Measurements of the dissolved isotope radium-226 from samples collected on the US GEOTRACES GP17-OCE cruise on R/V Roger Revelle (RR2214) in the South Pacific and Southern Oceans from December 2022 to January 2023

Website: https://www.bco-dmo.org/dataset/944841
Data Type: Cruise Results
Version: 1
Version Date: 2024-12-11

Project
» US GEOTRACES GP17-OCE: Investigating the role of the Southern Ocean's biogeochemical divide in shaping the global distributions of radium and barium isotopes (GP17-OCE Ra and Ba isotopes)
» US GEOTRACES GP17-OCE and GP17-ANT: Sources and Rates of Trace Element and Isotope Cycling Derived from the Radium Quartet (GP17-OCE and GP17-ANT Radium Isotopes)
» US GEOTRACES GP17 Section: South Pacific and Southern Ocean (GP17-OCE) (GP17-OCE)

Program
» U.S. GEOTRACES (U.S. GEOTRACES)

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Abstract
This dataset includes measurements of the dissolved isotope radium-226 in the South Pacific and Southern Ocean. Samples were collected on the US GEOTRACES GP17-OCE cruise (Papeete, Tahiti to Punta Arenas, Chile) on R/V Roger Revelle from December 2022 to January 2023. Radium-223, radium-224, and radium-228 data will be made available in the future.

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Coverage

Location: South Pacific and Southern Ocean
Spatial Extent: **N**:-19.999869 **E**:-75.097157 **S**:-67.000234 **W**:-152.000281
Temporal Extent: 2022-12-04 - 2023-01-24

Methods & Sampling

At sea, Radium-226 samples were collected following the GEOTRACES cookbook. Samples were collected from a 30-liter (L) Niskin mounted directly above a McLane large volume in situ pump WTS-LV (>1000 meters) or on the ODF CTD Rosette (<1000 meters). These samples (10-25 L) were recirculated through 20 grams (g) of manganese (Mn) oxide impregnated acrylic fiber at approximately <1 liter per minute (L/min) using small pumps. The Mn fibers from the Niskin bottles were rinsed with deionized water back at Woods Hole Oceanographic Institution (WHOI), partially dried, and sealed within a fiber holder after being flushed with helium equivalent to 30 column volumes. Samples were stored for a minimum of 12 days and analyzed for 226Ra via 222Rn ingrowth using alpha scintillation counting (Key et al., 1979). Samples were counted for 1-20 hours depending on the activity on the fiber, which resulted in counting uncertainties of ~2% dependent upon 226Ra content on the fiber and sample volume.

Data Processing Description

The data were corrected for decay from the time of sampling. 223Raxs was corrected for 227Ac, 224Raxs was corrected for 228Th. The radium activity of the water samples (cartridges) were corrected from the measured radium on acrylic fiber (<1L/min) using the emanation technique. Data is originally calculated in disintegrations per minute per liter (dpm/L) and is converted to milli-Becquerels per kilogram (mBq/kg) using the in situ density (rho) from the deployment at time of sampling (ODF) or the nearest available depth for the station (surface and McLane pumps).

Quality Flags:
Data were flagged using the SeaDataNet quality flag scheme. For more information on SeaDataNet flags, see: https://www.geotraces.org/geotraces-quality-flag-policy/ and https://www.seadatanet.org/Standards/Data-Quality-Control.

Quality flag definitions:
0 = No quality control;
1 = Good value;
2 = Probably good value;
3 = Probably bad value;
4 = Bad value;
5 = Changed value;
6 = Value below detection;
7 = Value in excess;
8 = Interpolated value;
9 = Missing value.

Supplemental File: The attached supplemental file, "226Ra_dpm101224.csv", contains the same data with 226Ra reported in units of dpm/100L.

BCO-DMO Processing Description

- Imported original file "226Ra.csv" into the BCO-DMO system.
- Renamed fields to comply with BCO-DMO naming conventions.
- Converted flag columns to integers (i.e. removed the trailing ".00").
- Saved the final file as "944841_v1_gp17-oce_radium_isotopes.csv"

Problem Description

Pump failures and loss during sampling resulted in some gaps in data, these samples have been flagged as missing values (quality flag 9). In cases where low volumes (<600L) were filtered due to pump malfunctions, data has been flagged as questionable (quality flag 3). Samples with activities below detection limits have also been flagged (quality flag 6), and no value is reported for those samples.

