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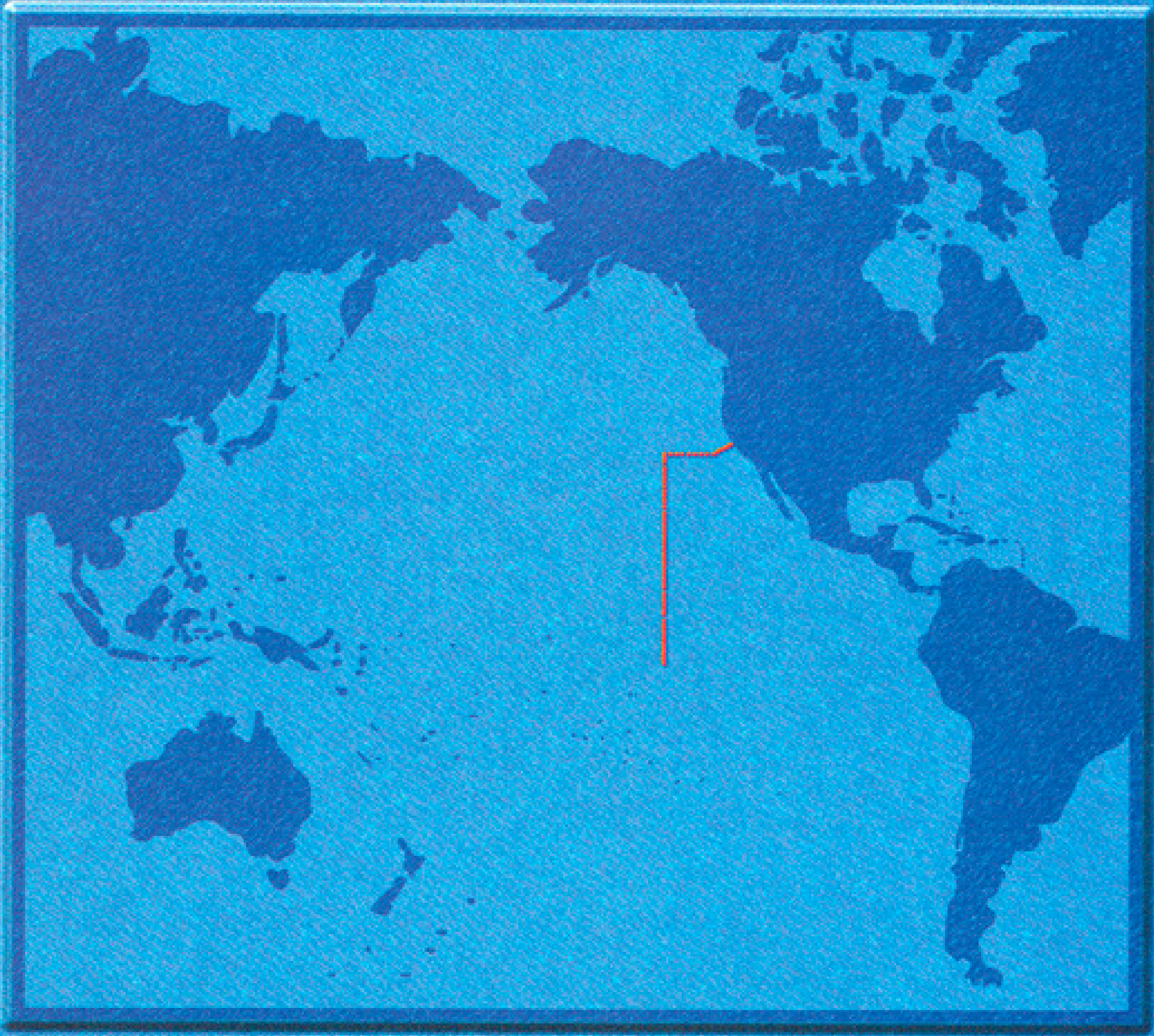
Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V Thomas Washington Cruise Tunes-1 in the Equatorial Pacific Ocean (WOCE Section P17C)



DISCLAIMER

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CARBON DIOXIDE, HYDROGRAPHIC, AND CHEMICAL DATA OBTAINED DURING THE R/V *THOMAS WASHINGTON* CRUISE TUNES-1 IN THE EQUATORIAL PACIFIC OCEAN (WOCE SECTION P17C)

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ABSTRACT

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This report discusses the procedures and methods used to obtain measurements of total carbon dioxide (TCO_2), total alkalinity (TALK), and radiocarbon ($\Delta^{14}C$), as well as hydrographic and chemical data, during the Research Vessel *Thomas Washington* Expedition TUNES-1 in the Equatorial Pacific Ocean (Section P17C). Conducted as part of the World Ocean Circulation Experiment (WOCE), the cruise began in San Diego, California, on May 31, 1991, and ended in Papeete, Tahiti, on July 11, 1991. WOCE Meridional Section P17C, along 135° W and between ~5° S and 36° N, was completed during the 42-day expedition. All 123 hydrographic stations (including 9 large-volume stations) were completed to the full water-column depth. Spacing between stations was 30 nautical miles, except between 3° N and 3° S, where it was 10 nautical miles. At 30 stations, CO_2 measurements were provided for the U.S. Department of Energy's Carbon Dioxide Program. Hydrographic and chemical measurements made along WOCE Section P17C included pressure, temperature, salinity, and oxygen (measured by conductivity, temperature, and depth sensor), as well as bottle measurements of salinity, oxygen, phosphate, nitrate, nitrite, silicate, chlorofluorocarbon (CFC)-11, CFC-12, $\Delta^{14}C$, TCO_2, and TALK. In addition, potential temperatures were calculated from the measured variables.

The TCO_2 concentration in 1022 seawater samples was determined by semiautomated coulometry using an improved version of the instrument earlier described by Johnson et al. (1985, 1987). The precision of these measurements was estimated to be better than ±0.01%. The desired accuracy was better than 4 μmol/kg.

The TALK concentration in 323 seawater samples was determined by an automated potentiometric acid titration system that was described by Bradshaw and Brewer (1988). The precision of the measurements was estimated to be better than 0.1%.

Fifty replicate samples were also collected for later shore-based reference analyses of TCO_2 and TALK by vacuum extraction and manometry in the laboratory of C. D. Keeling of Scripps Institution of Oceanography.

The data set is available, free of charge, as a numeric data package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of two oceanographic data files; two FORTRAN 77 data-retrieval-routine files; a documentation file; and this printed report, which describes the contents and format of all files and the procedures and methods used to obtain the data.

Keywords: carbon dioxide; total alkalinity; World Ocean Circulation Experiment (WOCE); Pacific Ocean; hydrographic measurements; carbon cycle

PART 1:

OVERVIEW

1. BACKGROUND INFORMATION

The World Ocean plays a dynamic role in the Earth's climate: it captures heat from the sun, transports it, and releases it thousands of miles away. These oceanic-solar-atmospheric interactions affect winds, rainfall patterns, and temperatures on a global scale. The oceans also play a major role in global carbon-cycle processes. Carbon is unevenly distributed in the oceans because of complex circulation patterns and biogeochemical cycles. The oceans are estimated to hold 38,000 gigatons of carbon, 50 times more than that in the atmosphere and 20 times more than plants, animals, and the soil. If only 2% of the carbon stored in the oceans were released, the level of atmospheric carbon dioxide (CO_2) would double. Every year, the amount of CO_2 exchanged across the sea surface is more than 15 times that produced by burning of fossil fuels, deforestation, and other human activities (Williams 1990).

To better understand the ocean's role in climate and climatic changes, several large experiments have been conducted, and others are under way. The largest oceanographic experiment ever attempted is the World Ocean Circulation Experiment (WOCE). A major component of the World Climate Research Program, WOCE brings together the expertise of scientists and technicians from more than 30 nations. In the United States, WOCE is supported by the federal government under the Global Change Research Program. The multiagency U.S. effort is led by the National Science Foundation and is supported by major contributions from the National Oceanic and Atmospheric Administration, the U.S. Department of Energy (DOE), the Office of Naval Research, and the National Aeronautics and Space Administration. Although total carbon dioxide (TCO_2) is not an official WOCE measurement, a coordinated effort, supported in the United States by DOE, is being made on WOCE cruises (through 1998) to measure the global, spatial, and temporal distributions of TCO_2 and other carbon-related parameters. The goal of the CO_2 survey includes estimation of the meridional transport of inorganic carbon in the Pacific Ocean in a manner analogous to the oceanic heat transport (Bryden and Hall 1980; Brewer et al. 1989; Roemmich and Wunsch 1985), evaluation of the exchange of CO_2 between the atmosphere and the ocean, and preparation of a database suitable for carbon-cycle modeling, and subsequent assessment of the anthropogenic CO_2 increase in the oceans. The final data set is expected to cover ~23,000 stations.

This report presents CO_2-related measurements obtained during the 42-day Leg 1 of the Research Vessel (R/V) *Thomas Washington* TUNES Expedition (TUNES-1) along the WOCE zonal Section P17C, which is located in the equatorial part of the Pacific Ocean along the 135° W meridian, between ~5° S and 36° N (Fig. 1).

The CO_2 investigation during the TUNES-1 Expedition was supported by a grant (No. DE-FGO2-90-ER60983) from DOE.

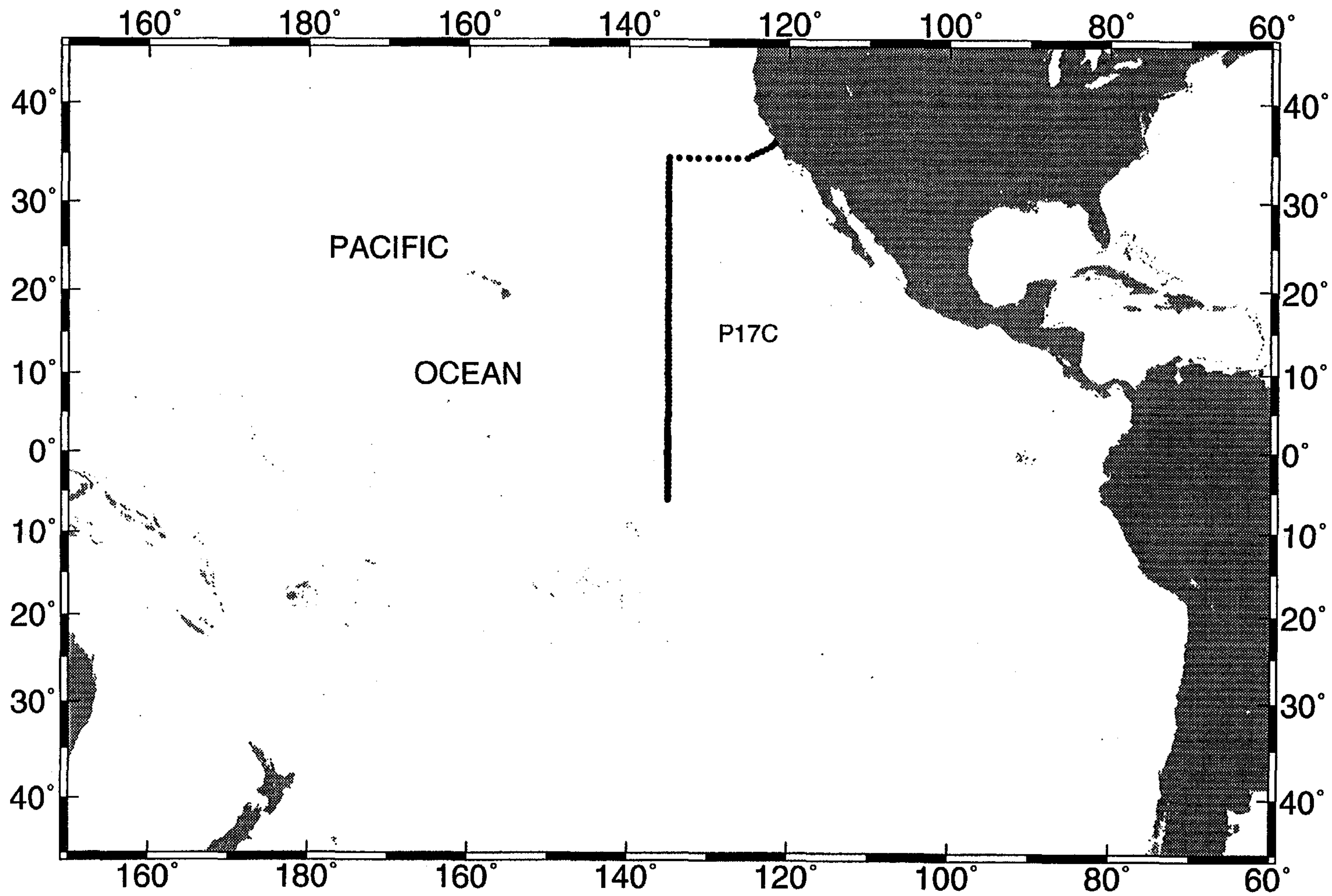

Figure 1. **Station locations during R/V *Thomas Washington* TUNES-1 Expedition.**

2. DESCRIPTION OF THE EXPEDITION

2.1 R/V *Thomas Washington* Cruise TUNES-1 Information

Ship name:	*Thomas Washington*
Cruise/Leg:	TUNES/1
Location:	Equatorial Pacific Ocean, WOCE Section P17C
Ports of call:	San Diego, California, to Papeete, Tahiti.
Dates:	May 31–July 11, 1991
Master:	T. Desjardins
Chief Scientist:	Mizuki Tsuchiya (SIO)

Parameters measured	**Institution**	**Principal investigators**
CTD[1,2]/oxygen[2]/salinity[2]/nutrients[2]	SIO	L. Talley, M. Tsuchiua
Nutrients (silicate, phosphate, nitrate, and nitrite)[2]	OSU	L. Gordon
Underway pCO_2 and nitrous oxide (N_2O)	SIO	Ray Weiss
Chlorofluorocarbons (CFCs)[2]	RSMAS	R. Fine
Helium/tritium	WHOI	W. Jenkins
Helium	UCSB	J. Lupton
ALACE floats	SIO	R. Davis
Acoustic Doppler current profiler (ADCP)	UH	E. Firing
TCO_2[2] and total alkalinity (TALK)[2]	WHOI	C. Goyet
TCO_2[2] and TALK[2] (shore-based analyses)	SIO	C. Keeling
$\Delta^{14}C$[2]	PU	R. Key
Surface drifters	SIO	P. Niller

Participating Institutions

SIO	Scripps Institution of Oceanography (University of California, San Diego)
OSU	Ohio State University
RSMAS	Rosenstiel School of Marine and Atmospheric Sciences (University of Miami)
WHOI	Woods Hole Oceanographic Institution
UCSB	University of California, Santa Barbara
UH	University of Hawaii
PU	Princeton University

[1]Conductivity, temperature, and depth sensor
[2]Measurements are reported in this data set

2.2 Brief Cruise Summary

On May 31, 1991, R/V *Thomas Washington* departed San Diego for the first of its three consecutive TUNES series WOCE legs. Stations were numbered consecutively from the beginning of the R/V *Thomas Washington* work on Leg 1, TUNES-1 Expedition, starting off the coast of California. The first station (no. 1) was occupied on June 2, 1991, at ~36° 10' N and 121° 44' W. The last station (no. 123) of the TUNES-1 Expedition was occupied on July 7, 1991, at ~5° 58' S and 135° 00' W. On July 11, 1991, R/V *Thomas Washington* arrived in Papeete, Tahiti.

