Dissolved thorium and protactinium isotopes (232Th, 230Th, 231Pa) in seawater from Leg 2 (Hilo, HI to Papeete, French Polynesia) of the US GEOTRACES Pacific Meridional Transect (PMT) cruise (GP15, RR1815) on R/V Roger Revelle from Oct-Nov 2018

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Project
» US GEOTRACES Pacific Meridional Transect (GP15) (U.S. GEOTRACES PMT)
» Collaborative Research: U.S. GEOTRACES Pacific Meridional Transect: Thorium-232, Thorium-230 and Protactinium-231 as tracers of trace element supply and removal (PMT Thorium Isotopes)

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

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Abstract

This dataset contains concentrations of dissolved thorium and protactinium isotopes (232Th, 230Th, 231Pa) in seawater collected during the U.S. GEOTRACES Pacific Meridional Transect (PMT) GP15, from Alaska to Tahiti, on the R/V Roger Revelle. The PMT expedition was divided into two legs, with cruise IDs RR1814 and RR1815. This dataset results from leg 2, RR1815; data from RR1814 are available in a separate BCO-DMO dataset. This is compiled data produced by three laboratories with the following associations: Lamont-Doherty Earth Observatory of Columbia University (LDEO), the University of Southern Mississippi (USM), and the University of Minnesota (UMN).

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Coverage

Location: North Pacific; Equatorial Pacific: South Pacific Ocean; 55 N to 20 S along 152 W
Spatial Extent: **N**:18.906 **E**:-151.986 **S**:-20 **W**:-155.258
Temporal Extent: 2018-10-25 - 2018-11-23

Methods & Sampling

Sampling Methods at Sea

BOTTLE Samples: Sampling methods at sea followed the GEOTRACES cookbook (Cutter et al., 2017). Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with 36 10-liter PVC Niskin bottles, managed and operated by the Ship-based Science Technical Support and the Ocean Data Facility (ODF) of Scripps Institution of Oceanography. The rosette was lowered from the ship on a standard conducting hydrowire. Niskin bottles were equipped with nylon-coated closure springs and Viton O-rings. After collection, seawater was drained through Teflon-lined Tygon tubing and filtered through Pall Acropak 500 filters on deck (gravity filtration, 0.8/0.45 micrometer (µm) pore size) into LDPE cubitainers. In a departure from previous US GEOTRACES cruises, and at the request of the group measuring neodymium (Nd) isotopes, shallow casts of the ODF rosette collected single 10-liter samples for thorium (Th) isotopes, Protactinium-231 (231Pa), and Nd isotopes, rather than each group getting a 5-liter sample for themselves. In the rest of this description, volumes should be doubled for the single 10-liter samples. Approximately 4-5 liters were collected per desired depth for each dissolved sample. Once filtered, samples were adjusted to a pH of ~2 with 20 milliliters (mL) 6 M HCl (redistilled Fisher Scientific Trace Metal grade HCl diluted 1:1 with 18.2 MΩ H2O), double-bagged, stored in pallet boxes on-deck until the end of the cruise, and then at room temperature once shipped to the participating laboratories for analysis.

FISH Samples: Parameter names include Th_232_D_CONC_ FISH, Th_230_D_CONC_ FISH, and Pa_231_D_CONC_ FISH. Selected samples were collected using a towed pumping system designed to collect uncontaminated water at 2-3 meters depth, indicated by FISH in the parameter name. FISH samples were filtered by a 0.2 µm Osmonics filter capsule. FISH samples from GP15 that were analyzed for Th and Pa were processed at UMN.

Analytical Methods at LDEO

In this section, it should be noted that the following reagents were Fisher Scientific OPTIMA grade: Ammonium Hydroxide (NH4OH), Perchloric Acid (HClO4), and Hydrofluoric Acid (HF). Hydrochloric Acid (HCl) and Nitric Acid (HNO3) were Fisher Trace Metal Grade acids that had been redistilled in Savillex Teflon Sub-Boiling Stills. In the on-shore laboratory, seawater samples were weighed and then aliquots of the artificial isotope yield monitors (spikes) 229Th (~1 picogram (pg)) and 233Pa (0.05-0.17 pg), and 25 milligrams (mg) dissolved iron (Fe), were added to each sample. The 10-liter samples got twice the amount of dissolved Fe as the 5-liter samples, but the same amounts of the yield monitors. After allowing 1 day for spike equilibration, the pH of each sample was raised to ~8.5 by the addition of concentrated NH4OH, which caused iron (oxy)hydroxide precipitates to form. Each sample cubitainer was fitted with a spigot cap, inverted, and the Fe precipitate was allowed to settle for 2 days. After 2 days, the spigots were opened and the overlying water was slowly drained, leaving only the iron oxyhydroxide precipitate and 250-500 mL of water. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with Milli-Q H2O. The precipitate was then dissolved in 16M HNO3 and transferred to a Teflon vial for a high-temperature (180-200°C) digestion with concentrated HClO4 and HF 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 Milli-Q H2O, centrifuged, and dissolved 16 M HNO3. After conversion to concentrated HCl, Th isotopes and Pa were purified by anion-exchange chromatography using 6 mL polypropylene columns each containing 1 mL of Bio-Rad AG1-X8, 100-200 mesh size resin. For 10-liter samples, 2 mL of the same resin was used for the primary column. Details can be found in Anderson et al., 2012. Separate, purified Th and Pa fractions were dried down at 180-200°C in the presence of 2 drops of concentrated HClO4 and taken up in 0.5 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, relative to the calibrated tracers 229Th and 233Pa added at the beginning of sample processing. Analyses were carried out on a Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS. To ensure the highest possible sensitivity, the instrument was equipped with a high-performance interface pump (Pfeiffer OnTool Booster 150 "Jet Pump"), high-performance sample (Jet) and skimmer (X) cones, and a desolvating nebulizer, CETAC Aridus I. For increased signal stability, an Elemental Scientific (ESI) Continuum syringe pump system was employed for sample introduction to the Aridus I. Sample uptake rate was ~100 microliters per minute (µL/min) and sample analysis time was on the order of 3 minutes.

