

LA JOLLA MEASUREMENTS OF RADIOCARBON IN THE OCEANS

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INTRODUCTION

The La Jolla Radiocarbon Laboratory has measured carbon-14 concentrations in seawater samples collected from 1957 through 1972. The dissolved inorganic carbon in seawater was extracted on board research vessels and was returned to the laboratory for processing and measurement. Both surface and sub-surface samples were collected, primarily from the Pacific Ocean, but also from the Indian Ocean. The purpose of the seawater measurements was to determine the distribution of bomb-produced radiocarbon in the surface water of the Pacific and Indian Oceans, the sub-surface penetration of bomb ^{14}C , the change in $^{14}\text{C}/^{12}\text{C}$ ratios with depth, and thus the rate of uptake of bomb ^{14}C by the oceans. This project was the basis of the author's doctoral dissertation (Linick, 1975).

The carbon dioxide of the atmosphere is constantly in exchange with the dissolved inorganic carbon of the sea, the oceans containing ca 60 times the amount of carbon dioxide found in the atmosphere (Revelle and Suess, 1957; Craig, 1958). This dissolved inorganic carbon is primarily in the form of bicarbonate because of the equilibrium constants of the aqueous carbon system. Prior to this century, both the quantities of dissolved inorganic carbon and the concentrations of carbon-14 were under approximately steady state conditions, as the atmospheric CO_2 concentration and the natural production rate of ^{14}C were approximately constant. Secular variations in the ^{14}C production rate and perhaps also changing oceanographic conditions have caused variations of up to 10% in the atmospheric ^{14}C levels during the past 7000 years (Suess, 1970). Since the beginning of this century, man has added sufficient ^{14}C -free carbon dioxide from the combustion of fossil fuels to increase measurably the concentration of carbon dioxide in the atmosphere and to decrease the atmospheric $^{14}\text{C}/^{12}\text{C}$ ratio; these quantities have also changed somewhat in surface seawater. Since 1954, the detonations of nuclear weapons, particularly the tests of the USA and USSR in 1961 and 1962, have released large quantities of additional radiocarbon into the atmosphere. The measurements of seawater samples monitored the transfer of this bomb-produced radiocarbon from the atmosphere into the oceans. In addition to the La Jolla measurements, seawater ^{14}C programs have been carried out by the New Zealand laboratory of T A Rafter, which measured samples from the South Pacific (Rafter, 1968; Rafter and O'Brien, 1970; Rafter and O'Brien, 1972), the Lamont laboratory of W S Broecker, which measured samples from the Atlantic

Ocean (Broecker and Olson, 1959; Broecker *et al*, 1960), and by several laboratories in Europe.

The sampling for this laboratory was performed primarily from research vessels of the Scripps Institute of Oceanography (SIO). Generally, 200 to 225L of seawater were obtained for each sample, almost filling a polyethylene-lined steel drum. Surface water was usually collected through a non-contaminating seawater pumping system aboard the ships; in such cases the water samples came from a few meters below the sea surface at the ship's bow. Several different systems involving metal barrels with remote closing devices were used for collection of sub-surface samples. Collection of sub-surface samples (depth profiles) had to be terminated after 1965, because continuation of funding of sub-surface water collection was denied by the U S Atomic Energy Commission. The carbon dioxide was extracted aboard the ship: The seawater was acidified with sulfuric acid and heated to ca 50°C. The CO₂ was absorbed in ca 0.70L of a solution ca 15 F in NH₄OH and 1 F in SrCl₂. The extraction system used for the last several years of sample collection involved recirculating for at least four hours the small amount of air above the seawater through a diffuser head immersed in the sealed bottle containing the absorber solution and returning the air (with seawater carbonate removed) to the drum via a diffuser head immersed deep into the water in the drum; a Masterflex peristaltic pump was used for this gas recirculation. The inorganic carbon originally dissolved in the seawater and then in the form of CO₂ gas was swept from the drum by the air and dissolved in the absorber solution. The absorber bottle containing the SrCO₃ precipitate plus absorber solution was sealed and eventually returned to the laboratory for processing. In the laboratory, the solution was decanted and the precipitate dried under vacuum. The SrCO₃ was then reacted with 2 F HCl on the high vacuum lines; the resulting CO₂ was converted to acetylene, our counting gas, in the usual manner. The method, detectors, and electronics used are those described by Linick (1977). Counting pressures from 400 to 1000mm Hg were utilized.

The ocean-atmosphere carbon system is quite complex. The atmospheric CO₂ exchanges at the ocean surface with that dissolved in the seawater. Once in the surface water, or so-called mixed layer, of the ocean, the distribution of dissolved CO₂ is dependent on several factors: (1) the horizontal movement of water currents; (2) the vertical movement of water, *ie*, upwelling and downwelling; (3) the stratification of water masses (eg, the barrier to exchange formed by the thermocline at the bottom of the mixed layer; (4) horizontal and vertical diffusion; and (5) particulate flux, *ie*, the incorporation of "new" CO₂ by near-surface organisms, transfer via the food chain, and eventual descent (and possible dissolution en route) of dead matter to the sea floor.

The data presented here constitute all of the seawater sample measurements by this laboratory from 1957 through 1976. The radio-carbon results are given as Δ values relative to 95% of NBS oxalic acid

activity, age-corrected to 1950 and isotopically-corrected to $\delta^{13}\text{C} = -25\text{‰}$ (PDB). Some values have been published previously, in particular, those listed in Tables 1 through 14 (Bien *et al.*, 1960, 1963a, 1963b, 1965; Bien and Suess, 1967). The author has re-evaluated the counting data for the years 1957 to 1969 and revised background and standard values. In a very few cases, counting data for certain samples were found to be invalid due to electronics or detector malfunctions. Such data, which had been included in previously-published tables have been omitted; in a few other cases, previously-unpublished results from 1957 to 1969 have been added here.

The measurements were carried out with an accuracy considered adequate for our purpose. A higher precision could have been achieved by using larger water samples and/or longer counting times. This, however, appeared uneconomical, time consuming, and unnecessary for the purpose of deducing basic oceanographic parameters. Likewise, measurements of the total content of inorganic carbon were considered superfluous.

As can be recognized easily, the data show an impressive minimum along the equator and in other regions of the Pacific Ocean where upwelling occurs. Consistently high Δ values are observed in the central areas of the large Pacific gyres. Evaluation of these data in terms of rates of ^{14}C -exchange, circulation, and upwelling is planned and will be published elsewhere. In this connection, continuation of these measurements for many more years appears desirable. With no further release of large ^{14}C quantities into the atmosphere the concentration differences in surface water should gradually disappear. Because of lack of funds we were not in a position to continue this program but fortunately Geosecs plans to continue these observations.

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PRESENTATION OF DATA

The measurements are given in several data tables. Each table gives results for one cruise, or sometimes for more than one cruise if only a few samples were collected on each cruise from the same approximate period of time. The tables are chronologically ordered, from earliest sampling to most recent. The tables which follow contain several columns of information that can be used in the interpretation of the radiocarbon data. An asterisk in place of a value indicates that the quantity was not measured or was otherwise unavailable. When $\delta^{13}\text{C}$ was not measured, a value of 0.0‰ was used in tables 1 through 15, a value of +1.2‰ in tables 16 through 26. Some column headings are described below:

Depth = sampling depth in meters below sea surface. Sample designated as being from Om may actually be from a few meters below the sea surface.

Salinity = as measured on a conductance bridge salinometer

σ_t = difference, ‰, between density of water of given temperature and salinity at 1 atm pressure and density of pure water at 4°C and 1 atm pressure. This is the accepted method of expressing the density of seawater. Values were calculated by the author from Knudsen (1953) and Matthews (1932) or from U S Navy Hydrographic Office (1956), which present tables of value for calculating σ_t for a given temperature and salinity.