During the 42-day expedition, 123 hydrographic stations (including 9 large-volume stations) were completed. All stations were sampled to the bottom and consisted of a rosette/CTD cast. Basic station spacing was 30 nautical miles, closing to 10 nautical miles between 3° S and 3° N. Sampling was performed primarily with a 36-place double-ring rosette of 10-L bottles and mounted CTD and transmissometer. CTD data consisted of pressure, temperature, conductivity, oxygen, and transmissometry. Water samples were collected for analyses of salt, oxygen, silicate, phosphate, nitrate, and nitrite at all stations and for CFC-11, CFC-12, helium, tritium, $\Delta^{14}C$, TCO_2, and TALK at selected stations. Underway measurements included ADCP, surface temperature, and surface water and atmospheric pCO_2 and N_2O.

3. DESCRIPTION OF VARIABLES AND METHODS

The data file **tun1.dat** (see Sect. 7 "File Descriptions" in Part 2) in this numeric data package (NDP) contains the following variables: station number, cast number, sample number, bottle number, CTD pressure, CTD temperature, CTD salinity, CTD oxygen, calculated potential temperature, bottle salinity, bottle oxygen, silicate, nitrate, nitrite, phosphate, CFC-11, CFC-12, $\Delta^{14}C$, calculated ^{14}C error, TCO_2, TALK, and data-quality flags. The station inventory file **tun1sta.inv** (see Part 2) contains the expedition code, section number, station number, cast number, sampling date (i.e., month, day, and year), sampling time, latitude, longitude, and bottom depth for each station.

3.1 Hydrographic Measurements

All CTD pressure, temperature, salinity, and oxygen values for the bottle data tabulations were obtained by averaging CTD data for a brief interval at the time the bottle was closed on the rosette. All reported CTD values were calibrated with reference to the International Temperature Scale of 1990 and processed with the methodology described in the documentation accompanying the final CTD data report for the TUNES-1 Expedition. The full cruise report, that includes details about processing the hydrographic data, and the final CTD data are available from the WOCE Hydrographic Programme (WHP) Office (WHPO) or the WHP Special Analysis Center.

Salinity samples were drawn into 200-mL Kimax high-alumina borosilicate glass bottles with custom-made plastic insert thimbles and Nalgene screw caps, which provided low container dissolution and sample evaporation. These bottles were rinsed three times before filling, and measurements were usually made within 8–36 h after collection. Salinity was determined on the basis of electrical conductivity measured by an SIO Oceanographic Data Facility (ODF)-modified Guildline Autosal Model 8400A salinometer, and the values were obtained according to the equations of the Practical Salinity Scale of 1978 (UNESCO 1981). The salinometer was standardized against Wormley P-114 standard seawater, with at least one fresh vial opened per cast. Accuracy estimates of bottle salinities run at sea are usually better then 0.002 relative to the specified batch of standard. Although laboratory precision of the Autosal can be as small as 0.0002 when running replicate samples under ideal conditions, at sea the expected precision was ~0.001 under normal conditions with a stable laboratory temperature.

Samples were collected for dissolved oxygen analyses soon after the rosette sampler was brought on board and after CFC and helium were drawn. Nominal 100- or 125-mL volume iodine flasks were carefully rinsed with minimal agitation, then filled through the use of a drawing tube, and allowed to overflow for at least two flask volumes. Reagents were added to fix the oxygen before stoppering. The flasks were shaken twice — immediately after drawing and then again after 20 min — to ensure thorough dispersion of the $Mn(OH)_2$ precipitate. The samples were analyzed within 4–36 h.

Dissolved oxygen samples were titrated in the volume-calibrated iodine flasks with a 1-mL microburet, using the whole-bottle Winkler titration following the technique of Carpenter (1965) with modifications by Culberson and Williams (1991). Standardizations were performed with 0.01 N potassium iodate solutions prepared from preweighed potassium iodate crystals. Standards were run at the beginning of each session of analyses, which typically included from one to three stations. Several standards were prepared. A comparison was then made to ensure that the results were reproducible and to preclude basing the entire cruise on one standard, which would introduce the possibility of a weighing error. A correction was made for the amount of oxygen added with the reagents. Combined reagent/seawater blanks were determined to account for oxidizing or reducing materials in the reagents and for a nominal level of natural iodate or other oxidizers/reducers in the seawater. These latter corrections are contrary to the recommendations of Culberson and Williams (1991), which call for the determination of reagent blanks in distilled water. ODF standard procedures have since been aligned with those recommended by Culberson and Williams (1991).

Oxygen concentrations were converted from milliliters per liter to micromoles per kilogram using the in situ temperature. Ideally, for whole-bottle titrations, the conversion temperature should be the temperature of the water issuing from the Niskin bottle spigot. The temperature of each sample was measured at the time it was drawn from the bottle; however, these values were not used in the conversion from milliliters per liter to micromoles per kilogram because the software was not available. Aberrant temperatures provided an additional flag, indicating that a bottle may not have tripped properly. Measured sample temperatures from middeep water samples were about 4–7°C warmer than the in situ temperature. Converted oxygen values, if this conversion with the measured sample temperature were made, would be about 0.08% higher for a 6°C warming (or about 0.2 μm/kg for a 250 μm/kg sample).

Analyses of nutrients (i.e., phosphate, silicate, nitrate, and nitrite), reported in micromoles per kilogram, were performed on a Technicon AutoAnalyzer®. The procedures used are described in Atlas et al. (1971). Standardizations were performed with solutions prepared aboard ship from preweighed standards; these solutions were used as working standards before and after each cast (approximately 36 samples) to correct for instrumental drift during analyses. Sets of 4–6 different concentrations of shipboard standards were analyzed periodically to determine the linearity of colorimetric response and the resulting correction factors. Hydrazine reduction of phosphomolybdic acid was used for phosphate analysis, while stannous chloride reduction of silicomolybdic acid was used for silicate analysis. Nitrite was analyzed by using diazotization and coupling to form dye; nitrate was reduced by copperized cadmium and then analyzed as nitrite.

Sampling for nutrients followed that for the tracer gases, CFCs, helium, tritium, $\Delta^{14}C$, dissolved oxygen, TCO_2, and TALK. Samples were drawn into narrow-mouth, screw-capped bottles of high-density polyethylene, which were rinsed twice before filling. The samples may have been refrigerated at 2–6°C for a maximum of 15 h. Nutrients were converted from micromoles per liter to micromoles per kilogram by dividing by sample density which was calculated at an assumed laboratory temperature of 25°C.

3.2 Chlorofluorocarbons Measurements

The concentrations of dissolved atmospheric chlorofluorocarbons, CFC-11 and CFC-12, were measured by shipboard electron-capture gas chromatography via methods similar to those described by Bullister and Weiss (1988). The measurements were done by the University of Miami group, P.I. Dr. Rana A. Fine, under the analytical direction of Kevin F. Sullivan. A total of 1628 water samples were analyzed from 79 of 124 stations and included eight pairs of duplicate water samples. The mean values of duplicate analyses are reported in the data file and are assigned a quality byte of 6.

Several times during the cruise, problems with the analytical system required extensive downtime. If samples were drawn but not analyzed, and the downtime exceeded 8 hours, some or all of these samples were discarded and fresh samples were drawn on the current station. This situation occurred after stations 16 and 24. In accordance with WHP protocol, the value for these samples has been reported as -999.900 and they have been assigned a quality byte of 5.

Occasionally after a routine analysis, the CFC values were clearly inappropriate based on the depth at which the Niskin was tripped. Other measured quantities showed unusual results on some of these occasions. Rather than discard these data, we are reporting their values and have assigned a data quality byte of 4.

The concentrations of the CFCs in air and water were calculated using external gaseous standards. The gaseous and aqueous analyses were first corrected for any signal due to the analytical system using a weighted average of the four surrounding appropriate blank analyses. The average gaseous blank value was $7.32e^{-6}$ picomole (pM) for CFC-12 and $3.16e^{-5}$ pM for CFC-11. The average aqueous blank value was $1.44e^{-5}$ pM for CFC-12 and $9.94e^{-5}$ pM for CFC-11.

The temporal variation of the detector was compensated for by calculating a normalization factor for each analysis. Equations that closely resemble straight lines were fit to groupings of normalized standard analyses to yield calibration curves. These calibration curves were applied to the sample analyses to result in the concentrations of the CFCs.

After the water concentrations were calculated, a final correction was applied. This correction was estimated from the samples collected in waters that were very likely free of CFCs and was to compensate for any trace CFCs originating from the sampling bottles and/or handling. The bottle blanks decreased during the cruise; therefore, different bottle blanks for each Niskin were estimated for sequential ranges of stations. For the 36 Niskins during the entire cruise the applied bottle blanks averaged 0.0016 pM/kg for CFC-12 and 0.0033 pM/kg for CFC-11. If the bottle blank was greater than the measured concentration, a negative concentration is reported in the data file.

The precision of the water analyses can be estimated from the results of duplicate syringes drawn on the same Niskin. For eight pairs of duplicate syringes the average percent standard deviation for all the pairs was 1.66% for CFC-12 and 0.68% for CFC-11. For the samples greater than 0.1 pM/kg, the average percent standard deviation was 1.28% for CFC-12 (n=4) and 0.33% for CFC-11 (n=5).

3.3 Radiocarbon Measurements

During the planning phase of WOCE, the accelerator mass spectrometry (AMS) technique for measuring ^{14}C was still relatively new in the United States. The general procedures had been worked out; however, no laboratory was prepared to handle the large number of samples expected from the WOCE program, nor had it been demonstrated that the AMS technique could deliver the required precision on a routine basis. The National Ocean Sciences AMS Facility (NOSAMS) at WHOI was established in 1989 to serve this purpose. In planning the WOCE Pacific field work, it was recognized that sample collection would begin well before NOSAMS could deliver the high precision offered by conventional beta counting techniques. Therefore, both techniques were utilized.

On those WOCE legs that included both large-volume (LV) and small-volume (SV) sampling, the LV stations were spaced at an average interval of once every five degrees (~300 nautical miles). LV stations normally included two casts of nine Gerard barrels each, covering the water column from ~1000 m to the bottom. The upper kilometer of a LV station was covered by 16 SV samples taken from the CTD/rosette cast. One to three SV stations were placed between each LV station. At SV stations, only the upper thermocline region was sampled. Sixteen SV samples were taken at these stations.

Radiocarbon was extracted from the LV samples at sea as $^{14}CO_2$, absorbed on excess NaOH and returned to shore in well-sealed glass bottles using a modification of the technique described by Fonselius and Östlund (1959). Once ashore the samples were sent to researches at one of two laboratories for analysis: G. Östlund, Tritium Laboratory, University of Miami, Miami; or M. Stuiver, Quaternary Isotope Laboratory, University of Washington, Seattle. A short description of the measurement procedure and a cross-check between these two laboratories are available in Stuiver et al. (1974). Stuiver reports an error estimate for each analysis that ranges from 2.5 to 4.0 per mille (‰), while Östlund reports a uniform sample error of 4‰. In both cases the reported uncertainty is primarily counting error and does not include any error due to sample collection.

All SV ^{14}C samples were collected from standard CTD/rosette casts into 500-mL glass bottles fitted with high-quality ground-glass stoppers. The samples were poisoned with $HgCl_2$ immediately after collection and then returned to the United States for extraction and analysis at NOSAMS. Details of the extraction, counting, etc., are available from Key (1991), McNichol and Jones (1991), Gagnon and Jones (1993), and Cohen et al. (1994). The standard used for the ^{14}C measurements is the National Bureau of Standards oxalic acid standard for radiocarbon dating. All results are reported as $\Delta^{14}C$, which is the deviation (in ‰) from unity of the activity ratio of sample to standard, isotope corrected to a sample $\delta^{13}C$ value of -25‰, where $\delta^{13}C$ was calculated from

$$\delta^{13}C = 1000 \times \frac{\left(\frac{^{13}C}{^{12}C}\right)_{sample} - \left(\frac{^{13}C}{^{12}C}\right)_{reference}}{\left(\frac{^{13}C}{^{12}C}\right)_{reference}},$$

to correct for fractionation and dilution by anthropogenic CO_2. For more information on standards and calculation methods, refer to the papers by Broecker and Olson (1961), Stuiver and Robinson (1974), and Stuiver (1980). As measurements were completed, the results were communicated from the analytical laboratory to the principal investigator responsible for the cruise via periodic data reports. R. Key gathered the $\Delta^{14}C$ data; merged it with hydrographic data supplied by either the chief scientist or WHPO; added WOCE quality-control flags; and finally submitted the data to

WHPO along with a final report for the WOCE Section P17C, Cruise TUNES, Leg 1 (Key, 1996a, b). All of the LV samples collected in the Pacific Ocean will be processed by 1997, and the Pacific SV samples will be completed by 1998.

During the GEOSECS Program, the precision of the LV technique was established as 2–4‰. This precision is primarily a function of sample counting time and has remained constant throughout the succeeding large-scale ocean-survey programs. At the beginning of WOCE, the ultimate precision of the AMS technique and the degree of compatibility of the AMS and LV data (i.e., the absence of systematic errors in either data set) were unknown. NOSAMS is currently processing water samples with a mean "external" precision of 3.6‰. This degree of precision is indicative of the AMS target preparation and counting and does not include any uncertainty resulting from sample collection, storage, or stripping. A better estimate of the sample precision can be obtained by comparing the results from duplicate samples. A summary of all the true WOCE duplicates (i.e., two different sample bottles rather than two analyses from the same bottle) analyzed at NOSAMS through mid-1996 shows that the average standard deviation for the pairs was 4.6‰. The reason for the difference between this number and the external precision estimate (3.6‰) is currently unknown; however, it is attributed to either sample collection or sample processing prior to counting. Sample storage experiments at NOSAMS and other facilities have so far indicated that this is not a source of error. A reproducibility of 3‰ is needed for the AMS technique to be equivalent to the average uncertainty for the LV technique.

3.4 Total CO_2 Measurements

During the TUNES-1 Expedition, 1022 seawater samples were analyzed for TCO_2 concentrations in seawater. The sampling frequency for measurements of the carbonate parameters was reduced to a complete depth profile (36 samples) at approximately every third hydrographic station (Fig. 2). This reduction in sampling was implemented not on the basis of any prearranged geophysical criterion but to accommodate the time constraints of the two analysts on board who performed CO_2 sampling and measurements. In other words, the CO_2 sampling strategy adopted was to measure as many samples as was technically and humanly possible.

For TCO_2 measurements, the seawater samples were drawn into 250-mL standard borosilicate glass, screw-cap bottles, poisoned with 50 μL of a saturated solution of mercuric chloride ($HgCl_2$), stored at room temperature, and analyzed on board (generally within 18 h). TCO_2 concentration was measured by semiautomated coulometry, using an improved version of the instrument earlier described by Johnson et al. (1985, 1987). This early "SOMMA-type" system did not have gas loops for calibration. Consequently, plans were to calibrate the system with standard solutions prepared as described in Goyet and Hacker (1992); however, these standard solutions could not be prepared on board during the cruise. The certified reference materials were used as standards to calibrate the TCO_2 extraction/coulometer system. The latter worked consistently well throughout the cruise. Precision of the measurements was estimated to be better than ±3 μmol/kg; the desired accuracy was better than ±4 μmol/kg.

The automated coulometric system forced the sample into the pipette using a pressurized headspace gas. Pure nitrogen (N_2) headspace gas was used for measurements of standards, and CO_2 headspace gas (290 ppm in air) was used for measurements of seawater samples. The volume of the pipette was calibrated with distilled water and seawater (volume was ~30 mL, depending on the individual pipette used), and there was no significant difference in the delivery volume as a result of possible differences in surface tension at different salinities. The sample was drained from the pipette into a stripper containing 1.5 mL of 8.5% phosphoric acid.

