High-Quality Marine Analytical Chemistry on a Global Scale

by David Turner and Ed Urban

Studies of ocean chemistry on a global scale have a long history, beginning with the Challenger Expedition in the 19th Century. In the modern era, the Geochemical Ocean Section Study (GEOSECS) programme in the 1970s provided the first global picture of inorganic carbon and its isotopes in the ocean and laid the basis for the first assessments of the extent to which the oceans take up fossil fuel CO_2 from the atmosphere. This foundation was later complemented by the World Ocean Circulation Experiment (WOCE) which, although focused primarily on physical oceanography, provided a wealth of information on nutrient and inorganic carbon distributions.

These programmes did not include trace metal measurements; their importance as micronutrients and tracers of ocean processes was yet to be fully understood and sampling and measurement techniques were still under development. Although trace element concentrations are in the picomolar to nanomolar range in the open ocean, the major analytical challenge to be addressed was not instrumental sensitivity, but avoidance of contamination. This was finally overcome in the 1970s through the development of "trace metal-clean" sampling and sample-handling methods that involve the use of Class 100 clean rooms, carefully purified reagents, and rigorous acid washing of bottles and equipment selected to avoid contamination or absorption of the elements of interest. The field has now truly come of age with the GEOTRACES programme, which was first introduced to the IUPAC community almost a decade ago (*Chemistry International*, Nov-Dec 2006, pp 4-5).

In order to meet the goals of the GEOTRACES programme (see box), it was necessary to address the question of quality assurance. The programme established a Standards and Intercalibration Committee to oversee this work, which began with a major challenge since there were no standard materials available at the very low trace metal concentrations present in open ocean waters. Through a series of intercalibration cruises and laboratory comparisons and the collection of large-volume samples from the Pacific Ocean that are used as standard materials, GEOTRACES has been able to demonstrate excellent quality assurance for the very challenging trace metal analyses carried out by laboratories all around the world. See Cutter (2013) for further details.

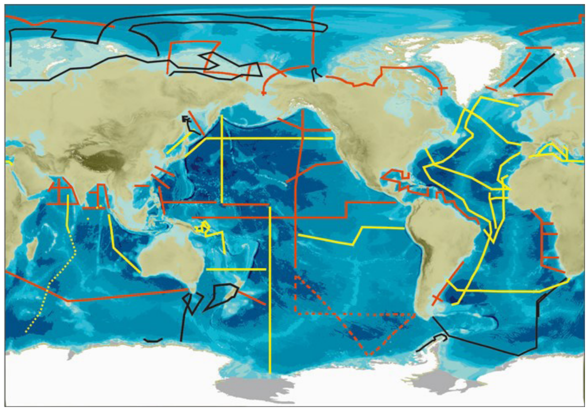

Fig. 1. Completed GEOTRACES sections in yellow and black, planned sections in red

GEOTRACES has now completed a significant proportion of the planned ocean sections, particularly in the Atlantic Ocean (Figure 1), and has released a first Intermediate Data Product, IDP (Mawji et al., 2015), which is freely available from the GEOTRACES website (www.geotraces.org). The IDP comprises datasets in several file formats (www.bodc.ac.uk/geotraces/data/idp2014/), together with the eGEOTRACES electronic atlas of section plots and animated 3D scenes for a selected ocean basin (www.egeotraces.org). For example, the Atlantic data for dissolved iron (Figure 2)

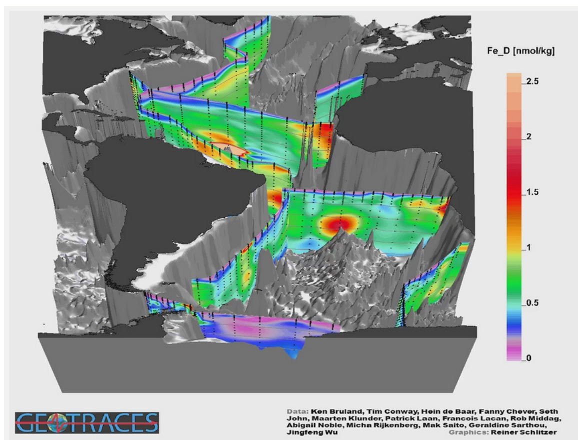

Fig. 2. Distribution of dissolved iron, a key micronutrient, in the Atlantic Ocean. This is a still picture from the 3D-animation. Halos of red indicate predominant sources of dissolved iron, such as the hydrothermal emissions from mid ocean ridges (mountain ranges) that run the length of the Atlantic Ocean.

show clearly for the first time the role of hydrothermal systems on the mid-Atlantic ridge as sources of iron to the ocean, and also show clearly the iron sources from coastal sediments. The Atlantic data for dissolved lead

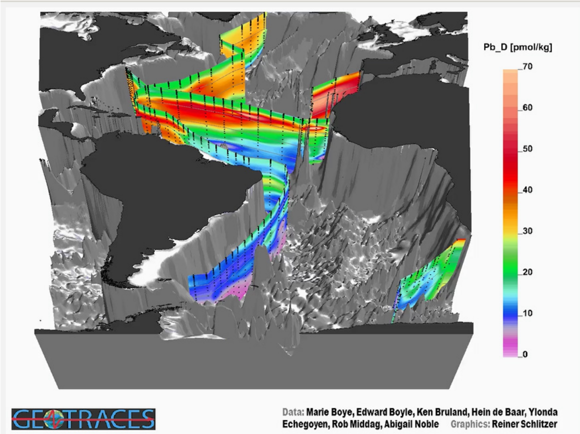

Fig. 3. Distribution of dissolved lead, a toxic trace metal, in the Atlantic Ocean. This is a still picture from the 3D-animation. High concentrations of lead, coloured red in the figure, indicate water masses that were at the ocean surface during the 20th Century, where they experienced high levels of lead deposition.

show the extent to which the anthropogenic lead signal has penetrated Atlantic waters (Figure 3), and also show that concentrations in the surface layers now reflect the lower atmospheric lead emissions following the introduction of unleaded petrol. This unprecedented collection of high-resolution, quality-controlled data for many trace elements and isotopes provides new opportunities for quantifying the rates of supply and removal in the different ocean basins, and for assessing the extent to which these are in balance. Such research will provide new insights into ocean biogeochemistry, and will develop our ability to predict how the oceans will respond to climate change.

The GEOTRACES programme is ongoing, with plans for completing the remaining sections (red in Figure 1) over the coming years. In order to ensure that GEOTRACES data continues to be available to the wider oceanographic community, a second Intermediate Data Product is already planned for release at the 2017 Goldschmidt Conference.

www.geotraces.org

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References

1. Cutter GA (2013). Intercalibration in chemical oceanography - Getting the right number. *Limnology and Oceanography-Methods* 11:418-424. doi:10.4319/lom.2013.11.418
2. Mawji E., *et al.* (2015). The GEOTRACES Intermediate Data Product 2014. *Marine Chemistry*. doi: 10.1016/j.marchem.2015.04.005

GEOTRACES Overriding Goals

Past: "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."

Present: "To determine global ocean distributions of selected trace elements and isotopes, including their concentration, chemical speciation, and physical form, and to evaluate the sources, sinks, and internal cycling of these species to characterize more completely the physical, chemical, and biological processes regulating their distributions."

Future: "To understand the processes involved in oceanic trace-element cycles sufficiently well that the response of these cycles to global change can be predicted, and their impact on the carbon cycle and climate understood."