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Related Publications

Key, R. M., Brewer, R. L., Stockwell, J. H., Guinasso, N. L., & Schink, D. R. (1979). Some improved techniques for measuring radon and radium in marine sediments and in seawater. Marine Chemistry, 7(3), 251–264. doi:10.1016/0304-4203(79)90042-2
Methods

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Parameters

Parameter	Description	Units
Cruise_ID	GEOTRACES cruise name	unitless
Station_ID	GEOTRACES station number	unitless
GEOTRC_CASTNO	GEOTRACES cast number	unitless
GEOTRC_INSTR	Sampling method	unitless
Start_Date_UTC	Date (UTC) at start of sample collection	unitless
Start_Time_UTC	Time (UTC) at start of sample collection	unitless
Start_ISO_DateTime_UTC	Date and time (UTC) at start of sample collection in ISO 8601 format	unitless
End_Date_UTC	Date (UTC) at end of sample collection	unitless
End_Time_UTC	Time (UTC) at end of sample collection	unitless
End_ISO_DateTime_UTC	Date and time (UTC) at end of sample collection in ISO 8601 format	unitless
Start_Latitude	Sample collection start Latitude; negative values = South	decimal degrees
Start_Longitude	Sample collection start Longitude; negative values = West	decimal degrees
End_Latitude	Sample collection end Latitude; negative values = South	decimal degrees

End_Longitude	Sample collection end Longitude; negative values = West	decimal degrees
Event_ID	GEOTRACES event number	unitless
Sample_ID	GEOTRACES sample number	unitless
Sample_Depth	Depth of sample collection	meters (m)
Ra_226_D_CONC_BOTTLE_xuuvtd	Dissolved Radium-226 activity from Niskin bottles	milliBecquerels per kilogram (mBq/kg)
SD1_Ra_226_D_CONC_BOTTLE_xuuvtd	One standard deviation of Ra_226_D_CONC_BOTTLE_xuuvtd	milliBecquerels per kilogram (mBq/kg)
Flag_Ra_226_D_CONC_BOTTLE_xuuvtd	Quality flag for Ra_226_D_CONC_BOTTLE_xuuvtd; refer to 'Data Processing' section of metadata for flag definitions	unitless
Ra_226_D_CONC_PUMP_faz5oh	Dissolved Radium-226 activity from pumps	milliBecquerels per kilogram (mBq/kg)
SD1_Ra_226_D_CONC_PUMP_faz5oh	One standard deviation of Ra_226_D_CONC_PUMP_faz5oh	milliBecquerels per kilogram (mBq/kg)
Flag_Ra_226_D_CONC_PUMP_faz5oh	Quality flag for Ra_226_D_CONC_PUMP_faz5oh	unitless
Ra_226_D_CONC_UWAY_0nplfd	Dissolved Radium-226 activity from the ship's underway system	milliBecquerels per kilogram (mBq/kg)
SD1_Ra_226_D_CONC_UWAY_0nplfd	One standard deviation of Ra_226_D_CONC_UWAY_0nplfd	milliBecquerels per kilogram (mBq/kg)
Flag_Ra_226_D_CONC_UWAY_0nplfd	Quality flag for Ra_226_D_CONC_UWAY_0nplfd	unitless

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Instruments

Dataset-specific Instrument Name	ODF CTD Rosette
Generic Instrument Name	CTD Sea-Bird SBE 911plus
Generic Instrument Description	The Sea-Bird SBE 911 plus is a type of CTD instrument package for continuous measurement of conductivity, temperature and pressure. The SBE 911 plus includes the SBE 9plus Underwater Unit and the SBE 11plus Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 plus and SBE 11 plus is called a SBE 911 plus. The SBE 9 plus uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 plus and SBE 4). The SBE 9 plus CTD can be configured with up to eight auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). more information from Sea-Bird Electronics

Dataset-specific Instrument Name	McLane Large Volume Pumping System WTS-LV
Generic Instrument Name	McLane Large Volume Pumping System WTS-LV
Generic Instrument Description	The WTS-LV is a Water Transfer System (WTS) Large Volume (LV) pumping instrument designed and manufactured by McLane Research Labs (Falmouth, MA, USA). It is a large-volume, single-event sampler that collects suspended and dissolved particulate samples in situ. Ambient water is drawn through a modular filter holder onto a 142-millimeter (mm) membrane without passing through the pump. The standard two-tier filter holder provides prefiltering and size fractioning. Collection targets include chlorophyll maximum, particulate trace metals, and phytoplankton. It features different flow rates and filter porosity to support a range of specimen collection. Sampling can be programmed to start at a scheduled time or begin with a countdown delay. It also features a dynamic pump speed algorithm that adjusts flow to protect the sample as material accumulates on the filter. Several pump options range from 0.5 to 30 liters per minute, with a max volume of 2,500 to 36,000 liters depending on the pump and battery pack used. The standard model is depth rated to 5,500 meters, with a deeper 7,000-meter option available. The operating temperature is -4 to 35 degrees Celsius. The WTS-LV is available in four different configurations: Standard, Upright, Bore Hole, and Dual Filter Sampler. The high-capacity upright WTS-LV model provides three times the battery life of the standard model. The Bore-Hole WTS-LV is designed to fit through a narrow opening such as a 30-centimeter borehole. The dual filter WTS-LV features two vertical intake 142 mm filter holders to allow simultaneous filtering using two different porosities.