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TABLE 1
Seawater samples collected by *Sayed el Wardami*

Lj no.	Sample Sta No.	Colln date (1957)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-441	1	8 Aug	50 13N	177 42W	0	*	*	*	*	-72 ± 13
-442	2	8 Aug	50 13N	177 42W	6000	*	*	*	*	-170 ± 12
-443	3	13 Aug	50 42N	177 17W	0	*	*	*	*	-81 ± 13
-444	7	13 Aug	51 08N	174 41E	6200	*	*	*	*	-76 ± 13
-445	8	19 Aug	52 40N	178 05E	3500	*	*	*	*	-221 ± 12
-447	10	14 Sept	52 00N	150 46E	5200	*	*	*	*	-196 ± 12

TABLE 2
Seawater samples from *Downwind Expedition*

Lj no.	Sample Sta No.	Colln date (1957)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-58	2	26 Oct	19 35N	125 00W	0	24.4	34.69	23.33	-0.5	-26 ± 21
-59	3	28 Oct	14 58N	127 31W	2987	1.66	34.69	27.76	-1.2	-191 ± 8
-60	4	30 Oct	11 00N	128 30W	350	10.9	34.65	26.55	-1.5	-74 ± 14
-61	5	31 Oct	07 08N	129 16W	3508	1.48	34.69	27.78	-1.4	-210 ± 6
-62	6	2 Nov	05 00N	130 00W	0	28.0	34.40	21.97	-0.1	-6 ± 8
-63	7	4 Nov	02 08S	131 27W	3473	1.52	34.69	27.77	-1.3	-195 ± 8
-66	8	5 Nov	07 00S	132 00W	0	26.7	34.68	22.60	-1.0	-38 ± 19
-67	9	8 Nov	14 29S	135 30W	3450	1.58	34.69	27.78	-1.8	-190 ± 6
-68	10	23 Nov	25 00S	145 00W	3569	1.54	34.65	27.74	-2.9	-167 ± 15
-69	11	28 Nov	34 50S	135 53W	0	17.7	35.05	25.41	-0.4	+6 ± 10
-88	12	1 Dec	40 35S	132 10W	3500	1.50	34.67	27.77	-1.2	-162 ± 7
-90	13	6 Dec	46 46S	123 53W	3550	*	*	*	-2.0	-168 ± 6
-91	14	8 Dec	46 30S	116 00W	0	9.2	34.67	26.85	-0.7	-21 ± 5
-93	15	14 Dec	40 37S	103 20W	3500	1.85	34.67	27.75	-2.5	-150 ± 7
-94	16	15 Dec	42 43S	096 05W	0	11.5	34.01	25.94	-0.6	-12 ± 7
	17	19 Dec	39 33S	084 10W	3508	1.46	34.68	27.78	-1.9	-159 ± 6

TABLE 3
Seawater samples from *Dorado* Expedition, *Horizon* Cruise 5910H (Reid), and SIO Pier

LJ no.	Cruise	Sample/Sta No.	Colln date (1959)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-146	Dorado	1	27 July	05 32N	120 05W	10	27.5	33.50	21.38	-1.2	-75 ± 8
-140	Dorado	2	27 July	05 32N	120 05W	487	7.88	34.67	27.05	-2.5	-144 ± 6
-147	Dorado	3	28 July	05 32N	120 05W	1077	4.12	34.63	27.50	-1.8	-192 ± 11
-139	Dorado	4	30 July	08 50N	120 09W	2280	1.97	34.70	27.76	-1.7	-244 ± 5
-137	Dorado	5	30 July	08 50N	120 09W	3376	1.58	34.70	27.79	-0.7	-204 ± 6
-149	Reid	1	14 Oct	30 27N	117 48W	10	19.30	33.48	23.80	+1.9	-9 ± 5
-150	Reid	2	14 Oct	30 27N	117 48W	75	15.85	33.44	24.60	+1.0	-38 ± 6
-151	Reid	3	14 Oct	30 27N	117 48W	120	13.40	33.48	25.15	+0.2	-42 ± 8
-152	Reid	4	14 Oct	30 27N	117 48W	390	6.60	33.16	26.04	-1.9	-98 ± 11
-153	Reid	5	14 Oct	30 27N	117 48W	580	5.68	34.34	27.10	-6.0	-166 ± 8
-154	Reid	6	14 Oct	30 27N	117 48W	1970	2.04	34.66	27.73	-1.6	-215 ± 5
-155	Reid	7	14 Oct	30 27N	117 48W	2480	1.80	34.67	27.75	+0.3	-227 ± 5
-127	SIO Pier	1	6 Aug	32 52N	117 44W	0	22.6	*	*	-2.3	-90 ± 10
-534	SIO Pier	2	31 Aug	32 52N	117 44W	0	*	*	*	*	-17 ± 15

TABLE 4
Seawater samples from *Limbo* and *Tethys* Expeditions

LJ no.	Cruise	Sample/Sta No.	Colln date (1960)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-285	Limbo	1	15 June	58 12N	139 07W	5	*	34.051	*	*	-155 ± 11
-582	Limbo	2	13 June	28 12N	139 07W	1607	*	34.57	*	-1.2	-246 ± 14
-283	Limbo	3	13 June	28 12N	139 07W	2463	*	34.65	*	-1.1	-234 ± 6
-281	Limbo	4	14 June	28 12N	139 07W	3519	*	34.68	*	-1.2	-228 ± 5
-328	Tethys	1	21 July	15 42N	155 22W	0	*	*	*	+1.8	-18 ± 12
-404	Tethys	2	26 July	07 03N	158 38W	0	*	*	*	*	-45 ± 13
-405	Tethys	3	29 July	08 14N	156 38W	0	*	*	*	*	-26 ± 13

TABLE 5
Seawater samples from *Monsoon Expedition*

LJ no.	Sample/Sta No.	Colln date (1960-1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-484	I-11	(1960) 19 Oct	10 31S	105 34E	0	28.4	34.41	22.18	*	-38 ± 13
-396	III-4	12 Nov	10 28S	099 00E	100	*	34.336	*	*	+15 ± 10
-398	III-4	12 Nov	10 28S	099 00E	343	10.44	34.675	26.63	*	-90 ± 20
-395	III-4	12 Nov	10 28S	099 00E	960	4.94	34.624	27.40	*	-87 ± 10
-393	III-4	12 Nov	10 28S	099 00E	3000	2.68	34.672	27.67	*	-108 ± 10
-394	III-4	12 Nov	10 28S	099 00E	3424	1.33	34.695	27.79	*	-102 ± 10
-498	I-1-6	24 Nov	10 31S	094 55E	350	10.27	34.631	26.63	*	-122 ± 12
-483	III-10	27 Nov	18 49S	088 33E	0	25.53	34.571	22.89	*	-24 ± 13
-496	III-12	29 Nov	13 00S	075 00E	356	14.05	35.410	26.52	*	-46 ± 8
-499	III-16	2 Dec	14 05S	072 15E	350	10.30	34.880	26.83	*	-62 ± 8
-487	III-20	5 Dec	17 15S	063 50E	0	*	*	*	*	+48 ± 11
-497	III-20	5 Dec	17 15S	063 50E	350	*	*	*	*	-66 ± 13
-490	IV-3	13 Dec	23 00S	064 10E	0	*	*	*	*	-25 ± 13
-351	IV-5	15 Dec	23 55S	073 53E	100	23.86	35.472	24.06	*	-16 ± 8
-406	IV-5	15 Dec	23 55S	073 53E	1016	*	*	*	*	-29 ± 10
-350	IV-5	15 Dec	23 55S	073 53E	1956	4.69	34.418	27.26	*	-99 ± 8
-349	IV-5	15 Dec	23 55S	073 53E	3339	2.54	34.818	27.80	*	-161 ± 8
-343	IV-5	15 Dec	23 55S	073 53E	0	1.41	34.803	27.88	*	-184 ± 8
-342	IV-9	18 Dec	33 21S	072 42E	0	18.32	35.50	25.59	+0.6	-52 ± 14
-405	IV-9	18 Dec	33 21S	072 42E	100	*	*	*	*	-47 ± 10
-339	IV-9	18 Dec	33 21S	072 42E	1000	5.44	34.406	27.16	-0.4	-110 ± 10
-392	IV-9	18 Dec	33 21S	072 42E	3050	1.62	*	*	0.0	-193 ± 10
-340	IV-9	18 Dec	33 21S	072 42E	3987	1.15	34.703	27.82	-0.6	-204 ± 10
-404	IV-11	21 Dec	42 08S	070 45E	0	10.88	34.430	26.37	*	-52 ± 7
-403	IV-11	21 Dec	42 03S	070 45E	100	*	*	*	*	-68 ± 10
-401	IV-11	21 Dec	42 03S	070 45E	1000	3.35	34.396	27.39	*	-134 ± 10
-402	IV-11	21 Dec	42 03S	070 45E	3000	1.55	34.742	27.82	*	-171 ± 10

