ANNUAL REPORT ON GEOTRACES ACTIVITIES IN UNITED STATES

May 1st, 2024 to April 30th, 2025

New GEOTRACES or GEOTRACES relevant scientific results

With 68 peer-reviewed publications in the past year (see attached list), there are too many results to describe them all. Therefore, the approach here is to begin by listing the projects involving U.S. GEOTRACES investigators that were featured as GEOTRACES science highlights during the reporting period (see: https://www.geotraces.org/category/science/newsflash/). Following that, we will briefly report on the status of GEOTRACES section GP17-ANT, which was completed in January 2024, and then on U.S. GEOTRACES process studies.

Science highlights, in reverse chronological order, with the name of the lead investigator, included:

Highlight Date	Lead P.I.	Synopsis
May 27, 2024	C. Basak	The role of hydrothermal sources in the global neodymium (Nd) cycle is often overlooked due to limited sampling. To investigate this, *Basak and colleagues (2024)* studied the impact of particulate matter on Nd distributions in the Southern East Pacific Rise Hydrothermal Plume. Their innovative approach combined measurements of dissolved and particulate Nd concentrations, dissolved Nd isotopic composition, suspended matter composition, and water mass proportions through optimum multiparameter analysis. Key findings from the study include: • The hydrothermal plume acts as a sink for dissolved Nd (dNd), with scavenging intensity decreasing with distance from the vent. • Near the vent, manganese (Mn) oxides are primarily responsible for Nd scavenging, while iron (Fe) hydroxides become more significant as distance increases. • This shift may be related to changes in Mn mineralogy within the particles. • Below the plume, there is an input of dNd, potentially from particle remineralization or sediment, which requires further investigation. • Although particles significantly influence dNd distributions, hydrothermal vents have a limited

		effect on the isotopic composition of surrounding water masses. Overall, the study highlights the critical roles of Mn oxides and Fe hydroxides in scavenging Nd and other rare earth elements (REE) in the ocean. The partition coefficient data provided contributes to a previously limited dataset, particularly in plumes, and opens new avenues for enhancing Nd cycle models. *doi: 10.1016/j.epsl.2024.118692*
September 6, 2024	E. Le Roy	Barium and radium-226 (^{226}Ra) are significant marine biogeochemical tracers, with distinct sources and processes affecting their concentrations. Barium primarily comes from rivers and groundwater, while ^{226}Ra originates from deep-sea sediments through thorium-230 (^{230}Th) decay. Both elements are removed from surface waters by incorporation into barite, with ^{226}Ra also undergoing radioactive decay. In their 2024 study, *Le Roy and colleagues* analyzed barium and ^{226}Ra data from the Pacific Ocean along 152°W during the GEOTRACES GP15 expedition. They combined this data with a statistical model to distinguish between biogeochemical processes and ocean circulation, yielding three main findings: 1. Significant biogeochemical removal of barium and ^{226}Ra occurs in the upper ocean, particularly in high productivity regions, due to microcrystalline barite formation. 2. The deep Pacific has some of the highest global levels of these elements, enriched by Antarctic Bottom Water and sediment interactions, with slow circulation allowing for accumulation. 3. ^{226}Ra exhibits distinct benthic patterns due to additional sources like ^{230}Th decay and hydrothermal venting. The study constructed a basin-wide mass balance for the Pacific Ocean, revealing a surface barium deficit and a deep ^{226}Ra excess, indicating a need for further research on barium replenishment and the fate of ^{226}Ra in this region. *doi: 10.1029/2023GB008005*
September 9, 2024	Y. Xiang	As interest in potential deep-sea mining projects grows, there is limited research on the geochemical