Dataset-specific Instrument Name	30-liter (L) Niskin
Generic Instrument Name	Niskin bottle
Generic Instrument Description	A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24, or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc.

Dataset-specific Instrument Name	Radium Delayed Coincidence (RaDeCC) counters
Generic Instrument Name	Radium Delayed Coincidence Counter
Dataset-specific Description	Samples were analyzed using Radium Delayed Coincidence (RaDeCC) counters and high-purity, well-type germanium detectors.
Generic Instrument Description	The RaDeCC is an alpha scintillation counter that distinguishes decay events of short-lived radium daughter products based on their contrasting half-lives. This system was pioneered by Giffin et al. (1963) and adapted for radium measurements by Moore and Arnold (1996). References: Giffin, C., A. Kaufman, W.S. Broecker (1963). Delayed coincidence counter for the assay of actinon and thoron. J. Geophys. Res., 68, pp. 1749-1757. Moore, W.S., R. Arnold (1996). Measurement of 223Ra and 224Ra in coastal waters using a delayed coincidence counter. J. Geophys. Res., 101 (1996), pp. 1321-1329. Charette, Matthew A.; Dulaiova, Henrieta; Gonneea, Meagan E.; Henderson, Paul B.; Moore, Willard S.; Scholten, Jan C.; Pham, M. K. (2012). GEOTRACES radium isotopes interlaboratory comparison experiment. Limnology and Oceanography - Methods, vol 10, pg 451.

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Deployments

RR2214

Website	https://www.bco-dmo.org/deployment/905754
Platform	R/V Roger Revelle
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/rogerrevelle_rr2214.pdf
Start Date	2022-12-01
End Date	2023-01-25
Description	The U.S. GEOTRACES GP17-OCE expedition departed Papeete, Tahiti (French Polynesia) on December 1st, 2022 and arrived in Punta Arenas, Chile on January 25th, 2023. The cruise took place in the South Pacific and Southern Oceans aboard the R/V Roger Revelle with a team of 34 scientists led by Ben Twining (Chief Scientist), Jessica Fitzsimmons, and Greg Cutter (Co-Chief Scientists). GP17 was planned as a two-leg expedition, with its first leg (GP17-OCE) as a southward extension of the 2018 GP15 Alaska-Tahiti expedition and a second leg (GP17-ANT; December 2023-January 2024) into coastal and shelf waters of Antarctica's Amundsen Sea. The GP17-OCE section encompassed three major transects: (1) a southbound pseudo-meridional section (~152-135 degrees West) from 20 degrees South to 67 degrees South; (2) an eastbound zonal transect from 135 degrees West to 100 degrees West; (3) and a northbound section returning to Chile (100-75 degrees West). Additional cruise information is available from the following sources: R2R: https://www.rvdata.us/search/cruise/RR2214 CCHDO: https://cchdo.ucsd.edu/cruise/33RR20221201 More information can also be found at: https://usgeotraces.ldeo.columbia.edu/content/gp17-oce

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Project Information

US GEOTRACES GP17-OCE: Investigating the role of the Southern Ocean's biogeochemical divide in shaping the global distributions of radium and barium isotopes (GP17-OCE Ra and Ba isotopes)

Coverage: Subtropical South Pacific, Sub-Antarctic Pacific, and Southern Oceans

NSF Award Abstract:
The GEOTRACES program aims to understand the distribution of trace elements and their isotopes in the oceans. Trace elements, by their very nature, are scarce. Despite their scarcity, trace elements are valuable tools for studying marine processes, such as: tracking chemical inputs to the ocean from the land or seafloor, identifying patterns of ocean mixing, and tracing ocean biology. This project will study these processes by measuring and modeling the distributions of two chemically similar elements — radium and barium. These measurements will be made on samples collected as part of the U.S. GEOTRACES GP17-OCE expedition. This expedition will collect samples from the Southern Ocean in late 2022. The Southern Ocean experiences deep mixing, which is important for bringing nutrients to the sea surface. Measuring radium and barium isotopes in these samples will help study the sources, cycling, and sinks of nutrients that support marine biology in the Southern Ocean and beyond. The findings will be shared with regional science teachers and students through a collaboration with the local Sea Grant Program, and the data will support the research of other scientists involved in GEOTRACES.

