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Indian Ocean Radiocarbon: Data from the Indigo 1, 2, and 3 Cruises

Environmental Sciences Division
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INDIAN OCEAN RADIOCARBON: DATA FROM THE INDIGO 1, 2, AND 3 CRUISES

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The Carbon Dioxide Information Analysis Center operates from within the Carbon Dioxide Information Analysis and Research Program, Oak Ridge National Laboratory. We respond to an average of 400 requests for numeric data packages (NDPs) each year and have distributed over 3000 copies of 34 NDPs since 1985. The 100 requested copies of NDP-036 (ORNL/CDIAC-41) are to stock the Center with copies of this document in order to fill anticipated requests for it.

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ABSTRACT

ÖSTLUND, H. GÖTE, and CHARLENE GRALL. 1991. Indian Ocean radiocarbon: Data from the INDIGO 1, 2, and 3 cruises. ORNL/CDIAC-41, NDP-036. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 196 pp.doi: 10.3334/CDIAC/otg.ndp036

This document presents ^{14}C activities (expressed in the internationally adopted $\Delta^{14}C$ scale) from water samples taken at various locations and depths in the Indian and Southern oceans through the Indien Gaz Ocean (INDIGO) project. These data were collected as part of the INDIGO 1, INDIGO 2, and INDIGO 3 cruises, which took place during the years 1985, 1986, and 1987, respectively. These data have been used to estimate the penetration of anthropogenic CO_2 in the Indian and Southern oceans. The document also presents supporting data for potential temperature, salinity, density (sigma-theta), $\delta^{13}C$, and total CO_2. All radiocarbon measurements have been examined statistically for quality of sample counts and stability of counting efficiency and background. In addition, all data have been reviewed by the Carbon Dioxide Information Analysis Center and assessed for gross accuracy and consistency (absence of obvious outliers and other anomalous values).

These data are available free of charge as a numeric data package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of this document and a magnetic tape containing machine-readable files. (The data files are also available on floppy diskettes, upon request.) This document provides sample listings of the Indian Ocean radiocarbon data as they appear on the magnetic tape, as well as a complete listing of these data in tabular form. This document also offers retrieval program listings (in FORTRAN and SAS* languages), furnishes information on sampling methods and data selection, defines limitations and restrictions of the data, and provides reprints of pertinent literature.

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*SAS is the registered trademark of SAS Institute, Inc., Cary, North Carolina 27511-8000.

PART 1

INFORMATION ABOUT THE NUMERIC DATA PACKAGE

1. NAME OF THE NUMERIC DATA PACKAGE

Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises.

2. CONTRIBUTORS

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3. KEYWORDS

INDIGO 1; INDIGO 2; INDIGO 3; Indian Ocean; Southern Ocean; carbon dioxide; carbon-14; carbonate; radiocarbon.

4. BACKGROUND INFORMATION

The Southern Ocean is a site of extensive mixing of deep waters from the world's oceans (Pacific, Atlantic, and Indian) and, in turn, a source for these same waters (Chen et al. 1986; Pickard and Emery 1982; Post et al. 1990). An understanding of the properties of Southern Ocean waters should, therefore, be very useful in furthering our understanding of the deep oceans. In particular, an understanding of the extent of penetration of anthropogenic CO_2 in the Southern Ocean should add to our understanding of the global biogeochemical cycle of carbon by providing information about the distribution and mixing of CO_2 in the deep oceans (Chen et al. 1986; Östlund and Grall 1988).

The Indien Gaz Ocean (INDIGO) project was established to study carbon chemistry in the Indian and Southern Oceans. Before the INDIGO project, little carbon sampling had been conducted in these oceans (Chen et al. 1986). INDIGO evolved as a joint cooperation between groups from France and the United States (Östlund and Grall 1988). The project was sponsored by the U.S. Department of Energy and the French Centre National de la Recherche Scientifique.

The vessel employed for the INDIGO project was the Marion Dufresne, a French research and supply vessel which is operated by TAAF (Terres Australes et Antarctiques Françaises), and which travels several times per year to the southern Indian Ocean (Chen et al. 1986). As part of the INDIGO project, the vessel collected deep ocean samples once a year for 3 years (1985-1987) in different regions of the Indian Ocean (Östlund and Grall 1988).

The INDIGO project comprised a number of research operations (see Chen et al. 1986). This document describes the results of analyses carried out by the University of Miami Tritium Laboratory. The task was to collect large samples of seawater at various locations and depths, extract the CO_2, and measure the radiocarbon content. These results were used along with measurements of $\delta^{13}C$ (carried out at the University of Washington Quaternary Research Center) to determine values of $\Delta^{14}C$ in the internationally accepted convention (Östlund and Grall 1988; Stuiver and Robinson 1974).

5. SOURCE AND SCOPE OF THE DATA

The INDIGO 1 cruise collected samples in the southern Indian Ocean from February 27 through March 26, 1985. Carbon-14 measurements were made from 74 samples collected at 13 stations located between latitudes 26°S and 48°S. The INDIGO 2 cruise began the following year and sampled the northwestern Indian Ocean from April 1 through April 30, 1986. Carbon-14 measurements were made from 91 samples at 14 stations located between latitudes 19°S and 9°N. The INDIGO 3 cruise traveled south into the Southern Ocean and collected samples from January 15 through February 13, 1987. Carbon-14 measurements were made from 68 samples collected at 7 stations located between latitudes 37°S and 65°S. A map showing the tracks and sampling stations of the three cruises is given in Östlund and Grall (1988), a reprint of which is included in the Appendix.

Technical details of sampling and ^{14}C measurement are also given in Östlund and Grall (1988). In brief, the procedure was as follows. Water samples were collected in 100-liter Niskin (GoFlo®) bottles and loaded onto casts holding 8 bottles. Two bottles were used at each sampling depth, giving a nominal sample size of 200 liters. Following collection, water samples were transferred through a krypton extraction system (as part of a separate study within the INDIGO project) and stored in barrels. CO_2 was extracted for storage by acidifying the sample with sulfuric acid, purging the released gas with nitrogen, and finally reabsorbing the extract in aqueous NaOH. In the laboratory, prior to ^{14}C measurement, the CO_2 was re-released through acidification, passed through a collection and purification system (consisting of a number of low-temperature traps and copper-silver ovens), and stored in stainless steel high-pressure cylinders for sufficient time to allow for the decay of any radon that might have originated from reagents used in the extraction and purification processes. A small amount of the purified CO_2 was used for mass spectrometric ^{13}C analysis, while the remainder was used for ^{14}C measurement by low-level gas proportional β-counting. After ^{14}C activity was measured, $\Delta^{14}C$ was calculated as the deviation (per mil) of sample ^{14}C activity from standard (oxalic acid) ^{14}C activity, with correction for the effects of isotope fractionation. In equation form, this is given as $\Delta^{14}C = [(A_{SN}/A_0)-1] * 1000$, where A_{SN} is the measured ^{14}C activity of the sample, corrected for isotope fractionation, and A_0 is the oxalic acid ^{14}C activity with the age corrected to 1950 A.D. and the ^{13}C normalized (Stuiver and Robinson 1974; Broecker and Olson 1961). A further discussion of the conventions used in reporting ^{14}C data may be found in Stuiver and Polach (1977).

Through the use of statistical tests, all measurements of ^{14}C activity, including samples, standards, backgrounds, and counting efficiencies, were examined periodically for quality and stability. In addition, corrections were made for the presence of small quantities of CO_2 present in the analytical reagents.

In addition to radiocarbon measurements, the data set described in this document also contains measurements for a number of hydrographic variables: potential temperature, salinity, and density (sigma-theta). Also included are measurements for $\delta^{13}C$ and for total CO_2. Readers interested in further information regarding hydrographic or CO_2 data should contact Dr. Alain Poisson of Université Pierre et Marie Curie.

6. APPLICATIONS OF THE DATA

The radiocarbon and total CO_2 data described in this document may be used to generate estimates of the penetration of anthropogenic CO_2 in the Indian Ocean. Such estimates should be useful to modelers, policymakers, and others needing information on the global biogeochemical cycle of carbon. In addition, these estimates may be used to compare with estimates of the penetration of other tracer elements, such as freons, tritium, and ^{85}Kr (Chen et al. 1986). The data may also be used in conjunction with other data reported in the literature. For example, several sampling locations were identical to those of the 1978 GEOSECS expedition (Östlund and Grall 1988). The data have also been used for comparison with results obtained by different ^{14}C counting methods (for example, Bard et al. 1988). Comparison with other reported data may also be used to investigate seasonal changes in carbonate chemistry in the Indian Ocean (Chen et al. 1986). The data from the South Indian Ocean may be particularly important because of the area's proximity to the major point of origin for the deep waters of the world's oceans (Chen et al. 1986; Pickard and Emery 1982).

7. LIMITATIONS AND RESTRICTIONS

The data set described in this document reports measurements of $\Delta^{14}C$ and several other variables for a total of 233 seawater samples. For 47 samples, values for total CO_2 are missing. For 80 samples, values for potential temperature and density (sigma-theta) are missing. For 4 of these 80 samples, values for salinity are also missing.

For both normal-size and small samples, the errors for $\Delta^{14}C$ have been estimated as 3.0-3.5 per mil for precision and 3.5-4.0 per mil for accuracy (Östlund and Grall 1988). The ^{14}C measurements on samples collected during the INDIGO II cruise are in good agreement with independent measurements made by accelerator mass spectrometry (Bard et al. 1988).

The INDIGO data do not constitute a homogeneous sampling of the Indian Ocean. Collectively, the three INDIGO cruises conducted sampling at only 34 stations, with no sampling in the north-central and eastern portions of the Indian Ocean. All samples were collected during the austral summer or autumn only. Stations were not sampled uniformly; for example, some stations were sampled at as many as 12 different depths, whereas others were sampled at only a single depth. Table 1 lists the sampling stations and their locations, along with sampling dates, number of ^{14}C measurements, and range of depths sampled during the INDIGO project.

Table 1. Sampling information for stations included in the Indian Ocean radiocarbon data set

Station	Latitude[a]	Longitude (E)	Date of sampling	Number of ^{14}C measurements	Depth or range of depths sampled (meters)
3	-27° 04'	56° 57'	2/27/85	9	0 - 4000
7	-37° 41'	57° 40'	3/03/85	9	0 - 2000
8	-40° 11'	57° 51'	3/04/85	1	150
9	-43° 08'	57° 57'	3/05/85	2	0 - 150
10	-45° 30'	57° 48'	3/05/85	1	150
11	-47° 40'	57° 50'	3/09/85	7	0 - 1500
17	-46° 31'	71° 11'	3/16/85	4	250 - 1000
19	-43° 20'	73° 45'	3/18/85	12	0 - 3500
21	-39° 36'	76° 23'	3/20/85	10	0 - 3500
22	-33° 49'	76° 20'	3/23/85	2	150 - 300
23	-30° 15'	74° 38'	3/24/85	12	0 - 3500
24	-29° 25'	70° 49'	3/25/85	1	300
25	-26° 59'	67° 07'	3/26/85	4	100 - 1500
27	-18° 54'	54° 47'	4/01/86	10	47 - 4505
30	-11° 15'	64° 27'	4/05/86	12	27 - 2005
31	-10° 42'	58° 09'	4/07/86	2	2 - 120
32	-12° 18'	53° 39'	4/08/86	11	63 - 4567
33	-11° 55'	50° 08'	4/09/86	2	2 - 120
34	-8° 50'	52° 15'	4/11/86	2	2 - 120
36	-6° 09'	50° 55'	4/12/86	12	25 - 4573
38	-1° 59'	60° 01'	4/15/86	11	23 - 2465
43	+3° 58'	56° 50'	4/18/86	12	25 - 4505
44	+0° 00'	56° 29'	4/19/86	1	2
45	-0° 03'	50° 57'	4/21/86	10	26 - 4804
50	-0° 01'	44° 31'	4/23/86	2	10 - 120
65	+5° 00'	52° 05'	4/28/86	2	10 - 120
69	+8° 52'	53° 17'	4/30/86	2	10 - 120
76	-59° 29'	69° 59'	1/15/87	12	25 - 3103
79	-64° 10'	84° 00'	1/18/87	9	25 - 3413
85	-62° 20'	49° 58'	1/23/87	11	27 - 4397
88	-61° 01'	32° 17'	1/27/87	11	25 - 4488
97	-41° 47'	18° 27'	2/04/87	12	30 - 3616
100	-37° 58'	36° 02'	2/08/87	6	717 - 4451
103	-47° 46'	58° 02'	2/13/87	7	535 - 3453

[a] Positive values denote north latitudes. Negative numbers denote south latitudes.

8. REFERENCES

Bard, E., M. Arnold, H. G. Östlund, P. Maurice, P. Monfray, and J.-C. Duplessy. 1988. Penetration of bomb radiocarbon in the tropical Indian Ocean measured by means of accelerator mass spectrometry. Earth and Planetary Science Letters 87:379-389.

Broecker, W. S., and E. A. Olson. 1961. Lamont radiocarbon measurements VIII. Radiocarbon 3:176-204.

Chen, C. T., A. Poisson, and C. Goyet. 1986. Preliminary Data Report for the INDIVAT 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean. DOE Technical Report No. TR029. U.S. Department of Energy, Carbon Dioxide Research Division, Washington, D.C.

Östlund, H. G., and C. Grall. 1988. INDIGO 1985-1987: Indian Ocean Radiocarbon. Tritium Laboratory Data Report No. 17. Tritium Laboratory, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida.

Pickard, G. L., and W. J. Emery. 1982. Descriptive Physical Oceanography: An Introduction, 4th ed. Pergamon Press, New York.

Post, W. M., T. H. Peng, W. R. Emanuel, A. W. King, V. H. Dale, and D. L. DeAngelis. 1990. The global carbon cycle. American Scientist 78:310-326.

Stuiver, M., and H. A. Polach. 1977. Discussion: Reporting of ^{14}C data. Radiocarbon 19:355-363.

Stuiver, M., and S. W. Robinson. 1974. University of Washington GEOSECS North Atlantic carbon-14 results. Earth and Planetary Science Letters 23:87-90.

This data package includes reprints of Chen et al. 1986 and Östlund and Grall 1988 (see Appendix).

9. DATA CHECKS PERFORMED BY CDIAC

The Carbon Dioxide Information Analysis Center (CDIAC) endeavors to provide quality assurance (QA) of all data before their distribution. CDIAC extensively reviews the data for reasonableness, accuracy, completeness, and consistency of form. Although these reviews have common objectives, their specific form must be tailored to each data set through a process that may involve considerable programming efforts. The entire QA process is an important part of CDIAC's effort to ensure that accurate, usable CO_2-related data are made available to researchers.

The following summarizes the QA checks that CDIAC performed on the Indian Ocean radiocarbon data.

1. Data were examined for overall consistency, including (1) a check for obvious outliers in the values of variables [such as salinity and density (sigma-theta)] that exhibit relatively low variability; (2) a check for gross departures from observed relationships, such as the decrease in potential temperature and $\Delta^{14}C$ with increasing ocean depth; and (3) a check for values outside of possible limits, such as values of depth that are greater than the given bottom depth.

2. The sampling locations (latitudes and longitudes) and times were examined for consistency with maps and cruise information supplied by Östlund and Grall (1988).

No errors or inconsistencies of the types described above were found in the Indian Ocean radiocarbon data received by CDIAC. The files distributed by CDIAC in this package are identical to the original files sent to CDIAC, except for the following alterations to ease the use of these data:

1. The original file containing information on the station location, date of sampling, and ocean bottom depth was merged with the file containing the sample information (cast, sample, sampling depth, potential temperature, salinity, sigma-theta, total CO_2, $\delta^{13}C$, and $\Delta^{14}C$).

2. The designations for missing values, given as blanks in the original files, were changed to the following: -9999 for missing values of potential temperature, sigma-theta, and salinity; -999 for missing values of total CO_2.

3. The values for longitude and latitude were padded with leading zeroes as necessary to make all entries a uniform length.

10. HOW TO OBTAIN THE PACKAGE

This document describes a data set detailing ^{14}C activities (expressed in the internationally adopted $\Delta^{14}C$ scale) analyzed from water samples taken at various locations and depths in the Indian Ocean as part of the INDIGO 1, INDIGO 2, and INDIGO 3 cruises during the years 1985-1987. The data set also includes supporting data for potential temperature, salinity, density (sigma-theta), $\delta^{13}C$, and total CO_2. These data are provided in tabular form in the document (Table 4) and are available from CDIAC upon request on nine-track magnetic tape or on floppy diskette (IBM PC format; high- or low-density, 5.25- or 3.5- inch diskette). Requests for magnetic tapes should include any specific instructions for transmitting the data as required by the user to access the data. Requests not accompanied by specific instructions will be filled on nine-track, 6250 BPI, standard-labeled tapes with characters written in EBCDIC (Extended Binary Codes Decimal Interchange Code) and files formatted as noted in Section 11. Requests should be addressed to the following:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, Tennessee 37831-6335
U.S.A.

The tapes and documentation can be ordered by telephone, fax machine, or electronic mail.

Telephone: (615) 574-0390
FTS 624-0390

Fax: (615) 574-2232
FTS 624-2232

BITNET eMail: CDP@ORNLSTC
INTERNET: CDP@STC10.ORNL.GOV

PART 2

INFORMATION ABOUT THE MAGNETIC TAPE

11. CONTENTS OF THE MAGNETIC TAPE

The following is a list of files that CDIAC distributes on magnetic tape along with this documentation.

File number and description	Number of logical records	Record format[a]	Block size	Record length
1. General descriptive information file	174	FB	8000	80
2. FORTRAN IV data retrieval code to read and print the Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises (File 4).	59	FB	8000	80
3. SAS[b] input/output routine to read and print the Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises (File 4).	23	FB	8000	80
4. Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises.	233	FB	5400	108
Total records	489			

[a] FB = fixed block.

[b] SAS is the registered trademark of SAS Institute, Inc., Cary, North Carolina 27511-8000.

12. DESCRIPTIVE FILE ON THE TAPE

The following is a listing of File 1 on the magnetic tape (or NDP036.DES on the floppy diskette) distributed by CDIAC. This file is intended to complement the documentation and provide details (i.e., variable descriptions, formats, and units) about the data file on the magnetic tape or floppy diskette.

TITLE OF THE DATA SET

Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises.

DATA CONTRIBUTORS

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University of Miami
Miami, Florida 33149

SOURCE AND SCOPE OF THE DATA

The data file included on this magnetic tape details ^{14}C activities from water samples taken at various locations and depths in the Indian Ocean. Values are presented in the internationally accepted $\Delta^{14}C$ convention (see, for example, Stuiver and Robinson 1974). The data were collected as part of the INDIGO 1, INDIGO 2, and INDIGO 3 cruises. The INDIGO 1 cruise collected samples in the southern Indian Ocean from February 27 through March 26, 1985. Carbon-14 measurements were made from 74 samples collected at 13 stations located between latitudes 26°S and 48°S. INDIGO 2 began the following year and sampled the northwestern Indian Ocean from April 1 through April 30, 1986. Carbon-14 measurements were made from 91 samples at 14 stations located between latitudes 19°S and 9°N. The INDIGO 3 cruise traveled south into the Southern Ocean and collected samples from January 15 through February 13, 1987. Carbon-14 measurements were made from 68 samples collected at 7 stations located between latitudes 37°S and 65°S.

These data have been used to estimate the penetration of anthropogenic CO_2 in the Indian Ocean and may be especially significant because of the inclusion of measurements from locations in the Southern Ocean near the major point of origin for the deep waters of the world's oceans. The data file also includes supporting measurements for potential temperature, salinity, density (sigma-theta), $\delta^{13}C$, and total CO_2.

DATA FORMAT

Four files are provided on this magnetic tape, including this descriptive file, a FORTRAN IV retrieval program, a SAS input/output routine, and a data file containing the Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises.

Table 2 (located in the documentation that accompanies this tape) presents a partial listing of the data file containing the Indian Ocean radiocarbon data (File 4 on the magnetic tape or INDIGO.DAT on the floppy diskette). The data file is formatted in the following way:

```
      CHARACTER STATION*3, DATE*6, CAST*3, SAMPLER*2
      INTEGER BOTTOM, LAT, LONG, DEPTH, POTTEMP, SALINITY,
     1        SIGTHETA, TCO2, DC13, DC14
   10 READ(2,100,END=99) STATION, DATE, BOTTOM, LAT, LONG, CAST,
     1                   DEPTH, POTTEMP, SALINITY, SIGTHETA,
     2                   TCO2, DC13, DC14, SAMPLER
C
  100 FORMAT(1X,A3,2X,A6,2X,I4,2X,I5,2X,I4,2X,A3,2X,I4,2X,I5,
     1       2X,I5,2X,I5,2X,I4,2X,I5,2X,I7,2X,A2)
```

where

STATION is the identifying number of the station (data collection site) (see Östlund and Grall 1988);

DATE is the date of sampling, presented in a six-digit format, indicating year, month, and day, respectively;

BOTTOM is the depth (in meters) of the ocean bottom at the site of sampling;

LAT is the latitude of the station, presented in degrees (first two digits) and minutes (last two digits), with north latitudes represented as positive;

LONG is the longitude (east) of the station, presented in degrees (first two digits) and minutes (last two digits);

CAST is the identifying number of the group of four Niskin sampling bottles simultaneously lowered into the water;

DEPTH is the depth (in meters) at which the sample was taken;

POTTEMP is the potential temperature (i.e., temperature corrected for the effect of adiabatic compression with increase in depth) given in °C * 1000 (see Pickard and Emery 1982);

SALINITY is the fraction of dissolved salts in sea water, given in ppt(w/w) * 1000;

SIGTHETA is sigma-theta (σ_θ), the density of seawater at the given salinity and potential temperature, given as [density (kg/m^3) - 1000] * 1000;

TCO2 is the total CO_2 in μmol/kg;

DC13 is $\delta^{13}C$, the deviation in per mil from standard ^{13}C:^{12}C ratio, calculated as $\delta^{13}C = [(R_{sa}/R_{st})-1] * 1000$, where R_{sa} and R_{st} are the ^{13}C:^{12}C ratios of sample and standard (obtained from the National Bureau of Standards), respectively (see Stuiver and Robinson 1974);

DC14 is $\Delta^{14}C$, the deviation in per mil of sample ^{14}C activity from standard ^{14}C activity, with correction for the effects of isotope fractionation, calculated as $\Delta^{14}C = [(A_{SN}/A_0)-1] * 1000$, where A_{SN} is the measured ^{14}C activity of the sample, corrected for isotope fractionation, and A_0 is the oxalic acid ^{14}C activity with the age corrected to 1950 A.D. and the ^{13}C normalized (see Stuiver and Robinson 1974; Östlund and Grall 1988; Stuiver and Polach 1977; Broecker and Olson 1961); and

SAMPLER is the identifying number of the Niskin bottle from which an individual sample was collected.

Stated in tabular form, the contents include the following.

Variable	Variable type	Variable width	Starting column	Ending column
STATION	Character	A3	2	4
DATE	Character	A6	7	12
BOTTOM	Numeric	I4	15	18
LAT	Numeric	I5	21	25
LONG	Numeric	I4	28	31
CAST	Character	A3	34	36
DEPTH	Numeric	I4	39	42
POTTEMP	Numeric	I5	45	49
SALINITY	Numeric	I5	52	56
SIGTHETA	Numeric	I5	59	63
TCO2	Numeric	I4	66	69
DC13	Numeric	I5	72	76
DC14	Numeric	I7	79	85
SAMPLER	Character	A2	88	89

Missing values for potential temperature, salinity, and sigma-theta are represented by -9999. Missing values for total CO_2 are represented by -999.

REFERENCES

Broecker, W. S., and E. A. Olson. 1961. Lamont radiocarbon measurements VIII. Radiocarbon 3:176-204.

Östlund, H. G., and C. Grall. 1988. INDIGO 1985-1987: Indian Ocean Radiocarbon. Tritium Laboratory Data Report No. 17. Tritium Laboratory, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida.

Pickard, G. L., and W. J. Emery. 1982. Descriptive Physical Oceanography: An Introduction, 4th ed. Pergamon Press, New York.

Stuiver, M., and H. A. Polach. 1977. Discussion: Reporting of ^{14}C data. Radiocarbon 19:355-363.

Stuiver, M., and S. W. Robinson. 1974. University of Washington GEOSECS North Atlantic carbon-14 results. Earth and Planetary Science Letters 23:87-90.

Table 2. Partial listing of the Indian Ocean radiocarbon data (as formatted in File 4 on the magnetic tape or INDIGO.DAT on the floppy diskette)

3	850227	5120	-2704	5657	101	0	-9999	35332	-9999	1982	600	108412	12
3	850227	5120	-2704	5657	103	300	-9999	35445	-9999	2099	30	96693	46
3	850227	5120	-2704	5657	104	500	-9999	35138	-9999	2195	40	67705	79
3	850227	5120	-2704	5657	201	750	-9999	34849	-9999	-999	310	36914	97
3	850227	5120	-2704	5657	202	1000	-9999	34546	-9999	2195	-720	-73725	56
3	850227	5120	-2704	5657	203	1250	-9999	34460	-9999	-999	60	-93161	34
3	850227	5120	-2704	5657	204	1500	-9999	34575	-9999	-999	-780	-147592	12
3	850227	5120	-2704	5657	301	2000	-9999	34736	-9999	2277	-880	-149699	67
3	850227	5120	-2704	5657	304	4000	-9999	34722	-9999	-999	-1300	-166623	12
7	850303	5100	-3741	5740	101	0	-9999	35540	-9999	2038	1070	114503	72
7	850303	5100	-3741	5740	204	150	-9999	35485	-9999	-999	480	115934	53
7	850303	5100	-3741	5740	103	300	-9999	35523	-9999	2099	250	118761	41
7	850303	5100	-3741	5740	104	500	-9999	35260	-9999	2110	740	89636	96
7	850303	5100	-3741	5740	201	750	-9999	34973	-9999	-999	-120	51003	26
7	850303	5100	-3741	5740	202	1000	-9999	34640	-9999	-999	30	-19362	79
7	850303	5100	-3741	5740	203	1250	-9999	34370	-9999	2195	130	-72338	14
7	850303	5100	-3741	5740	102	1500	-9999	34402	-9999	2228	-180	-88128	35
7	850303	5100	-3741	5740	301	2000	-9999	34589	-9999	-999	-170	-137236	26
8	850304	4920	-4011	5751	101	150	-9999	35454	-9999	-999	630	108824	72
9	850305	4750	-4308	5757	102	0	-9999	34717	-9999	2041	1440	65699	35
9	850305	4750	-4308	5757	101	150	-9999	34371	-9999	2099	790	76768	35
10	850305	4470	-4530	5748	101	150	-9999	33930	-9999	-999	800	12724	35
11	850309	4650	-4740	5750	101	0	-9999	33751	-9999	-999	1150	-4125	75
11	850309	4650	-4740	5750	103	300	-9999	34143	-9999	2171	660	-41379	12
11	850309	4650	-4740	5750	104	500	-9999	34241	-9999	2201	120	-86286	43
11	850309	4650	-4740	5750	201	750	-9999	34390	-9999	-999	-10	-116246	75
11	850309	4650	-4740	5750	202	1000	-9999	34553	-9999	2251	-700	-150839	96
11	850309	4650	-4740	5750	203	1250	-9999	34659	-9999	2256	-100	-147907	21
11	850309	4650	-4740	5750	204	1500	-9999	34718	-9999	-999	-100	-141474	34
17	850316	1830	-4631	7111	202	250	-9999	34101	-9999	-999	860	-39763	45
17	850316	1830	-4631	7111	203	500	-9999	34293	-9999	2235	380	-94242	31
17	850316	1830	-4631	7111	204	700	-9999	34503	-9999	-999	290	-136323	69
17	850316	1830	-4631	7111	101	1000	-9999	34564	-9999	-999	-610	-150760	75
19	850318	3650	-4320	7345	301	0	-9999	34700	-9999	2113	1520	83840	31
19	850318	3650	-4320	7345	302	150	-9999	35195	-9999	2155	850	88414	96
19	850318	3650	-4320	7345	303	300	-9999	35073	-9999	2187	870	77200	72
19	850318	3650	-4320	7345	304	500	-9999	34816	-9999	2235	1050	39731	54
19	850318	3650	-4320	7345	201	750	-9999	34506	-9999	-999	760	-23335	69
19	850318	3650	-4320	7345	202	1000	-9999	34354	-9999	2258	650	-66920	72
19	850318	3650	-4320	7345	203	1250	-9999	34403	-9999	-999	320	-112306	54
19	850318	3650	-4320	7345	204	1500	-9999	34523	-9999	2259	400	-128861	31
19	850318	3650	-4320	7345	101	2000	-9999	34690	-9999	2274	90	-136718	72
19	850318	3650	-4320	7345	102	2500	-9999	34752	-9999	-999	260	-158605	45
19	850318	3650	-4320	7345	103	3000	-9999	34755	-9999	-999	570	-155577	31
19	850318	3650	-4320	7345	104	3500	-9999	34722	-9999	-999	260	-164552	69
21	850320	3600	-3936	7623	301	0	-9999	35179	-9999	2039	1400	97376	74
21	850320	3600	-3936	7623	302	150	-9999	35239	-9999	2081	710	92673	52
21	850320	3600	-3936	7623	303	300	-9999	35113	-9999	-999	970	89336	13
21	850320	3600	-3936	7623	304	500	-9999	34888	-9999	2108	-5240	44612	96
21	850320	3600	-3936	7623	202	1000	-9999	34381	-9999	2198	560	-69754	74
21	850320	3600	-3936	7623	203	1250	-9999	34375	-9999	2221	410	-98088	31
21	850320	3600	-3936	7623	101	2000	-9999	34665	-9999	2244	-160	-154328	47
21	850320	3600	-3936	7623	102	2500	-9999	34737	-9999	2258	-300	-156857	13
21	850320	3600	-3936	7623	103	3000	-9999	34725	-9999	-999	-380	-168975	69
21	850320	3600	-3936	7623	104	3500	-9999	34717	-9999	2286	-160	-170214	52
22	850323	3380	-3349	7620	101	150	-9999	35361	-9999	2073	720	117005	24
22	850323	3380	-3349	7620	102	300	-9999	35184	-9999	2093	490	97694	13
23	850324	3800	-3015	7438	301	0	-9999	36015	-9999	2055	1530	127073	96
23	850324	3800	-3015	7438	302	150	-9999	35377	-9999	2078	1100	109287	75
23	850324	3800	-3015	7438	303	300	-9999	35165	-9999	2094	-100	91418	42
23	850324	3800	-3015	7438	304	500	-9999	34945	-9999	2107	710	62251	13
23	850324	3800	-3015	7438	201	750	-9999	34689	-9999	-999	920	8096	75

13. LISTING OF THE FORTRAN IV DATA RETRIEVAL PROGRAM

The following is a listing of the FORTRAN IV data retrieval program provided on magnetic tape (File 2) by CDIAC to read and print the Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises (File 4). The job control language (JCL) statements shown below are not provided in the file on the magnetic tape. The JCL statements required will vary for each individual requesting these data. The JCL statements shown below are provided to illustrate the statements that would be required by an individual at ORNL who has requested these data on a nine-track, 6250 BPI, standard-labeled tape with characters written in EBCDIC and who is attempting to read the tape on an IBM mainframe (e.g., IBM 3090).

```
//UIDIND JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
// EXEC FORTQCLG
//FORT.SYSIN DD *
C
C*****************************************************************
C  FORTRAN PROGRAM TO READ AND PRINT THE INDIAN OCEAN RADIOCARBON
C    DATA FROM THE INDIGO 1, 2, and 3 CRUISES.
C*****************************************************************
C
      CHARACTER STATION*3, DATE*6, CAST*3, SAMPLER*2
      INTEGER BOTTOM, LAT, LONG, DEPTH, POTTEMP, SALINITY,
     1        SIGTHETA, TCO2, DC13, DC14, NREC
C
C*****************************************************************
C * INITIALIZE A COUNTER FOR THE NUMBER OF RECORDS READ/WRITTEN.
C*****************************************************************
C
      NREC=0
C
C*****************************************************************
C * READ THE STATION INFORMATION.
C*****************************************************************
C
   10 READ(5,100,END=99) STATION, DATE, BOTTOM, LAT, LONG, CAST,
     1                   DEPTH, POTTEMP, SALINITY, SIGTHETA,
     2                   TCO2, DC13, DC14, SAMPLER
C
  100 FORMAT(1X,A3,2X,A6,2X,I4,2X,I5,2X,I4,2X,A3,2X,I4,2X,I5,
     1       2X,I5,2X,I5,2X,I4,2X,I5,2X,I7,2X,A2)
C
C*****************************************************************
C * TEST THE RECORD COUNTER FOR THE PURPOSE OF WRITING A
C * DESCRIPTIVE HEADER AT THE TOP OF EACH PRINTER PAGE.
C*****************************************************************
C
      IF(MOD(NREC,45).EQ.0) WRITE(6,101)
C
  101 FORMAT(1H1, 1X,'STATION',3X,'DATE',2X,'BOTTOM',2X,'LAT',
     1       3X,'LONG',1X,'CAST',1X,'DEPTH',1X,'POTTEMP',1X,
```

```
     2         'SALINITY',1X,'SIGTHETA',2X,'TCO2',3X,'DC13',4X,
     3         'DC14',2X,'SAMP'/)
C
      WRITE(6,102) STATION, DATE, BOTTOM, LAT, LONG, CAST,
     1             DEPTH, POTTEMP, SALINITY, SIGTHETA,
     2             TCO2, DC13, DC14, SAMPLER
C
  102 FORMAT (4X,A3,4X,A6,2X,I4,2X,I5,2X,I4,2X,A3,2X,I4,2X,I5,
     1        3X,I5,4X,I5,4X,I4,2X,I5,2X,I7,2X,A2)
C
C*****************************************************************
C * INSERT A BLANK LINE BETWEEN EACH 5 LINES OF OUTPUT.
C*****************************************************************
C
      NREC=NREC+1
C
      IF(MOD(NREC,5).EQ.0) WRITE(6,103)
  103 FORMAT(1X)
C
      GO TO 10
   99 CONTINUE
      STOP
      END
/*
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL,
// DISP=(,PASS),DSN=TAB.NDP036.RADIOCAR.DATA,LABEL=(4,SL)
//GO.FT06F001 DD *
//
```

14. LISTING OF THE SAS INPUT/OUTPUT RETRIEVAL PROGRAM

The following is a listing of the SAS* data retrieval program provided on magnetic tape (File 3) by CDIAC to read and print the Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises (File 4). The JCL statements shown below are not provided in the file on the magnetic tape. The JCL statements required will vary for each individual requesting these data. The JCL statements shown below are provided to illustrate the statements that would be required by an individual at ORNL who has requested these data on a nine-track, 6250 BPI, standard-labeled tape with characters written in EBCDIC and who is attempting to read the tape on an IBM mainframe (e.g., IBM 3090).

```
//UIDIND JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//STEP1 EXEC SAS,SASRGN=4096K,WORK=1600
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL,DISP=(,PASS),
// DSN=TAB.NDP036.RADIOCAR.DATA,LABEL=(4,SL)
//FT06F001 DD SYSOUT=A
//SYSIN DD *

DATA INDIGO;
INFILE IN;
INPUT STATION $ 2-4 DATE $ 7-12 BOTTOM 15-18 LAT 21-25 LONG 28-31
   CAST $ 34-36 DEPTH 39-42 POTTEMP 45-49 SALINITY 52-56
   SIGTHETA 59-63 TCO2 66-69 DC13 72-76 DC14 79-85
   SAMPLER $ 88-89;
FILE PRINT NOTITLE;
IF _N_ EQ 1 THEN DO;
PUT @2 'STATION' @12 'DATE' @18 'BOTTOM' @26 'LAT' @32 'LONG'
   @37 'CAST' @42 'DEPTH' @48 'POTTEMP' @56 'SALINITY'
   @65 'SIGTHETA' @75 'TCO2' @82 'DC13' @90 'DC14' @96 'SAMP'/;
END;
PUT STATION 4-6 DATE 11-16 BOTTOM 19-22 LAT 25-29 LONG 32-35
   CAST 38-40 DEPTH 43-46 POTTEMP 49-53 SALINITY 57-61 SIGTHETA
   66-70 TCO2 75-78 DC13 81-85 DC14 88-94 SAMPLER 97-98;
IF MOD(_N_,5) EQ 0 THEN PUT;
IF MOD(_N_,45) EQ 0 THEN DO;
PUT _PAGE_;
PUT @2 'STATION' @12 'DATE' @18 'BOTTOM' @26 'LAT' @32 'LONG'
   @37 'CAST' @42 'DEPTH' @48 'POTTEMP' @56 'SALINITY'
   @65 'SIGTHETA' @75 'TCO2' @82 'DC13' @90 'DC14' @96 'SAMP'/;
END;
RUN;

/*
//
```

---

*SAS is the registered trademark of SAS Institute, Inc., Cary, North Carolina 27511-8000.

15. VERIFICATION OF DATA TRANSPORT

The Indian Ocean radiocarbon data file can be read by using the FORTRAN or SAS input/output routines provided. Users should verify that the data file has been correctly transported to their systems by generating some or all of the statistics presented in Tables 3 and 4. These statistics were generated in SAS (through the MEANS procedure) but can be duplicated in other statistical packages or languages. If the statistics generated by the user differ from those presented here, the data file may have been corrupted in transport.

These statistics are presented only as a tool to ensure proper reading of the data file. They are not to be construed as summarizing the Indian Ocean radiocarbon data.

