Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.22113

Controls and distributions of trace elements in the oceans: an updated view

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Almost the entire periodic table of chemical elements are represented in the dissolved phase of the oceans. However, while major elements that make up salinity (such as Na and Cl) are present at molar concentrations in seawater, many elements are only present at femto- ($1x10^{-15}$) to nano- ($1x10^{-9}$) molar levels. Such elements, classified as the 'trace elements' or TEIs include a range of bioactive metals (e.g. Fe, Zn, Mn, Co, Cd, Cu, Ni, Cr), useful tracers for past and present ocean processes (e.g. Al, He, Th, Pa, Ra, Rn, REE), and anthropogenic pollutants (e.g. Hg, Pb), amongst others. Each trace element's distribution throughout—and residence time in—the oceans is determined by a distinct combination of biogeochemical processes, including elemental physiochemistry and speciation, addition from external sources (atmosphere, rivers, sediments, hydrothermal venting), removal by internal processes or at sinks (particle-scavenging, sediments, hydrothermal systems), and redistribution within the oceans by both biological cycling and physical circulation.

Here we present an updated view of the the distributions of the marine trace elements in the modern ocean (and the which control these distributions), drawing on over a decade of new data from the international GEOTRACES program. We emphasize the growing shift in thinking from the classical vertical understanding of trace elemental cycling from seminal studies in the 1970s-1990s, to a 3D view with the availability of large WOCE-style GEOTRACES datasets, where many trace element distributions are dominated by physical ocean circulation and pre-formed tracers, overprinted by local processes. We also highlight the need for consideration of multiple boundary sources for many trace elements (especially Fe), the advantage of multi-tracer and isotopic approaches in interrogating biogeochemical questions, and an increasing appreciation of the role of processes in the Southern Ocean and ocean circulation in setting the global distribution of many trace elements throughout the modern oceans.

This abstract draws from [1], which is an update from earlier versions of the Treatise of Geochemistry by Bruland, K.W., Lohan, M.C, and Middag, R.

[1] Conway, T. M., and Middag, R. 2024. *Treatise of Geochemistry, 3rd Edition.*