

Seawater dissolved ²³²Thorium, ²³⁰Thorium and ²³¹Protactinium from R/V Knorr KN193-06 and KN195-08 in the eastern N. Pacific and Sargasso Sea from 2008-2009 (GEOTRACES IC project)

Website: <https://www.bco-dmo.org/dataset/3828>

Version:

Version Date: 2012-12-31

Project

» [GEOTRACES InterCalibration](#) (GEOTRACES IC)

Program

» [U.S. GEOTRACES](#) (U.S. GEOTRACES)

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Dataset Description

GEOTRACES Baseline profiles of seawater dissolved thorium and protactinium in the forms ²³²Th, ²³⁰Th, and ²³¹Pa at SAFe in the SAFe station in the subtropical N. Pacific and the BATS station in the subtropical N. Atlantic.

BCO-DMO Note: "Trace Metal Pump - Towed" removed as an instrument. Was inadvertently included. 20Oct2014/srg

Methods & Sampling

Sampling and Analytical Methodology - BATS station:

Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with 24 10-liter PVC Niskin bottles. The carousel was lowered from the ship with steel wire. Niskin bottles were equipped with nylon-coated closure springs and Viton O-rings. After collection seawater was filtered by in-line filtration (47 mm 0.45 µm pore diameter Supor polysulfone membranes in acid cleaned Teflon filter holders) from pressurized Niskin bottles. Bottles were pressurized at 8-10 psi (54-70 kPa) with a system that distributed filtered air from a compressor via a manifold to each bottle through a fitting placed in its air vent. Each distribution line from the manifold was fitted with a valve so that each bottle could be pressurized or vented independently, while still allowing for the possibility to simultaneously filter all the bottles. Pressurized

bottles were held closed with Irwin Quick-Grip bar clamps spanning the endcaps. No attempt was made to evaluate the blank contributed by the pressurization scheme. Filtered water was collected in low-density polyethylene cubitainers (10 liter volume; Hedwin Corp.). Approximately 9-10 L was collected per desired depth. Prior to the cruise, the tubing, filters and cubitainers were cleaned by immersion in 1.2 M HCl (Fisher Scientific Trace Metal Grade) for 4-5 days. Once filtered, samples were adjusted to a pH ~2 with ultra-clean 6 M HCl (Fisher Scientific OPTIMA grade) and were double bagged for storage at room temperature until analysis.

In the on-shore laboratory, samples were weighed to determine sample size, taking into account the weight of the cubitainer and of the acid added at sea. Then weighed aliquots of the artificial isotope yield monitors ^{229}Th (20 pg) and ^{233}Pa (0.5 pg) and 15 mg dissolved Fe were added to each sample. After allowing 1 day for spike equilibration, the pH of each sample was raised to 8-8.5 (checked with pH paper) by adding concentrated NH_4OH (Fisher Scientific OPTIMA grade) which caused iron (oxy)hydroxide precipitates to form. This precipitate was allowed to settle for 1-2 days before the overlying seawater was siphoned off. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with Milli-Q H_2O (>18 MO) to remove the major seawater ions. The precipitate was then dissolved in 16 M HNO_3 (Fisher Scientific OPTIMA grade) and transferred to a Teflon beaker for a high-temperature (180-200°C) digestion with HClO_4 and HF (Fisher Scientific OPTIMA grade) on a hotplate in a HEPA-filtered laminar flow hood. After total dissolution of the sample, another precipitation of iron (oxy)hydroxide followed and the precipitate was washed with Mill-Q H_2O , centrifuged, and dissolved in 12 M HCl for a series of anion-exchange chromatography using 6 mL polypropylene columns each containing Bio-rad resin (AG1-X8, 100-200 mesh size) and a 45 μm porous polyethylene frit (for details see Anderson et al., 2012). The final column elutions were dried down at 180°C in the presence of 2 drops of HClO_4 and taken up in approximately 1 mL of 0.16 M HNO_3 /0.026 M HF for mass spectrometric analysis.