This chamber and the added acid were purged of any CO_2 with pure N_2 carrier gas before the sample was added. In the stripper, the CO_2 gas was extracted from the acidified sample by a continuous flow of pure N_2 gas through a frit at the bottom of the stripper. The gas (mainly CO_2, N_2, and water vapor) was passed through a condenser thermostated with 4°C water and magnesium perchlorate [$Mg(ClO_4)_2$] to remove water vapor. It was then passed through silica gel to remove residual aerosols and traces of hydrogen sulfide (H_2S) and phosphoric acid (H_3PO_4) before being bubbled into a commercially available coulometric solution containing ethanolamine [$NH_2(CH_2)_2OH$], dimethyl sulfoxide [$(CH_3)_2SO$], and thymolphthalein dye (made by UIC, Inc., Joliet, Illinois). A coil made from glass tubing with thermostated water flowing through it was placed in the cell to maintain the solution at 24°C. The pH of the solution was monitored on total CO_2 coulometer (UIC, Inc.) by monitoring the thymolphthalein-absorbance indicator at ~610 nm. Hydroxide (OH^-) ions were generated by the coulometer circuitry to maintain absorbance of the solution at a constant value. The analytical procedure was controlled by a microcomputer that also recorded the coulometric titration and computed the total CO_2 extracted from the sample based on the amount of OH^- generated to reach the endpoint.

3.5 Total Alkalinity Measurements

TALK samples were collected in 250-mL standard borosilicate glass, screw-cap bottles and poisoned with 50 μL of saturated $HgCl_2$ solution. The samples were stored at room temperature and measured on board, generally within 18 h. TALK was determined by potentiometric titration; the method used was derived from one first described by Dyrssen (1965) and later modified by Bradshaw et al. (1981). The automated titration was performed in a closed cell maintained at constant temperature (25 ± 0.1°C); the ionic strength of the hydrochloric acid solution (0.1 N) was adjusted with NaCl to increase its similarity to seawater. The ratio of the acid normality to the cell volume was calibrated before and after the sample analysis. Calibration consisted of preparing solutions of known TALK concentration and measuring them as described by Brewer et al. (1986). The precision of the measurements was estimated to be better than 0.1%.

3.6 Shore-Based Replicate Measurements

The replicate samples from 56 Niskin bottles at 18 stations were collected for shore-based reference analyses at the laboratory of C. D. Keeling of SIO. The TCO_2 measurements were produced by vacuum-extraction/manometric analysis, and the TALK values, by potentiometric titration. Both measurements were performed under controlled laboratory conditions using standards. The replicate sample standard deviation (s) for this large data set of 50 unflagged pairs is 1.9 μmol/kg after the three replicate pairs with deltas greater then $3s$ (a replicate sample standard deviation calculated from the set of analyses on duplicate samples) were omitted (Guenther et al. 1994). Figure 3 displays the performance of the replicate sampling program during TUNES Leg 1 for a subset of all data including only near surface (0–10 m) and deep (~3000 m) data. Two data points with replicate sample singlets are omitted, as well as one with a ship-minus-shore difference of −30.6 μmol/kg and one with a replicate delta greater then 4.0 μmol/kg (Guenther et al. 1994).

For the 17 comparisons, the replicate s is 0.9 μmol/kg, similar to the s calculated for the entire data set. Figure 3 illustrates that the near-surface data are in better agreement than the deep data. Because 12 of the 17 comparisons are between values for surface data, their better agreement weighs the subset and produces lack of agreement with the entire data set. Figure 3 illustrates better performance of the replicate sampling program at the onset of TUNES-1, with more *scatter of the* data evident towards the end of the leg (Guenther et al. 1994).

Tables 1 and 2, reprinted from Guenther et al. 1994, summarize the replicate shore-based measurements of TCO_2 and TALK and their comparisons with shipboard measurements.

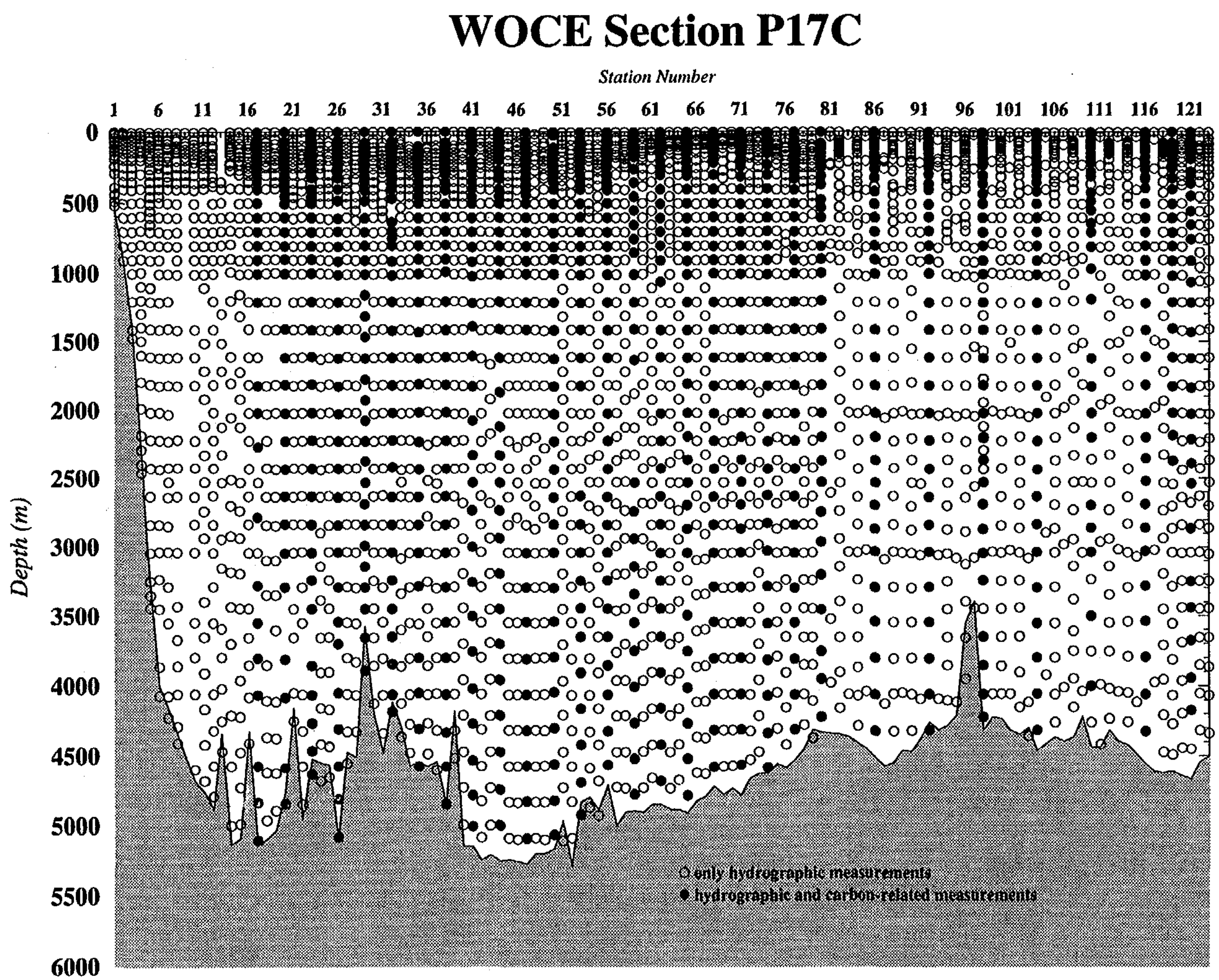

Figure 2. Sampling depths at all hydrographic stations occupied during R/V *Thomas Washington* TUNES-1 Expedition.

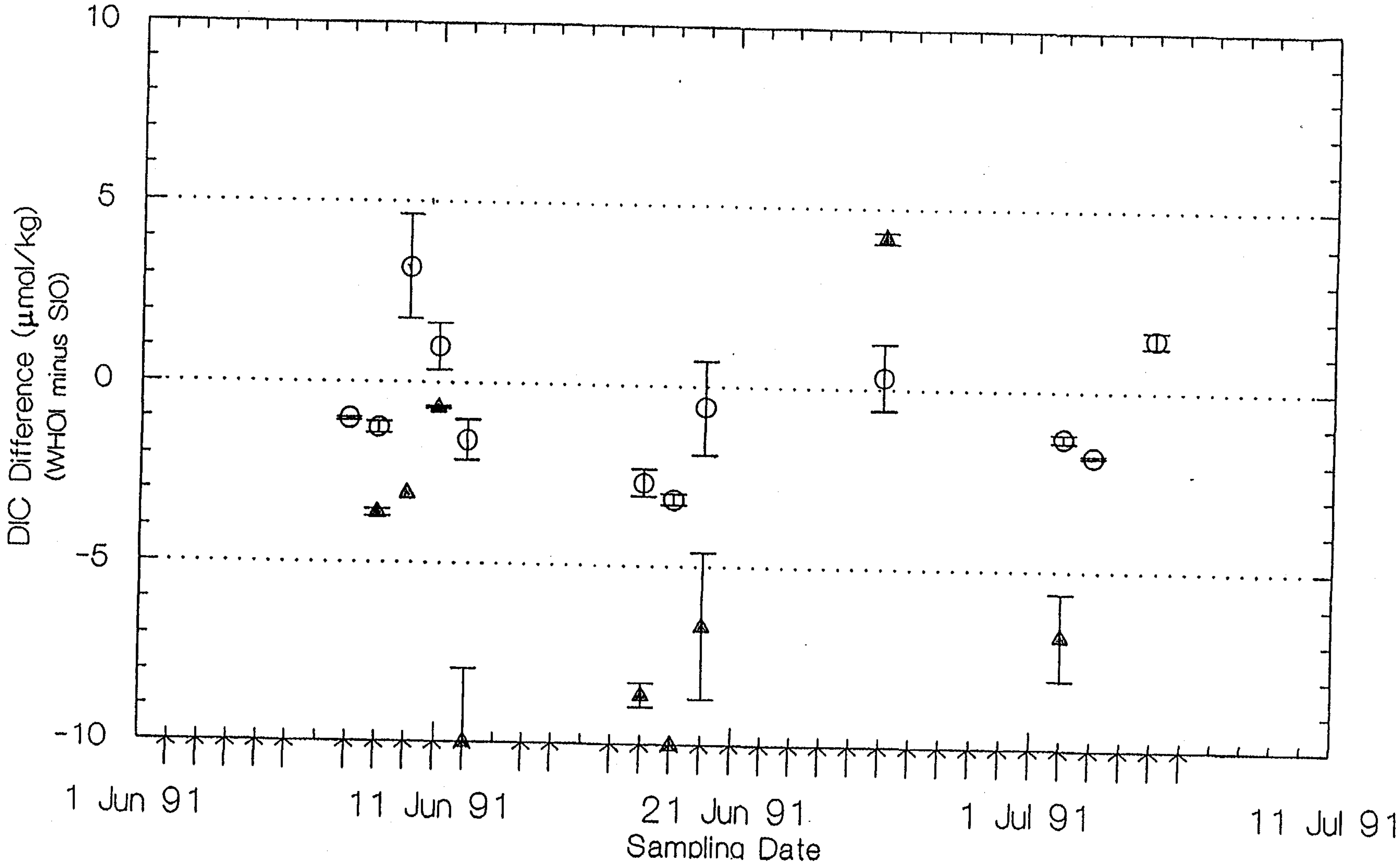

Fig. 3. Shipboard minus shore-based TCO_2 measurements vs date of surface and deep samples. Open circles represent near-surface samples; shaded triangles represent deep samples; vertical bracketed lines represent replicate pair deltas; and arrows indicate dates replicate samples were collected.

Table 1. Summary of TCO_2 replicate data collected during R/V *Thomas Washington* TUNES-1 Expedition

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1   1991 Pacific WOCE Line P17C

SUMMARY OF DISSOLVED INORGANIC CARBON DATA

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	EXTRAC DATE	ANALYSIS DATE	MANO TYPE	SAMPLE BOTTLE	RUN	FLAG	S.I.O. RUN	RUN DELTA	BOTTLE DIC	BOTTLE DELTA	"NISKIN" AVG	WHOI DIC	WHOI -S.I.O.
												(µMOLES/KG SW)						
1	35-33N	1	1	1	03JUN91	20AUG91	22AUG91	S	S3750	001		1982.51		1982.51				
5	122-52W					21AUG91	22AUG91	S	S3751	001		1983.22		1983.22	+0.71	1982.86		
1	34-49N	1	1	1	04JUN91	21AUG91	22AUG91	S	S3772	001		1984.63		1984.63				
8	124-35W					22AUG91	22AUG91	S	S3773	001		1982.71		1982.71	-1.92	1983.67		
		1	3	66		21AUG91	22AUG91	S	S3770	001		2027.65		2027.65				
						21AUG91	22AUG91	S	S3771	001		2028.92		2028.92	+1.27	2028.29		
1	34-35N	1	29	2896	05JUN91	22AUG91	28AUG91	S	S3774	001		2377.63		2377.63		2377.63		
11	127-38W																	
1	34-35N	1	1	2	07JUN91	22AUG91	28AUG91	S	S3781	001		1993.44		1993.44				
14	131-19W					23AUG91	28AUG91	S	S3782	001		1986.40		1986.40	-7.04	1989.92		
1	34-36N	2	1	1	08JUN91	09SEP91	12SEP91	S	S3806	001		1988.39		1988.39				
17	134-58W					10SEP91	12SEP91	S	S3807	001		1988.47		1988.47	+0.08	1988.43	1987.4	-1.03
		2	2	52		10SEP91	12SEP91	S	S3804	001		1982.28		1982.28				
						09SEP91	12SEP91	S	S3805	001		1984.65		1984.65	+2.37	1983.47	1982.5	-0.97
		2	4	98		09SEP91	12SEP91	S	S3802	001		1993.50		1993.50		1993.50	1975.9	-17.60
		2	8	201		29AUG91	29AUG91	S	S3800	001		2098.60		2098.60				
						29AUG91	29AUG91	S	S3801	001		2107.24		2107.24	+8.64	2102.92	2096.8	-6.12
		2	10	300		28AUG91	29AUG91	S	S3798	001		2179.95		2179.95				
						28AUG91	29AUG91	S	S3799	001		2180.55		2180.55	+0.60	2180.25	2177.6	-2.65
		2	12	401		26AUG91	29AUG91	S	S3796	001		2235.29		2235.29				
						26AUG91	29AUG91	S	S3797	001		2234.32		2234.32	-0.97	2234.81	2225.6	-9.21
		2	14	601		26AUG91	28AUG91	S	S3794	001		2309.78		2309.78				
						26AUG91	29AUG91	S	S3795	001		2311.76		2311.76	+1.98	2310.77	2302.8	-7.97
		2	17	899		26AUG91	28AUG91	S	S3792	001		2365.29		2365.29				
						26AUG91	28AUG91	S	S3793	001		2367.90		2367.90	+2.61	2366.59	2351.1	-15.49
		2	19	1200		23AUG91	28AUG91	S	S3790	001		2373.67		2373.67				
						23AUG91	28AUG91	S	S3791	001		2373.97		2373.97	+0.30	2373.82		
		2	21	1600		23AUG91	28AUG91	S	S3788	001		2377.93		2377.93				
						23AUG91	28AUG91	S	S3789	001		2386.04		2386.04	+8.11	2381.99		

MANOMETER TYPE:
S = QUARTZ SPIRAL MANOMETER DATUM
M = CONSTANT VOLUME MERCURY MANOMETER DATUM
BOTTLE TYPE:
R = RODAVISS   S = S TYPE

FLAGS:
F: No Hg found in bottle
G: Severe bottle leak
EX: Data excluded from analysis

Table 1 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1 1991 Pacific WOCE Line P17C