The last 25 years have seen a paradigm shift in our understanding of the controls on marine nutrient cycles. Rather than arising from local vertical processes, the large-scale distributions of many elements are now thought to arise from processes occurring in the Southern Ocean, which are then communicated to lower latitudes through lateral circulation. A circulation-driven mechanism is also hypothesized to contribute to the global distributions of radium and barium isotopes, but this remains to be tested. In this project, researchers from the Woods Hole Oceanographic Institution will test this hypothesis by analyzing radium and barium isotopes in dissolved and particulate samples collected from the Pacific Sector of the Southern Ocean. These measurements will establish compositions for the southern-sourced mode/intermediate and bottom waters that are important end-members in the global overturning circulation. The team will also study the processes that control the composition of the end-members — particle formation and dissolution, interactions with sediments, hydrothermalism — and assess their significance using statistical and mechanistic modeling. The results will reveal the role of the Southern Ocean in controlling the global distributions of radium and barium isotopes, which will help refine the application of these tracers as tools for studying biogeochemical processes in the present and past oceans.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

US GEOTRACES GP17-OCE and GP17-ANT: Sources and Rates of Trace Element and Isotope Cycling Derived from the Radium Quartet (GP17-OCE and GP17-ANT Radium Isotopes)

Coverage: Pacific Ocean, Southern Ocean, Amundsen Sea

NSF Award Abstract:
The goal of the GEOTRACES program is to “identify processes and quantify fluxes that control the distribution of trace elements and isotopes (TEIs) in the ocean and to establish the sensitivity of these distributions to changing environmental conditions”. This ambitious objective requires coordinated seagoing field work for collection of samples to measure many elements simultaneously across the earth’s major ocean basins. However, these comprehensive global concentration maps for trace elements cannot be properly interpreted without concurrent measurement of radioactive tracers like radium isotopes that can provide time scales of their ocean input. In this project, the investigators will measure the abundance and distribution of radium isotopes in the Southern Ocean between the southern tip of South America and Antarctica, including a detailed characterization of the Antarctic coastal marine environment. The project will support a postdoctoral research associate and involve two undergraduate student researchers in post-cruise analyses.

The main motivation of the proposed research is to utilize the quartet of radium (Ra) isotopes (224Ra, 223Ra, 228Ra, 226Ra) to enable source identification and flux quantification of TEIs during the forthcoming US GEOTRACES GP17-OCE and GP17-ANT expeditions. Measurement of Ra isotopes will allow the team to address several key questions related to ocean margin and benthic boundary processes and their role in supplying and transporting TEIs to marine ecosystems including: (1) What are the rates of lateral transport of TEIs from the Antarctic and Patagonian continental margins out to and including the high nutrient low chlorophyll (HNLC) Southern Ocean? (2) What are the TEI fluxes associated with Antarctic glacial meltwater? and (3) What are the

time scales of TEI transport associated with Pacific-Antarctic Ridge neutrally buoyant hydrothermal plumes? Boundary inputs are considered to be the dominant source of many key TEIs to the ocean including iron, however, TEI concentrations must be coupled with input and transport rates to determine their effect on marine biogeochemical cycles. The wide range of Ra isotope half-lives (3.66 days to 1600 years) allow for the quantification of TEI transport processes on time scales relevant to ocean mixing processes. The proposed coupled Ra-TEI measurements will allow the full value of the distribution of numerous TEIs as measured by GEOTRACES PIs to be realized.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

US GEOTRACES GP17 Section: South Pacific and Southern Ocean (GP17-OCE) (GP17-OCE)

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

Coverage: Papeete, Tahiti to Punta Arenas, Chile

The U.S. GEOTRACES GP17-OCE expedition departed Papeete, Tahiti (French Polynesia) on December 1st, 2022 and arrived in Punta Arenas, Chile on January 25th, 2023. The cruise took place in the South Pacific and Southern Oceans aboard the R/V Roger Revelle (cruise ID RR2214) with a team of 34 scientists lead by Ben Twining (Chief Scientist), Jessica Fitzsimmons and Greg Cutter (Co-Chief Scientists). GP17 was planned as a two-leg expedition, with its first leg (GP17-OCE) as a southward extension of the 2018 GP15 Alaska-Tahiti expedition and a second leg (GP17-ANT; December 2023-January 2024) into coastal and shelf waters of Antarctica's Amundsen Sea.