All measurements were made in low-resolution mode ($M/\Delta m \approx 300$), peak jumping in Escan mode across the central 5% of the flat-topped peaks. Measurements were made on a MasCom discrete dynode Secondary Electron Multiplier (SEM). 229Th, 230Th, 231Pa, and 233Pa were measured in Counting mode, while the 232Th signal was large enough that it had to be measured in Analog mode. Two solutions of SRM129, a natural uranium (U) standard, were run multiple times throughout each run. One solution was in a concentration range where 238U and 235U were both measured in Counting mode, allowing us to determine the mass bias/amu (values varied from -0.5%/amu to +0.2%/amu). In the other, more concentrated solution, 238U was measured in Analog mode and 235U was measured in Counting mode, yielding a measurement of the Analog/Counting Correction Factor (typical values varied from 0.9 to 1.1). These corrections assume that the mass bias and Analog/Counting Correction Factor measured on U isotopes can be applied to Th and Pa isotope measurements. Each sample measurement was bracketed by measurement of an aliquot of the run solution (0.16 M HNO3/0.026 M HF), which was used to correct for the instrumental background count rates. To correct for tailing of 232Th into the minor Th and Pa isotopes, a set of external 232Th standards were run at concentrations bracketing the expected 232Th concentrations in the samples. The analysis routine for these standards was identical to the analysis routine for samples, so we could see the changing beam intensities at the minor masses as we increased the concentration of the 232Th standards. The 232Th count rates in our Pa fractions were quite low after separation of Pa from Th during anion-exchange chromatography, reflecting mainly reagent blanks, compared to the 232Th signal intensity in the Th fraction. The regressions of 229Th, 230Th, 231Pa, and 233Pa signals as a function of the 232Th signal in the standards was used to correct for tailing of 232Th in samples. Only in rare cases was a tail correction of 232Th on 231Pa and 233Pa necessary, while it was almost always the case that tail corrections of 232Th on 229Th and 230Th were performed.

Water samples were analyzed in batches of 15. Procedural blanks were determined by processing 4-5 liters of Milli-Q H2O in an acid-cleaned cubitainer acidified to pH ~2 with 6 M HCl (Fisher Scientific OPTIMA grade) as a sample in each batch. Two procedural blanks were processed with each batch, with about half of the procedural blanks acidified at sea during RR1814-15 and the other half acidified in the on-shore laboratory before sample processing. The difference in the procedural blank values for 232Th, 230Th, and 231Pa between acidifying procedural blanks at sea or in the on-shore laboratory was statistically insignificant. An aliquot of intercalibrated in-house standard solutions of 232Th, 230Th, and 231Pa; SW STD 2010-1, referred to by Anderson et al. (2012) was added to an acid-cleaned Teflon beaker along with weighed aliquots of 229Th and 233Pa spike. Spiked SW STDs were equilibrated for at least 1 day. They were then dried down and dissolved in concentrated (12 M) HCl (Fisher Scientific OPTIMA grade) and processed with samples for each batch.

The same amount of the SW STD 2010-1, together with 229Th and 233Pa solutions, were also added to an acid-cleaned cubitainer with ~4-5 liters of Milli-Q H2O. Spikes and SW STD were equilibrated for at least 1 day. The cubitainer with the SW STD was processed equivalently to all sample cubitainers.

Samples were corrected using the pooled average of all procedural blanks analyzed during the processing of RR1814-15 dissolved samples. The average procedural blanks for 232Th, 230Th, and 231Pa are shown in the "Table 1" Supplemental File. The limit of detection (LOD) is the smallest quantity of each isotope in samples that can reliably be detected or that can be statistically distinguished from a procedural blank. The LOD was considered to be two standard deviations above the average of the procedural blanks.

Further details on the analysis of seawater dissolved radionuclides are given by Anderson et al. (2012).

Analytical Methods at USM

Processing of samples at USM was very similar to that at LDEO with the main differences being spiking ratios (due to a slightly lower sensitivity ICP-MS) and acid chemistry (no perchloric acid is allowed at the USM location). In the on-shore laboratory, seawater 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 229Th (10 pg) and 233Pa (~0.8 pg) and 10 mg dissolved Fe were added to each sample. After allowing 1 day for spike equilibration, the pH of each sample was raised to 8-9 by adding ~10-14 mL of concentrated NH4OH (Fisher Scientific OPTIMA grade) which caused iron (oxy)hydroxide precipitates to form. Each sample cubitainer was fitted with a nozzle cap, inverted, and the Fe precipitate was allowed to settle for 2 days. After 2 days, the nozzle caps were opened and the pH~8-9 water was slowly drained, leaving only the iron oxyhydroxide precipitate and 250-500 mL of water. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with Milli-Q H2O (>18 MΩ) to remove the major seawater ions. The precipitate was then dissolved in 8M HNO3 (Fisher Scientific OPTIMA grade) and transferred to a Teflon beaker for acid digestions. First, the nitric sample solution was dried to near dry at 180-200°C. The sample was then taken up in 1-2 mL 8 M HNO3, the beakers capped and the samples refluxed at 180°C for at least 3 hours. The sample was then cooled, uncapped, retaining all sample drops in the beaker, heated again to 180°C for an HF (Optima) addition of 1 mL. This solution was dried at 180°C to a white precipitate that is dissolvable in optima HCl. After total dissolution of the sample, another precipitation of iron (oxy)hydroxide followed and the precipitate was washed with Milli-Q H2O, centrifuged, and dissolved in 8M HCl (Fisher Scientific OPTIMA grade) for a series of anion-exchange chromatography using 6 mL polypropylene columns each containing a 1 mL bed of Bio-rad resin (AG1-X8, 100-200 mesh size) and a 45 µm porous polyethylene frit (Anderson et al., 2012). The final column elutions were dried down at 180-200°C in the presence of 2 drops of concentrated HNO3 (Fisher Scientific OPTIMA grade) and taken up in 1.0 mL of 0.32 M HNO3 (Fisher Scientific OPTIMA grade) for mass spectrometric analysis. Digestions and columns were done in a standard fume hood, but whenever samples were sealed (i.e., no acid fumes) they were handled in a benchtop HEPA-filtered laminar flow hood.

