

# Dissolved thorium and protactinium isotopes ( $^{232}\text{Th}$ , $^{230}\text{Th}$ , $^{231}\text{Pa}$ ) 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

**Website:** <https://www.bco-dmo.org/dataset/919783>

**Data Type:** Cruise Results

**Version:** 1

**Version Date:** 2024-03-15

## 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)

Contributors	Affiliation	Role
<a href="#">Anderson, Robert F.</a>	Lamont-Doherty Earth Observatory (LDEO)	Principal Investigator
<a href="#">Edwards, R. Lawrence</a>	University of Minnesota	Principal Investigator
<a href="#">Hayes, Christopher T.</a>	University of Southern Mississippi (USM)	Principal Investigator
<a href="#">Cheng, Hai</a>	University of Minnesota	Co-Principal Investigator
<a href="#">Fleisher, Martin Q.</a>	Lamont-Doherty Earth Observatory (LDEO)	Co-Principal Investigator
<a href="#">Black, Erin E.</a>	Lamont-Doherty Earth Observatory (LDEO)	Analyst
<a href="#">Li, Xianglei</a>	University of Minnesota Twin Cities (UMTC)	Analyst
<a href="#">Redmond, Neil</a>	University of Southern Mississippi (USM)	Analyst
<a href="#">Rauch, Shannon</a>	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

## Abstract

This dataset contains concentrations of dissolved thorium and protactinium isotopes ( $^{232}\text{Th}$ ,  $^{230}\text{Th}$ ,  $^{231}\text{Pa}$ ) 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 1, RR1814; data from RR1815 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).

## Table of Contents

- [Coverage](#)
- [Dataset Description](#)
  - [Methods & Sampling](#)
  - [Data Processing Description](#)
  - [BCO-DMO Processing Description](#)
- [Data Files](#)
- [Supplemental Files](#)
- [Related Publications](#)
- [Related Datasets](#)
- [Parameters](#)
- [Instruments](#)
- [Deployments](#)
- [Project Information](#)
- [Program Information](#)
- [Funding](#)

## Coverage

**Location:** North Pacific; Equatorial Pacific; South Pacific Ocean; 55 N to 20 S along 152 W  
**Spatial Extent:** N:56.059 E:-151.999 S:19.681 W:-156.963  
**Temporal Extent:** 2018-09-24 - 2018-10-21

## 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 ( $\mu\text{m}$ ) 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  $\sim 2$  with 20 milliliters (mL) 6 M HCl (redistilled Fisher Scientific Trace Metal grade HCl diluted 1:1 with 18.2 M $\Omega$  H<sub>2</sub>O), 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  $\mu\text{m}$  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 (NH<sub>4</sub>OH), Perchloric Acid (HClO<sub>4</sub>), and Hydrofluoric Acid (HF). Hydrochloric Acid (HCl) and Nitric Acid (HNO<sub>3</sub>) 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 ( $\sim 1$  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  $\sim 8.5$  by the addition of concentrated NH<sub>4</sub>OH, 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 H<sub>2</sub>O. The precipitate was then dissolved in 16M HNO<sub>3</sub> and transferred to a Teflon vial for a high-temperature (180-200°C) digestion with concentrated HClO<sub>4</sub> 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 H<sub>2</sub>O, centrifuged, and dissolved 16 M HNO<sub>3</sub>. 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 HClO<sub>4</sub> and taken up in 0.5 mL of 0.16 M HNO<sub>3</sub>/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  $\sim 100$  microliters per minute ( $\mu\text{L}/\text{min}$ ) 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 HNO<sub>3</sub>/0.026 M HF), which was used to correct for the instrumental background count rates. To correct for tailing of <sup>232</sup>Th into the minor Th and Pa isotopes, a set of external <sup>232</sup>Th standards were run at concentrations bracketing the expected <sup>232</sup>Th 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 <sup>232</sup>Th standards. The <sup>232</sup>Th 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 <sup>232</sup>Th signal intensity in the Th fraction. The regressions of <sup>229</sup>Th, <sup>230</sup>Th, <sup>231</sup>Pa, and <sup>233</sup>Pa signals as a function of the <sup>232</sup>Th signal in the standards was used to correct for tailing of <sup>232</sup>Th in samples. Only in rare cases was a tail correction of <sup>232</sup>Th on <sup>231</sup>Pa and <sup>233</sup>Pa necessary, while it was almost always the case that tail corrections of <sup>232</sup>Th on <sup>229</sup>Th and <sup>230</sup>Th were performed.

