Mineral Weathering in the Arctic

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Calcium-magnesium carbonates in marine sediments are the ultimate "geologic" sink of atmospheric carbon dioxide. Calcium and magnesium are supplied by weathering of silicate minerals found in rocks on the continents. Silicate weathering and transport of dissolved calcium and magnesium to the ocean are thus of paramount importance for the long-term stability of Earth's climate. Globally, mineral weathering consumes about 0.3 Gt (300,000,000 tons) of carbon per year, a flow that is only slightly smaller than the flow of organic carbon from rivers. Mineral weathering reactions are temperature- and runoff-dependent, and both factors are thought to increase with rising atmospheric carbon dioxide concentrations. Weathering rates should, therefore, increase over the next 50-100 years during which atmospheric carbon dioxide concentrations may more than double.

With support from the Clark Arctic Research Initiative, we proposed to investigate mineral weathering in several Arctic rivers in Canada and Russia with a specific focus on the spring flood period. This logistically-difficult project was conducted in collaboration with colleagues at the Woods Hole Research Center (WHRC) and our organic chemistry colleagues here at WHOI, whose project to work on the organic aspects of Arctic River chemistry was also funded by the Clark Arctic Research Initiative. This collaborative work will provide unprecedented insights into the most important flow period of Arctic rivers.

Arctic rivers are responding to environmental changes, including the thawing of permafrost that modifies water movement through Arctic soils. These changes not only mobilize soil carbon, but also increase the surface area of minerals that are in contact with soil moisture. Since Arctic rivers are important sources of freshwater nutrients to the Arctic Ocean, investigations of the chemical makeup of large Arctic rivers are important to understanding the impact of global climate change on the Arctic in general. This project was a baseline study against which future studies of Arctic rivers conducted at higher atmospheric CO_2 concentrations can be compared.

Our project utilized samples from six Arctic Rivers, with particular emphasis on the Lena and Ob (Figure 1, next page). These rivers are as large as or larger than the Mississippi River. We were fortunate to obtain samples taken during the ice break-up period in late May/early June of 2007. The chemical composition of the Lena during the spring thaw (freshet) varied significantly. During the onset of the high-flow period, the concentration of some chemicals, including those that are indicators of silicate weathering such as sodium, increased by as much as a factor of four. At peak flow, concentrations were typically slightly lower than during the onset of the spring freshet. In contrast to the Lena, the chemical composition of the Ob showed less systematic variation but large day-to-day variability of up to a factor of three. Even larger variations were observed in the concentration of sensitive trace elements, which can vary by an order of magnitude during the spring period.

Figure 1: Watersheds of the six largest Arctic rivers. Together, these rivers contribute more than 50% of the riverine freshwater entering the Arctic Ocean.

The chemical data have been published in the PhD thesis of MIT/WHOI Joint Program Student Christian Miller, who is also preparing two additional manuscripts with more detailed interpretations of the observed chemical variations. In particular, we want to put the new results into the context of existing data for the Lena and Ob Rivers that do not include data for the spring freshet and also do not include data (at monthly resolution) for multiple years.

Funding for this project helped us establish working relationships with scientists at the Woods Hole Research Center (WHRC). This collaboration has matured during the grant period and has led to the formation of a “World River Group” that includes scientists from WHOI and the WHRC. This year, the National Science Foundation awarded us a $2.4M grant to investigate the biogeochemistry of large river systems, with a particular focus on the export of terrestrial carbon to the ocean. Our group is currently studying the Lena, Kolyma, Fraser, Congo, Ganges, Brahmaputra and Yangtze Rivers, and we have begun to explore chemical variations along the Danube and Mackenzie Rivers with our collaborators in Europe.

We are grateful to the Clark Arctic Research Initiative for making the collaboration with WHRC possible, and for leveraging the grant from the National Science Foundation to continue this research.