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GEOTRACES International Program:

Open Access Database of Seawater Trace Metal and Isotope Data Available

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ABSTRACT

GEOTRACES (https://www.geotraces.org/) is an international marine chemical program involving scientists from more than 35 countries collaborating together since 2010 in building an online atlas and open access database of high-quality hydrographical and geochemical data, under the name of GEOTRACES Intermediate Data Product. By freely releasing its data, GEOTRACES wishes to strengthen and intensify the collaboration within the marine research community itself, but also wants to invite other ocean professionals to use the data for their research and professional activities. The data product includes chemical elements that are essential for marine life, both macro- and micronutrients, contaminants, radioactive and stable isotopes used to reconstruct ocean conditions in the past, accompanied by a broad suite of hydrographic parameters and biological data.

Anticipated beneficiaries of GEOTRACES products include scientists studying the sustained health of marine ecosystems and their sensitivity to changes in their chemical environment; paleoceanographers seeking to reconstruct past changes in the ocean environment; and scientists and policymakers who seek a better understanding of the transport and fate of contaminants in the ocean. In addition, GEOTRACES data provide a baseline against which future changes can be assessed, as for example, the impact of deep sea seabed mineral extraction.

Vision and Potential Transformative Impact

The GEOTRACES Intermediate Data Product contains "trace element" data, referring to their low abundance in the ocean. Indeed, elements such as iron (Fe), zinc (Zn), cobalt (Co), cadmium (Cd), and manganese (Mn) are micronutrients essential for marine life (and serve as co-factors in enzymes that are used in photosynthesis and respiration), but are often present in seawater in extremely low concentrations (orders of magnitude of 10^{-7} mol/kg to 10^{-15} mol/kg). For most of them, their isotopes are measured too since they add inestimable complementary information on their marine behavior. Partly because of this low concentration, and also because of the relatively recent recognition of the importance of these micronutrients, the knowledge of their attributes is incomplete. This lack of understanding is the fundamental limitation on the assessment of the chemical controls on ecosystem health and biological carbon uptake in the oceans. This is the primary focus of the international GEOTRACES program.

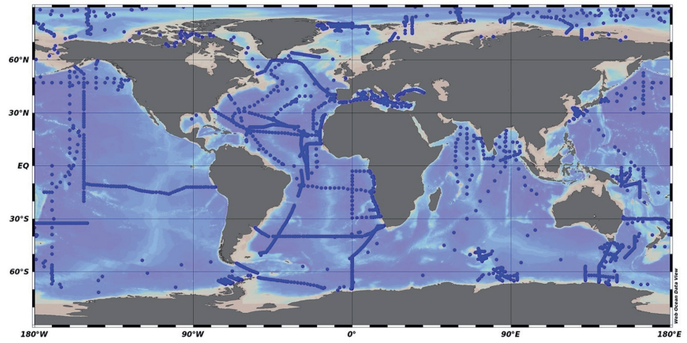

FIGURE 1. Map showing the GEOTRACES Seawater discrete sample data available. Source: Schlitzer, Reiner and Sebastian Mieruch-Schnülle, webODV Explore, https://explore.webodv.awi.de, 2021.

Trace element analysis was often compromised by contamination until the development and implementation of contamination-free methods that revolutionized marine chemistry. Despite these advances, the volume and geographic coverage of high-quality of trace metal data by the end of the 20th century were insufficient. GEOTRACES has now radically transformed this through the development of new technologies combined with international cooperation. GEOTRACES trace metal data also includes radioactive and stable isotopes [protactinium (Pa), thorium (Th), radium (Ra), neodymium (Nd), rare earth elements (REE), etc.], providing diagnostic information about the physical, geological, and chemical processes that supply or remove solutes in the ocean; and providing information about ocean conditions in the past.