-374	IV-11	21 Dec	42 08S	070 45E	3400	1.25	34.689	27.79	*	-166 ± 10
-488	IV-16	25 Dec	37 51S	084 45E	0	*	*	*	*	+15 ± 10
-359	IV-19	29 Dec	36 18S	098 41E	0	15.40	35.151	26.01	*	-26 ± 14
-383	IV-19	29 Dec	36 18S	098 41E	100	*	*	*	*	-24 ± 9
-369	IV-19	29 Dec	36 18S	098 41E	1066	4.47	34.377	27.26	*	-96 ± 8
-355	IV-19	29 Dec	36 18S	098 41E	3469	1.17	34.718	27.82	*	-142 ± 8
-486	IV-20	(1961)	33 14S	108 45E	0	18.32	35.50	25.60	*	-5 ± 9
-489	V-4	12 Jan	49 29S	132 17E	0	9.3	34.339	26.58	*	-14 ± 11
-321	VI-11	7 Feb	58 20S	168 58E	0	6.32	34.038	26.77	+0.4	-57 ± 12
-320	VI-11	7 Feb	58 20S	168 58E	740	3.38	34.924	27.24	-0.5	-109 ± 7
-319	VI-11	7 Feb	58 20S	168 58E	1400	2.43	*	*	-1.3	-152 ± 7
-318	VI-11	7 Feb	58 20S	168 58E	2100	*	34.766	*	-2.0	-152 ± 17
-317	VI-11	7 Feb	58 20S	168 58E	2944	1.48	34.372	27.53	-1.1	-170 ± 9
-316	VI-11	7 Feb	58 20S	168 58E	3825	*	34.277	*	-1.4	-176 ± 6
-410	VI-17	13 Feb	64 11S	168 58W	0	1.70	34.009	27.23	*	-124 ± 6
-412	VI-20	15 Feb	60 12S	171 32W	0	5.50	34.002	26.85	*	-80 ± 7
-414	VI-23	16 Feb	57 34S	144 15W	0	*	*	*	*	-58 ± 10
-413	VI-24	17 Feb	55 39S	177 51W	0	*	*	*	*	-60 ± 7
-417	VI-26	19 Feb	52 37S	178 57W	0	*	*	*	*	-41 ± 7
-418	VI-28	20 Feb	49 42S	178 52W	0	9.3	34.34	26.58	*	-52 ± 10
-408	VII-9	3 Mar	40 22S	164 24W	0	*	*	*	*	-22 ± 6
-409	VII-14	5 Mar	36 27S	163 09W	0	*	*	*	*	-19 ± 6
-326	VII-16	7 Mar	34 04S	161 54W	0	21.4	35.103	24.50	*	-26 ± 16
-327	VII-16	7 Mar	34 04S	161 54W	3350	*	*	*	*	-218 ± 10
-415	VII-19	9 Mar	30 26S	160 32W	0	*	34.8	*	*	-3 ± 7
-325	VII-23	11 Mar	26 29S	160 33W	0	27.2	35.56	23.10	*	-37 ± 7
-324	VII-23	11 Mar	26 29S	160 33W	3500	*	*	*	*	-213 ± 10
-416	VII-25	12 Mar	24 41S	155 15W	0	*	34.88	*	*	-22 ± 6

TABLE 6
Seawater samples from *Swan Song* Expedition

LJ no.	Sample/Sta No.	Colln date (1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-420	2	20 Aug	27 27N	150 35W	10	25.04	35.283	23.56	*	-4 ± 30
-421	3	20 Aug	27 27N	150 35W	716	4.55	34.194	27.11	*	-172 ± 6
-425	5	20 Aug	27 27N	150 35W	1042	3.84	34.436	27.37	*	-206 ± 10
-426	6	20 Aug	27 27N	150 35W	2300	1.85	34.665	27.73	*	-240 ± 10
-427	7	20 Aug	27 27N	150 35W	3165	1.55	34.677	27.77	*	-231 ± 7
-428	8	20 Aug	27 27N	150 35W	3630	1.50	34.684	27.78	*	-229 ± 10

TABLE 7
Seawater samples from *Horizon* Cruise 6109G-H

LJ no.	Sample/Sta No.	Colln date (1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-429	1	21 Sept	44 55N	134 56W	0	16.70	32.756	23.89	*	+10 ± 6
-430	2	21 Sept	44 55N	134 56W	1200	3.00	34.306	27.36	*	-194 ± 6
-431	3	21 Sept	44 55N	134 56W	1700	2.08	34.567	27.64	*	-243 ± 10
-432	4	21 Sept	44 55N	134 56W	2188	1.80	34.615	27.70	*	-242 ± 10
-435	5	21 Sept	44 55N	134 56W	2600	1.65	34.645	27.73	*	-210 ± 6
-436	6	21 Sept	44 55N	134 56W	2996	1.58	34.625	27.73	*	-249 ± 10
-439	7	21 Sept	44 55N	134 56W	3400	1.56	34.635	27.73	*	-242 ± 10
-440	8	21 Sept	44 55N	134 56W	3630	1.55	34.679	27.76	*	-224 ± 6

TABLE 8
(A) Seawater samples from *Risepac* Expedition

LJ no.	Sample Sta No.	Colln date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-480	148	7 Jan	12 05S	142 32W	0	*	*	*	*	-15 ± 21
-478	148	7 Jan	12 05S	142 32W	800	*	34.49	*	*	-160 ± 10
-481	148	7 Jan	12 05S	142 32W	1250	3.51	34.51	27.47	*	-78 ± 13
-482	148	7 Jan	12 05S	142 32W	1724	2.50	34.56	27.60	*	-158 ± 9
-464	148	8 Jan	12 05S	142 32W	2266	1.93	34.60	27.67	*	-165 ± 10
-466	148	8 Jan	12 05S	142 32W	2763	1.76	34.61	27.71	*	-150 ± 10
-463	148	8 Jan	12 05S	142 32W	3277	1.62	34.64	27.73	*	-190 ± 10
-465	148	8 Jan	12 05S	142 32W	3772	1.42	34.65	27.75	*	-165 ± 20
-479	148	8 Jan	12 05S	142 32W	4190	1.35	34.63	27.75	*	-196 ± 11
-477	148	7 Jan	12 05S	142 32W	4600	1.36	34.63	27.75	*	-159 ± 8
-467	172	20 Jan	14 55N	133 52W	10	*	34.13	*	*	+35 ± 11
-468	172	20 Jan	14 55N	133 52W	753	6.08	34.51	27.18	*	-138 ± 21
-470	172	21 Jan	14 55N	133 52W	1039	4.38	34.56	27.41	*	-170 ± 10
-476	172	21 Jan	14 55N	133 52W	1240	3.72	34.59	27.51	*	-196 ± 10
-475	172	21 Jan	14 55N	133 52W	1711	2.68	34.61	27.63	*	-213 ± 10
-473	172	21 Jan	14 55N	133 52W	2384	1.89	34.67	27.74	*	-215 ± 10
-471	172	21 Jan	14 55N	133 52W	2757	1.73	34.70	27.78	*	-235 ± 10
-474	172	21 Jan	14 55N	133 52W	3479	1.53	34.67	27.76	*	-215 ± 10

(B) Seawater samples from *Argo* Cruise 6201A

-460	3	10 Jan	32 36N	118 11W	975	4.36	34.472	27.36	*	-195 ± 10
-461	5	12 Jan	31 52N	118 51W	969	4.18	34.499	27.39	*	-195 ± 10
-462	8	15 Jan	29 09N	117 40W	3621	1.63	34.682	27.77	*	-232 ± 10

