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Coastal aquifers as major players in alkalinity fluxes and potential moderators for glacial-interglacial transitions

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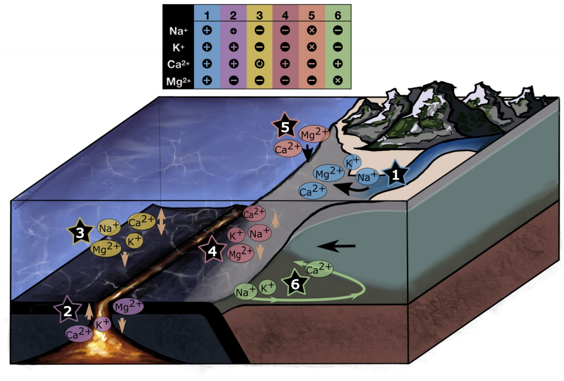

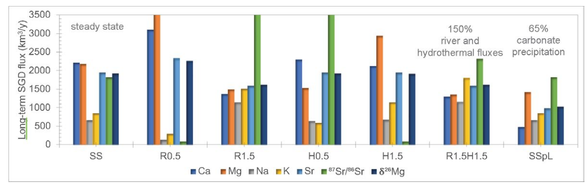

Understanding the fluxes of major elements to and from the ocean is crucial for comprehending the carbon cycle, particularly through the effects on calcium carbonate saturation and preservation. Our study compiles a comprehensive database from coastal aquifers' onshore wells, revealing how long-term interactions (>several years) between circulating seawater and aquifer sediments alter major elements, enriching calcium and strontium while depleting potassium and sodium. Using a multi-element Monte Carlo simulation informed by these findings and strontium and magnesium isotopic data, we estimate the long-term submarine groundwater discharge (SGD) from coastal aquifers to be ~2000 km³/year, suggesting their contribution to ocean chemistry is comparable to that of rivers. Sensitivity analysis of chemical budgets under varying scenarios further supports the substantial role of long-term SGD, highlighting potential underestimations in current models of river and hydrothermal fluxes or overestimations of carbonate precipitation.

Exploring the interplay between climate shifts over glacial-interglacial time scales and sea level changes, our study reveals how these factors crucially influence solute fluxes through coastal aquifers, particularly impacting the balance between calcium and the alkalinity of potassium and sodium. Our findings indicate that sea level rise leads to a reduced flux of calcium, whereas a decrease in sea level enhances calcium flux. This understanding allows us to hypothesize that coastal aquifers dynamically interact with climate variations by potentially increasing atmospheric CO_2 levels during global cooling phases and decreasing CO_2 levels during warming phases. Through preliminary calculations of the ocean's charge balance and carbonate system, we propose that coastal aquifers act as a negative feedback mechanism. This process is capable of moderating the transitions between glacial and interglacial periods by adjusting atmospheric CO_2 concentrations in response to sea level changes. Our research underscores the pivotal role of coastal aquifers in the Earth's climate system, suggesting their potential to moderate glacial-interglacial transitions through solute flux adjustments, thereby acting as a critical counterbalance in the global carbon cycle.