Table 3. Characteristics of numeric variables in the Indian Ocean radiocarbon data set

Variable	Number of observations	Mean	Minimum value	Maximum value
BOTTOM	233	4488.8	1830.0	5573.0
LAT	233	-2995.3	-6410.0	852.0
LONG	233	5721.8	1827.0	8400.0
DEPTH	233	1147.0	0.0	4804.0
POTTEMP	233	1560.9	-9999.0	30274.0
SALINITY	233	34039.1	-9999.0	36055.0
SIGTHETA	233	14158.4	-9999.0	27871.0
TCO2	233	1554.4	-999.0	3353.0
DC13	233	112.6	-5240.0	1530.0
DC14	233	-58774.7	-188930.0	127073.0

The following is a listing of the SAS program used to generate the statistics described in the table.

```
DATA SUMSTATS;
INFILE IN;
INPUT BOTTOM 15-18 LAT 21-25 LONG 28-31 DEPTH 39-42 POTTEMP 45-49
   SALINITY 52-56 SIGTHETA 59-63 TCO2 66-69 DC13 72-76 DC14 79-85;
PROC MEANS DATA=SUMSTATS MAXDEC=1;
   VAR BOTTOM LAT LONG DEPTH POTTEMP SALINITY SIGTHETA TCO2 DC13
       DC14;
RUN;
```

Table 4. Indian Ocean radiocarbon data from the INDIGO 1, 2, and 3 cruises

STATION	DATE	BOTTOM	LAT°	LONG°	CAST	DEPTH	POTTEMP	SALINITY	SIGTHETA	TCO2	DC13	DC14	SAMP
3	850227	5120	-2704	5657	101	0	-9999	35332	-9999	1982	600	108412	12
3	850227	5120	-2704	5657	103	300	-9999	35445	-9999	2099	30	96693	46
3	850227	5120	-2704	5657	104	500	-9999	35138	-9999	2195	40	67705	79
3	850227	5120	-2704	5657	201	750	-9999	34849	-9999	-999	310	36914	97
3	850227	5120	-2704	5657	202	1000	-9999	34546	-9999	2195	-720	-73725	56
3	850227	5120	-2704	5657	203	1250	-9999	34460	-9999	-999	60	-93161	34
3	850227	5120	-2704	5657	204	1500	-9999	34575	-9999	-999	-780	-147592	12
3	850227	5120	-2704	5657	301	2000	-9999	34736	-9999	2277	-880	-149699	67
3	850227	5120	-2704	5657	304	4000	-9999	34722	-9999	-999	-1300	-166623	12
7	850303	5100	-3741	5740	101	0	-9999	35540	-9999	2038	1070	114503	72
7	850303	5100	-3741	5740	204	150	-9999	35485	-9999	-999	480	115934	53
7	850303	5100	-3741	5740	103	300	-9999	35523	-9999	2099	250	118761	41
7	850303	5100	-3741	5740	104	500	-9999	35260	-9999	2110	740	89636	96
7	850303	5100	-3741	5740	201	750	-9999	34973	-9999	-999	-120	51003	26
7	850303	5100	-3741	5740	202	1000	-9999	34640	-9999	-999	30	-19362	79
7	850303	5100	-3741	5740	203	1250	-9999	34370	-9999	2195	130	-72338	14
7	850303	5100	-3741	5740	102	1500	-9999	34402	-9999	2228	-180	-88128	35
7	850303	5100	-3741	5740	301	2000	-9999	34589	-9999	-999	-170	-137236	26
8	850304	4920	-4011	5751	101	150	-9999	35454	-9999	-999	630	108824	72
9	850305	4750	-4308	5757	102	0	-9999	34717	-9999	2041	1440	65699	35
9	850305	4750	-4308	5757	101	150	-9999	34371	-9999	2099	790	76768	35
10	850305	4470	-4530	5748	101	150	-9999	33930	-9999	-999	800	12724	35
11	850309	4650	-4740	5750	101	0	-9999	33751	-9999	-999	1150	-4125	75
11	850309	4650	-4740	5750	103	300	-9999	34143	-9999	2171	660	-41379	12
11	850309	4650	-4740	5750	104	500	-9999	34241	-9999	2201	120	-86286	43
11	850309	4650	-4740	5750	201	750	-9999	34390	-9999	-999	-10	-116246	75
11	850309	4650	-4740	5750	202	1000	-9999	34553	-9999	2251	-700	-150839	96
11	850309	4650	-4740	5750	203	1250	-9999	34659	-9999	2256	-100	-147907	21
11	850309	4650	-4740	5750	204	1500	-9999	34718	-9999	-999	-100	-141474	34
17	850316	1830	-4631	7111	202	250	-9999	34101	-9999	-999	860	-39763	45
17	850316	1830	-4631	7111	203	500	-9999	34293	-9999	2235	380	-94242	31
17	850316	1830	-4631	7111	204	700	-9999	34503	-9999	-999	290	-136323	69
17	850316	1830	-4631	7111	101	1000	-9999	34564	-9999	-999	-610	-150760	75
19	850318	3650	-4320	7345	301	0	-9999	34700	-9999	2113	1520	83840	31
19	850318	3650	-4320	7345	302	150	-9999	35195	-9999	2155	850	88414	96
19	850318	3650	-4320	7345	303	300	-9999	35073	-9999	2187	870	77200	72
19	850318	3650	-4320	7345	304	500	-9999	34816	-9999	2235	1050	39731	54
19	850318	3650	-4320	7345	201	750	-9999	34506	-9999	-999	760	-23335	69
19	850318	3650	-4320	7345	202	1000	-9999	34354	-9999	2258	650	-66920	72
19	850318	3650	-4320	7345	203	1250	-9999	34403	-9999	-999	320	-112306	54
19	850318	3650	-4320	7345	204	1500	-9999	34523	-9999	2259	400	-128861	31
19	850318	3650	-4320	7345	101	2000	-9999	34690	-9999	2274	90	-136718	72
19	850318	3650	-4320	7345	102	2500	-9999	34752	-9999	-999	260	-158605	45
19	850318	3650	-4320	7345	103	3000	-9999	34755	-9999	-999	570	-155577	31
19	850318	3650	-4320	7345	104	3500	-9999	34722	-9999	-999	260	-164552	69
21	850320	3600	-3936	7623	301	0	-9999	35179	-9999	2039	1400	97376	74
21	850320	3600	-3936	7623	302	150	-9999	35239	-9999	2081	710	92673	52
21	850320	3600	-3936	7623	303	300	-9999	35113	-9999	-999	970	89336	13
21	850320	3600	-3936	7623	304	500	-9999	34888	-9999	2108	-5240	44612	96
21	850320	3600	-3936	7623	202	1000	-9999	34381	-9999	2198	560	-69754	74

Table 4. (continued)

STATION	DATE	BOTTOM	LAT[a]	LONG[a]	CAST	DEPTH	POTTEMP	SALINITY	SIGTHETA	TCO2	DC13	DC14	SAMP
21	850320	3600	-3936	7623	203	1250	-9999	34375	-9999	2221	410	-98088	31
21	850320	3600	-3936	7623	101	2000	-9999	34665	-9999	2244	-160	-154328	47
21	850320	3600	-3936	7623	102	2500	-9999	34737	-9999	2258	-300	-156857	13
21	850320	3600	-3936	7623	103	3000	-9999	34725	-9999	-999	-380	-168975	69
21	850320	3600	-3936	7623	104	3500	-9999	34717	-9999	2286	-160	-170214	52
22	850323	3380	-3349	7620	101	150	-9999	35361	-9999	2073	720	117005	24
22	850323	3380	-3349	7620	102	300	-9999	35184	-9999	2093	490	97694	13
23	850324	3800	-3015	7438	301	0	-9999	36015	-9999	2055	1530	127073	96
23	850324	3800	-3015	7438	302	150	-9999	35377	-9999	2078	1100	109287	75
23	850324	3800	-3015	7438	303	300	-9999	35165	-9999	2094	-100	91418	42
23	850324	3800	-3015	7438	304	500	-9999	34945	-9999	2107	710	62251	13
23	850324	3800	-3015	7438	201	750	-9999	34689	-9999	-999	920	8096	75
23	850324	3800	-3015	7438	202	1000	-9999	34407	-9999	-999	340	-93697	42
23	850324	3800	-3015	7438	203	1250	-9999	34460	-9999	-999	110	-137155	31
23	850324	3800	-3015	7438	204	1500	-9999	34576	-9999	2260	130	-149080	96
23	850324	3800	-3015	7438	101	2000	-9999	34710	-9999	-999	-280	-168491	75
23	850324	3800	-3015	7438	102	2500	-9999	34726	-9999	-999	-260	-167660	42
23	850324	3800	-3015	7438	103	3000	-9999	34723	-9999	-999	-420	-174538	13
23	850324	3800	-3015	7438	104	3500	-9999	34719	-9999	-999	730	-173272	96
24	850325	3930	-2925	7049	102	300	-9999	35418	-9999	-999	1480	119906	69
25	850326	5220	-2659	6707	101	100	-9999	35763	-9999	-999	720	107321	69
25	850326	5220	-2659	6707	102	300	-9999	35431	-9999	-999	1420	123739	96
25	850326	5220	-2659	6707	103	750	-9999	34789	-9999	-999	1120	40700	42
25	850326	5220	-2659	6707	104	1500	-9999	34568	-9999	-999	430	-159418	13
27	860401	4740	-1854	5447	101	47	27179	35148	22774	1962	1420	113593	87
27	860401	4740	-1854	5447	301	66	26085	35263	23207	1957	970	92235	89
27	860401	4740	-1854	5447	102	121	20787	35425	24877	2043	470	121250	63
27	860401	4740	-1854	5447	201	211	16745	35446	25918	2103	140	91568	21
27	860401	4740	-1854	5447	202	614	9888	34805	26819	2124	1320	42475	98
27	860401	4740	-1854	5447	302	1227	4321	34639	27465	2266	410	-126431	76
27	860401	4740	-1854	5447	203	1419	3354	34650	27573	2265	170	-150229	76
27	860401	4740	-1854	5447	204	2425	2788	34738	27695	2290	-470	-165748	43
27	860401	4740	-1854	5447	303	2635	1767	34737	27779	2299	-420	-177037	43
27	860401	4740	-1854	5447	304	4505	795	34719	27833	2280	-1420	-163695	21
30	860405	3975	-1115	6427	301	27	28374	34961	22245	1998	450	72400	98
30	860405	3975	-1115	6427	302	73	18277	34989	25196	2141	-50	40197	76
30	860405	3975	-1115	6427	303	117	16081	35098	25805	2160	-820	29498	43
30	860405	3975	-1115	6427	304	227	13378	35050	26356	2186	-240	-5863	21
30	860405	3975	-1115	6427	201	406	10371	34873	26789	2179	1240	-15803	12
30	860405	3975	-1115	6427	102	505	8944	34784	26958	2179	270	-81334	76
30	860405	3975	-1115	6427	202	706	7389	34737	27157	2264	280	-119004	34
30	860405	3975	-1115	6427	103	984	6420	34757	27285	2300	-390	-149946	43
30	860405	3975	-1115	6427	203	1009	5770	34729	27379	2302	-260	-156512	67
30	860405	3975	-1115	6427	204	1508	3583	34753	27632	2316	-530	-170229	89
30	860405	3975	-1115	6427	101	1842	2665	34735	27704	2305	-180	-166886	98
30	860405	3975	-1115	6427	104	2005	2247	34728	27734	2300	-1250	-180884	21
31	860407	4035	-1042	5809	101	2	-9999	-9999	-9999	-999	670	98951	99
31	860407	4035	-1042	5809	102	120	17150	35355	25752	2115	1190	58697	99
32	860408	4673	-1218	5339	302	63	21918	34964	24215	2028	1070	80595	76
32	860408	4673	-1218	5339	303	103	19421	35145	25025	2121	580	59422	43

Table 4. (continued)

STATION	DATE	BOTTOM	LAT°	LONG°	CAST	DEPTH	POTTEMP	SALINITY	SIGTHETA	TCO2	DC13	DC14	SAMP
32	860408	4673	-1218	5339	304	200	14321	35091	26190	2163	230	19894	21
32	860408	4673	-1218	5339	201	406	9943	34851	26846	2177	470	-22912	98
32	860408	4673	-1218	5339	202	707	7598	34728	27120	2246	20	-95759	76
32	860408	4673	-1218	5339	203	1008	5710	34763	27402	2284	180	-135551	54
32	860408	4673	-1218	5339	204	1510	3474	34727	27622	2298	110	-167308	32
32	860408	4673	-1218	5339	101	2037	2943	34735	27679	2302	20	-155273	98
32	860408	4673	-1218	5339	102	2799	1595	34742	27796	2317	40	-171447	76
32	860408	4673	-1218	5339	103	3533	1220	34738	27820	2314	900	-176247	41
32	860408	4673	-1218	5339	104	4567	759	34717	27834	2286	-120	-166904	21
33	860409	3590	-1155	5008	101	2	-9999	-9999	-9999	-999	980	101213	99
33	860409	3590	-1155	5008	102	120	20812	35321	24791	2032	380	87459	99
34	860411	4141	-0850	5215	101	2	-9999	-9999	-9999	-999	850	97198	99
34	860411	4141	-0850	5215	102	120	16566	35161	25741	-999	120	46625	99
36	860412	4927	-0609	5055	301	25	27594	35245	22713	1964	1210	92183	98
36	860412	4927	-0609	5055	302	66	21497	35291	24580	2061	1120	80479	76
36	860412	4927	-0609	5055	303	106	17552	35317	25626	2129	350	64063	54
36	860412	4927	-0609	5055	304	207	12742	35071	26500	2172	-630	5908	32
36	860412	4927	-0609	5055	201	417	9552	34884	26937	2136	390	-47977	39
36	860412	4927	-0609	5055	202	715	7577	34813	27190	2268	200	-125163	17
36	860412	4927	-0609	5055	203	1035	6104	34824	27401	2300	-200	-142006	65
36	860412	4927	-0609	5055	204	1550	4281	34777	27579	2313	-510	-166491	42
36	860412	4927	-0609	5055	101	2035	3180	34762	27678	2314	-110	-158700	98
36	860412	4927	-0609	5055	102	2796	1586	34745	27799	2318	-60	-180587	76
36	860412	4927	-0609	5055	205	3553	1286	34739	27816	2315	-310	-169612	10
36	860412	4927	-0609	5055	104	4573	913	34725	27830	2292	-1450	-174731	21
38	860415	4460	-0159	6001	201	23	30274	35179	21769	1955	1080	70938	98
38	860415	4460	-0159	6001	202	61	23667	35489	24112	2053	1230	84107	76
38	860415	4460	-0159	6001	203	97	20222	35385	24998	2096	40	67135	43
38	860415	4460	-0159	6001	204	191	14522	35227	26252	2144	360	43972	52
38	860415	4460	-0159	6001	301	404	10541	34975	26839	2183	180	-27960	25
38	860415	4460	-0159	6001	302	704	8165	35033	27275	2251	880	-115937	34
38	860415	4460	-0159	6001	303	1003	6414	34967	27473	2287	-390	-148209	67
38	860415	4460	-0159	6001	304	1502	4078	34849	27658	2304	210	-169776	89
38	860415	4460	-0159	6001	101	1973	2555	34783	27752	2298	80	-168341	49
38	860415	4460	-0159	6001	104	1987	2534	34785	27755	2298	-640	-180819	32
38	860415	4460	-0159	6001	102	2465	1911	34756	27783	2295	-1140	-188930	87
43	860418	4675	0358	5650	301	25	29004	35234	22241	1939	1110	71372	98
43	860418	4675	0358	5650	302	65	24776	35535	23816	1962	1040	89955	76
43	860418	4675	0358	5650	303	105	20550	35435	24948	2073	80	57323	54
43	860418	4675	0358	5650	304	205	13880	35219	26382	2200	-180	2596	32
43	860418	4675	0358	5650	201	401	10711	35089	26897	2204	130	-74135	98
43	860418	4675	0358	5650	202	699	8554	35185	27334	2253	-360	-115771	76
43	860418	4675	0358	5650	203	991	6594	35008	27481	2277	-840	-158164	54
43	860418	4675	0358	5650	204	1491	4484	34916	27667	2293	-530	-168494	32
43	860418	4675	0358	5650	101	2005	3783	34795	27646	2298	-170	-175924	98
43	860418	4675	0358	5650	102	2755	1717	34755	27797	2295	80	-182711	76
43	860418	4675	0358	5650	103	3505	1350	34759	27828	2287	-1080	-169648	54
43	860418	4675	0358	5650	104	4505	891	34731	27836	2284	-240	-183284	32
44	860419	4485	0000	5629	101	2	-9999	-9999	-9999	-999	870	87966	99
45	860421	5058	-0003	5057	301	26	28784	35221	22304	1989	1340	68039	54

Table 4. (continued)

STATION	DATE	BOTTOM	LAT[a]	LONG[a]	CAST	DEPTH	POTTEMP	SALINITY	SIGTHETA	TCO2	DC13	DC14	SAMP
45	860421	5058	-0003	5057	302	118	19259	35435	25288	2098	920	86757	32
45	860421	5058	-0003	5057	201	203	14110	35208	26325	2151	130	19050	23
45	860421	5058	-0003	5057	202	401	10701	35001	26831	2189	590	-27876	45
45	860421	5058	-0003	5057	203	699	8484	35045	27235	2286	-310	-125038	67
45	860421	5058	-0003	5057	204	996	6743	34989	27446	2297	-260	-143734	89
45	860421	5058	-0003	5057	101	2057	2616	34773	27738	2308	-120	-180351	87
45	860421	5058	-0003	5057	102	2813	1614	34747	27799	2366	10	-178713	65
45	860421	5058	-0003	5057	103	3579	1303	34731	27808	2437	-310	-181590	43
45	860421	5058	-0003	5057	104	4804	915	34725	27830	2414	-320	-172145	21
50	860423	3082	-0001	4431	101	10	29376	35337	22193	1966	996	83778	99
50	860423	3082	-0001	4431	102	120	17835	35339	25573	2111	-420	62249	99
65	860428	5090	0500	5205	101	10	29760	35452	22150	1975	1350	77089	99
65	860428	5090	0500	5205	102	120	20110	35449	25077	2122	70	50478	99
69	860430	4960	0852	5317	101	10	29919	35145	21865	1963	1100	80662	99
69	860430	4960	0852	5317	102	120	24870	36055	24180	2088	540	63460	99
76	870115	4431	-5929	6959	301	25	1332	33666	26951	2133	-970	-37556	87
76	870115	4431	-5929	6959	302	56	736	33677	26998	2135	1140	-23685	65
76	870115	4431	-5929	6959	303	107	-1565	33826	27220	2159	940	-51374	43
76	870115	4431	-5929	6959	304	220	1257	34311	27474	2227	270	-103576	21
76	870115	4431	-5929	6959	201	401	2004	34558	27617	2258	-350	-146158	87
76	870115	4431	-5929	6959	202	683	2016	34684	27717	2253	-90	-144319	65
76	870115	4431	-5929	6959	203	970	1892	34738	27770	3353	450	-142995	43
76	870115	4431	-5929	6959	204	1447	1474	34751	27812	2248	-1280	-141552	21
76	870115	4431	-5929	6959	101	1933	972	34722	27824	2255	-1870	-147479	97
76	870115	4431	-5929	6959	104	2438	565	34704	27835	2260	-330	-148702	21
76	870115	4431	-5929	6959	102	2541	479	34696	27834	2265	240	-157979	65
76	870115	4431	-5929	6959	103	3103	185	34686	27843	2264	-1130	-147878	43
79	870118	3939	-6410	8400	301	25	1055	33801	27078	2133	480	-92789	87
79	870118	3939	-6410	8400	302	54	-1223	34101	27433	2189	160	-112278	65
79	870118	3939	-6410	8400	303	103	-1522	34313	27615	2203	500	-120557	43
79	870118	3939	-6410	8400	304	210	-979	34439	27698	2226	-810	-96839	12
79	870118	3939	-6410	8400	101	399	1396	34671	27754	2255	50	-148463	65
79	870118	3939	-6410	8400	103	977	862	34708	27820	2260	-80	-157137	21
79	870118	3939	-6410	8400	201	1471	437	34692	27833	2265	210	-156306	87
79	870118	3939	-6410	8400	202	1957	192	34679	27837	2266	-250	-158430	65
79	870118	3939	-6410	8400	204	3413	-384	34684	27871	2262	-80	-148855	21
85	870123	5048	-6220	4958	301	27	945	33749	27043	2155	810	-69517	98
85	870123	5048	-6220	4958	302	59	341	33907	27206	2160	400	-60049	76
85	870123	5048	-6220	4958	303	111	-1402	34079	27421	2189	620	-76556	54
85	870123	5048	-6220	4958	304	227	1676	34567	27650	2268	-710	-136964	32
85	870123	5048	-6220	4958	201	405	1779	34689	27740	2261	-30	-154170	87
85	870123	5048	-6220	4958	203	990	1223	34730	27813	2258	60	-153017	43
85	870123	5048	-6220	4958	204	1472	725	34713	27833	2265	-250	-134901	21
85	870123	5048	-6220	4958	101	2109	267	34691	27842	2269	-380	-158755	13
85	870123	5048	-6220	4958	102	2645	30	34677	27844	2266	50	-159792	45
85	870123	5048	-6220	4958	103	3229	-240	34665	27848	2262	280	-162619	67
85	870123	5048	-6220	4958	104	4397	-574	34663	27862	2259	-840	-158045	89
88	870127	5189	-6101	3217	301	25	1250	33787	27054	2141	600	-58215	98
88	870127	5189	-6101	3217	302	55	-111	33796	27140	2152	-290	-64742	76
88	870127	5189	-6101	3217	303	106	-1176	34109	27438	2153	1050	-71682	54

Table 4. (continued)

STATION	DATE	BOTTOM	LAT[a]	LONG[a]	CAST	DEPTH	POTTEMP	SALINITY	SIGTHETA	TCO2	DC13	DC14	SAMP
88	870127	5189	-6101	3217	304	216	1301	34586	27692	2256	-1450	-132737	21
88	870127	5189	-6101	3217	101	412	1486	34695	27766	2263	-80	-151886	98
88	870127	5189	-6101	3217	102	710	1167	34723	27812	2261	20	-159942	76
88	870127	5189	-6101	3217	103	1008	785	34715	27830	2261	60	-154063	54
88	870127	5189	-6101	3217	104	1504	333	34691	27838	2266	-840	-151780	31
88	870127	5189	-6101	3217	201	2152	152	34681	27841	2264	-210	-149146	98
88	870127	5189	-6101	3217	202	2699	-188	34676	27854	2265	-1680	-156205	76
88	870127	5189	-6101	3217	204	4488	-610	34668	27868	2256	-550	-152562	21
97	870204	4899	-4147	1827	301	30	19870	35593	25250	2018	820	102184	98
97	870204	4899	-4147	1827	302	55	19866	35592	25250	2019	-210	122701	76
97	870204	4899	-4147	1827	303	106	18353	35645	25679	2037	770	108225	54
97	870204	4899	-4147	1827	304	216	15886	35493	26154	2084	90	121955	21
97	870204	4899	-4147	1827	101	412	12115	35103	26648	2113	-360	65365	98
97	870204	4899	-4147	1827	201	510	10829	35057	26851	2157	450	58498	98
97	870204	4899	-4147	1827	102	710	7276	34663	27115	2204	620	-52189	76
97	870204	4899	-4147	1827	103	1008	3766	34281	27238	2257	-640	-64282	54
97	870204	4899	-4147	1827	202	1239	3453	34539	27474	2126	-3120	-92635	76
97	870204	4899	-4147	1827	104	1504	2739	34612	27599	2252	10	-113937	21
97	870204	4899	-4147	1827	203	2033	2508	34807	27775	2233	490	-124451	54
97	870204	4899	-4147	1827	204	3616	1549	34785	27834	2241	130	-136632	21
100	870208	5573	-3758	3602	102	717	9019	34675	26861	2124	410	36413	76
100	870208	5573	-3758	3602	103	1018	5643	34485	27190	2149	710	-65240	54
100	870208	5573	-3758	3602	301	1370	3754	34477	27395	2221	170	-99626	89
100	870208	5573	-3758	3602	201	2139	2422	34673	27675	2255	660	-72412	98
100	870208	5573	-3758	3602	202	2682	2013	34763	27781	2257	-700	-114244	76
100	870208	5573	-3758	3602	204	4451	-9999	34725	-9999	2242	120	-80236	21
103	870213	4154	-4746	5802	101	535	2856	34257	27305	-999	260	-64974	45
103	870213	4154	-4746	5802	102	1083	2312	34587	27616	-999	-1900	-110394	98
103	870213	4154	-4746	5802	201	1583	2191	34735	27744	-999	170	-122576	12
103	870213	4154	-4746	5802	103	2000	-9999	34771	-9999	-999	200	-138707	76
103	870213	4154	-4746	5802	202	2475	1350	34745	27816	-999	-210	-142662	67
103	870213	4154	-4746	5802	203	2973	835	34724	27834	-999	-580	-129265	89
103	870213	4154	-4746	5802	204	3453	591	34707	27836	-999	-3360	-147771	54

[a] Latitudes and longitudes are given in degrees-minutes. North latitudes and East longitudes are positive.

APPENDIX

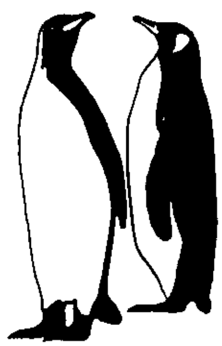
REPRINTS OF PERTINENT LITERATURE

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE
MIAMI, FLORIDA 33149

INDIGO

1985 - 1987

INDIAN OCEAN RADIOCARBON



TRITIUM LABORATORY

DATA REPORT #17

by

H. Gote Ostlund and Charlene Grall

This Report constitutes the Final Report
for the following ORNL subcontract:
Martin Marietta 19X-89648C-DOE I.N.R.
Indian Ocean Radiocarbon

April 1988

Note: This Data Report supersedes all Data Releases issued on these results.

Copies of this Data Report, or any other Tritium Laboratory Data Report, may be obtained by addressing the Tritium Laboratory, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami FL 33149, USA.

A 5 1/4" DOS standard floppy disc has been prepared based on this Report and is available upon request. It contains all radiocarbon and selected hydrographic data tabulated in ASCII format.

Cover design by Charlene Grall.

TRITIUM LABORATORY DATA REPORTS

1 TRITIUM IN THE TROPOSPHERE AND SURFACE WATER OF NORTH ATLANTIC OCEAN 1964-70, H.G. Ostlund, R.D. Stearns, and R. Brescher. July 1971.

9 GEOSECS INDIAN OCEAN, Radiocarbon and Tritium Results, H.G. Ostlund, R. Oleson and R. Brescher. October 1980.

#11 ANTARCTIC TRITIUM 1977-1979, A.S. Mason and H.G. Ostlund. November 1981.

#12 GEOSECS TRITIUM, Atlantic Ocean 1972-73, Pacific Ocean 1973-74, Indian Ocean 1977-78, Station 347 Revisits, H.G. Ostlund and R. Brescher. December 1982.

#13 NAGS TRITIUM, North Atlantic Gyre Studies and Associated Projects, H.G. Ostlund. June 1984.

#14 ATMOSPHERIC TRITIUM 1968-1984, H.G. Ostlund and A.S. Mason. April 1985.

#15 EQUATORIAL PACIFIC TRITIUM, H.G. Ostlund, C. Grall, and R.E. Brescher. April 1986.

#16 TTO NORTH AND TROPICAL ATLANTIC TRITIUM AND RADIOCARBON, H.G. Ostlund and C. Grall. February 1987.

#17 INDIGO 1985-1987, Indian Ocean Radiocarbon, H.G. Ostlund and C. Grall. April 1988. THIS REPORT.

NOTE: Data Reports #s 2, 3, 4, 5, 6, 7, 8, 10 have been superseded by #s 12, 13, and 14.

PREFACE

This data report lists all radiocarbon data for the Indian Ocean on samples collected during INDIGO I, INDIGO II and INDIGO III, 1985-1987. In the listings are included numbers previously reported in the following informal Data Releases to our colleagues in these projects:

87-21: INDIGO I, 1985. Radiocarbon Results (Amended).

87-22: INDIGO II, 1986. Radiocarbon Results.

Additional quality control may have slightly changed some earlier data which are hereby superseded; in particular, some radiocarbon data were adjusted by a thorough review of measurement standards. The following paper utilizes parts of results of this Report: Bard, et al., "Penetration of bomb radiocarbon in the tropical Indian Ocean measured by means of accelerator mass spectrometry" (1).

The data in this report are hereby in the public domain to be used by anyone. Conventional reference is appreciated. A 5 1/4" floppy disc, containing all radiocarbon data in addition to some hydrographic data, in PC-DOS ASCII format, is available upon request.

ACKNOWLEDGEMENTS

The excellent cooperation of Dr. A. Poisson of UPMC*, the entire French scientific party, TAAF, and the crew of R/V Marion Dufresne is hereby thankfully acknowledged. We would like to particularly thank Drs. L. Merlivat and P. Jean-Baptiste of the Saclay group for their untiring assistance throughout the INDIGO Project. Mr. Ted Tankard, formally of the University of Miami was responsible for the collection of the C14 samples on INDIGO II and III and to him we extend our thanks.

We would also like to express our appreciation to the U.S. Department of Energy and Martin Marietta for support under ORNL Subcontract #19X-89648C-DOE I.N.R.

*Abbreviations:

UPMC Université Pierre et Marie Curie

TAAF Terres Australes et Antarctiques Francaises

Saclay Centre d'Etudes Nucléaires de Saclay

TABLE OF CONTENTS

INDIGO RADIOCARBON

I. BACKGROUND INFORMATION

The project INDIGO (INDIEN GAZ OCEAN) was a joint cooperative effort with French scientific personnel under the auspices of the U.S. Department of Energy and the Centre National de la Recherche Scientifique. The main objective was to study carbonate chemistry and carbon dioxide (CO_2) penetration in the Indian Ocean. The information obtained could then be used to further clarify the global oceanic carbon cycle.

The objective of the University of Miami Tritium Laboratory was to collect large volume water samples, extract the CO_2 and measure radiocarbon. The information will be used in conjunction with total CO_2 data to estimate the extent of penetration of anthropogenic CO_2 into the Indian Ocean.

II. CRUISE DESCRIPTIONS

Three cruises on R/V Marion Dufresne, operated by TAAF, took place during the course of the project. Alain Poisson, of UPMC, was Chief Scientist. INDIGO I explored the Southern Indian Ocean from Madagascar to 53°S during the late austral summer, 23 February - 30 March, 1985. Several GEOSECS stations were re-sampled. However, due to unforseen circumstances, the cruise did not continue as far south as originally planned. A total of 74 C14 measurements resulted from sampling on 13 of 26 stations occupied.

INDIGO II resumed sampling the following year, 28 March - 3 May, 1986 investigating the Northwestern Indian Ocean from Madagascar to the Red Sea. The cruise track, continuing the numerical station sequence from INDIGO I, included stations 27-74. A total of 91 samples was collected and analyzed for C14 from 14 stations, five of which were GEOSECS reoccupations.

Stations 75-103 comprised INDIGO III which took place during the austral summer, 3 January - 27 February, 1987. The cruise track headed south, successfully reaching Antarctica, and occupying 28 stations. Seawater samples were collected from seven stations, (three GEOSECS reoccupations). A total of 68 C14 samples was measured.

III. TECHNICAL PROCEDURES

Sampling

During the entire INDIGO project, 233 radiocarbon samples were successfully extracted and analyzed.

Water samples were collected on board the French research vessel, Marion Dufresne, using 100 liter GoFlo samplers. Each sample consisted of water from a pair of GoFlo bottles. A cast usually included 4 pairs of bottles, the individuals of each pair separated by 10 - 15 m. On deck, water collected was transferred via vinyl hose through a krypton (Kr) extraction system, and stored in a 200 liter barrel for C14 extraction. A typical seawater sample was approximately 190 liters, given the loss of sample residual in the GoFlo bottles and water used to flush the Kr extraction unit and lines. (The Kr extraction was not part of our project).

Extraction of CO_2 was performed by acidifying the seawater sample with 50 ml of concentrated sulfuric acid and purging the released CO_2 gas using nitrogen. The CO_2 was then absorbed in 450 ml of 4N NaOH. Typical yield was approximately 9 lit-atm of CO_2, 95 to 98% of the total dissolved CO_2 in the sample. Bottles with the NaOH-carbonate mixture were shipped to Miami.

Occasionally, a single GoFlo bottle would mistrip, and the subsequent sample would be only 100 liters. Extraction was done in the usual manner but yield was only 4-5 lit-atm of CO_2.

Preparation of Sampling Gas

In the laboratory, CO_2 was released from the NaOH solution by adding phosphoric acid. Nitrogen gas, the carrier, transfered CO_2 and any other evolved gases to collection traps maintained at -196°C by liquid nitrogen. After pumping on the solid CO_2, this gas was then passed through a purification system consisting of a series of cold traps to remove water vapor, and two copper-silver ovens to remove gaseous electronegative impurities, mainly chlorine and oxygen. Remaining impurities were removed by pumping on condensed CO_2 at a temperature of -196°C. It is our experience that yields are about 99.7% of the total CO_2 contained in the NaOH solution.

At this point, a small aliquot of purified gas was removed for mass-spectrometric δ C13 analysis. The remaining gas was stored in a stainless steel high pressure cylinder for 14 to 21 days before counting to allow any radon to decay (half-life is 4 days). The radon originated from the phosphoric acid, and occasionally from the glass of the NaOH bottles.

Below follows a description of our standard C14 measurement technique and special modifications for this project.

Counting

We have four 2.5 liter low-level gas proportional counting tubes for C14, using CO_2 gas samples. The counters are shielded by 2.5 cm of selected lead, a ring of anti-coincidence Geiger counters, 10 cm of paraffin wax, boric acid and/or borated polyethylene, and at least 20 cm of iron, plus the walls and ceiling of the building. The counter is filled with the sample to a working pressure of 45 psi. The proper operating voltage, dependent on temperature and pressure in the counter, is adjusted to produce the most efficient and stable C14 detection. This is done by an external radioactive source, usually ^{60}Co. Gas amplification is continually monitored by the distribution of meson counts in selected energy channels. Each sample is counted for at least two separate periods of about 20 hours each, in different counters, with an interim waiting time of at least 7 days. Inconsistency between the two counts prompts an additional measurement in a third counter. For the short samples in this series, two counters were temporarily standardized to work at half pressure. These samples were counted for a total of 4 to 6 days in different counters.

Backgrounds and Standards

Background count rates, typically 3.5 cpm, are determined weekly by measuring C14-free CO_2 gas. The standard material for C14 measurements is the NBS oxalic acid standard, RM49 and SRM4990C, for radiocarbon dating. The CO_2 prepared from this standard is counted for two days every week in each counter, to determine counting efficiency; typical count rate for an ocean surface sample is 43 cpm above background.

Update

Periodically, usually every five weeks, all measurements in all counters for the preceding time period are recomputed, statistical tests are applied, and results scrutinized for flaws in quality of sample counts and stability of associates at UPMC, and Philippe Jean-Baptiste, Saclay. Total CO_2 data were supplied by Arthur Chen, Oregon State University, and Alain Poisson.

We calculated potential temperature from in situ temperature, pressure, and salinity by the equations of Bryden (5). The density (sigma-theta) values were calculated according to the International one-atmosphere equation of state of seawater according to Millero and Poisson (6), which generates absolute densities in units of kg/m^3. Total CO_2 data were presented in µ mol/kg. For serious use of the hydrographic data, please refer to Alain Poisson. For CO_2 data please contact Arthur Chen or Alain Poisson.

VII. COMMENTS TO FIGURES AND TABLES

Sections

Radiocarbon is expressed as Δ C14 °/°°. The horizontal scale distance is measured in latitude. The vertical scale depth is measured in meters. Dots indicate measured samples. Due to scant data coverage in several areas, some subjectivity enters in drawing the isopleths.

Profiles

Radiocarbon is plotted as ΔC14 °/°° versus depth in meters. The bottom depth is marked by a horizontal line when it falls inside graph limits.

Tables

Positions are stated in degrees and minutes. SMPL# is the cast and bottle number. GER represents the GoFlo bottle numbers of each pair. The first digit is the shallower of the two. DC14 is Δ C14 °/°° and dC13 is δ C13 °/°°. TCO_2 is total dissolved carbonate in µ moles/kg. In some tables, a small letter, c, follows the potential temperature indicating this value was interpolated using CTD data.

VIII. COMMENTS TO RADIOCARBON RESULTS

Some of the southern GEOSECS reoccupation stations (G421, G427, G428) show a marked difference in C14 content compared to the original GEOSECS data cf. Fig. 4. The penetration of bomb C14 into deeper layers within the subtropical gyre (15°S-45°S) is apparent when the contours of the top 2000m are compared. North of 15°S, penetration of C14 is clearly less effective. Deep waters south of the equator appear infiltrated by water higher in C14 either of Atlantic or circumpolar origin. The C14 data at INDIGO stations 11, 103 are unsupported by a lack of data below 2000 on stations to the north and so the -150 contour is represented as a broken line. Also values are within the error, $\pm\sigma$, of the contour lines which may disturb the pattern. Taking this into account, the deep water C14 picture confirms the GEOSECS results.

IX. REFERENCES

(1) Bard, E., M. Arnold, H.G. Ostlund, P. Maurice, P. Monfray and J-C Duplessy, 1988. Penetration of bomb radiocarbon in the tropical Indian Ocean measured by means of accelerator mass spectrometry. Earth Planet. Sci. Lett., 87, 379-389.

(2) Broecker, W.S., and E.A. Olson, 1961. Lamont radiocarbon measurements VIII. Radiocarbon, 3, 176-274.

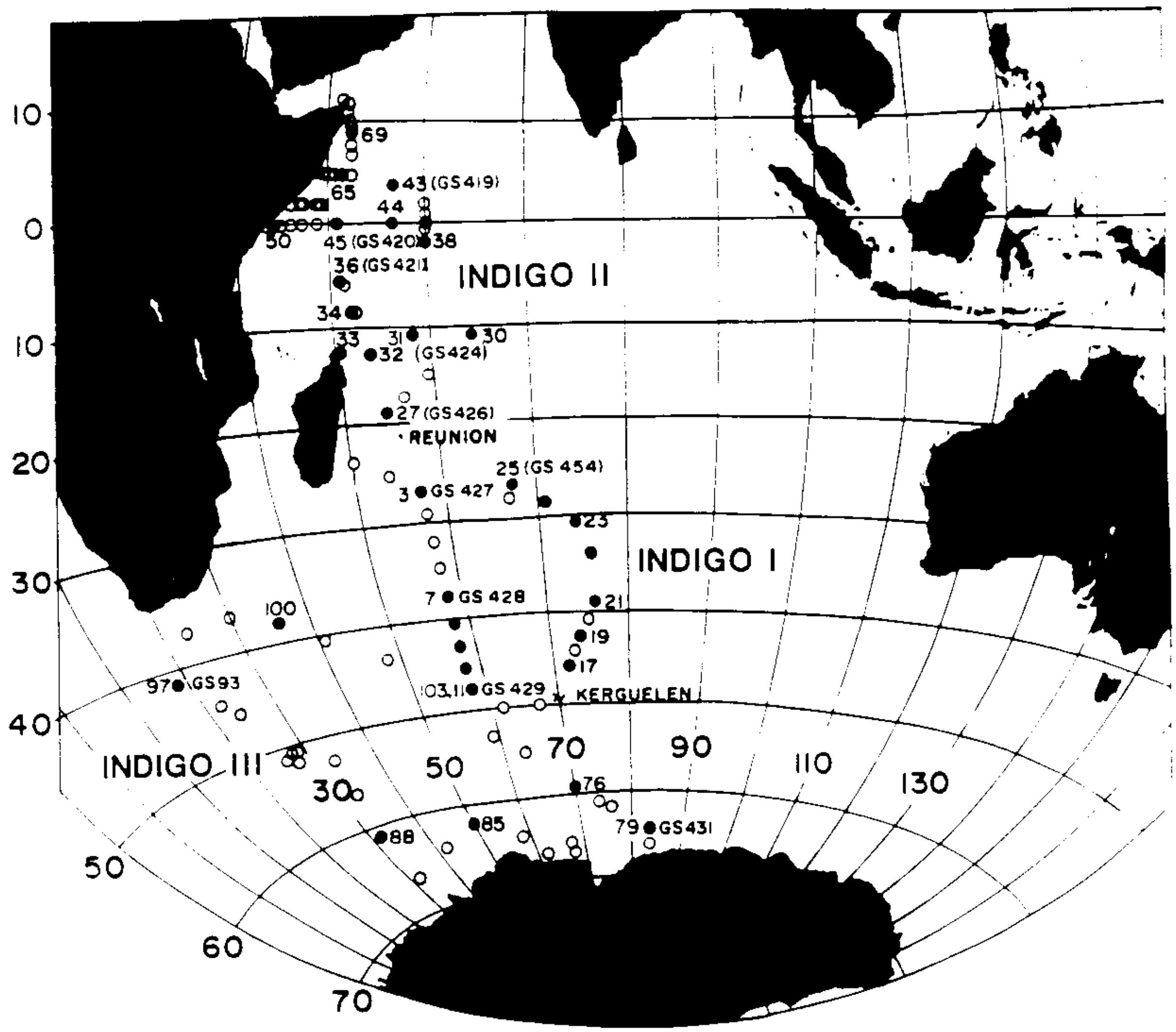
(3) Stuiver, M., and W.S. Robinson, 1974. University of Washington GEOSECS North Atlantic carbon-14 results. Earth Planet. Sci. Lett., 23, 87-90.

(4) Stuiver, M. and H.A. Polach, 1977. Discussion reporting of ^{14}C data. Radiocarbon, 19, (3), 355-363.

(5) Bryden, H.L., 1973. New polynomials for thermal expansion, adiabatic temperature gradient and potential temperature of sea water. Deep-Sea Res., 20, 401-408.

(6) Millero, F.J. and A. Poisson, 1981. International one-atmosphere equation of state of seawater. Deep-Sea Res., 28, (6A), 625-629.

INDIGO EXPEDITIONS I(1985), II (1986), III (1987)



○ - Station
● - C14 Station

Figure 1. INDIGO 1985 - 1987 cruise track.

SECTIONS

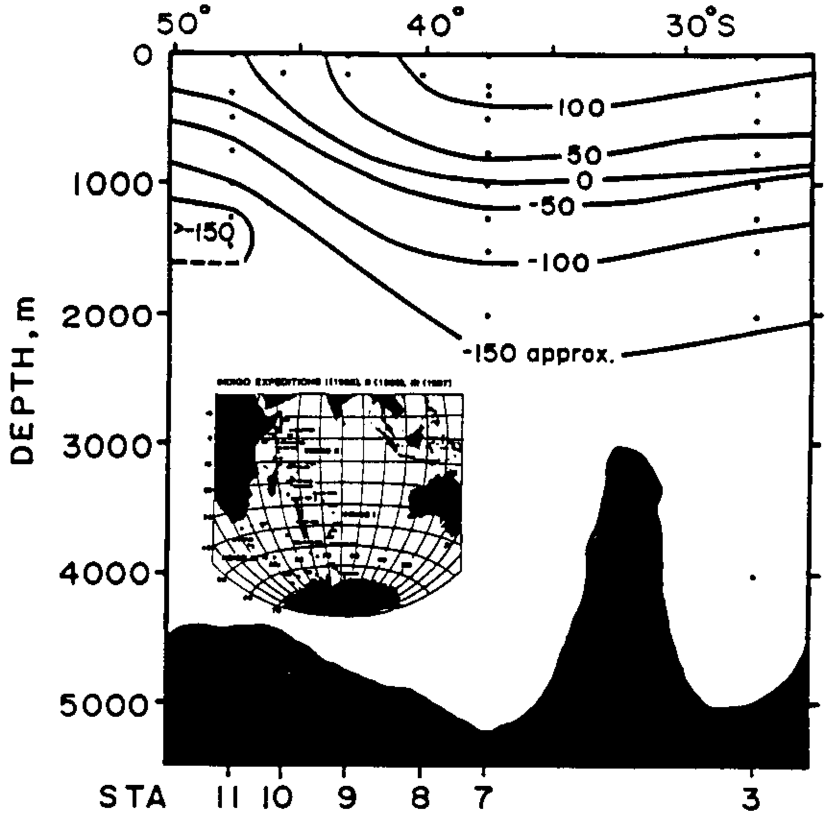


Figure 2a. Western C14 section of INDIGO I cruise.

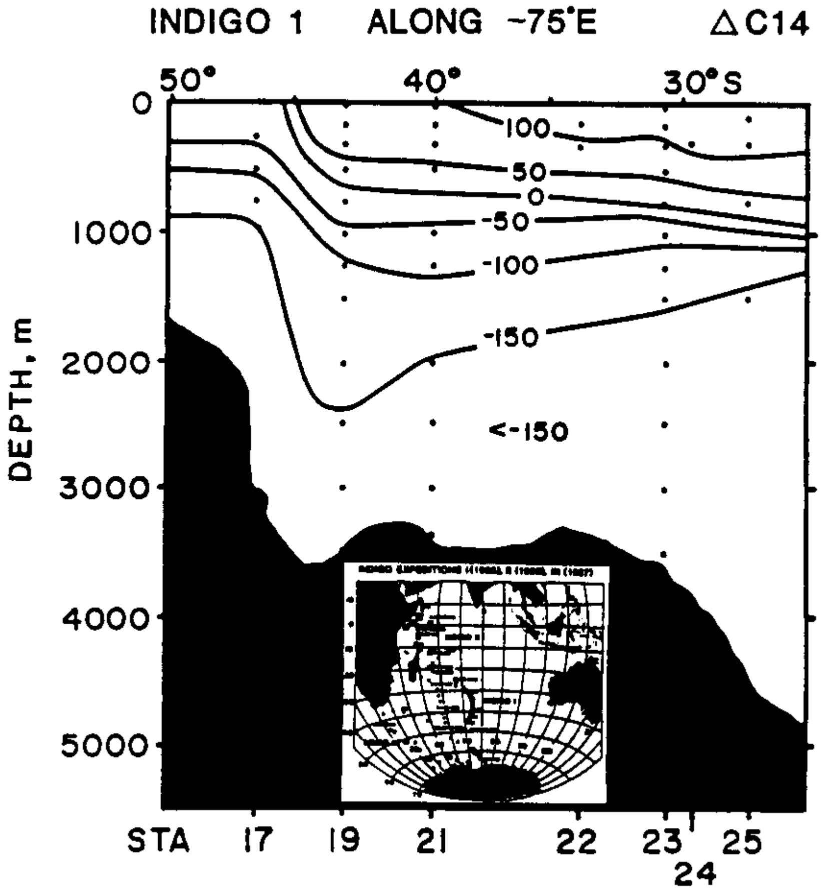


Figure 2b. Eastern C14 section of INDIGO I cruise.