TABLE 9
Seawater samples from *Lustad* Expedition

LJ no.	Sample/Sta No.	Colln date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-538	0-1	20 May	35 02N	140 08W	0	16.53	34.30	25.10	*	+40 ± 8
-541	0-3	24 May	35 01N	159 58W	0	18.06	34.49	24.88	*	+52 ± 9
-542	0-3	24 May	35 01N	159 58W	50	15.27	34.51	25.55	*	+27 ± 15
-543	0-3	24 May	35 01N	159 58W	100	14.84	34.48	25.62	*	+1 ± 15
-545	0-3	24 May	35 01N	159 58W	1000	3.46	34.30	27.30	*	-151 ± 15
-547	0-3	24 May	35 01N	159 58W	3500	1.96	34.59	27.66	*	-240 ± 14
-548	0-3	24 May	35 01N	159 58W	4500	1.54	34.68	27.76	*	-200 ± 8
-549	0-4	26 May	35 46N	170 14W	0	17.50	34.69	25.17	*	+37 ± 15
-550	0-5	28 May	35 05N	180 00	0	17.79	34.80	25.19	*	+42 ± 15
-551	0-5	28 May	35 05N	180 00	50	17.40	34.76	25.25	*	+40 ± 15
-552	0-5	28 May	35 05N	180 00	100	15.48	34.68	25.63	*	-34 ± 15
-553	0-5	28 May	35 05N	180 00	500	7.99	34.06	26.56	*	-58 ± 15
-554	0-5	28 May	35 05N	180 00	1000	3.58	34.28	27.27	*	-183 ± 14
-555	0-5	28 May	35 05N	180 00	2000	1.95	34.59	27.66	*	-210 ± 14
-557	0-6	31 May	35 00N	170 02E	0	*	*	*	*	+37 ± 16
-558	0-7	2 June	34 46N	160 20E	0	20.4	34.78	24.52	*	+7 ± 15
-559	0-8	4 June	30 16N	147 49E	0	*	*	*	*	+40 ± 15
-560	0-9	6 June	27 10N	140 00E	0	25.02	35.00	23.36	*	+45 ± 15
-661	98	6 Oct	08 16N	070 37E	0	28.46	36.36	23.29	*	-9 ± 23
-662	98	6 Oct	08 16N	070 37E	100	20.45	35.51	25.04	*	-62 ± 15
-663	98	6 Oct	08 16N	070 37E	200	13.37	35.20	26.49	*	+8 ± 23
-664	98	6 Oct	08 16N	070 37E	400	10.85	35.17	26.96	*	-112 ± 15
-665	98	6 Oct	08 16N	070 37E	600	9.54	35.12	27.14	*	-116 ± 15
-666	98	6 Oct	08 16N	070 37E	800	8.38	35.08	27.30	*	-119 ± 15
-667	98	6 Oct	08 16N	070 37E	1000	7.18	35.05	27.45	*	-133 ± 15
-668	98	6 Oct	08 16N	070 37E	1995	2.73	34.80	27.78	*	-172 ± 14
-669	98	6 Oct	08 16N	070 37E	3200	1.71	34.73	27.80	*	-178 ± 15
-670	98	6 Oct	08 16N	070 37E	3800	1.66	34.73	27.80	*	-214 ± 28
-671	101	10 Oct	05 21S	075 06E	0	27.94	34.52	22.08	*	-31 ± 23

-672	101	10 Oct	05 21S	075 06E	1000	5.78	34.78	27.43	*	-144 ± 11
-673	101	10 Oct	05 21S	075 06E	2970	1.78	34.74	27.81	*	-153 ± 11
-674	101	10 Oct	05 21S	075 06E	5000	1.38	34.72	27.82	*	-130 ± 11
-675	103A	14 Oct	05 54S	063 47E	0	27.94	34.52	22.08	*	-35 ± 36
-676	103A	14 Oct	05 54S	063 47E	400	5.85	34.78	27.43	*	-172 ± 11
-677	103A	14 Oct	05 54S	063 47E	2943	1.76	34.74	27.81	*	-172 ± 11
-678	103A	14 Oct	05 54S	063 47E	3920	1.60	34.72	27.80	*	-164 ± 11
-679	106A	21 Oct	09 54S	056 20E	0	26.32	35.065	23.01	*	0 ± 16
-680	106A	21 Oct	09 54S	056 20E	3480	*	*	*	*	-164 ± 11
-681	106B	24 Oct	13 41S	059 42E	0	*	*	*	*	+14 ± 11
-682	106C	25 Oct	17 19S	057 42E	0	*	*	*	*	+18 ± 17
-683	108A	31 Oct	22 00S	057 30E	0	*	*	*	*	+19 ± 11
-684	109	2 Nov	26 54S	058 11E	0	21.84	35.56	24.72	*	+3 ± 12
-685	109	2 Nov	26 54S	058 11E	5450	0.93	34.70	27.84	*	-150 ± 11
-686	110	4 Nov	30 30S	061 53E	0	18.66	35.584	25.57	*	-5 ± 11
-687	110	4 Nov	30 30S	061 53E	3400	1.37	34.720	27.82	*	-157 ± 10
-688	110	4 Nov	30 30S	061 53E	4400	0.58	34.688	27.84	*	-162 ± 10
-689	111	7 Nov	39 45S	064 00E	0	14.57	35.372	26.38	*	-6 ± 16
-690	111	7 Nov	39 45S	064 00E	4800	0.7	34.70	27.85	*	-125 ± 15
-691	112	10 Nov	51 07S	065 51E	0	1.63	33.903	27.15	*	-51 ± 15
-692	112A	10 Nov	51 07S	065 51E	0	1.63	33.903	27.15	*	-10 ± 15
-693	112	10 Nov	51 07S	065 51E	3185	0.74	34.71	27.85	*	-137 ± 15
-695	113A	20 Nov	37 56S	087 38E	0	14.2	35.2	26.33	*	-22 ± 15
-696	114	22 Nov	33 48S	096 01E	0	14.90	35.41	26.34	*	-32 ± 15
-697	114	22 Nov	33 48S	096 01E	4300	*	*	*	*	-107 ± 15
-698	116	25 Nov	34 11S	105 49E	0	16.64	35.737	26.19	*	+5 ± 16
-699	116	25 Nov	34 11S	105 49E	3430	1.50	34.73	27.82	*	-159 ± 15
-700	117	26 Nov	32 49S	108 39E	5325	*	*	*	*	-161 ± 15

TABLE 10
Seawater samples from *Zephyrus* Expedition

LJ no.	Sample/Sta No.	Colln date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{O}$ (‰)	Δ (‰)
-657	32	4 Aug	40 40N	005 48E	0	*	*	*	*	+15 ± 16
-659	32	4 Aug	40 40N	005 48E	2675	*	*	*	*	-39 ± 16
-660	54	4 Oct	33 12N	028 39E	0	*	*	*	*	+17 ± 15
-653	64	14 Nov	20 40N	038 13E	0	*	*	*	*	+1 ± 15
-654	64	14 Nov	20 40N	038 13E	900	*	*	*	*	-85 ± 15
-655	64	14 Nov	20 40N	038 13E	1325	*	*	*	*	-72 ± 15
-656	66	17 Nov	16 34N	041 04E	0	*	*	*	*	+16 ± 16

TABLE 11
Seawater samples from *Amphitrite* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{O}$ (‰)	Δ (‰)
-877	2-1	16 Jan	16 22S	161 49W	0	*	*	*	*	+4 ± 8
-876	3-1	1 Feb	11 25S	157 30W	0	*	*	*	*	+25 ± 8
-878	3-2	19 Feb	00 00	138 58W	0	*	*	*	*	+7 ± 8
-879	3-3	21 Feb	05 00N	134 00W	0	*	*	*	*	+17 ± 10
-880	3-4	23 Feb	10 00N	133 00W	0	*	*	*	*	+25 ± 8
-881	3-5	24 Feb	15 00N	130 00W	0	*	*	*	*	+54 ± 8
-882	3-6	26 Feb	20 00N	126 40W	0	*	*	*	*	+51 ± 8
-883	3-7	27 Feb	25 00N	123 00W	0	*	*	*	*	+87 ± 11

TABLE 12
Seawater samples from *Dodo* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-1052	1	4 Aug	01 16S	041 30E	0	24.62	35.207	23.64	*	-7 ± 20
-1053	14	9 Aug	01 58S	049 20E	0	25.74	35.246	23.64	*	+15 ± 21
-1054	22	12 Aug	02 00N	045 38E	0	24.30	35.016	23.59	*	-27 ± 20
-1055	33	15 Aug	05 00N	050 51E	0	25.07	35.462	23.70	*	-11 ± 20
-1056	33	15 Aug	05 00N	050 51E	4700	*	*	*	*	-197 ± 17
-1057	42	18 Aug	09 18N	051 03E	0	13.32	35.113	26.44	*	-52 ± 20
-1058	47	20 Aug	08 53N	053 09E	4700	*	*	*	*	-137 ± 18
-1059	62	27 Aug	10 14N	053 01E	0	25.89	35.837	23.73	*	+22 ± 21
-1060	62	27 Aug	10 14N	053 01E	4200	*	*	*	*	-177 ± 18
-1061	70	30 Aug	02 07N	055 04E	0	27.02	35.321	22.98	*	+31 ± 10
-1062	70	30 Aug	02 07N	055 04E	4700	*	*	*	*	-179 ± 18
-1063	80	3 Sept	05 52S	055 00E	0	25.42	35.226	23.42	*	+29 ± 11
-1066	80	3 Sept	05 52S	055 00E	100	*	*	*	*	-29 ± 10
-1067	80	3 Sept	05 52S	055 00E	200	*	*	*	*	-126 ± 10
-1065	80	3 Sept	05 52S	055 00E	300	*	*	*	*	-35 ± 20
-1064	80	3 Sept	05 52S	055 00E	500	*	*	*	*	-75 ± 9