		and environmental impacts of mining dewatering waste plumes and accidental spills from riser pipes and mining platforms into abyssal waters. *Xiang and colleagues (2024)* conducted laboratory incubation experiments simulating mining discharge into anoxic waters, reflecting conditions overlying potential mining sites in the North Pacific Ocean. Their findings reveal that during the approximately 100 days it takes for crushed manganese (Mn) nodules to sink through the 600 m-thick oxygen-depleted zone (ODZ), manganese nodules undergo reductive dissolution, leading to the release of metals, particularly cobalt (Co) and copper (Cu), which could become significantly enriched in the waste plume compared to background seawater concentrations. The study indicates that cobalt and copper may be the most enriched trace metals, with copper levels raising concerns due to its toxicity to certain phytoplankton. This potential enrichment highlights the need for further evaluation of the ecological impacts on mesopelagic communities and the broader ecosystem. *doi: 10.1021/acsestwater.4c00166*
October 15, 2024	M. Sieber	The international GEOTRACES program has highlighted the critical role of marine sediments as a source of dissolved iron (dFe) in the world's oceans. In the GEOTRACES North Pacific GP15 section, researchers presented data on dFe alongside other sediment-source tracers, such as dissolved δ^{56}Fe, manganese (Mn), radium-228 (^{228}Ra), and particulate iron (Fe). This multi-tracer approach allowed for the identification of three distinct dFe depth maxima at the Alaskan margin. Two of these maxima, found at shelf and abyssal depths, are attributed to local Alaskan sedimentary sources. In contrast, the third mid-depth dFe maximum, which lacks ^{228}Ra, is determined to be an advected signal from sedimentary sources on the Asian margin, approximately 5,000 km away. *Sieber and co-authors (2024)* further utilized this multi-tracer strategy, coupled with an oceanic circulation model, to quantify oceanic processes. Their findings revealed that while two of the identified dFe plumes originate from local shelf and abyssal sediments, the intermediate depth plume

		results from the long-distance transport of dissolved iron from Asian marginal sediments. This research underscores the significant eastward transport of iron from Asian marginal seas into the North Pacific, emphasizing the importance of diagnostic sedimentary tracers in understanding marine trace metal budgets. *doi: 10.1029/2024GL110836*
October 17, 2024	J. Li	Primary production in the sunlit surface ocean is primarily regulated by the availability of key nutrients, including nitrate, phosphate, and iron (Fe), which are essential for phytoplankton to convert carbon dioxide into biomass. Below the surface, the remineralization of sinking organic matter regenerates nutrients, while microbial metabolism in the upper mesopelagic zone (200–500 m) is thought to be limited by the supply of labile organic carbon. However, the role of nutrients in influencing microbial production in the mesopelagic has been underexplored. *Li and co-authors (2024)* investigated the distribution and uptake of siderophores—bacterial metabolites that indicate microbial Fe deficiency—along the GEOTRACES cruise GP15 in the eastern Pacific Ocean. Their findings show that siderophore concentrations are elevated not only in chronically Fe-limited surface waters but also in the twilight zone beneath the North and South Pacific subtropical gyres. This suggests that bacterial Fe deficiency due to low iron availability is likely characteristic of the twilight zone in several large ocean basins, significantly expanding the regions of the marine water column where nutrient limitations affect microbial metabolism. These insights have potential implications for ocean carbon storage and the overall marine carbon cycle. *doi: 10.1038/s41586-024-07905-z*
December 5, 2024	D. Planaj	Disequilibria between long-lived parent isotopes and short-lived particle-reactive daughters, particularly the progeny of Radium-226 (^{226}Ra) and Lead-210 and Polonium-210 (^{210}Pb and ^{210}Po), have been extensively used as tracers in aquatic systems to quantify various oceanic biogeochemical processes. Over the past six decades, vertical profiles of ^{210}Po and ^{210}Pb in the deep ocean have