Concentrations of ^{232}Th , ^{230}Th and ^{231}Pa were calculated by isotope dilution using nuclide ratios determined on a VG Elemental AXIOM Single Collector Magnetic Sector ICP-MS with a Resolving Power of ~400 to ensure the highest sensitivity. All measurements were done using a peak jumping routine in ion counting mode. A solution of SRM129, a natural U standard, was run to determine the mass bias correction (assuming that the mass fractionation for Th and Pa are the same as for U). Each sample measurement was bracketed by measurement of an aliquot of the run solution, used to correct for the instrument background count rates on the masses measured. To correct for potential tailing of ^{232}Th into the minor Th and Pa isotopes, beam intensities were measured at the half masses above and below each mass for ^{230}Th , ^{231}Pa , and ^{233}Pa . Tailing under each minor isotope was estimated as the log mean intensity of the half masses on either side of each minor isotope.

Water samples were analyzed in batches of 10-12. Procedural blanks were determined by processing 4-5 L of Milli-Q water in an acid-cleaned cubitainer acidified to pH ~2 with 6 M HCl as a sample in each batch. Total procedural blanks for ^{232}Th , ^{230}Th , and ^{231}Pa ranged from 63-93 pg, 12.1-12.4 fg, and 1.9-2.4 fg respectively.

Sampling and Analytical Methodology - SAFe station:

Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with 24 10-liter PVC Niskin bottles. The carousel was lowered from the ship with steel wire. Niskin bottles were equipped with nylon-coated closure springs and Viton O-rings. After collection seawater was drained with Teflon-lined Tygon™ tubing and filtered through Pall Acropak™ 500 filters on deck (gravity filtration, 0.8/0.45 μm pore size) into low-density polyethylene cubitainers (1 gallon volume; Hedwin Corp.). Approximately 4 L was collected per desired depth. Prior to the cruise, the tubing, filters and cubitainers were cleaned by immersion in 1.2 M HCl (Fisher Scientific Trace Metal Grade) for 4-5 days. Once filtered, samples were adjusted to a pH ~2 with ultra-clean 6 M HCl (Fisher Scientific OPTIMA grade) and were double bagged for storage at room temperature until analysis.

In the on-shore laboratory, samples were weighed to determine sample size, taking into account the weight of the cubitainer and of the acid added at sea. Then weighed aliquots of the artificial isotope yield monitors ^{229}Th (20 pg) and ^{233}Pa (0.5 pg) and 15 mg dissolved Fe were added to each sample. After allowing 1 day for spike equilibration, the pH of each sample was raised to 8-8.5 (checked with pH paper) by adding concentrated NH_4OH (Fisher Scientific OPTIMA grade) which caused iron (oxy)hydroxide precipitates to form. This precipitate was allowed to settle for 1-2 days before the overlying seawater was siphoned off. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with Milli-Q H_2O (>18 MO) to remove the major seawater ions. The precipitate was then dissolved in 16 M HNO_3 (Fisher Scientific OPTIMA grade) and transferred to a Teflon beaker for a high-temperature (180-200°C) digestion with HClO_4 and HF (Fisher Scientific OPTIMA grade) on a hotplate in a HEPA-filtered laminar flow hood. After total dissolution of the sample, another precipitation of iron (oxy)hydroxide followed and the precipitate was washed with Mill-Q H_2O ,

centrifuged, and dissolved in 12 M HCl for a series of anion-exchange chromatography using 6 mL polypropylene columns each containing a bed of Bio-rad resin (AG1-X8, 100-200 mesh size) and a 45 μm porous polyethylene frit (for details see Anderson et al., 2012). The final column elutions were dried down at 180°C in the presence of 2 drops of HClO₄ and taken up in approximately 1 mL of 0.16 M HNO₃/0.026 M HF for mass spectrometric analysis.

Concentrations of ²³²Th, ²³⁰Th and ²³¹Pa were calculated by isotope dilution using nuclide ratios determined on a VG Elemental AXIOM Single Collector Magnetic Sector ICP-MS with a Resolving Power of ~400 to ensure the highest sensitivity. All measurements were done using a peak jumping routine in ion counting mode. A solution of SRM129, a natural U standard, was run to determine the mass bias correction (assuming that the mass fractionation for Th and Pa are the same as for U). Each sample measurement was bracketed by measurement of an aliquot of the run solution, used to correct for the instrument background count rates on the masses measured. To correct for potential tailing of ²³²Th into the minor Th and Pa isotopes, beam intensities were measured at the half masses above and below each mass for ²³⁰Th, ²³¹Pa, and ²³³Pa. Tailing under each minor isotope was estimated as the log mean intensity of the half masses on either side of each minor isotope.