TABLE 13
Seawater samples from *Ursa Major* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-1026	1	7 Aug	33 48N	135 01W	0	*	*	*	*	+183 ± 12
-1027	4	11 Aug	35 01N	155 00W	0	24.26	34.716	23.39	*	+148 ± 16
-1028	4	14 Aug	35 01N	155 00W	3500	1.49	34.69	27.78	*	-185 ± 10
-1033	9	15 Aug	45 00N	155 00W	0	15.85	33.031	24.29	*	+143 ± 12
-1031	9	15 Aug	45 00N	155 00W	100	7.68	33.382	26.07	*	+30 ± 25
-1032	9	15 Aug	45 00N	155 00W	200	7.22	33.905	26.54	*	-60 ± 21
-1040	9	15 Aug	45 00N	155 00W	500	3.96	34.00	27.02	*	-125 ± 20
-1039	9	15 Aug	45 00N	155 00W	998	3.10	34.354	27.39	*	-166 ± 10
-1038	9	15 Aug	45 00N	155 00W	4064	*	*	*	*	-199 ± 10
-1037	11	16 Aug	49 00N	154 58W	0	11.59	32.654	24.86	*	+115 ± 11
-1036	11	16 Aug	49 00N	154 58W	107	4.48	32.865	26.07	*	+50 ± 23
-1034	11	16 Aug	49 00N	154 58W	210	3.52	33.687	26.81	*	-68 ± 11
-1035	11	16 Aug	49 00N	154 58W	498	3.52	34.106	27.15	*	-120 ± 9
-1043	11	16 Aug	49 00N	154 58W	1021	2.81	34.393	27.44	*	-176 ± 9
-1041	11	16 Aug	49 00N	154 58W	2000	*	*	*	*	-174 ± 9
-1042	13	18 Aug	54 34N	155 00W	0	11.5	32.721	24.94	*	+114 ± 12
-1044	20	26 Aug	52 56N	155 03W	0	*	*	*	*	+44 ± 9
-1049	24	28 Aug	47 38N	155 00W	0	*	*	*	*	+75 ± 10
-1045	28	4 Sept	42 09N	155 02W	0	*	*	*	*	+40 ± 11
-1046	32	7 Sept	36 49N	155 00W	0	*	*	*	*	+123 ± 12
-1048	36	10 Sept	31 29N	155 00W	0	*	*	*	*	+123 ± 12
-1047	39	12 Sept	27 21N	155 00W	0	*	*	*	*	+137 ± 12

TABLE 14
(A) Seawater samples from *La Pared* Expedition

LJ no.	Sample/Sta No.	Colln date (1965)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-1406	0	29 Apr	27 44N	118 14W	0	*	*	*	*	+100 ± 8
-1407	5	1 May	21 00N	119 14W	0	21.9	34.02	23.53	*	+96 ± 13
-1408	5	1 May	21 00N	119 14W	100	17.0	34.05	24.81	*	+119 ± 6
-1409	5	1 May	21 00N	119 14W	200	11.0	34.23	26.20	*	-25 ± 7
-1410	5	1 May	21 00N	119 14W	300	9.3	34.47	26.69	*	-93 ± 6
-1411	5	1 May	21 00N	119 14W	400	8.1	34.47	26.87	*	-108 ± 6
-1412	5	1 May	21 00N	119 14W	500	*	*	*	*	-129 ± 7
-1417	15	4 May	15 55N	119 57W	0	*	*	*	*	+88 ± 7
-1419	15	4 May	15 55N	119 57W	200	*	*	*	*	-74 ± 7
-1420	15	4 May	15 55N	119 57W	300	*	*	*	*	-84 ± 7
-1421	15	4 May	15 55N	119 57W	400	*	*	*	*	-90 ± 7
-1423	15	4 May	15 55N	119 57W	500	*	*	*	*	-121 ± 7
-1424	3	28 Oct	32 52N	117 44W	0	*	*	*	*	+49 ± 8

(B) Seawater sample from SIO Pier

-1424	3	28 Oct	32 52N	117 44W	0	*	*	*	*	+49 ± 8
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TABLE 15
Seawater samples from *Zetes* Expedition

LJ no.	Sample/Sta No.	Colln date (1966)	Lat	Long	Depth	Ttemp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{O}$ (‰)	Δ (‰)
-1428	I-01	11 Jan	26 00N	155 00W	0	22.5	*	*	*	+136 ± 10
-1430	I-03	12 Jan	28 00N	155 00W	0	21.5	*	*	*	+134 ± 9
-1432	I-05	13 Jan	30 00N	155 00W	0	19	*	*	*	+125 ± 9
-1433	I-07	14 Jan	32 00N	155 00W	0	18	*	*	*	+127 ± 9
-1429	I-09	15 Jan	34 00N	155 00W	0	16.5	*	*	*	+142 ± 10
-1435	I-11	16 Jan	36 00N	155 00W	0	14.5	*	*	*	+73 ± 33
-1431	I-13	17 Jan	40 00N	155 00W	0	12	*	*	*	+80 ± 9
-1436	I-15	18 Jan	42 00N	155 00W	0	10.8	*	*	*	+218 ± 32
-1439	I-17	19 Jan	44 00N	155 00W	0	<9	*	*	*	+120 ± 12
-1440	I-19	19 Jan	46 00N	155 00W	0	7.3	*	*	*	+134 ± 25
-1443	I-21	20 Jan	48 00N	155 00W	0	6.5	*	*	*	+108 ± 25
-1437	I-23	21 Jan	50 00N	155 00W	0	5.2	*	*	*	+123 ± 9
-1438	I-25	22 Jan	52 00N	155 00W	0	4.0	*	*	*	+101 ± 9
-1441	I-27	22 Jan	54 00N	155 00W	0	3.5	*	*	*	+55 ± 9
-1442	I-29	22 Jan	56 00N	155 00W	0	<4	*	*	*	+60 ± 9
-1442	I-31	23 Jan	54 40N	158 40W	0	*	*	*	*	+30 ± 16
-1616	II-00	28 Jan	54 00N	165 00W	0	3.5	31.78	25.31	*	+121 ± 10
-1611	II-01	29 Jan	54 00N	165 00W	0	4.2	32.70	25.96	*	+81 ± 10
-1609	II-06	30 Jan	50 45N	165 24W	0	4.2	32.90	25.96	*	+128 ± 10
-1614	II-09	31 Jan	48 00N	165 00W	0	5.7	33.12	25.95	*	+131 ± 9
-1612	II-13	1 Feb	45 06N	165 04W	0	7.1	33.33	25.99	*	+104 ± 12
-1610	II-16	1 Feb	43 30N	165 00W	0	8.0	33.70	26.05	*	+34 ± 30
-1615	II-19	2 Feb	42 00N	165 00W	0	9.5	33.20	26.61	*	+20 ± 10
-1619	II-44	11 Feb	52 00N	168 00E	0	1.3	33.20	26.65	*	+20 ± 20
-1617	II-62	14 Feb	59 00N	167 30E	0	0.5	33.16	26.52	*	+2 ± 8
-1601	II-67	15 Feb	57 00N	172 00E	0	2.1	33.10	26.49	*	-22 ± 16
-1603	II-69	17 Feb	55 15N	175 00E	0	1.8	33.10	26.49	*	-6 ± 8
-1606	II-73	18 Feb	53 00N	176 00E	0	2.7	33.23	26.53	*	+87 ± 10
-1620	II-121	2 Mar	42 30N	175 00E	0	7.4	*	*	*	+20 ± 10
-1602	II-131	5 Mar	43 15N	168 00E	0	*	*	*	*	+60 ± 8
-1604	II-135	6 Mar	43 45N	164 00E	0	5.0	33.49	26.50	*	+82 ± 10
-1621	II-140	8 Mar	50 00N	162 20E	0	1.1	33.12	26.55	*	-36 ± 22
-1605	II-143	8 Mar	51 00N	161 45E	0	*	*	*	*	+41 ± 8
-1607	II-150	10 Mar	52 30N	160 45E	0	-1.35	*	*	*	+43 ± 11
-1622	II-160	16 Mar	47 40N	150 10E	0	-1.3	32.76	26.38	*	+20 ± 20
-1623	II-163	17 Mar	45 20N	152 50E	0	0.07	33.12	26.61	*	+23 ± 8
-1608	II-167	19 Mar	41 40N	156 40E	0	5.2	33.62	26.58	*	+23 ± 8
-1624	II-170	20 Mar	39 30N	158 30E	0	11.04	34.30	26.25	*	+32 ± 19