		consistently shown disequilibrium, with activity ratios (AR) deviating from the expected secular equilibrium of 1.0. A comprehensive review of published data on ^{210}Po, ^{210}Pb, and ^{226}Ra was conducted, analyzing sample size, methodology, and statistical approaches. This study calculated total water column inventories and average activities of these isotopes, revealing that ^{210}Po activities are highest in the Pacific Ocean and lowest in the Arctic Ocean. The AR trends in small and large particles varied, and the fractionation factors indicated a similar pattern across different ocean basins. The research found widespread disequilibrium in deep water and varying residence times for ^{210}Pb, with surface water concentrations correlating with latitude and decreasing from mid-latitudes to the poles. In response to the observed disequilibrium in published ^{210}Po:^{210}Pb profiles, *Mark Baskaran and graduate student, Denada Planaj,* conducted a critical review of deep-water profiles to evaluate this issue. They calculated inventories and assessed how the ^{210}Po /^{210}Pb activity ratio varied throughout the water column. Their findings highlighted data quality issues, leading to the compilation of papers reporting 'unusual ^{210}Po and recommendations for future analyses of ^{210}Po /^{210}Pb in water samples. This work underscores the need for improved methodologies in studying these isotopes to better understand their behavior in marine environments. *doi: 10.1016/j.earscirev.2024.104759*
January 7, 2025	C. Hoffman	*Hoffman and colleagues (2024)* conducted the first study of siderophores and siderophore-producing microbes in 11 geochemically distinct hydrothermal plume environments along the Mid-Atlantic Ridge. This research included a range of hydrothermal vent conditions, from alkaline, low iron (Fe) to acidic, high-temperature, high-Fe plumes, with samples collected from both near-field and diffuse environments. The study revealed that at sites with strong Fe-binding organic ligands (L_1), dissolved Fe concentrations were closely coupled to L_1 ligands in a nearly 1:1 ratio, with siderophores identified as part of these ligands in the neutrally buoyant plume.

		The presence of amphiphilic siderophores and siderophore-producing bacteria suggests microbial utilization of siderophores to access particulate hydrothermal iron and facilitate the exchange of dissolved and particulate iron. Hydrothermal vents are significant sources of iron to seawater, but only a portion is soluble enough to impact the deep-ocean iron inventory. Siderophores, known for their high iron-binding affinities, were measured across a 1,700 km section of the Mid-Atlantic Ridge, showing that their type and diversity vary with proximity to the vent. The tight coupling of strong ligands and dissolved iron, along with the presence of siderophores linked to microbial genera, indicates that biological production of ligands significantly influences iron chemistry in hydrothermal systems. *doi: 10.5194/bg-21-5233-2024*
January 31, 2025	Z. Bunnell	*Bunnell and co-authors (2025)* investigated the isotopic compositions of total, size-fractionated, and water-soluble aerosol iron (Fe) and zinc (Zn) along the North Pacific GEOTRACES GP15 section (Alaska-Tahiti) during the low dust season. Their findings revealed distinct aerosol provinces: Asian aerosols, particularly crustal dust, dominated at higher latitudes (52–32°N), while heavier-than-crustal wildfire aerosols from North America were prevalent in the Equatorial Pacific (20°N to 20°S). The study showed that soluble aerosol Fe was isotopically lighter than crustal sources across the transect, indicating a significant anthropogenic contribution to Pacific Fe. This was corroborated by a global aerosol deposition model, which suggested that an isotopically heavy endmember for wildfire Fe results from pyroconvective entrainment of soil particles. For Zn, the entire GP15 section exhibited light isotopic compositions (bulk: −0.12 ± 0.08‰ and soluble: −0.17 ± 0.14‰), reflecting dominant non-crustal anthropogenic sources. Overall, the analysis highlighted the complex interplay of natural and anthropogenic influences on aerosol composition in the North Pacific. *doi: 10.1029/2024GL113877*
March 7, 2025	P. Quay	During the GEOTRACES GP15 cruise in the Pacific Ocean, *Quay and colleagues (2025)* assessed

		organic matter (OM) export rates based on surface budgets of nutrients (phosphate and nitrate) and dissolved oxygen, focusing on regions between 50°N and 20°S. The study revealed that OM export rates were highest in the subarctic and equatorial regions (9-12 mmol C/m²/yr) and lowest in the subtropical gyres (3-5 mmol C/m²/yr), with rates correlating with surface chlorophyll concentrations. Export efficiency followed a similar regional trend. Satellite-based estimates of OM export also showed comparable regional variations but exhibited a broader range, influenced by the specific productivity algorithms used. Both budget-based and satellite-derived OM export rates were found to be 3 to 15 times higher than particle loss estimates based on ^{234}Th and sediment trap collections. This discrepancy is attributed to significant export of organic matter in non-particle forms and differences in integration times, with budget estimates reflecting longer periods (months) compared to particle sinking fluxes (weeks). Overall, the findings highlight the complexity of OM export dynamics in the Pacific Ocean, emphasizing the importance of both dissolved organic matter and zooplankton migration, particularly in oligotrophic subtropical gyres. *doi: 10.1029/2024GB008277*
March 20, 2025	S. Jiang	Recent studies, particularly by *Jiang et al. (2025)*, investigate the distribution and sources of anthropogenic lead (Pb) in the Pacific Ocean using data from the GEOTRACES GP15 transect from Alaska to Tahiti along 152°W. This research highlights the complex dynamics of Pb cycling, revealing distinct sources—American, Australian, and Chinese—through isotope analysis (^{206}Pb/^{207}Pb, ^{208}Pb/^{206}Pb, and ^{206}Pb/^{204}Pb). Key findings include significant spatial variations in Pb sources, with northern Pacific Pb primarily from Chinese and American sources, while southern Pacific Pb is mainly from Australian and American sources. The study emphasizes the role of advective transport in Pb distribution, particularly in the Sub-Antarctic Mode Water (SAMW) and the penetration of Pacific Bottom Water.