Water samples were analyzed in batches of 10-12. Procedural blanks were determined by processing 3-4 L of Milli-Q water in an acid-cleaned cubitainer acidified to pH ~2 with 6 M HCl as a sample in each batch. An aliquot of an intercalibrated working standard solution of ²³²Th, ²³⁰Th and ²³¹Pa, SW STD 2010-1 referred to by Anderson et al. (2012), was added to a separate cubitainer with 4 L of Milli-Q water (acidified to pH 2) and also processed like a sample in each batch. Total procedural blanks for ²³²Th, ²³⁰Th, and ²³¹Pa ranged from 19-24 pg, 1.4-2.8 fg, and 0.4 fg respectively.

To test the overall method, an aliquot of an intercalibrated working standard solution of ²³²Th, ²³⁰Th and ²³¹Pa, SW STD 2010-1 referred to by Anderson et al. (2012), was added to a separate cubitainer with 3 L of Milli-Q water (acidified to pH 2) and also processed like a sample.

Further details on sampling and analysis are given by Anderson et al. (2012).

Data Processing Description

Data Processing:

The reported errors for radionuclide concentrations represent the propagation of one sigma errors based on the standard deviation of five sequences of isotope ratios collected by ICP-MS, estimated error in the ²²⁹Th or ²³³Pa spike concentration, and the blank correction of the individual isotopes for each sample batch.

Analysis of all samples was completed over the course of 2 years. A correction was made to account for the ingrowth of ²³⁰Th and ²³¹Pa due to the decay of the natural ²³⁴U and ²³⁵U preserved in the acidified samples during the period of time between sample collection and U-Th/Pa separation during anion exchange chromatography. Thus, the reported ²³⁰Th and ²³¹Pa concentrations have been corrected to represent their concentrations at the time of sampling. U concentrations in the samples were estimated using the bottle salinity (S) measured from the CTD and the U-Salinity relationship of North Pacific seawater (Chen et al., 1986), $[U] = (0.1115 \cdot S - 0.6356) \text{ ng U (g seawater)}^{-1}$. We used seawater U-isotopic compositions of ²³⁴U/²³⁸U = 1.1468 activity ratio (Andersen et al., 2010), and ²³⁸U/²³⁵U = 137.824 mole ratio (Weyer et al., 2008), to calculate [²³⁴U] and [²³⁵U] respectively based on [U]. In our manuscript (Anderson et al., 2012) we converted gravimetric concentration (fg/kg) into volumetric activities (dpm m⁻³) for easier comparison to historical data. The half-lives used were 75,690 yrs for ²³⁰Th (Cheng et al., 2000), 32,760 yrs for ²³¹Pa (Robert et al., 1969), 245,250 yrs for ²³⁴U (Cheng et al., 2000), and 7.0381 x 10⁸ yrs for ²³⁵U (Jaffey et al. 1971).

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Data Files

File**GT_IntCal_ThPa.csv**(Comma Separated Values (.csv), 4.54 KB)

MD5:8b5621e4633120fb75fd38cba41930e9

Primary data file for dataset ID 3828

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Parameters

Parameter	Description	Units
cruise_id	cruise ID number	dimensionless
station	station number within cruise	dimensionless
lat	station latitude; North is positive	decimal degrees
lon	station longitude; East is positive	decimal degrees
depth_max	station water depth	meters
depth	water depth at which bottle tripped	meters
event	event number from event log	dimensionless
date_collected	date sample was collected	mm/dd/yy
year	year sample was collected	yyyy
month	month sample was collected	1 to 12
day	day of month sample was collected	1 to 31
yrday_gmt	year day sample was collected; 1 is Jan. 1 and 365 is Dec. 31	1 t 365
bottle	Niskin bottle of 24-bottle sequence	dimensionless
sample	GEOTRACES sample identification number	integer
date_U_separation	date Uranium was separated from Th/Pa	mm/dd/yy
Th232	Dissolved ²³² Thorium concentration (picograms ²³² Th per kilogram seawater
Th232_err	1 sigma uncertainty in dissolved ²³² Th	picograms ²³² Th per kilogram seawater
Th232_flag	Data quality flag for dissolved ²³² Th	1 = good; 2 = questionable; 3 = rejected; 4=blanks too large to obtain data; 5= ²³² Th tail too large to obtain data
Th230	Dissolved ²³⁰ Thorium conc. (femtograms ²³⁰ Th per kilogram seawater
Th230_err	1 sigma uncertainty in dissolved ²³⁰ Th	femtograms ²³⁰ Th per kilogram seawater
Th230_flag	Data quality flag for dissolved ²³⁰ Th	1 = good; 2 = questionable; 3 = rejected; 4=blanks too large to obtain data; 5= ²³² Th tail too large to obtain data
Pa231	Dissolved ²³¹ Protactinium conc. (femtograms ²³¹ Pa per kilogram seawater
Pa231_err	1 sigma uncertainty in dissolved ²³¹ Pa	femtograms ²³¹ Pa per kilogram seawater
Pa231_flag	Data quality flag for dissolved ²³¹ Pa	1 = good; 2 = questionable; 3 = rejected; 4=blanks too large to obtain data; 5= ²³² Th tail too large to obtain data