Concentrations of 232Th, 230Th and 231Pa were calculated by isotope dilution, relative to the calibrated tracers 229Th and 233Pa added at the beginning of sample processing. Analyses were carried out on a Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS. This model lacks the high-performance Interface pump (Jet Pump Aridus I™) mentioned above, but we did utilize the specially designed sample (Jet) and skimmer (X) cones which increased sensitivity. All measurements were made in low-resolution mode (Δm/M≈300), peak jumping in Escan mode across the central 5% of the flat-topped peaks. Measurements were made on a MasCom™ SEM; 229Th, 230Th, 231Pa, and 233Pa were measured in Counting mode, while the 232Th signals were large enough that they were measured in Analog mode. Two solutions of SRM129, a natural U standard, were run multiple times throughout each run. One solution was in a concentration range where 238U and 235U were both measured in Counting mode, allowing us to determine the mass bias/amu (typical values varied from -0.5%/amu to +0.2%/amu). In the other, more concentrated solution, 238U was measured in Analog mode and 235U was measured in Counting mode, yielding a measurement of the Analog/Counting Correction Factor (typical values varied from 0.9 to 1.1). These corrections assume that the mass bias and Analog/Counting Correction Factor measured on U isotopes can be applied to Th and Pa isotope measurements. Each sample measurement was bracketed by measurement of an aliquot of the run solution (0.32 M HNO3), which was used to correct for the instrumental background count rates. Tailing of 232Th into the minor Th and Pa isotopes was monitored by counting at the half-masses surrounding 230Th and 231Pa. Tailing corrections were typically small (<0.5% and often negligible).

Water samples were analyzed in batches of 14 to 22 (12 batches total). Procedural blanks were determined by processing 4-5 L of Milli-Q H2O in an acid-cleaned cubitainer acidified to pH ~2 with 6 M HCl (Fisher Scientific OPTIMA grade) as a sample in each batch (n = 12 total procedural blanks). A smaller number (n = 3) of "at-sea" blanks were analyzed which were cubitainers filled with MQ-H2O and acidified at sea. "At-sea" blanks fell into the range of blanks reported below. In addition to the procedural blanks, with every batch an aliquot of one of two intercalibrated working standard solutions of 232Th, 230Th, and 231Pa, SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has ~6 times lower 232Th activity, were added to acidified MQ-H2O and treated like a sample. Sample concentrations were corrected using the procedural blank analyzed within each batch of samples. Procedural blank, limit of detection and the results of the reference material solutions are reported in the "Table 2" Supplemental File. The limit of detection (LOD) is the smallest quantity of each isotope in samples that can reliably be detected or that can be statistically distinguished from a procedural blank. The LOD was considered to be two standard deviations above the average of the procedural blanks and we have scaled the limit of detection into the equivalent concentration in a 5 liter sample. In some cases our sample analyses approach or go below these limits of detection and in these cases we have flagged those data as below detection. Our results for SWS 2010-1 are within the consensus range from the intercalibration exercise (Anderson et al., 2012). Consensus values for SWS2015-1 have not been yet been coordinated but they agree with the reports of the LDEO lab. As an additional measure of our internal consistency, we analyzed a set of 4 replicate samples that were Niskin bottles fired at the same depth at a station but from a different cast (casts were designed to overlap for at least one depth). Our %error agreement with these replicates were similar to the %RSD reported for the standard reference material solutions.

Analytical Methods at UMN

The procedures described below apply to FISH samples as well as to BOTTLE samples. All of the FISH samples from GP15 analyzed for 232Th, 230Th, and 231Pa were processed at UMN.

In the on-shore laboratory, 1-liter aliquots of the seawater samples were weighed to determine sample size, taking into account the weight of the subsample container and of the acid added at sea. Then, weighed aliquots of the artificial isotope yield monitors 229Th (1 pg) and 233Pa (0.2-0.6 pg) and 3 mg dissolved Fe were added to each sample. After allowing 3 days for spike equilibration (at a temperature of about 40°C), the pH of each sample was raised to 8.0-8.5 by adding concentrated NH4OH which caused iron (oxy)hydroxide precipitates to form. This precipitate was allowed to settle for 1-2 days before the overlaying seawater was siphoned off. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with deionized H2O (>18 MΩ) to remove the major seawater ions. The precipitate was then dissolved in 14 M HNO3 and transferred to a Teflon beaker. It was then dried down and taken up in 7 M HNO3 for anion-exchange chromatography using Bio-rad resin (AG1-X8, 100-200 mesh size) and a polyethylene frit. Initial separation was done on Teflon columns with a 0.75 mL column volume (CV). The sample was loaded in 0.75 mL (1 CV) of 7 M HNO3, followed by 1.125 mL (1.5 CV) of 7 M HNO3 (to wash Fe and other undesired elements off the resin), 2.25 mL (3 CV) of 8 M HCl (to collect Th fraction), and 2.25 mL (3 CV) of 8 M HCl/0.015 M HF (to collect Pa fraction). The Pa and Th fractions were then dried down in the presence of 2 drops of concentrated HClO4 and taken up in 7 M HNO3. They were each passed through second and third columns (each with 0.5 mL column volumes) using similar elution schemes. The final Pa and Th fractions were then dried down in the presence of 2 drops of concentrated HClO4 and dissolved in weak nitric acid for analysis on the mass spectrometer.

Concentrations of 232Th, 230Th, and 231Pa were calculated by isotope dilution using nuclide ratios determined on a Thermo-Finnigan Neptune Multicollector ICP-MS. All measurements were done using a peak jumping routine in ion Counting mode on the discreet dynode multiplier behind the retarding potential quadrupole. A solution of 233U-236U tracer 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 (weak nitric acid), which was used to correct for the instrument background count rates on the masses measured.