9

INDIGO EXPEDITIONS I (1985), II (1986), III (1987)

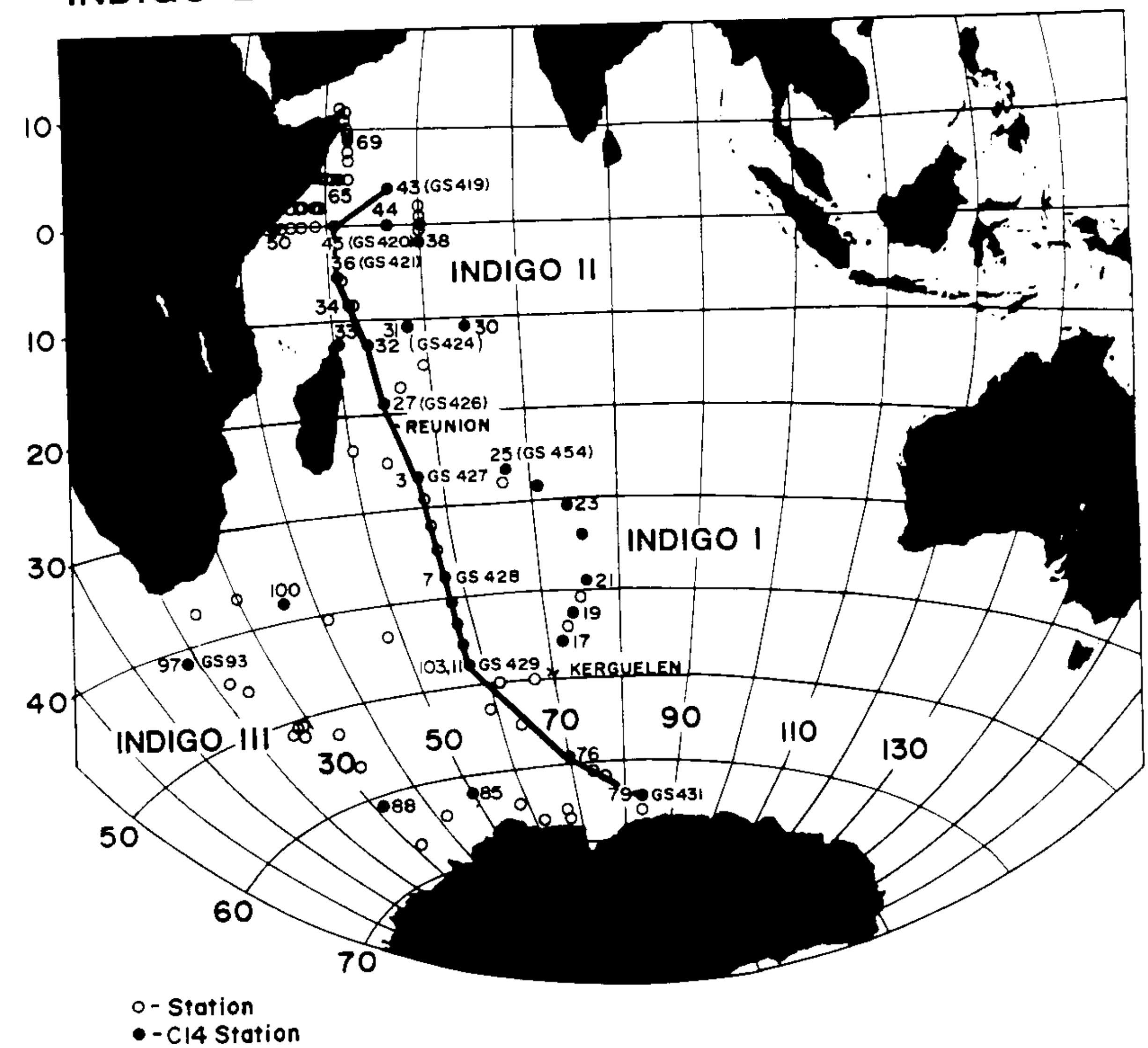


Figure 3. Section of INDIGO cruise track which reoccupies original GEOSECS track.

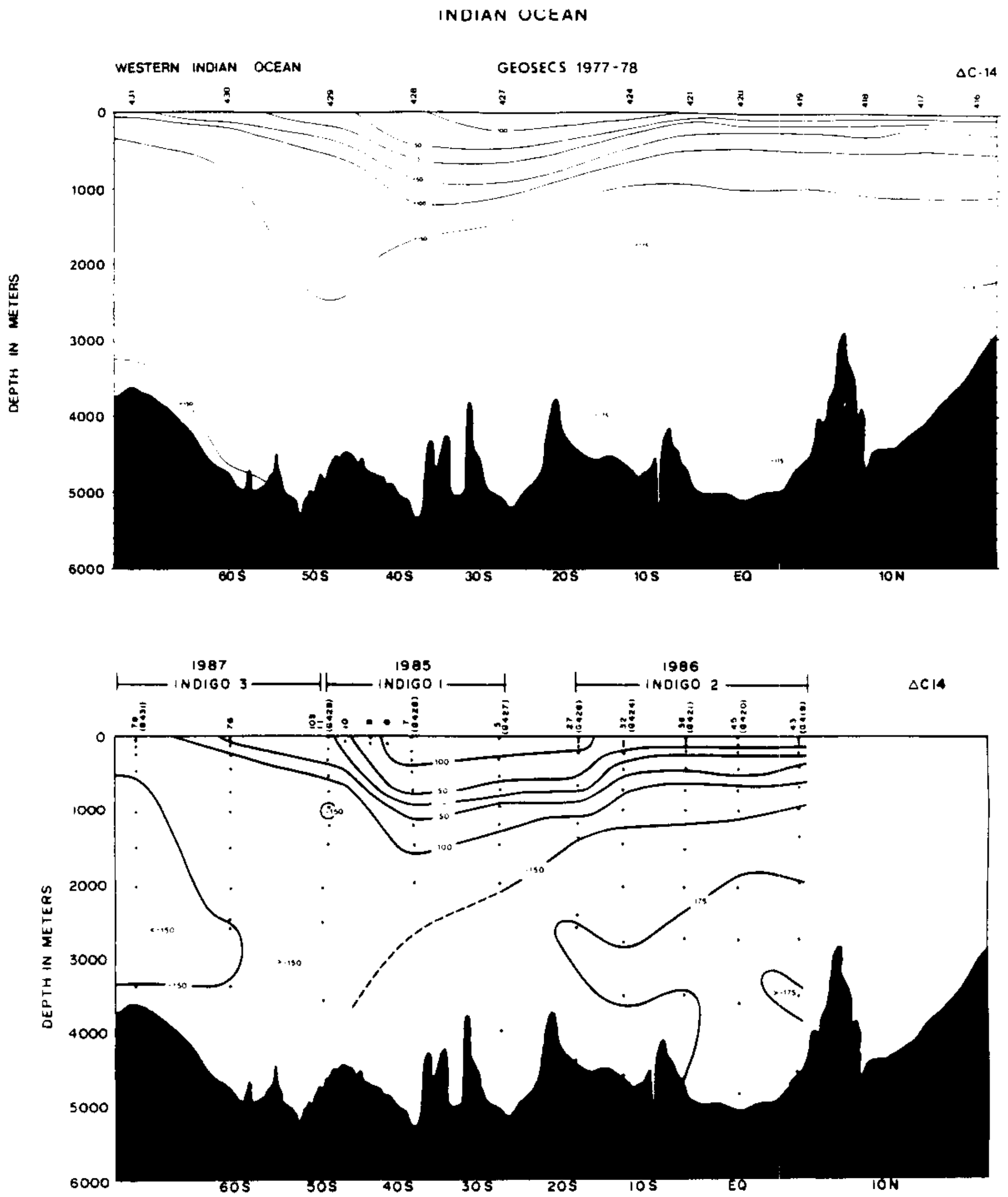
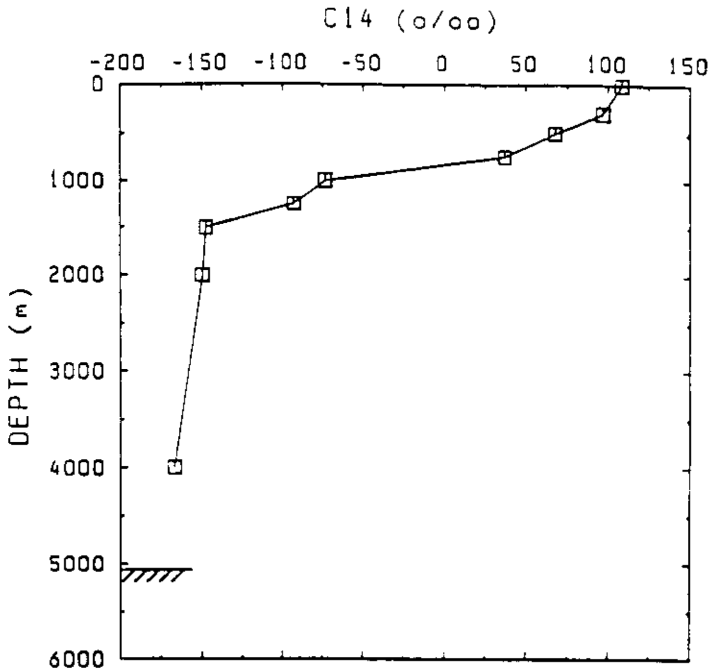


Figure 4. Comparative sections of Western Indian Ocean. Upper section is GEOSECS, 1977 - 1978; lower is INDIGO, 1985 -1987.

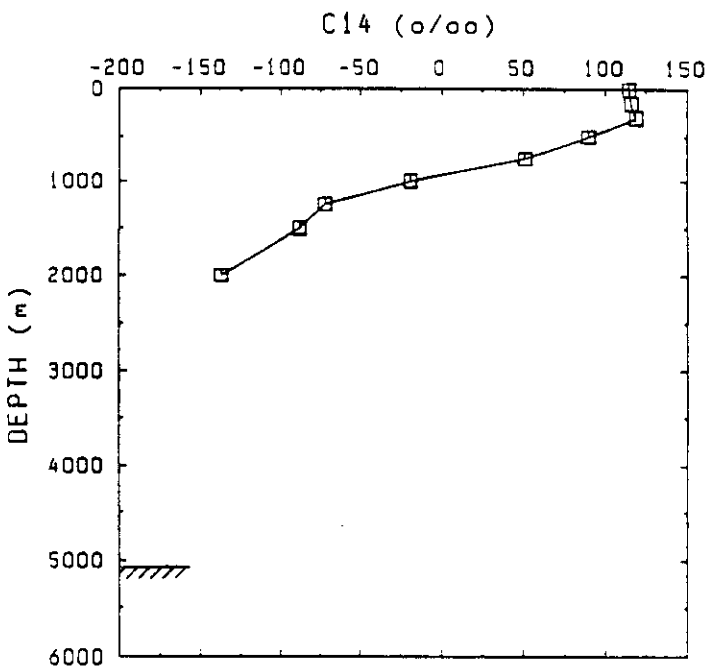
SECTIONS

PROFILES

REFER TO MAPS AND TABLES
FOR STATION POSITIONS


C14 (o/oo)
-200
-150
-100
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 3


C14 (o/oo)
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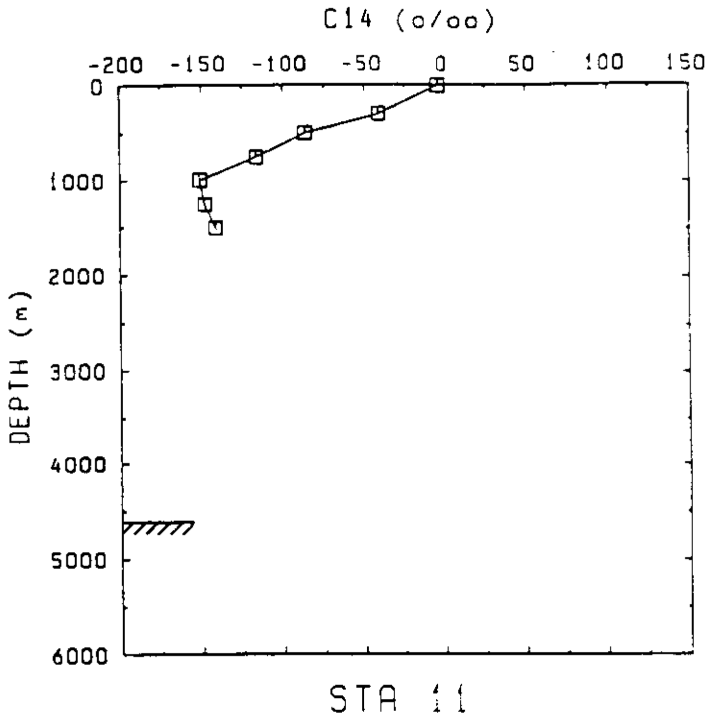
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 7


C14 (o/oo)
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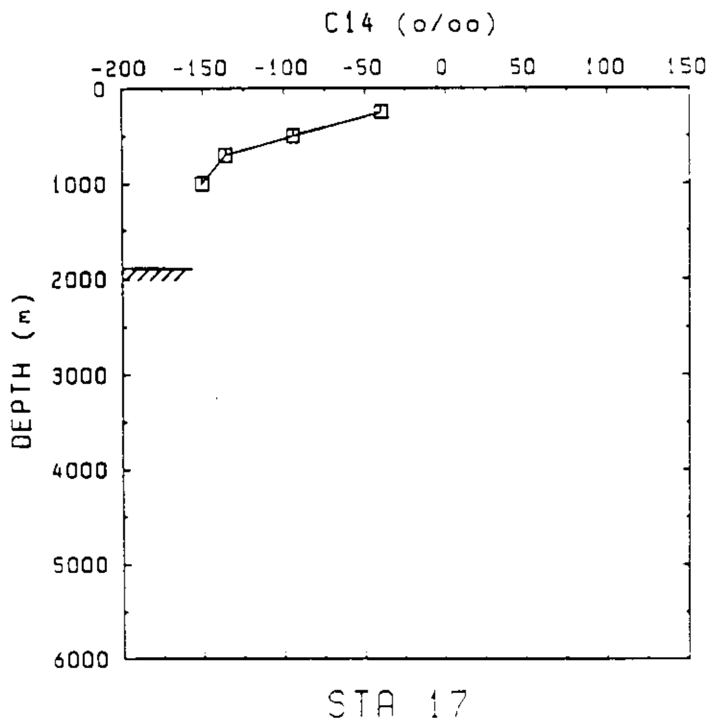
0
1000
2000
3000
4000
5000
6000
DEPTH (m)
STA 11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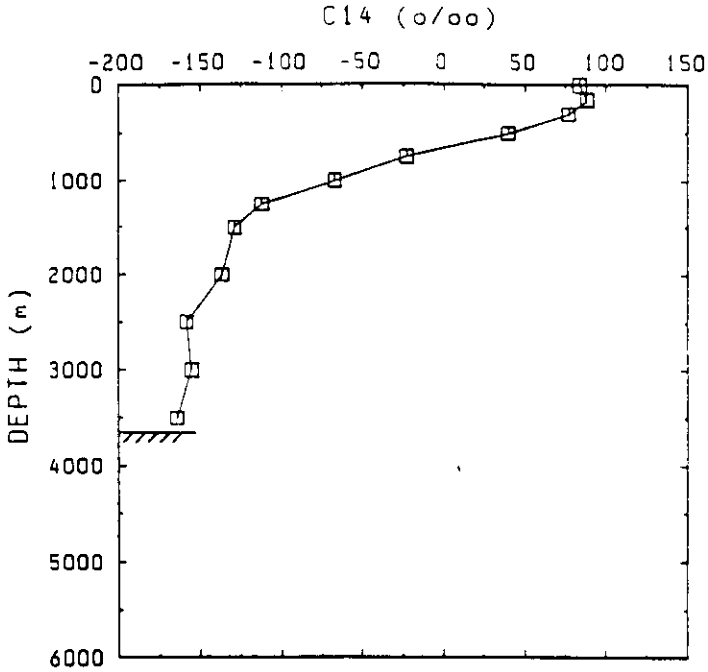
-200 -150 -100 -50 0 50 100 150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)
STA 17


C14 (o/oo)
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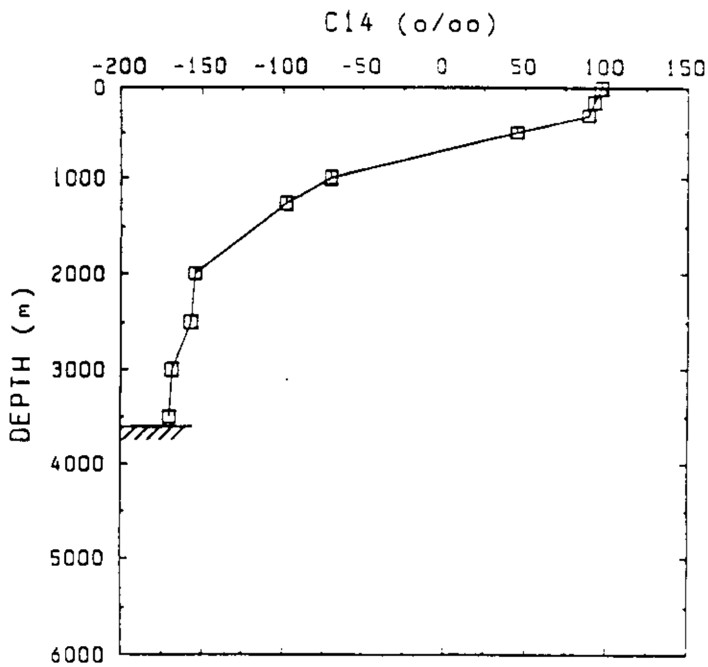
DEPTH (m)
0
1000
2000
3000
4000
5000
6000

STA 19


C14 (o/oo)
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DEPTH (m)
0
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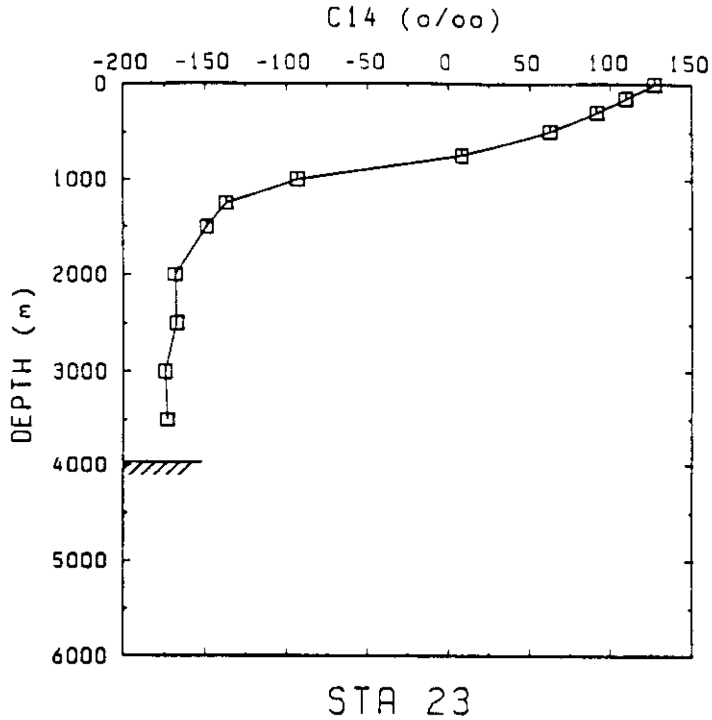
2000
3000
4000
5000
6000

STA 21


C14 (o/oo)
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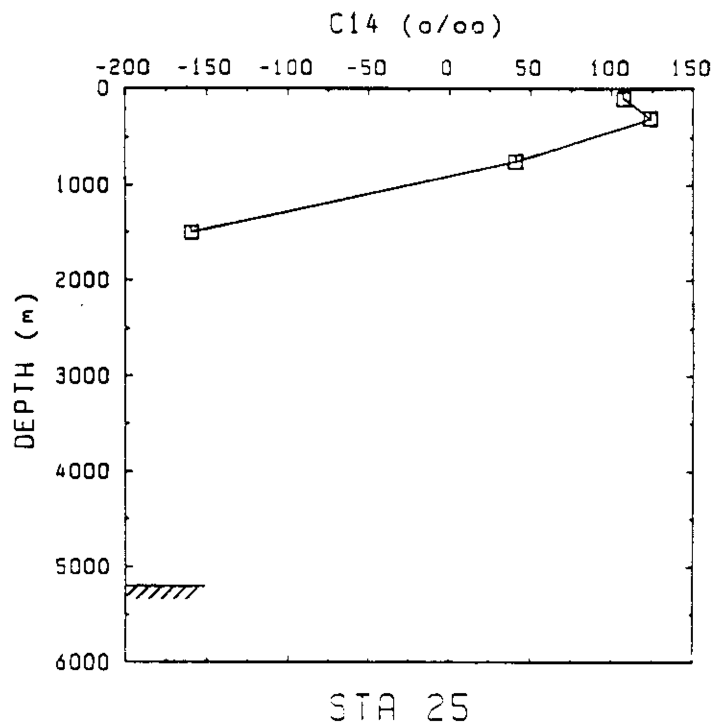
0
1000
2000
3000
4000
5000
6000
DEPTH (m)
STA 23


C14 (o/oo)
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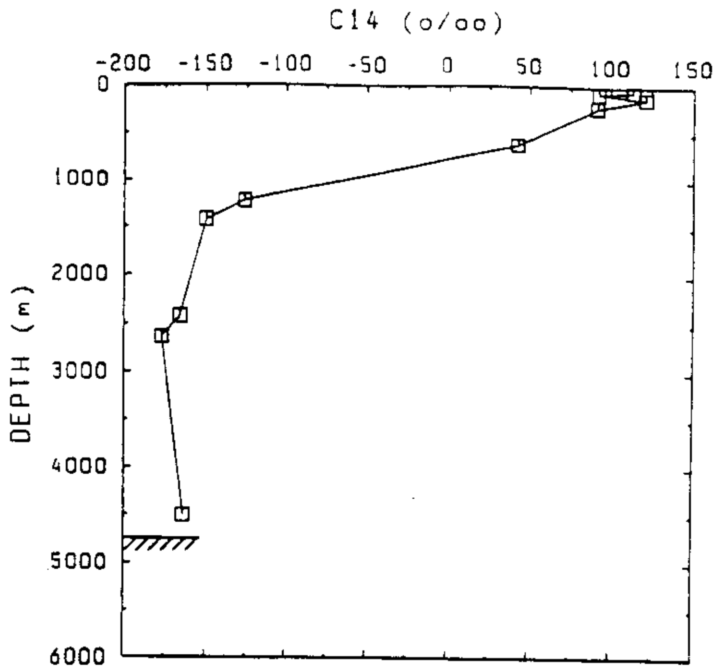
0
1000
2000
3000
4000
5000
6000
DEPTH (m)
STA 25


C14 (o/oo)
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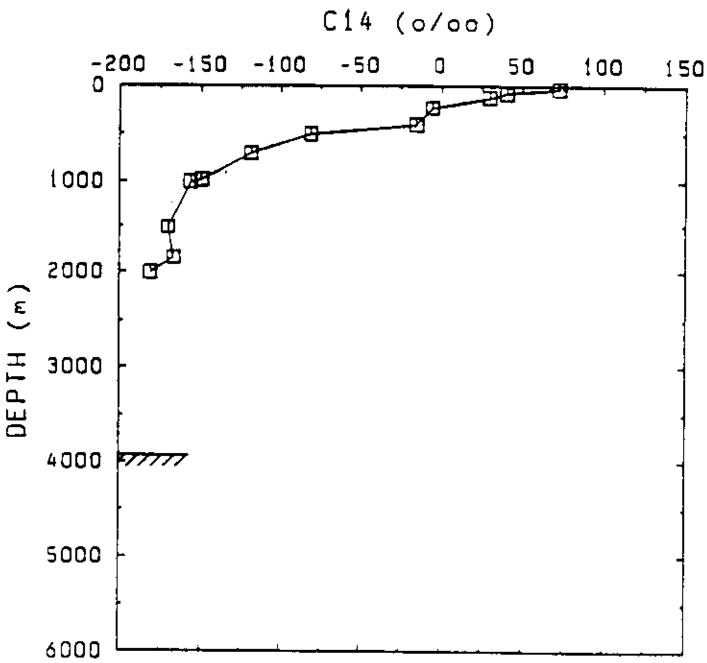
DEPTH (m)
0
1000
2000
3000
4000
5000
6000

STA 27


C14 (o/oo)
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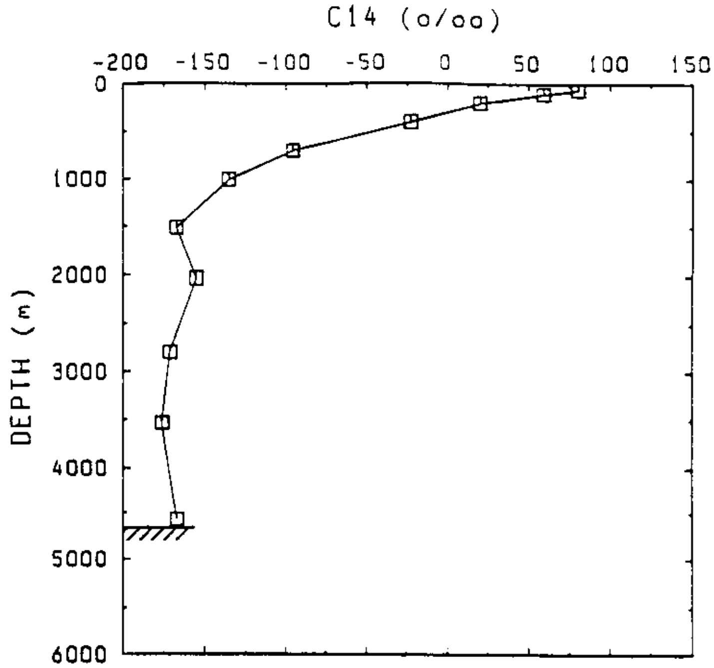
DEPTH (m)
0
1000
2000
3000
4000
5000
6000

STA 30


C14 (o/oo)
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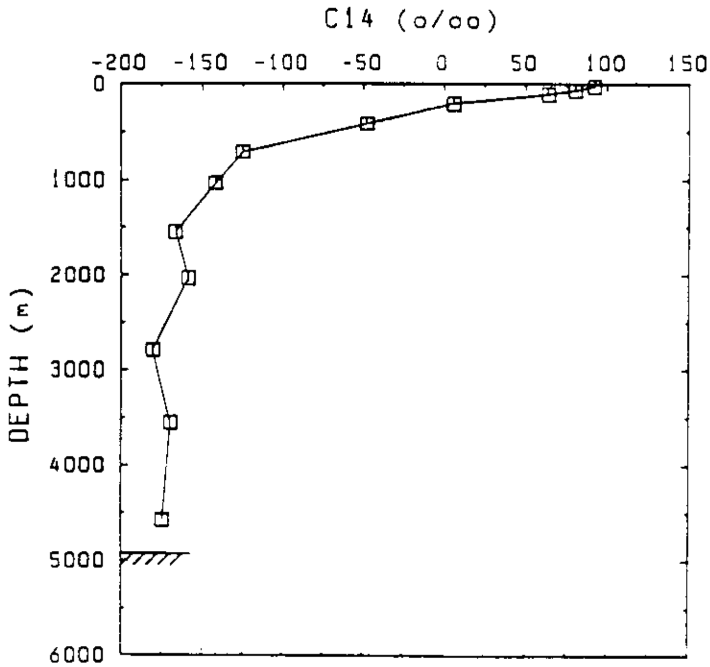
0 1000 2000 3000 4000 5000 6000
DEPTH (m)

STA 32


C14 (o/oo)
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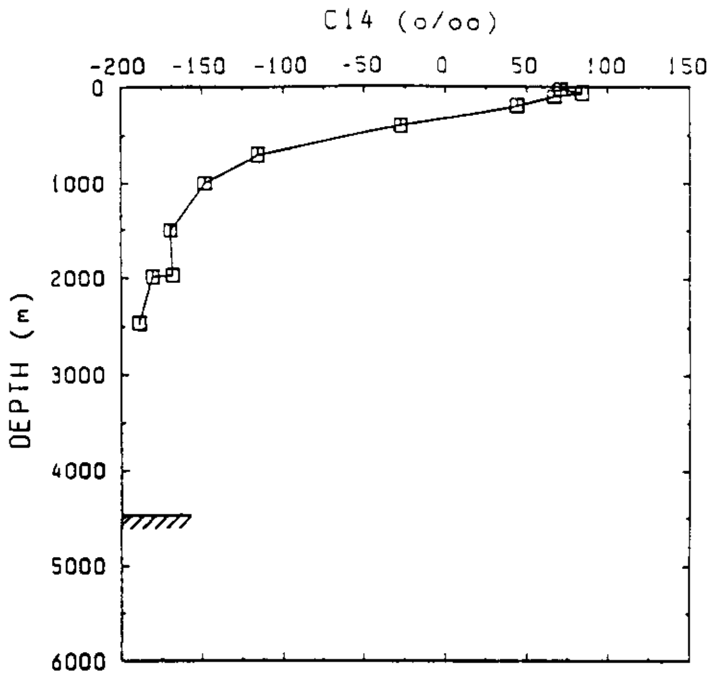
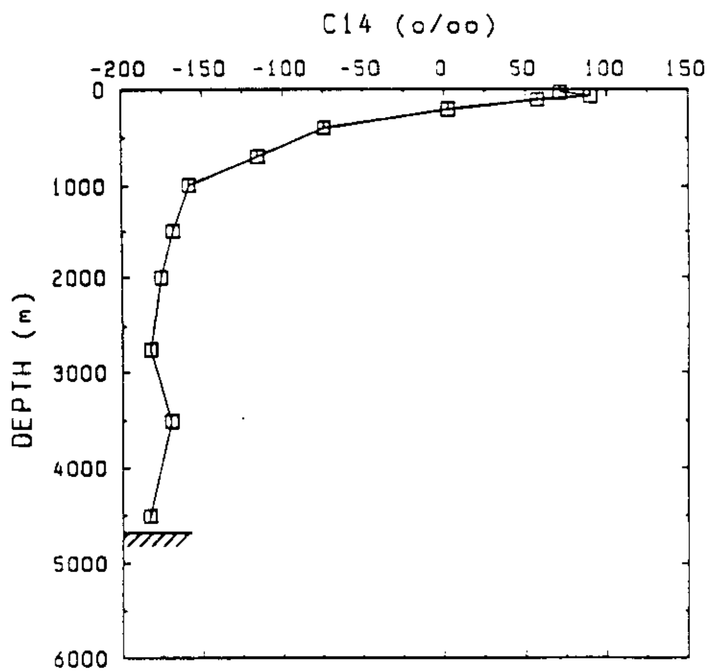
DEPTH (m)

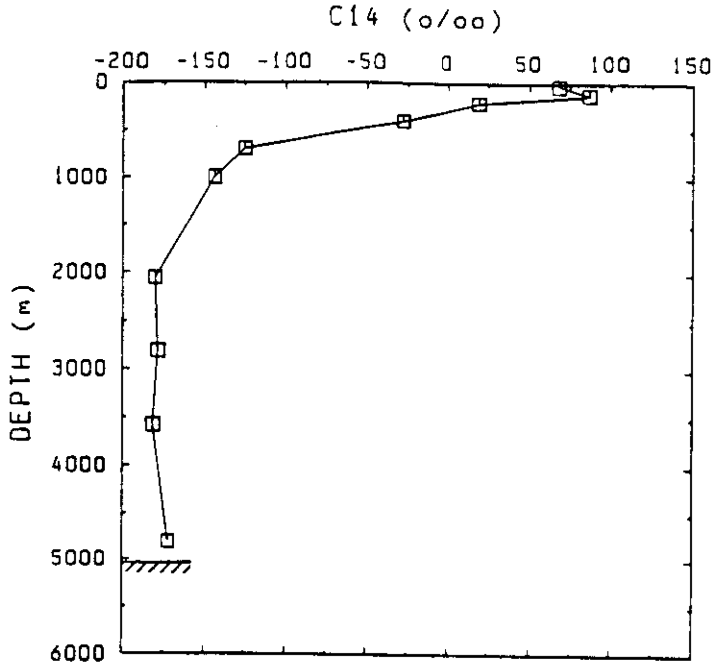
STA 36


C14 (o/oo)
-200 -150 -100 -50 0 50 100 150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

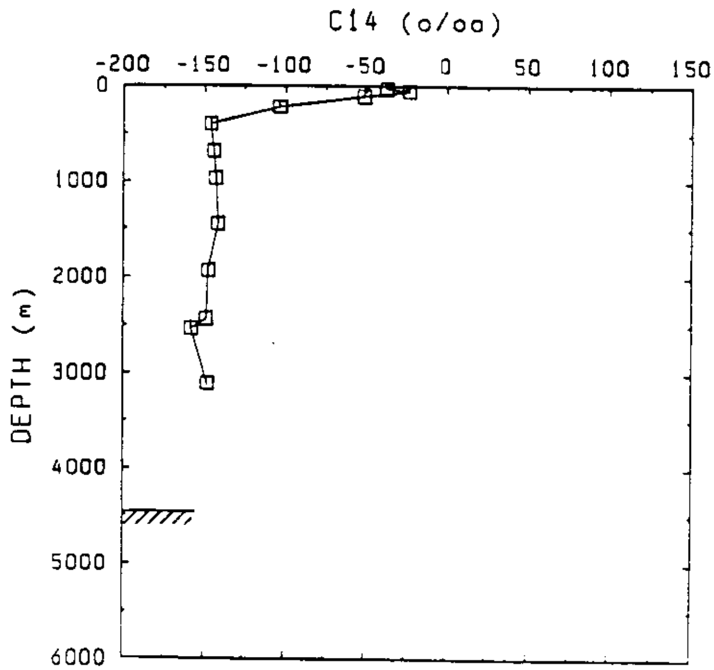
STA 38


C14 (o/oo)
-200 -150 -100 -50 0 50 100 150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 43


C14 (o/oo)
-200
-150
-100
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 45


C14 (o/oo)
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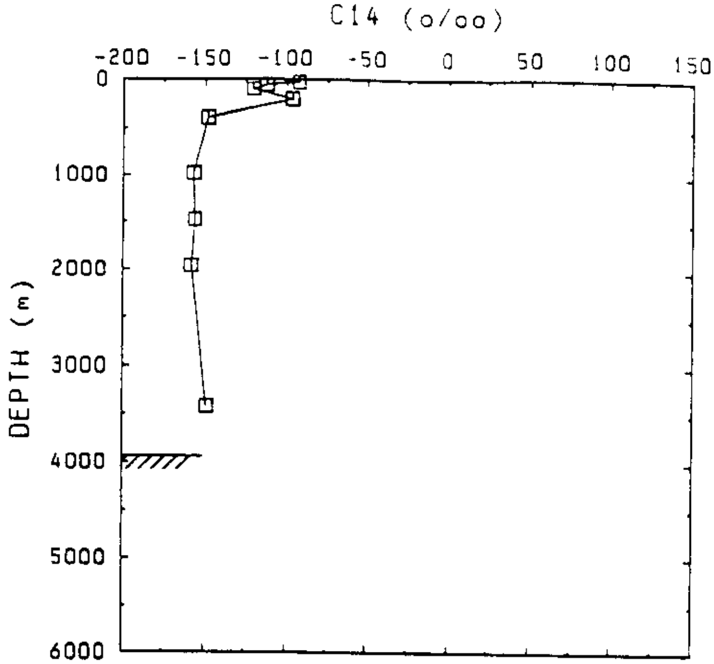
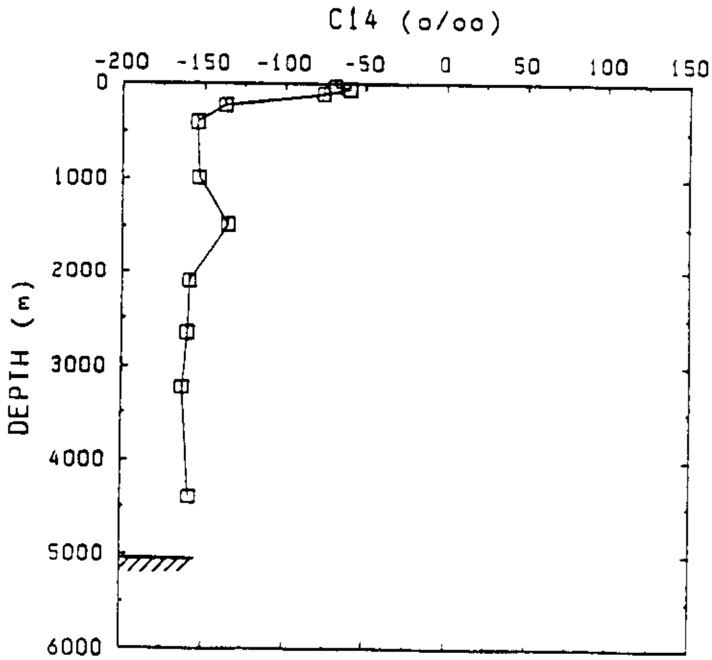
-150
-100
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

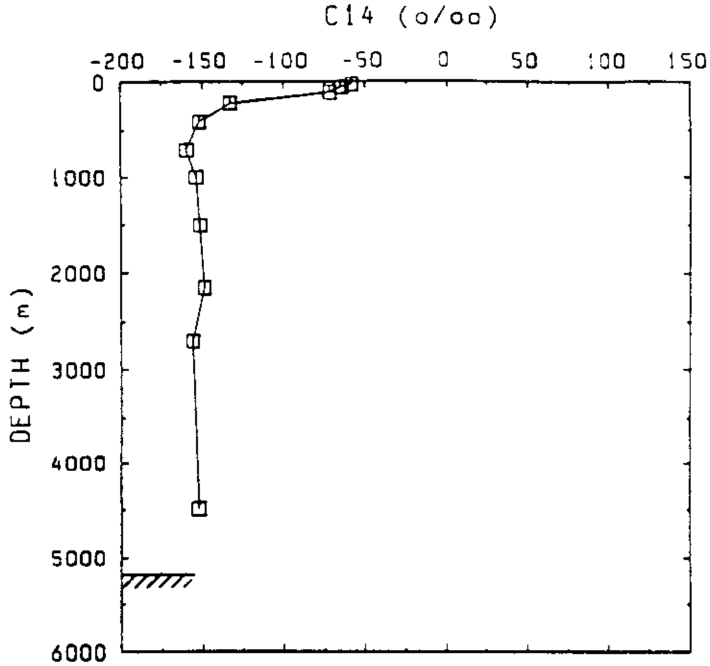
STA 76


C14 (o/oo)
-200
-150
-100
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 79


C14 (o/oo)
-200
-150
-100
-50
0
50
100
150
0
1000
2000
3000
4000
5000
6000
DEPTH (m)

STA 85


C14 (o/oo)
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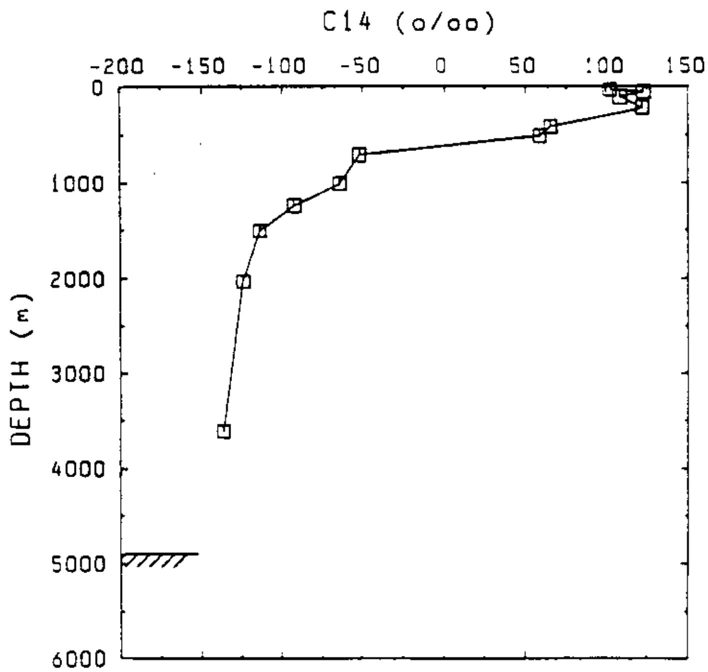
0 1000 2000 3000 4000 5000 6000
DEPTH (m)

STA 88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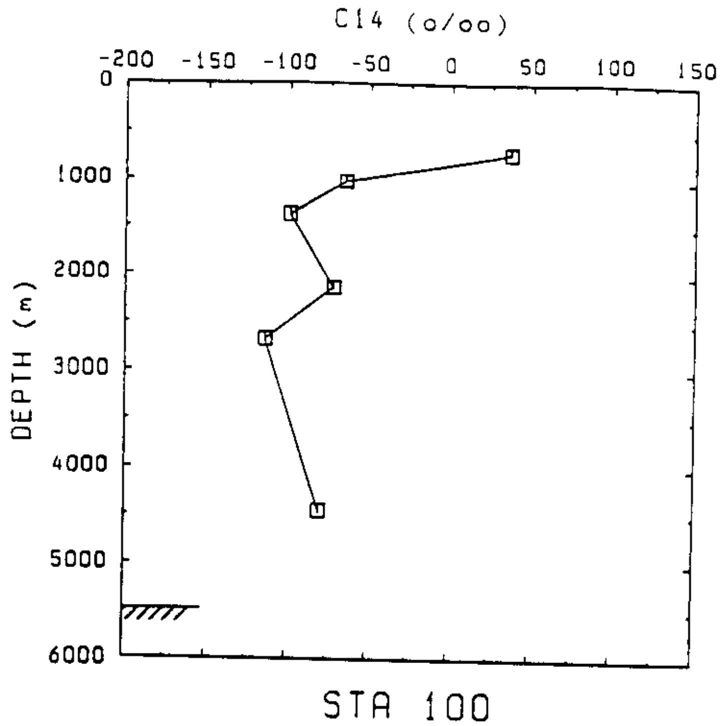
DEPTH (m)

STA 97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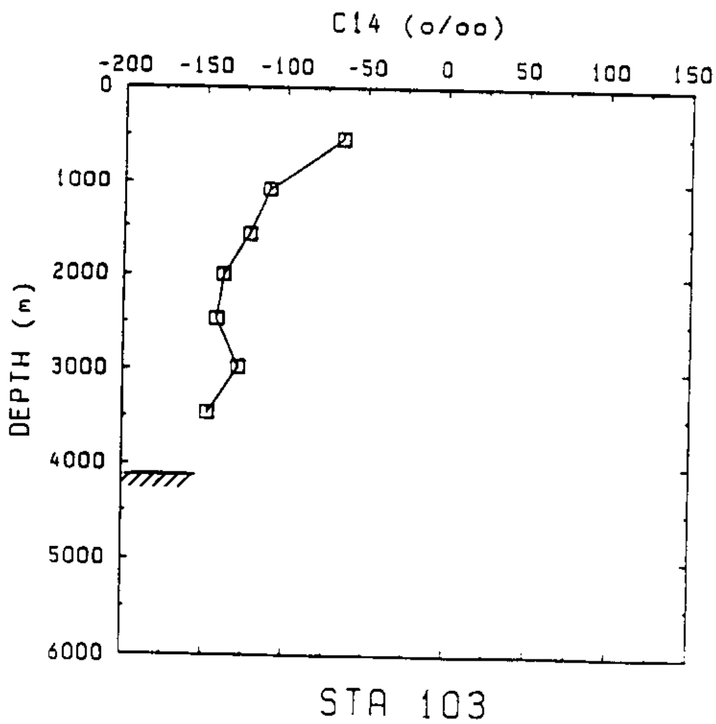
DEPTH (m)
STA 100


C14 (o/oo)
-200 -150 -100 -50 0 50 100 150
0 1000 2000 3000 4000 5000 6000
DEPTH (m)
STA 103

TABLES

INDIGO 1 1985

STATION 3

POSITION 27 04 S 56 57 E DATE 85/02/27 BOTTOM 5120 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	0		35.332		108.4	0.6	1982	12
103	300		35.445		96.7	0.0	2099	46
104	500		35.138		67.7	0.0	2195	79
201	750		34.849		36.9	0.3		97
202	1000		34.546		-73.7	-0.7	2195	56
203	1250		34.460		-93.2	0.1		34
204	1500		34.575		-147.6	-0.8		12
301	2000		34.736		-149.7	-0.9	2277	67
304	4000		34.722		-166.6	-1.3		12