		The high-resolution depth transect shows distinct Pb isotope contours and gradients, indicating reversible particle exchange influenced by high-productivity particle veils. This work, alongside Lanning et al. (2023), enhances our understanding of Pb cycling and its potential as an oceanographic tracer, providing insights into the sources and dynamics of Pb in marine environments. *doi: 10.1029/2024JC021674*
March 27, 2025	Y. He	Recent research by *He and colleagues (2025)* investigates the transport and transformation of mercury (Hg) in the Arctic, focusing on the contributions of methylated mercury (MeHg), particularly dimethylmercury (DMHg). Conducted during a cruise from coastal Alaska through the Bering and Chukchi Seas in May-June 2021, the study utilized high-resolution measurements of DMHg in surface seawater and analyzed rain and aerosol Hg speciation data. Key findings include a significant fivefold increase in the MeHg-to-total Hg (THg) fraction in rain and a tenfold increase in aerosols, both closely associated with elevated surface DMHg concentrations. The highest DMHg evasion rates (~9.4 picomoles per square meter per hour) were observed in upwelling waters near the Aleutian Islands. The study highlights that DMHg released from the ocean surface is converted into MeHg in the atmosphere, which can be transported over long distances (up to 1,700 kilometers) before returning to the ocean through precipitation and aerosol deposition. This process poses risks to human health and ecosystems, particularly in remote areas far from the original DMHg sources. Overall, the research underscores the importance of understanding DMHg evasion and its role in Hg cycling, revealing a previously underappreciated pathway of Hg transport that has significant implications for ecological risk and human health in the rapidly changing Arctic environment. *doi: 10.1126/sciadv.adr3805*

GEOTRACES or GEOTRACES relevant cruises

Section Cruises

The U.S. GEOTRACES Section GP17 has been completed in two expeditions. The first leg (GP17-OCE) included a southward extension of the 2018 GP15 Alaska-Tahiti expedition, while the second leg (GP17-ANT) focused on coastal and shelf waters of Antarctica's Amundsen Sea. GP17-OCE was completed in January 2023, and the U.S. GEOTRACES GP17-ANT expedition was completed in January 2024. Analysis of samples collected on both expeditions continues.

Detailed information about each expedition was provided in the two previous annual reports. Briefly, GP17-OCE sampled different regimes of the South Pacific and the Pacific sector of the Southern Ocean. The ultra-oligotrophic South Pacific Gyre was sampled to investigate the impacts of productivity on the scavenging of TEIs, as well as the effects of TEI processes within the ultra-deep chlorophyll maximum. Particular emphasis was given to the role of micro nutrients in regulating the efficiency of the biological pump within the Antarctic Circumpolar Current. At the same time, investigators sampled to identify sources of TEIs and the processes controlling composition of major water masses formed in the Southern Ocean, including Sub-Antarctic Mode Water (SAMW), and Antarctic Intermediate Water (AAIW). Hydrothermal processes were found to affect TEI distributions along the Pacific Antarctic Ridge as well as within Pacific Deep Water. This expedition also provided the opportunity to study the impact of continental margins on Pacific Deep Water TEI distributions.

GP17-OCE held virtual synthesis seminars from January through March 2025 on a biweekly basis. The virtual seminars prepared investigators for an in-person synthesis workshop held at Texas A&M University from March 10 to 12, 2025. Early data from GP17-OCE were submitted in time to be included in IDP2025, including hydrography and macronutrient data, pigments, dissolved barium concentrations, dissolved ^{226}Ra, size-fractionated PIC, dissolved gallium, dissolved total and labile cobalt, and aerosol and seawater ^{7}Be.