Water samples were analyzed in batches of 15. Procedural blanks were determined by processing 4-5 liters of Milli-Q H<sub>2</sub>O 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 <sup>232</sup>Th, <sup>230</sup>Th, and <sup>231</sup>Pa between acidifying procedural blanks at sea or in the on-shore laboratory was statistically insignificant. An aliquot of intercalibrated in-house standard solutions of <sup>232</sup>Th, <sup>230</sup>Th, and <sup>231</sup>Pa; SW STD 2010-1, referred to by Anderson et al. (2012) was added to an acid-cleaned Teflon beaker along with weighed aliquots of <sup>229</sup>Th and <sup>233</sup>Pa 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 <sup>229</sup>Th and <sup>233</sup>Pa solutions, were also added to an acid-cleaned cubitainer with ~4-5 liters of Milli-Q H<sub>2</sub>O. 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 <sup>232</sup>Th, <sup>230</sup>Th, and <sup>231</sup>Pa 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 <sup>229</sup>Th (10 pg) and <sup>233</sup>Pa (~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 NH<sub>4</sub>OH (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 H<sub>2</sub>O (>18 MΩ) to remove the major seawater ions. The precipitate was then dissolved in 8M HNO<sub>3</sub> (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 HNO<sub>3</sub>, 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 H<sub>2</sub>O, 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 HNO<sub>3</sub> (Fisher Scientific OPTIMA grade) and taken up in 1.0 mL of 0.32 M HNO<sub>3</sub> (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 <sup>232</sup>Th, <sup>230</sup>Th and <sup>231</sup>Pa were calculated by isotope dilution, relative to the calibrated tracers <sup>229</sup>Th and <sup>233</sup>Pa 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 ( $\Delta m/M \approx 300$ ), peak jumping in Escan mode across the central 5% of the flat-topped peaks. Measurements were made on a MasCom™ SEM; <sup>229</sup>Th, <sup>230</sup>Th, <sup>231</sup>Pa, and <sup>233</sup>Pa were measured in Counting mode, while the <sup>232</sup>Th 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  $^{238}\text{U}$  and  $^{235}\text{U}$  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,  $^{238}\text{U}$  was measured in Analog mode and  $^{235}\text{U}$  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  $\text{HNO}_3$ ), which was used to correct for the instrumental background count rates. Tailing of  $^{232}\text{Th}$  into the minor Th and Pa isotopes was monitored by counting at the half-masses surrounding  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ . 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  $\text{H}_2\text{O}$  in an acid-cleaned cubitainer acidified to pH  $\sim 2$  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- $\text{H}_2\text{O}$  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  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ , and  $^{231}\text{Pa}$ , SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has  $\sim 6$  times lower  $^{232}\text{Th}$  activity, were added to acidified MQ- $\text{H}_2\text{O}$  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  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ , and  $^{231}\text{Pa}$  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  $^{229}\text{Th}$  (1 pg) and  $^{233}\text{Pa}$  (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  $40^\circ\text{C}$ ), the pH of each sample was raised to 8.0-8.5 by adding concentrated  $\text{NH}_4\text{OH}$  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  $\text{H}_2\text{O}$  ( $>18\text{ M}\Omega$ ) to remove the major seawater ions. The precipitate was then dissolved in 14 M  $\text{HNO}_3$  and transferred to a Teflon beaker. It was then dried down and taken up in 7 M  $\text{HNO}_3$  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  $\text{HNO}_3$ , followed by 1.125 mL (1.5 CV) of 7 M  $\text{HNO}_3$  (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  $\text{HClO}_4$  and taken up in 7 M  $\text{HNO}_3$ . 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  $\text{HClO}_4$  and dissolved in weak nitric acid for analysis on the mass spectrometer.

Concentrations of  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ , and  $^{231}\text{Pa}$  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  $^{233}\text{U}$ - $^{236}\text{U}$  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  $^{232}\text{Th}$ ,  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ , SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has  $\sim 6$  times lower  $^{232}\text{Th}$  activity, was added to a separate acid-cleaned Teflon beaker along with weighed aliquots of  $^{229}\text{Th}$  and  $^{233}\text{Pa}$  spike. Spikes and SW STD were equilibrated for 3 days. They were then dried down and taken up in 7 M  $\text{HNO}_3$  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  $^{232}\text{Th}$ ,  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  were  $0.6021 \pm 0.0045\text{ pg/kg}$ ,  $0.33 \pm 0.19\text{ fg/kg}$ , and  $0.037 \pm$

