom Water**	**−105±6**	**−4.2**	**−142±6**

Coll. January 22, 1957; 16° 34′ S Lat, 28° 03′ W Long; 5330 m depth.

L-410N. (137)	**Antarctic Bottom Water**	**−88±5**	**−5.0**	**−124±5**

Coll. February 1, 1957; 33° 43′ S Lat, 45° 18′ W Long; 4380 m depth.

B. CO_2 obtained from acidified samples of sea water from Pacific Ocean. Samples in this group coll. by Univ. of Washington research vessel *Brown Bear*, under the direction of S. El Wardani.

L-470A.	**North Pacific Basin**	**−180±7**	**0.3**	**−222±7**

Coll. August 15, 1957; 50° 55′ N Lat, 177° 23′ E Long; 5200 m depth.

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	δC^{14}	δC^{13}	Δ
L-470B. Aluetian Trench	**–158±8**	**–0.9**	**–199±8**

Coll. August 17, 1957; 51° 08′ N Lat, 174° 41′ E Long; 6200 m depth.

L-470C. North Pacific Surface Water	**–34±5**	**0.6**	**–83±5**

Coll. August 14, 1957; 50° 42′ N Lat, 177° 17′ E Long; 1 m depth.

L-470D. North Pacific Surface Water	**89±6**	**0.9**	**33±6**

Coll. August 30, 1957; 53° 10′ N Lat, 162° 22′ W Long; 1 m depth.

C. CO_2 obtained from acidified samples of sea water from deep basins of the Caribbean Sea. Samples in this group coll. by the scientific staff of Columbia University research vessel *Vema* under the direction of M. Ewing, R. Gerard, and B. Heezen. These results are discussed in a paper by Broecker, Gerard, Heezen, and Ewing (in press). The numbers in parentheses beside each laboratory number are the index numbers used by Broecker and others in that paper.

L-529J. (138) Columbia Basin	**–53±5**	**–0.6**	**–99±5**

Coll. November 7, 1958; 14° 05′ N Lat, 75° 25′ W Long; 2316 m depth.

L-419P. (139) Columbia Basin	**–49±7**	**–5.6**	**–86±7**

Coll. July 29, 1957; 17° 00′ N Lat, 74° 24′ W Long; 2341 m depth.

L-529K. (140) Columbia Basin	**–43±13**	**–0.8**	**–89±13**

Coll. November 7, 1958; 14° 05′ N Lat, 75° 25′ W Long; 3262 m depth.

L-529L. (141) Columbia Basin	**–49±7**	**0.5**	**–98±7**

Coll. November 7, 1958; 14° 05′ N Lat, 75° 25′ W Long; 3790 m depth.

L-326W. (142) Columbia Basin	**–55±7**	**–1.0**	**–100±7**

Coll. January 1, 1956; 17° 31′ N Lat, 73° 22′ W Long; 4265 m depth.

L-529H. (143) Cayman Trough	**–32±5**	**–0.5**	**–79±5**

Coll. November 5, 1958; 19° 31′ N Lat, 74° 59′ W Long; 1647 m depth.

L-529G. (144) Cayman Trough	**–26±5**	**–0.5**	**–74±5**

Coll. November 5, 1958; 19° 31′ N Lat, 74° 59′ W Long; 1893 m depth.

L-326S. (145) Cayman Trough	**–24±5**	**2.7**	**–78±5**

Coll. December 23, 1955; 19° 15′ N Lat, 79° 30′ W Long; 2560 m depth.

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	δC^{14}	δC^{13}	Δ
L-326T. (146) Cayman Trough	**–43±7**	**–3.7**	**–84±7**

Coll. December 24, 1955; 19° 10′ N Lat, 78° 00′ W Long; 4755 m depth.

L-419Q. (147) Cayman Trough	**–28±7**	**–5.9**	**–65±7**

Coll. July 30, 1957; 19° 33′ N Lat, 75° 02′ W Long; 4844 m depth.

L-419K. (148) Granada Basin	**–55±7**	**–11.3**	**–81±7**

Coll. July 11, 1957; 12° 45′ N Lat, 63° 06′ W Long; 2468 m depth.

L-419L. (149) Cariaco Trench	**–23±7**	**–16.6**	**–39±7**

Coll. July 13, 1957; 10° 36′ N Lat, 65° 04′ W Long; 550 m depth.

L-419M. (150) Cariaco Trench	**3±7**	**–7.7**	**–32±7**

Coll. July 14, 1957; 10° 39′ N Lat, 65° 43′ W Long; 1152 m depth.