SUMMARY OF DISSOLVED INORGANIC CARBON DATA (cont)

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	EXTRAC DATE	ANALYSIS DATE	MANO TYPE	SAMPLE BOTTLE	RUN	FLAG	S.I.O. RUN	RUN DELTA	BOTTLE DIC	BOTTLE DELTA	"NISKIN" AVG	WHOI DIC	WHOI -S.I.O.
												(µMOLES/KG SW)						
1	33- 4N	1	1	1	09JUN91	20SEP91	26SEP91	S	S3810	001		2002.42		2002.42				
20	135-00W					20SEP91	26SEP91	S	S3811	001		2002.10		2002.10	-0.32	2002.26	2001.0	-1.26
		1	28	2798		17SEP91	20SEP91	S	S3808	001		2362.65		2362.65				
						19SEP91	20SEP91	S	S3809	001		2362.85		2362.85	+0.20	2362.75	2359.1	-3.65
1	31-32N	1	1	0	10JUN91	24SEP91	26SEP91	S	S3814	001		2007.87		2007.87				
23	135- 0W					24SEP91	26SEP91	S	S3815	001		2010.70		2010.70	+2.83	2009.29	2012.5	3.21
		1	28	3003		24SEP91	26SEP91	S	S3813	001		2356.61		2356.61		2356.61	2353.5	-3.11
1	30- 2N	2	1	1	11JUN91	19AUG91	22AUG91	S	R4478	001		2021.92		2021.92				
26	134-57W					19AUG91	22AUG91	S	R4479	001		2020.63		2020.63	-1.29	2021.28	2022.3	1.02
		2	2	64		09AUG91	12AUG91	S	R4476	001		2031.34		2031.34				
						09AUG91	12AUG91	S	R4477	001		2027.18		2027.18	-4.16	2029.26	2020.8	-8.46
		2	4	109		08AUG91	12AUG91	S	R4474	001		2032.43		2032.43				
						08AUG91	12AUG91	S	R4475	001		2030.79		2030.79	-1.64	2031.61	2021.7	-9.91
		2	7	206		06AUG91	07AUG91	S	R4472	001		2044.07		2044.07				
						08AUG91	12AUG91	S	R4473	001		2043.64		2043.64	-0.43	2043.85	2041.7	-2.15
		2	10	324		06AUG91	07AUG91	S	R4470	001		2099.91		2099.91				
						06AUG91	07AUG91	S	R4471	001		2099.87		2099.87	-0.04	2099.89	2099.3	-0.59
		2	11	400		05AUG91	07AUG91	S	R4468	001	EX	2166.40						
						05AUG91	07AUG91	S	R4469	001		2149.91		2149.91		2149.91	2146.1	-3.81
		2	13	606		05AUG91	07AUG91	S	R4466	001		2283.85		2283.85				
						05AUG91	07AUG91	S	R4467	001		2284.53		2284.53	+0.68	2284.19	2282.1	-2.09
		2	16	909		26SEP91	26SEP91	S	S3824	001		2354.87		2354.87				
						26SEP91	26SEP91	S	S3825	001		2354.57		2354.57	-0.30	2354.72	2351.5	-3.22
		2	18	1202		27SEP91	02OCT91	S	S3822	001		2374.15		2374.15				
						27SEP91	02OCT91	S	S3823	001		2370.18		2370.18	-3.97	2372.17	2365.6	-6.57
		2	20	1605		25SEP91	26SEP91	S	S3820	001		2372.06		2372.06				
						27SEP91	02OCT91	S	S3821	001		2371.81		2371.81	-0.25	2371.94	2368.7	-3.24

MANOMETER TYPE:
S = QUARTZ SPIRAL MANOMETER DATUM
M = CONSTANT VOLUME MERCURY MANOMETER DATUM
BOTTLE TYPE:
R = RODAVISS S = S TYPE

FLAGS:
F: No Hg found in bottle
G: Severe bottle leak
EX: Data excluded from analysis

Table 1 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1   1991 Pacific WOCE Line P17C

SUMMARY OF DISSOLVED INORGANIC CARBON DATA (cont)

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	EXTRAC DATE	ANALYSIS DATE	MANO TYPE	SAMPLE BOTTLE	RUN	FLAG	S.I.O. RUN	RUN DELTA	BOTTLE DIC	BOTTLE DELTA	"NISKIN" AVG	WHOI DIC	WHOI -S.I.O.
												(µMOLES/KG SW)						
1	30- 2N	2	22	2007	11JUN91	25SEP91	26SEP91	S	S3818	001		2366.87		2366.87				
26	134-57W					26SEP91	26SEP91	S	S3819	001		2372.19		2372.19	+5.32	2369.53	2366.7	-2.83
		2	27	3000		25SEP91	26SEP91	S	S3816	001		2356.27		2356.27				
						25SEP91	26SEP91	S	S3817	001		2356.34		2356.34	+0.07	2356.31	2355.6	-0.71
1	28-30N	1	1	1	12JUN91	20AUG91	22AUG91	S	R4482	001		2021.52		2021.52				
29	135-00W					20AUG91	22AUG91	S	R4483	001		2022.63		2022.63	+1.11	2022.08	2020.5	-1.58
		1	31	2951		20AUG91	22AUG91	S	R4480	001		2382.18		2382.18				
						20AUG91	22AUG91	S	R4481	001		2378.02		2378.02	-4.16	2380.10	2349.5	-30.60
1	19-30N	1	1	0	18JUN91	10SEP91	12SEP91	S	R4486	001		1979.78		1979.78				
47	135- 0W					10SEP91	13SEP91	S	R4487	001		1979.01		1979.01	-0.77	1979.40	1976.7	-2.70
		1	27	3005		10SEP91	12SEP91	S	S3884	001		2350.86		2350.86				
						10SEP91	12SEP91	S	S3885	001		2351.54		2351.54	+0.68	2351.20	2342.6	-8.60
1	18- 0N	1	1	0	19JUN91	11SEP91	13SEP91	S	R4490	001		1950.81		1950.81				
50	135- 0W					11SEP91	13SEP91	S	R4491	001		1951.11		1951.11	+0.30	1950.96	1947.8	-3.16
		1	27	2999		11SEP91	13SEP91	S	R4488	001		2368.76		2368.76		2368.76	2347.1	-21.66
1	16-30N	1	1	0	20JUN91	02OCT91	02OCT91	S	S3894	001		1944.28		1944.28				
53	135- 0W					04OCT91	10OCT91	S	S3895	001		1946.88		1946.88	+2.60	1945.58	1945.0	-0.58
		1	2	50		01OCT91	02OCT91	S	S3892	001		1944.71		1944.71				
						01OCT91	02OCT91	S	S3893	001		1943.80		1943.80	-0.91	1944.26	1943.7	-0.56
		1	4	112		30SEP91	02OCT91	S	S3890	001		2018.80		2018.80				
						30SEP91	02OCT91	S	S3891	001		2018.45		2018.45	-0.35	2018.63	2017.3	-1.33
		1	8	188		30SEP91	02OCT91	S	S3888	001		2159.93		2159.93				
						30SEP91	02OCT91	S	S3889	001		2160.18		2160.18	+0.25	2160.05	2159.1	-0.95
		1	10	300		26SEP91	02OCT91	S	S3886	001		2261.14		2261.14				
						27SEP91	02OCT91	S	S3887	001		2260.40		2260.40	-0.74	2260.77	2259.3	-1.47
		1	12	402		19SEP91	20SEP91	S	R4504	001		2287.13		2287.13				
						19SEP91	20SEP91	S	R4505	001		2284.44		2284.44	-2.69	2285.78	2281.5	-4.28

MANOMETER TYPE:
S = QUARTZ SPIRAL MANOMETER DATUM
M = CONSTANT VOLUME MERCURY MANOMETER DATUM
BOTTLE TYPE:
R = RODAVISS   S = S TYPE

FLAGS:
F: No Hg found in bottle
G: Severe bottle leak
EX: Data excluded from analysis

Table 1 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1   1991 Pacific WOCE Line P17C

SUMMARY OF DISSOLVED INORGANIC CARBON DATA (cont)

Units for S.I.O. RUN through WHOI -S.I.O.: (µMOLES/KG SW)

LEG STN	LAT. LONG.	CAST NISK	DEPTH (M)	SAMPLE DATE	EXTRAC DATE	ANALYSIS DATE	MANO TYPE	SAMPLE BOTTLE	RUN	FLAG	S.I.O. RUN	RUN DELTA	BOTTLE DIC	BOTTLE DELTA	"NISKIN" AVG	WHOI DIC	WHOI -S.I.O.
1	16-30N	1 14	597	20JUN91	18SEP91	20SEP91	S	R4502	001		2314.33		2314.33				
53	135- 0W				18SEP91	20SEP91	S	R4503	001		2316.53		2316.53	+2.20	2315.43	2306.8	-8.63
		1 17	904		17SEP91	20SEP91	S	R4500	001		2343.16		2343.16				
					17SEP91	20SEP91	S	R4501	001		2342.63		2342.63	-0.53	2342.90	2337.4	-5.50
		1 19	1205		16SEP91	20SEP91	S	R4498	001		2360.09		2360.09				
					17SEP91	20SEP91	S	R4499	001		2359.18		2359.18	-0.91	2359.64	2350.7	-8.94
		1 21	1602		13SEP91	13SEP91	S	R4496	001		2369.00		2369.00		2369.00	2359.2	-9.80
		1 23	2008		13SEP91	13SEP91	S	R4494	001		2368.43		2368.43				
					13SEP91	13SEP91	S	R4495	001		2367.86		2367.86	-0.57	2368.15		
		1 28	3000		12SEP91	13SEP91	S	R4492	001		2357.88		2357.88				
					13SEP91	13SEP91	S	R4493	001		2353.83		2353.83	-4.05	2355.85	2349.2	-6.65
1	6- 0N	1 1	-1	26JUN91	05DEC91	05DEC91	M	R4522	001		1914.53		1914.53				
74	135-00W				05DEC91	12DEC91	S	R4522	001		1915.16		1915.16				
					05DEC91	06DEC91	M	R4523	001		1916.39		1916.39	+1.86	1915.46	1915.8	0.34
					05DEC91	12DEC91	S	R4523	001		1916.71		1916.71	+1.55	1915.94	1915.8	-0.14
		1 29	2992		05DEC91	05DEC91	M	R4520	001		2353.96		2353.96				
					05DEC91	09DEC91	S	R4520	001		2353.74		2353.74				
					05DEC91	05DEC91	M	R4521	001		2354.24		2354.24	+0.28	2354.10	2358.3	4.20
					05DEC91	09DEC91	S	R4521	001		2354.81		2354.81	+1.07	2354.28	2358.3	4.02
1	1-00S	1 1	0	03JUL91	09DEC91	10DEC91	M	S3986	001		2017.01		2017.01				
104	135- 0W				09DEC91	13DEC91	S	S3986	001		2017.31		2017.31				
					09DEC91	10DEC91	M	S3987	001		2016.77		2016.77	-0.24	2016.89	2015.6	-1.29
					09DEC91	13DEC91	S	S3987	001		2016.76		2016.76	-0.55	2017.04	2015.6	-1.44
		1 30	2999		06DEC91	06DEC91	M	R4544	001		2340.10		2340.10				
					06DEC91	12DEC91	S	R4544	001		2339.57		2339.57				
					06DEC91	06DEC91	M	R4545	001		2342.51		2342.51	+2.41	2341.31	2334.5	-6.81
					06DEC91	12DEC91	S	R4545	001		2342.36		2342.36	+2.79	2340.97	2334.5	-6.47
1	1-58S	1 30	2998	04JUL91	06DEC91	06DEC91	M	S3988	001		2332.03		2332.03				
110	135- 0W				06DEC91	12DEC91	S	S3988	001		2331.71		2331.71				
					06DEC91	06DEC91	M	S3989	001		2331.95		2331.95	-0.08	2331.99	2330.2	-1.79
					06DEC91	12DEC91	S	S3989	001		2332.40		2332.40	+0.69	2332.05	2330.2	-1.85

MANOMETER TYPE:
S = QUARTZ SPIRAL MANOMETER DATUM
M = CONSTANT VOLUME MERCURY MANOMETER DATUM
BOTTLE TYPE:
R = RODAVISS   S = S TYPE

FLAGS:
F: No Hg found in bottle
G: Severe bottle leak
EX: Data excluded from analysis

Table 1 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1   1991 Pacific WOCE Line P17C

SUMMARY OF DISSOLVED INORGANIC CARBON DATA (cont)

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	EXTRAC DATE	ANALYSIS DATE	MANO TYPE	SAMPLE BOTTLE	RUN	FLAG	S.I.O. RUN (µMOLES/KG SW)	RUN DELTA (µMOLES/KG SW)	BOTTLE DIC (µMOLES/KG SW)	BOTTLE DELTA (µMOLES/KG SW)	"NISKIN" AVG (µMOLES/KG SW)	WHOI DIC (µMOLES/KG SW)	WHOI -S.I.O. (µMOLES/KG SW)
1	4-00S	1	1	0	05JUL91	10DEC91	10DEC91	M	S4019	001		2004.84		2004.84				
119	135- 0W					10DEC91	13DEC91	S	S4019	001		2006.22		2006.22				
						10DEC91	11DEC91	M	S4020	001		2004.38		2004.38	-0.46	2004.61	2006.1	1.49
						10DEC91	13DEC91	S	S4020	001		2006.65		2006.65	+0.43	2006.44	2006.1	-0.34
		1	29	3001		10DEC91	10DEC91	M	S4017	001		2329.60		2329.60				
						10DEC91	13DEC91	S	S4017	001		2328.97		2328.97				
						10DEC91	10DEC91	M	S4018	001		2327.62		2327.62	-1.98	2328.61		
						10DEC91	13DEC91	S	S4018	001		2327.83		2327.83	-1.14	2328.40		

MANOMETER TYPE:
S = QUARTZ SPIRAL MANOMETER DATUM
M = CONSTANT VOLUME MERCURY MANOMETER DATUM
BOTTLE TYPE:
R = RODAVISS   S = S TYPE

FLAGS:
F: No Hg found in bottle
G: Severe bottle leak
EX: Data excluded from analysis

NOTE: Dilution factor of 1.000170 has been applied.

