

Mechanical-chemical weathering linkage: Erosion and solute fluxes due to glaciers

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Mechanical and chemical weathering processes are usually so tightly coupled that it is difficult to determine which drives which. Glaciers present a simplified case in which physical erosion processes clearly dominate: sediment fluxes substantially exceed solute fluxes, and the erosional products from a glacier, once the carapace of weathered rock is removed at the beginning of glaciation, consist of fresh rock fragments ranging in size from clay to boulders. It is possible to ask in this system whether increasing erosion rates impacts chemical weathering fluxes. The answer highlights the importance of both physical erosion and climatic factors in driving weathering fluxes.

Erosion rates under glaciers can exceed the highest non-glacial erosion rates (Hallet et al., 1996). About half the sediment produced is finer than fine sand. A small 7 km² glacier eroding at 1.5 mm/y can produce nearly 8000 km² of mineral surface area. Although this surface area production rate can reasonably predict the silicate weathering flux, low (0°C) temperatures at the glacier bed keep these fluxes low (Anderson, 2005). Even the high water fluxes typically found through glaciers are insufficient to compensate for low temperatures. The subglacial environment is one in which erosion rates appear to drive silicate weathering fluxes, but these fluxes are damped due to the low temperature environment.

The linkage between erosion and chemical weathering becomes extended over time and space when one considers the fate of glacially-derived sediments. Silt-sized glacial loess blankets large areas. Accumulations of as little as 5 cm may double silicate weathering fluxes from the depositional environment. Thus, surface area production by mechanical processes alone is insufficient to enhance silicate weathering fluxes. Appropriate environmental conditions (temperature, water flux) are required as well.

References

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Non-steady state erosion of shales in the Mackenzie River basin (Canada): Evidence from boron isotopes

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The Mackenzie River basin (Canada) is mostly made of shales. Both the denudation rates of carbonates and silicates have been previously determined (Millot et al., 2003). It is therefore an ideal place to look at the mechanisms of sedimentary silicates weathering under cold climatic conditions.

We have analyzed boron isotopes in samples of the river waters. Boron has two isotopes (¹⁰B and ¹¹B) that are strongly fractionated by adsorption processes on mineral surfaces. Boron isotopes in waters are therefore an appropriate proxy for investigating interactions at the water/mineral interface.

The B isotopic compositions measured in the river waters of the Mackenzie show a large range of variations (from +3.5‰ in the Rocky and Mackenzie Mountains up to +29‰ in the interior plains). Examination of the water chemistry demonstrates that dissolved B is regulated by weathering reactions involving silicates with minor contributions of atmospheric inputs and dissolution of carbonates and evaporites. This conclusion is confirmed by a clear correlation between B isotopes and the total dissolved load originating from the weathering of silicates.

The relative enrichment in ¹¹B found in river waters of the lowlands compared to the source rocks, is explained by ion exchange reactions of B onto clay minerals in soils and groundwaters system. This implies that dissolved B in rivers is regulated by surface reactions onto B adsorbing surfaces and is therefore affected by both the nature of the weathered minerals and the hydrological setting of the basin (water pathways).

Comparison of B carried by the solid and the dissolved phases in rivers also indicates that the weathering mechanisms responsible for the release of B are clearly out of steady state conditions. Because of the correlation between dissolved B and total solutes, this rises the question of the global impact of groundwaters on geochemical fluxes and of the mechanisms of the cation release during the weathering of sedimentary silicates.