D. Organisms deriving their organic and inorganic carbon from the dissolved CO_2 in sea water.

L-444. (38) Benguela Current	**–64±15**	**–17.7**	**–78±15**

Organic material from plankton coll. at a depth of 73 m by the scientific staff of Columbia Univ. research vessel *Vema* on May 5, 1957 (22° 34′ S Lat, 14° 12′ E Long; subm. by R. Menzies, Univ. of Southern California.

L-570. McMurdo Sound, Antarctica	**–148±7**	**–24.7**	**–149±7**

Flesh from right rear flipper of freshly killed seal (77° S Lat, 165° E Long). Coll. by J. Mulligan, U.S.A.R.P., December 17, 1959; subm. by T. Pewe, U. S. Geol. Survey. Result is in the same range as the Δ values obtained by Rafter and Fergusson (1958) for the dissolved CO_2 in surface waters adjacent to the Antarctic. The low C^{14} concentration in these waters results in an apparent radiocarbon age of 1300 yr for the marine organisms living in this area.

L-112D. Adak, Aleutian Islands	**–79±9**	**1.3**	**–127±9**

Clam shells bearing dried meat from a lagoon (51° 40′ N Lat, 176° 30′ W Long). Coll. July 1950 by H. Powers, U. S. Geol. Survey. Whether the low value results from freshwater drainage into the lagoon, the upwelling of deep

	δC^{14}	δC^{13}	Δ
water, or a non-zero age for the shells is not known.			
L-584A. Eniwetok Atoll Living coral from a reef off Bogan Island (11° 30′ N Lat, 162° 10′ E Long). Coll. 1946 by J. Tracey, U. S. Geol. Survey.	**–30±5**	**–2.4**	**–74±5**
L-595. Vancouver Island, B. C. Living barnacles (49° N Lat, 124° W Long). Coll. 1959; subm. by J. Fyles, Geol. Survey of Canada.	**–5±5**	**–0.3**	**–54±5**
L-599A. Bay of Arcachon, France Pelecypods (*Cardium edule* L.) from Atlantic Ocean along the coast of Southwestern France (44° 35′ N Lat, 01° 25′ W Long). Coll. 1952; subm. by W. Zagwijn, Geol. Survey of the Netherlands.	**–8±5**	**(0.3)**	**(–58±5)**
L-599B. Wijk aan Zee, Netherlands Pelecypods (*Cardium edule* L.) from the North Sea coast (52° 30′ N Lat, 04° 25′ E Long). Coll. May, 1960 by W. Zagwijn.	**–9±7**	**(0.3)**	**(–59±7)**
L-576A. Jamaica, B.W.I. Gastropods (*Liiona pica* L) coll. 1929 or 1930 (18° N Lat, 78° W Long); subm. by H. Rehder, National Museum, Washington, D. C.	**5±5**	**1.3**	**–48±5**
L-576F. Jamaica, B.W.I. Gastropods (*Liiona pica* L) coll. 1884 (18° N Lat, 78° W Long); subm. by H. Rehder.	**10±5**	**1.3**	**–43±5**
L-576B. Bahama Islands Gastropods (*Strombus raninus*) coll. 1950 (26° N Lat, 78° W Long); subm. by N. Newell, American Museum of Natural History.	**2±5**	**1.4**	**–51±5**
L-576G. Bahama Islands Gastropods (*Strombus raninus*) coll. during the 1880s (26° N Lat, 78° W Long); subm. by H. Rehder.	**–2±7**	**1.6**	**–55±7**
L-593C. Bahama Islands Pelecypods (*Codakia orbicularis*) coll. June 1958 at Bimini Cay (25° 45′ N Lat, 79° 15′ W Long); subm. by J. Imbrie and A. McIntyre, Columbia Univ.	**27±7**	**(0.3)**	**(–25±7)**

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	δC^{14}	δC^{13}	Δ
L-576C. Kollafjord, Iceland	**−8±6**	**(3.4)**	**(−64±6)**

Gastropods (*Nucella lapillus* L) coll. 1946 from Faxa Bay (22° N Lat, 64° W Long); subm. by H. Einarsson, Univ. Research Institute, Reykjavik, Iceland.

L-576H. Kollafjord, Iceland	**−13±6**	**3.4**	**−69±6**

Gastropods (*Nucella lapillus* L) coll. 1900 from Faxa Bay (22° N Lat, 64° W Long); subm. by G. Thorson, Univ. of Copenhagen.

L-576I. Kollafjord, Iceland	**−16±6**	**3.4**	**−72±6**

Gastropods (*Nucella lapillus* L) coll. 1840 from Faxa Bay (22° N Lat, 64° W Long); subm. by G. Thorson.

