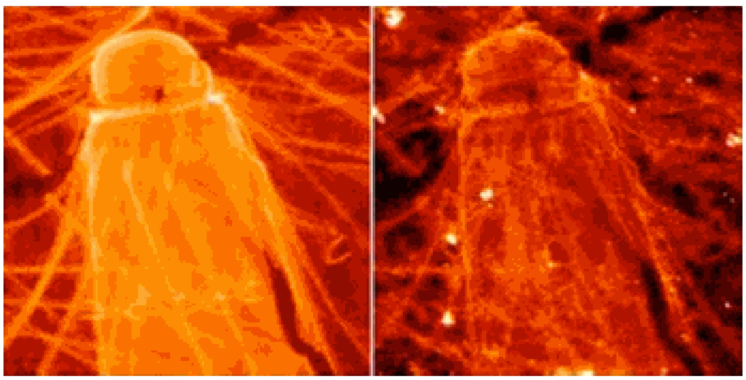
The fate of bioavailable iron in Antarctic coastal seas

December 13 2013, by Dana Desonie



On the left is an XRF micrograph map of silicon distribution in the diatom Corethron spp. On the right is a map of the distribution of iron in the same diatom. (The images are 66 µm in width.) Lighter colors indicate higher concentrations. Note how the distribution of iron mirrors the distribution of silicon.

Science is exploring many options for carbon dioxide sequestration in order to mitigate the climatological impact of CO2. One of these is geoengineering: deliberate, large-scale intervention in the Earth's natural systems to counteract climate change. Understanding all of the possible effects of geoengineering, such as the results of iron fertilization on marine ecosystems, is vital. In iron fertilization, which has been discussed as a way to sequester carbon dioxide from the atmosphere, iron is introduced to the surface ocean to stimulate a phytoplankton bloom in locations where iron is the limiting nutrient. Carbon taken up by the phytoplankton is later sequestered in deep sea sediments.

Researchers using the U.S. Department of Energy Office of Science's Advanced Photon Source found that iron was incorporated into biogenic silica in diatoms from the Southern Ocean and was then lost from the ecosystem. The loss of bioavailable iron could favor the growth of phytoplankton species that are less efficient at assimilating carbon, the opposite of the desired result of iron fertilization.

Diatoms, single-celled algae that have a cell wall of silica, account for nearly half of the annual marine carbon fixation worldwide, and dominate many phytoplankton communities in Antarctic coastal seas. After the organisms die, their dense siliceous shells descend into the deep ocean. The sequestration of carbon in deep sea sediments is a crucial sink for carbon dioxide, an important greenhouse gas. Iron is a limiting nutrient in phytoplankton communities in these seasonally ice-covered seas, which include some of the most biologically productive regions of the Southern Ocean, like the Ross Sea. Bioavailable iron limits biological production and also affects the composition of the phytoplankton community.

The availability of iron, therefore, can limit uptake of atmospheric carbon dioxide, with important implications for the climate. Understanding iron cycling in Antarctic phytoplankton is crucial for determining whether iron fertilization can be an effective strategy for reducing atmospheric carbon dioxide.

In the Ross Sea, bioavailable iron enters the area through snow melt and dust deposition. Iron removal is calculated to be about equal to iron input. Fertilizing the surface ocean with iron increases biological productivity, but the resulting carbon dioxide removal will be much less than expected due to the increased productivity of diatoms, which incorporate and remove the bioavailable iron.

The resultant decrease in iron favors plankton communities with lower iron requirements. Phaeocystis antarctica, a non-siliceous prymnesiophyte, dominates some Southern Ocean phytoplankton communities, but loses out to diatoms when bioavailable iron is low. P. antarctica assimilates more carbon dioxide than diatoms, so a shift to a diatom-rich phytoplankton community may reduce carbon dioxide sequestration, the opposite of the desired effect.

In this investigation, the researchers from the Georgia Institute of Technology, the University of Georgia, the Bigelow Laboratory for Ocean Sciences, the Skidaway Institute of Oceanography, and Argonne National Laboratory discovered an important sink for iron in some marine systems. Utilizing X-ray Science Division beamlines 2-ID-D and 2-ID-E at the Argonne Advanced Photon Source, the researchers performed x-ray fluorescence (XRF) microscopy and x-ray absorption near-edge structure spectroscopy on samples of the diatom genera Fragilariopsis and Corethron from the Ross Sea.

Two morphologically distinct forms of iron were discovered: one reduced form was structurally incorporated into the biogenic silica; the second form was hot spots of iron that were more oxidized.

The researchers conclude that the iron was incorporated into the biogenic silica because iron in contact with seawater would become at least partially oxidized. This incorporated organic iron has a better chance of surviving diagenesis (the conversion, as by compaction or chemical reaction, of sediment into rock) deep in a frustule (the 2-valved siliceous shell of a diatom) than it would in a surface coating or in the protoplasm. When the siliceous diatoms sink to the sea floor, the iron is sequestered from the marine ecosystem. The loss of iron from the surface may reduce biological productivity in locations where iron is limiting.

This research leads to a greater understanding of the dynamics of iron cycling in the Southern Ocean with possible implications for improving carbon sequestration.

More information: Ellery D. Ingall, Julia M. Diaz, Amelia F. Longo, et al. "Role of biogenic silica in the removal of iron from the Antarctic seas," *Nat. Comm.* 4, 1981 (2013). DOI: 10.1038/ncomms2981

Provided by Argonne National Laboratory