TABLE 16
Seawater samples from *USS Radford* Cruise 6809-R

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-1821	1	10 Sept	53 20N	157 50W	0	10.6	34.027	26.11	*	+97 ± 17
-1919	4	11 Sept	47 56N	158 09W	0	12.2	32.559	24.68	*	+136 ± 13
-1920	6	12 Sept	44 00N	158 02W	0	14.1	33.046	24.69	*	+130 ± 13
-1918	7	12 Sept	42 00N	157 50W	0	16.9	33.165	24.16	*	+121 ± 13
-1912	8	12 Sept	40 00N	157 50W	0	20.2	33.760	23.79	*	+107 ± 14
-1914	12	14 Sept	32 09N	157 47W	0	25.9	35.286	23.32	*	+120 ± 34
-1916	13	14 Sept	30 00N	157 50W	0	26.9	35.187	22.93	*	+165 ± 18
-1917	14	14 Sept	28 14N	157 45W	0	26.5	35.226	23.08	*	+152 ± 20
-1911	15	15 Sept	26 14N	157 49W	0	26.5	34.877	22.81	*	+131 ± 24
-1915	16	15 Sept	24 00N	157 50W	0	27.3	34.707	22.43	*	+137 ± 18

TABLE 17
Seawater samples from *Slyx* Expedition

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-1926	0	11 Nov	13 53S	170 58W	0	27.7	35.336	22.77	*	+59 ± 17
-1929	1	8 Aug	12 00S	169 47W	0	27.2	35.679	23.19	*	+97 ± 11
-1928	2	8 Aug	10 00S	169 07W	0	27.8	35.467	22.84	*	+76 ± 13
-1927	3	9 Aug	08 05S	168 13W	0	28.3	35.597	22.77	*	+68 ± 22
-1955	4	10 Aug	05 56S	167 26W	0	27.9	35.635	22.94	*	+132 ± 17
-1951	5	10 Aug	04 00S	167 52W	0	27.3	35.419	22.97	*	+67 ± 19
-1962	6	11 Aug	02 00S	166 16W	0	27.9	35.421	22.78	*	+43 ± 15
-1924	7	11 Aug	00 00	165 42W	0	26.7	35.432	23.17	*	+54 ± 16
-1956	12	22 Nov	11 01N	155 04W	0	27.1	33.877	21.88	*	+225 ± 10
-1957	13	22 Nov	12 47N	155 38W	0	26.9	34.229	22.20	*	+119 ± 10

TABLE 18
(A) Seawater samples from *Piquero* Expedition

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{O}$ (‰)	Δ (‰)
-1966	1	12 Dec	20 00N	114 50W	0	*	34.409	*	*	+128 ± 7
-1967	2	12 Dec	16 00N	114 07W	0	*	33.625	*	*	+106 ± 11
-1968	3	14 Dec	12 00N	113 24W	0	*	33.503	*	*	+95 ± 7
-1969	4	14 Dec	08 00N	112 41W	0	*	33.962	*	*	+95 ± 17
-1970	5	15 Dec	04 00N	111 57W	0	*	34.524	*	*	+86 ± 8
-1971	6	16 Dec	00 00	111 15W	0	*	34.590	*	*	+43 ± 13
-1972	7	18 Dec	04 00S	109 51W	0	*	35.471	*	*	+21 ± 7
-1973	8	19 Dec	08 00S	108 30W	0	*	*	*	*	+26 ± 15
-1983	9	20 Dec	12 00S	104 30W	0	*	35.740	*	*	+55 ± 8
-1980	10	22 Dec	16 00S	100 27W	0	*	36.058	*	*	+76 ± 9
-1985	11	24 Dec	20 00S	096 26W	0	*	35.878	*	*	+93 ± 9
-1989	12	25 Dec	25 05S	091 00W	0	*	35.315	*	*	+143 ± 7
-1991	13	(1969) 20 Jan	62 25S	062 00W	0	*	33.938	*	*	-38 ± 9
-1993	14	23 Jan	60 00S	064 00W	0	*	33.889	*	*	-22 ± 6
-2014	15	25 Jan	58 00S	066 20W	0	*	34.117	*	*	+11 ± 24
-2015	16	28 Jan	56 12S	071 52W	0	*	34.115	*	*	+29 ± 11
-1974	17	30 Jan	60 25S	079 30W	0	*	34.168	*	*	+22 ± 8
-1975	18	1 Feb	59 20S	082 50W	0	*	34.129	*	*	+17 ± 8
-1976	19	1 Feb	58 00S	086 45W	0	*	34.128	*	*	+23 ± 8
-1977	20	9 Feb	54 22S	090 00W	0	*	34.201	*	*	+31 ± 19
-1978	21	10 Feb	51 20S	090 40W	0	*	34.135	*	*	+41 ± 6
-1979	22	11 Feb	48 42S	091 18W	0	*	34.102	*	*	+77 ± 11
-2016	23	3 Mar	30 01S	082 00W	0	*	34.750	*	*	+158 ± 7
-1923	4	20 Feb	32 52N	117 44W	0	*	*	*	*	+138 ± 15

(B) Seawater sample from SIO Pier

TABLE 19
Seawater samples from *Scan* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-2031	1	14 Apr	28 19N	139 54W	0	19.5	35.208	25.08	*	+169 ± 11
-2035	2	16 Apr	23 50N	139 47W	0	21.5	34.707	24.16	*	+158 ± 12
-2036	4	17 Apr	20 10N	140 23W	0	21.3	34.513	24.07	*	+158 ± 10
-2038	5	19 Apr	17 56N	139 56W	0	22.0	34.190	23.63	*	+147 ± 12
-2041	6	20 Apr	14 00N	140 31W	0	24.5	34.183	22.91	*	+140 ± 7
-2043	7	23 Apr	12 04N	140 23W	0	25.7	34.014	22.42	*	+64 ± 10
-2046	8	24 Apr	09 52N	140 22W	0	26.7	34.464	22.44	*	+83 ± 6
-2054	9	24 Apr	07 47N	140 23W	0	27.5	34.210	22.00	*	+100 ± 9
-2055	10	29 Apr	04 28N	140 17W	0	27.7	35.011	22.53	*	+62 ± 7
-2056	11	16 June	30 05N	140 03E	0	23.3	34.623	23.59	*	+140 ± 11
-2062	12	17 June	28 21N	142 19E	0	23.0	34.431	23.54	*	+204 ± 10
-2063	13	18 June	26 50N	141 28E	0	24.2	34.435	23.18	*	+196 ± 13
-2065	14	19 June	23 29N	142 59E	0	29.1	34.924	22.01	*	+170 ± 13
-2069	15	20 June	21 14N	142 47E	0	29.1	35.043	22.10	*	+181 ± 10
-2071	16	21 June	19 52N	142 22E	0	29.0	34.939	22.05	*	+184 ± 9
-2072	17	21 June	18 23N	141 42E	0	29.1	34.674	21.82	*	+160 ± 10

TABLE 20
Seawater samples from *Climax II* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-2074	1	7 Sept	28 23N	155 20W	0	24.3	35.152	23.69	*	+169 ± 20
-2101	2	10 Sept	26 28N	155 41W	0	25.3	35.110	23.37	*	+221 ± 15
-2103	3	10 Sept	24 30N	156 25W	0	*	35.042	*	*	+141 ± 14
-2104	4	20 Sept	17 58N	155 38W	0	*	34.589	*	*	+160 ± 11
-2105	5	21 Sept	15 43N	155 00W	0	*	34.477	*	*	+167 ± 9
-2106	6	22 Sept	13 19N	154 59W	0	*	34.348	*	*	+109 ± 10
-2108	7	22 Sept	12 00N	155 02W	0	*	33.675	*	*	+136 ± 17
-2114	9	23 Sept	07 58N	154 55W	0	*	34.360	*	*	+49 ± 20
-2117	10	24 Sept	05 49N	154 57W	0	*	34.810	*	*	+54 ± 16
-2140	11	25 Sept	01 54N	155 05W	0	*	34.936	*	*	+57 ± 9
-2310	12	26 Sept	01 04S	154 58W	0	*	35.210	*	-1.1	+47 ± 8
-2139	13	27 Sept	03 02S	154 59W	0	*	35.327	*	*	+45 ± 10
-2311	14	28 Sept	05 52S	155 02W	0	*	35.398	*	+1.7	+48 ± 8
-2313	15	28 Sept	07 03S	155 03W	0	*	35.399	*	+1.1	+48 ± 8
-2369	16	29 Sept	09 14S	155 02W	0	*	35.719	*	+2.0	+54 ± 8
-2137	17	29 Sept	11 06S	155 03W	0	*	35.926	*	*	+124 ± 18
-2135	18	30 Sept	13 02S	155 00W	0	*	35.962	*	*	+92 ± 17
-2131	19	30 Sept	15 23S	155 00W	0	*	35.921	*	*	+121 ± 10
-2129	20	1 Oct	18 29S	155 01W	0	*	35.880	*	*	+127 ± 10
-2123	21	2 Oct	22 01S	155 01W	0	*	35.864	*	*	+97 ± 26
-2121	22	3 Oct	24 04S	155 00W	0	*	35.785	*	*	+133 ± 10