Table 2. Summary of TALK replicate data collected during R/V *Thomas Washington* TUNES-1 Expedition

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1 1991 Pacific WOCE Line P17C

SUMMARY OF ALKALINITY DATA

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	ANALYSIS DATE	TITR SYST	SAMPLE BOTTLE	TRIAL	FLAG	S.I.O. TRIAL	TRIAL DELTA	BOTTLE ALK	BOTTLE DELTA	"NISKIN" AVG	WHOI ALK	WHOI -S.I.O.
											(µEQUIV/KG SW)						
1	35-33N	1	1	1	03JUN91	22AUG91	G	S3750	1		2204.15		2204.15				
5	122-52W					29AUG91	G	S3751	1		2205.13		2205.13	+0.98	2204.64		
1	34-49N	1	1	1	04JUN91	22AUG91	G	S3772	1	EX	2316.17						
8	124-35W					22AUG91	G	S3772	2		2209.65		2209.65				
						22AUG91	G	S3773	1		2203.60		2203.60	-6.05	2206.63		
		1	3	66		29AUG91	G	S3770	1		2220.45		2220.45				
						30AUG91	G	S3771	1		2219.65		2219.65	-0.80	2220.05		
1	34-35N	1	29	2896	05JUN91	30AUG91	G	S3774	1		2435.74		2435.74		2435.74		
11	124-35W																
1	34-35N	1	1	2	07JUN91	30AUG91	G	S3781	1		2218.35		2218.35				
14	131-19W					23AUG91	G	S3782	1		2217.58		2217.58	-0.77	2217.97		
1	34-36N	2	1	1	08JUN91	10SEP91	G	S3806	1		2220.01		2220.01				
17	134-58W					10SEP91	G	S3807	1		2218.75		2218.75	-1.26	2219.38	2240.88	21.50
		2	2	52		11SEP91	G	S3804	1	X	2222.88						
						09SEP91	G	S3805	1		2217.63		2217.63		2217.63	2228.51	10.88
		2	4	98		09SEP91	G	S3802	1		2223.61		2223.61				
						09SEP91	G	S3803	1		2222.49		2222.49	-1.12	2223.05		
		2	8	201		30AUG91	G	S3800	1		2228.37		2228.37				
						30AUG91	G	S3801	1		2224.11		2224.11	-4.26	2226.24	2237.92	11.68
		2	10	300		28AUG91	G	S3798	1		2265.57		2265.57				
						28AUG91	G	S3799	1		2266.51		2266.51	+0.94	2266.04	2285.16	19.12
		2	12	401		28AUG91	G	S3796	1		2285.54		2285.54				
						28AUG91	G	S3797	1		2281.77		2281.77	-3.77	2283.66		
		2	14	601		26AUG91	G	S3794	1		2315.58		2315.58				
						28AUG91	G	S3795	1	EX	2333.46						
						28AUG91	G	S3795	2	EX	2325.05				2315.58		
		2	17	899		26AUG91	G	S3792	1		2364.40		2364.40				
						26AUG91	G	S3793	1		2364.20		2364.20	-0.20	2364.30		
		2	19	1200		30AUG91	G	S3790	1		2398.41		2398.41				
						30AUG91	G	S3791	1		2390.65		2390.65	-7.76	2394.53		

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Table 2 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1 1991 Pacific WOCE Line P17C

SUMMARY OF ALKALINITY DATA (cont.)

LEG STN	LAT. LONG.	CAST	NISK	DEPTH (M)	SAMPLE DATE	ANALYSIS DATE	TITR SYST	SAMPLE BOTTLE	TRIAL	FLAG	S.I.O. TRIAL	TRIAL DELTA	BOTTLE ALK	BOTTLE DELTA	"NISKIN" AVG	WHOI ALK	WHOI -S.I.O.
											(µEQUIV/KG SW)						
1	34-36N	2	21	1600	08JUN91	30AUG91	G	S3788	1		2411.69		2411.69				
17	134-58W					30AUG91	G	S3789	1		2411.69		2411.69	+0.00	2411.69		
1	33- 4N	1	1	1	09JUN91	20SEP91	G	S3810	1		2248.16		2248.16				
20	135-00W					25SEP91	G	S3811	1		2247.08		2247.08	-1.08	2247.62	2257.66	10.04
		1	28	2798		17SEP91	G	S3808	1	EX	2432.87						
						19SEP91	G	S3809	1		2443.29		2443.29		2443.29		
1	31-32N	1	1	0	10JUN91	25SEP91	G	S3814	1		2271.47		2271.47				
23	135- 0W					25SEP91	G	S3815	1		2268.13		2268.13	-3.34	2269.80		
		1	28	3003		25SEP91	G	S3812	1		2433.30		2433.30				
						25SEP91	G	S3813	1		2433.64		2433.64	+0.34	2433.47		
1	30- 2N	2	1	1	11JUN91	20AUG91	G	R4478	1		2293.17		2293.17				
26	134-57W					20AUG91	G	R4479	1		2300.12		2300.12	+6.95	2296.65	2312.16	15.51
		2	2	64		09AUG91	G	R4476	1		2300.65		2300.65				
						13AUG91	G	R4477	1		2301.02		2301.02	+0.37	2300.83	2310.21	9.38
		2	4	109		09AUG91	G	R4474	1		2305.69		2305.69				
						12AUG91	G	R4475	1		2302.70		2302.70	-2.99	2304.20	2311.85	7.65
		2	7	206		06AUG91	G	R4472	1		2265.51		2265.51				
						09AUG91	G	R4473	1		2264.61		2264.61	-0.90	2265.06	2277.49	12.43
		2	10	324		06AUG91	G	R4470	1		2256.03		2256.03				
						06AUG91	G	R4471	1		2256.65		2256.65	+0.62	2256.34	2262.15	5.81
		2	11	400		12AUG91	G	R4468	1		2261.41		2261.41				
						12AUG91	G	R4469	1		2262.53		2262.53	+1.12	2261.97	2276.06	14.09
		2	13	606		05AUG91	G	R4466	1		2304.68		2304.68				
						06AUG91	G	R4467	1		2304.19		2304.19	-0.49	2304.44		
		2	16	909		30SEP91	G	S3824	2		2355.35		2355.35				
						26SEP91	G	S3825	1		2323.83		2323.83	-31.52	2339.59		
		2	18	1202		30SEP91	G	S3822	1		2393.21		2393.21				
						02OCT91	G	S3823	1		2385.28		2385.28	-7.93	2389.25		

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Table 2 (continued)

THE CARBON DIOXIDE PROJECT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
TUNES Leg 1 1991 Pacific WOCE Line P17C

SUMMARY OF ALKALINITY DATA (cont.)

LEG STN	LAT. LONG.	CAST NISK	DEPTH (M)	SAMPLE DATE	ANALYSIS DATE	TITR SYST	SAMPLE BOTTLE	TRIAL	FLAG	S.I.O. TRIAL	TRIAL DELTA	BOTTLE ALK	BOTTLE DELTA	"NISKIN" AVG	WHOI ALK	WHOI -S.I.O.
										(µEQUIV/KG SW)						
1	30- 2N	2 20	1605	11JUN91	26SEP91	G	S3820	1		2407.50		2407.50				
26	134-57W				01OCT91	G	S3821	1		2407.56		2407.56	+0.06	2407.53		
		2 22	2007		02OCT91	G	S3818	1		2414.88		2414.88				
					26SEP91	G	S3819	1		2417.05		2417.05	+2.17	2415.97		
		2 27	3000		25SEP91	G	S3816	1		2439.46		2439.46				
					25SEP91	G	S3817	1		2432.16		2432.16	-7.30	2435.81		
1	28-30N	1 1	1	12JUN91	21AUG91	G	R4482	1		2294.95		2294.95				
29	135-00W				21AUG91	G	R4483	1		2290.86		2290.86	-4.09	2292.91	2306.02	13.11
		1 31	2951		20AUG91	G	R4480	1		2442.89		2442.89				
					20AUG91	G	R4481	1	X	2432.56						
					21AUG91	G	R4481	2		2435.40		2435.40	-7.49	2439.15		
1	19-30N	1 1	0	18JUN91	10SEP91	G	R4486	1		2290.66		2290.66				
47	135- 0W				10SEP91	G	R4487	1		2294.47		2294.47	+3.81	2292.56	2298.90	6.34
		1 27	3005		10SEP91	G	S3884	1		2435.33		2435.33				
					10SEP91	G	S3885	1		2434.26		2434.26	-1.07	2434.80		
1	18- 0N	1 1	0	19JUN91	11SEP91	G	R4490	1		2269.78		2269.78				
50	135- 0W				11SEP91	G	R4491	1		2277.37		2277.37	+7.59	2273.58	2282.90	9.32
		1 27	2999		11SEP91	G	R4488	1		2396.89		2396.89				
					12SEP91	G	R4489	1		2393.93		2393.93	-2.96	2395.41		
1	16-30N	1 1	0	20JUN91	23OCT91	G	S3894	1		2272.47		2272.47				
53	135- 0W				23OCT91	G	S3895	1		2272.31		2272.31	-0.16	2272.39	2254.90	-17.49
		1 2	50		22OCT91	G	S3893	1		2270.20		2270.20		2270.20	2286.90	16.70
		1 4	112		02OCT91	G	S3890	1		2294.04		2294.04				
					22OCT91	G	S3891	1		2298.05		2298.05	+4.01	2296.05	2316.90	20.85
		1 8	188		01OCT91	G	S3888	1		2266.82		2266.82				
					02OCT91	G	S3889	1		2263.21		2263.21	-3.61	2265.02	2270.60	5.58
		1 10	300		01OCT91	G	S3886	1		2293.99		2293.99				
					02OCT91	G	S3887	1		2294.72		2294.72	+0.73	2294.35	2300.90	6.55
		1 12	402		19SEP91	G	R4504	1		2304.53		2304.53				
					19SEP91	G	R4505	1		2306.77		2306.77	+2.24	2305.65	2311.00	5.35

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TUNES Leg 1 1991 Pacific WOCE Line P17C

SUMMARY OF ALKALINITY DATA (cont.)

LEG STN	LAT. LONG.	CAST NISK	DEPTH (M)	SAMPLE DATE	ANALYSIS DATE	TITR SYST	SAMPLE BOTTLE	TRIAL	FLAG	S.I.O. TRIAL	TRIAL DELTA	BOTTLE ALK	BOTTLE DELTA	"NISKIN" AVG	WHOI ALK	WHOI -S.I.O.
										(µEQUIV/KG SW)						
1	16-30N	1 14	597	20JUN91	19SEP91	G	R4502	1		2328.49		2328.49				
53	135- 0W				19SEP91	G	R4503	1		2323.91		2323.91	-4.58	2326.20	2330.90	4.70
		1 17	904		17SEP91	G	R4500	1		2363.87		2363.87				
					17SEP91	G	R4501	1		2360.56		2360.56	-3.31	2362.22		
		1 19	1205		19SEP91	G	R4498	1		2370.66		2370.66				
					19SEP91	G	R4499	1		2377.91		2377.91	+7.25	2374.28		
		1 21	1602		18SEP91	G	R4496	1		2407.97		2407.97		2407.97		
		1 23	2008		13SEP91	G	R4494	1	EX	2428.50						
					18SEP91	G	R4494	2		2417.21		2417.21				
					17SEP91	G	R4495	1		2417.42		2417.42	+0.21	2417.31		
		1 28	3000		12SEP91	G	R4492	1		2424.59						
					13SEP91	G	R4492	2		2424.81	+0.22	2424.70				
					13SEP91	G	R4493	1		2439.80		2439.80	+15.10	2432.25		
1	6- 0N	1 1	-1	26JUN91	09JAN92	V	R4522	1		2255.26		2255.26				
74	135-00W				09JAN92	V	R4523	1		2268.50		2268.50	+13.24	2261.88	2251.00	-10.88
		1 29	2992		09JAN92	V	R4520	1		2436.85		2436.85				
					09JAN92	V	R4521	1		2429.18		2429.18	-7.67	2433.02		
1	1-00S	1 1	0	03JUL91	13JAN92	V	S3986	1		2324.91		2324.91				
104	135- 0W				13JAN92	V	S3987	1		2324.52		2324.52	-0.39	2324.72	2328.50	3.78
		1 30	2999		13JAN92	V	R4544	1		2418.96		2418.96				
					13JAN92	V	R4545	1		2416.92		2416.92	-2.04	2417.94		
1	1-58S	1 30	2998	04JUL91	17JAN92	V	S3988	1		2425.00		2425.00				
110	135- 0W				17JAN92	V	S3989	1		2421.67		2421.67	-3.33	2423.33		
1	4-00S	1 1	0	05JUL91	20JAN92	V	S4019	1		2321.88		2321.88				
119	135- 0W				20JAN92	V	S4020	1		2320.64		2320.64	-1.24	2321.26	2331.10	9.84
		1 29	3001		28JAN92	V	S4017	2		2420.98		2420.98				
					28JAN92	V	S4018	2		2422.30		2422.30	+1.32	2421.64		

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NOTE: Dilution factor of 1.000170 has been applied.

4. DATA CHECKS AND PROCESSING PERFORMED BY CDIAC

An important part of the NDP process at the Carbon Dioxide Information Analysis Center (CDIAC) involves the quality assurance (QA) review of data before distribution. To guarantee data of the highest possible quality, CDIAC conducts extensive QA reviews that involve examining the data for completeness, reasonableness, and accuracy. Although they have common objectives, these reviews are tailored to each data set and often require extensive programming efforts. In short, the QA process is a critical component in the value-added concept of supplying accurate, usable data for researchers.

The following information summarizes the data-processing and QA checks performed by CDIAC on the data obtained during the R/V *Thomas Washington* TUNES-1 Expedition in the South Pacific Ocean (WOCE Section P17C).

1. Carbon-related data and preliminary hydrographic measurements were provided to CDIAC by Catherine Goyet of WHOI; $\Delta^{14}C$ data were contributed by Robert M. Key of Princeton University; the CFC data were contributed by Kevin F. Sullivan of Miami University. The final hydrographic measurements and the station information files were provided by the WHPO after quality evaluation. A FORTRAN 77 retrieval code was written and used to merge and reformat all data files.

2. The designation for missing values, given as "–9.0" in the original files, was changed to "–999.9."

3. To check for obvious outliers, all data were plotted with a PLOTNEST.C program written by Stewart C. Sutherland (Lamont-Doherty Earth Observatory). The program plots a series of nested profiles, using the station number as an offset; the first station is defined at the beginning, and subsequent stations are offset by a fixed interval (Figs. 4–7). Several outliers were identified and removed after consultation with the principal investigators.

4. To identify "noisy" data and possible systematic, methodological errors, property-property plots for all parameters were generated (Fig. 8), carefully examined, and compared with plots from previous expeditions in the South Pacific Ocean.

5. Dates and times were checked for bogus values (e.g., values of MONTH <1 or> 12, DAY <1 or >31, YEAR ≠1991, TIME <0000 or >2400).

6. Station locations (latitudes and longitudes) and sampling times were examined for consistency with maps and cruise information supplied by the WHPO.

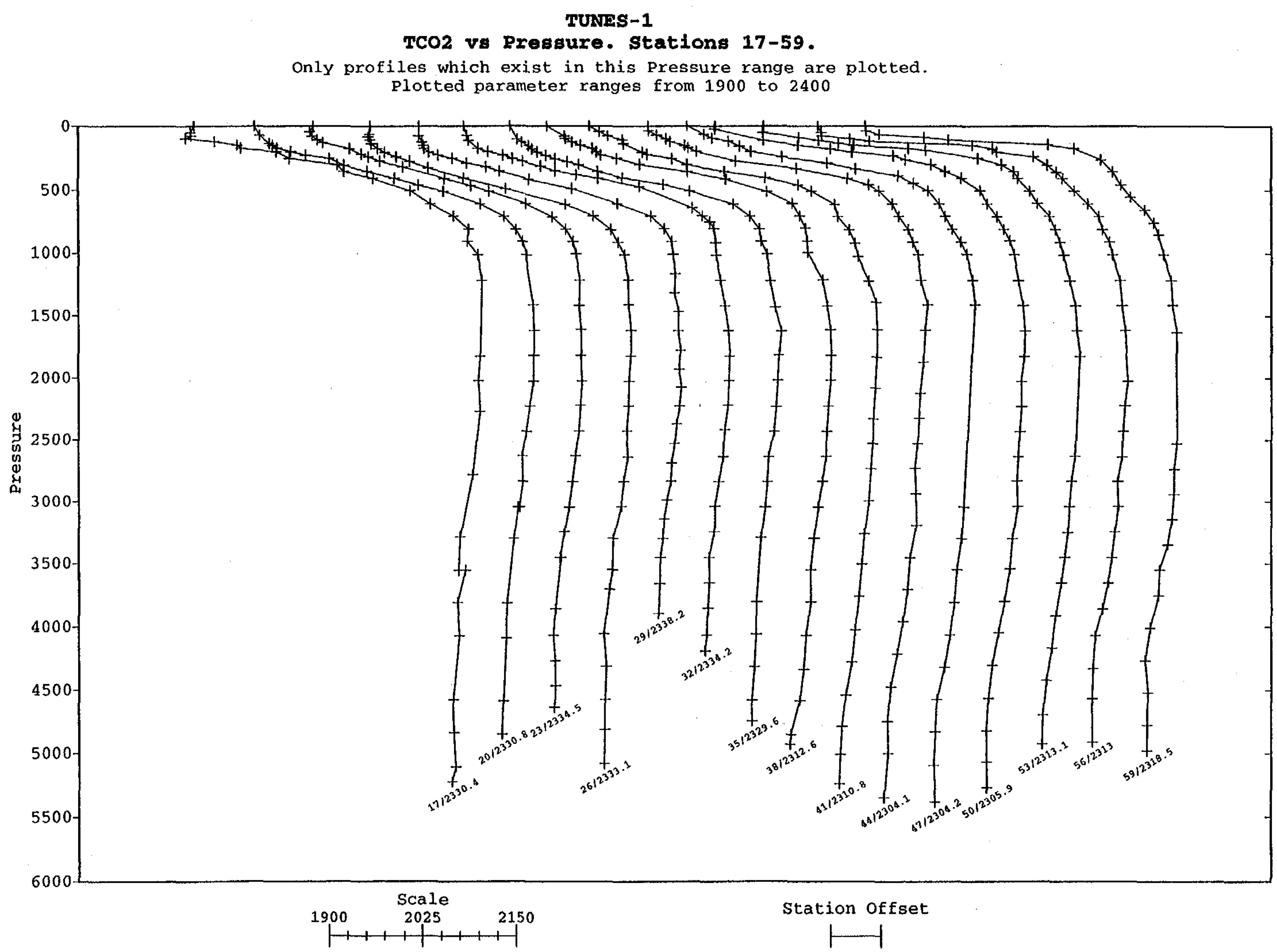

Figure 4. Nested profiles: Total carbon (μmol/kg) vs pressure (dbar) for stations 17–59.