For the more recent expedition, a primary objective of GP17-ANT was to determine the sources of trace element nutrients that support the intense phytoplankton blooms that are often observed in coastal regions around Antarctica. Essential micronutrients include iron, zinc, manganese, copper, nickel and cobalt. Other trace elements and isotopes (TEIs; e.g., aluminum, manganese, and isotopes of nitrogen, thorium and neodymium) are intended to help constrain the source(es) of micronutrients.

For GP17-ANT, post-cruise data, except HPLC pigments, are finalized and posted on a Google Drive for use by all participants. Claudia Giulivi and Rob Sherrell are undertaking an analysis of circulation and hydrographic properties across sampling stations. Science project teams (total of 23 projects) are at various stages of completion of their analyses and several are close to completion.

Efforts are being made to compare GP17-ANT results with the results from other programs in the Amundsen Sea, including ARTEMIS and ASPIRE, as well as recent work in the vicinity of the West Antarctic Peninsula. U.S. investigators are also exploring the potential for connections with recent/ongoing work in Amundsen Sea by Korea and China. Potential collaborations with the U.K. IronMan project (Jan-Feb 2026) in the Antarctic Circumpolar Current, and in the vicinity of the West Antarctic Peninsula, are also being explored.

Process Study Cruises

There were no process study cruises during the reporting year.

New projects and/or funding

- There is no new funding for U.S. GEOTRACES during the current reporting period. Proposals for two process studies, one for work in the Gulf of Mexico and one to work off the west coast of the U.S., were submitted to the U.S. NSF during the reporting year. Both proposals were declined. Because of uncertainty for future funding in the U.S. for ocean chemistry research, there are no plans at the current time to resubmit either proposal.

- A proposal to support the U.S. GEOTRACES project office for three more years, beginning October 1, 2025, was submitted to the U.S. NSF in February 2025. The final outcome of the proposal is unknown at the present time.

GEOTRACES workshops and meetings organized

- The U.S. GEOTRACES Scientific Steering Committee (SSC) met in person in Alexandria, Virginia, on June 20 and 21, 2024. During the meeting, cruise activities and plans for data management were reviewed. The SSC also discussed procedures for implementing future U.S. GEOTRACES process studies and various aspects of preserving GEOTRACES infrastructure.
- A data synthesis workshop for the U.S. GEOTRACES process study (STING: Submarine groundwater discharge, Trichodesmium spp., iron and nitrogen in the Gulf of Mexico; GApr18) was held in St. Petersburg, Florida, in February 2025.
- A data synthesis workshop for the U.S. GEOTRACES section GP17-OCE was held at Texas A&M University from March 10 to 12, 2025.

Outreach activities conducted

- U.S. GEOTRACES created a virtual reality experience during GP17-OCE. Production of this virtual reality outreach product was under the direction of Christina Wiederwohl, at Texas A&M University. Before it was completed, a beta version was shared with the U.S. GEOTRACES SSC by Jessica Fitzsimmons on June 21, 2024. Later, in 2024, the finished project 'Sailing with GEOTRACES' Virtual Reality product was published online at https://at-sea.artsci.tamu.edu/gameintro.html.
- During the reporting period, the U.S. GEOTRACES Project Office published two issues of the seasonal Newsletter, covering project updates, events, science highlights, featured

publications, and funding opportunities. The issues are distributed via the U.S. GEOTRACES mailing list and are also available on the website at <https://usgeotraces.ldeo.columbia.edu/content/newsletters>.

Other GEOTRACES activities

- Other activities are covered below.