INDIGO 1 1985

STATION 7

POSITION 37 41 S 57 40 E DATE 85/03/03 BOTTOM 5100 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	0		35.540		114.5	1.1	2038	72
204	150		35.485		115.9	0.5		53
103	300		35.523		118.8	0.3	2099	41
104	500		35.260		89.6	0.7	2110	96
201	750		34.973		51.0	-0.1		26
202	1000		34.640		-19.4	0.0		79 *
203	1250		34.370		-72.3	0.1	2195	14
102	1500		34.402		-88.1	-0.2	2228	35
301	2000		34.589		-137.2	-0.2		26

* - 100 liter sample

INDIGO 1 1985

STATION 8

POSITION 40 11 S 57 51 E DATE 85/03/04 BOTTOM 4920 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	150		35.454		108.8	0.6		72

INDIGO 1 1985

STATION 9

POSITION 43 08 S 57 57 E DATE 85/03/05 BOTTOM 4750 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
102	0		34.717		65.7	1.4	2041	35
101	150		34.371		76.8	0.8	2099	35

INDIGO 1 1985

STATION 10

POSITION 45 30 S 57 48 E DATE 85/03/05 BOTTOM 4470 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	150		33.930		12.7	0.8		35

INDIGO 1 1985

STATION 11

POSITION 47 39 S 57 55 E DATE 85/03/09 BOTTOM 4650 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	0		33.751		-4.1	1.2		75
103	300		34.143		-41.4	0.7	2171	12
104	500		34.241		-86.3	0.1	2201	43
201	750		34.390		-116.2	0.0		75
202	1000		34.553		-150.8	-0.7	2251	96
203	1250		34.659		-147.9	-0.1	2256	21
204	1500		34.718		-141.5	-0.1		34 *

* - 100 liter sample

INDIGO 1 1985

STATION 17

POSITION 46 30 S 71 11 E DATE 85/03/16 BOTTOM 1830 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
202	250		34.101		-39.8	0.9		45
203	500		34.293		-94.2	0.4	2235	31
204	700		34.503		-136.3	0.3		69
101	850		34.564		-150.8	-0.6		75 *

* - 100 liter sample

INDIGO 1 1985

STATION 19

POSITION 43 19 S 73 48 E DATE 85/03/18 BOTTOM 3650 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
301	0		34.705		83.8	1.5	2113	31
302	150		35.195		88.4	0.9	2155	96
303	300		35.073		77.2	0.9	2187	72
304	500		34.816		39.7	1.1	2235	54
201	750		34.506		-23.3	0.8		69
202	1000		34.354		-66.9	0.7	2258	72
203	1250		34.403		-112.3	0.3		54
204	1500		34.523		-128.9	0.4	2259	31
101	2000		34.690		-136.7	0.1	2274	72
102	2500		34.752		-158.6	0.3		45
103	3000		34.755		-155.6	0.6		31
104	3500		34.722		-164.6	0.3		69

INDIGO 1 1985

STATION 21

POSITION 39 34 S 76 23 E DATE 85/03/19 BOTTOM 3600 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
301	0		35.179		97.4	1.4	2039	74
302	150		35.239		92.7	0.7	2081	52
303	300		35.113		89.3	1.0		13
304	500		34.888		44.6	-5.2	2108	96
202	1000		34.381		-69.8	0.6	2198	74
203	1250		34.375		-98.1	0.4	2221	31
101	2000		34.665		-154.3	-0.2	2244	47
102	2500		34.737		-156.9	-0.3	2258	13
103	3000		34.725		-169.0	-0.4		69
104	3500		34.717		-170.2	-0.2	2286	52

INDIGO 1 1985

STATION 22

POSITION 33 49 S 76 20 E DATE 85/03/23 BOTTOM 3380 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	150		35.361		117.0	0.7	2073	24
102	300		35.184		97.7	0.5	2093	13

INDIGO 1 1985

STATION 23

POSITION 30 15 S 74 38 E DATE 85/03/24 BOTTOM 3800 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER	
301	0		36.015		127.1	1.5	2055	96	
302	150		35.377		109.3	1.1	2078	75	
303	300		35.165		91.4	-0.1	2094	42	
304	500		34.945		62.3	0.7	2107	13	
201	750		34.689		8.1	0.9		75	
202	1000		34.407		-93.7	0.3		42	
203	1250		34.460		-137.2	0.1		31	
204	1500		34.576		-149.1	0.1	2260	96	
101	2000		34.710		-168.5	-0.3		75	*
102	2500		34.726		-167.7	-0.3		42	
103	3000		34.723		-174.5	-0.4		13	
104	3500		34.719		-173.3	0.7		96	

* - 100 liter sample

INDIGO 1 1985

STATION 24

POSITION 29 25 S 70 49 E DATE 85/03/25 BOTTOM 3930 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
102	300		35.418		119.9	1.5		69

INDIGO 1 1985

STATION 25

POSITION 26 59 S 67 07 E DATE 85/03/26 BOTTOM 5220 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	100		35.763		107.3	0.7		69
102	300		35.431		123.7	1.4		96
103	750		34.789		40.7	1.1		42
104	1500		34.568		-159.4	0.4		13

INDIGO 2 1986

STATION 27

POSITION 18 54 S 54 47 E DATE 86/04/01 BOTTOM 4740 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
101	47	27.18c	35.148	22.774	113.6	1.4	1962	87
301	66	26.09c	35.263	23.207	92.2	1.0	1957	89
102	121	20.79	35.425	24.877	121.3	0.5	2043	63
201	211	16.75	35.446	25.918	91.6	0.1	2103	21
202	614	9.89	34.805	26.819	42.5	1.3	2124	98
302	1227	4.32c	34.639	27.465	-126.4	0.4	2266	76
203	1419	3.35	34.650	27.573	-150.2	0.2	2265	76
204	2425	2.79	34.738	27.695	-165.7	-0.5	2290	43
303	2635	1.77c	34.737	27.779	-177.0	-0.4	2299	43
304	4505	0.79c	34.719	27.833	-163.7	-1.4	2280	21

INDIGO 2 1986

STATION 30

POSITION 11 15 S 64 27 E DATE 86/04/05 BOTTOM 3975 M

SMPL #	DEPTH M	PTEMP C	SALIN o/oo	SIGMA THETA	RADIOCARBON DC14	dC13	TCO2	GER
301	27	28.37	34.961	22.245	72.4	0.5	1998	98
302	73	18.28	34.989	25.196	40.2	-0.1	2141	76
303	117	16.08	35.098	25.805	29.5	-0.8	2160	43
304	227	13.38	35.050	26.356	-5.9	-0.2	2186	21
201	406	10.37c	34.873	26.789	-15.8	1.2	2179	12
102	505	8.94	34.784	26.958	-81.3	0.3	2179	76
202	706	7.39	34.737	27.157	-119.0	0.3	2264	34
103	984	6.42	34.757	27.285	-149.9	-0.4	2300	43
203	1009	5.77c	34.729	27.379	-156.5	-0.3	2302	67
204	1508	3.58	34.753	27.632	-170.2	-0.5	2316	89
101	1842	2.66	34.735	27.704	-166.9	-0.2	2305	98
104	2005	2.25c	34.728	27.734	-180.9	-1.3	2300	21

INDIGO 2 1986

STATION 31

POSITION 10 42 S 58 09 E DATE 86/04/07 BOTTOM 4035 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	2				99.0	0.7		pump
102	120	17.15	35.355	25.752	58.7	1.2	2115	pump

INDIGO 2 1986

STATION 32

POSITION 12 18 S 53 39 E DATE 86/04/08 BOTTOM 4673 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
302	63	21.92	34.964	24.215	80.6	1.1	2028	76
303	103	19.42	35.145	25.025	59.4	0.6	2121	43
304	200	14.32	35.091	26.190	19.9	0.2	2163	21
201	406	9.94	34.851	26.846	-22.9	0.5	2177	98
202	707	7.60	34.728	27.120	-95.8	0.0	2246	76
203	1008	5.71	34.763	27.402	-135.6	0.2	2284	54
204	1510	3.47c	34.727	27.622	-167.3	0.1	2298	32
101	2037	2.94	34.735	27.679	-155.3	0.0	2302	98
102	2799	1.60	34.742	27.796	-171.4	0.0	2317	76
103	3533	1.22c	34.738	27.820	-176.2	0.9	2314	41
104	4567	0.76c	34.717	27.834	-166.9	-0.1	2286	21

INDIGO 2 1986

STATION 33

POSITION 11 55 S 50 08 E DATE 86/04/09 BOTTOM 3590 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	2				101.2	1.0		pump
102	120	20.81	35.321	24.791	87.5	0.4	2032	pump

INDIGO 2 1986

STATION 34

POSITION 8 50 S 52 15 E DATE 86/04/11 BOTTOM 4141 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	2				97.2	0.9		pump
102	120	16.57	35.161	25.741	46.6	0.1		pump

INDIGO 2 1986

STATION 36

POSITION 6 09 S 50 55 E DATE 86/04/12 BOTTOM 4927 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
301	25	27.59	35.245	22.713	92.2	1.2	1964	98
302	66	21.50	35.291	24.580	80.5	1.1	2061	76
303	106	17.55	35.317	25.626	64.1	0.4	2129	54
304	207	12.74	35.071	26.500	5.9	-0.6	2172	32
201	417	9.55	34.884	26.937	-48.0	0.4	2136	39
202	715	7.58	34.813	27.190	-125.2	0.2	2268	17
203	1035	6.10	34.824	27.401	-142.0	-0.2	2300	65
204	1550	4.28	34.777	27.579	-166.5	-0.5	2313	42
101	2035	3.18	34.762	27.678	-158.7	-0.1	2314	98
102	2796	1.59	34.745	27.799	-180.6	-0.1	2318	76
205	3553	1.29	34.739	27.816	-169.6	-0.3	2315	10 *
104	4573	0.91 c	34.725	27.830	-174.7	-1.5	2292	21

* - 100 liter sample

INDIGO 2 1986

STATION 38

POSITION 1 59 S 60 01 E DATE 86/04/15 BOTTOM 4460 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
201	23	30.27c	35.179	21.769	70.9	1.1	1955	98
202	61	23.67c	35.489	24.112	84.1	1.2	2053	76
203	97	20.22c	35.385	24.998	67.1	0.0	2096	43
204	191	14.52c	35.227	26.252	44.0	0.4	2144	52
301	404	10.54	34.975	26.839	-28.0	0.2	2183	25
302	704	8.17	35.033	27.275	-115.9	0.9	2251	34
303	1003	6.41	34.967	27.473	-148.2	-0.4	2287	67
304	1502	4.08	34.849	27.658	-169.8	0.2	2304	89
101	1973	2.55	34.783	27.752	-168.3	0.1	2298	49
104	1987	2.53	34.785	27.755	-180.8	-0.6	2298	32
102	2465	1.91c	34.756	27.783	-188.9	-1.1	2295	87

INDIGO 2 1986

STATION 43

POSITION 3 58 N 56 50 E DATE 86/04/18 BOTTOM 4675 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
301	25	29.00	35.234	22.241	71.4	1.1	1939	98
302	65	24.78	35.535	23.816	90.0	1.0	1962	76
303	105	20.55	35.435	24.948	57.3	0.1	2073	54
304	205	13.88	35.219	26.382	2.6	-0.2	2200	32
201	401	10.71	35.089	26.897	-74.1	0.1	2204	98
202	699	8.55	35.185	27.334	-115.8	-0.4	2253	76
203	991	6.59	35.008	27.481	-158.2	-0.8	2277	54
204	1491	4.48	34.916	27.667	-168.5	-0.5	2293	32
101	2005	3.78	34.795	27.646	-175.9	-0.2	2298	98
102	2755	1.72	34.755	27.797	-182.7	0.1	2295	76
103	3505	1.35	34.759	27.828	-169.6	-1.1	2287	54
104	4505	0.89	34.731	27.836	-183.3	-0.2	2284	32

INDIGO 2 1986

STATION 44

POSITION 00 00 S 56 29 E DATE 86/04/19 BOTTOM 4485 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
101	2				88.0	0.9		pump

INDIGO 2 1986

STATION 45

POSITION 00 03 S 50 57 E DATE 86/04/21 BOTTOM 5058 M

SMPL	DEPTH	PTEMP	SALIN	SIGMA	RADIOCARBON			
#	M	C	o/oo	THETA	DC14	dC13	TCO2	GER
301	26	28.78	35.221	22.304	68.0	1.3	1989	54
302	118	19.26	35.435	25.288	86.8	0.9	2098	32
201	203	14.11	35.208	26.325	19.0	0.1	2151	23
202	401	10.70	35.001	26.831	-27.9	0.6	2189	45
203	699	8.48	35.045	27.235	-125.0	-0.3	2286	67
204	996	6.74	34.989	27.446	-143.7	-0.3	2297	89
101	2057	2.62c	34.773	27.738	-180.4	-0.1	2308	37
102	2813	1.61c	34.747	27.799	-178.7	0.0	2366	65
103	3579	1.30c	34.731	27.808	-181.6	-0.3	2437	43
104	4804	0.91c	34.725	27.830	-172.1	-0.3	2414	21

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TR029

Preliminary Data Report for the INDIVAT 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean

CO2

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Office of Basic Energy Sciences
Carbon Dioxide Research Division
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TR029

Preliminary Data Report for the INDIVAT 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean

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Under Contract No. DE-AC05-84OR21400

Preliminary Data Report for the INDIVAT 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean

EXECUTIVE SUMMARY

1) OBJECTIVES OF THE STUDY

The overall objectives of our research are to quantify the oceanic penetration of excess CO_2 by using carbonate data directly and thereby to understand more fully the oceanic carbon cycle. Given these objectives, our investigation of the carbonate chemistry of the Indian Ocean has the following specific goals:

(1) to obtain the first winter carbonate data in the South Indian Ocean, which is near the major point of origin for the bottom waters in the world oceans;

(2) to evaluate seasonal and cross-frontal (Subtropical and Antarctic Front) variations of carbonate chemistry;

(3) to estimate the penetration depth of the excess, anthropogenic CO_2 in the Indian Ocean based on both carbonate and transient tracer data; and

(4) to compare the results with data reported in the literature.

This report presents the experimental data and a limited preliminary analysis from the first two of a series of cruises scheduled in the Indian Ocean between 1984 and 1987. The data are being released quickly so that the oceanographic community can have access to them for interdisciplinary studies. A full report will be prepared after the tracer data become available.

2) INDIVAT 1 EXPEDITION

Concurrent pH, total alkalinity, total CO_2, and nitrate data were obtained in the southwestern Indian Ocean in the late austral Winter (July) of 1984 as part of the INDIVAT 1 Expedition (INDIEN VALORISATION de TRANSIT) aboard the French vessel, R/V MARION DUFRESNE. These data represent the initial concentrations of pH, alkalinity, total CO_2, and nitrate in the important source region of Antarctic Intermediate Water at the time of its formation. For the first time, we can evaluate the variations in the carbon and nitrogen cycles in the Antarctic Intermediate Water in the Indian Ocean with reference to the source water in winter.

3) INDIGO 1/INDIVAT 3 EXPEDITION

Concurrent pH, total alkalinity, and total CO_2 data were obtained in the southwestern Indian Ocean in the austral summer (Feb-March) of 1985 as part of the INDIGO 1/INDIVAT 3 Expedition (INDIGO stands for INDIEN GAZ OCEAN) aboard the MARION DUFRESNE. These summer data were compared with the winter data from INDIVAT 1 and with the summer data obtained in 1978 during the GEOSECS Expedition.

PCO_2 and tracer data (freons, tritium, C-14, Kr-85) are not yet available.

4) SUMMARY OF OUR PRELIMINARY RESULTS

- The surface pH and normalized nitrate, alkalinity and total CO_2 values are found to correlate linearly with temperature;
- Small deviations from the linearity are related to the Subtropical Front and the equatorial upwelling;
- Large variations in nitrate are found in surface waters collected at the same station but in different seasons; however, there is less variation between normalized nitrate concentrations in waters with the same temperature;
- There seems to be a seasonal difference in alkalinity and total CO_2, even when compared at the same salinity and temperature;
- The decrease in alkalinity and total CO_2 between the Antarctic Waters and the Indian Central Water found north of the Subtropical Front can be attributed tentatively to the decrease in nitrate and the increase in temperature;
- The remnant North Atlantic Deep Water (NADP), which has a very weak salinity signal, is identified clearly by pH and total CO_2 data; nutrient, oxygen, and calcium data also help in tracing NADP;
- Our alkalinity and total CO_2 data for subsurface waters agree well with GEOSECS data for GS 427 and 428 but not for GS 429.

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Chapter 1.

INTRODUCTION

1.1 Background

Deep waters from the Atlantic, the Pacific and the Indian oceans move to the Southern Ocean and mix there. The resultant relatively homogeneous water becomes the major source of the Antarctic Bottom Water (AABW), which spreads back out into the deep world oceans. Consequently, the chemistry of Southern Ocean water is a baseline for the deep world oceans. We must therefore learn the carbonate chemistry of the Southern Ocean water in order to understand the global biogeochemical cycle of carbon. Unfortunately, only a few high-precision carbonate sampling programs have been conducted in the Indian Ocean section of the Southern Ocean (we know of only 7 such stations south of 30°S). Not knowing the characteristic properties of the water near its origin, therefore, makes it difficult, if not impossible, to interpret variations in the carbonate chemistry or to calculate excess CO_2 in the Indian Ocean. Furthermore, the scant data in the southern Indian Ocean were all collected in the summer; whether the summer data are representative of the mainly winter-formed deep waters is uncertain (Chen and Pytkowicz, 1979; Chen, 1982a,b).

In the summer of 1981, while on board the R/V MILLER FREEMAN in the North Pacific, R.A. Feely (PMEL, NOAA) and C.T. Chen discussed the importance of collecting more carbonate data, especially winter data, in the southern Indian Ocean. R. Byrne, who was also on board, later joined our discussion. Being cognizant that scientists in France at that time also had become interested in the study of the anthropogenic CO_2 problem, Chen and Feely then contacted A. Poisson regarding the possibility of a joint program. Poisson's response was quick and gratifying; during the summer of 1982 he came to visit with Feely and J. Cline (PMEL) at NOAA, Seattle and with Chen at Oregon State University (OSU) staying two months at OSU. Partly as a result of the assistance of Feely and Cline, the freon detection technique was transferred to Poisson's laboratory.

Cruise plans were formulated and further discussions followed in December 1982, when Poisson visited OSU again, and in July 1983, when Chen and Poisson met in Hamburg. By that time, more scientists were involved, including Chen, Byrne, and Ostlund, all of whom are funded by DOE through ORNL. Unfortunately, other obligations at PMEL did not allow Feely to be actively involved in the programs.

Two separate programs were planned, INDIVAT and INDIGO. INDIVAT (INDIEN VALORISATION de TRANSIT) takes advantage of the fact that the French research/supply vessel, MARION DUFRESNE, travels from La Réunion to Crozet, Kerguelen, Amsterdam, and back to La Réunion three to four times per year. TAAF (TERRES AUSTRALES et ANTARCTIQUES FRANÇAISES), which operates the vessel, gave permission for us to use the ship during the next four years to collect and measure surface samples during transit. Because the vessel crosses the Subtropical and Antarctic Fronts many times a year, it provides an excellent opportunity to study the seasonal variation of carbonate chemistry in the formation region of the Antarctic Intermediate Water in the Indian Ocean.

In addition, TAAF also agreed to permit us to reoccupy two GEOSECS stations (GS 427 and 429) during each INDIVAT cruise. Deep samples provide us with a means to calibrate our results in order to compare them with data reported in the literature. In addition, we can determine how much the seasonal variation affects the water column. Such information is essential for comparisons from year to year.

The second program, the INDIGO (INDIEN GAZ OCEAN), involves the use of the MARION DUFRESNE as a research vessel to collect deep samples in different regions of the Indian Ocean once a year for a minimum of four years. TAAF pays for the ship operations at a cost of 170,000 French francs per day.

The first INDIVAT expedition was successfully completed in July 1984. INDIVAT 2 had to be cancelled due to logistical problems. The combined INDIGO 1/INDIVAT 3 expedition was carried out in February/March 1985 (Chen and Poisson, 1986).

1.2 Organization of this report

The main purpose of this report is to provide prompt publication of the carbonate and nitrate data measured by Chen. Our collaborators and interested scientists in the community will be able to use such data for interdisciplinary studies. A full report will not be published until the tracer data (freons, tritium, C-14 and Kr-85) become available.

Limited discussions of the INDIVAT 1 and INDIGO 1/INDIVAT 3 results are given in Chapters 2 and 3. In Chapter 4, these results are compared with data reported in the literature, and we offer some preliminary conclusions. Chen's data on pH, alkalinity, total CO_2, and nitrate are listed in the appendices.

Chapter 2.

INDIVAT 1 EXPEDITION

2.1 Outline of the INDIVAT 1 expedition

The MARION DUFRESNE departed La Reunion on 3 July 1984, reoccupied GS 427 on 5 July, and reoccupied GS 429 on 19 July after a stop in Crozet. The vessel then proceeded to Kerguelen and Amsterdam and returned to La Reunion on 4 August. The cruise track is shown in Fig. 1. The Subtropical Front was near 40°S and the Antarctic Front was near 47°S.

While underway, surface samples were collected hourly from a seawater intake located at the bow 4 m below the surface. Temperature and salinity at the intake were recorded by a thermosalinograph. Seawater was then pumped through a rubber tube to a van near the laboratory where samples were taken. Because of the delay in sampling, the recorded temperature and salinity may not always match the samples taken, especially near an oceanic front. Because of the long time (approximately 5 minutes) required to obtain all samples (salinity, oxygen, pH, alkalinity, total CO_2, PCO_2 nitrate, phosphate, and silicate), the water which flows out of the tube at the beginning of sampling may be somewhat different from the water flowing out at the end of sampling. This may have caused some discrepancies in the data. Deep samples at GS427 and 429 were obtained using a CTD-Rosette.

2.2 Experimental technique

Salinity samples were analyzed with a Guildline Salinometer, usually within 48 hours. The pH samples were all analyzed at 25 ± 0.02°C with a Radiometer combination electrode within 30 minutes. NBS 4.004 and 7.415 buffers were used to calibrate the electrode. The reproducibility of the pH measurements is better than ± 0.003 units for replicate samples. The electrode drift (assumed to be linear) was determined at approximately 10 day intervals. The drift was approximately 0.002 unit/day and the correction was made to the measured values.

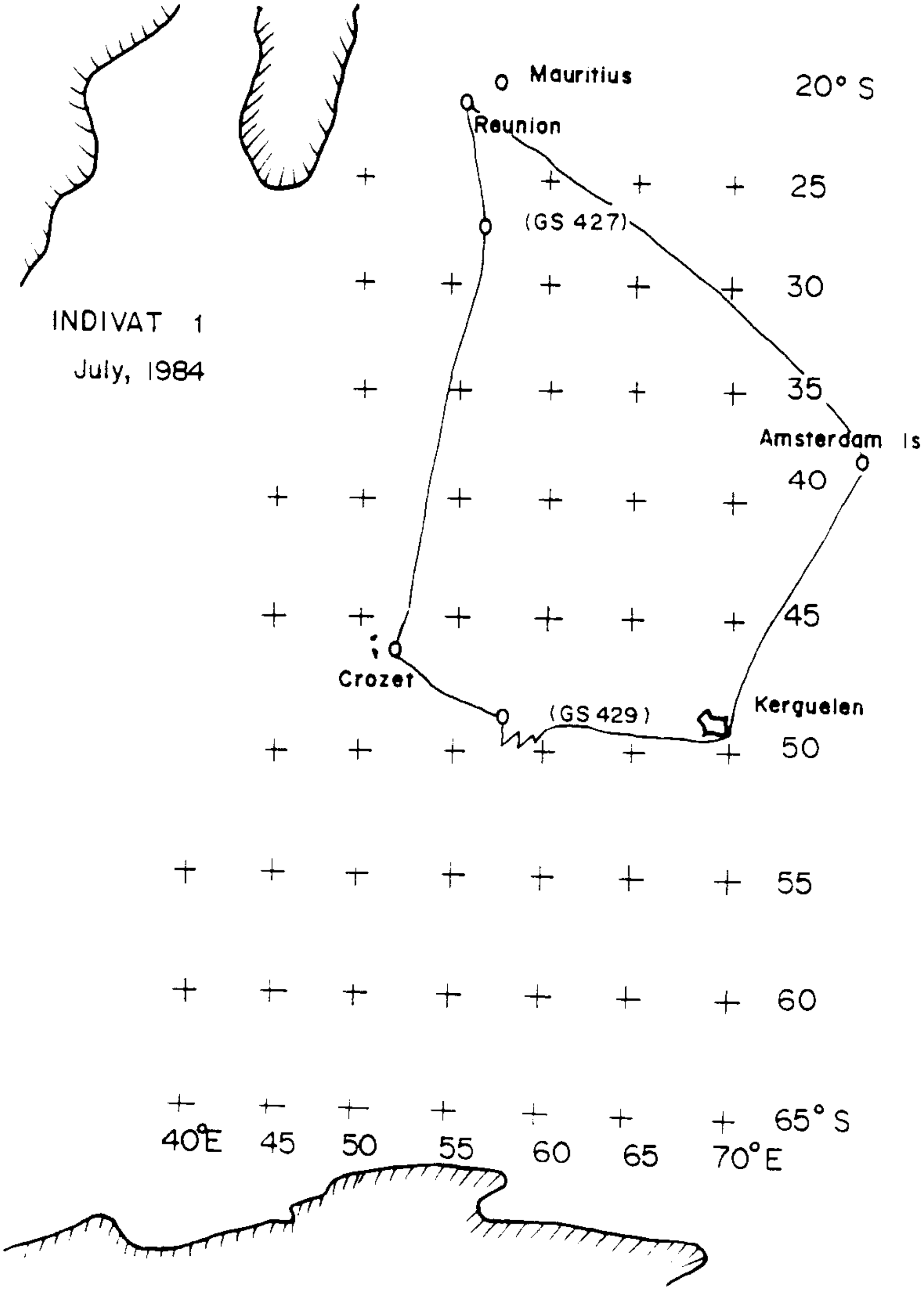

Fig. 1. The cruise track of INDIVAT 1.

The CTD-Rosette used to obtain deep samples malfunctioned once and all 11 bottles were closed at approximately 3400 m at GS427. Four replicate samples were taken from each bottle. The standard deviation of the pH data (44 points) is 0.0027 pH unit (1σ) which includes random error in both sampling and analysis. The standard deviation corresponds to roughly 1 μmol/kg in total CO_2.

Alkalinity and total CO_2 were determined at 25° ± 0.02°C with an Apple II-controlled titration cell using a program similar to that of Bradshaw et al. (1981). These measurements have a precision of ± 4 μeq/kg for alkalinity and ± 5 μmol/kg for total CO_2 and were performed within 12 hours of sampling. Nitrate was analyzed within 12 hours using the flow-injection method of Johnson and Petty (1983). The precision was ± 0.2 μmol/kg. pH, alkalinity, total CO_2, and nitrate data obtained by Chen are listed in Appendix I.

2.3 Chemistry of the surface waters

Many chemical properties, especially when normalized to a constant salinity to remove the effects of evaporation and precipitation, are known to correlate linearly with temperature (e.g., nitrate: Chen et al., 1982b; pH, phosphate and silicate: Chen, 1984; calcium: Chen et al., 1982a; alkalinity: Edmond, 1974; and total CO_2 : Chen and Millero, 1979). Our normalized nitrate ($NNO_3 = NO_3 \times 35/S$) values for surface waters are also found to correlate linearly with surface temperature (Fig. 2) between 2° and 17°C. We did not measure nitrate for samples above 17°C because the values are known to be very low.

pH, normalized alkalinity ($NTA = TA \times 35/S$), and normalized total CO_2 ($NTCO_2 = TCO_2 \times 35/S$) also correlate linearly with temperature (Figs. 3 and 4). There may be a slight change in slope at 13°C for NTA and $NTCO_2$ near the Subtropical Front near 40°S. The NTA slope also changes slightly at 4°C near the Antarctic Front.

It is not clear why such linear correlations exist. We assume that the biological activity reduces the NNO_3 concentration from 28 μmol/kg in the Circumpolar Current near 50°S to 0 μmol/kg in the subtropical region near 35°S at a rate linearly correlated with the warming of the water from 2°C to 17°C. Given the Redfield C/N ratio of 106/16, this consumption of nitrate must produce 185.5 μmol/kg of

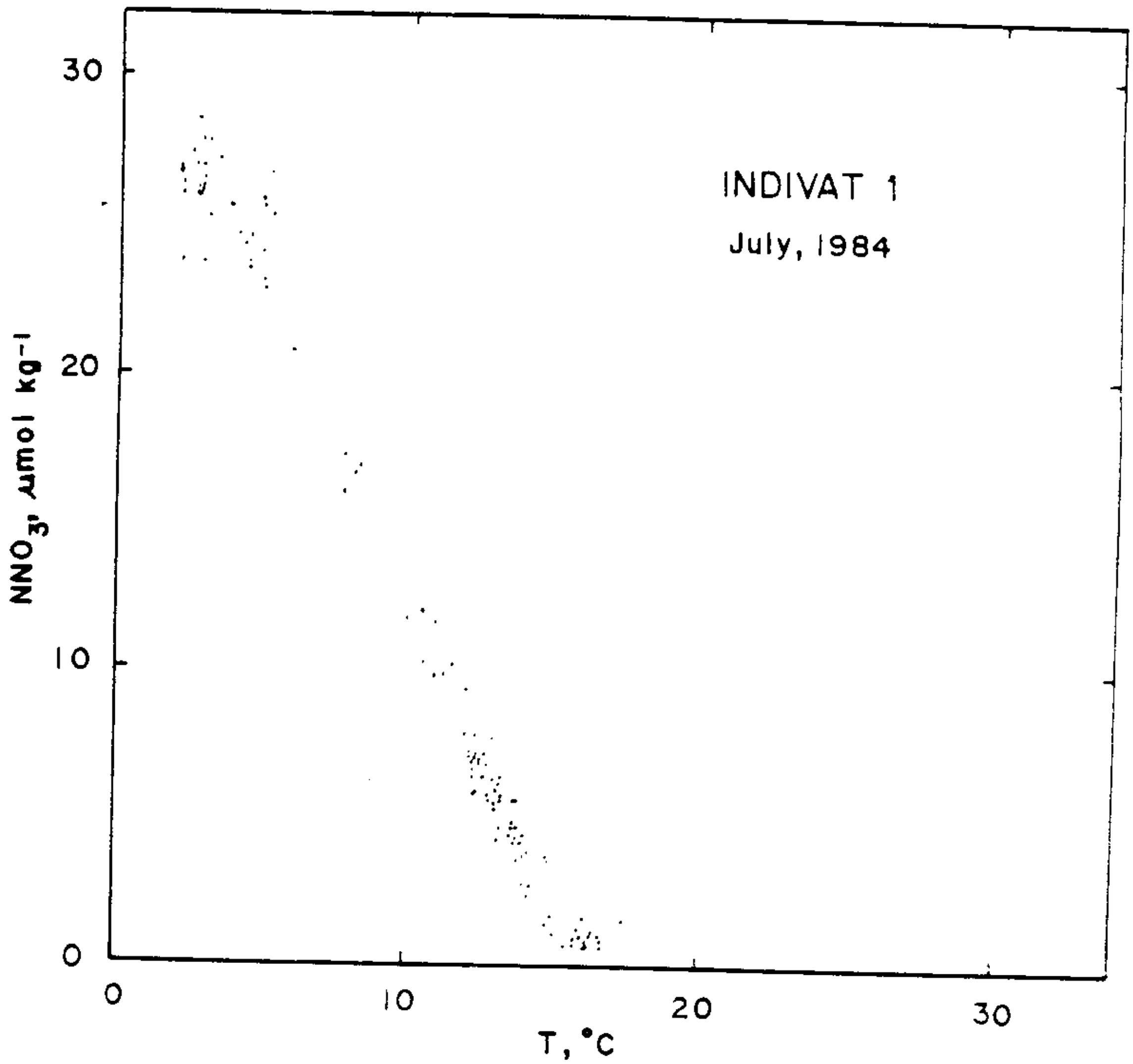

Fig. 2. Normalized nitrate vs. temperature for surface samples collected during INDIVAT 1.

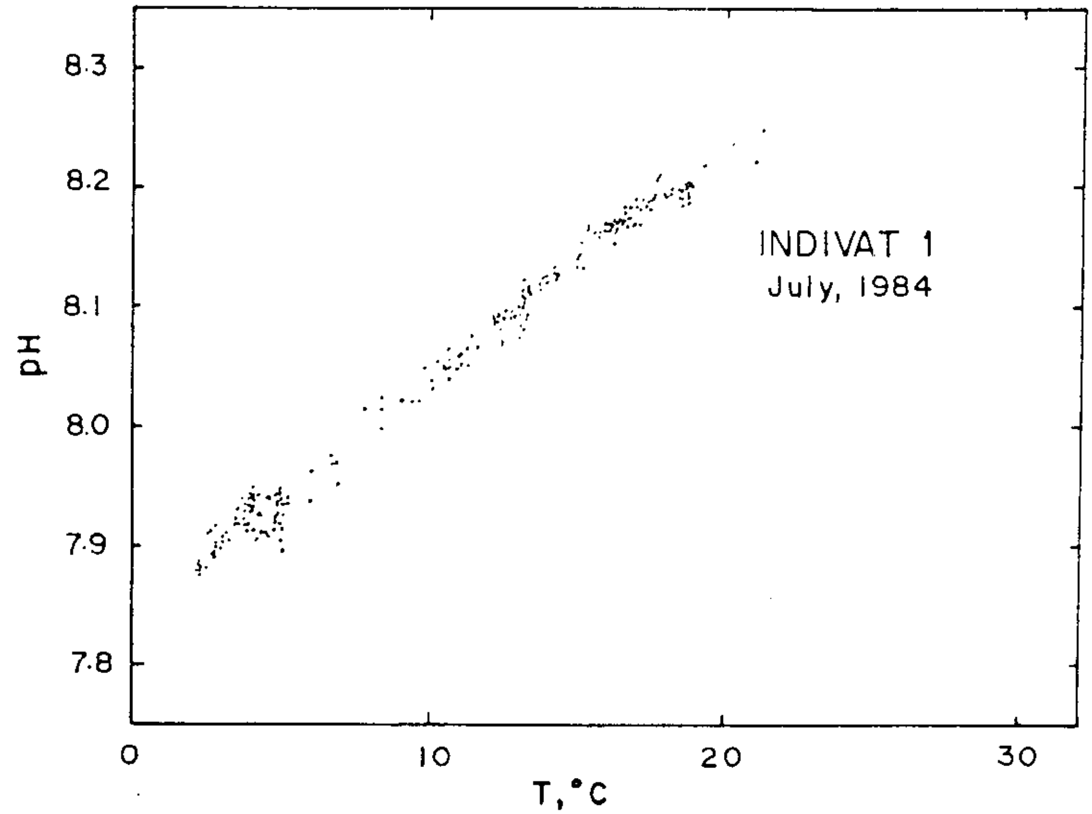

Fig. 3. pH (25°C) vs. temperature for surface samples collected during INDIVAT 1.

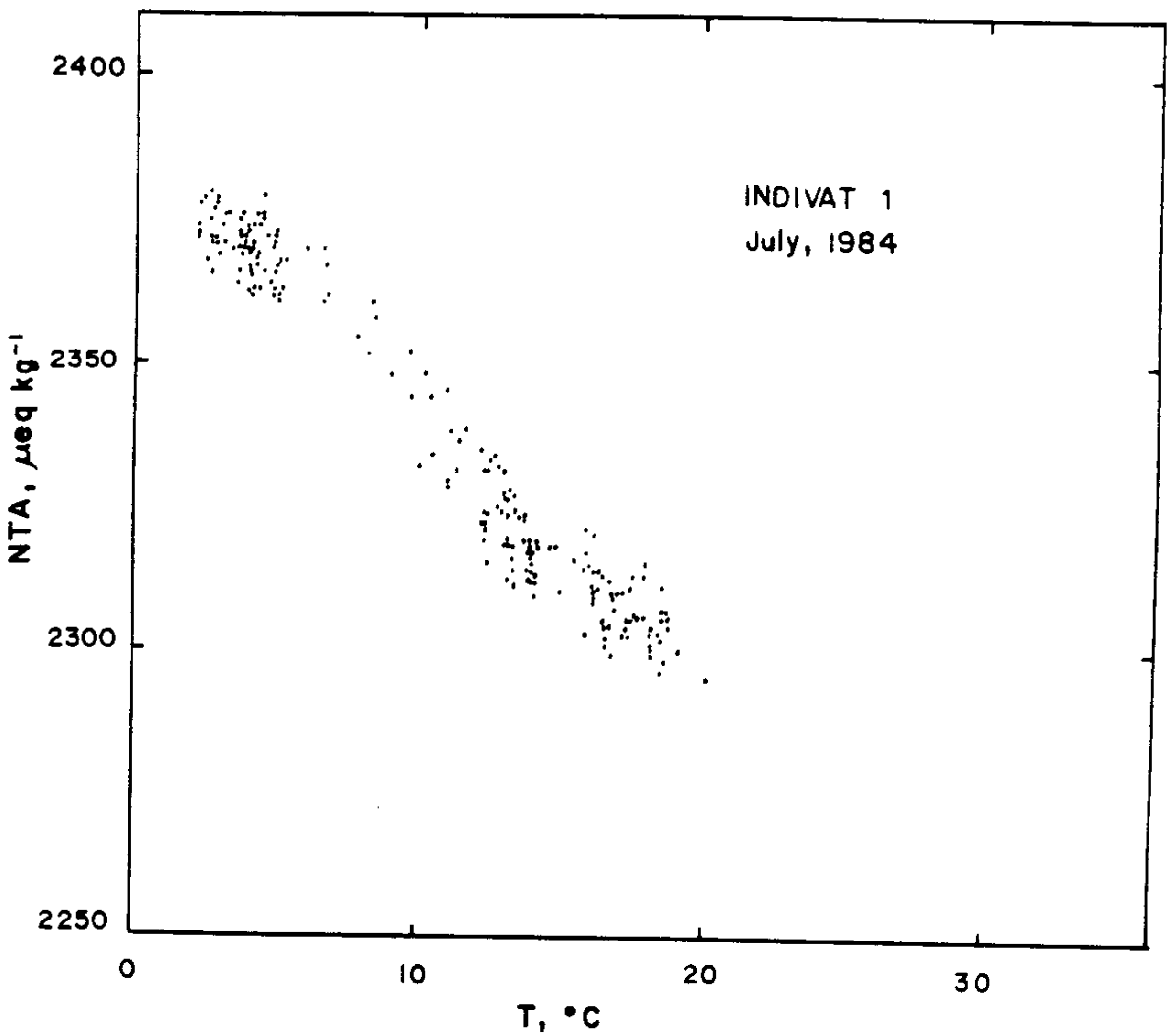

Fig. 4(a). Normalized alkalinity vs. temperature for surface samples collected during INDIVAT 1.

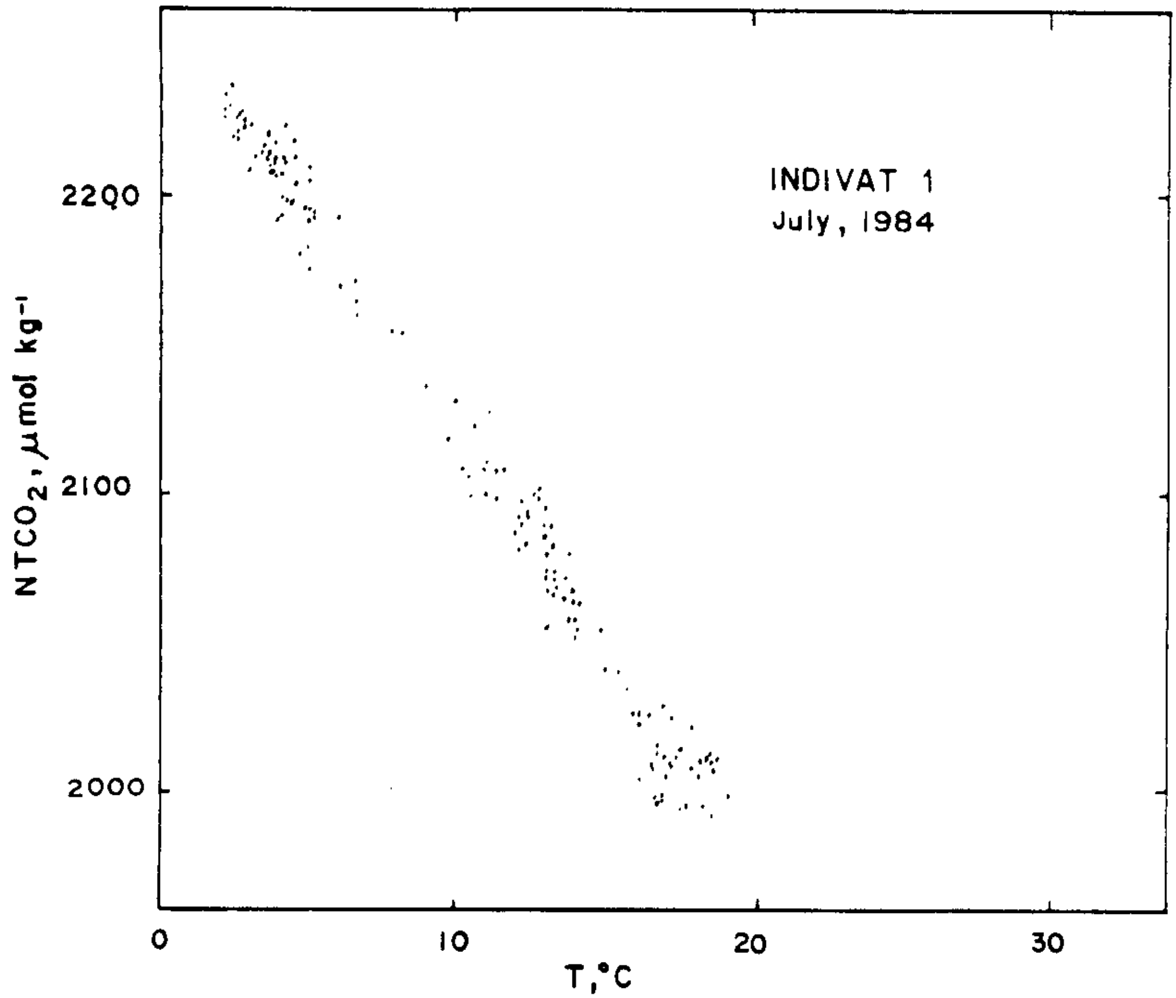

Fig. 4(b). Normalized total CO_2 vs. temperature for surface samples collected during INDIVAT 1.

organic carbon. At the same time, the $NTCO_2$ must be reduced by the same amount. In addition, the warming of seawater drives out dissolved CO_2 and reduces the $NTCO_2$ by 8 μmol/kg.