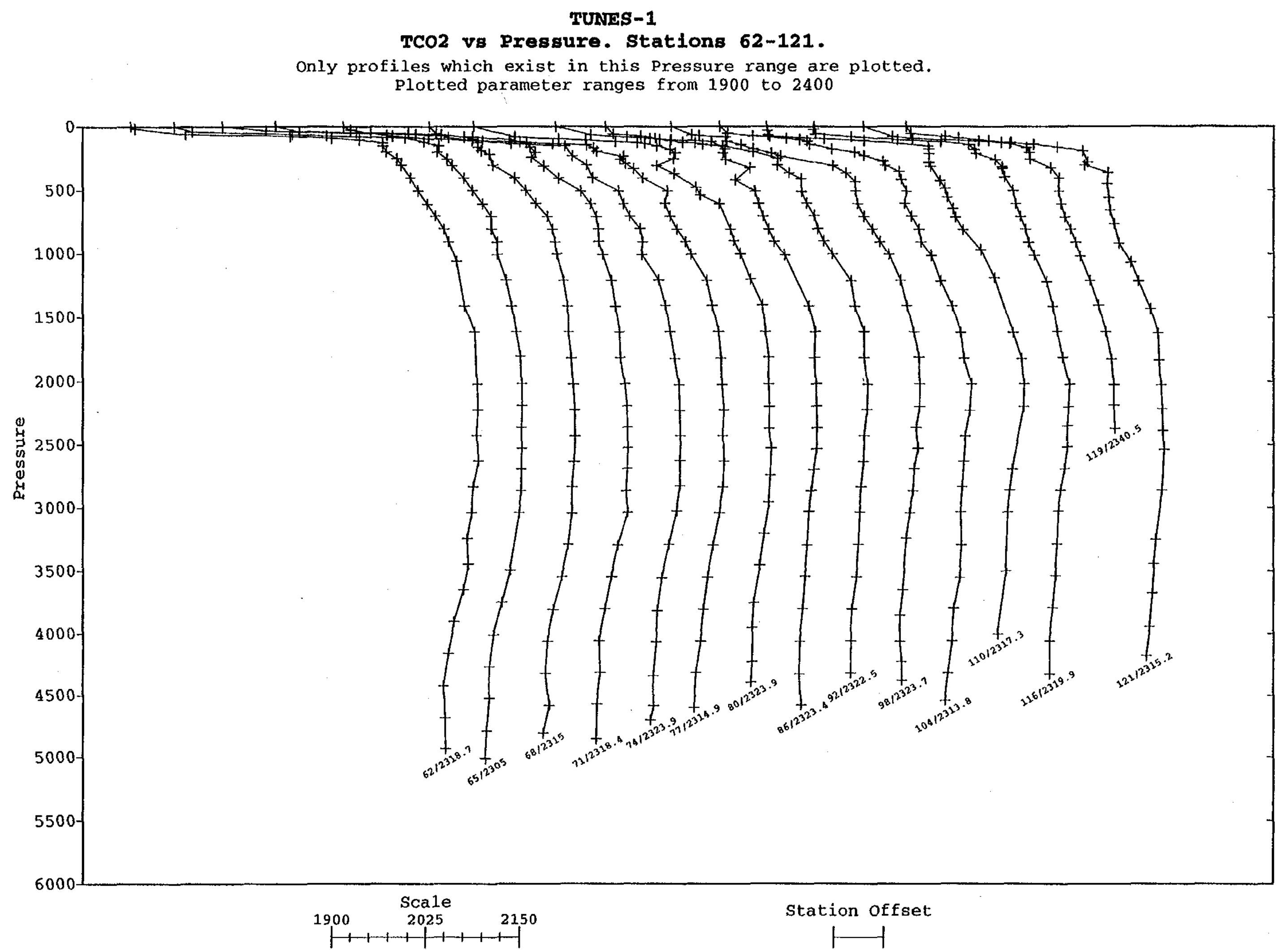

Figure 5. Nested profiles: Total carbon (μmol/kg) vs pressure (dbar) for stations 62–121.

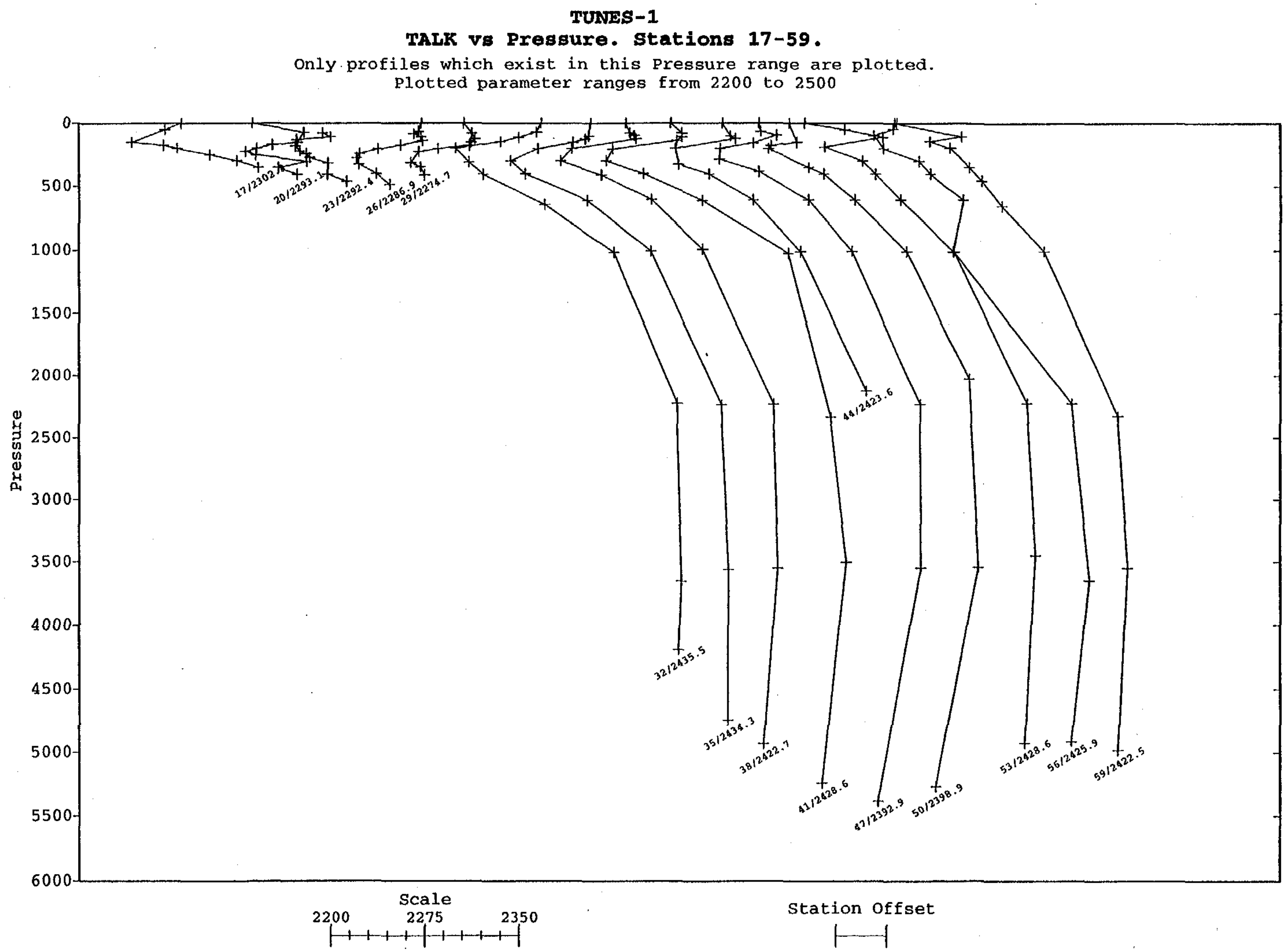

Figure 6. Nested profiles: Total alkalinity (μmol/kg) vs pressure (dbar) for stations 17–59.

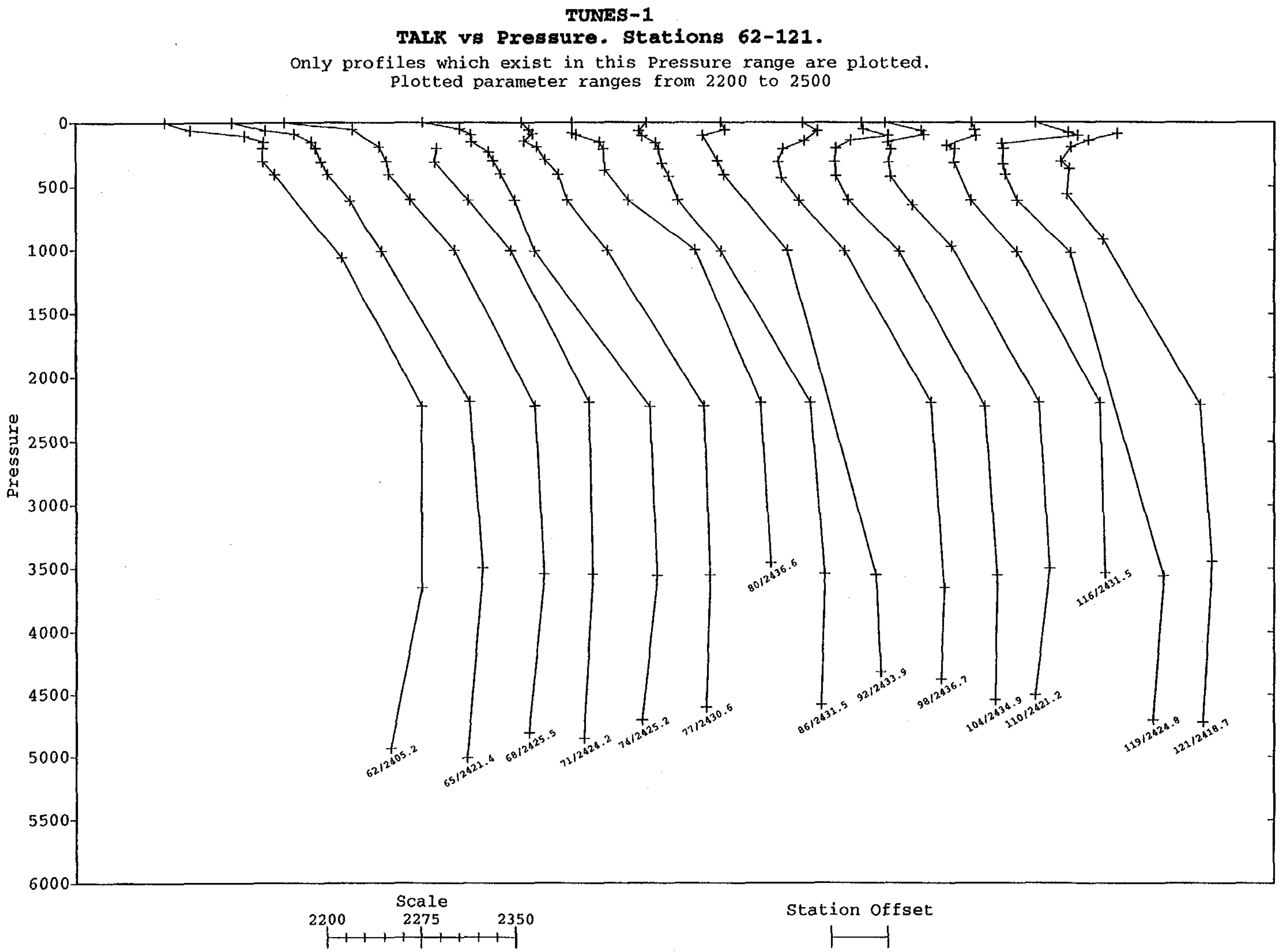

Figure 7. Nested profiles: Total alkalinity (μmol/kg) vs pressure (dbar) for stations 62–121.

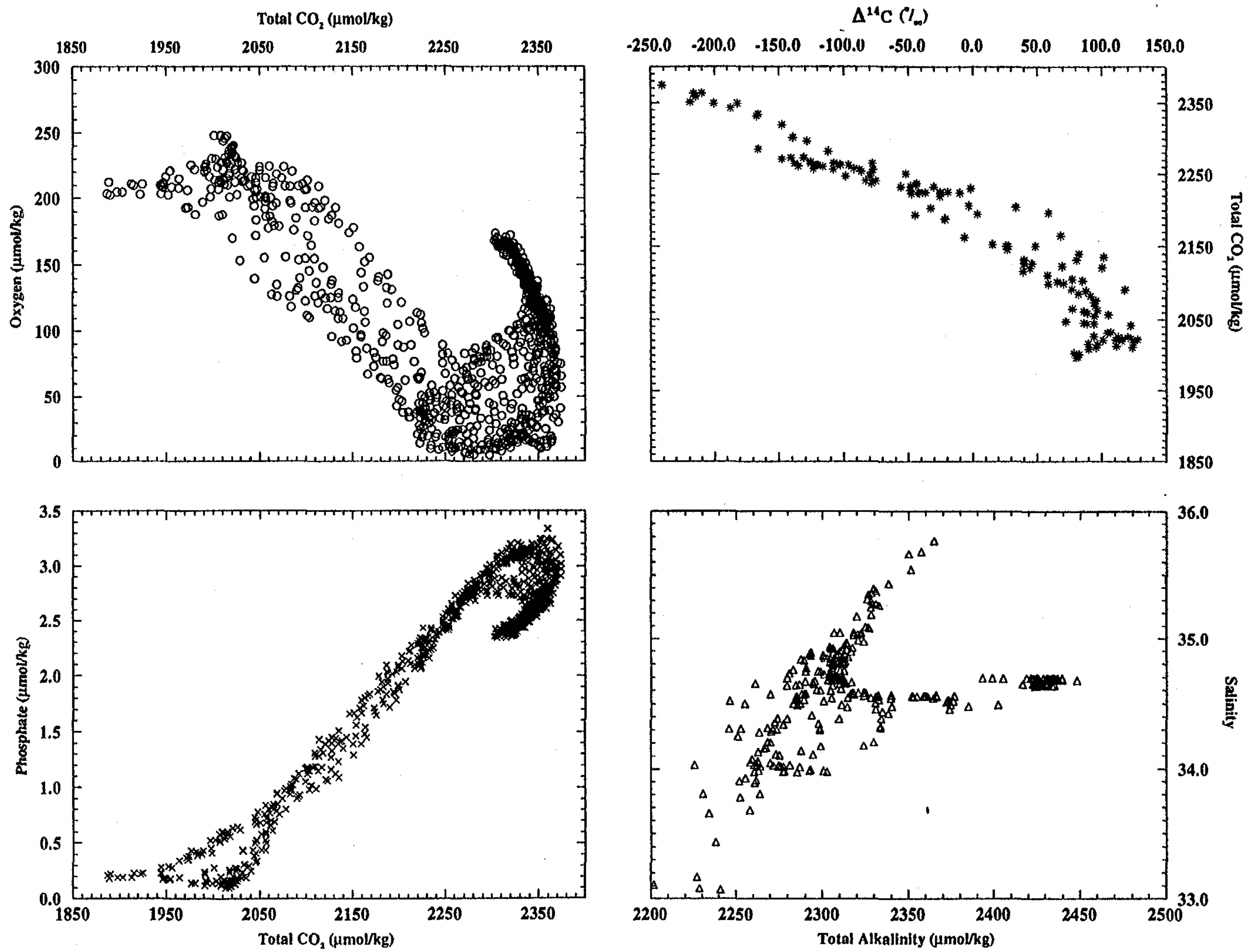

Figure 8. Property-property plots for all stations occupied during R/V *Thomas Washington* TUNES-1 Expedition.