New GEOTRACES or GEOTRACES-relevant publications (published or in press)

- A list of publications is appended at the end of this report including:
    - Articles are still being published as part of the Special (virtual) Issue of the U.S. GEOTRACES Pacific Meridional Transect (GEOTRACES Section GP15) <https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1944-9224.GP15>.
    - A special issue of *Oceanography Magazine* (doi:10.5670/oceanog.2024.415;<https://usgeotraces.ldeo.columbia.edu/news/twenty-years-geotraces>), celebrating 20 years of GEOTRACES, was compiled by guest editors Tim M. Conway, Jessica N. Fitzsimmons, Rob Middag, Taryn L. Noble, and Hélène Planquette. Conway and Fitzsimmons are members of the U.S. GEOTRACES community, and the cost of the special issue was covered by the U.S. NSF through the grant to the U.S. GEOTRACES project office.
    - The third edition of the *Treatise on Geochemistry* (https://www.sciencedirect.com/referencework/9780323997638/treatise-on-geochemistry) contains 12 papers authored or co-authored by U.S. GEOTRACES investigators.

Papers in the special volume of *Oceanography Magazine* and papers in the *Treatise on Geochemistry* are provided in separate lists appended to this report.

Completed GEOTRACES PhD or Master theses

- A list of dissertations is included in the publications appended at the end of this report.

GEOTRACES presentations in international conferences

The number of U.S. GEOTRACES presentations at international meetings and conferences is too large to track. However, we note a special session at the recent Fall AGU Meeting (December 2024, Washington, D.C., USA) that was organized by U.S. GEOTRACES investigators. The special session, titled "Trace Element Distributions and Cycling Across Ocean Basins," was organized by Ben Twining, Jessica Fitzsimmons, and Greg Cutter. The session included 39 total presentations (16 from GP17-OCE), 9 oral presentations (5 from GP17-OCE) and 30 poster presentations (11 from GP17-OCE).

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2024-2025 U.S. GEOTRACES and GEOTRACES-related Publications

References 1 May 2024 – 30 April 2025 plus papers missed in previous reports

68 Publications, 5 PhD Dissertations, 0 Masters theses

Related Publications include:

1) U.S. GEOTRACES PIs publishing results that support the GEOTRACES mission but the results are not from GEOTRACES cruises,
2) Papers that use data from U.S. GEOTRACES cruises but do not include U.S. GEOTRACES PIs as co-authors, and
3) Papers describing international collaboration on which U.S. GEOTRACES PIs appear as co-authors.

Peer-reviewed Journal Publications

Albers, E., A. Diehl, J. N. Fitzsimmons, L. T. Jensen, F. Klein, J. M. McDermott, A. Purser, J. S. Seewald, M. Walter, G. Wegener, W. Bach, A. Boetius, and C. R. German (2025), Ultramafic-influenced submarine venting on basaltic seafloor at the Polaris site, 87°N, Gakkel Ridge, *Earth and Planetary Science Letters*, *651*, 119166, doi:https://doi.org/10.1016/j.epsl.2024.119166.

Bian, X., S.-C. Yang, R. J. Raad, N. J. Hawco, J. Sakowski, K.-F. Huang, K. P. Kong, T. M. Conway, and S. G. John (2024a), A rapid procedure for isotopic purification of copper and nickel from seawater using an automated chromatography system, *Analytica Chimica Acta*, *1312*, 342753, doi:https://doi.org/10.1016/j.aca.2024.342753.

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Bunnell, Z. B., M. Sieber, D. S. Hamilton, C. M. Marsay, C. S. Buck, W. M. Landing, S. G. John, and T. M. Conway (2025), The Influence of Natural, Anthropogenic, and Wildfire Sources on Iron and Zinc Aerosols Delivered to the North Pacific Ocean, *Geophysical Research Letters*, *52*(3), e2024GL113877, doi:https://doi.org/10.1029/2024GL113877.

Cochran, J. K., Z. Wei, E. Horowitz, P. Fitzgerald, C. Heilbrun, M. Stephens, P. J. Lam, E. Le Roy, and M. Charette (2024), 210Po and 210Pb Distributions Along the GEOTRACES Pacific Meridional Transect (GP15): Tracers of Scavenging and Particulate Organic Carbon (POC) Export, *Global Biogeochemical Cycles*, *38*(11), e2024GB008243, doi:https://doi.org/10.1029/2024GB008243.

Crusius, J., C. A. Lao, T. M. Holmes, and J. W. Murray (2024), Alaskan Glacial Dust Is an Important Iron Source to Surface Waters of the Gulf of Alaska, *Geophysical Research Letters*, *51*(12), e2023GL106778, doi:https://doi.org/10.1029/2023GL106778.

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