Water samples were analyzed in batches of 28-56. Procedural blanks were determined by performing a complete chemical procedure on 1 L of Milli-Q water with each batch of samples. An aliquot of one of two intercalibrated working standard solutions of 232Th, 230Th and 231Pa, SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has ~6 times lower 232Th activity, was added to a separate acid-cleaned Teflon beaker along with weighed aliquots of 229Th and 233Pa spike. Spikes and SW STD were equilibrated for 3 days. They were then dried down and taken up in 7 M HNO3 for anion-exchange chromatography and processed like a sample with each batch. RR1814-15 dissolved samples were corrected using the procedural blank analyzed during the same sample batch. The average procedural blanks for 232Th, 230Th and 231Pa were 0.6021 ± 0.0045 pg/kg, 0.33 ± 0.19 fg/kg, and 0.037 ±

0.010 fg/kg, respectively. The limit of detection (LOD) is the smallest quantity of each isotope in samples that can reliably be detected or that can be statistically distinguished from a procedural blank. The LOD was considered to be two standard deviations above the average of the procedural blanks. Our LOD for 232Th, 230Th and 231Pa were 0.009 pg/kg, 0.38 fg/kg, and 0.02 fg/kg, respectively. Procedural blank, limit of detection, and the results of the reference material solutions are reported in the "Table 3" Supplemental File.

Data Processing Description

Data Processing:
The reported errors for radionuclide concentrations represent the propagation of one sigma errors based on the standard isotope ratios collected by ICP-MS, estimated error in the 229Th or 233Pa spike concentration, and the blank correction of the individual isotopes. For LDEO, samples were corrected for blanks using the pooled average of all procedural blanks analyzed during processing of RR1814-15 dissolved samples, while for USM and UMN, samples were corrected for blanks using the procedural blank analyzed during the same sample batch.

Analysis of all samples was completed over the course of several 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 processed at LDEO and at USM were estimated using the bottle salinity (S) measured from the CTD and the U-Salinity relationship in seawater (Owens et al., 2011), [U] = (0.100 * S – 0.326) 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]. U concentrations in the samples processed at UMN were estimated using the bottle salinity (S) measured from the CTD for the intercalibration samples collected at Station 35, and salinity measured with a salinometer for the FISH samples. The U/Salinity relationship used for these samples was the same as that described above for samples analyzed at LDEO and USM.

Individual uncertainties for protactinium and thorium were calculated to include contributions from (a) blank correction using the variance of the blanks measured over the course of the analyses, (b) standard error of the ratios of the analysis (typically close to counting statistics) and (c) spike calibration. For protactinium we also included assessment of the correction from the yield correction, mass bias and instrument background. In order to assess the reproducibility of the procedure, repeat analyses were performed on the GEOTRACES 2010-1 and 2015-1 artificial seawater standards. For standards run alongside GP15 dissolved samples at LDEO, the reproducibility for each isotope was 2.40% for 232Th, 0.91% for 230Th, and 1.93% for 231Pa on SW STD 2010-1. SW STD 2015-1 was not analyzed with GP15 seawater samples at LDEO. At USM the reproducibility for each isotope was 10% for 232Th, 10% for 230Th, and 18% for 231Pa on SW STD 2010-1, and improved to 1.1% for 232Th, 0.5% for 230Th, and 5.8% for 231Pa during subsequent analysis of SW STD 2015-1. At UMN, the reproducibility for each isotope was 1.2% for 232Th, 1.8% for 230Th, and 2.1% for 231Pa on SW STD 2015-1. SW STD 2010-1 was not analyzed at UMN with GP15 seawater samples.

Notes on Derived Parameters:
Th_230_D_XS_CONC_BOTTLE:
The dissolved excess 230Th concentration refers to the measured dissolved 230Th corrected for a contribution of 230Th due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of 230Th produced in the water by decay of dissolved 234U. We estimate the lithogenic 230Th using measured dissolved 232Th and a lithogenic 230Th /232Th ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002) and a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_BOTTLE = Th_230_D_CONC_BOTTLE – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_BOTTLE

Pa_231_D_XS_CONC_BOTTLE:
The dissolved excess 231Pa concentration refers to the measured dissolved 231Pa corrected for a contribution of 231Pa due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of 231Pa produced in the water by decay of dissolved 235U. We estimate the 231Pa using measured dissolved 232Th and a lithogenic 231Pa/232Th ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McClennan, 1995) and secular equilibrium between 231Pa and 235U in the lithogenic material. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_BOTTLE = Pa_231_D_CONC_BOTTLE – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_BOTTLE

Th_230_D_XS_CONC_FISH:
The dissolved excess 230Th concentration refers to the measured dissolved 230Th corrected for a contribution of 230Th due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of 230Th produced in the water by decay of dissolved 234U. We estimate the lithogenic

230Th using measured dissolved 232Th and a lithogenic 230Th /232Th ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002) and a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_FISH = Th_230_D_CONC_FISH – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_FISH.

Pa_231_D_XS_CONC_FISH:
The dissolved excess 231Pa concentration refers to the measured dissolved 231Pa corrected for a contribution of 231Pa due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of 231Pa produced in the water by decay of dissolved 235U. We estimate the 231Pa using measured dissolved 232Th and a lithogenic 231Pa/232Th ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McClennan, 1995) and secular equilibrium between 231Pa and 235U in the lithogenic material. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_FISH = Pa_231_D_CONC_FISH – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_FISH.

Quality Flags:
SeaDataNet quality flags have been assigned to all measured and derived parameters. More information on SeaDataNet quality flags is available from GEOTRACES at https://www.geotraces.org/geotraces-quality-flag-policy/ and from SeaDataNet at https://www.seadatanet.org/Standards/Data-Quality-Control. In summary:

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;
A = value phenomenon uncertain.

The SeaDataNet quality flags assigned to the derived parameters are based on the SeaDataNet quality flags assigned to the measured parameters and are defined as:

1 = good value = both Th-230 (Pa-231) and Th-232 are flagged as good (1);

2 = probably good value = either Th-230 (Pa-231) is flagged as good (1) and Th-232 is flagged as probably good (2), probably bad (3), or bad (4), or Th-230 (Pa-231) is flagged as probably good (2) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

3 = probably bad value = Th-230 (Pa-231) is flagged as probably bad (3) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

4 = bad value = Th-230 (Pa-231) is flagged as bad (4) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

6 = value below detection = either or both Th-230 (Pa-231) and Th-232 are flagged as below detection (6) and neither are flagged as missing (9);

9 = missing value = either or both Th-230 (Pa-231) and Th-232 are flagged as missing (9).