5. HOW TO OBTAIN THE DATA AND DOCUMENTATION

This database is available on request in machine-readable form, without charge, from CDIAC. CDIAC will also distribute subsets of the database as needed. It can be acquired on 9-track magnetic tape; 8-mm tape; 150-MB, 0.25-in. tape cartridge; MAC- or IBM-formatted floppy diskettes; or from CDIAC's anonymous file transfer protocol (FTP) area via the Internet (see FTP address below). Requests should include any specific media instructions required by the user to access the data (e.g., 1600 or 6250 BPI, labeled or nonlabeled, ASCII or EBCDIC characters, and variable- or fixed-length records; 3.5- or 5.25-in. floppy diskettes, high or low density; and 8200 or 8500 format, 8-mm tape). Magnetic tape requests not accompanied by specific instructions will be filled on 9-track, 6250-BPI, nonlabeled tapes with ASCII characters. Requests should be addressed to

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6335
U.S.A.

Telephone: 423-574-0390 or 423-574-3645
Fax: 423-574-2232

Electronic mail: cdiac@ornl.gov

The data files can also be acquired from CDIAC's anonymous FTP area via the Internet:

- FTP to cdiac.esd.ornl.gov (128.219.24.36),
- enter "ftp" or "anonymous" as the user ID,
- enter your electronic mail address as the password (e.g.,"alex@alex.esd.ornl.gov"),[1]
- change to the directory "/pub/ndp062," and
- acquire the files using the FTP "get" or "mget" command.

As an alternative, one can access the following World Wide Web URL
http://cdiac.esd.ornl.gov/ftpdir/ftpinst.html

[1]Please enter your correct address. This address is used by CDIAC to inform data recipients of revisions and updates.

6. REFERENCES

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PART 2:

CONTENT AND FORMAT OF DATA FILES

7. FILE DESCRIPTIONS

This section describes the content and format of each of the five files that comprise this NDP (Table 3). Because CDIAC distributes the data set in several ways (e.g., via anonymous FTP, on floppy diskette, and on 9-track magnetic tape), each of the five files is referenced by both an ASCII file name, which is given in lowercase, boldfaced type (e.g., **ndp062.doc**), and a file number. The remainder of this section describes (or lists, where appropriate) the contents of each file. The files are discussed in the order in which they appear on the magnetic tape.

Table 3. Content, size, and format of data files

File number, name, and description	Logical records	File size in bytes	Block size	Record length
1. **ndp062.doc**: a detailed description of the cruise network, the two FORTRAN 77 data-retrieval routines, and the two oceanographic data files	1,654	129,660	8,000	80
2. **stainv.for**: a FORTRAN 77 data-retrieval routine to read and print **tun1sta.inv** (File 4)	45	1,344	8,000	80
3. **tun1dat.for:** a FORTRAN 77 data-retrieval routine to read and print **tun1.dat** (File 5)	49	2,099	8,000	80
4. **tun1sta.inv**: a listing of the station locations, sampling dates, and corrected sounding bottom depths for each of all stations	117	8,253	8,000	80
5. **tun1.dat:** hydrographic, carbon dioxide, and chemical data from all stations	3,283	567,182	16,000	160
Total	5,148	717,538		

ndp062.doc (File 1)

This file contains a detailed description of the data set, the two FORTRAN 77 data-retrieval routines, and the two oceanographic data files. It exists primarily for the benefit of individuals who acquire this database as machine-readable data files from CDIAC.

stainv.for (File 2)

This file contains a FORTRAN 77 data-retrieval routine to read and print **tun1sta.inv** (File 4). The following is a listing of this program. For additional information regarding variable definitions, variable length, variable type, units, and codes, please see the description for **tun1sta.inv**.

```
c*****************************************************************
c* This is a Fortran retrieval code to read and format the       *
c* station inventory cruise TUNES-1 R/V Washington WOCE P17C line*
c*****************************************************************

c*Defines variables*

       INTEGER  stat, cast, depth
       REAL latdcm, londcm
       CHARACTER expo*11, sect*4, date*6, time*4
       OPEN (unit=1, file='tun1sta.inv')
       OPEN (unit=2, file='tunes1sta.inv')
       write (2, 5)

c*Writes out column labels*

 5     format (3X, 'STATIONS INVENTORY: R/V THOMAS WASHINGTON',/,
     1 3X,'EXPOCODE',1X,'SECT',1X,'STNBR',2X,'CAST',
     2 5X,'DATE',2X,'TIME',2X,'LATITUDE',2X,'LONGITUDE',2X,
     3 'DEPTH',/)

c*Sets up a loop to read and format all the data in the file*
       read (1, 6)
 6     format (///////////)

 7     CONTINUE
       read (1, 10, end=999) expo, sect, stat, cast, date, time,
     1 latdcm, londcm, depth

 10    format (A11, 1X, A4, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 3X,
     1 F7.3, 3X, F8.3, 3X, I4)

       write (2, 20) expo, sect, stat, cast, date, time,
     1 latdcm, londcm, depth

 20    format (A11, 1X, A4, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 3X,
     1 F7.3, 3X, F8.3, 3X, I4)

       GOTO 7
 999   close(unit=5)
       close(unit=2)
       stop
       end
```

tun1dat.for (File 3)

This file contains a FORTRAN 77 data-retrieval routine to read and print **tun1.dat** (File 5). The following is a listing of this program. For additional information regarding variable definitions, variable length, variable type, units, and codes, please see the description for **tun1.dat**.

```
c*****************************************************************
c* FORTRAN 77 data retrieval routine to read and print the      *
c* file named "tun1.dat" (File 5).                              *
c*****************************************************************
      CHARACTER qualt*14
      INTEGER sta, cast, samp, bot
      REAL pre, ctdtmp, ctdsal, ctdoxy, theta, sal, oxy, silca
      REAL nitrat, nitrit, phspht, cfc11, cfc12, delc14, c14err
      REAL tcarb, talk
      OPEN (unit=1, file='tun1.dat')
      OPEN (unit=2, file='tunes1.dat')
      write (2, 5)

5     format (2X,'STNNBR',2X,'CASTNO',2X,'SAMPNO',2X,'BTLNBR',2X,
     1 'CTDPRS',2X,'CTDTMP',2X,'CTDSAL',2X,'CTDOXY',3X,'THETA',4X,
     2 'SALNTY',2X,'OXYGEN',2X,'SILCAT',2X,'NITRAT',2X,'NITRIT',2X,
     3 'PHSPHT',3X,'CFC-11',3X,'CFC-12',2X, 'DELC14',2X,'C14ERR',2X,
     4 'TCARBN',2X,'ALKALI',9X,'QUALT1',/,
     5 36X,'DBAR',2X,'ITS-90',2X,'PSS-78',1X,'UMOL/KG',2X,'ITS-90',
     6 4X,'PSS-78',1X,5('UMOL/KG',1X,),1X,'PMOL/KG',2X,'PMOL/KG',2X,
     7 '/MILLE',2X, 'PERCNT',1X,2('UMOL/KG',1X,),13X,'*',/,
     8 25X,'*******',17X,2('*******',1X,),
     8 10X,6('*******',1X,),1X,'*******',2X,2('*******',1X,),8X,
     9 2('*******',1X,),13X,'*',)

      read (1, 6)
6     format (////////////)

7     CONTINUE
      read (1, 10, end=999) sta, cast, samp, bot, pre, ctdtmp,
     1 ctdsal, ctdoxy, theta, sal, oxy, silca, nitrat, nitrit,
     2 phspht, cfc11, cfc12, delc14, c14err, tcarb, talk, qualt

10    format (5X, I3, 7X, I1, 6X, I2, 5X, I3, 1X, F7.1, 1X, F7.4,
     1 1X, F7.4, 1X, F7.1, 1X, F7.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F8.3, 1X, F8.3, 1X, F7.1,
     3 1X, F7.1, 1X, F7.1, 1X, F7.1, 1X, A14)

      write (2, 20) sta, cast, samp, bot, pre, ctdtmp,
     1 ctdsal, ctdoxy, theta, sal, oxy, silca, nitrat, nitrit,
     2 phspht, cfc11, cfc12, delc14, c14err, tcarb, talk, qualt

20    format (5X, I3, 7X, I1, 6X, I2, 5X, I3, 1X, F7.1, 1X, F7.4,
     1 1X, F7.4, 1X, F7.1, 1X, F7.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F8.3, 1X, F8.3, 1X, F7.1,
     3 1X, F7.1, 1X, F7.1, 1X, F7.1, 1X, A14)

      GOTO 7
999   close(unit=1)
      close(unit=2)
      stop
      end
```

tun1sta.inv (File 4)

This file provides station inventory information for each of the 123 stations occupied during the R/V *Thomas Washington* TUNES-1 Expedition. Each record of the file contains an expocode, section number, station number, cast number, sampling date, sampling time, latitude, longitude, and sounding depth. The file is sorted by station number and can be read by using the following FORTRAN 77 code (contained in **stainv.for**, File 2):

```
      INTEGER  stat, cast, depth
      REAL latdcm, londcm
      CHARACTER expo*11, sect*4, date*6, time*4

      read (1, 10, end=999) expo, sect, stat, cast, date, time,
     1 latdcm, londcm, depth

 10   format (A11, 1X, A4, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 3X,
     1 F7.3, 3X, F8.3, 3X, I4)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
expo	Character	11	1	11
sect	Character	4	13	16
stat	Numeric	3	20	22
cast	Numeric	1	28	28
date	Character	6	32	37
time	Character	4	40	43
latdcm	Numeric	7	47	53
londcm	Numeric	8	57	64
depth	Numeric	4	68	71

where

expo is the expocode of the cruise;

sect is the WOCE section number;

stat is the station number (values range from 1 to 123);

date is the sampling date (month/day/year);

time is the sampling time at the bottom (Greenwich mean time);

latdcm is the latitude of the station (in decimal degrees, negative values indicate the Southern Hemisphere);

londcm is the longitude of the station (in decimal degrees, negative values indicate the Western Hemisphere); and

depth is the corrected sounding bottom depth of the station (meters).

tun1.dat (File 5)

This file provides hydrographic, CO_2, and chemical data for the 123 stations occupied during the R/V *Thomas Washington* TUNES-1 Expedition. Each record contains a station number, cast number, sample number, bottle number, CTD pressure, CTD temperature, CTD salinity, CTD oxygen, potential temperature, bottle salinity, bottle oxygen, silicate, nitrate, nitrite, phosphate, CFC-11, CFC-12, $\Delta^{14}C$, ^{14}C error, TCO_2, TALK, and data-quality flags. The file is sorted by station number and pressure and can be read by using the following FORTRAN 77 code (contained in **tun1dat.for**, File 3):

```
      CHARACTER qualt*14
      INTEGER sta, cast, samp, bot
      REAL pre, ctdtmp, ctdsal, ctdoxy, theta, sal, oxy, silca
      REAL nitrat, nitrit, phspht, cfc11, cfc12, delc14, c14err
      REAL tcarb, talk

 10   format (5X, I3, 7X, I1, 6X, I2, 5X, I3, 1X, F7.1, 1X, F7.4,
     1 1X, F7.4, 1X, F7.1, 1X, F7.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F8.3, 1X, F8.3, 1X, F7.1,
     3 1X, F7.1, 1X, F7.1, 1X, F7.1, 1X, A14)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
sta	Numeric	3	6	8
cast	Numeric	1	16	16
samp	Numeric	2	23	24
bot	Numeric	2	31	32
pre	Numeric	6	35	40
ctdtmp	Numeric	7	42	48
ctdsal	Numeric	7	50	56
ctdoxy	Numeric	7	58	64
theta	Numeric	7	66	72
sal	Numeric	9	74	82
oxy	Numeric	7	84	90
silca	Numeric	7	92	98

nitrat	Numeric	7	100	106
nitrit	Numeric	7	108	114
phspht	Numeric	7	116	122
cfc11	Numeric	8	124	131
cfc12	Numeric	8	133	140
delc14	Numeric	7	142	148
c14err	Numeric	7	150	156
tcarb	Numeric	7	158	164
talk	Numeric	7	166	172
qualt	Character	14	174	187

where

sta is the station number;

cast is the cast number;

samp is the sample number;

bot[b] is the bottle number;

pre is the CTD pressure (dbar);

ctdtmp is the CTD temperature (°C);

ctdsal[b] is the CTD salinity (on the practical salinity scale);

ctdoxy[b] is the CTD oxygen concentration (μmol/kg);

theta is the potential temperature (°C);

sal[b] is the bottle salinity;

oxy[b] is the bottle oxygen concentration (μmol/kg);

silca[b] is the silicate concentration (μmol/kg);

nitrat[b] is the nitrate concentration (μmol/kg);

nitrit[b] is the nitrite concentration (μmol/kg);

phspht[b] is the phosphate concentration (μmol/kg);

cfc11[b] is the trichlorofluoromethane-11 (CCl_3F) concentration (pmol/kg);

cfc12[b] is the dichlorodifluoromethane-12 (CCl_2F_2) concentration (pmol/kg);

delc14[b] is the radiocarbon $\Delta^{14}C$ (per mille);

c14err is the error of $\Delta^{14}C$ (percent);

tcarb[b] is the total carbon dioxide concentration (μmol/kg);

talk[b] is the total alkalinity (μmol/kg); and

qualt is a 14-digit character variable that contains data-quality flag codes for parameters underlined with asterisks (*) in the output file.

---

[b]Variables that are underlined with asterisks in the data file to indicate they have data-quality flag. Data-quality flags are defined as follows:

1 = sample for this measurement was drawn from water bottle but results of analyses were not received;
2 = acceptable measurement;
3 = questionable measurement;
4 = bad measurement;
5 = not reported;
6 = mean of replicate measurements;
7 = manual chromatographic peak measurement;
8 = irregular digital chromatographic peak integration;
9 = sample was not drawn for this measurement from this bottle.