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 <sup>232</sup>Th, <sup>230</sup>Th and <sup>231</sup>Pa 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 <sup>229</sup>Th or <sup>233</sup>Pa 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 <sup>230</sup>Th and <sup>231</sup>Pa due to the decay of the natural <sup>234</sup>U and <sup>235</sup>U 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 <sup>230</sup>Th and <sup>231</sup>Pa 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),  $[U] = (0.100 * S - 0.326) \text{ ng U (g seawater)}^{-1}$ . We used seawater U-isotopic compositions of <sup>234</sup>U/<sup>238</sup>U = 1.1468 activity ratio (Andersen et al., 2010), and <sup>238</sup>U/<sup>235</sup>U = 137.824 mole ratio (Weyer et al., 2008), to calculate [<sup>234</sup>U] and [<sup>235</sup>U] 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 <sup>232</sup>Th, 0.91% for <sup>230</sup>Th, and 1.93% for <sup>231</sup>Pa 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 <sup>232</sup>Th, 10% for <sup>230</sup>Th, and 18% for <sup>231</sup>Pa on SW STD 2010-1, and improved to 1.1% for <sup>232</sup>Th, 0.5% for <sup>230</sup>Th, and 5.8% for <sup>231</sup>Pa during subsequent analysis of SW STD 2015-1. At UMN, the reproducibility for each isotope was 1.2% for <sup>232</sup>Th, 1.8% for <sup>230</sup>Th, and 2.1% for <sup>231</sup>Pa 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 <sup>230</sup>Th concentration refers to the measured dissolved <sup>230</sup>Th corrected for a contribution of <sup>230</sup>Th due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of <sup>230</sup>Th produced in the water by decay of dissolved <sup>234</sup>U. We estimate the lithogenic <sup>230</sup>Th using measured dissolved <sup>232</sup>Th and a lithogenic <sup>230</sup>Th/<sup>232</sup>Th 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.

$$\text{Th}_{230\_D\_XS\_CONC\_BOTTLE} = \text{Th}_{230\_D\_CONC\_BOTTLE} - 4.0e-6 * 1.7473e5 * \text{Th}_{232\_D\_CONC\_BOTTLE}$$

#### Pa\_231\_D\_XS\_CONC\_BOTTLE:

The dissolved excess <sup>231</sup>Pa concentration refers to the measured dissolved <sup>231</sup>Pa corrected for a contribution of <sup>231</sup>Pa due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of <sup>231</sup>Pa produced in the water by decay of dissolved <sup>235</sup>U. We estimate the <sup>231</sup>Pa using measured dissolved <sup>232</sup>Th and a lithogenic <sup>231</sup>Pa/<sup>232</sup>Th 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 <sup>231</sup>Pa and <sup>235</sup>U in the lithogenic material. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

$$\text{Pa}_{231\_D\_XS\_CONC\_BOTTLE} = \text{Pa}_{231\_D\_CONC\_BOTTLE} - 8.8e-8 * 4.0370e5 * \text{Th}_{232\_D\_CONC\_BOTTLE}$$

#### Th\_230\_D\_XS\_CONC\_FISH:

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

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

$$\text{Th}_{230\_D\_XS\_CONC\_FISH} = \text{Th}_{230\_D\_CONC\_FISH} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232\_D\_CONC\_FISH}.$$

#### **Pa<sub>231</sub>\_D\_XS\_CONC\_FISH:**

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

$$\text{Pa}_{231\_D\_XS\_CONC\_FISH} = \text{Pa}_{231\_D\_CONC\_FISH} - 8.8\text{e-}8 * 4.0370\text{e}5 * \text{Th}_{232\_D\_CONC\_FISH}.$$

#### **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 ( $^{231}\text{Pa}$ ) and Th-232 are flagged as good (1);

2 = probably good value = either Th-230 ( $^{231}\text{Pa}$ ) is flagged as good (1) and Th-232 is flagged as probably good (2), probably bad (3), or bad (4), or Th-230 ( $^{231}\text{Pa}$ ) 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 ( $^{231}\text{Pa}$ ) 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 ( $^{231}\text{Pa}$ ) 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 ( $^{231}\text{Pa}$ ) and Th-232 are flagged as below detection (6) and neither are flagged as missing (9);

9 = missing value = either or both Th-230 ( $^{231}\text{Pa}$ ) 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<sub>232</sub>\_D\_CONC\_BOTTLE, Th<sub>230</sub>\_D\_CONC\_BOTTLE and Pa<sub>231</sub>\_D\_CONC\_BOTTLE, as well as Th<sub>232</sub>\_D\_CONC\_FISH, Th<sub>230</sub>\_D\_CONC\_FISH and Pa<sub>231</sub>\_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  $\mu\text{m}$  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 ( $10\text{e-}6$  Bq,  $\mu\text{Bq}$  or micro-Bq) per kilogram water for  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ , and picomole ( $10\text{e-}12$  mol, pmol) per kilogram water for  $^{232}\text{Th}$ . 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

- Imported original file "GEOTRACES GP15 RR1814 Dissolved 230Th 232Th 231Pa Data.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 "919783\_v1\_rr1814\_dissolved\_th\_and\_pa.csv".