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Instruments

Dataset-specific Instrument Name	CTD Sea-Bird
Generic Instrument Name	CTD Sea-Bird
Dataset-specific Description	The carousel was fitted with 24-liter Niskin bottles. The carousel was lowered from the ship with steel wire. Niskin bottles were equipped with nylon-coated closure springs and Viton O-rings.
Generic Instrument Description	Conductivity, Temperature, Depth (CTD) sensor package from SeaBird Electronics, no specific unit identified. This instrument designation is used when specific make and model are not known. See also other SeaBird instruments listed under CTD. More information from Sea-Bird Electronics.

Dataset-specific Instrument Name	Mass Spectrometer
Generic Instrument Name	Mass Spectrometer
Dataset-specific Description	VG Elemental AXIOM Single Collector Magnetic Sector ICP-MS with a Resolving Power of ~400
Generic Instrument Description	General term for instruments used to measure the mass-to-charge ratio of ions; generally used to find the composition of a sample by generating a mass spectrum representing the masses of sample components.

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Deployments

KN195-08

Website	https://www.bco-dmo.org/deployment/57842
Platform	R/V Knorr
Start Date	2009-05-06
End Date	2009-05-29
Description	<p>GEOTRACES intercalibration cruise 2 (May 2009) GEOTRACES completed the first Intercalibration cruise from June 8 to July 12, 2008, collecting water and particle samples for analysis and intercalibration. The second intercalibration cruise is planned for May 2009 in the eastern North Pacific and will include sampling near the North Pacific SAFE Station at 30°N 140°W, and the Santa Barbara Basin, 34.25°N 120°W. This International GEOTRACES intercalibration exercise aims to provide reference materials that could be distributed to the international community and reference profiles of Trace Elements and their Isotopes to ensure compatibility and consistency of GEOTRACES data. Sampling Activities: for full details see cruise synopsis or cruise report when available Pre-cruise Sampling Activity Summary: This is a 'trace metal clean' cruise, during which the researchers plan to use the following sampling devices and gear: ship's standard CTD with 24x10L Niskin bottle rosette Ken Buesseler's McLane in situ pumps and MITESS vane samplers a trace metal-clean GEOTRACES carousel with GO-Flo bottles (like the one used during IC 1 in 2008. This will be deployed using the newly developed method described by Glosten Associates. The plan is to use this system for up to 10 casts per day. a towed/stationary fish (depressor and weighted torpedo) for pumping trace metal clean water to the MLML sampling and GEOTRACES clean vans, deployed using our aluminum pivoting boom just like in 2008. We will be testing several different towed fish during the transits. Jim Bishop's MULFVS pumping system (http://www-ocean.lbl.gov/MULVFSops.html) An EOS paper (Johnson, 2007) describes the SAFE station and efforts to establish the SAFE dissolved Fe in seawater standards.K.S. Johnson et al. 2007. Developing standards for dissolved iron in seawater, EOS 88 (11), pp. 131-132 (http://boyle.mit.edu/~ed/PDFs/Johnson(2007)EOS88_131.pdf) Cruise information and original data are available from the NSF R2R data catalog.</p>

KN193-06

Website	https://www.bco-dmo.org/deployment/58676
Platform	R/V Knorr
Start Date	2008-06-29
End Date	2008-07-12