TABLE 21
Seawater samples from *Dragon* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-2077	1	8 June	11 43N	119 17W	0	26.9	34.053	22.07	*	+104 ± 7
-2080	2	9 June	15 05N	118 55W	0	24.8	34.359	22.95	*	+109 ± 10
-2083	3	10 June	17 04N	118 39W	0	24.0	34.411	23.22	*	+124 ± 9
-2088	4	10 June	19 00N	118 25W	0	23.3	34.423	23.44	*	+132 ± 10
-2092	5	11 June	21 04N	118 16W	0	22.6	34.570	23.75	*	+151 ± 8
-2093	6	11 June	23 01N	118 02W	0	20.5	34.273	24.10	*	+188 ± 20
-2094	7	12 June	23 13N	118 16W	0	19.0	33.981	24.27	*	+193 ± 9

TABLE 22
Seawater samples from North Pacific Study Cruises of USCGC *Acushnet* and from Weather Station "P"

Lj no.	Cruise	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-2022	NPSC-3	1	22 May	50 00N	158 00W	0	5.4	32.845	25.95	*	+107 ± 12
-2023	NPSC-3	2	22 May	48 00N	158 00W	0	6.6	32.789	25.76	*	+54 ± 15
-2020	NPSC-3	3	23 May	46 00N	158 00W	0	7.2	33.010	25.86	*	+130 ± 16
-2024	NPSC-3	5	27 May	40 00N	158 00W	0	10.5	33.664	25.85	*	+81 ± 11
-2025	NPSC-3	6	27 May	38 00N	158 00W	0	12.5	34.147	25.80	*	+73 ± 10
-2018	NPSC-5	1	6 Dec	43 01N	157 40W	0	9.5	33.177	25.64	*	+133 ± 12
-2029	NPSC-5	2	8 Dec	41 00N	148 02W	0	12.2	*	*	*	+133 ± 16
-2418	Sta P	1	(1970) 14 Feb	50 00N	145 00W	0	8.1	32.648	25.45	-1.8	+146 ± 15
-2421	Sta P	3	22 Feb	50 00N	145 00W	0	8.5	32.678	25.41	-1.1	+83 ± 19
-2427	NPSC-6	1	23 Apr	44 00N	164 00W	0	7.4	33.49	26.20	-0.2	+94 ± 6
-2438	NPSC-6	2	25 Apr	41 00N	157 45W	0	10.1	33.61	25.87	0.0	+102 ± 8
-2460	NPSC-6	3	26 Apr	44 00N	157 40W	0	7.6	33.10	25.86	-0.1	+125 ± 10
-2462	NPSC-6	4	28 Apr	44 00N	148 00W	0	8.4	32.98	25.66	-0.8	+164 ± 7
-2495	NPSC-6	5	29 Apr	41 00N	148 02W	0	11.5	33.55	25.59	-2.8	+123 ± 9
-2678	NPSC-7	1	29 June	29 59N	165 01W	0	25.5	34.985	23.21	+1.4	+169 ± 8
-2498	NPSC-7	2	30 June	31 00N	164 27W	0	23.7	34.720	23.55	+1.4	+111 ± 11
-2500	NPSC-7	3	1 July	34 00N	162 48W	0	23.0	34.503	23.59	+1.1	+145 ± 29
-2504	NPSC-7	5	2 July	38 00N	160 15W	0	17.7	34.026	24.63	+2.0	+94 ± 12
-2681	NPSC-7	6	2 July	40 00N	159 14W	0	14.5	33.644	25.06	+0.6	+73 ± 9
-2691	NPSC-7	7	3 July	42 00N	158 16W	0	11.9	33.260	25.29	+2.2	+116 ± 12
-2693	NPSC-7	8	6 July	43 31N	157 45W	0	10.8	33.173	25.42	+2.2	+99 ± 7

TABLE 23
Seawater samples from *Hudson 70* Expedition†

LJ no.	Sample/Sta No.	Colln date (1970)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-2149	5	28 Apr	59 59S	149 59W	0	0.4	34.60	27.79	+0.3	+61 ± 16
-2153	6	28 Apr	58 20S	149 51W	0	1.1	34.39	27.57	+0.3	+54 ± 21
-2158	7	29 Apr	56 35S	149 58W	0	1.9	34.28	27.44	*	+68 ± 10
-2159	9	1 May	49 56S	150 00W	0	9.8	34.79	26.85	*	+77 ± 10
-2163	10	2 May	45 00S	149 59W	0	11.1	34.61	26.48	*	+77 ± 17
-2325	11	3 May	40 00S	150 01W	0	15.2	34.72	25.74	-3.9	+98 ± 12
-2384	12	5 May	35 03S	150 00W	0	18.2	35.41	25.56	+1.5	+132 ± 11
-2402	13	6 May	29 59S	149 58W	0	21.6	35.52	24.75	*	+137 ± 6
-2298	14	8 May	24 59S	150 01W	0	24.2	35.70	24.14	+0.3	+143 ± 9
-2404	15	10 May	19 58S	150 02W	0	26.8	35.80	23.42	*	+132 ± 8
-2307	16	17 May	15 03S	150 00W	0	29.0	35.74	22.65	+2.3	+124 ± 9
-2406	17	18 May	09 50S	150 02W	0	29.2	36.04	22.82	*	+90 ± 8
-2299	18	19 May	05 00S	150 04W	0	28.6	35.08	22.29	+1.7	+58 ± 6
-2429	19	20 May	02 55S	150 09W	0	28.5	35.22	22.43	+2.3	+51 ± 9
-2386	20	21 May	01 30S	150 03W	0	27.7	35.38	22.81	+2.0	+62 ± 10
-2432	21	21 May	00 03S	149 56W	0	27.1	35.38	23.01	*	+43 ± 16
-2300	22	22 May	01 40N	149 58W	0	27.6	35.12	22.65	+2.1	+64 ± 8
-2434	23	22 May	03 00N	149 59W	0	28.3	34.98	22.31	*	+71 ± 10
-2388	24	22 May	04 46N	150 00W	0	28.3	34.52	21.96	+1.3	+65 ± 6
-2408	25	24 May	10 00N	150 01W	0	26.8	34.76	22.63	*	+90 ± 6
-2302	26	26 May	16 01N	150 02W	0	25.2	34.71	23.10	+2.0	+131 ± 6
-2410	27	27 May	20 10N	150 03W	0	24.2	34.66	23.35	*	+152 ± 7
-2390	28	28 May	25 00N	150 01W	0	23.3	35.19	23.02	*	+194 ± 8
-2412	29	29 May	28 48N	149 57W	0	22.8	35.52	24.41	+1.3	+190 ± 7
-2304	30	31 May	35 54N	149 58W	0	18.2	34.22	24.65	+0.8	+144 ± 6
-2414	31	1 June	40 02N	149 58W	0	13.6	33.76	25.34	*	+171 ± 7
-2392	32	3 June	45 00N	149 59W	0	9.2	33.16	25.67	*	+169 ± 6
-2423	33	4 June	49 07N	150 00W	0	6.6	33.16	26.05	+0.6	+133 ± 14
-2305	34	5 June	54 33N	150 06W	0	6.1	33.28	26.21	+1.5	+80 ± 7

† Samples coll for C S Wong, Canadian Dept Environment; Marine Sci Dir, Pacific Region; Ocean Chemistry Div, Victoria, British Columbia, Canada, and were measured by La Jolla Lab before Canadian lab began operation.