Concentrations below the limit of detection (LOD) are indicated as "nd" and flagged with "6". The missing data identifier, "nd", also refers to no data available when flagged with "9" (i.e., no analysis).

Notes on Parameter Names:
Parameter names in the form Th_232_D_CONC_BOTTLE, Th_230_D_CONC_BOTTLE and Pa_231_D_CONC_BOTTLE, as well as Th_232_D_CONC_FISH, Th_230_D_CONC_ FISH and Pa_231_D_CONC_ FISH, are adopted based on a recommendation from the GEOTRACES community (https://www.geotraces.org/parameter-naming-conventions/).

"Dissolved" (D) here refers to that which passed through stacked 0.8/0.45 µm Acropak™ 500 filter capsules sampled from conventional Niskin bottles on a CTD rosette (BOTTLE Number of the Rosette indicated with GSNIS-#). All seawater samples were weighed directly in the on-shore laboratory to determine sample size, taking into account acid added at sea.

Units of Measurement:
Radionuclide concentrations are given as micro-Becquerel (10e-6 Bq, µBq or micro-Bq) per kilogram water for 230Th and 231Pa, and picomole (10e-12 mol, pmol) per kilogram water for 232Th. Becquerel is the SI unit for radioactivity

and is defined as 1 disintegration per second. These units are recommended by the GEOTRACES community.

BCO-DMO Processing Description

Version 1 (date: 2024-03-15):
- Imported original file "GEOTRACES GP15 RR1815 Dissolved 230Th 232Th 231Pa Data Corrd10Feb24.xlsx" into the BCO-DMO system.
- Flagged "nd" as a missing data value (missing data are empty/blank in the final CSV file).
- Renamed fields to comply with BCO-DMO naming conventions.
- Created the Start_ISO_DateTime_UTC and End_ISO_DateTime_UTC fields in ISO 8601 format.
- PI R. Anderson provided a modified copy of the data file in which data values have been rounded to significant figures.
- Published this final file as "920078_v1_rr1815_dissolved_th_and_pa.csv".

Version 2 (date: 2024-08-01):
- PI R. Anderson provided a new copy of the data file, named "920078_v2_rr1815_dissolved_th_and_pa.xlsx", that includes corrections. Specifically, for RR1815 (GEOTRACES GP15 Leg 2), at Station 35, the Th_232_D_CONC_BOTTLE data from the University of Minnesota (UMN) were not corrected for blanks in the version 1 file. This has been corrected in version 2.
- Imported original file "920078_v2_rr1815_dissolved_th_and_pa.xlsx" into the BCO-DMO system.
- Published the final file as "920078_v2_rr1815_dissolved_th_and_pa.csv".

Version 3 (date: 2025-04-17):
- PI R. Anderson provided a new copy of the data file, named "919783_v1_rr1814_dissolved_th_and_pa_corrd_6Apr25.xlsx", identifying corrections needed to several FISH event numbers.
- Imported file "919783_v1_rr1814_dissolved_th_and_pa_corrd_6Apr25.xlsx" into the BCO-DMO system.
- Corrected event numbers for the following sample numbers: 14127, 14138, 14785, 14787.
- Published the final file as "920078_v3_rr1815_dissolved_th_and_pa.csv".

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Data Files

File
920078_v3_rr1815_dissolved_th_and_pa.csv (Comma Separated Values (.csv), 50.22 KB) MD5:a92fe0d1841e69adad5c87dac3733189 Primary data file for dataset ID 920078, version 3

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Supplemental Files

File
Table1.pdf (Portable Document Format (.pdf), 616.21 KB) MD5:a0e331de0d6c0a532b1eb3bedf842a48 Supplemental file for dataset IDs 919783 and 920078. Contains information on the procedural blank, limit of detection, and the results of the reference material solutions analyzed by LDEO.
Table2.pdf (Portable Document Format (.pdf), 676.19 KB) MD5:49fe1f19ea3dbe95374812d2e9536450 Supplemental file for dataset IDs 919783 and 920078. Contains information on the procedural blank, limit of detection, and the results of the reference material solutions analyzed by USM.
Table3.pdf (Portable Document Format (.pdf), 620.63 KB) MD5:a73556d62c6d0d4219fa6974b101e10f Supplemental file for dataset IDs 919783 and 920078. Contains information on the procedural blank, limit of detection, and the results of the reference material solutions analyzed by UMN.

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Related Publications

Andersen, M. B., Stirling, C. H., Zimmermann, B., & Halliday, A. N. (2010). Precise determination of the open ocean 234U/238U composition. Geochemistry, Geophysics, Geosystems, 11(12), n/a–n/a. doi:10.1029/2010gc003318
Methods

Anderson, R. F., Fleisher, M. Q., Robinson, L. F., Edwards, R. L., Hoff, J. A., Moran, S. B., … Francois, R. (2012). GEOTRACES intercalibration of 230Th, 232Th, 231Pa, and prospects for 10Be. Limnology and Oceanography: Methods, 10(4), 179–213. doi:10.4319/lom.2012.10.179
Methods

Cheng, H., Edwards, R. L., Hoff, J., Gallup, C. D., Richards, D. A., & Asmerom, Y. (2000). The half-lives of uranium-234 and thorium-230. Chemical Geology, 169(1-2), 17–33. doi:10.1016/s0009-2541(99)00157-6
General

Cheng, H., Edwards, R. L., Shen, C.-C., Polyak, V. J., Asmerom, Y., Woodhead, J., … Alexander Jr., E. C. (2013). Improvements in 230Th dating, 230Th and 234U half-life values, and U–Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. Earth and Planetary Science Letters, 371-372, 82–91. doi:10.1016/j.epsl.2013.04.006
General

Cutter, Gregory, Casciotti, Karen, Croot, Peter, Geibert, Walter, Heimbürger, Lars-Eric, Lohan, Maeve, Planquette, Hélène, van de Flierdt, Tina (2017) Sampling and Sample-handling Protocols for GEOTRACES Cruises. Version 3, August 2017. Toulouse, France, GEOTRACES International Project Office, 139pp. & Appendices. DOI: http://dx.doi.org/10.25607/OBP-2
Methods