Description	<p>GEOTRACES intercalibration cruise 1 (June 2008) Original cruise data are available from the NSF R2R data catalog GEOTRACES completed the first Intercalibration cruise from June 8 to July 12, 2008, collecting water and particle samples for analysis and intercalibration. This intercalibration exercise aimed to provide reference materials that could be distributed to the international community and reference profiles of Trace Elements and their Isotopes to ensure compatibility and consistency of GEOTRACES data. The exercise involved a two leg cruise with the first (KN193-5) focusing on the collection of seawater reference material and the second (KN193-6) on particles. The R/V Knorr departed Norfolk, Virginia USA and transected to the BATS station southeast of Bermuda where the bulk of sampling took place. Scientific crew change for the second leg of the cruise was in Bermuda on June 27 and particle sampling began at BATS with underway sampling during the return leg to Norfolk, arriving on July 12. The research performed on this cruise was designed to support the three primary objectives of the U.S. GEOTRACES Intercalibration effort: (1) Develop and test the US GEOTRACES sampling systems and procedures for dissolved and particulate TEIs. Results will comprise a community resource for use in all future US GEOTRACES' cruises; (2) Using these systems, conduct a thorough intercalibration for all the key GEOTRACES TEIs, and as many others as possible, in the dissolved and particulate phases through the participation of the worldwide TEI community; (3) Establish a GEOTRACES Baseline Station in the western North Atlantic, specifically at the Bermuda Atlantic Time Series Station, as part of the Intercalibration Cruise. This research is a collaborative effort among 3 Principal Investigators (Cutter, Old Dominion U.; Bruland, U. of California, Santa Cruz; R. Sherrell, Rutgers U.), but participation in the intercalibration component of GEOTRACES is international and will involve at least 80 other laboratories. If you are interested in participating in this exercise, note that selected samples for intercalibration will also be available after the cruise. For general information about the intercalibration effort please contact Greg Cutter Sampling Activities: Intercalibration cruise with CTD's, several water pump systems, and trace metal water collecting Cruise Participants: (from the pre-cruise letter) Dr. Gregory Cutter, Chief Scientist, Old Dominion University Dr. Edward Boyle, Massachusetts Institute of Technology Dr. Seth John, California Institute of Technology Dr. Kenneth Bruland, University of California, Santa Cruz Mr. Matthew Brown, University of California, Santa Cruz Ms. Sherry Lippiatt, University of California, Santa Cruz Dr. Maeve Lohan, University of Plymouth, UK Mr. Geoffrey Smith, University of California, Santa Cruz Ms. Bettina Sohst, University of California, Santa Cruz Mr. Juan Santos-Echeandia, Marine Research Institute (IIM-CSIC), Spain Dr. Jay Cullen, University of Victoria, Canada Mr. Curtis Barnes, Old Dominion University Mr. Peter Morton, Old Dominion University Mr. Brandon Gipson, Old Dominion University Ms. Carie Lingle, Old Dominion University Dr. Carl Lamborg, Woods Hole Oceanographic Institution Dr. William Landing, Florida State University Ms. Kathleen Gosnell, Florida State University Dr. Robert Mason, University of Connecticut Ms. Susan Gichuki, University of Connecticut Mr. Maxime Grand, University of Hawaii Dr. Mariko Hatta, University of Hawaii Dr. Hajime Obata, University of Tokyo Dr. Robert Sherrell, Rutgers University Ms. Tali Babila, Rutgers University Ms. Christine Theodore, Rutgers University Dr. Silke Severmann, University of California, Riverside Dr. Kazuhiro Norisue, Institute for Chemical Research, Kyoto University, Japan Dr. Jingfeng Wu, University of Alaska, Fairbanks Dr. Chundi Li, South China Sea Institute of Oceanology Dr. Robert Rember, University of Alaska, Fairbanks Dr. Ana Aguilar-Islas, University of Alaska, Fairbanks Mr. James Avery, Woods Hole Oceanographic Institution Ms. Amy Simoneau, Woods Hole Oceanographic Institution</p>
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Project Information

GEOTRACES InterCalibration (GEOTRACES IC)

Website: <http://www.geotraces.org/science/intercalibration>

Coverage: Sargasso Sea, eastern North Pacific

An international intercalibration effort has been assigned a high priority during the initial phase of GEOTRACES to ensure that results from different cruises, and from different labs, can be compared in a meaningful way.