Production of organic carbon as soft tissue is associated with the production of inorganic carbon as hard tissue and shells at roughly a four-to-one ratio (Broecker and Peng, 1982). Thus, the production of 185.5 μmol/kg in organic carbon should result in a further reduction of 46.4 μmol/kg in $NTCO_2$ and 63 μeq/kg in NTA after the effect of nitrate and phosphate on alkalinity is taken into consideration (Brewer et al., 1975; Dyrssen, 1977; Chen et al., 1982a). Consequently, we expect a total reduction in CO_2 of 240 μmol/kg. We observed a reduction of 215 μmol/kg. We also observed a NTA reduction of 70 μeq/kg. These correlations further quantify the relationships between the carbon cycle and the nutrient cycle and indicate that biological activity contributes to most of the reduction in nitrates, alkalinity and total CO_2 .

For waters north of 35°S (waters warmer than 17°C), nitrate concentration is so low that other sources of nitrogen, such as ammonia, may be important in biological consumption. Thus, the Redfield ratio is no longer applicable. Further, the effect of equatorial upwelling becomes important, and simple linear relations cease to exist.

2.4 Chemistry of the subsurface waters

Only limited samples were collected at two stations, GS 427 and 429. The temperature, salinity, pH, NTA and $NTCO_2$ for these stations are plotted vs. depth in Figs. 5 and 6, respectively. GS 427 is north of the Subtropical Front, Antarctic Intermediate Water (AAIW) is found here as a S-min layer at approximately 1000 m. A pH-min is located slightly below this depth. NTA and $NTCO_2$ seem to increase with depth, but at a faster rate near surface.

GS 429 is south of the Antarctic Front. AAIW is absent here (Fig. 6). T, S, pH, NTA, $NTCO_2$ and NNO_3 (not shown on Fig. 6) remain constant above 150 m due to winter mixing. To our knowledge, this is the first time such winter data have been reported in the Indian Ocean section of the Circumpolar Water.

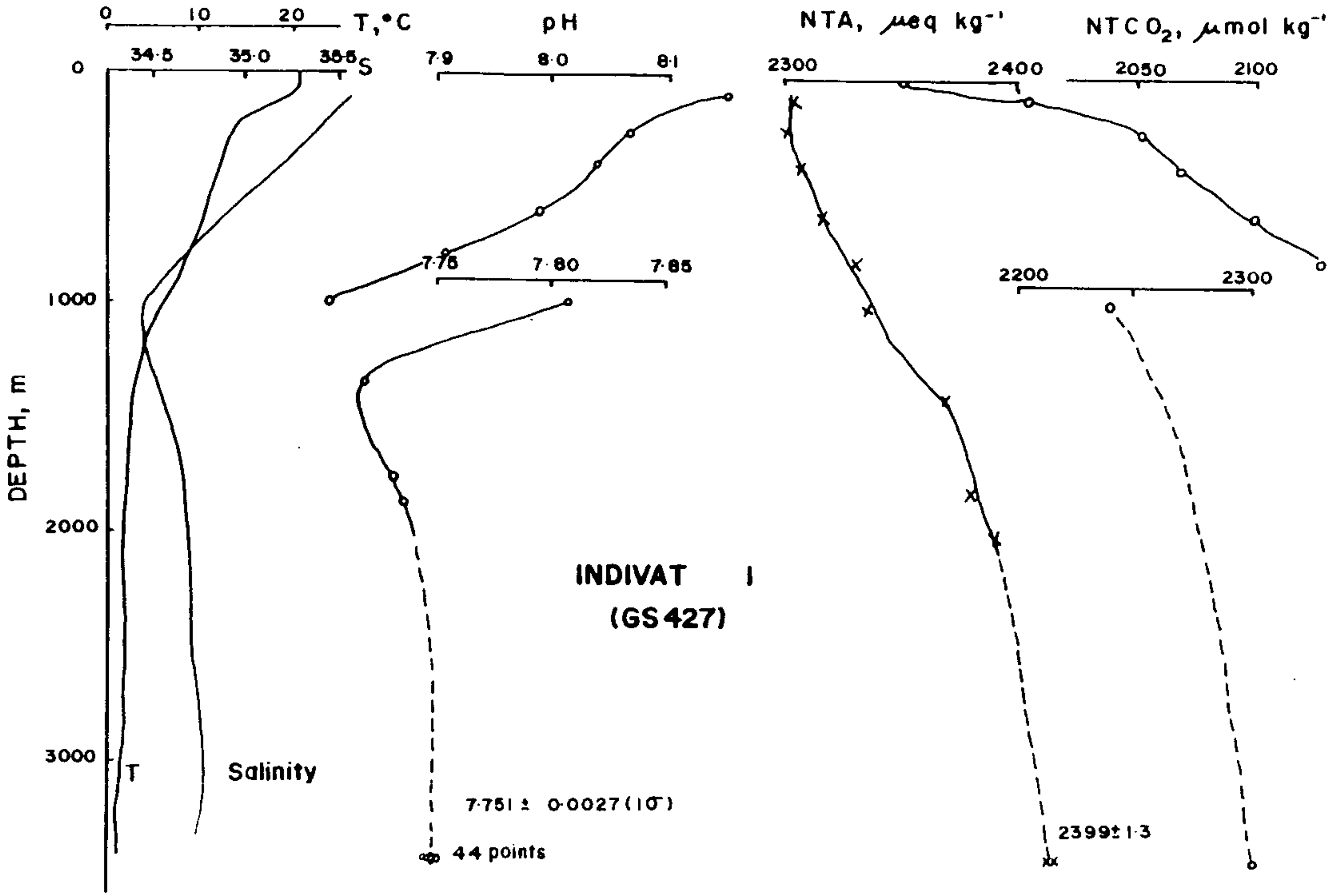

Fig. 5. Vertical profiles of temperature, salinity, pH, NTA, and $NTCO_2$ at GS 427 reoccupied during INDIVAT 1.

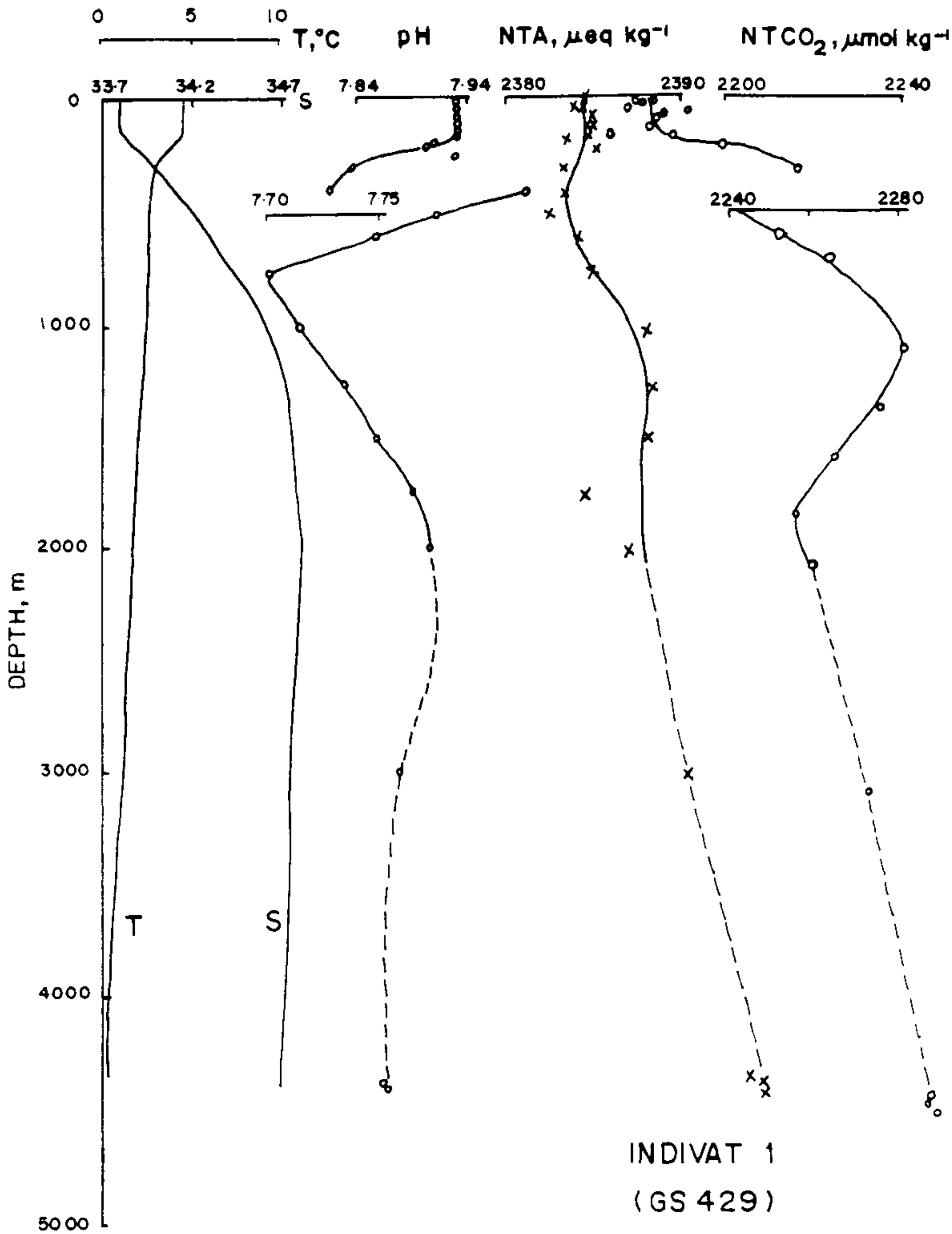

Fig. 6. Vertical profiles of temperature, salinity, pH, NTA, and $NTCO_2$ at GS 429 reoccupied during INDIVAT 1.

There is a very pronounced pH-min at 800 m with a $NTCO_2$-max immediately below it. A very weak S-max exists at about 2000 m reflecting the influence of the North Atlantic Deep Water (NADP) which is low in $NTCO_2$ (minimum; Fig. 6) and low in nutrients but high in pH (maximum; Fig. 6). The pH and $NTCO_2$ signals are much stronger than the salinity signal and are quite useful as tracers in the Southern Ocean (Chen, 1984; Chen and Rodman, 1985). More discussion on the movements of water masses is given in Chapter 3.

Chapter 3.

INDIGO 1/INDIVAT 3 EXPEDITION

3.1 Outline of the INDIGO 1/INDIVAT 3 expedition

The first INDIGO expedition (with emphasis on subsurface samples) and the third INDIVAT expedition (with emphasis on underway surface samples) were combined. R/V MARION DUFRESNE departed from La Réunion on 23 February 1985 and returned on 30 March. Carbonate data were collected from 23 stations including four GEOSECS stations (427-429, 454). The attempt to reach the Antarctic Continent was unsuccessful because of foul weather. The cruise track is given in Fig. 7. The Subtropical Front was at approximately 43°S and the Antarctic Front was near 52°S.

A large number of physical and chemical properties were measured, including temperature, salinity, oxygen, nitrate, phosphate, silicate, pH, alkalinity, total CO_2, pCO_2, calcium, magnesium, boron, Kr-85, tritium, C-14, freons, and particulates. The data in this report only includes pH, alkalinity, and total CO_2 measured by Chen (Appendices II and III). INDIGO 1 or INDIGO 1/INDIVAT 3 are used to denote this data set.

3.2 Experimental technique

Sampling and analytical techniques were similar to those described under section 2.2 for the INDIVAT 1 expedition. The only difference is that underway samples were collected near the underwater intake and the Thermosalinograph. Consequently, the recorded temperature and salinity for the INDIGO 1/INDIVAT 3 expedition correlate much better with the samples taken than during the previous expedition.

3.3 Chemistry of the surface waters

The normalized nitrate concentrations are plotted versus temperature in Fig. 8 (data taken from Poisson et al., in preparation). The linear trend between 4° and 17°C is evident. There is essentially no nitrate above 17°C. NPO_4 shows the same trend. pH also correlates linearly with temperature below 17°C (Fig.

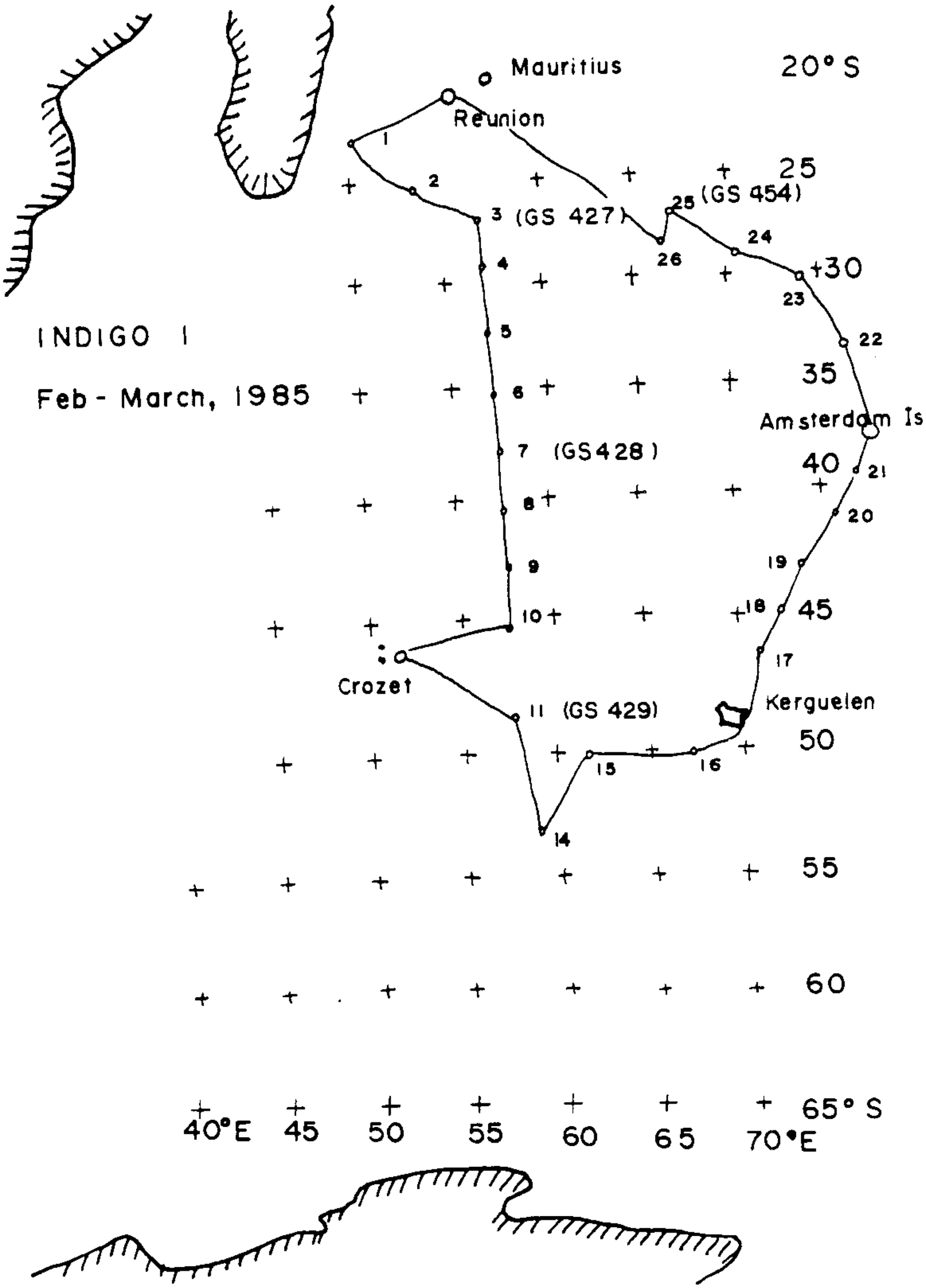

Fig. 7. The cruise track of INDIGO 1/INDIVAT 3.

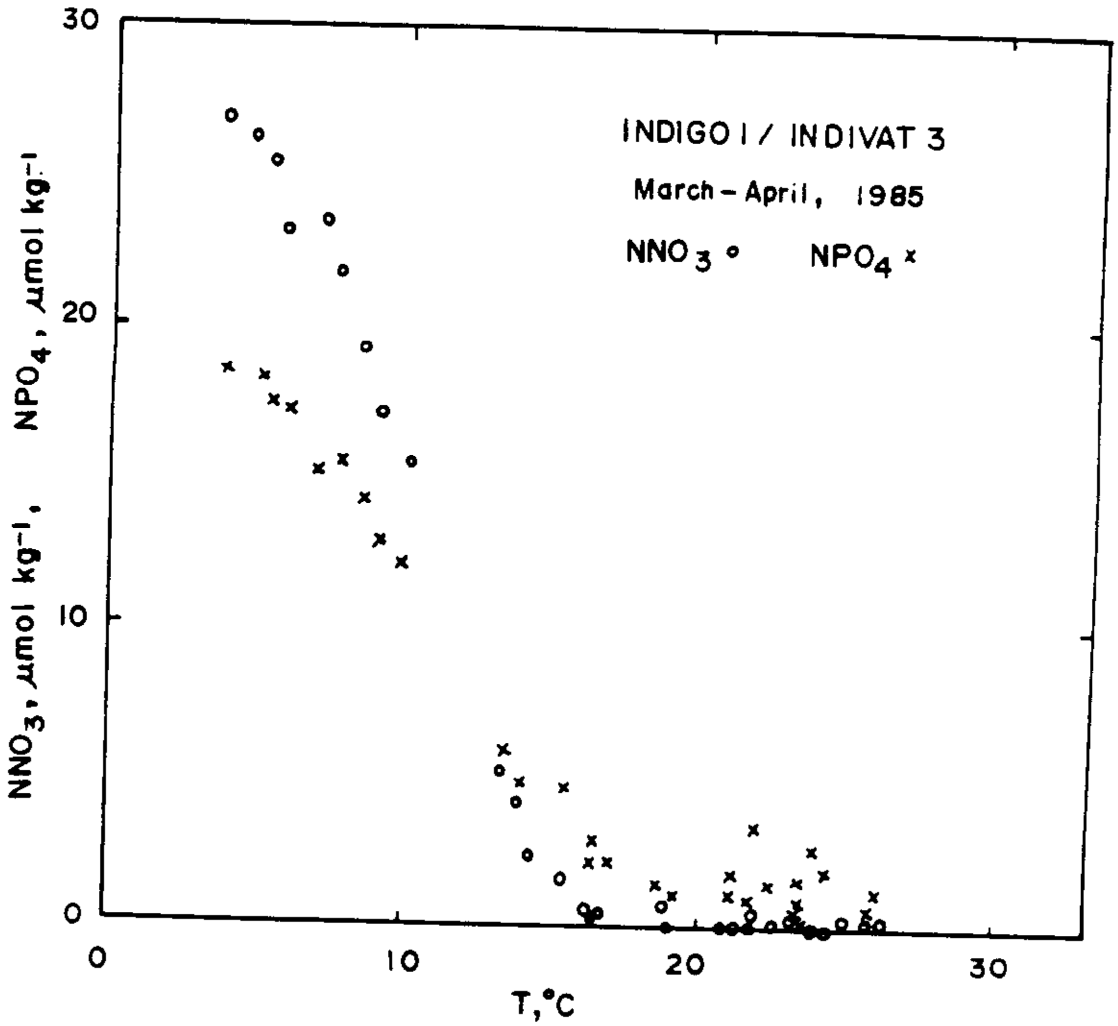

Fig. 8. Normalized nitrate and phosphate vs. temperature for surface samples collected during INDIGO 1/INDIVAT 3.

9) except for a slight change in slope near 13°C near the Subtropical Front. There seems to be a pH-stat between 17 and 23°C, a phenomenon which was not observed during INDIVAT 1 (Fig. 3). The pH seems to increase again with temperature above 23°C.

NTA and $NTCO_2$ values decrease almost linearly with temperature (Fig. 10a,b). The slightly lowered rate of decrease in these values near 13°C found during INDIVAT 1 (Fig. 4a,b) near the Subtropical Front (now at about 43°S) persists. There is also a change in slope at approximately 20°C. We suspect these changes in slope are caused partly by equatorial upwelling. The upwelled water has high NTA and $NTCO_2$ concentrations but low pH values, causing the slopes to change accordingly.

The decrease in NNO_3 of 28 μmol/kg between 4 and 17°C corresponds to the decrease of 239 μmol/kg in $NTCO_2$ and 63 μeq/kg in NTA. We observe a decrease in $NTCO_2$ and NTA of 200 μmol/kg and 75 μeq/kg, respectively.

3.4 Chemistry of the subsurface waters

The temperature cross-section for the stations occupied during the INDIGO 1/INDIVAT 3 expedition is given in Fig. 11. Upwelling is evident for the southernmost stations (G 10-16, Appendix II). The upwelling is also shown clearly in the salinity cross-section (Fig. 12). In addition, Fig. 12 shows the Subtropical Front near 43°S and the low salinity tongue of AAIW. One particularly interesting feature is the core of S-max water found at about 2700 m at G 9 near 43°S. This is probably the core of NADW, characterized by high salinity and pH but low nitrate, phosphate, NTA, $NTCO_2$, pCO_2, NCa (normalized calcium = Ca x 35/S) and AOU (apparent oxygen utilization) (Redfield, 1960; Jacobs and Georgi, 1977).

The pH cross-section is given in Fig. 13. Decomposition of soft tissue decreases the pH with increasing water depth. The water near the bottom, however, is affected by AABW, which is in turn contributed by NADW which has a relatively high pH value (Chen, 1984). As a result, a pH-min layer is formed. The pH-min core found at stations G 15 and 16 at about 600 m depth is probably one of the oldest parcels of water found during this expedition. This conjecture cannot be confirmed until C-14 data become available.

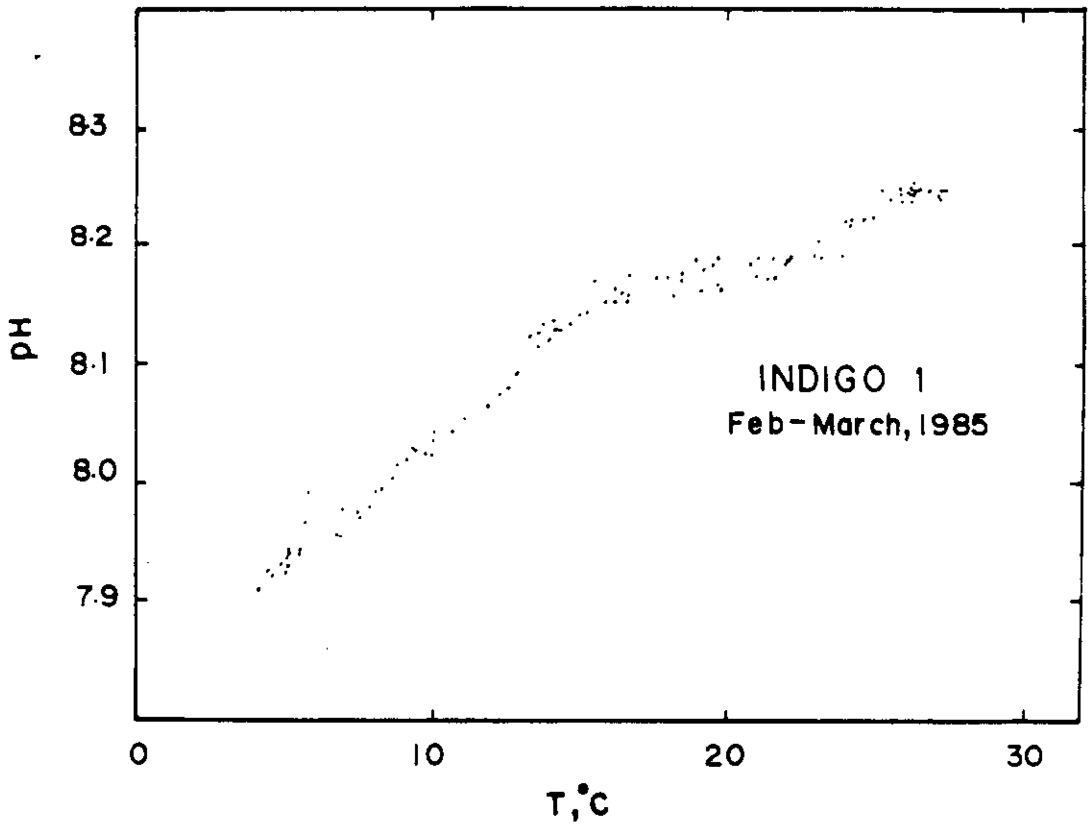

Fig. 9. pH (25°C) vs. temperature for surface samples collected during INDIGO 1/INDIVAT 3.

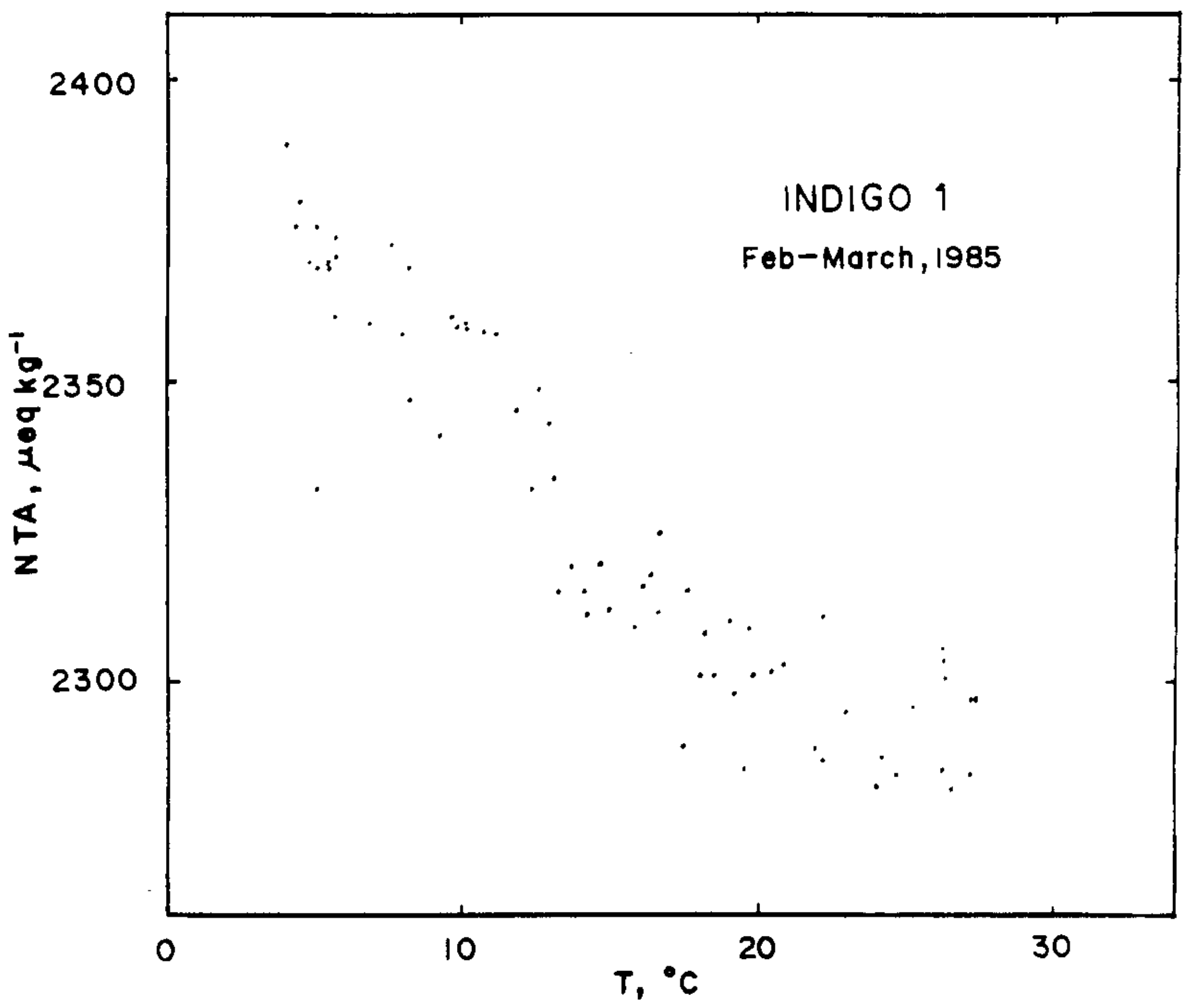

Fig. 10(a) Normalized alkalinity vs. temperature for surface samples collected during INDIGO 1/INDIVAT 3.

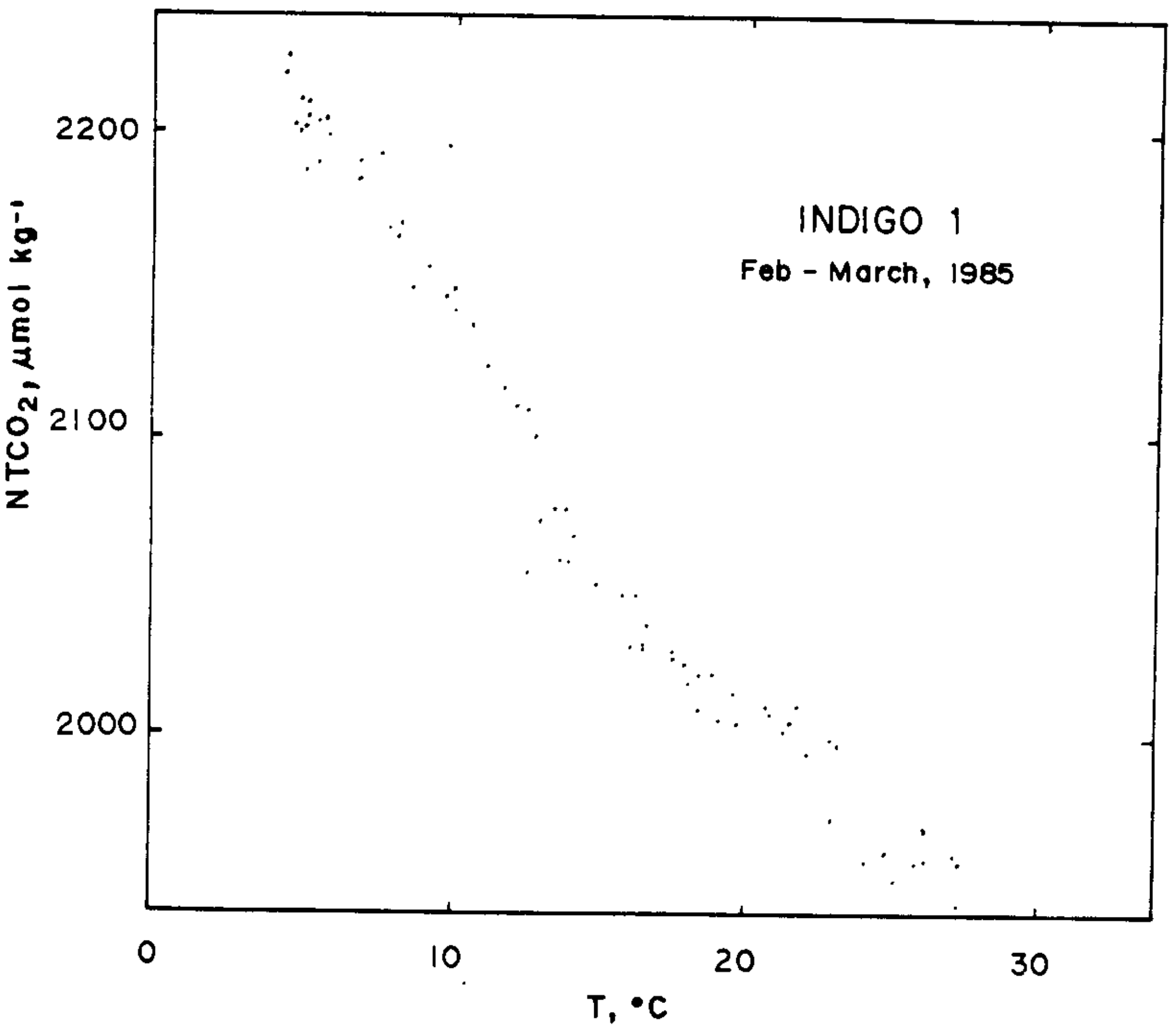

Fig. 10(b). Normalized total CO_2 vs. temperature for surface samples collected during INDIGO 1/INDIVAT 3.

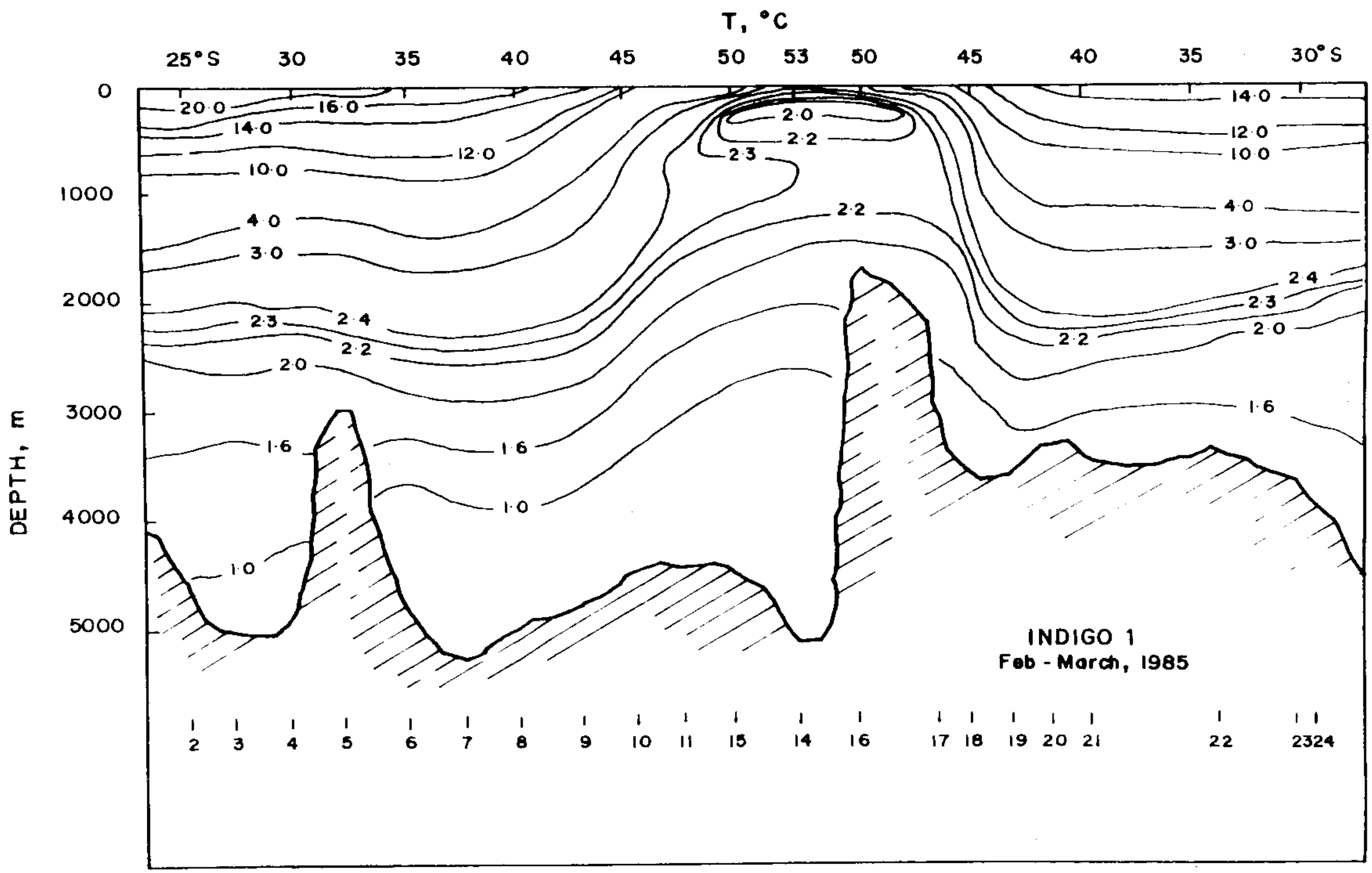

Fig. 11. The temperature cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

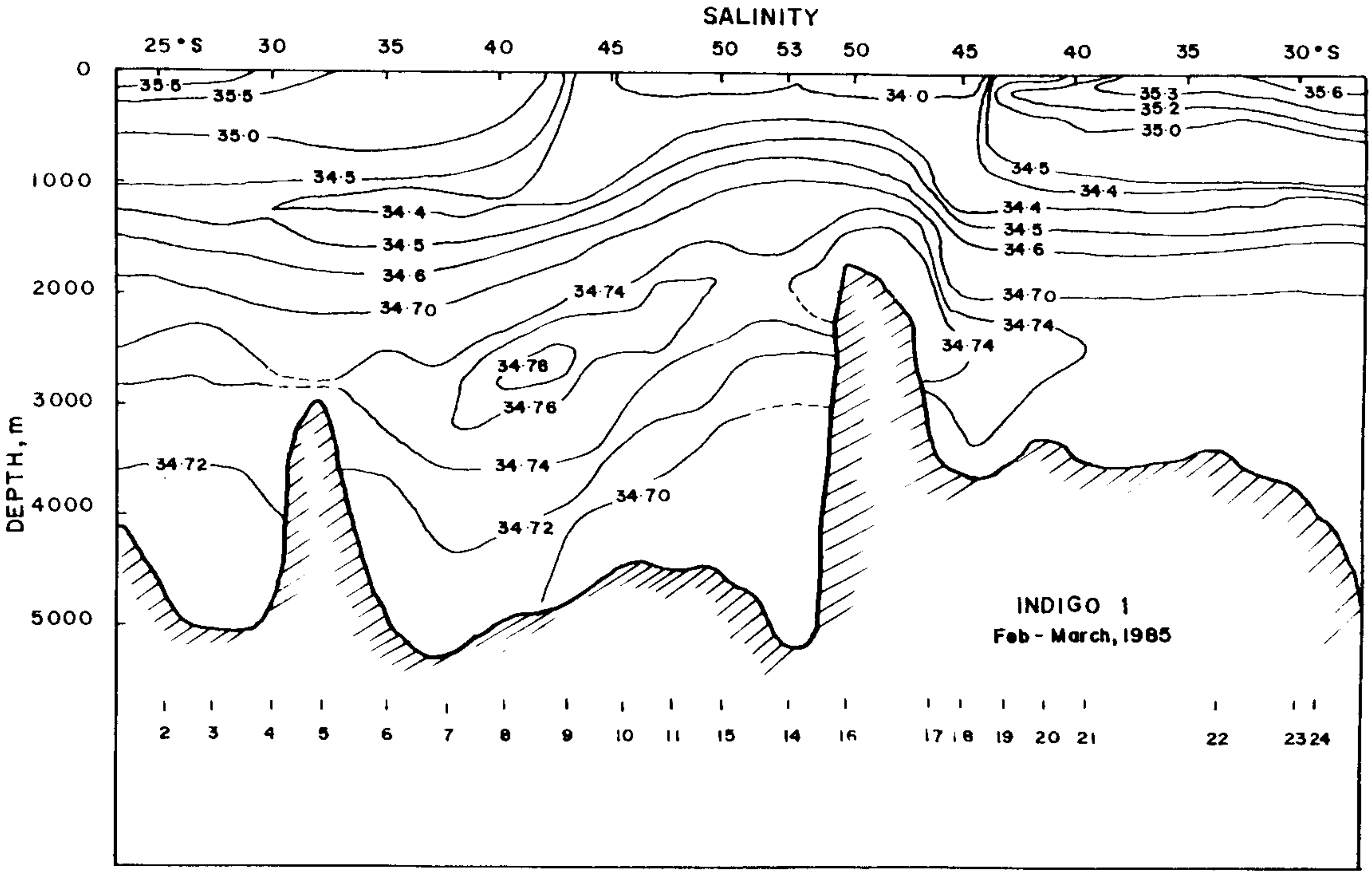

Fig. 12. The salinity cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

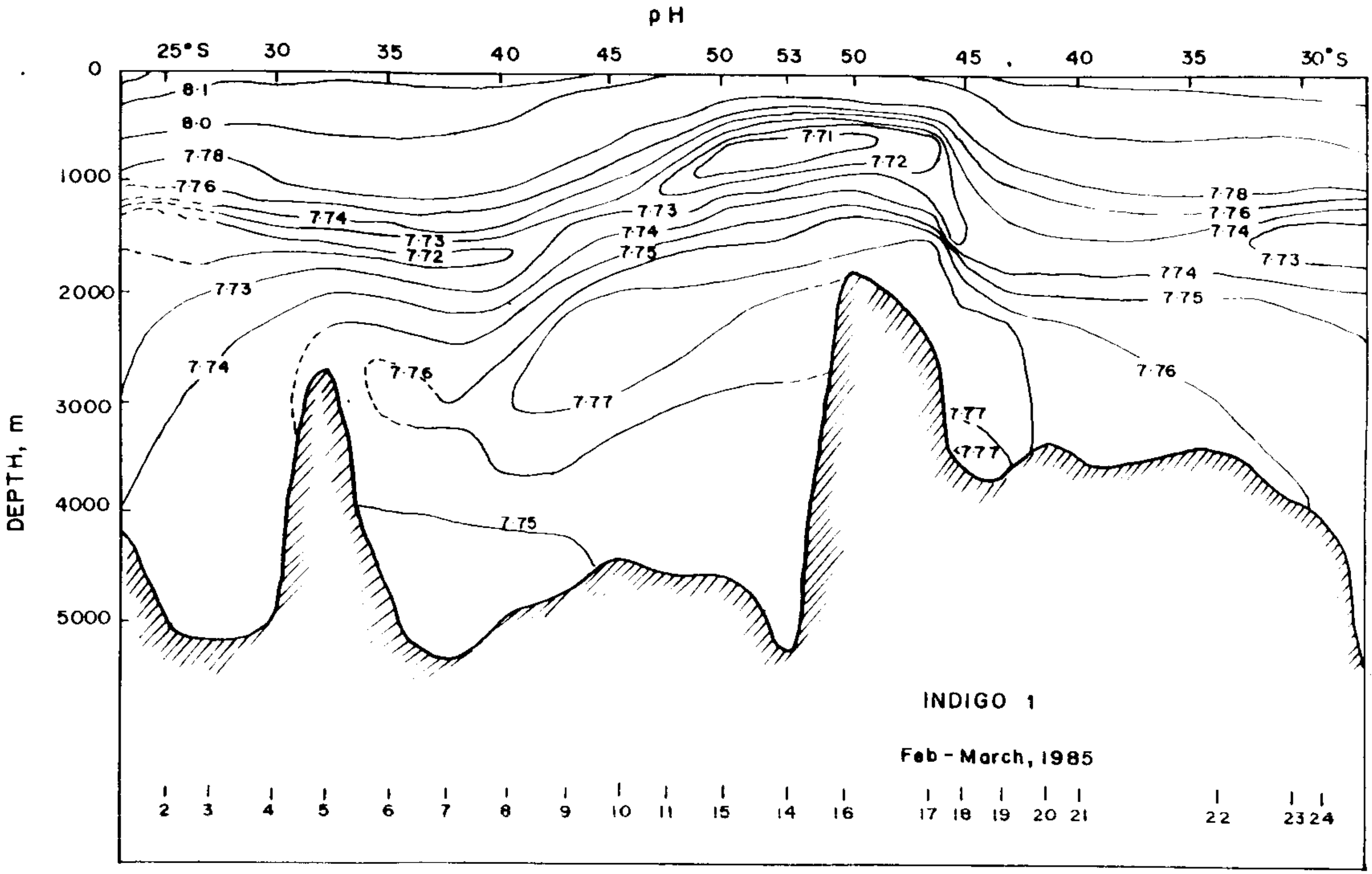

Fig. 13. The pH cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

The NTA cross-section is given in Fig. 14. In regions north of the Subtropical Front NTA increases almost monotonically because of the dissolution of calcareous hard tissue and shells. South of the Subtropical Front, the water contains mainly siliceous organisms so that the increase in NTA with depth is small. Because Circumpolar upwelling brings deep water (and its high NTA) to the surface, the entire region south of the front is high in NTA throughout the water column. Biological consumption reduces surface NTA again when the water flows northward. Note the NTA-max at G 1 caused by the undercutting of AABW.