[ [table of contents](#) | [back to top](#) ]

---

## Data Files

File
<b>919783_v1_rr1814_dissolved_th_and_pa.csv</b> (Comma Separated Values (.csv), 47.15 KB) MD5:f2c5359d633e24dce771fee5ad0bdbaf
Primary data file for dataset ID 919783, version 1

[ [table of contents](#) | [back to top](#) ]

---

## Supplemental Files

File
<b>Table1.pdf</b> (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.
<b>Table2.pdf</b> (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.
<b>Table3.pdf</b> (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.

[ [table of contents](#) | [back to top](#) ]

---

## 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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/10.1016/j.epsl.2013.04.006)

*General*

Cutter, Gregory, Casciotti, Karen, Croot, Peter, Geibert, Walter, Heimbürger, Lars-Eric, Lohan, Maeve, Planquette, H  l  ne, 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 <sup>238</sup>U-salinity relationship in seawater: Implications for the <sup>238</sup>U-<sup>234</sup>Th disequilibrium method. *Marine Chemistry*, 127(1-4), 31-39.

doi:[10.1016/j.marchem.2011.07.005](https://doi.org/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](https://doi.org/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 <sup>231</sup>Pa in Dissolved and Particulate Fractions of Seawater by Isotope Dilution Thermal Ionization Mass Spectroscopy. *Analytical Chemistry*, 75(5), 1075-1079. doi:[10.1021/ac026247r](https://doi.org/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](https://doi.org/10.1016/s0009-2541(01)00404-1)

*General*

Shen, C.-C., Wu, C.-C., Cheng, H., Edwards, R. L., Hsieh, Y.-T., Gallet, S., ... Sp  tl, C. (2012). High-precision and high-resolution carbonate <sup>230</sup>Th dating by MC-ICP-MS with SEM protocols. *Geochimica et Cosmochimica Acta*, 99, 71-86.

doi:[10.1016/j.gca.2012.09.018](https://doi.org/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 <sup>238</sup>U/<sup>235</sup>U. *Geochimica et Cosmochimica Acta*, 72(2), 345-359. doi:[10.1016/j.gca.2007.11.012](https://doi.org/10.1016/j.gca.2007.11.012)

*Methods*

[ [table of contents](#) | [back to top](#) ]

---

## Related Datasets

### IsContinuedBy

---

Anderson, R. F., Fleisher, M. Q., Edwards, R. L., Cheng, H., Hayes, C. T., Li, X., Black, E. E., Redmond, N. (2024) **Dissolved thorium and protactinium isotopes (<sup>232</sup>Th, <sup>230</sup>Th, <sup>231</sup>Pa) 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**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2) Version Date 2024-08-01 doi:10.26008/1912/bco-dmo.920078.2 [[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. (2024) **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 2024-10-23 <http://lod.bco-dmo.org/id/dataset/940589> [[view at BCO-DMO](#)]

[ [table of contents](#) | [back to top](#) ]

---

## 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_m5ivgp	Concentration (or activity) of dissolved 230Th from bottle samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Th_230_D_CONC_BOTTLE_m5ivgp	One standard deviation of Th_230_D_CONC_BOTTLE_m5ivgp	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_CONC_BOTTLE_m5ivgp	Quality flag for Th_230_D_CONC_BOTTLE_m5ivgp	unitless
Th_232_D_CONC_BOTTLE_vwrb8w	Concentration (or activity) of dissolved 232Th from bottle samples	picomole per kilogram water (pmol/kg)
SD1_Th_232_D_CONC_BOTTLE_vwrb8w	One standard deviation of Th_232_D_CONC_BOTTLE_vwrb8w	picomole per kilogram water (pmol/kg)
Flag_Th_232_D_CONC_BOTTLE_vwrb8w	Quality flag for Th_232_D_CONC_BOTTLE_vwrb8w	unitless
Pa_231_D_CONC_BOTTLE_iam4fq	Concentration (or activity) of dissolved 231Pa from bottle samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Pa_231_D_CONC_BOTTLE_iam4fq	One standard deviation of Pa_231_D_CONC_BOTTLE_iam4fq	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_CONC_BOTTLE_iam4fq	Quality flag for Pa_231_D_CONC_BOTTLE_iam4fq	unitless
Th_230_D_CONC_FISH_iwqaix	Concentration (or activity) of dissolved 230Th from towed GeoFish samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Th_230_D_CONC_FISH_iwqaix	One standard deviation of Th_230_D_CONC_FISH_iwqaix	micro-Becquerel per kilogram water (uBq/kg)
Flag_Th_230_D_CONC_FISH_iwqaix	Quality flag for Th_230_D_CONC_FISH_iwqaix	unitless