8. VERIFICATION OF DATA TRANSPORT

The data files contained in this NDP can be read by using the FORTRAN 77 data-retrieval programs provided. Users should visually examine each data file to verify that the data were correctly transported to their systems. To facilitate the visual inspection process, partial listings of each data file are provided in Tables 4 and 5. Each of these tables contains the first five and last five lines of a data file.

Table 4. Partial listing of "tun1sta.inv" (File 4)

First five lines of the file:

```
31WTTUNES/1 P17C      1      1    060291  1029     36.172    -121.737     552
31WTTUNES/1 P17C      2      1    060291  1311     36.100    -121.833     908
31WTTUNES/1 P17C      3      1    060291  1631     35.980    -121.993    1408
31WTTUNES/1 P17C      4      1    060291  2116     35.790    -122.278    2308
31WTTUNES/1 P17C      5      1    060391  0410     35.548    -122.863    3262
```

Last five lines of the file:

```
31WTTUNES/1 P17C    119      1    070591  1926     -3.993    -135.000    4613
31WTTUNES/1 P17C    120      1    070691  0142     -4.467    -135.000    4647
31WTTUNES/1 P17C    121      1    070691  0828     -5.008    -135.008    4667
31WTTUNES/1 P17C    122      1    070791  0243     -5.502    -135.002    4543
31WTTUNES/1 P17C    123      1    070791  0853     -5.978    -135.003    4505
```

Table 5. Partial listing of "tun1.dat" (File 5)

First five lines of the file:

```
      1       1      19      19       2.1 10.1244 33.7425     215.7 10.1242    33.7326     216.7     27.97     22.99      0.22
1.85 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22322222299999
      1       1      20      20      11.0  9.8955 33.7926     200.4  9.8943    33.7902     190.0     28.66     24.06      0.20
1.92 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22322222299999
      1       1      21      21      16.3  9.4207 33.8343     184.6  9.4189    33.8177     172.8     30.03     24.74      0.18
1.97 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22322222299999
      1       1      22      22      41.9  9.0988 33.8850     141.3  9.0943    33.8706     145.5     31.69     25.82      0.19
2.00 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22222222299999
      1       1      23      23      66.8  8.8049 33.9302     119.7  8.7979    33.9275     123.1     33.54     27.29      0.20
2.10 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22222222299999
```

Last five lines of the file:

```
    123       1      32      32    3655.3  1.5087 34.6871     157.8  1.2263    34.6867     156.9    141.57     35.71      0.00
2.44 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22222222299999
    123       1      33      33    3865.5  1.4639 34.6893     161.5  1.1605    34.6896     160.3    141.38     35.35      0.00
2.43 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22222222299999
    123       1      34      34    4068.1  1.4369 34.6936     164.3  1.1123    34.6928     165.5    138.99     35.14      0.00
2.41 -999.900 -999.900  -999.9  -999.9  -999.9  -999.9 22222222299999
    123       1      35      35    4340.0  1.4221 34.6963     171.5  1.0677    34.6950     171.6    135.67     34.68      0.00
2.37   -0.003    0.000  -999.9  -999.9  -999.9  -999.9 22222222272999
    123       1      36      36    4581.5  1.4385 34.6987    -999.9  1.0560    34.6960     173.1    134.38     34.63      0.00
2.37   -0.001    0.009  -999.9  -999.9  -999.9  -999.9 32923222272999
```

APPENDIX:

STATION INVENTORY

APPENDIX:
STATION INVENTORY

This appendix lists station inventory information for the 123 sites occupied during the R/V *Thomas Washington* TUNES-1 Expedition in the South Pacific Ocean. The meanings of the column headings in Table A.1 are as follows.

EXPOCODE is the expocode of the cruise;

SECT is the WOCE section number;

STNBR is the station number;

CAST is the cast number;

DATE is the sampling date (month/day/year);

TIME is the sampling time at the bottom (Greenwich mean time);

LATITUDE is the latitude of the station (in decimal degrees). Stations in the Southern Hemisphere have negative latitudes;

LONGITUDE is the longitude of the station (in decimal degrees). Stations in the Western Hemisphere have negative longitudes; and

DEPTH is the corrected sounding bottom depth of each station (meters).

Table A.1. Station inventory information for the 123 sites occupied during R/V *Thomas Washington* TUNES-1 Expedition

```
*********************************************************************
*  Source:    C. Goyet                          R. M. Key           *
* Woods Hole Oceanographic Institution      Princeton University    *
*           Woods Hole, MA                      Princeton, NJ       *
*                                                                   *
*           M. Tsuchiya                       K. F. Sullivan        *
* Scripps Institution of Oceanography   RSMAS/University of Miami *
*           San Diego, CA                       Miami, FL           *
*********************************************************************
*  STATION INVENTORY: R/V THOMAS WASHINGTON
```

EXPOCODE	SECT	STNBR	CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH
31WTTUNES/1	P17C	1	1	060291	1029	36.172	-121.737	552
31WTTUNES/1	P17C	2	1	060291	1311	36.100	-121.833	908
31WTTUNES/1	P17C	3	1	060291	1631	35.980	-121.993	1408
31WTTUNES/1	P17C	4	1	060291	2116	35.790	-122.278	2308
31WTTUNES/1	P17C	5	1	060391	0410	35.548	-122.863	3262
31WTTUNES/1	P17C	6	1	060391	1137	35.298	-123.433	4005
31WTTUNES/1	P17C	7	1	060391	2007	35.075	-124.017	4160
31WTTUNES/1	P17C	8	1	060491	0338	34.817	-124.582	4343
31WTTUNES/1	P17C	9	1	060491	1308	34.582	-125.157	4519
31WTTUNES/1	P17C	10	1	060591	0216	34.582	-126.400	4682
31WTTUNES/1	P17C	11	1	060591	1445	34.577	-127.635	4765
31WTTUNES/1	P17C	12	1	060691	0202	34.583	-128.847	4887
31WTTUNES/1	P17C	13	1	060691	1259	34.585	-130.087	4338
31WTTUNES/1	P17C	14	1	060791	0009	34.585	-131.320	5133
31WTTUNES/1	P17C	15	1	060791	1123	34.588	-132.442	5091
31WTTUNES/1	P17C	16	1	060791	2207	34.583	-133.770	4323
31WTTUNES/1	P17C	17	2	060891	1508	34.598	-134.963	5141
31WTTUNES/1	P17C	18	1	060991	0536	34.067	-135.000	5097
31WTTUNES/1	P17C	19	1	060991	1240	33.567	-135.002	5033
31WTTUNES/1	P17C	20	1	060991	2007	33.065	-134.997	4763
31WTTUNES/1	P17C	21	1	061091	0302	32.597	-135.000	4161
31WTTUNES/1	P17C	22	1	061091	1003	32.035	-135.002	4943
31WTTUNES/1	P17C	23	1	061091	1617	31.532	-135.002	4527
31WTTUNES/1	P17C	24	1	061091	2313	31.018	-135.000	4553
31WTTUNES/1	P17C	25	1	061191	0553	30.518	-135.000	4567
31WTTUNES/1	P17C	26	2	061191	1934	30.033	-134.952	5090
31WTTUNES/1	P17C	27	1	061291	0728	29.508	-135.002	4478
31WTTUNES/1	P17C	28	1	061291	1431	28.997	-134.998	4511
31WTTUNES/1	P17C	29	1	061291	2046	28.498	-134.997	3579
31WTTUNES/1	P17C	30	1	061391	0309	28.005	-135.002	4197
31WTTUNES/1	P17C	31	1	061391	0947	27.510	-135.002	4477
31WTTUNES/1	P17C	32	1	061391	1621	27.000	-134.998	4120
31WTTUNES/1	P17C	33	1	061391	2239	26.502	-135.000	4297
31WTTUNES/1	P17C	34	2	061491	1106	26.040	-134.970	4573
31WTTUNES/1	P17C	35	1	061491	1737	25.498	-134.997	4547
31WTTUNES/1	P17C	36	1	061491	2335	25.002	-135.000	4578
31WTTUNES/1	P17C	37	1	061591	0637	24.502	-135.005	4545
31WTTUNES/1	P17C	38	1	061591	1323	23.998	-135.000	4849
31WTTUNES/1	P17C	39	1	061591	2000	23.503	-135.005	4184
31WTTUNES/1	P17C	40	1	061691	0232	23.000	-135.000	5145
31WTTUNES/1	P17C	41	1	061691	0926	22.498	-135.002	5147
31WTTUNES/1	P17C	42	1	061691	1652	22.037	-134.997	5245
31WTTUNES/1	P17C	43	1	061691	2302	21.525	-135.002	5211
31WTTUNES/1	P17C	44	1	061791	0531	21.008	-135.000	5252
31WTTUNES/1	P17C	45	1	061791	1217	20.497	-134.998	5244
31WTTUNES/1	P17C	46	2	061891	0108	19.982	-135.017	5257
31WTTUNES/1	P17C	47	1	061891	1134	19.500	-135.000	5274
31WTTUNES/1	P17C	48	1	061891	1759	18.998	-135.000	5199
31WTTUNES/1	P17C	49	1	061991	0035	18.498	-134.998	5200
31WTTUNES/1	P17C	50	1	061991	0715	18.000	-135.005	5166
31WTTUNES/1	P17C	51	1	061991	1330	17.500	-134.997	4968
31WTTUNES/1	P17C	52	1	061991	2003	17.000	-135.000	5281

Table A.1 (continued)

31WTTUNES/1	P17C	53	1	062091	0232	16.500	-135.000	4832
31WTTUNES/1	P17C	54	1	062091	0913	15.997	-135.002	4801
31WTTUNES/1	P17C	55	1	062091	1549	15.498	-134.998	4888
31WTTUNES/1	P17C	56	1	062091	2216	15.000	-135.007	4715
31WTTUNES/1	P17C	57	2	062191	0958	14.462	-134.978	5001
31WTTUNES/1	P17C	58	1	062191	2006	14.000	-135.000	4906
31WTTUNES/1	P17C	59	1	062291	0225	13.502	-135.000	4896
31WTTUNES/1	P17C	60	1	062291	0920	13.002	-135.003	4908
31WTTUNES/1	P17C	61	1	062291	1549	12.500	-134.997	4849
31WTTUNES/1	P17C	62	1	062291	2233	12.000	-134.998	4852
31WTTUNES/1	P17C	63	1	062391	0505	11.503	-135.000	4884
31WTTUNES/1	P17C	64	1	062391	1158	11.002	-135.000	4888
31WTTUNES/1	P17C	65	1	062391	1823	10.500	-134.998	4909
31WTTUNES/1	P17C	66	2	062491	0617	9.965	-135.057	4824
31WTTUNES/1	P17C	67	1	062491	1656	9.517	-134.993	4794
31WTTUNES/1	P17C	68	1	062491	2339	8.995	-135.000	4723
31WTTUNES/1	P17C	69	1	062591	0539	8.520	-134.998	4779
31WTTUNES/1	P17C	70	1	062591	1203	8.000	-134.998	4737
31WTTUNES/1	P17C	71	1	062591	1815	7.497	-134.998	4785
31WTTUNES/1	P17C	72	1	062691	0016	7.027	-134.997	4664
31WTTUNES/1	P17C	73	1	062691	0618	6.523	-135.000	4631
31WTTUNES/1	P17C	74	1	062691	1235	6.002	-134.998	4626
31WTTUNES/1	P17C	75	1	062691	1910	5.495	-134.995	4560
31WTTUNES/1	P17C	76	2	062791	0652	4.992	-134.972	4586
31WTTUNES/1	P17C	77	1	062791	1602	4.498	-134.998	4532
31WTTUNES/1	P17C	78	1	062791	2208	4.010	-135.002	4452
31WTTUNES/1	P17C	79	1	062891	0417	3.517	-135.002	4312
31WTTUNES/1	P17C	80	1	062891	1030	3.033	-135.012	4331
31WTTUNES/1	P17C	81	1	062891	1533	2.828	-135.008	4340
31WTTUNES/1	P17C	82	1	062891	1931	2.668	-135.002	4349
31WTTUNES/1	P17C	83	1	062891	2354	2.500	-135.003	4366
31WTTUNES/1	P17C	84	1	062991	0352	2.350	-135.002	4411
31WTTUNES/1	P17C	85	1	062991	0835	2.170	-135.002	4453
31WTTUNES/1	P17C	86	1	062991	1243	2.000	-134.990	4516
31WTTUNES/1	P17C	87	1	062991	1743	1.833	-134.998	4574
31WTTUNES/1	P17C	88	1	062991	2133	1.668	-135.000	4549
31WTTUNES/1	P17C	89	1	063091	0203	1.500	-134.998	4461
31WTTUNES/1	P17C	90	1	063091	0620	1.335	-134.998	4469
31WTTUNES/1	P17C	91	1	063091	1050	1.165	-134.998	4378
31WTTUNES/1	P17C	92	1	063091	1444	0.990	-135.000	4260
31WTTUNES/1	P17C	93	1	063091	1901	0.833	-134.997	4313
31WTTUNES/1	P17C	94	1	063091	2252	0.672	-134.995	4284
31WTTUNES/1	P17C	95	1	070191	0311	0.498	-134.990	4212
31WTTUNES/1	P17C	96	1	070191	0658	0.337	-134.998	3551
31WTTUNES/1	P17C	97	1	070191	1130	0.165	-135.053	3401
31WTTUNES/1	P17C	98	2	070191	2043	0.003	-135.157	4318
31WTTUNES/1	P17C	98	4	070291	0312	-0.012	-135.125	4318
31WTTUNES/1	P17C	99	1	070291	0802	-0.163	-135.167	4223
31WTTUNES/1	P17C	100	1	070291	1216	-0.332	-135.000	4236
31WTTUNES/1	P17C	101	1	070291	1626	-0.502	-135.000	4319
31WTTUNES/1	P17C	102	1	070291	2009	-0.667	-135.000	4349
31WTTUNES/1	P17C	103	1	070391	0013	-0.832	-135.003	4300
31WTTUNES/1	P17C	104	1	070391	0359	-0.993	-135.002	4463
31WTTUNES/1	P17C	105	1	070391	0816	-1.142	-135.002	4486
31WTTUNES/1	P17C	106	1	070391	1156	-1.325	-135.000	4365
31WTTUNES/1	P17C	107	1	070391	1619	-1.502	-134.997	4396
31WTTUNES/1	P17C	108	1	070391	1959	-1.662	-135.000	4365
31WTTUNES/1	P17C	109	1	070391	2358	-1.825	-134.997	4219
31WTTUNES/1	P17C	110	1	070491	0347	-1.973	-135.002	4439
31WTTUNES/1	P17C	111	1	070491	0806	-2.150	-135.002	4438
31WTTUNES/1	P17C	112	1	070491	1148	-2.328	-134.998	4319
31WTTUNES/1	P17C	113	1	070491	1615	-2.502	-135.000	4395
31WTTUNES/1	P17C	114	1	070491	2000	-2.662	-135.000	4422
31WTTUNES/1	P17C	115	1	070591	0001	-2.828	-135.000	4488
31WTTUNES/1	P17C	116	1	070591	0354	-2.998	-135.002	4559
31WTTUNES/1	P17C	117	1	070591	0850	-3.230	-135.002	4614

Table A.1 (continued)

31WTTUNES/1	P17C	118	1	070591	1314	-3.488	-135.002	4622
31WTTUNES/1	P17C	119	1	070591	1926	-3.993	-135.000	4613
31WTTUNES/1	P17C	120	1	070691	0142	-4.467	-135.000	4647
31WTTUNES/1	P17C	121	1	070691	0828	-5.008	-135.008	4667
31WTTUNES/1	P17C	122	1	070791	0243	-5.502	-135.002	4543
31WTTUNES/1	P17C	123	1	070791	0853	-5.978	-135.003	4505

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