While the original data from the Intercalibration cruises are not available online, consensus values for the SAFe and North Atlantic GEOTRACES Reference Seawater Samples are available from the GEOTRACES Program Office: [Standards and Reference Materials](#)

The ultimate goal for the intercalibration component of the international GEOTRACES program is to achieve the best accuracy possible (lowest random and systematic errors) for the suite of GEOTRACES' Trace Elements and Isotopes (TEI) as a prelude to the sampling program, and continuing effort throughout the sampling and analysis program. To achieve this goal, there will be two primary efforts:

(1) Evaluate and develop GEOTRACES sample acquisition, handling, and storage protocols during initial Intercalibration Cruises;

(2) Identify existing GEOTRACES primary standards and certified reference materials (CRMs) for the TEI suite (and where needed, producing reference materials or primary standards), including the establishment of GEOTRACES Baseline Stations that can be used to evaluate accuracy from sampling to analysis (to facilitate intercalibration for TEIs that do not have CRMs).

Tentative schedule of Intercalibration events:

- June - July 2008. 1st Intercalibration cruise (Sargasso Sea): evaluate sampling apparatus and handling methods (diss and part), collect and distribute intercalibration samples, sample storage experiments, establish Baseline Station at BATS
- Dec. 2008. Second Intercalibration workshop (AGU): evaluate and interpret intercalibration results, planning for 2nd cruise
- Spring 2009. 2nd Intercalibration cruise (eastern North Pacific): final testing of complete sampling system and procedures, intercalibrate with other (non-US) sampling systems, speciation + total TEI intercalibration, determine the time to occupy one GEOTRACES station (for cruise planning purposes)
- Jan.-Feb 2010. Third Intercalibration workshop: finalize complete intercalibration results, begin assembling GEOTRACES User Manuals

GEOTRACES intercalibration cruise 1 June 2008

GEOTRACES completed the first Intercalibration cruise from June 8 to July 12, 2008 to collect intercalibration water and particle samples. This intercalibration exercise aimed to provide reference materials that could be distributed to the international community and reference profiles of Trace Elements and their Isotopes to ensure compatibility and consistency of GEOTRACES data.

GEOTRACES intercalibration cruise 2 May 2009

The second intercalibration cruise is planned for May 2009 in the eastern North Pacific and will include sampling near the North Pacific SAFe Station at 30°N, 140°W.

If you are interested in participating in this exercise, note that selected samples for intercalibration will also be available after the cruise. For general information about the intercalibration effort please contact Greg Cutter.

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Program Information

U.S. GEOTRACES (U.S. GEOTRACES)

Website: <http://www.geotraces.org/>

Coverage: Global

GEOTRACES is a [SCOR](#) sponsored program; and funding for program infrastructure development is provided by the [U.S. National Science Foundation](#).

GEOTRACES gained momentum following a special symposium, SO2: Biogeochemical cycling of trace elements and isotopes in the ocean and applications to constrain contemporary marine processes (GEOSECS II), at a 2003 Goldschmidt meeting convened in Japan. The GEOSECS II acronym referred to the Geochemical Ocean Section Studies To determine full water column distributions of selected trace elements and isotopes, including

their concentration, chemical speciation, and physical form, along a sufficient number of sections in each ocean basin to establish the principal relationships between these distributions and with more traditional hydrographic parameters;

- * To evaluate the sources, sinks, and internal cycling of these species and thereby characterize more completely the physical, chemical and biological processes regulating their distributions, and the sensitivity of these processes to global change; and

- * To understand the processes that control the concentrations of geochemical species used for proxies of the past environment, both in the water column and in the substrates that reflect the water column.

GEOTRACES will be global in scope, consisting of ocean sections complemented by regional process studies. Sections and process studies will combine fieldwork, laboratory experiments and modelling. Beyond realizing the scientific objectives identified above, a natural outcome of this work will be to build a community of marine scientists who understand the processes regulating trace element cycles sufficiently well to exploit this knowledge reliably in future interdisciplinary studies.

Expand "Projects" below for information about and data resulting from individual US GEOTRACES research projects.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0752402

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