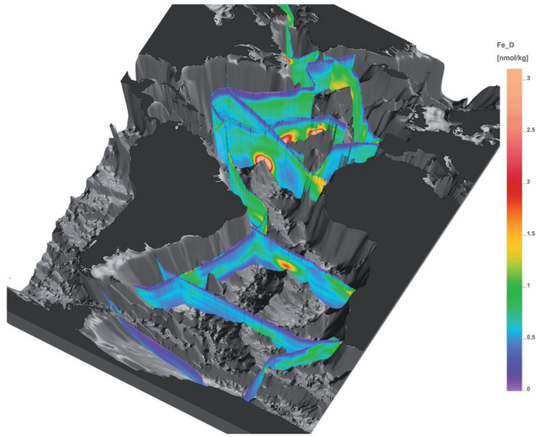

FIGURE 2. Fixed 3D image of dissolved iron concentrations in the Atlantic Ocean. Warm colors indicate high concentrations. Source: Schlitzer, Reiner, eGEOTRACES–Electronic Atlas of GEOTRACES Sections and Animated 3D Scenes, http://www.egeotraces.org, 2021. Data creators for Figure 2: Eric Achterberg, Hein J de Baar, Andrew Bowie,,Kenneth W. Bruland, Kristen N. Buck, Fanny Chever, Manuel Colombo,Tim Conway, Jay T. Cullen, Morgane Gallinari, Gideon Henderson, Sarah Jackson, David Janssen, Seth John, Maarten Klunder, Korinna Kunde, Patrick Laan, Francois Lacan, Maeve Lohan, Alastair Lough,,Christopher Measures, Rob Middag, Kristin Orians, Hélène Planquette, Catherine Pradoux, Micha J. A. Rijkenberg, Mak Saito,,Geraldine Sarthou, Christian Schlosser, Peter Sedwick, Abigail Smith,,Bettina Sohst, Brent Summers, Charles-Edouard Thuroczy, Jingfeng Wu.

Contaminants such as, for example lead (Pb) and mercury (Hg), are also included in the collection of data. By collecting contaminant data, GEOTRACES aims at improving the prediction of the transport of the fate of ocean contamination, and thus help protecting the environment.

These data are accompanied by a suite of hydrographic parameters used to trace water masses including carbonate chemistry and biological data necessary to assess the biological response to micronutrient availability as well as the impact of biota on trace element distributions.

Thus, GEOTRACES provides sound basic findings, essential to achieve a sustainable ocean, that solution-oriented science can use.

Opportunities for International Participation and Collaboration

At the heart of the GEOTRACES program was the realization that the ocean was too large for one nation to compile the information needed to characterize the biogeochemical cycles of trace elements and isotopes. Thus, the scientists were aware that international collaboration was essential and established a truly international scientific cooperation sharing the workload involved with sampling globally (Figure 1). To date, 131 research voyages have been completed. GEOTRACES scientists also collaborate in the development of new technologies to accelerate the collection and analysis of samples, the intercalibration of those technologies to ensure internal consistency among the participating labs, the development of a data management system to facilitate access to the results that includes an online portal to submit these data (https://geotraces-portal.sedoo.fr/pi/), and a broad collaborative effort to model, synthesize, and interpret the results. An International Project Office, located in Toulouse, France, coordinates these activities.

The GEOTRACES Intermediate Data Product

The most updated version of the GEOTRACES Intermediate Data Product was released in November 2021. It consists of two parts:

(1) the digital data and

(2) the eGEOTRACES Electronic Atlas

The digital data contains hydrographic and biogeochemical data from 77 cruises covering the global ocean. It is possible to download the data as a bulk download (https://www.bodc.ac.uk/geotraces/data/dp) or as subsets of data (https://geotraces.webodv.awi.de/). An online tool is also available in order to analyze, explore and view these data without downloading it (webODV Explore tool https://explore.webodv.awi.de/).

The eGEOTRACES Electronic Atlas (available at https://www.egeotraces.org) is based on the digital data package and provides section plots and animated 3D scenes for many of the parameters (Figure 2), allowing quick overviews of the occurrence of geochemically relevant tracers. The 3D scenes provide geographical context crucial for correctly assessing the data. The numerous links to other tracers, sections, and basins found on each section plot and 3D animation allows quick switching between parameters and domains and facilitates comparative studies.

The eGEOTRACES Atlas is an important tool for teaching and outreach activities and also facilitates conveying societally relevant scientific results to interested laymen or decision makers.

Examples of Future GEOTRACES Data Uses

GEOTRACES data provide a baseline to assess any future perturbation of the natural distribution of chemical elements due to human activities. For example, it is anticipated that growth of seabed mineral extraction may alter future trace element distributions in the deep sea; GEOTRACES will allow assessing these changes.

Another example is the growing use of gadolinium (Gd) in medical procedures leading to its release into the environment. Although not yet detectable in the open ocean, an anthropogenic signal has been measured in coastal waters. Again, GEOTRACES data will serve to assess the changes of the natural distribution of Gd, or of any of the other Rare Earth Elements (REEs) experiencing growing use in the industry.

Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers, and Technologists

GEOTRACES is training young researchers (particularly through GEOTRACES international summer schools and training workshops), and developed capacity for GEOTRACES science worldwide by providing guidance and expertise to build trace element and isotope capability as well as promote shared facilities. So far, 35 scientific and training workshops have been organized and the third summer school is planned to be held in July 2022 in Germany (https://geotraces2022.sciencesconf.org/). This has resulted in the formation of a strong, well-qualified, and interactive research community of marine geochemists who are answering questions about how trace elements affect, and respond to, the interactions of humankind with the ocean.