Fig. 15 gives the $NTCO_2$ cross-section. The resolution is coarser than the pH plot because of the relatively poor precision of the $NTCO_2$ data. Nevertheless, the major features, such as the core of $NTCO_2$-min water at G 9 (also shown on S and pH plots), the $NTCO_2$-max at G 3 (also shown on NTA plot), and the effect of Circumpolar upwelling (also shown on T, S, pH, and NTA plots), are preserved. By way of comparison, the apparent oxygen utilization cross-section is presented in Fig. 16 (data from Poisson et al., in preparation). The similarity between Figs. 15 and 16 is apparent. The AOU cross-section shows a maximum at the southernmost stations. This maximum corresponds to the pH minimum found on Fig. 13.

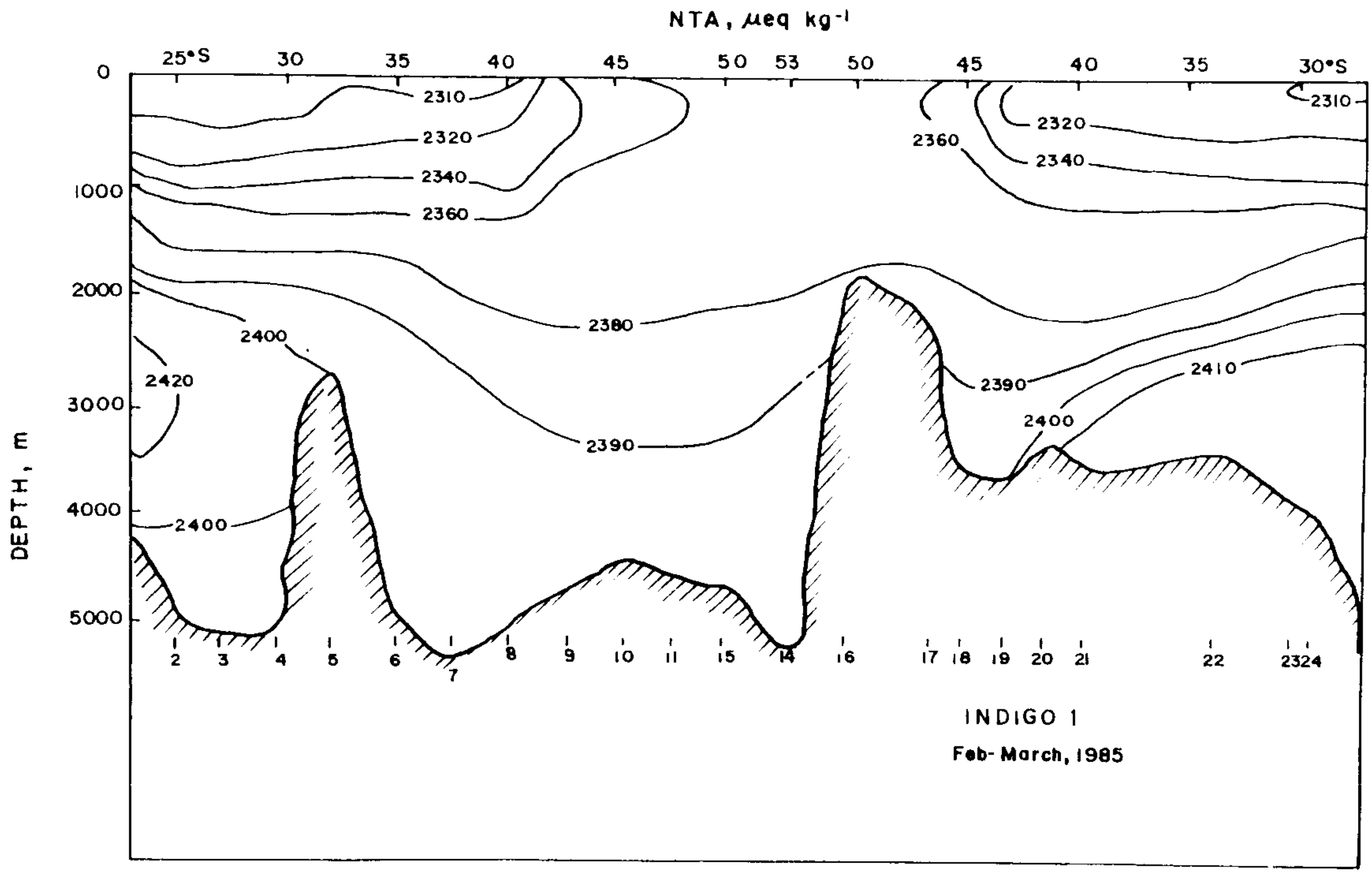

Fig. 14. The NTA cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

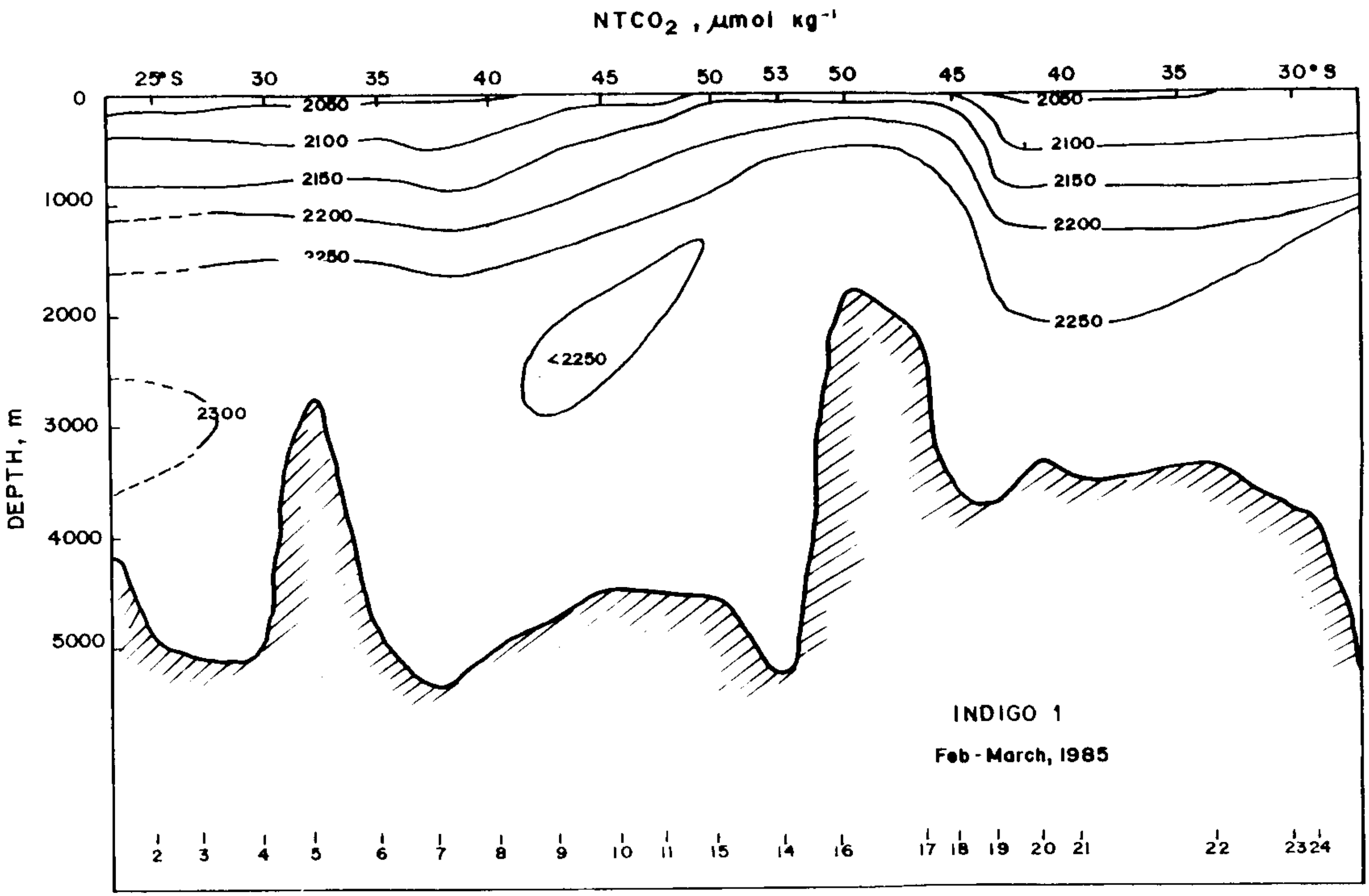

Fig. 15. The $NTCO_2$ cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

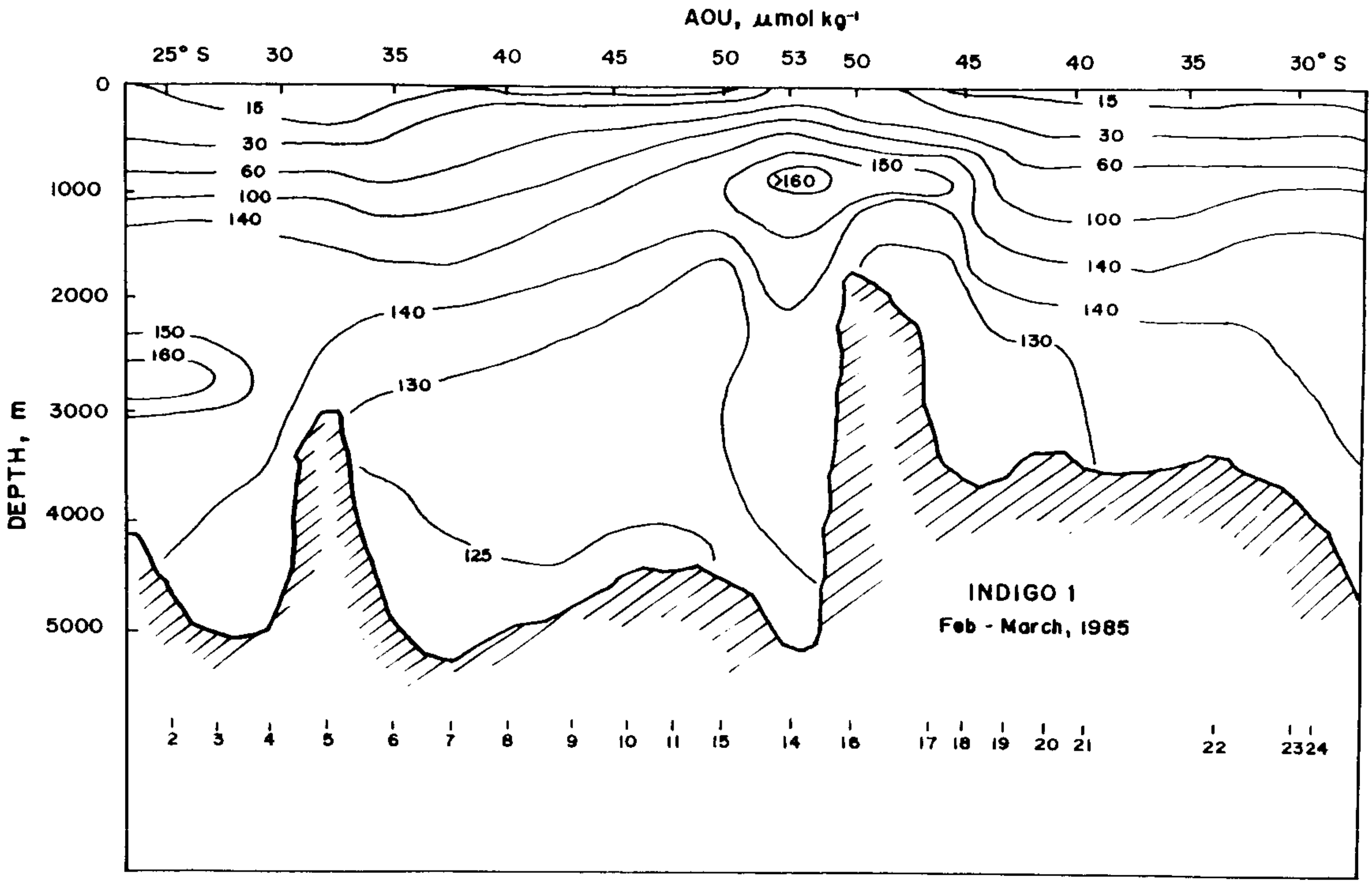

Fig. 16. The AOU cross-section for stations occupied during the INDIGO 1/INDIVAT 3 Expedition.

Chapter 4.

COMPARISON OF INDIVAT 1 AND INDIGO 1/INDIVAT 3 DATA WITH GEOSECS DATA

Comparison of data collected at the same locations, but at different times is difficult because one can never be sure that the same waters, especially surface waters, were sampled. Surface NO_3 values, for example, show significant variations over three cruises to the same location. At GS 429 occupied in summer (Feb. 1978), the surface concentration was 20.2 μmol/kg (Weiss et al., 1983). The INDIGO 1/INDIVAT 3 value at the same station was 21.2 μmol/kg (March 1985) and the INDIVAT 1 value was 24.5 μmol/kg (July 1984). The correlations between NNO_3 and temperature, however, changed only slightly, with the INDIGO 1/INDIVAT 3 concentrations being systematically higher (Figs. 2, 8 and 17). We also do not see a difference between the pH-temperature correlation for data collected in winter (Fig. 3) and those obtained in summer (Fig. 9), given the statistical accuracy of the data.

Significant differences exist, however, in surface NTA and $NTCO_2$ values among the three cruises. INDIGO 1/INDIVAT 3 seems to have produced the highest NTA and $NTCO_2$ values. These NTA values (Fig. 10) are approximately 5 μeq/kg higher than the INDIVAT 1 (Fig. 4) values, which are in turn 10 μeq/kg higher than the GEOSECS values (Fig. 18). The INDIGO 1/INDIVAT 3 $NTCO_2$ values are approximately 20 μmol/kg higher than the INDIVAT 1 values, which are in turn 10 μmol/kg higher than GEOSECS. These differences may indicate either seasonal effects, or systematic analytical differences but data to be collected from subsequent cruises are needed for the confirmation of this. The NTA and $NTCO_2$ results measured independently by Poisson and coworkers (unpublished) during INDIGO 1/INDIVAT 3 are shown in Fig. 19. They tend to agree with Chen's data shown in Fig. 10a,b.

Fig. 20 shows the vertical profiles of NTA and $NTCO_2$ which were collected at GS 427 during INDIVAT 1 and during INDIGO 1/INDIVAT 3 by Chen and by Poisson independently of each other. The GEOSECS data are plotted in Fig. 21. These four sets of data generally agree to

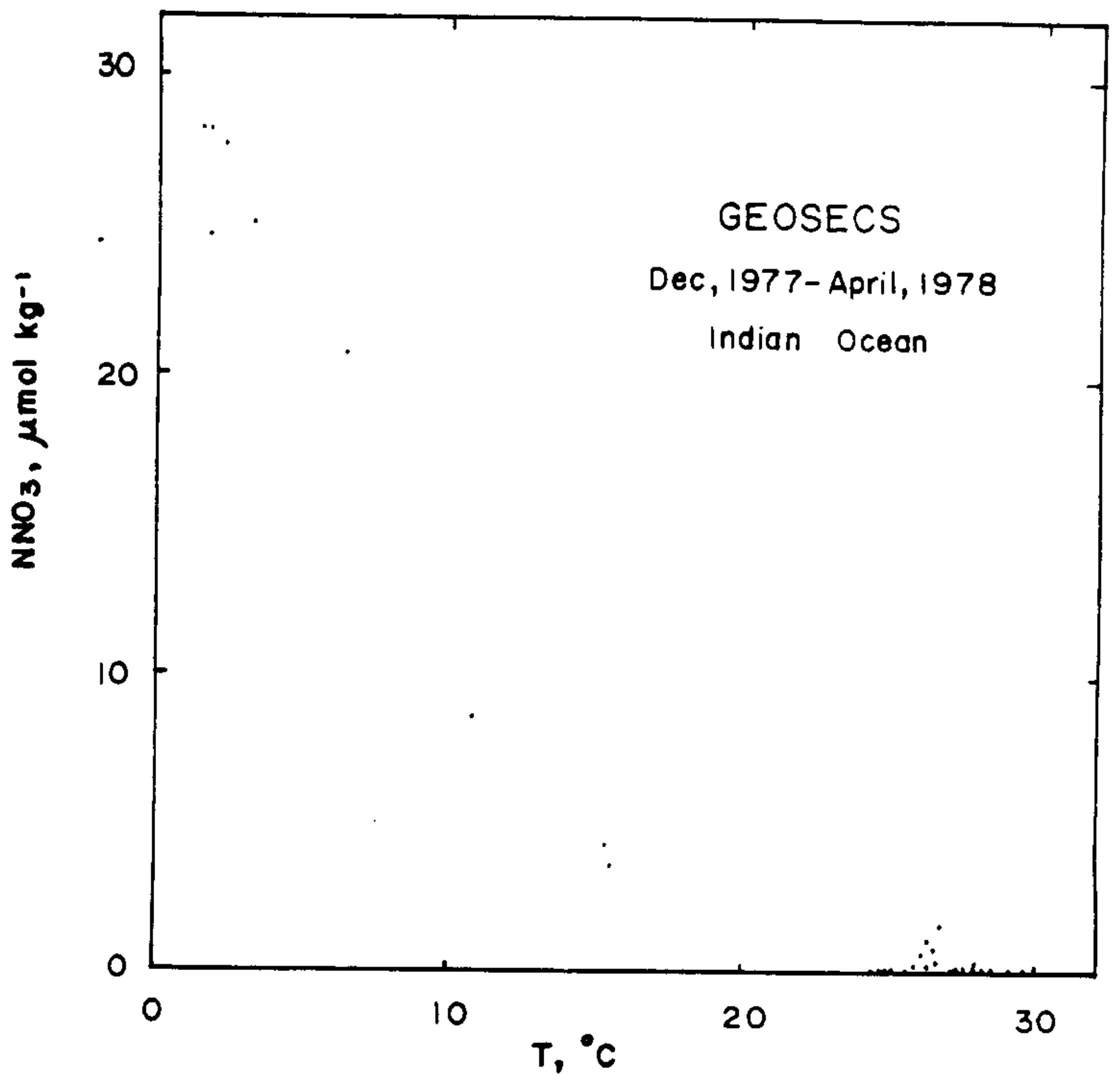

Fig. 17. Normalized nitrate vs. temperature for surface samples collected during GEOSECS.

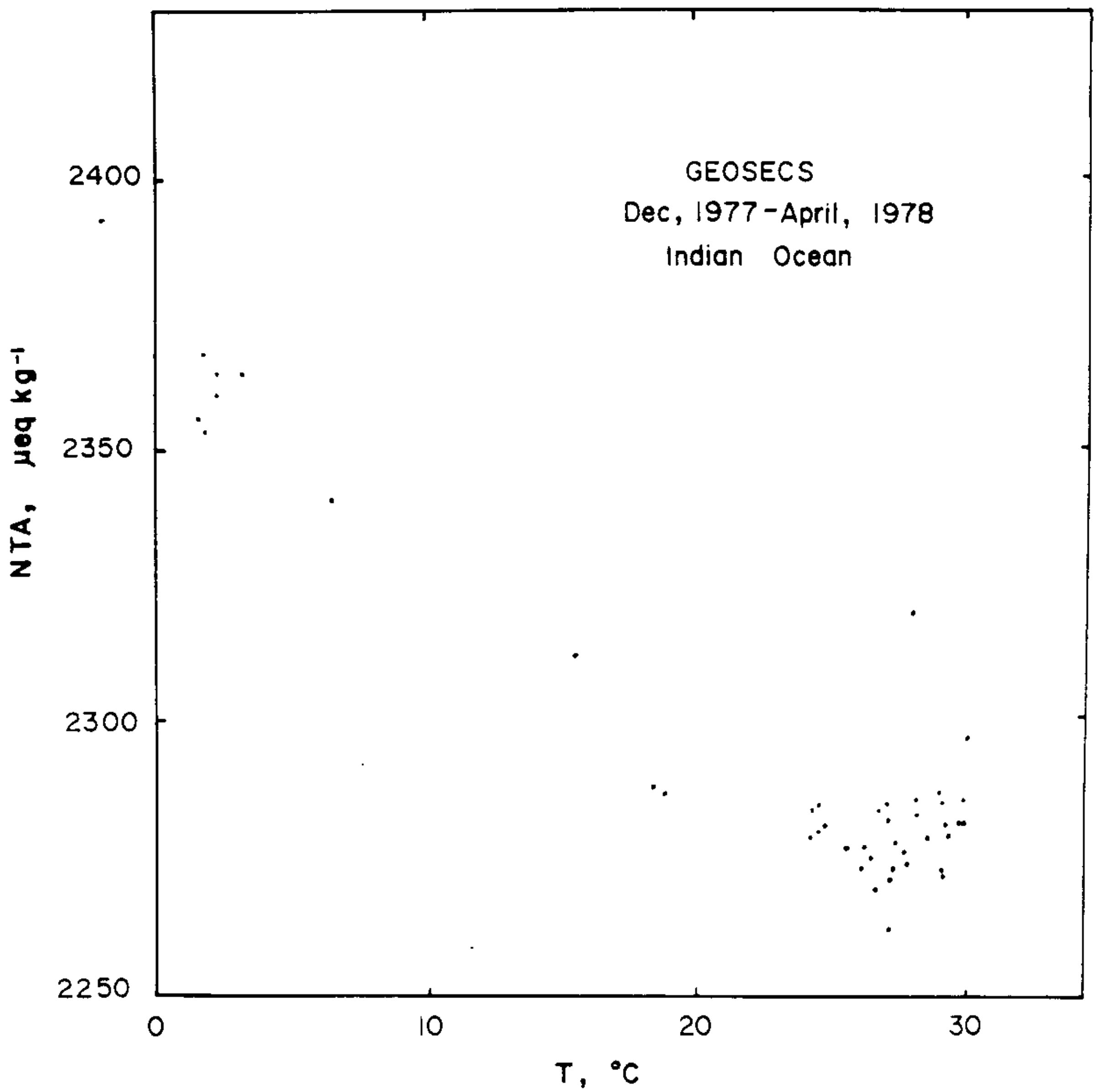

Fig. 18(a). Normalized alkalinity vs. temperature for surface samples collected during GEOSECS.

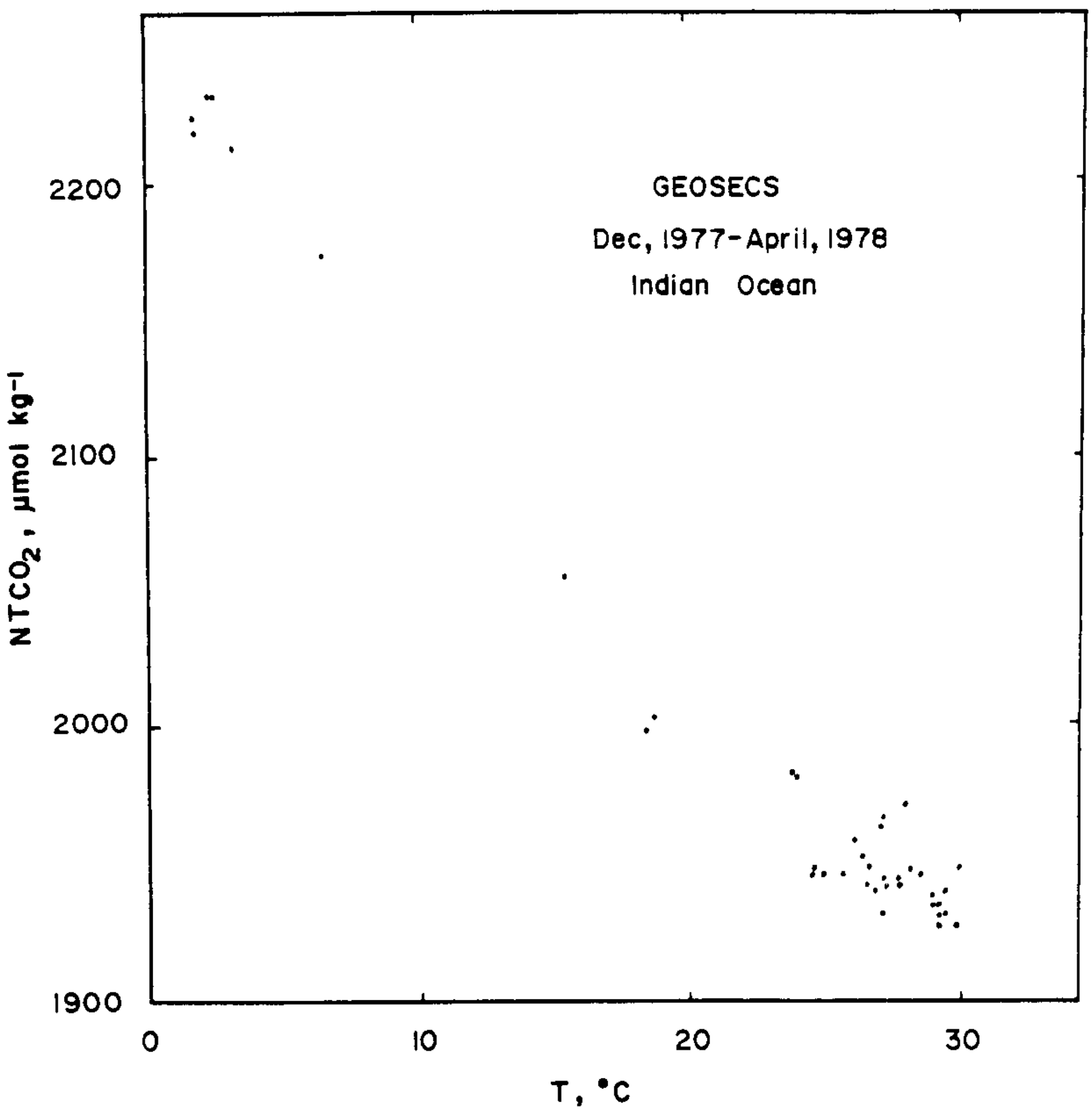

Fig. 18(b). Normalized total CO_2 vs. temperature for surface samples collected during GEOSECS.

within 10 μeq/kg for NTA and 10 μmol/kg for $NTCO_2$, variations only slightly larger than the combined experimental error. The agreement is equally good at GS 428 (Figs. 22 and 23).

Significant differences exist, however, among different data sets at GS 429 (Figs. 24 and 25). The data show a large difference in $NTCO_2$ near surface, with the winter INDIVAT 1 values the highest, obviously due to seasonal effect. The systematic difference for subsurface water, however, is probably due to analytical errors. Poisson's NTA values are approximately 10 μeq/kg higher than the GEOSECS data, with Chen's data in between the two. We suspect that the GEOSECS NTA data are a few microequivalents too low. Furthermore, although the $NTCO_2$ data show much scatter, we suspect that the GEOSECS $NTCO_2$ data are also a few micromoles too low.

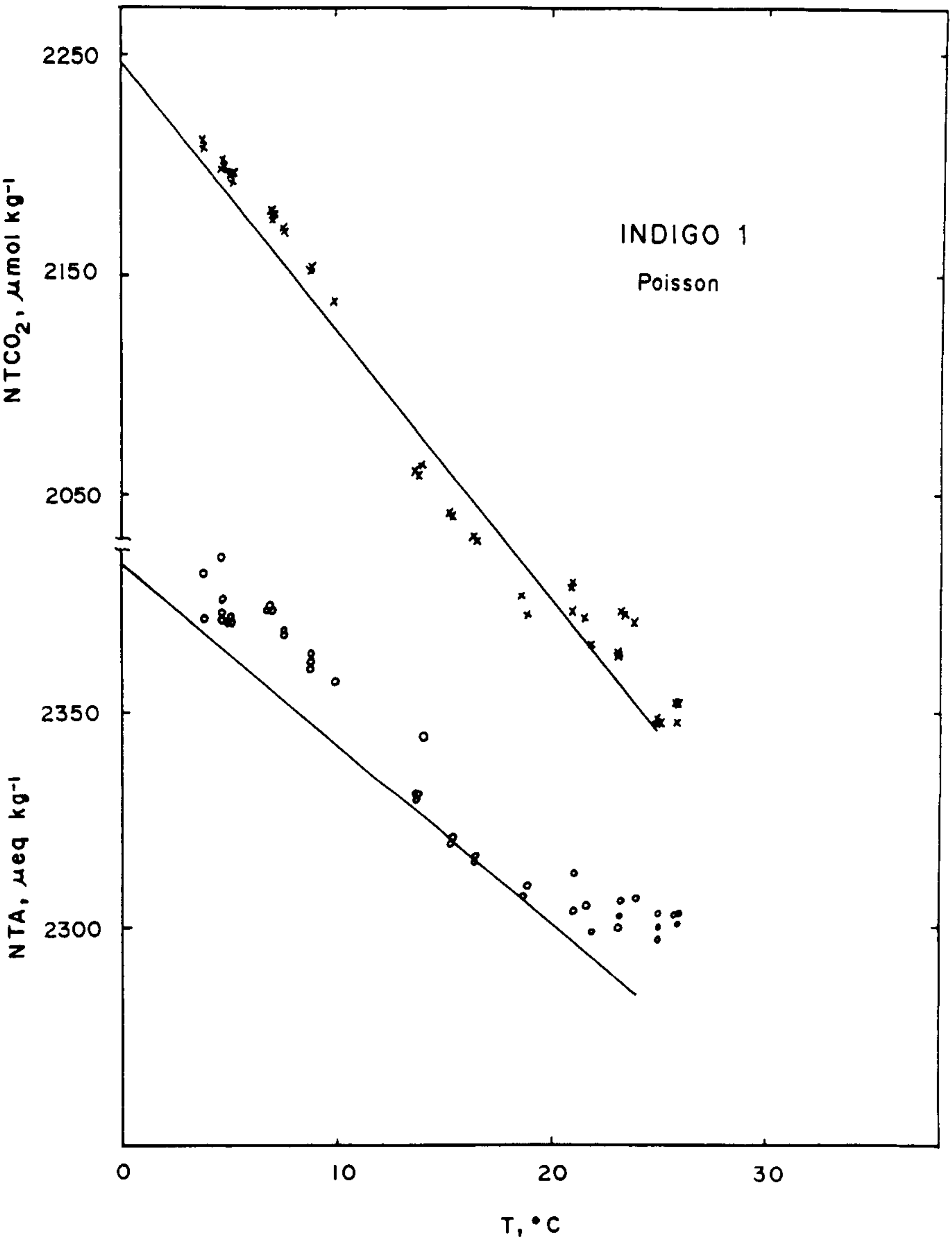

Fig. 19. Normalized alkalinity and total CO_2 vs. temperature for surface samples collected during INDIGO 1/INDIVAT 3; measured by Poisson and coworkers. The two lines show the best fit for the GEOSECS data.

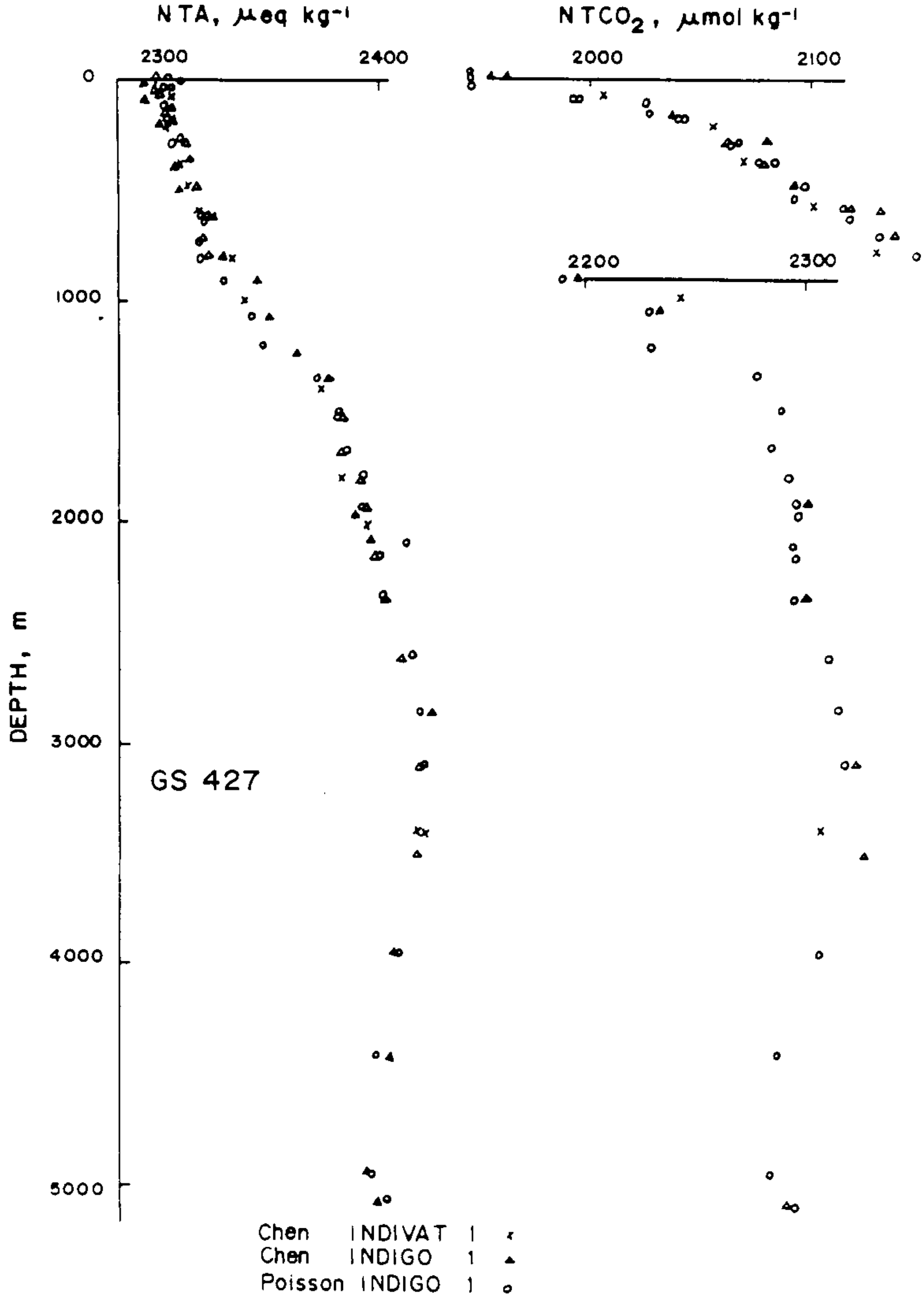

Fig. 20. Vertical profiles of NTA and $NTCO_2$ at GS 427. The crosses are Chen's data from INDIVAT 1. The triangles are Chen's data and the circles are Poisson's, both from INDIGO 1/INDIVAT 3.

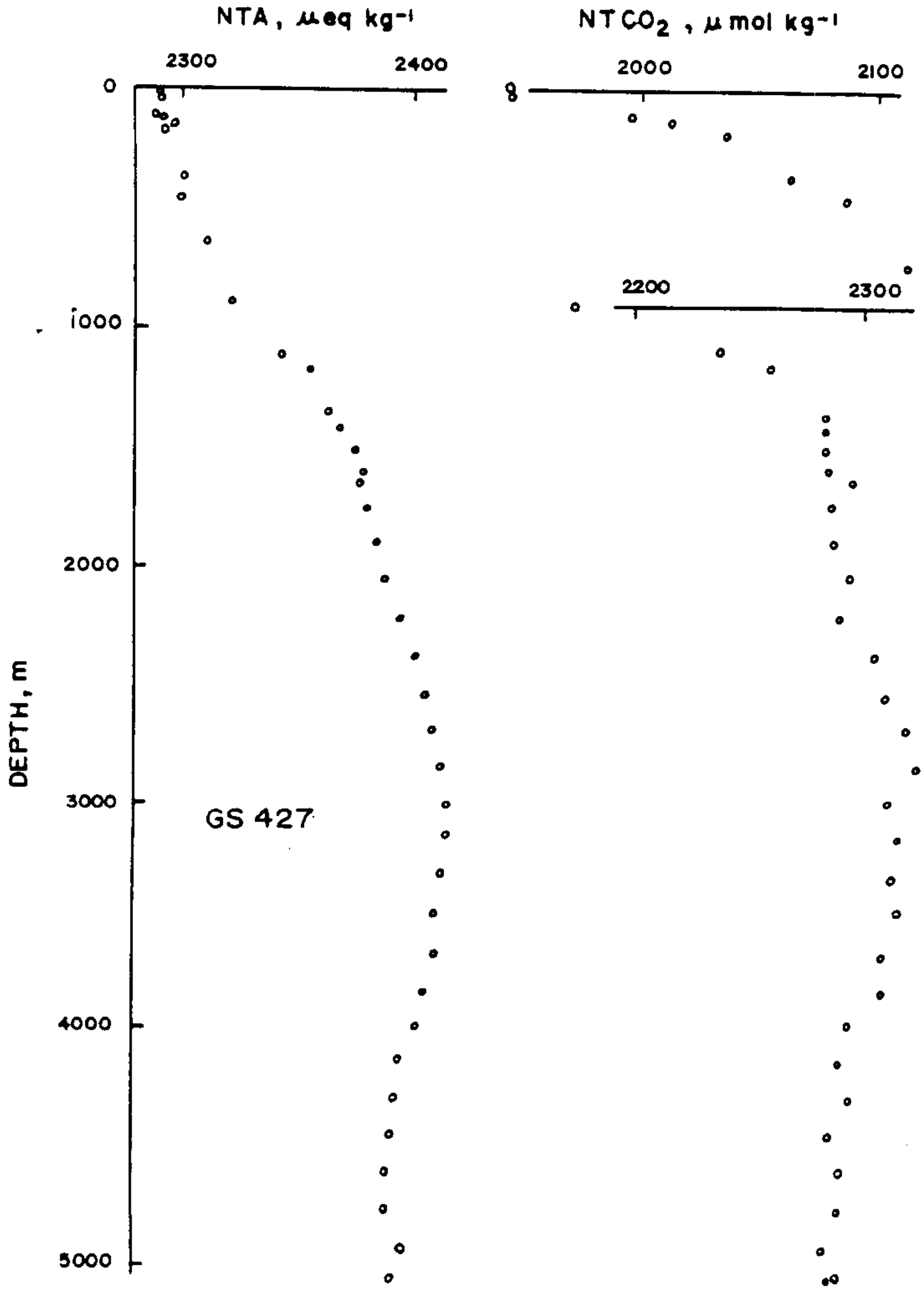

Fig. 21. Vertical profiles of NTA and $NTCO_2$ at GS 427 as measured during the GEOSECS Expedition.

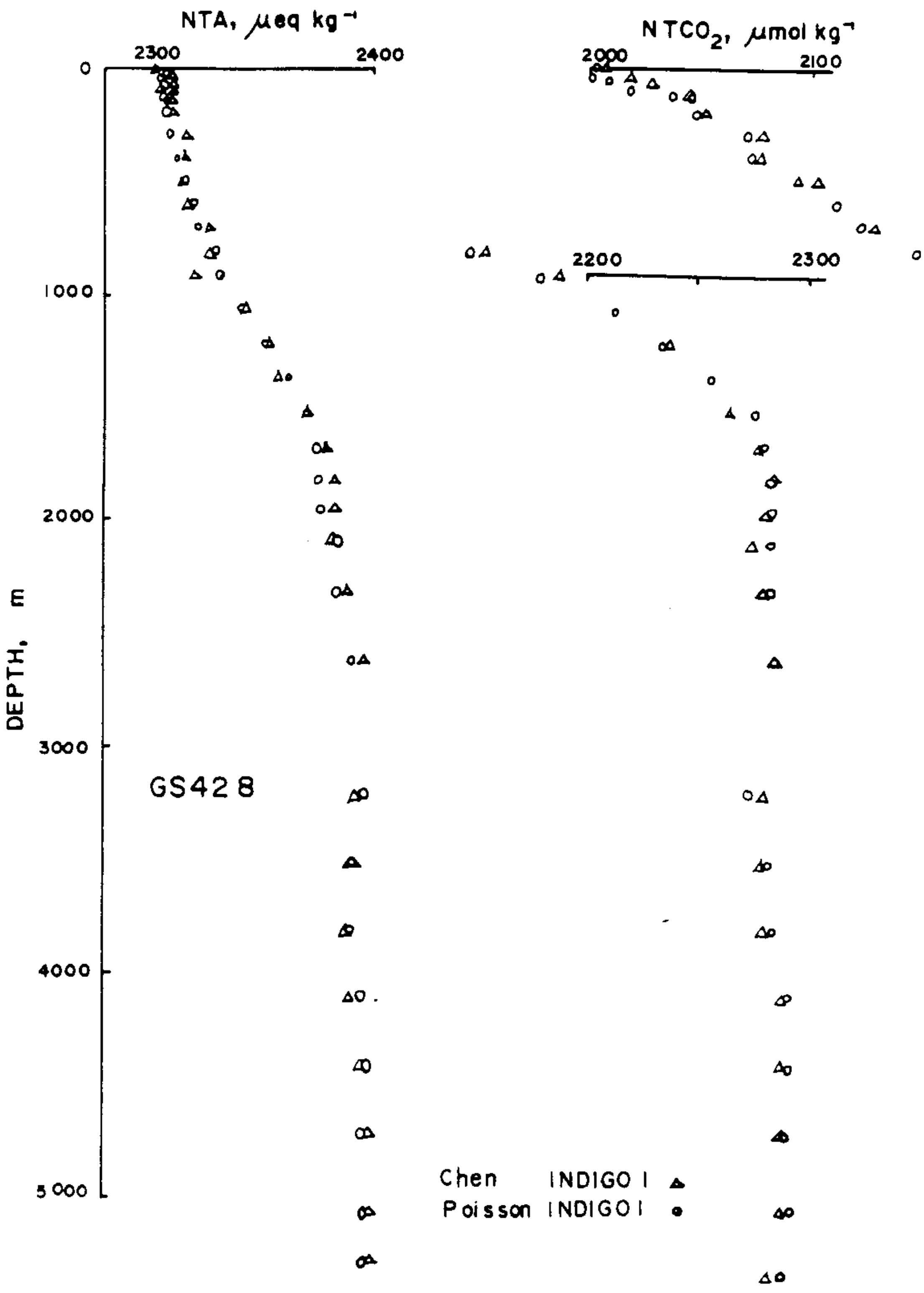

Fig. 22. Vertical profiles of NTA and $NTCO_2$ at GS 428. The triangles are Chen's data and the circles are Poisson's, both from INDIGO 1/ INDIVAT 3.