Owens, S. A., Buesseler, K. O., & Sims, K. W. W. (2011). Re-evaluating the 238U-salinity relationship in seawater: Implications for the 238U–234Th disequilibrium method. Marine Chemistry, 127(1-4), 31–39. doi:10.1016/j.marchem.2011.07.005
Methods

Roy-Barman, M., Coppola, L., & Souhaut, M. (2002). Thorium isotopes in the western Mediterranean Sea: an insight into the marine particle dynamics. Earth and Planetary Science Letters, 196(3-4), 161–174. doi:10.1016/s0012-821x(01)00606-9
Methods

Shen, C.-C., Cheng, H., Edwards, R. L., Moran, S. B., Edmonds, H. N., Hoff, J. A., & Thomas, R. B. (2003). Measurement of Attogram Quantities of 231Pa in Dissolved and Particulate Fractions of Seawater by Isotope Dilution Thermal Ionization Mass Spectroscopy. Analytical Chemistry, 75(5), 1075–1079. doi:10.1021/ac026247r
General

Shen, C.-C., Edwards, R. L., Cheng, H., Dorale, J. A., Thomas, R. B., Moran, S. B., … Edmonds, H. N. (2002). Uranium and thorium isotopic and concentration measurements by magnetic sector inductively coupled plasma mass spectrometry. Chemical Geology, 185(3-4), 165–178. doi:10.1016/s0009-2541(01)00404-1
General

Shen, C.-C., Wu, C.-C., Cheng, H., Edwards, R. L., Hsieh, Y.-T., Gallet, S., … Spötl, C. (2012). High-precision and high-resolution carbonate 230Th dating by MC-ICP-MS with SEM protocols. Geochimica et Cosmochimica Acta, 99, 71–86. doi:10.1016/j.gca.2012.09.018
General

Weyer, S., Anbar, A. D., Gerdes, A., Gordon, G. W., Algeo, T. J., & Boyle, E. A. (2008). Natural fractionation of 238U/235U. Geochimica et Cosmochimica Acta, 72(2), 345–359. doi:10.1016/j.gca.2007.11.012
Methods

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Related Datasets

Continues

Anderson, R. F., Fleisher, M. Q., Edwards, R. L., Cheng, H., Hayes, C. T., Li, X., Black, E. E., Redmond, N. (2025) **Dissolved thorium and protactinium isotopes (232Th, 230Th, 231Pa) in seawater from Leg 1 (Seattle, WA to Hilo, HI) of the US GEOTRACES Pacific Meridional Transect (PMT) cruise (GP15, RR1814) on R/V Roger Revelle from September to October 2018.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2) Version Date 2025-04-17 doi:10.26008/1912/bco-dmo.919783.2 [view at BCO-DMO]
Relationship Description: GP15 was made up of two cruise legs, RR1814 (Leg 1) and RR1815 (Leg 2)

IsRelatedTo

Hammond, D. E., Kemnitz, N. (2025) **Activity of actinium-227 from water samples collected on Leg 1 (Seattle, WA to Hilo, HI) of the US GEOTRACES Pacific Meridional Transect (PMT) cruise (GP15, RR1814) on R/V Roger Revelle from September to October 2018.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-01-23 doi:10.26008/1912/bco-dmo.940589.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Station_ID	Station ID number	unitless
Start_Date_UTC	Date at start of sample collection event	unitless
Start_Time_UTC	Time (UTC) at start of sample collection event	unitless
Start_ISO_DateTime_UTC	Date and time (UTC) at start of sample collection event in ISO 8601 format	unitless
End_Date_UTC	Date at end of sample collection event	unitless
End_Time_UTC	Time (UTC) at end of sample collection event	unitless
End_ISO_DateTime_UTC	Date and time (UTC) at end of sample collection event in ISO 8601 format	unitless
Start_Latitude	Latitude at start of sample collection event; negative values = South	decimal degrees
Start_Longitude	Longitude at start of sample collection event; negative values = West	decimal degrees
End_Latitude	Latitude at end of sample collection event; negative values = South	decimal degrees
End_Longitude	Longitude at end of sample collection event; negative values = West	decimal degrees
Cast_number	Cast number	unitless
Event_ID	Event ID number	unitless
Sample_ID	GEOTRACES sample ID number	unitless

Sample_Depth	Sample depth	meters (m)
Lab_ID	Identifies the lab where the sample was analyzed (LDEO, UMN, or USM)	unitless
Bottle_ID	Bottle ID number	unitless
Th_230_D_CONC_BOTTLE_aajvje	Concentration (or activity) of dissolved 230Th from bottle samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Th_230_D_CONC_BOTTLE_aajvje	One standard deviation of Th_230_D_CONC_BOTTLE_aajvje	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_CONC_BOTTLE_aajvje	Quality flag for Th_230_D_CONC_BOTTLE_aajvje	unitless
Th_232_D_CONC_BOTTLE_mj1tw8	Concentration (or activity) of dissolved 232Th from bottle samples	picomole per kilogram water (pmol/kg)
SD1_Th_232_D_CONC_BOTTLE_mj1tw8	One standard deviation of Th_232_D_CONC_BOTTLE_mj1tw8	picomole per kilogram water (pmol/kg)
Flag_Th_232_D_CONC_BOTTLE_mj1tw8	Quality flag for Th_232_D_CONC_BOTTLE_mj1tw8	unitless
Pa_231_D_CONC_BOTTLE_v1dtl3	Concentration (or activity) of dissolved 231Pa from bottle samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Pa_231_D_CONC_BOTTLE_v1dtl3	One standard deviation of Pa_231_D_CONC_BOTTLE_v1dtl3	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_CONC_BOTTLE_v1dtl3	Quality flag for Pa_231_D_CONC_BOTTLE_v1dtl3	unitless
Th_230_D_CONC_FISH_wzead9	Concentration (or activity) of dissolved 230Th from towed GeoFish samples	micro-Becquerel per kilogram water (uBq/kg)