TABLE 24
Seawater samples from *Seven-Tow* Expedition

LJ no.	Sample/Sta No.	Colln date (1970)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-2436	1	8 Apr	18 04N	161 27W	0	24.7	34.804	23.32	-0.2	+176 ± 8
-2440	2	9 Apr	15 41N	164 18W	0	26.2	34.525	22.65	+0.5	+145 ± 6
-2442	3	10 Apr	14 00N	166 21W	0	26.9	34.493	22.40	*	+133 ± 8
-2445	4	11 Apr	12 00N	168 56W	0	27.3	34.570	22.33	+1.8	+115 ± 9
-2447	5	11 Apr	09 57N	170 53W	0	27.5	34.492	22.21	*	+128 ± 8
-2449	6	12 Apr	07 59N	174 08W	0	28.8	34.802	22.02	-1.0	+113 ± 9
-2451	7	14 Apr	06 00N	176 40W	0	29.1	34.972	22.04	+1.2	+84 ± 8
-2454	9	15 Apr	01 54N	174 53W	0	27.8	35.080	22.55	+1.7	+56 ± 7
-2456	10	15 Apr	00 04S	174 00W	0	27.8	35.163	22.61	-0.5	+42 ± 11
-2458	11	19 Apr	01 59S	169 56W	0	28.5	35.333	22.52	+0.6	+57 ± 7
-2464	12	20 Apr	03 56S	170 16W	0	28.5	35.300	22.49	-0.6	+60 ± 7
-2466	13	20 Apr	06 04S	170 34W	0	29.6	35.159	22.04	-4.0	+94 ± 19
-2468	14	21 Apr	08 03S	170 44W	0	29.7	34.852	21.75	+0.1	+87 ± 10
-2475	16	6 June	07 49S	168 34W	0	30.4	35.123	21.69	+0.1	+94 ± 8
-2477	17	6 June	05 49S	168 08W	0	30.8	34.594	21.16	-2.4	+82 ± 10
-2479	18	7 June	03 52S	167 23W	0	30.2	35.250	21.86	0.0	+54 ± 9
-2481	19	7 June	01 50S	166 36W	0	29.4	35.329	22.21	+1.8	+66 ± 9
-2483	20	8 June	00 06S	165 52W	0	29.5	35.335	22.18	+0.2	+81 ± 14
-2485	21	8 June	02 08N	165 00W	0	29.0	34.857	22.00	0.0	+45 ± 16
-2486	22	10 June	04 04N	163 38W	0	29.4	34.625	21.68	+2.2	+75 ± 9
-2489	23	11 June	05 51N	160 50W	0	29.5	34.608	21.64	+0.9	+68 ± 9
-2491	24	12 June	07 57N	159 16W	0	29.4	34.551	21.63	+0.7	+24 ± 12
-2493	25	17 June	09 52N	155 22W	0	30.8	34.729	21.27	+2.4	+86 ± 7
-2507	26	4 July	23 54N	156 48W	0	25.0	34.977	23.36	+2.5	+150 ± 18
-2509	27	5 July	26 27N	155 47W	0	24.8	35.278	23.64	-0.2	+192 ± 11
-2512	28	5 July	27 58N	155 13W	0	24.6	35.295	23.72	+0.1	+188 ± 9
-2514	29	7 July	30 03N	156 11W	0	23.6	35.065	23.84	+1.9	+157 ± 9
-2518	31	12 July	33 58N	155 13W	0	23.5	35.020	23.84	+2.1	+158 ± 12
-2520	32	13 July	35 56N	161 09W	0	23.0	34.377	23.50	+1.7	+114 ± 8
-2533	33	13 July	37 52N	162 53W	0	20.7	33.973	23.82	+2.3	+76 ± 11
-2538	34	14 July	40 00N	164 47W	0	16.3	33.971	24.92	+1.7	+67 ± 9
-2560	35	15 July	42 01N	165 44W	0	14.0	33.579	25.12	+2.4	+88 ± 9
-2564	36	17 July	44 03N	166 30W	0	12.4	33.543	25.41	+2.0	+91 ± 9

TABLE 25
Seawater samples from *Aries* Expedition

LJ no.	Sample/Sta No.	Colln date (1971)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{18}\text{C}$ (‰)	Δ (‰)
-2522	1	3 Feb	68 22S	176 02E	0	-0.5	34.086	27.42	+1.7	-69 ± 7
-2524	2	5 Feb	70 00S	168 34E	0	-1.8	34.043	27.43	+1.9	-112 ± 9
-2526	3	10 Feb	67 51S	160 24E	0	-0.3	33.437	26.88	+1.8	-86 ± 7
-2528	4	15 Feb	65 59S	160 35E	0	0.8	33.627	26.99	+1.7	-99 ± 9
-2543	5	15 Feb	63 59S	158 53E	0	0.9	33.794	27.11	+2.0	-84 ± 7
-2542	6	16 Feb	62 00S	159 01E	0	1.6	33.927	27.17	+2.0	-93 ± 7
-2545	7	16 Feb	59 10S	162 34E	0	5.5	33.825	26.71	+2.7	+17 ± 10
-2547	9	1 Mar	40 44S	177 33E	0	18.3	*	*	+3.2	+86 ± 7
-2532	10	2 Mar	38 48S	178 01E	0	19.6	*	*	+2.3	+77 ± 9
-2549	11	3 Mar	36 32S	173 05W	0	20.2	*	*	+2.4	+92 ± 7
-2534	12	4 Mar	34 49S	169 23W	0	19.6	35.278	25.10	+2.6	+131 ± 10
-2536	14	6 Mar	30 51S	160 54W	0	23.6	35.661	24.29	+1.7	+129 ± 8
-2552	15	7 Mar	28 49S	156 41W	0	25.0	35.520	23.77	+2.6	+146 ± 7
-2538	16-17	13 Mar	25 45S	154 19W	0	25.4	35.600	23.71	+2.0	+131 ± 12
-2700	18-19	2 Apr	14 13S	151 37W	0	28.3	35.946	23.04	+1.8	+93 ± 9
-2703	20	3 Apr	09 02S	154 20W	0	28.1	35.692	22.91	+3.1	+85 ± 8
-2705	21-23	4 Apr	04 41S	156 26W	0	27.3	35.451	22.99	+4.5	+50 ± 14
-2706	24-33	23 Apr	01 32N	152 14W	0	26.3	35.071	23.02	+2.6	+33 ± 11

TABLE 26
Seawater samples from South-Tow Expedition

LJ no.	Sample/Sta No.	Colln date (1972)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}\text{C}$ (‰)	Δ (‰)
-2729	1	8 Jan	23 48N	119 52W	0	17.0	33.65	24.51	+1.7	-202 ± 6
-2738	2	8 Jan	21 51N	120 23W	0	17.8	34.22	24.75	+1.6	+196 ± 6
-2742	3	9 Jan	19 58N	120 51W	0	19.1	34.35	24.53	+2.0	+189 ± 6
-2744	4	9 Jan	16 16N	122 00W	0	23.2	33.83	23.02	+1.0	+114 ± 6
-2731	5	10 Jan	11 38N	122 33W	0	24.2	34.33	23.10	+0.8	+39 ± 8
-2746	6	12 Jan	10 04N	123 11W	0	24.7	34.22	22.88	+0.2	+119 ± 6
-2748	7	14 Jan	07 34N	123 41W	0	25.0	33.98	22.60	+1.1	+79 ± 8
-2736	9	21 Jan	00 09S	125 32W	0	23.7	34.90	23.68	+1.7	+39 ± 6
-2752	10	22 Jan	02 02S	125 53W	0	23.8	34.83	23.60	+0.7	-28 ± 10
-2756	12	23 Jan	06 06S	126 37W	0	24.8	35.05	23.47	+1.7	+25 ± 6
-2740	13	23 Jan	08 02S	127 01W	0	25.6	35.15	23.30	+0.6	+25 ± 6
-2758	14	24 Jan	10 01S	127 22W	0	26.5	35.46	23.25	+1.7	+31 ± 8
-2760	15	25 Jan	13 57S	128 07W	0	27.8	35.86	23.14	+1.6	+57 ± 9
-2762	16	25 Jan	15 52S	128 24W	0	27.8	36.075	23.30	+1.6	+74 ± 9
-2764	17-18	26 Jan	19 57S	129 16W	0	27.5	36.600	23.79	+1.6	+157 ± 17
-2766	19	30 Jan	24 09S	129 28W	0	26.8	35.819	23.43	+1.4	+176 ± 9
-2768	20-21	16 Feb	21 22S	149 04W	0	28.0	35.931	23.13	+1.2	+161 ± 12
-2772	22-24	17 Feb	25 21S	148 25W	0	27.3	35.49	23.02	+0.9	+169 ± 10
-2775	25-26	18 Feb	30 50S	143 47W	0	24.5	35.25	23.72	+1.0	+182 ± 24
-2777	27-29	20 Feb	37 11S	139 34W	0	18.9	34.562	24.74	+2.0	+187 ± 10
-2779	30	21 Feb	40 01S	138 00W	0	15.9	34.180	25.17	+1.2	+131 ± 8
-2781	31-33	22 Feb	44 29S	134 50W	0	14.7	34.247	25.48	+1.4	+68 ± 9
-2783	34-37	1 Mar	49 31S	121 19W	0	12.0	34.317	26.09	+0.4	+69 ± 9