The South Pacific and Southern Oceans sampled by GP17-OCE play critical roles in global water mass circulation and associated global transfer of heat, carbon, and nutrients. Specific oceanographic regions of interest for GP17-OCE included: the most oligotrophic gyre in the global ocean, the Antarctic Circumpolar Current (ACC) frontal region, the previously unexplored Pacific- Antarctic Ridge, the Pacific Deep Water (PDW) flow along the continental slope of South America, and the continental margin inputs potentially emanating from South America.

Further information is available on the US GEOTRACES website and in the cruise report (PDF).

NSF Project Title: Collaborative Research: Management and Implementation of US GEOTRACES GP17 Section: South Pacific and Southern Ocean (GP17-OCE)

NSF Award Abstract:
This award will support the management and implementation of a research expedition from Tahiti to Chile that will enable sampling for a broad suite of trace elements and isotopes (TEI) across oceanographic regions of importance to global nutrient and carbon cycling as part of the U.S. GEOTRACES program. GEOTRACES is a global effort in the field of Chemical Oceanography, the goal of which is to understand the distributions of trace elements and their isotopes in the ocean. Determining the distributions of these elements and isotopes will increase understanding of processes that shape their distributions, such as ocean currents and material fluxes, and also the processes that depend on these elements, such as the growth of phytoplankton and the support of ocean ecosystems. The proposed cruise will cross the South Pacific Gyre, the Antarctic Circumpolar Current, iron-limited Antarctic waters, and the Chilean margin. In combination with a proposed companion GEOTRACES expedition on a research icebreaker (GP17-ANT) that will be joined by two overlapping stations, the team of investigators will create an ocean section from the ocean's most nutrient-poor waters to its highly-productive Antarctic polar region - a region that plays an outsized role in modulating the global carbon cycle. The expedition will support and provide management infrastructure for additional participating science projects focused on measuring specific external fluxes and internal cycling of TEIs along this section.

The South Pacific Gyre and Pacific sector of the Southern Ocean play critical roles in global water mass circulation and associated global transfer of heat, carbon, and nutrients, but they are chronically understudied for TEIs due to their remote locale. These are regions of strong, dynamic fronts where sub-surface water masses upwell and subduct, and biological and chemical processes in these zones determine nutrient stoichiometries and tracer concentrations in waters exported to lower latitudes. The Pacific sector represents an end member of extremely low external TEI surface fluxes and thus an important region to constrain inputs from the rapidly-changing Antarctic continent. Compared to other ocean basins, TEI cycling in these regions is

thought to be dominated by internal cycling processes such as biological uptake, regeneration, and scavenging, and these are poorly represented in global ocean models. The cruise will enable funded investigators to address research questions such as: 1) what are relative rates of external TEI fluxes to this region, including dust, sediment, hydrothermal, and cryospheric fluxes? 2) What are the (micro) nutrient regimes that support productivity, and what impacts do biomass accumulation, export, and regeneration have on TEI cycling and stoichiometries of exported material? 3) What are TEI and nutrient stoichiometries of subducting water masses, and how do scavenging and regeneration impact these during transport northward? This management project has several objectives: 1) plan and coordinate a 55-day research cruise in 2021-2022; 2) use both conventional and trace-metal 'clean' sampling systems to obtain TEI samples, as well as facilitate sampling for atmospheric aerosols and large volume particles and radionuclides; 3) acquire hydrographic data and samples for salinity, dissolved oxygen, algal pigments, and macro-nutrients; and deliver these data to relevant repositories; 4) ensure that proper QA/QC protocols, as well as GEOTRACES intercalibration protocols, are followed and reported; 5) prepare the final cruise report to be posted with data; 6) coordinate between all funded cruise investigators, as well as with leaders of proposed GP17-ANT cruise; and 7) conduct broader impact efforts that will engage the public in oceanographic research using immersive technology. The motivations for and at-sea challenges of this work will be communicated to the general public through creation of immersive 360/Virtual Reality experiences, via a collaboration with the Texas A&M University Visualization LIVE Lab. Through Virtual Reality, users will experience firsthand what life and TEI data collection at sea entail. Virtual reality/digital games and 360° experiences will be distributed through GEOTRACES outreach websites, through PI engagement with local schools, libraries, STEM summer camps, and adult service organizations, and through a collaboration with the National Academy of Sciences.

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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, S02: 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-2048604
NSF Division of Ocean Sciences (NSF OCE)	OCE-2048067

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