SD1_Th_230_D_CONC_FISH_wzead9	One standard deviation of Th_230_D_CONC_FISH_wzead9	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_CONC_FISH_wzead9	Quality flag for Th_230_D_CONC_FISH_wzead9	unitless
Th_232_D_CONC_FISH_n9lapa	Concentration (or activity) of dissolved 232Th from towed GeoFish samples	picomole per kilogram water (pmol/kg)
SD1_Th_232_D_CONC_FISH_n9lapa	One standard deviation of Th_232_D_CONC_FISH_n9lapa	picomole per kilogram water (pmol/kg)
Flag_Th_232_D_CONC_FISH_n9lapa	Quality flag for Th_232_D_CONC_FISH_n9lapa	unitless
Pa_231_D_CONC_FISH_gltn2v	Concentration (or activity) of dissolved 231Pa from towed GeoFish samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Pa_231_D_CONC_FISH_gltn2v	One standard deviation of Pa_231_D_CONC_FISH_gltn2v	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_CONC_FISH_gltn2v	Quality flag for Pa_231_D_CONC_FISH_gltn2v	unitless
Th_230_D_XS_CONC_BOTTLE	The dissolved excess 230Th concentration refers to the measured dissolved 230Th corrected for a contribution of 230Th due to the partial dissolution of uranium-bearing minerals, or lithogenics; from bottle samples.	micro-Becquerel per kilogram water (uBq/kg)
SD1_Th_230_D_XS_CONC_BOTTLE	One standard deviation of Th_230_D_XS_CONC_BOTTLE	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_XS_CONC_BOTTLE	Quality flag for Th_230_D_XS_CONC_BOTTLE	unitless
Pa_231_D_XS_CONC_BOTTLE	The dissolved excess 231Pa concentration refers to the measured dissolved 231Pa corrected for a contribution of 231Pa due to the partial dissolution of uranium-bearing minerals, or lithogenics; from bottle samples	micro-Becquerel per kilogram water (uBq/kg)

SD1_Pa_231_D_XS_CONC_BOTTLE	One standard deviation of Pa_231_D_XS_CONC_BOTTLE	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_XS_CONC_BOTTLE	Quality flag for Pa_231_D_XS_CONC_BOTTLE	unitless
Th_230_D_XS_CONC_FISH	The dissolved excess 230Th concentration refers to the measured dissolved 230Th corrected for a contribution of 230Th due to the partial dissolution of uranium-bearing minerals, or lithogenics; from towed GeoFish samples.	micro-Becquerel per kilogram water (uBq/kg)
SD1_Th_230_D_XS_CONC_FISH	One standard deviation of Th_230_D_XS_CONC_FISH	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_XS_CONC_FISH	Quality flag for Th_230_D_XS_CONC_FISH	unitless
Pa_231_D_XS_CONC_FISH	The dissolved excess 231Pa concentration refers to the measured dissolved 231Pa corrected for a contribution of 231Pa due to the partial dissolution of uranium-bearing minerals, or lithogenics; from towed GeoFish samples.	micro-Becquerel per kilogram water (uBq/kg)
SD1_Pa_231_D_XS_CONC_FISH	One standard deviation of Pa_231_D_XS_CONC_FISH	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_XS_CONC_FISH	Quality flag for Pa_231_D_XS_CONC_FISH	unitless

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Instruments

Dataset-specific Instrument Name	centrifuge tubes
Generic Instrument Name	Centrifuge
Generic Instrument Description	A machine with a rapidly rotating container that applies centrifugal force to its contents, typically to separate fluids of different densities (e.g., cream from milk) or liquids from solids.

Dataset-specific Instrument Name	Sea-Bird Electronics CTD
Generic Instrument Name	CTD Sea-Bird
Dataset-specific Description	Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with 36 10-liter PVC Niskin bottles, managed and operated by Ship-based Science Technical Support and the Ocean Data Facility of Scripps Institution of Oceanography.
Generic Instrument Description	A Conductivity, Temperature, Depth (CTD) sensor package from SeaBird Electronics. This instrument designation is used when specific make and model are not known or when a more specific term is not available in the BCO-DMO vocabulary. Refer to the dataset-specific metadata for more information about the specific CTD used. More information from: http://www.seabird.com/

Dataset-specific Instrument Name	towed pumping system
Generic Instrument Name	GeoFish Towed near-Surface Sampler
Dataset-specific Description	Selected samples were collected using a towed pumping system designed to collect uncontaminated water at 2-3 m depth.
Generic Instrument Description	The GeoFish towed sampler is a custom designed near surface (

Dataset-specific Instrument Name	anion-exchange chromatography
Generic Instrument Name	Ion Chromatograph
Generic Instrument Description	Ion chromatography is a form of liquid chromatography that measures concentrations of ionic species by separating them based on their interaction with a resin. Ionic species separate differently depending on species type and size. Ion chromatographs are able to measure concentrations of major anions, such as fluoride, chloride, nitrate, nitrite, and sulfate, as well as major cations such as lithium, sodium, ammonium, potassium, calcium, and magnesium in the parts-per-billion (ppb) range. (from http://serc.carleton.edu/microbelife/research_methods/biogeochemical/ic....)

Dataset-specific Instrument Name	10-liter PVC Niskin bottles
Generic Instrument Name	Niskin bottle
Dataset-specific Description	Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with 36 10-liter PVC Niskin bottles, managed and operated by Ship-based Science Technical Support and the Ocean Data Facility of Scripps Institution of Oceanography.
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	Thermo-Finnigan Neptune Multicollector ICP-MS
Generic Instrument Name	Thermo Finnigan Neptune inductively coupled plasma mass spectrometer
Generic Instrument Description	A laboratory high mass resolution inductively coupled plasma mass spectrometer (ICP-MS) designed for elemental and isotopic analysis. The instrument is based on a multicollector platform, comprising eight moveable collector supports and one fixed center channel equipped with a Faraday cup and, optionally, an ion counter with or without a retardation lens. The Faraday cup is connected to a current amplifier, whose signal is digitized by a high linearity voltage to frequency converter. The instrument was originally manufactured by Thermo Finnigan, which has since been replaced by Thermo Scientific (part of Thermo Fisher Scientific). This model is no longer in production.

