GEOTRACES: Studying the Global Marine Biogeochemistry of Trace Elements and Isotopes

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There is a growing international interest among geochemists and oceanographers in building a coordinated global study of the marine biogeochemical cycles of selected trace elements and isotopic tracers. This is reflected by the increasing numbers of contributions to corresponding special sessions at meetings such as the 2001 AGU Fall Meeting, the 2002 Goldschmidt Meeting, and the 2003 European Geophysical Union Annual Meeting. With support from the U.S. National Science Foundation's Chemical Oceanography program, the Centre National de Recherche Scientifique in France, the University Paul Sabatier, and the Observatoire Midi-Pyrénées, an international planning workshop was recently held to define the scientific goals for such a global study.

Eighty-five scientists from 15 nations representing fields as diverse as physical oceanography, dynamic and biogeochemical ocean modeling, ocean geochemistry, and paleoceanography attended the workshop. There was a broad consensus recognizing the need for a coordinated research effort in the spirit of the 1970s Geochemical Ocean Sections Study (GEOSECS) program, which led to fundamental advances in the understanding of ocean circulation and biogeochemical cycles. Dramatic advances have been made in analytical techniques, chemical sensors, and modeling since the days of GEOSECS, but progress in understanding the global biogeochemical cycles of trace elements and their isotopes has been limited by the lack of a large-scale coordinated effort. Workshop participants enthusiastically endorsed the development of such a program, for which the name GEOTRACES was adopted.

The primary objectives of GEOTRACES are to determine global distributions of selected trace elements and isotopic tracers (TEIs) in the ocean; to evaluate the oceanic sources, sinks, and internal cycling of TEIs and thereby characterize more completely their global biogeochemical cycles; and to build and maintain a core community of marine scientists who understand the chemical, physical, and biological processes regulating the distribution and properties of trace elements and isotopes well enough to exploit them reliably in future interdisciplinary studies.

The added insight into the behavior of TEIs that will be gained through GEOTRACES will provide essential information for a broad spectrum of oceanographic and climate research, ranging from:

- the processes controlling the distribution and speciation of biolimiting micronutrients and their impact on ecosystem structure (e.g., Fe, Cu, Zn, etc.);
- the use of geochemical tracers to characterize the distributions and trajectories of ocean water masses and establish mean transport and mixing rates on time scales that are not readily amenable to direct measurements;
- the development of geochemical tracers such as natural radionuclides to quantify processes involved in the ocean carbon cycle (e.g., export flux of biogenic materials from the euphotic zone, re-mineralization in the mesopelagic zone, delivery, and sequestration to the deep sea);
- the development and calibration of marine sedimentary proxies for past ocean dynamics and biogeochemical cycling, and;
- the assessment of the transport and fate of pollutants.

The establishment of a close and synergistic relationship between observations and modelling (forward and inverse) was also viewed as essential for streamlining the field programs and optimizing data interpretation.

The unifying goal of GEOTRACES is to develop a global suite of basin-scale sections of TEI distributions. A striking example of the need for a greatly expanded ocean data base is provided by Fe, the concentration of which is thought to limit phytoplankton growth and to regulate the structure of planktonic ecosystems in high-nutrient, low-chlorophyll (HNLC) regions. Fe has also been invoked to control nitrogen fixation in the oligotrophic central gyres. Notwithstanding the perceived importance of this trace element, there is almost a complete lack of reliable sea water data for dissolved Fe concentrations and speciation. Consequently, a clear understanding and reliable modeling of the processes supplying dissolved Fe to surface waters and their sensitivity to climate change is not possible at present.

A similar situation exists for other biolimiting trace elements. Likewise, a limited number of sea water profiles of the isotopic composition of some elements—for example, Nd, Pb, Th, and Pa—provide tantalizing glimpses of the potential of these geochemical tracers to contribute to our understanding of past and present ocean circulation. Full realization of this potential, however, requires synoptic data bases that can only be obtained through a concerted international sampling program.

The workshop participants also recognized that, in addition to large-scale transects, there will be a need for process studies at key locations in the oceans if we are to better understand the factors controlling the sources, sinks, and internal cycling of TEIs. For example, process studies will be required for elucidating the mechanism of metal dissolution from aeolian dust in surface waters, for understanding the exchange of metals and isotopic signatures between margin sediments and adjacent water masses, and for documenting the role of redox and scavenging reactions within hydrothermal plumes. Detailed mechanistic studies will also be essential for the development and calibration of proxies in the modern ocean to enable their reliable application to studying, for example, past ocean circulation or productivity. Target sites for process studies were identified during the workshop, and an initial effort was made to link these to cross-basin sections.

Further development and refinements of both process studies and basin sections are expected to take place during regional and national planning workshops to be held during the coming year. These process studies will be conducted in close collaboration with other ocean research initiatives, such as WCRP (CLIVAR), IGBP/SCOR (IMBER, SOLAS, LOICZ, GLOBEC), RIDGE, MARGINS, IMAGES/PAGES, and various modeling programs to ensure synergy between the different programs and avoid duplications of effort. GEOTRACES itself is pursuing a status as a Scientific Committee on Oceanic Research (SCOR) working group, and an associated status under the umbrella of the new International Geosphere-Biosphere Program Integrated Marine Biogeochemistry and Ecosystem Research (IMBER).

To further the development of the GEOTRACES program and foster a community-wide discussion of its goals and implementation, the GEOTRACES Web site (http://www.ldeo.columbia.edu/res/proj/geotraces) will be updated frequently with planning information; and the workshop report, and eventually the science plan, will be posted there for comments. Special sessions dedicated to the scientific objectives of the GEOTRACES program will also be held at the 2004 AGU Ocean Sciences Meeting, to be held 26–30 January 2004 in Portland, Oregon, and at the 14th Goldschmidt Meeting to be held 6–11 June 2004 in Copenhagen, Denmark.

The international GEOTRACES planning workshop was held 13–16 April 2003, in Toulouse, France.

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