L-576J. Oahu, Hawaii	**−8±6**	**2.2**	**−62±6**

Gastropods (*Trechus intertextus*) coll. 1840 or 1841 (22° N Lat, 158° W Long); subm. by H. Rehder.

L-576D. Pearl Harbor, Hawaii	**−380±12**	**2.9**	**−415±12**

Gastropods (*Trechus intertextus*) coll. 1936 (22° N Lat, 158° W Long); subm. by H. Rehder.

L-576E. Tahiti	**−5±5**	**3.7**	**−62±5**

Gastropods (*Turbo setosus*) coll. 1957 (18° S Lat, 149° W Long); subm. by H. Rehder.

L-576K. Moorea	**2±5**	**4.7**	**−58±5**

Gastropods (*Turbo setosus*) coll. early 1880s (18° S Lat, 149° W Long); subm. by H. Rehder.

III. SAMPLES UTILIZING CO_2 FROM TERRESTRIAL WATERS

A. Lake Samples

L-487J. Mono Lake, California	**−105±15**	**4.0**	**−157±15**

Dissolved CO_2 coll. by passing lake waters through an anion exchange column (37° 59′ N Lat, 119° 08′ W Long). Coll. August 23, 1958 by O. Schaeffer, Brookhaven National Laboratory.

L-415GGG. Great Salt Lake, Utah	**−93±6**	**2.1**	**−142±6**

Dissolved CO_2 coll. by acidifying lake water and bubbling with N_2. Coll. (40° 50′ N Lat, 112° 35′ W Long) June 1958 by R. Cohenour, Salt Lake City, Utah (Broecker and Olson, 1960).

	δC^{14}	δC^{13}	Δ
L-542. Great Salt Lake, Utah	−39±9	−16.7	−55±9

Brine shrimp (40° 50′ N Lat, 112° 35′ W Long); coll. August 1959 by C. Sanders, Ogden, Utah (Broecker and Olson, 1960).

B. River Samples

L-487F. San Francisco Flycasting Club	−8±6	−4.8	−48±6

Pelecypods (*Margaritifera margaritifera falcata* (Gould)) living on a sandy shoal in Truckee River ca. 5 mi E of Truckee, California (39° 23′ N Lat, 120° 07′ W Long). Coll. August 25, 1958 by W. Broecker and O. Schaeffer (Broecker and Olson, 1960).

L-487G. San Francisco Flycasting Club	−22±6	−22.0	−28±6

Meat from the above shells (L-487F) (Broecker and Olson, 1960).

L-487H. San Francisco Flycasting Club	−1±7	−10.2	−31±7

Dissolved CO_2 coll. by passing river water through an anion exchange column. From same locality as L-487F. Coll. August 25, 1958 (Broecker and Olson, 1960).

L-415S. Ogden, Utah	−146±6	−33.9	−131±6

Plants growing within waters of Weber River near Rt. 91 bridge (41° 10′ N Lat, 111° 50′ W Long). Coll. September 1957 by A. Walton and W. Broecker (Broecker and Olson, 1960).

L-487O. Ogden, Utah	−116±9	−25.4	−115±9

Plants growing within waters of Weber River near Rt. 91 bridge (41° 10′ N Lat, 111° 50′ W Long). Coll. September 10, 1958 by W. Broecker (Broecker and Olson, 1960).

C. Ground Water Samples

L-500C. Onandaga Cave, Missouri	−90±15	−9.0	−119±15

Dripstone carbonate ca. 3 mm thick, removed from broken rock used to define a pathway through the cave (38° 02′ N Lat, 97° 15′ W Long). Coll. November 8, 1958 by W. Broecker and E. Olson.

L-451C. Crystal Palace Cave, California	−63±8	−8.9	−93±8

Dripstone carbonate, coating and replacing a piece of lumber brought into the cave by miners

	δC^{14}	δC^{13}	Δ
ca. 1880. The recency of the wood was confirmed by a radiocarbon analysis ($\Delta = -5 \pm 10$.) Subm. by R. de Saussure, Berkeley, California.			

D. Hot Springs Sample

L-487P. Bridgeport, California	—	**−0.8**	—

Carbonate forming a one-quarter-inch coating on a wooden bathtub fed by a hot spring (38° 08′ N Lat, 119° 10′ W Long). Despite exposure to the atmosphere, sample contained only 2.0 ± 0.8% of the activity of the oxalic-acid standard. Coll. September 1958 by P. Orr and W. Broecker.

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