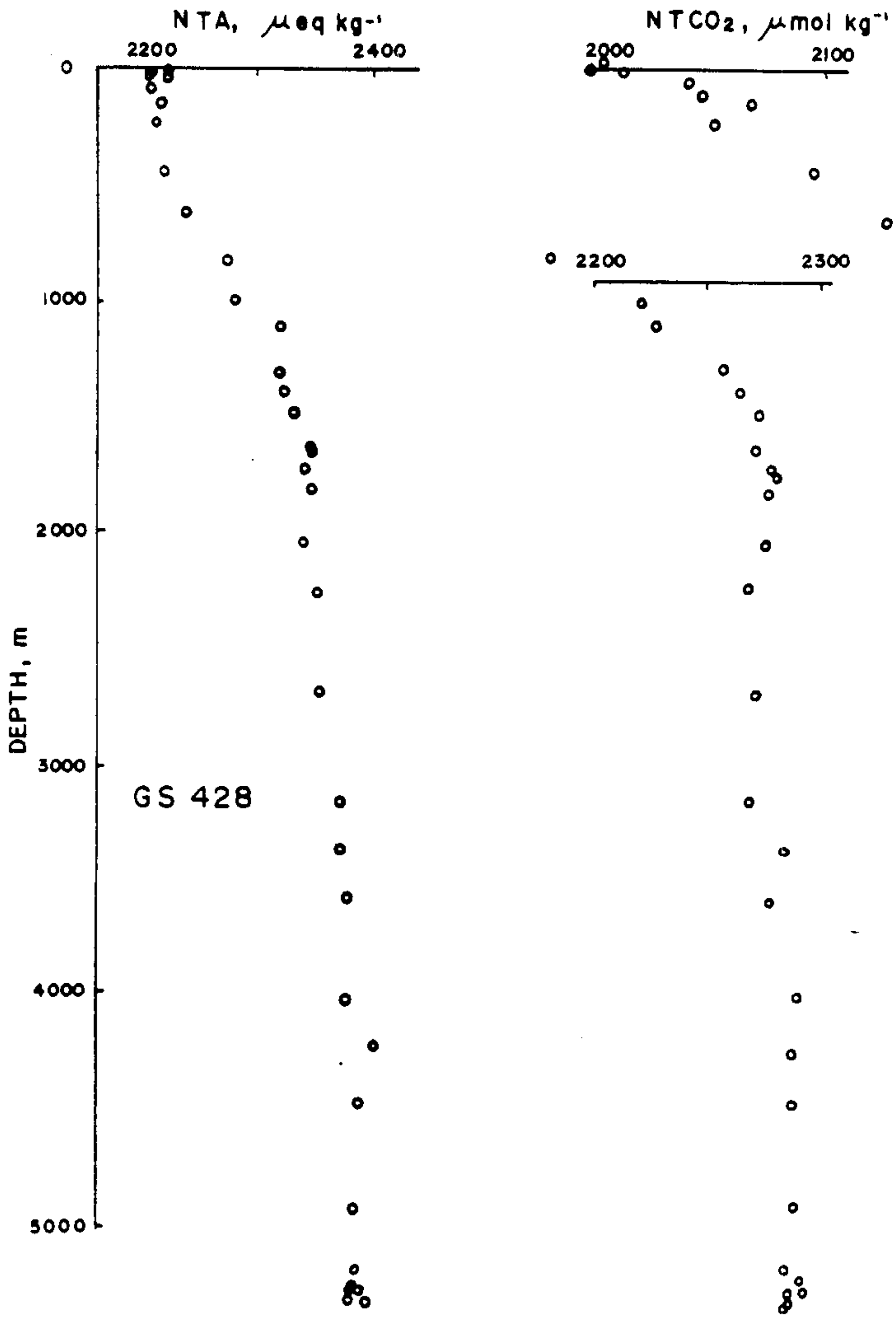

Fig. 23. Vertical profiles of NTA and $NTCO_2$ at GS 428 as measured during the GEOSECS Expedition.

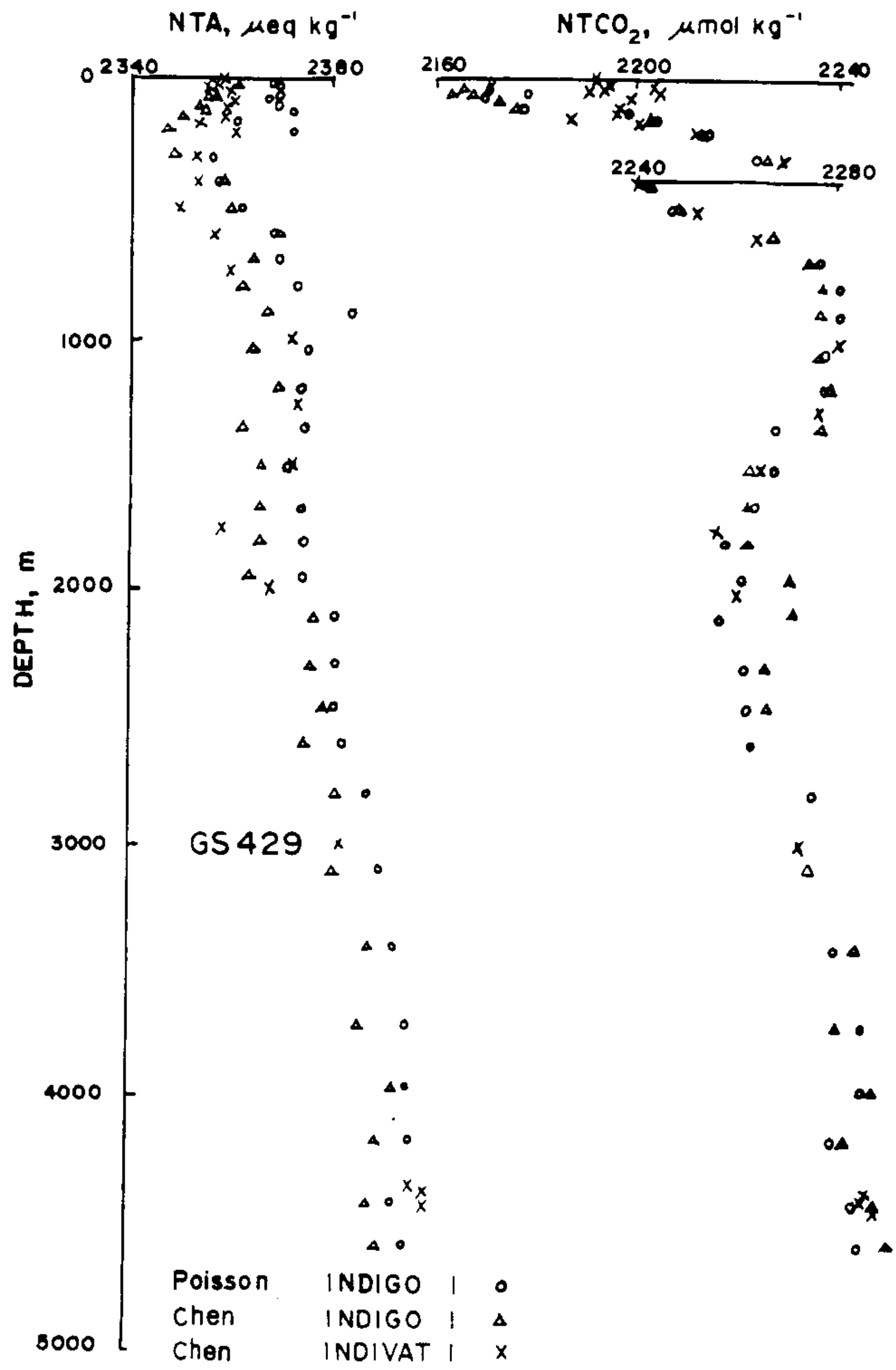

Fig. 24. Vertical profiles of NTA and $NTCO_2$ at GS 429. The crosses are Chen's data from INDIVAT 1. The triangles are Chen's data and the circles are Poisson's, both from INDIGO 1/INDIVAT 3.

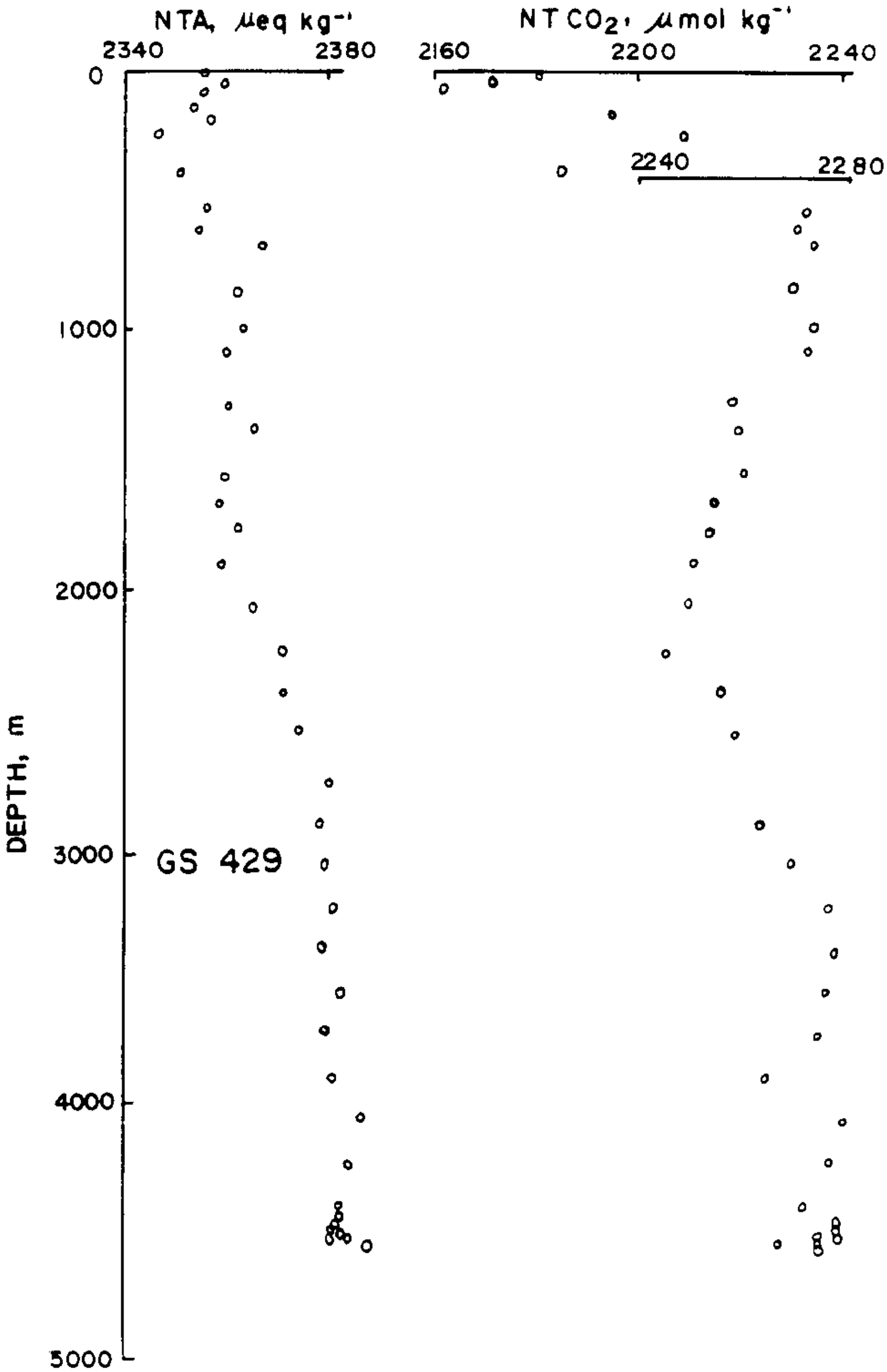

Fig. 25. Vertical profiles of NTA and $NTCO_2$ at GS 429 as measured during the GEOSECS Expedition.

REFERENCES

Bradshaw, A.L., P.G. Brewer, D.K. Shafer and R.T. Williams (1981). Measurements of total carbon dioxide and alkalinity by potentiometric titration in the GEOSECS program. Earth Planet. Sci. Lett. 55, 99-115.

Brewer, P.G., G.T.F. Wong, M.P. Bacon and D.W. Spencer (1975). An oceanic calcium problem? Earth Planet. Sci. Lett. 26, 81-87.

Broecker, W.S. and T.-H. Peng (1982). Tracers in the sea. Eldigio Press, 690 pp.

Chen, C.T. (1982a). Oceanic penetration of excess CO_2 in a cross-section between Alaska and Hawaii. Geophysical Research Letters 9, 117-119.

Chen, C.T. (1982b). On the distribution of anthropogenic CO_2 in the Atlantic and Southern Oceans. Deep-Sea Res. 29, 563-580.

Chen, C.T. (1984). Carbonate chemistry of the Weddell Sea, DOE technical report, DOE/EV/10611-4, 118 pp.

Chen, C.T. and F.J. Millero (1979). Gradual increase of oceanic carbon dioxide. Nature 277, 205-206.

Chen, C.T. and R.M. Pytkowicz (1979). On the total CO_2-titration alkalinity-oxygen system in the Pacific Ocean. Nature 281, 362-365.

Chen, C.T., R.M. Pytkowicz and E.J. Olson (1982a). Evaluation of the calcium problem in the South Pacific. Geochemical Journal 16, 1-10.

Chen, C.T., F.J. Millero and R.M. Pytkowicz (1982b). Comment on 'calculating the oceanic CO_2 increase: a need for caution' by A.M. Shiller. J. Geophys. Res. 87, 2083-2085.

Chen, C.T. and A. Poisson (1984). Excess carbon dioxide in the Weddell Sea. Antarctic Journal 1984 Review, 74-75.

Chen, C.T. and M.R. Rodman (1985). Use of acid balance value to trace water-mass tracer in the Weddell Sea. Antarctic Journal, in press.

Chen, C.T. and A. Poisson (1986). Indian Ocean gas study. EOS Oceanography Report, in press.

Dyrssen, D. (1977). The chemistry of plankton production and decomposition in seawater, in Oceanic Sound Scattering Production, N.R. Andersen and B.J. Zahuranec, eds., Plenum Press, N.Y., pp. 65-84.

Edmond, J.M. (1974). On the dissolution of carbonate and silicate in the deep ocean. Deep-Sea Res. 21, 455-480.

Jacobs, S.S. and D.T. Georgi (1977). Observations on the southwest Indian/Antarctic Ocean, in A Voyage of Discovery: George Deacon 70th Anni. Vol. 24, M. Angel, ed., Supplement to Deep-Sea Res., 43-84.

Johnson, K.S. and R.L. Petty (1983). Determination of nitrate and nitrite in seawater by flow injection analysis. Limnol. Oceanogr. 28, 1260-1266.

Poisson, A. and C.T. Chen (1985). Why is there little excess CO_2 in the Antarctic Bottom Water?, in preparation.

Weiss, R.F., W.S. Broecker, H. Craig and D. Spencer (1983). GEOSECS Indian Ocean Expedition, V. 5., Hydrographic Data 1977-1978. U.S. Government Printing Office, Washington, D.C., 48 pp.

Appendix I: INDIVAT 1 Data*

*Temperature and salinity data in parentheses are values estimated from the shipboard thermosalinograph

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
7.5 1140	27°04'S 56°59'E	20.92	(35.52)	8.222	-	-
7.5 1430	27°04'S 56°59'E	21.2	(35.51)	8.252	-	-
7.6 0830	30°50'S 55°50'E	20.18	(35.42)	8.243	2322	-
7.6 1000	31°00'S 55°48'E	19.2	(35.46)	8.224	2335	2009
7.6 1130	31°20'S 55°42'E	18.18	(35.56)	8.202	2335	-
7.6 1310	31°42'S 55°35'E	18.25	(35.57)	8.192	2342	2028
7.6 1400	31°53'S 55°29'E	18.45	35.602	8.192	2335	-
7.6 1430	32°02'S 55°28'E	18.4	(35.60)	8.191	-	-
7.6 1600	32°19'S 55°19'E	18.6	35.581	8.200	2343	2027
7.6 1800	32°43'S 55°10'E	18.83	(35.58)	8.201	2345	-
7.6 1810	32°47'S 55°09'E	18.85	35.59	8.200	-	-
7.6 2000	33°09'S 55°00'E	18.64	(35.57)	8.187	-	-
7.6 2030	33°19'S 54°57'E	18.68	(35.56)	8.193	-	-
7.6 2200	33°36'S 54°51'E	18.70	35.563	8.196	2335	-
7.6 2230	33°42'S 54°49'E	18.45	(35.57)	8.183	-	-
7.6 2330	33°57'S 55°45'E	17.4	(35.55)	8.189	2340	-

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
7.7 0100	34°14'S 54°38'E	17.55	35.550	8.195	2341	-
7.7 0300	34°41'S 54°32'E	17.68	35.571	8.208	2343	2028
7.7 0320	34°40'S 54°32'E	17.5	(35.56)	8.204	2348	2026
7.7 0500	35°00'S 54°27'E	17.20	35.555	8.192	2342	2042
7.7 0600	35°15'S 54°22'E	17.08	(35.58)	8.183	2347	2038
7.7 0700	35°24'S 54°18'E	16.60	35.573	8.185	2341	-
7.7 0900	35°49'S 54°09'E	16.58	35.560	8.182	2343	2042
7.7 0912	35°51'S 54°09'E	16.60	(35.58)	8.181	-	-
7.7 1030	36°01'S 54°05'E	16.62	(35.58)	8.184	-	-
7.7 1100	36°04'S 54°04'E	16.64	35.580	8.183	2340	-
7.7 1200	35°15'S 54°00'E	16.85	35.591	8.182	2340	2047
7.7 1320	36°33'S 53°54'E	16.9	(35.59)	8.184	-	-
7.7 1400	36°41'S 53°52'E	16.90	35.594	8.193	2348	2033
7.7 1540	37°01'S 53°40'E	16.88	(35.59)	8.180	-	-
7.7 1600	27°05'S 53°40'E	16.90	35.589	8.186	2338	2041
7.7 1800	37°30'S 53°32'E	16.92	35.594	8.187	2349	2033

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
7.7 1830	37°39'S 53°29'E	16.9	(35.59)	8.186	-	-
7.7 2000	37°54'S 53°24'E	16.71	35.586	8.178	2343	-
7.7 2030	38°03'S 53°21'E	16.77	(35.59)	8.184	-	-
7.7 2200	38°23'S 53°14'E	16.63	(35.59)	8.178	2339	2041
7.7 2400	38°49'S 53°05'E	16.77	35.594	8.169	2345	2032
7.8 0200	39°12'S 52°56'E	17.01	35.591	8.171	2349	2046
7.8 0300	39°31'S 52°55'E	16.2	35.59	8.153	2349	2039
7.8 0400	39°43'S 52°53'E	15.2	(35.40)	8.134	2330	-
7.8 0500	39°57'S 52°47'E	13.1	(35.03)	8.112	2314	2058
7.8 0600	40°09'S 52°40'E	10.20	34.153	8.056	2291	2058
7.8 0800	40°32'S 52°29'E	9.00	33.937	8.022	2277	2072
7.8 0840	40°43'S 52°25'E	9.35	(33.93)	8.024	-	-
7.8 1000	40°59'S 52°18'E	9.55	33.930	8.023	2280	-
7.8 1100	41°13'S 52°12'E	10.1	(34.26)	8.035	-	-
7.8 1130	41°19'S 52°10'E	10.5	(34.37)	8.047	2292	2062
7.8 1200	41°25'S 52°07'E	10.90	34.26	8.059	2295	2065

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
7.8 1400	41°51.7'S 51°56.7'E	9.70	34.293	8.052	2297	2076
7.8 1510	42°03'S 51°41'E	10.6	(34.45)	8.064	-	-
7.8 1535	42°08'S 51°39'E	11.1	(34.46)	8.051	2307	2095
7.8 1600	42°12'S 51°37'E	11.40	34.477	8.078	2301	2067
7.8 1800	42°38'S 51°31'E	10.38	(34.14)	8.048	2286	2054
7.8 2000	43°05'S 51°24'E	6.65	33.839	7.974	2288	2089
7.8 2040	43°15'S 51°20'E	6.6	(33.73)	7.974	2284	2086
7.8 2130	43°26'S 51°16'E	6.8	(33.73)	7.971	-	-
7.8 2200	43°32'S 51°13'E	6.66	33.620	7.973	2269	2086
7.8 2400	43°58'S 51°02'E	6.85	33.714	7.953	-	-
7.9 0200	44°25'S 50°50'E	6.12	33.735	7.964	2275	2092
7.9 0320	44°45'S 50°44'E	5.03	(33.80)	7.940	-	-
7.9 0400	44°53'S 50°42'E	4.88	33.74	7.948	2285	2117
7.9 0535	45°18'S 50°33'E	4.71	(33.80)	7.920	-	-
7.9 0600	45°21'S 50°31'E	4.70	33.850	7.923	2285	2108
7.9 0800	45°48'S 50°20'E	4.98	33.807	7.902	2286	2117

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
7.9 1000	45°50'S 50°35'E	5.00	33.780	7.898	2280	2115
7.9 1200	45°03'S 50°51'E	4.9	(33.77)	7.908	2288	2098
7.9 1315	46°11'S 51°05'E	4.75	(33.76)	7.915	-	-
7.9 1440	46°16'S 51°34'E	4.2	(33.78)	7.904	2292	2022
7.9 1600	46°23'S 51°55'E	4.27	(33.78)	7.912	2281	2120
7.11 0800	46°29'S 51°49'E	4.16	(33.86)	-	2294	2135
7.11 1040	46°26'S 51°55'E	4.20	(33.86)	-	2290	2139
7.13 1000	46°55'S 52°40'E	3.68	(33.85)	7.924	2294	2137
7.13 1100	46°55'S 52°20'E	3.68	(33.86)	7.931	2297	2133
7.13 1200	46°55'S 52°20'E	3.68	(33.86)	7.934	2293	2135
7.13 1310	46°56'S 52°20'E	3.8	(33.84)	7.919	2293	2133
7.13 1400	46°55'S 52°20'E	3.51	(33.83)	7.933	2285	2135
7.13 1500	46°57'S 52°14'E	3.6	(33.80)	7.913	2285	-
7.13 1700	46°57'S 52°14'E	3.5	(33.80)	7.918	-	-
7.16 1800	46°39'S 52°20'E	3.98	(33.827)	7.944	2284	2135
7.16 2000	46°48'S 52°37'E	3.62	33.845	7.938	2295	2142

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
7.16 2200	47°01'S 52°54'E	3.90	33.794	7.938	2288	2141
7.16 2400	47°12'S 53°13'E	3.70	33.819	7.935	2295	2139
7.17 0200	47°19'S 53°05'E	3.65	33.816	7.938	2292	2145
7.17 0300	47°26'S 52°57'E	3.95	(33.81)	7.954	-	-
7.17 0400	47°30'S 53°02'E	3.65	33.814	7.943	2289	2132
7.17 0510	47°39'S 53°15'E	4.0	(33.79)	7.941	-	-
7.17 0600	47°44'S 53°23'E	3.85	33.796	7.937	2291	2137
7.17 0800	47°56'S 53°40'E	3.85	33.801	7.928	2292	2117
7.17 0900	47°57'S 53°41'E	3.8	(33.80)	7.930	-	-
7.17 1000	47°58'S 53°41'E	3.75	(33.81)	7.921	-	-
7.17 1100	47°58'S 53°41'E	3.75	(33.82)	7.914	-	-
7.17 1200	47°58'S 53°42'E	3.75	(33.82)	7.926	-	-
7.17 1300	47°58'S 53°41'E	3.76	(33.82)	7.925	-	-
7.17 1400	47°57'S 53°43'E	3.90	(33.82)	7.930	-	-
7.17 1500	47°57'S 53°42'E	3.94	(33.83)	7.916	-	-
7.17 1600	47°58'S 53°42'E	3.96	(33.83)	7.920	-	-

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.17 1700	47°59'S 53°43'E	3.99	(33.83)	7.914	-	-	
7.17 1800	48°03'S 53°50'E	3.92	33.796	7.932	2284	2132	
7.17 2000	48°11'S 54°05'E	3.67	33.814	7.922	2294	2145	
7.17 2200	48°23'S 54°22'E	3.99	33.785	7.931	2285	-	
7.17 2400	48°33'S 54°38'E	4.00	33.801	7.939	2285	-	
7.18 0200	48°44'S 54°53'E	4.05	33.802	7.942	2281	2124	
7.18 0400	48°54'S 54°49'E	3.72	33.804	7.937	2289	2135	
7.18 0500	48°57'S 54°48'E	3.8	(33.80)	7.938	-	-	
7.18 0600	48°59'S 54°39'E	3.93	33.803	7.936	2288	2132	
7.18 0800	49°03'S 54°32'E	3.76	33.803	7.934	2290	2135	
7.18 1800	49°02'S 54°29'E	3.79	33.803	7.931	2290	2135	24.7
7.18 2000	48°49'S 54°59'E	4.20	33.803	7.923	2287	2147	
7.18 2200	48°32'S 55°30'E	4.90	33.787	7.942	2284	2120	
7.18 2400	48°20'S 58°07'E	4.85	(33.786)	7.946	2284	2121	24.7
7.19 0200	48°07'S 56°33'E	4.80	33.785	7.946	2289	2119	
7.19 0400	47°56'S 57°07'E	4.61	33.790	7.943	2290	2127	

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.19 0500	47°48'S 57°25'E	4.51	(33.80)	7.940	-	-	
7.19 0600	47°44'S 57°39'E	4.51	33.797	7.938	2285	2128	
7.19 1800	47°47'S 58°29'E	5.07	33.805	7.926	2282	2117	
7.19 2000	47°54'S 59°02'E	5.15	33.769	7.935	2285	-	24.5
7.19 2200	48°03'S 59°43'E	5.12	33.773	7.935	2285	-	25.9
7.19 2400	48°09'S 60°21'E	4.95	33.788	7.938	2279	2106	25.0
7.20 0200	48°18'S 60°59'E	5.05	33.787	7.940	2281	2118	
7.20 0400	48°25'S 61°40'E	3.42	(33.81)	7.918	2289	2139	
7.20 0455	48°30'S 62°01'E	3.40	(33.80)	7.924	-	-	26.4
7.20 0600	48°34'S 62°21'E	3.20	33.836	7.904	2297	2139	
7.20 0635	48°37'S 62°33'E	3.05	(33.84)	7.909	2295	2144	
7.20 0800	48°42'S 63°01'E	3.10	33.846	7.907	2297	-	26.9
7.20 0925	48°48'S 63°29'E	2.96	(33.84)	7.898	-	-	
7.20 1000	48°51'S 63°40'E	2.9	33.866	7.902	2290	-	
7.20 1110	48°56'S 64°55'E	2.7	(33.85)	7.895	-	-	27.6
7.20 1200	48°59'S 64°20'E	2.66	33.861	7.895	2289	2148	-

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.20 1400	49°07'S 65°06'E	2.80	33.850	7.900	2292	2140	27.0
7.20 1535	49°13'S 65°36'E	2.8	(33.86)	7.904	-	-	-
7.20 1600	49°14'S 65°42'E	2.80	(33.870)	7.905	2302	-	23.1
7.20 1800	49°23'S 66°22'E	3.10	33.836	7.911	2291	2149	24.5
7.20 2000	49°31'S 67°02'E	2.70	33.832	7.918	2297	-	25.4
7.20 2200	49°39'S 67°44'E	2.60	33.851	7.914	2301	2146	-
7.20 2220	49°40'S 67°51'E	2.42	(33.85)	7.913	-	-	-
7.20 2400	49°46'S 68°19'E	2.53	(33.86)	7.914	2290	2146	26.5
7.21 0200	49°51'S 68°59'E	2.58	33.839	7.917	2296	-	26.1
7.21 0400	49°48'S 69°37'E	2.80	33.767	7.915	2288	2146	25.4
7.21 0500	49°46'S 70°02'E	2.80	(33.63)	7.915	-	-	25.6
7.21 0600	49°38'S 70°21'E	2.80	33.653	7.918	2286	2136	25.6
7.23 1800	49°25'S 70°36'E	2.68	33.544	7.878	2273	2135	25.1
7.23 2000	48°58'S 70°53'E	2.65	33.806	7.894	2290	2151	25.2
7.23 2055	48°47'S 71°01'E	(2.20)	(33.92)	7.885	-	-	25.3
7.23 2145	48°34'S 71°08'E	(2.20)	(33.93)	7.882	-	-	25.7

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.23 2200	48°34'S 71°09'E	2.20	33.926	7.883	2301	2160	26.0
7.23 2220	48°35'S 71°09'E	(2.20)	(33.93)	7.880	-	-	26.2
7.23 2310	48°23'S 71°16'E	(2.20)	(33.93)	7.879	2300	2158	26.1
7.23 2400	48°10'S 71°24'E	2.20	33.933	7.885	2300	2165	25.9
7.24 0200	47°42'S 71°42'E	2.40	33.884	7.883	2303	2160	
7.24 0400	47°20'S 71°56'E	2.33	33.915	7.884	2304	2161	23.0
7.24 0500	47°07'S 72°05'S	(2.7)	(33.83)	7.894	-	-	25.1
7.24 0600	46°54'S 72°12'E	4.31	33.786	7.910	2292	2141	23.6
7.24 0800	46°30'S 72°29'E	4.13	33.791	7.904	2292	2137	23.8
7.24 0900	46°17'S 72°38'E	4.45	33.764	7.907	2292	2135	23.8
7.24 1000	46°05'S 72°45'E	4.90	33.821	7.917	2287	2131	23.3
7.24 1100	45°53'S 72°53'E	4.90	33.834	7.926	2284	-	22.1
7.24 1200	45°42'S 72°57'E	4.90	33.827	7.915	2293	2136	22.4
7.24 1300	45°27'S 73°04'E	4.46	33.786	7.911	2297	2141	23.0
7.24 1400	45°14'S 73°13'E	4.45	(33.786)	7.912	2293	-	22.8
7.24 1500	45°04'S 73°24'E	6.00	33.872	7.938	2294	2122	20.2

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg	NO_3 µmol/kg
7.24 1600	44°54'S 73°31'E	10.60	34.590	8.037	2308	2098	10.1
7.24 1700	44°41'S 73°42'E	11.00	34.625	8.051	2304	2087	9.7
7.24 1800	44°30'S 78°49'E	11.30	34.697	8.051	2313	2090	9.8
7.24 1900	44°19'S 73°56'E	(10.0)	34.556	8.041	2312	2104	11.7
7.24 2000	44°05'S 74°02'E	8.30	34.30	8.005	2313	-	16.9
7.24 2100	43°53'S 74°07'E	(7.8)	34.200	8.016	2301	2106	15.6
7.24 2200	43°41'S 74°14'E	8.20	34.194	8.015	2298	2125	16.2
7.24 2300	43°30'S 74°20'E	8.40	34.241	8.025	2307	-	16.5
7.24 2400	43°18'S 74°31'E	(11.0)	34.690	8.059	2308	2081	11.5
7.25 0100	43°07'S 74°35'E	10.55	34.639	8.055	-	-	11.9
7.25 0200	42°57'S 74°43'E	11.60	34.735	8.064	2320	2093	10.1
7.25 0300	42°44'S 74°53'E	12.80	35.120	8.092	2340	2109	6.8
7.25 0400	42°33'S 75°00'E	13.12	35.214	8.102	2332	2081	5.9
7.25 0500	42°21'S 75°08'E	12.43	35.081	8.090	2321	2089	7.2
7.25 0600	42°10'S 75°14'E	12.45	35.081	8.093	2325	2099	
7.25 0700	41°58'S 75°20'E	12.03	34.968	8.086	2317	-	9.4

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg	NO_3 µmol/kg
7.25 0800	41°48'S 75°25'E	12.15	34.996	8.092	2335	2093	7.9
7.25 0900		12.23	35.039	8.092	2325	-	7.3
7.25 1000	41°30'S 75°35'E	12.30	35.044	8.088	2324	-	6.9
7.25 1100	41°20'S 75°41'E	12.25	35.050	8.091	2325	-	7.1
7.25 1200	41°10'S 75°47'E	12.70	35.060	8.089	2338	2104	7.2
7.25 1300	40°59'S 75°56'E	13.00	35.184	8.101	2338	2101	6.3
7.25 1400	40°47'S 76°02'E	13.15	35.207	8.108	2342	2102	5.5
7.25 1500	40°35'S 76°08'E	13.05	35.209	8.104	2340	2092	5.9
7.25 1600	40°25'S 76°14'E	12.50	35.122	8.098	2341	2095	5.9
7.25 1700	40°13'S 76°19'E	12.70	35.150	8.096	2329	-	6.5
7.25 1800	40°02'S 76°24'E	12.85	35.137	8.092	2333	-	5.6
7.25 1900	39°51'S 76°29'E	12.25	35.038	8.086	2327	2087	7.0
7.25 2000	39°40'S 76°34'E	12.25	35.040	8.091	2334	2092	6.6
7.25 2100	39°25'S 76°40'E	12.30	35.047	8.093	2322	-	6.4
7.25 2200	39°18'S 76°44'E	12.31	35.044	8.091	2322	2101	7.2
7.25 2300	39°07'S 76°49'E	12.40	35.111	8.069	2338	2089	7.8

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.25 2400	38°55'S 76°55'E	12.39	35.024	8.068	2338	2094	7.0
7.26 0100	38°43'S 77°04'E	13.00	(35.13)	8.076	2335	2094	7.7
7.26 0200	38°33'S 77°10'E	13.05	35.135	8.081	2336	2104	5.9
7.26 0300	38°23'S 77°17'E	13.00	35.139	8.084	2340	2094	6.3
7.26 0400	38°11'S 77°25'E	13.28	35.163	8.089	2329	2079	6.4
7.26 0500	38°01'S 77°33'E	13.26	35.169	8.093	2325	2079	5.9
7.26 0600	37°48'S 77°34'E	13.28	35.163	8.094	2335	2084	6.4
7.29 0800	37°40'S 77°27'E	13.27	35.212	8.117	2325	2086	5.7
7.29 0900	37°35'S 77°21'E	13.10	35.212	8.123	2333	2088	5.4
7.29 1000	37°28'S 77°11'E	13.10	35.124	8.116	2331	2085	5.9
7.29 1100	37°19'S 77°00'E	13.25	35.159	8.115	2338	-	6.2
7.29 1300	37°05'S 76°34'E	13.70	35.204	8.114	2336	2084	5.7
7.29 1400	36°57'S 76°22'E	13.30	(35.18)	8.112	2328	2078	4.7
7.29 1500	36°47'S 76°10'E	13.13	(35.25)	8.116	2333	2087	4.3
7.29 1600	36°39'S 76°00'E	13.80	35.286	8.119	2336	2097	5.0
7.29 1700	36°31'S 75°50'E	13.90	35.305	8.128	2339	2075	4.9

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.29 1800	36°22'S 75°38'E	13.90	(35.30)	8.128	2338	-	5.7
7.29 1900	36°15'S 75°28'E	13.72	35.255	8.116	2336	-	4.5
7.29 2000	36°07'S 75°17'E	13.72	35.266	8.124	2340	2082	4.9
7.29 2100	35°58'S 75°05'E	13.81	35.293	8.124	2334	2075	4.8
7.29 2200	35°49'S 74°52'E	14.05	35.324	8.134	-	-	3.8
7.29 2300	35°40'S 74°48'E	14.05	(35.32)	8.132	2330	2071	2.9
7.30 0000	35°32'S 74°29'E	14.15	35.346	8.126	2336	-	2.8
7.30 0100	35°25'S 74°19'E	14.10	(35.33)	8.126	2341	2074	4.5
7.30 0200	35°16'S 74°07'E	13.88	35.293	8.121	2337	-	4.5
7.30 0300	35°07'S 73°55'E	13.75	(35.29)	8.119	2333	2080	4.2
7.30 0400	34°58'S 73°45'E	13.89	35.282	8.120	2336	-	3.7
7.30 0500	34°48'S 73°32'E	13.90	(35.30)	8.122	2339	2076	4.7
7.30 0600	34°40'S 73°21'E	13.90	35.321	8.122	2337	-	4.1
7.30 0700	34°31'S 73°10'E	13.91	(35.32)	8.123	2343	2083	4.2
7.30 0800	34°22'S 72°59'E	14.05	35.321	8.126	2334	2086	4.3
7.30 0900	34°12'S 72°46'E	14.05	(35.26)	8.125	2336	-	4.3

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.30 1000	34°03'S 72°34'E	14.20	(35.29)	8.128	2337	2081	3.9
7.30 1025	33°58'S 72°28'E	(14.85)	(35.37)	8.134	-	-	1.5
7.30 1100	33°53'S 72°21'E	14.85	(35.28)	8.143	2337	2072	3.7
7.30 1200	33°45'S 72°09'E	15.00	35.422	8.145	2338	-	1.7
7.30 1300	33°35'S 71°57'E	15.75	(35.53)	8.164	2349	2066	0.8
7.30 1400	33°25'S 71°44'E	16.35	(35.64)	8.165	2356	-	1.1
7.30 1500	33°16'S 71°32'E	16.20	(35.65)	8.172	2351	-	1.7
7.30 1600	33°09'S 71°21'E	15.05	35.390	8.156	2338	2065	1.2
7.30 1700	33°00'S 71°10'E	16.25	(35.60)	8.170	2350	2061	0.9
7.30 1800	33°50'S 70°56'E	16.25	35.622	8.169	2355	2063	0.7
7.30 1900	32°42'S 70°44'E	15.50	35.572	8.164	2354	2074	0.7
7.30 2000	32°32'S 70°32'E	16.35	35.612	8.170	2351	-	1.1
7.30 2100	32°23'S 70°21'E	16.10	35.625	8.168	2356	2063	1.0
7.30 2200	32°13'S 70°08'E	15.85	35.422	8.168	2349	-	0.9
7.30 2300	32°04'S 69°56'E	15.90	35.522	8.167	2351	-	0.9
7.31 0000	31°53'S 69°41'E	16.17	35.578	8.166	2358	-	1.7

Time	Location	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg	NO_3 μmol/kg
7.31 0100	31°58'S 69°19'E	16.17	35.585	8.170	2347	2056	1.6
7.31 0200	31°27'S 69°07'E	15.90	35.566	8.165	2341	-	1.4
7.31 0300	31°17'S 68°55'E	16.50	35.591	8.176	2352	2061	1.3
7.31 0400	31°08'S 68°43'E	16.75	35.677	8.167	2357	-	1.0
7.31 0500	30°58'S 68°30'E	17.40	35.740	8.183	2352	2056	1.7
7.31 0600	30°50'S 68°18'E	16.99	35.711	8.182	2354	2070	
7.31 0700	30°40'S 68°06'E	17.29	35.677	8.183	2355	2064	
7.31 0800	30°30'S 67°56'E	17.55	35.662	8.191	2357	2053	
7.31 0900	38°18'S 67°49'E	17.95	35.717	8.189	2360	2063	
7.31 1000	30°04'S 67°42'E	18.00	35.840	8.198	2361	-	
7.31 1200	29°45'S 67°35'E	17.95	35.808	8.193	2368	2055	
7.31 1300	29°35'S 67°30'E	18.18	35.840	8.194	2358	2054	
7.31 1400	29°25'S 67°25'E	18.60	35.866	8.202	2359	2063	
7.31 1500	29°16'S 67°20'E	18.58	35.868	8.201	2364	-	
7.31 1600	29°07'S 67°14'E	18.80	35.822	8.206	2359	2059	
7.31 1700	28°56'S 67°08'E	18.65	35.825	8.206	2362	2055	

Time	Location	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
7.31 1800	28°46'S 67°02'E	18.60	35.847	8.202	2367	2061
7.31 1900	28°36'S 66°58'E	18.58	35.838	8.201	2358	2054
7.31 2000	28°26'S 66°53'E	18.51	35.817	8.199	2357	2059
7.31 2100	28°15'S 66°48'E	18.20	35.780	8.194	2353	2056

GS 427 7.5.84 27°S, 57°E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
10	20.7	33.34	8.237	2329	1978
20	20.7	35. ?	8.232	2329	1980
100	19.01	35.567	8.149	2340	2035
250	14.0	35.369	8.068	2325	2075
400	12.6	35.203	8.038	2320	2080
600	10.7	34.931	7.989	2311	2095
800	8.79	34.653	7.905	2308	2127
1000	5.40	34.455	7.808	2300	2204
1400	3.20	34.526	7.719	2339	-
1800	2.40	34.662	7.732	2359	-
2000	2.64	34.687	7.736	2371	-
3400	1.40	-	7.754	2400	2284
3400	1.40	34.729	7.754	2398	-
3400	1.40	34.728	7.754	-	-
3400	1.40	34.729	7.754	-	-
3400	1.40	34.732	7.751	-	-
3400	1.40	34.728	7.752	-	-
3400	1.40	34.725	7.753	-	-
3400	1.40	34.719	7.750	-	-
3400	1.40	34.724	7.748	-	-
3400	1.40	34.713	7.748	-	-
3400	1.40	34.721	7.747	2400	-

GS 429 7.19.84 48°S, 55°E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg	NO_3 µmol/kg
0	4.57	33.800	7.928	2277	2117	24.5
10	4.57	33.830	7.929	2278	2122	24.5
20	4.57	33.793	7.923	2275	2119	24.0
30	4.57	33.796	7.928	2279	2115	24.2
40	4.57	33.789	7.925	2277	2128	24.6
50	4.57	33.794	7.927	2277	2129	23.8
70	4.57	33.794	7.929	2279	2123	24.0
100	4.57	33.796	7.933	2277	2121	23.8
125	4.55	33.800	7.934	2276	2120	24.0
150	4.50	33.804	7.932	2277	2111	24.4
175	4.00	33.855	7.911	2277	2128	26.4
200	3.57	33.869	7.908	2284	2140	26.9
250	-	-	7.926	-	-	28.1
300	2.80	34.046	7.837	2289	2168	29.4
400	2.70	34.110	7.818	2293	2183	31.2
500	2.39	34.227	7.776	2298	2202	32.5
600	2.57	34.269	7.748	2307	2216	33.9
750	2.42	34.470	7.703	2323	-	36.1
1000	2.39	34.620	7.715	2346	2255	34.2
1250	2.38	34.702	7.735	2353	2256	31.6
1500	2.32	34.705	7.750	2352	2245	30.9
1750	2.25	34.781	7.765	2343	2242	30.3
2000	1.96	34.786	7.774	2353	2246	30.6
3000	1.10	34.746	7.759	2365	2258	31.6
4330	0.17	34.691	7.748	2366	2263	33.3
4360	0.16	34.689	7.751	2369	2262	33.2
4400	0.15	34.651	7.749	2366	2262	33.2