Dataset-specific Instrument Name	Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS
Generic Instrument Name	Thermo Scientific ELEMENT XR high resolution inductively coupled plasma mass spectrometer
Generic Instrument Description	A high-resolution (HR) inductively coupled plasma (ICP) mass spectrometer (MS) composed of a dual mode secondary electron multiplier (SEM) and a Faraday detector. The ELEMENT XR instrument has a dynamic range of 5 x 10^7 to 1 x 10^12 counts per second (cps), and allows simultaneous measurement of elements at concentrations over 1000 ug/g.

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Deployments

RR1815

Website	https://www.bco-dmo.org/deployment/776917
Platform	R/V Roger Revelle
Report	https://datadocs.bco-dmo.org/docs/geotraces/GEOTRACES_PMT/casciotti/data_docs/GP15_Cruise_Report_with_ODF_Report.pdf
Start Date	2018-10-24
End Date	2018-11-24
Description	Additional cruise information is available from the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/RR1815

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Project Information

US GEOTRACES Pacific Meridional Transect (GP15) (U.S. GEOTRACES PMT)

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

Coverage: Pacific Meridional Transect along 152W (GP15)

A 60-day research cruise took place in 2018 along a transect form Alaska to Tahiti at 152° W. A description of the project titled "*Collaborative Research: Management and implementation of the US GEOTRACES Pacific Meridional Transect*", funded by NSF, is below. Further project information is available on the US GEOTRACES website and on the cruise blog. A detailed cruise report is also available as a PDF.

Description from NSF award abstract:
GEOTRACES is a global effort in the field of Chemical Oceanography in which the United States plays a major role. The goal of the GEOTRACES program is to understand the distributions of many elements and their isotopes in the ocean. Until quite recently, these elements could not be measured at a global scale. Understanding the distributions of these elements and isotopes will increase the understanding of processes that shape their distributions and also the processes that depend on these elements. For example, many "trace elements" (elements that are present in very low amounts) are also important for life, and their presence or absence can play a vital role in the population of marine ecosystems. This project will launch the next major U.S. GEOTRACES expedition in the Pacific Ocean between Alaska and Tahiti. The award made here would support all of the major infrastructure for this expedition, including the research vessel, the sampling equipment, and some of the core oceanographic measurements. This project will also support the personnel needed to lead the expedition and collect the samples.

This project would support the essential sampling operations and infrastructure for the U.S. GEOTRACES Pacific Meridional Transect along 152° W to support a large variety of individual science projects on trace element and isotope (TEI) biogeochemistry that will follow. Thus, the major objectives of this management proposal are: (1) plan and coordinate a 60 day research cruise in 2018; (2) obtain representative samples for a wide variety of TEIs using a conventional CTD/rosette, GEOTRACES Trace Element Sampling Systems, and in situ pumps; (3) acquire conventional CTD hydrographic data along with discrete samples for salinity, dissolved oxygen, algal pigments, and dissolved nutrients at micro- and nanomolar levels; (4) ensure that proper QA/QC protocols are followed and reported, as well as fulfilling all GEOTRACES intercalibration protocols; (5) prepare and deliver all hydrographic data to the GEOTRACES Data Assembly Centre (via the US BCO-DMO data center); and (6) coordinate all cruise communications between investigators, including preparation of a hydrographic report/publication. This project would also provide baseline measurements of TEIs in the Clarion-Clipperton fracture zone (~7.5°N-17°N, ~155°W-115°W) where large-scale deep sea mining is planned. Environmental impact assessments are underway in partnership with the mining industry, but the effect of mining activities on TEIs in the water column is one that could be uniquely assessed by the GEOTRACES community. In support of efforts to communicate the science to a wide audience the investigators will recruit an early career freelance science journalist with interests in marine science and oceanography to participate on the cruise and do public outreach, photography and/or videography, and social media from the ship, as well as to submit articles about the research to national media. The project would also support several graduate students.

Collaborative Research: U.S. GEOTRACES Pacific Meridional Transect: Thorium-232, Thorium-230 and Protactinium-231 as tracers of trace element supply and removal (PMT Thorium Isotopes)

NSF Award Abstract:
The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes in the oceans. Many trace elements are essential for life and their extremely low concentrations in seawater are thought to limit biological productivity (fertility) throughout much of the ocean. This limitation, in turn, partially constrains the level of fisheries that can be supported by marine ecosystems as well as the ocean's capacity to absorb carbon dioxide from the atmosphere. Whereas the importance of these trace-element micronutrients is well established, many basic features of their ocean distribution remain unknown. Measurements of other elements and isotopes can be used to understand the processes that influence the distributions of the micronutrient elements. Two naturally-occurring radioactive isotopes that are particularly important in this regard are thorium-230 and protactinium-231, which have been designated as key parameters to be measured as part of GEOTRACES. This project will focus on the measurement of these two isotopes in order to provide critical information about the processes that supply iron to the Pacific Ocean, as well as the rates of those processes. The project will support an early career investigator, a postdoctoral researcher, and students at the undergraduate and graduate levels.

Samples of seawater and of suspended particulate material will be collected along a north-south transect between Alaska and Tahiti to examine the processes that supply and remove trace elements. These samples will be analyzed for naturally-occurring radionuclides thorium-232, thorium-230 and protactinium-231. Aerosol samples and sediments collected along the transect will be analyzed as well. In collaboration with other investigators involved in the expedition, this project will:

1) Interpret the distributions of thorium-232 and thorium-230 to quantify the supply of iron and other trace elements delivered by dust as well as the trace elements supplied by chemical reactions in volcanic sediments along the Alaskan margin,
2) Determine the sinking flux of major particulate phases and of particulate trace elements throughout the water column to quantify their rate of removal from the ocean, and
3) Compare the rate of trace element removal among contrasting environmental regimes to be encountered along the Alaska to Tahiti transect to identify the key physical, chemical and biological factors, such as dust supply and biological productivity, that regulate the rate of trace element removal from the ocean.

Note: Additional datasets from cruises PE17-24 and PS1718 were collected as complementary activities to this project and were supported by NSF award OCE-1737023.

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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-1737023
NSF Division of Ocean Sciences (NSF OCE)	OCE-1737224
NSF Division of Ocean Sciences (NSF OCE)	OCE-1736677

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