

Glacial weathering congruency constrained by nanoparticle analyses and dissolution kinetics

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The chemical weathering of silicate minerals is the primary geologic source of alkalinity and ultimate sink for CO₂ in the ocean-atmosphere system. The temperature dependence of this reaction creates a negative feedback thought to partially regulates Earth's climate over geologic timescales. Understanding the controls on silicate weathering besides temperature is therefore required to accurately assess the buffering capacity of the weathering-climate feedback. However, major knowledge gaps exist regarding the effects of glaciation on chemical weathering. Of particular interest, observations suggest systematic differences between glaciated and non-glaciated watersheds in weathering congruency, i.e. the amounts and types of secondary phases. The formation of secondary clay minerals can affect the alkalinity budget and drive large changes in river chemistry, leading to potentially biased estimates of silicate weathering fluxes and their associated climate effects. However, the mechanistic controls on secondary clay formation remain elusive.

In this study, we attempt to constrain the role of glaciers in weathering congruency by comparing chemical and isotopic compositions of riverine dissolved loads and suspended sediments from a recently deglaciated and a currently glaciated catchment in Iceland. Dissolved germanium to silicon ratios (Ge/Si) and silicon isotope ratios ($\delta^{30}\text{Si}$) both indicate elevated weathering congruency in the glacial catchment. Nanoparticles (< 1 micron) were detected and analyzed by single-particle mass spectrometry in glacial rivers. These nanoparticles may be generated from glacial abrasion as no nanoparticle was detected in non-glacial rivers. Across glacial samples, 30 – 70% of the nanoparticles share similar elemental composition as anorthite, while others are compositionally more diverse, which likely represent secondary phases. Correlations between dissolved $\delta^{30}\text{Si}$, suspended sediment $\delta^{30}\text{Si}$, and the fraction of anorthite nanoparticles suggest that the dissolution of anorthite nanoparticles during transport may explain the observed higher weathering congruency in glacial rivers. However, the apparent persistence of anorthite in undersaturated waters imply possible

protection by leached layer from complete dissolution. The dissolution kinetics of the anorthite nanoparticles will be modeled to accurately assess their stability and residence time in rivers, elucidating the mechanisms through which glaciers control weathering congruency and the associated carbon cycle implications.