Appendix II: INDIGO 1 Data

G1 2.24.85 23.00S, 50.00E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
4*	26.13	35.01	8.247	2296	1969
2	25.88	35.014	8.239	2299	1958
33	25.85	35.016	8.239	2305	1965
54	23.12	35.416	8.233	2345	2010
73	22.59	35.418	8.223	2326	-
100	22.17	35.425	8.211	2321	-
125	21.91	35.467	8.196	2322	2019
149	21.39	35.527	8.177	2342	2034
199	19.65	35.596	8.140	2342	2057
299	16.32	35.539	8.091	2334	2082
400	13.85	35.327	8.042	2335	-
499	12.47	35.144	8.012	2322	-
597	11.43	35.008	7.997	2321	-
697	10.29	34.854	7.963	2314	2123
800	8.920	34.697	7.911	2301	2143
896	7.466	34.567	7.851	2298	2162
1050	5.21	34.470	7.762	2319	-
1200	4.16	34.500	7.724	2341	-
1351	3.63	34.593	7.703	2352	-
1499	3.10	34.624	7.715	2355	-
1600	2.92	34.650	7.719	2361	-
1804	2.59	34.696	7.730	2370	-
1947	2.48	34.714	7.729	2385	-
2099	2.36	34.727	7.723	2399	-
2300	2.23	34.737	7.725	2403	-
2501	2.14	34.739	7.728	2410	-
2702	2.03	34.742	7.727	2411	-
2898	1.94	34.740	7.726	2416	-

G1 2.24.85 23.00S, 50.00E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3006	1.85	34.734	7.729	-	-
3300	1.73	34.734	7.731	2398	-
3499	1.53	-	7.737	2403	-
3699	1.33	34.717	7.738	2388	-
3907	1.20	34.714	7.741	2389	-
4049	1.13	34.713	7.738	2391	-
4259	1.04	34.715	7.737	2388	-

* taken from underwater intake

G2 2.25.85 25.12S, 53.32E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
99	21.76	35.501	8.185	2331	2025
127	21.13	35.541	8.173	2333	2035
149	20.63	35.573	8.167	2337	-
149	20.63	35.568	8.163	2332	-
198	19.05	35.604	8.141	2338	-
300	15.86	35.494	8.077	2331	-
300	15.86	35.495	8.079	2337	2093
399	13.89	35.334	8.050	2330	-
399	13.89	35.334	8.047	2325	2092
485	12.56	35.152	8.017	2315	2092
575	11.70	35.035	8.008	2319	2106
575	11.70	35.034	8.006	2312	2102
1349	3.69	-	7.710	2348	-
1349	3.69	34.551	7.708	2345	-
1349	3.69	34.549	7.712	2336	-
1499	3.19	35.578	7.710	2347	-
1499	3.19	35.577	7.713	2346	-
1651	2.81	34.635	7.719	2355	-
1651	2.81	34.635	7.718	2361	-
1800	2.59	34.684	7.725	2361	-
1800	2.59	34.680	7.726	2365	-
1800	2.59	34.680	7.723	2364	-
1951	2.45	34.708	7.729	2387	-
2102	2.33	34.726	7.735	2376	-
2299	2.18	34.736	7.733	2391	-
2549	2.05	34.741	7.735	2395	-
2798	1.92	34.738	7.735	2404	-
3048	1.77	34.734	7.739	2402	-
3048	1.77	34.734	7.736	2402	-
3299	1.60	34.727	7.740	2399	-

G2 2.25.85 25.12S, 53.32E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3601	1.40	34.722	7.737	2392	-
3905	1.25	34.717	7.742	2390	-
4118	1.11	34.712	7.743	2383	-
4500	0.97	34.707	7.748	2367	-
4800	0.95	34.706	7.739	2382	-
4958	0.96	34.705	7.745	2366	-

G3 2.27.85 27.04S, 56.57E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
9	24.94	35.369	8.246	2327	1982
36	24.93	34.440	8.245	2321	-
36	24.93	35.374	8.246	2319	-
100	18.67	35.600	8.169	2337	-
124	17.68	35.623	8.115	2344	-
148	16.94	35.588	8.110	2343	-
199	15.82	35.525	8.089	2335	-
300	14.33	35.376	8.060	2336	2099
402	13.37	35.257	8.037	2324	-
500	12.39	35.119	8.012	2315	-
623	10.86	34.911	7.973	2312	2125
699	10.41	34.859	7.962	2307	2127
802	9.19	34.723	7.918	2308	2139
903	7.43	34.556	7.858	2311	2164
1047	5.54	34.448	7.790	2309	2195
1191	4.35	34.440	7.747	2324	-
1349	3.65	34.509	7.720	2341	-
1500	3.09	34.581	7.708	2352	-
1648	2.81	34.623	7.713	2355	-
1801	2.56	34.664	7.722	2366	-
1943	2.38	34.722	7.726	2374	2277
2100	2.28	34.720	7.732	2373	-
1948	2.40	34.697	7.731	2369	-
2147	2.27	34.724	7.752	2377	-
2342	2.18	34.744	7.753	2382	2078
2599	1.98	34.745	7.743	2391	-
2858	1.81	34.738	7.737	2404	-
3095	1.68	34.736	7.747	2398	2303
3498	1.42	34.723	7.741	2395	2304
3949	1.20	34.717	7.744	2385	-

G3 2.27.85 27.04S, 56.57E (continued)

Depth	T	S	pH(25°C)	TA $\mu eq/kg$	TCO_2 $\mu mol/kg$
4397	1.01	34.710	7.940	2381	-
4928	0.94	34.705	7.744	2372	-
5077	0.94	34.706	7.744	2370	2260

Keeling's samples

16	24.91	35.342	8.246	2317	1973
36	24.91	-	8.246	2315	-
100	18.96	35.605	8.174	2330	-
199	15.95	35.539	8.094	2338	2065
298	14.20	35.375	8.062	2334	2084
401	13.10	35.218	8.036	2322	2089
497	12.13	35.094	8.010	2319	2195
598	11.11	34.958	7.986	2314	2111
798	9.01	34.716	7.922	2301	-

G4 2.28.85 29.40S, 57.09E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
8	23.11	35.603	8.206	2337	2006
34	23.08	35.596	8.205	2339	2008
54	22.14	35.611	8.199	2339	-
75	18.79	35.622	8.170	2339	2032
101	17.82	35.620	8.154	2347	2041
126	16.38	35.561	8.113	2356	2069
201	15.14	35.487	8.092	2338	-
300	14.26	35.382	8.064	2341	2079
399	13.26	35.254	8.039	-	-
499	12.18	35.094	8.011	2322	2104
596	11.44	34.990	7.994	2326	2106
699	10.47	34.866	7.965	2316	2119
801	9.27	34.733	7.924	2313	2132
900	7.90	34.599	7.876	2306	2148
1049	5.69	34.447	7.807	2304	-
1200	4.26	34.419	7.760	2318	-
1349	3.51	34.494	7.728	2333	-
1500	3.14	34.555	7.720	2355	2256
1648	2.85	34.613	7.723	2349	-
1799	2.62	34.655	7.728	2372	2265
1950	2.50	34.685	7.730	2370	-
2100	2.31	34.706	7.732	2376	2276
2298	2.19	34.726	7.740	-	-
2547	2.06	34.737	7.744	2380	-
2797	1.93	34.739	7.743	2398	-
3050	1.79	34.737	7.738	2397	-
3349	1.62	34.733	7.743	2401	2290
3650	1.40	34.725	7.743	2398	2284
3946	1.22	34.720	7.744	2370	-
4248	1.06	34.715	7.744	2377	2364

G4 2.28.85 29.40S, 57.09E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
4549	0.98	34.708	7.745	2360	-
4905	0.95	34.706	7.744	2372	-
5065	0.95	34.724	7.745	2387	2278

G5 3.1.85 32.09S, 57.15E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
5	21.63	35.511	8.184	2343	2033
35	21.26	35.528	8.184	2343	2033
53	17.64	35.503	8.170		
75	16.51	35.506	8.158		
99	15.57	35.502	8.113		
127	25.35	35.507	8.107		
144	15.21	35.504	8.103		
201	14.85	35.463	8.096		
303	14.32	35.402	8.085		
398	13.85	35.331	8.069		
497	12.90	35.192	8.035		
601	11.66	35.009	8.997		
699	10.86	34.903	8.973		
798	9.38	34.735	8.921		
899	8.06	34.612	8.882		
1050	5.91	34.442	7.818		
1200	4.26	34.386	7.765		
1349	3.56	34.416	7.740		
1501	3.11	34.487	7.724		
1647	2.80	34.554	7.719		
1799	2.52	34.636	7.729		
1951	2.33	34.679	7.740		
2098	2.24	34.713	7.743		
2252	2.10	34.715	7.751		
2400	1.97	34.730	7.750		
2495	1.87	34.733	7.750		
2588	1.86	34.732	7.754		
2720	1.79	34.736	7.751		

G6 3.2.85 35.02S, 57.21E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
5	20.99	35.526	8.176	2341	-
35	20.02	35.530	8.174	2348	-
55	18.42	35.505	8.163	2344	2044
75	17.51	35.509	8.149	2340	2051
100	16.35	35.514	8.122	2356	-
125	15.87	35.508	8.108	2338	2082
150	15.36	35.499	8.096	2344	2081
200	14.96	35.465	8.091	2338	2084
300	14.27	35.378	8.068	2342	2093
400	13.65	35.296	8.048	2332	2100
500	12.87	35.180	8.026	2328	-
600	12.03	35.058	8.006	2320	2113
637	11.16	34.940	7.982	2319	2119
772	10.48	34.853	7.962	2315	2123
898	8.98	34.694	7.909	2310	2143
1048	6.67	34.393	7.836	2304	2170
1200	4.55	34.382	7.780	2307	2201
1349	3.79	34.411	7.752	2322	2220
1500	3.38	34.454	7.734	2334	-
1651	3.01	34.516	7.720	2343	2251
1800	2.78	34.594	7.723	2348	2255
1949	2.62	34.649	7.729	2358	2256
2105	2.48	34.691	7.739	2365	2260
2297	2.38	34.718	7.747	2364	2258
2489	2.25	34.743	7.759	2369	2259
2698	2.11	34.755	7.764	2369	2251
2899	1.90	34.749	7.764	2370	-
3149	1.60	34.743	7.761	2372	2265
3418	1.31	34.727	7.757	2374	2270
3752	0.89	34.710	7.749	2371	-

G6 3.2.85 35.02S, 57.21E (continued)

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
4050	0.62	34.694	7.745	2374	-
4348	0.52	34.687	7.742	2369	-
4669	0.52	34.687	7.745	2385	-
4823	0.53	34.686	7.749	2385	2278

G7 3.3.85 37.41S, 57.40E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
6.9	18.56	35.528	8.171	2336	2038
36.9	17.71	35.572	8.173	2348	-
55.7	17.31	35.550	8.158	2346	2051
75.2	17.02	35.543	8.146	2345	2058
100.6	16.42	35.502	8.146	2337	-
125.1	16.10	35.519	8.108	2343	2075
150.2	15.77	35.500	8.095	2342	-
210.5	15.30	35.475	8.090	2340	2080
300.6	14.27	35.350	8.057	2340	2099
400.2	13.68	35.288	8.056	2328	2092
500.0	12.70	35.137	8.025	2324	2110
600.1	11.79	35.017	7.999	2318	-
702	11.07	34.921	7.977	2322	2124
802	9.68	34.768	7.934	2312	2140
901	8.23	34.621	7.884	2295	2164
1050	6.25	34.456	7.828	2307	-
1202	4.70	34.370	7.793	2312	2195
1353	3.84	34.387	7.761	2317	-
1502	3.33	34.442	7.736	2333	2228
1646	2.98	34.524	7.718	2348	2247
1800	2.82	34.574	7.722	2355	2257
1936	2.67	34.632	7.726	2357	2258
2089	2.53	34.678	7.738	2360	2253
2300	2.37	34.722	7.756	2370	2262
2594	2.14	34.740	7.754	2379	2268
3199	1.74	34.757	7.761	2376	2264
3500	1.51	34.793	7.759	2373	2262
3800	1.18	34.730	7.753	2371	2261
4092	0.77	34.705	7.749	2371	2268
4400	0.55	34.692	7.747	2378	2268

G7 3.3.85 37.41S, 57.40E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
4697	0.49	34.708	7.746	2380	2270
5050	0.45	34.687	7.744	2379	2268
5267	0.47	34.683	7.744	2377	2275

G8 3.4.85 40.11S, 57.52E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
10	18.858	35.589	8.189	2347	-
33.5	18.811	35.583	8.187	2330	2026
55	17.705	35.564	8.136		
72.5	17.360	35.574	8.125		
100	17.003	35.572	8.120		
124.5	16.559	35.533	8.105		
150	15.969	35.454	8.091		
200	15.051	35.373	8.071		
299	13.794	35.289	8.042		
401	12.822	35.164	8.124		
500	11.838	35.031	7.998		
602	10.763	34.895	7.968		
700	9.650	34.773	7.934		
800	8.289	34.608	7.882		
901	7.165	34.544	7.846		
1044	5.681	34.433	7.810		
1201	4.304	34.393	7.772		
1350	3.831	34.453	7.740		
1500	3.551	34.501	7.727		
1651	2.777	34.503	7.712		
1802	2.889	34.618	7.726		
1951	2.672	34.636	7.727		
2104	2.545	34.684	7.733		
2298	2.459	34.737	7.751		
2499	2.360	34.768	-		
2697	2.203	-	-		
2990	2.099	34.775	7.773		
3101	1.924	34.767	7.768		
3402	1.650	34.772	-		

G8 3.4.85 40.11S, 57.52E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3703	1.319	-	-		
4005	0.985	34.716	7.745		
4351	0.633	34.697	7.741		
4696	0.461	34.686	7.742		
4859	0.419	34.685	7.750		

G9 3.5.85 43.08S, 57.57E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
4	13.6	-	8.114	2296	2041
10	14.013	34.433	8.123	2308	2042
34	13.519	34.328	8.111	2311	2071
55	13.021	34.332	8.098	2292	2045
73	12.951	34.586	8.086	2305	2061
100	11.946	34.646	8.043	2303	2077
124	10.922	34.652	7.811	2312	2095
149	11.076	34.769	7.809	2300	2099
200	10.410	34.729	7.992	2302	2102
299	9.362	34.618	7.955	2304	-
398	8.958	34.662	7.914	2304	2136
500	7.741	34.578	7.869	2302	2257
602	5.131	34.265	7.842	2293	2161
701	4.605	34.272	7.823	2294	2166
801	3.808	34.258	7.800	2304	-
901	3.379	34.266	7.785	2307	2191
1050	3.326	34.392	7.750	2335	2222
1201	3.253	34.484	7.731	2338	-
1349	3.076	34.557	7.728	2347	-
1502	2.834	34.612	7.734	2353	2253
1650	2.722	34.661	7.742	2350	-
1802	2.573	34.695	7.746	2352	-
1950	2.490	34.724	7.760	2353	-
2101	2.393	34.750	7.765	2365	2239
2301	2.270	34.768	7.779	2364	-
2503	2.138	34.811	7.780	2371	2244
2701	2.018	34.776	7.780	2366	2244
2900	1.836	34.765	7.773	2376	2247
3149	1.664	34.752	7.770	2376	2256
3398	1.415	34.744	7.765	2371	-

G9 3.5.85 43.08S, 57.57E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3647	1.105	34.724	7.757	2378	2259
3947	0.722	34.703	7.746	2374	-
4246	0.482	34.691	7.746	2372	-
4568	0.319	34.682	7.745	2381	-
4725	0.248	34.676	7.746	2382	-

G10 3.6.85 45.29S, 54.45E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
4*	9.80	33.78	8.024	2276	2071
5	9.913	33.784	8.024	2277	2073
35	9.698	33.775	8.018	2280	2075
56	9.530	33.789	8.016		
75	9.040	33.793	8.006		
101	7.669	33.832	7.968		
126	6.258	33.867	7.943		
150	5.046	33.894	7.912		
201	5.576	34.123	7.884		
300	4.450	34.141	7.851		
400	3.874	34.185	7.824		
502	3.490	34.215	7.801		
601	2.958	34.230	7.778		
701	2.726	34.283	7.754		
799	2.706	34.344	7.741		
900	2.720	34.421	7.726		
1050	2.936	34.544	7.727		
1200	2.630	34.587	7.724		
1350	2.655	34.654	7.742		
1500	2.530	34.690	7.748		
1643	2.442	34.717	7.755		
1801	2.332	34.741	7.760		
1950	2.228	34.754	7.771		
2105	2.135	34.764	7.774		
2299	1.985	34.763	7.779		
2450	1.856	34.758	7.778		
2648	1.680	34.755	7.773		
2855	1.479	34.742	7.771		
3075	1.280	34.734	7.764		
3273	1.059	34.718	7.760		

G10 3.6.85 45.29S, 54.45E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3524	0.801	34.702	7.755		
3724	0.581	34.694	7.751		
4073	0.473	34.680	7.753		
4273	0.362	34.675	7.754		
4426	0.206	34.669	7.754		

G11 3.9.85 47.61S, 54.47E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
10	7.446	33.754	7.975	2275	-
34	7.453	33.755	7.975	2278	2089
54	7.394	33.751	7.975	2271	2086
75	7.298	33.755	7.970	2273	2091
100	6.835	33.769	7.965	2271	2096
124	4.170	33.868	7.899	2278	2125
149	3.898	33.901	7.884	2276	2134
199	3.536	33.998	7.859	2279	2150
300	3.177	34.151	7.817	2291	2171
400	2.806	34.200	7.787	2304	2191
499	2.629	34.247	7.769	2309	2201
601	2.404	34.331	7.740	2324	2224
700	2.405	34.405	7.725	2324	2235
800	2.439	-34.46	7.711	2325	2242
900	2.434	34.519	7.711	2334	2245
1050	2.405	34.598	7.717	2337	2251
1200	2.385	34.653	7.728	2345	2256
1351	2.359	34.699	7.738	2342	2257
1501	2.292	34.729	7.756	2348	2245
1650	2.211	34.745	7.763	2347	2247
1801	2.126	34.761	7.770	2350	2248
1950	2.024	34.739	7.759	2346	2254
2100	1.909	34.772	7.774	2361	2257
2297	1.730	34.764	7.776	2360	2251
2450	1.603	34.758	7.776	2363	2251
2599	1.478	34.750	7.771	2358	2248
2800	1.288	34.738	7.764	2363	-
3100	1.023	34.718	7.764	2362	2257
3401	0.767	34.706	7.753	2368	2266
3701	0.538	34.693	7.753	2365	2261

G11 3.9.85 47.41S, 54.47E (continued)

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
3949	0.412	34.683	7.752	2371	2268
4149	0.280	34.679	7.750	2368	2262
4399	0.157	34.672	7.751	2366	2269
4564	0.099	34.667	7.753	2367	2270

G14 3.10.85 53.02S, 58.56E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
19	3.814				
54	3.813	33.908	7.901	2295	2145
100	3.798	33.907	7.901	2290	2131
150	1.803	34.003	7.851	2293	2167
198	1.727	34.077	7.817	2283	2177
300	2.130	34.241	7.749	2305	2209
502	2.199	34.421	7.707	2324	2239
699	2.309	34.569	7.703	2338	2261
898	2.278	34.653	7.719	2345	2258
1200	2.188	34.720	7.748	2349	2245
1599	1.934	34.663	7.725	2247	2253
2003	1.582	34.754	7.768	2356	-
2300	1.318	34.737	7.763	2362	2257
2500	1.157	34.728	7.757	2362	2252
2799	0.895	34.712	7.760	2359	2257
3102	0.641	34.696	7.755	2365	2255
3400	0.456	34.685	7.751	2368	2261
3698	0.278	34.675	7.749	2362	2264
3998	0.140	34.671	7.745	2370	2267
4295	0.012	34.664	7.754	2363	2256
4647	-0.066	34.660	7.749	2365	2253
5069	-0.070	34.658	7.756	2363	2254
5217	-0.066	34.655	7.759	2366	2263

G15 3.13.85 50.11S, 61.45E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
10	5.065	33.839	7.929	2282	2133
34	5.061	33.843	7.933	2285	2132
57	5.060	33.848	7.928		
75	5.058	33.840	7.930		
101	4.359	33.851	7.914		
125	3.703	33.883	7.899		
152	2.666	33.914	7.874		
198	2.028	33.957	7.858		
299	2.071	34.128	7.784		
402	2.180	34.253	7.738		
500	2.216	34.370	7.708		
603	2.290	34.466	7.696		
695	2.312	34.507	7.695		
800	2.332	34.558	7.705		
897	2.336	34.600	7.710		
1051	2.315	34.662	7.723		
1200	2.268	34.695	7.739		
1321	2.214	34.729	7.748		
1499	2.119	34.748	7.753		
1648	2.013	34.757	7.763		
1800	1.901	34.760	7.770		
1950	1.771	34.759	7.769		
2104	1.626	34.754	7.769		
2298	1.456	34.747	7.767		
2500	1.252	34.739	7.768		
2700	1.090	34.722	7.763		
2900	0.931	34.715	7.760		
3090	0.758	34.707	7.753		
3302	0.616	34.694	7.750		
3501	0.502	34.699	7.748		

G15 3.13.85 50.11S, 61.45E (continued)

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3800	0.339	34.678	7.746		
4099	0.137	34.675	7.747		
4398	-0.017	34.746	7.771		
4543	-0.060	34.664	7.748		

G16 3.13.85 50.31S, 67.16E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
4	4.731	33.884	7.925	2289	2133
35	4.733	33.853	7.926	2291	2137
55	4.737	33.881	7.928	2287	2135
75	4.733	33.884	7.929	2287	2131
102	3.174	33.901	7.904	2288	2151
126	1.851	33.965	7.870	2293	2162
151	1.740	33.953	7.869	2296	2156
200	1.628	33.998	7.851	2297	2173
301	1.990	34.211	7.756	2309	2222
400	2.090	34.312	7.729	2309	2228
501	2.164	34.401	7.709	2324	2242
602	2.284	34.497	7.699	2330	2261
700	2.290	34.565	7.707	2329	2254
800	2.223	34.605	7.716	2348	2259
901	2.222	34.656	7.725	2344	2255
1000	2.228	34.685	7.737	-	-
1100	2.220	34.715	7.742	2351	2259
1200	2.171	34.734	7.750	-	2250
1301	2.119	34.748	7.763	2354	2254
1400	2.036	34.757	7.765	2357	2254
1501	1.936	34.761	7.767	2356	2251
1600	1.817	34.770	7.774	2356	2243
1750	1.698	34.767	7.774	2362	2250

G17 3.17.85 46.33S, 71.11E

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
5	6.966	33.734	7.978	2282	2113
35	6.953	33.733	7.976	2288	-
55	6.882	33.732	7.983	2290	2109
74	5.047	~33.80	7.939	2281	2121
100	3.677	33.851	7.908	2287	2141
126	3.277	33.872	7.894	2281	2147
151	3.108	~33.936	7.888	2290	2155
200	2.851	34.033	7.844	2290	-
300	2.615	34.133	7.807	2300	2187
400	2.331	34.231	7.764	2313	2211
499	2.254	34.328	7.729	2320	2235
598	2.338	34.415	7.721	2328	2242
700	2.431	34.506	7.720	2335	2254
800	2.403	34.563	7.718	2341	2258
897	2.328	34.602	7.718	2342	2257
1046	2.267	34.649	7.731	2347	2258
1200	2.228	34.710	7.749	2346	2252
1350	2.147	34.747	7.777	2356	2254
1490	2.043	34.754	7.779	2357	2259
1649	2.000	34.765	7.787	2358	2253
1802	1.894	34.765	7.787	2363	2266
1947	1.73	34.763	7.787	2369	2274

G18 3.17.85 45.10S, 72.21E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
6	8.751	33.792	8.005	2270	2075
35	8.732	33.790	7.999	2268	2069
55	8.666	33.794	8.002		
73	8.508	33.829	7.996		
100	8.846	34.258	7.977		
125	7.792	34.226	7.952		
153	7.250	34.219	7.938		
199	6.332	34.152	7.915		
298	6.149	34.320	7.870		
401	5.036	34.297	7.835		
501	4.167	34.262	7.817		
599	3.750	34.287	7.793		
700	3.400	34.303	7.775		
800	3.119	34.342	7.761		
901	3.009	34.408	7.744		
1200	2.698	34.541	7.725		
1350	2.661	34.620	7.728		
1500	2.518	34.681	7.744		
1650	2.466	34.707	7.752		
1802	2.387	34.733	7.761		
1951	2.302	34.749	7.768		
2099	2.187	34.761	7.772		
2299	2.073	34.771	7.780		
2499	1.890	34.767	7.776		
2749	1.674	-	7.772		
2999	1.388	34.740	7.772		
3250	1.132	34.726	7.765		
3468	0.964	34.721	7.761		
3621	0.904	34.717	7.754		

G19 3.18.85 43.19S, 73.48E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
10	13.650	34.707	8.127	2299	2037
35	13.652	34.706	8.127	2300	2042
57	13.658	34.711	8.123	2303	-
73	13.700	34.749	8.123	2300	2040
100	13.972	35.145	8.100	2312	2065
124	13.663	35.223	8.074	2310	2066
149.3	13.358	35.205	8.069	-	-
148.2	13.352	35.206	8.068	-	-
147.5	13.352	35.206	8.067	-	-
149.3	13.351	35.207	8.069	2313	2085
201	12.911	35.147	8.060	2307	2085
300	12.173	35.042	8.038	2305	2088
400	11.102	34.888	7.995	2299	2102
500	9.884	34.738	7.963	2294	2113
600	8.876	34.665	7.924	2289	2125
700	7.555	34.553	7.883	2281	2142
800	6.311	34.458	7.849	2290	2153
901	4.814	34.335	7.823	2297	2172
1050	3.950	34.351	7.784	2306	2198
1200	3.477	34.388	7.761	2320	2217
1351	3.085	34.452	7.746	2325	2230
1500	2.891	34.525	7.731	2330	2239
1650	2.729	34.589	7.734	2348	2249
1800	2.600	34.642	7.742	2345	2241
1949	2.522	34.683	7.750	2346	2247
2100	2.454	-34.701	7.757	2348	2244
2203	2.303	34.742	7.773	2354	2243
2499	2.171	34.759	7.775	2352	2240
2747	2.005	34.757	7.778	2364	2250
3000	1.817	34.748	7.776	2370	2253

G19 3.18.85 43.19S, 73.48E (continued)

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
3243	1.612	34.746	7.778	2368	2248
3397	1.403	34.731	7.774	2378	2264
3626	1.196	34.720	7.768	2375	-

G20 3.19.85 41.26S, 75.71E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
5	15.29	34.983	8.143	2326	-
35	15.24	34.992	8.142	2314	2049
55	14.30	34.920	8.103		
75	14.17	35.219	8.085		
99	13.53	35.239	8.069		
124	13.18	35.205	8.065		
156	12.97	35.173	8.058		
201	12.655	35.120	8.059		
299	12.319	35.083	8.052		
400	11.575	34.960	8.013		
501	10.494	34.833	7.972		
600	9.436	34.725	7.939		
701	8.072	34.599	7.889		
800	6.632	34.480	7.851		
899	5.468	34.396	7.824		
1050	4.221	34.351	7.794		
1200	3.573	34.384	7.762		
1353	3.185	34.448	7.740		
1500	2.926	34.511	7.727		
1651	2.729	34.583	7.728		
1799	2.617	34.637	7.738		
1948	2.521	34.680	7.745		
2100	2.448	34.710	7.754		
2300	2.281	34.738	7.764		
2500	2.098	34.746	7.764		
2749	1.887	34.743	7.765		
2999	1.695	34.732	7.763		
3198	1.525	34.726	7.762		
3322	1.485	34.723	7.763		
3324	-	34.722	7.764		

G21 3.20.85 39.37S, 76.23E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
9	16.635	35.176	8.155	2314	2039
10	16.375	35.178	8.154	2319	2041
36	16.297	35.180	8.153	2319	2043
56	16.178	35.174	8.145	2320	2044
74	14.981	35.191	8.108	2307	2060
100	14.166	35.309	8.088	2320	-
126	14.034	35.344	8.089	2326	2078
153	13.777	35.297	8.077	2322	2081
199	13.160	35.208	8.058	2316	2087
301	12.569	35.121	8.052	2311	-
400	12.182	35.061	8.035	2306	2090
500	11.262	34.924	7.992	2310	2108
599	10.135	34.786	7.954	2302	2121
699	8.918	34.672	7.910	2293	2132
800	7.694	34.565	7.872	2301	2158
900	6.405	34.462	7.840	2301	2167
1051	4.863	34.373	7.801	2303	2198
1200	3.846	34.360	7.769	2316	2221
1353	3.326	34.423	7.746	2327	-
1500	3.055	34.482	7.726	2325	2232
1651	2.842	34.548	7.721	2336	2241
1800	2.662	34.618	7.728	2343	2243
1949	2.548	34.664	7.736	2345	2244
2100	2.413	34.700	7.748	2347	2244
2299	2.231	34.730	7.758	2361	2256
2501	2.042	34.738	7.756	2364	2258
2752	1.797	34.730	7.756	2381	2273
3049	1.584	34.721	7.756	2382	-
3348	1.488	34.725	7.749	2396	2287
3552	1.434	34.719	7.754	2398	2286

G22 3.23.85 33.51S, 76.27E

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
10	20.993	35.471	8.185	2329	2033
10	20.989	35.470	8.185	2336	2031
35	20.526	35.443	8.184	2331	2035
55	17.297	35.336	8.170	2333	2039
75	14.833	35.368	8.122	2327	2065
99	14.232	35.368	8.094	2321	2074
125	14.104	35.367	8.094	2324	2071
150	14.015	35.361	8.092	2324	2073
200	13.609	35.292	8.084	2317	2079
299	12.968	35.184	8.066	2309	2093
299	12.972	35.182	8.068	2314	2086
400	12.435	35.107	8.048	2310	2090
499	11.747	35.008	8.024	2310	2101
601	10.713	34.875	7.990	2301	2109
700	9.761	34.762	7.957	2299	2121
800	8.266	34.616	7.902	2294	2140
899	6.866	34.498	7.858	2294	2160
1051	4.892	34.374	7.810	2308	-
1200	3.864	34.379	7.772	2314	2192
1352	3.313	34.440	7.747	2322	2229
1495	2.940	34.518	7.731	2326	2240
1650	2.738	34.579	7.733	2342	2249
1800	2.563	34.648	7.740	2349	2253
1950	2.417	34.692	7.752	2352	2250
2099	2.288	34.711	7.759	2366	-
2300	2.051	34.725	7.759	2371	2265
2500	1.901	34.726	7.759	2383	2281
2749	1.752	34.724	7.760	2386	2288
3000	1.616	34.722	7.764	2398	2287
3200	1.557	34.720	7.765	2396	-

G22 3.23.85 33.51S, 76.27E (continued)

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
3350	1.555	34.719	7.767	2383	2283
3350	1.556	34.725	7.766	2392	-

G23 3.24.85

Depth	T	S	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
9	23.177	36.009	8.189	2372	2055
34	22.215	35.984	8.187	2371	-
55	17.980	35.657	8.172	2353	2057
74	17.059	35.637	8.162	2331	-
100	15.845	35.563	8.144	2337	2064
125	14.811	35.483	8.110	2336	2075
150	14.228	35.385	8.094	2329	2078
202	13.611	35.302	8.079	2320	2084
299	12.732	35.165	8.050	2316	2094
399	11.899	35.047	8.022	2308	2099
499	11.241	34.959	8.005	2306	2107
600	10.422	34.852	7.988	2306	2112
700	9.543	34.639	7.952	2295	2125
800	8.521	34.637	7.912	2299	-
902	7.185	34.525	7.863	2300	2159
1050	5.060	34.407	7.794	2304	-
1201	4.027	34.421	7.752	2326	2218
1351	3.523	34.500	7.727	2340	2251
1500	3.189	34.560	7.722	2345	2260
1653	2.893	34.616	7.727	2353	-
1800	2.618	34.662	7.737	2352	-
1999	2.314	34.698	7.748	2368	2267
2200	2.105	34.721	7.756	2375	2269
2400	1.908	34.720	7.757	2384	2283
2600	1.809	34.722	7.758	2387	2291
2797	1.712	34.721	7.760	2390	2284
3000	1.639	34.725	7.760	2395	-
3199	1.600	34.720	7.758	2385	2283
3399	1.568	34.720	7.761	2387	2286
3598	1.517	34.720	7.761	2392	-

G23 3.24.85 (continued)

Depth	T	S	pH(25°C)	TA μeq/kg	TCO_2 μmol/kg
3798	1.442	34.715	7.763	2400	2289
3925	1.455	34.717	7.763	2396	-

G24 3.25.85 29.25S, 70.49E

Depth	T	S	pH(25°C)
5	23.895	35.909	8.190
35	23.098	35.986	8.190
55	22.861	35.982	8.189
75	17.899	35.722	8.171
100	16.449	35.654	8.154
150	14.615	35.440	8.094
200	13.595	35.304	8.071
298	12.720	35.171	8.043
397	11.990	35.066	8.024
498	11.050	34.931	8.002
600	10.155	34.811	7.973
698	9.259	34.698	7.939
798	8.055	34.590	7.890
893	6.750	34.486	7.843
1052	4.732	34.380	7.789
1199	3.771	34.415	7.751
1349	3.314	34.495	7.727
1501	2.959	34.568	7.722
1650	2.690	34.634	7.732
1800	2.468	34.673	7.740
2000	2.249	34.700	7.749
2200	2.073	34.714	7.752
2401	1.950	34.720	7.751
2849	1.822	34.726	7.753
2949	1.703	34.724	7.753
3249	1.578	34.721	7.756
3394	1.479	34.718	7.758
3598	1.371	34.713	7.759
3782	1.256	34.711	7.761
3966	1.222	34.709	7.762

G25 3.26.85 26.59S, 67.08E

Depth	T	S	pH(25°C)
8	25.792	35.627	8.262
49	21.892	35.637	8.212
54	21.266	35.646	8.210
74	20.444	35.678	8.206
99	19.709	35.760	8.196
124	18.869	35.777	8.178
148	18.182	35.769	8.162
199	16.915	35.732	8.133
299	14.436	35.410	8.083
400	13.244	35.247	8.056
500	12.246	35.098	8.030
603	11.223	34.963	8.006
701	10.137	34.820	7.980
801	9.096	34.704	7.937
901	7.975	34.596	7.898
1050	5.451	34.425	7.806
1201	4.160	34.445	7.750
1351	3.523	34.511	7.727
1501	3.163	34.578	7.721
1650	2.848	-	7.721
1800	2.533	34.676	7.727
1951	2.341	34.694	7.739
2098	2.177	34.711	7.744
2304	2.004	34.721	7.749
2498	1.889	34.725	7.749
2699	1.782	34.723	7.751
2898	1.733	34.723	7.748
3143	1.678	34.723	7.754
3398	1.626	34.721	7.756
3649	1.594	34.718	7.758

G25 3.26.85 26.59S, 67.08E (continued)

Depth	T	S	pH(25°C)
3899	1.571	34.720	7.755
4198	1.587	34.720	7.755
4499	1.603	34.719	7.756
4799	1.627	34.718	7.757
5098	1.656	34.723	7.751
5292	1.680	34.719	7.759

Appendix III: INDIVAT 3 Data

INDIVAT 3 Data

Date	Time	Location	T	S*	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
2.23	1100	20.5S, 55.3E	27.35	(35.04)	8.251	2300	1946
	1430	20.5S, 55.3E	27.2	(32.28)	8.240	-	-
	1800	21.0S, 55.0E	27.3	(35.17)	8.246	2295	1967
	2130	21.1S, 54.2E	27.2	(35.21)	8.242	2311	1972
2.24	0700	22.0S, 52.3E	26.45	(35.29)	8.252	2320	-
	0730	22.0S, 52.1E	26.2	(35.31)	8.247	2315	1976
	0900	22.1S, 51.5E	26.25	(35.21)	8.245	2318	1981
	1000	22.2S, 51.4E	26.25	(35.20)	8.247	2314	1979
	1200	22.3S, 51.2E	26.45	(35.25)	8.247	-	-
	1600	22.5S, 50.2E	26.2	(35.03)	8.246	2306	-
	1900	23.00S, 50.00E	26.13	35.01	8.247	-	-
2.25	0700	23.36S, 51.00E	26.47	(35.43)	8.253	-	-
	1130	23.45S, 51.19E	26.28	(35.48)	8.257	-	-
	1450	24.12S, 51.58E	26.3	(35.47)	8.258	-	-
	1640	24.26S, 52.19E	25.55	(35.19)	8.242	-	-
2.26	1140	25.31S, 54.09E	26.2	(35.92)	8.238	-	-
	1640	26.05S, 55.08E	25.85	-	8.248	-	-
	2100	26.33S, 55.58E	25.2	(35.42)	8.250	2324	1975
2.28	0730	28.47S, 57.03E	24.1	(35.70)	8.219	2333	1997
	0900	29.03S, 51.03E	24.61	(35.72)	8.244	2331	-
	1030	29.19S, 45.03E	24.0	(35.71)	8.221	2328	-
3.1	1700	32.33S, 57.18E	22.15	(35.64)	8.187	2329	2030
	1930	33.10S, 57.21E	21.75	(35.62)	8.176	-	-
	2100	33.31S, 57.22E	21.43	(35.59)	8.175	2341	2036

Date	Time	Location	T	S*	pH(25°C)	TA $\mu eq/kg$	TCO_2 $\mu mol/kg$
3.2	1520	36.04S, 57.27E	19.83	(35.59)	8.164	2340	2038
	1630	36.22S, 57.30E	19.7	(35.64)	8.168	-	-
	2130	37.30S, 57.36E	19.15	(35.60)	8.164	2332	2039
3.3	1910	37.59S, 57.52E	18.2	(35.39)	8.160	2334	2039
3.4	1600	40.20S, 57.53E	17.6	(35.38)	8.176	2340	2049
	1630	40.25S, 57.53E	16.68	(35.19)	8.177	2338	2047
	1940	41.20S, 57.53E	16.2	(35.37)	8.165	2340	2050
3.5	1400	43.10S, 57.57E	13.6	34.43	8.113	2296	2041
	1415	43.12S, 57.57E	12.91	(34.13)	8.093	2285	2048
	1425	43.16S, 57.57E	12.6	(34.09)	8.081	2288	2053
	2115	44.53S, 57.47E	12.3	(34.02)	8.077	2267	2050
	2140	44.59S, 57.47E	11.85	(33.98)	8.066	2278	2054
	2200	45.04S, 57.48E	11.25	(33.93)	8.056	2276	2058
	2250	45.16S, 57.48E	10.75	(33.86)	8.044	2280	2066
	2340	45.28S, 57.48E	10.1	(33.82)	8.037	2279	2069
	2350	45.29S, 57.48E	9.8	33.78	8.024	2276	2071
3.8	1220	46.31S, 52.22E	6.89	(32.86)	7.956	-	-
	1305	46.30S, 52.40E	6.72	(33.57)	7.955	-	-
	1530	46.46S, 53.24E	6.75	(33.63)	7.955	2270	2102
	1900	47.02S, 54.35E	7.87	(33.63)	7.980	2268	2086
	2040	47.09S, 55.08E	8.21	(33.65)	7.994	2276	2081
3.10	0510	50.14S, 58.19E	4.85	(33.57)	7.933	2273	2123
	0750	50.43S, 58.23E	5.10	(33.55)	7.938	2278	2115
	1210	51.28S, 58.30E	4.36	(33.60)	7.922	2281	2132

Date	Time	Location	T	S*	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3.12	0810	52.51S, 61.49E	4.05	(33.47)	7.910	2285	-
	1350	52.02S, 62.47E	4.48	(33.59)	7.925	2284	2137
	2005	50.44S, 62.55E	5.05	(33.65)	7.931	2278	2126
	2200	50.30S, 62.43E	5.50	(33.64)	7.944	2277	2119
3.13	1015	50.12S, 61.51E	5.10	(35.66)	7.929	-	-
	1250	50.15S, 62.47E	5.52	(33.66)	7.940	2270	2107
3.16	1415	48.38S, 70.43E	5.10	(33.68)	7.935	2244	2105
	1720	47.58S, 70.53E	5.72	(33.67)	7.969	2271	2122
	2025	47.18S, 71.03E	5.80	(33.65)	7.991	2382	2112
3.17	1015	46.14S, 71.31E	7.60	(33.68)	7.971	2283	2111
	1210	48.47S, 71.51E	8.31	33.752	7.995	2263	2093
	1255	45.41S, 71.58E	9.20	(33.75)	8.019	2258	2079
	1335	45.32S, 72.04E	10.10	(33.84)	8.045	2281	2078
	1355	45.28S, 72.07E	9.55	(33.78)	8.028	2279	-
3.18	0310	44.13S, 73.10E	13.31	34.675	8.124	2294	2052
	0640	43.39S, 73.40E	14.06	(34.84)	8.137	2304	2048
	0715	43.33S, 73.44E	13.77	(34.79)	8.134	2305	2046
3.19	0315	42.26S, 74.27E	14.15	34.827	8.133	2300	2056
	0715	41.45S, 74.55E	14.35	(34.82)	8.131	-	-
	0840	41.32S, 75.07E	14.65	(34.87)	8.136	2311	-
	0850	41.30S, 75.09E	15.00	(34.93)	8.143	2307	2046
	1540	41.14S, 75.24E	15.88	(35.05)	8.151	2312	2049
	1755	40.47S, 75.40E	16.25	(35.12)	8.153	-	-
	1910	40.30S, 75.51E	16.42	35.179	8.154	2330	2057

Date	Time	Location	T	S*	pH(25°C)	TA µeq/kg	TCO_2 µmol/kg
3.20	1605	39.14S, 78.53E	16.62	35.197	8.156	2325	2041
3.22	1905	37.16S, 77.25E	17.55	(35.18)	8.172	2301	2035
	2025	36.58S, 77.21E	18.00	(35.24)	8.174	2317	2038
	2040	36.54S, 77.20E	18.50	(35.30)	8.177	2321	2037
	2050	36.52S, 77.19E	19.04	(35.37)	8.181	2334	2041
	2210	36.36S, 77.14E	19.50	(35.42)	8.186	2312	-
3.23	0230	35.35S, 76.52E	19.67	(35.36)	8.188	2333	2035
	0800	34.27S, 76.31E	20.85	(35.48)	8.184	2335	2038
	1955	33.07S, 76.01E	21.90	(35.74)	8.185	2337	2043
	2345	32.17S, 75.34E	22.15	35.719	8.187	2359	-
3.24	0540	30.53S, 74.55E	22.93	(36.06)	8.190	2364	2057
3.25	0610	29.50S, 72.35E	24.25	35.960	8.221	-	-
3.26	0540	28.02S, 68.38E	25.80	35.606	8.249	-	-

* numbers in parenthesis are obtained from the ship's thermosalinograph

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