Th_232_D_CONC_FISH_c2ikyx	Concentration (or activity) of dissolved 232Th from towed GeoFish samples	picomole per kilogram water (pmol/kg)
SD1_Th_232_D_CONC_FISH_c2ikyx	One standard deviation of Th_232_D_CONC_FISH_c2ikyx	picomole per kilogram water (pmol/kg)
Flag_Th_232_D_CONC_FISH_c2ikyx	Quality flag for Th_232_D_CONC_FISH_c2ikyx	unitless
Pa_231_D_CONC_FISH_cvbbws	Concentration (or activity) of dissolved 231Pa from towed GeoFish samples	micro-Becquerel per kilogram water (uBq/kg)
SD1_Pa_231_D_CONC_FISH_cvbbws	One standard deviation of Pa_231_D_CONC_FISH_cvbbws	micro-Becquerel per kilogram water (uBq/kg)
Flag_Pa_231_D_CONC_FISH_cvbbws	Quality flag for Pa_231_D_CONC_FISH_cvbbws	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

[ [table of contents](#) | [back to top](#) ]

## Instruments

<b>Dataset-specific Instrument Name</b>	centrifuge tubes
<b>Generic Instrument Name</b>	Centrifuge
<b>Generic Instrument Description</b>	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.

<b>Dataset-specific Instrument Name</b>	Sea-Bird Electronics CTD
<b>Generic Instrument Name</b>	CTD Sea-Bird
<b>Dataset-specific Description</b>	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.
<b>Generic Instrument Description</b>	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.

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

<b>Dataset-specific Instrument Name</b>	anion-exchange chromatography
<b>Generic Instrument Name</b>	Ion Chromatograph
<b>Generic Instrument Description</b>	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 <a href="http://serc.carleton.edu/microbelife/research_methods/biogeochemical/ic...">http://serc.carleton.edu/microbelife/research_methods/biogeochemical/ic...</a> )

<b>Dataset-specific Instrument Name</b>	10-liter PVC Niskin bottles
<b>Generic Instrument Name</b>	Niskin bottle
<b>Dataset-specific Description</b>	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.
<b>Generic Instrument Description</b>	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.

<b>Dataset-specific Instrument Name</b>	Thermo-Finnigan Neptune Multicollector ICP-MS
<b>Generic Instrument Name</b>	Thermo Finnigan Neptune inductively coupled plasma mass spectrometer
<b>Generic Instrument Description</b>	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.

<b>Dataset-specific Instrument Name</b>	Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS
<b>Generic Instrument Name</b>	Thermo Scientific ELEMENT XR high resolution inductively coupled plasma mass spectrometer
<b>Generic Instrument Description</b>	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 $5 \times 10^7$ to $1 \times 10^{12}$ counts per second (cps), and allows simultaneous measurement of elements at concentrations over 1000 ug/g.

[ [table of contents](#) | [back to top](#) ]

## Deployments

### RR1814

<b>Website</b>	<a href="https://www.bco-dmo.org/deployment/776913">https://www.bco-dmo.org/deployment/776913</a>
<b>Platform</b>	R/V Roger Revelle
<b>Report</b>	<a href="https://datadocs.bco-dmo.org/docs/geotraces/GEOTRACES_PMT/casciotti/data_docs/GP15_Cruise_Report_with_ODF_Report.pdf">https://datadocs.bco-dmo.org/docs/geotraces/GEOTRACES_PMT/casciotti/data_docs/GP15_Cruise_Report_with_ODF_Report.pdf</a>
<b>Start Date</b>	2018-09-18
<b>End Date</b>	2018-10-21
<b>Description</b>	Additional cruise information is available from the Rolling Deck to Repository (R2R): <a href="https://www.rvdata.us/search/cruise/RR1814">https://www.rvdata.us/search/cruise/RR1814</a>

[ [table of contents](#) | [back to top](#) ]

## 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 from 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.

[ [table of contents](#) | [back to top](#) ]

---

## **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.

[ [table of contents](#) | [back to top](#) ]

---

## Funding

Funding Source	Award
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1737023</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1737224</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1736677</a>

[ [table of contents](#) | [back to top](#) ]