Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34809

Kinetic and thermodynamic constraints on reverse weathering reactions in the Precambrian oceans

AVA TAGGART AND BENJAMIN M. TUTOLO
University of Calgary

Reverse weathering represents a key feedback between Earth's silica and carbon cycles, allowing for enhanced reconstruction of the controls on Earth's climate across geologic time. This process reverses the effect of CO_2 uptake during silicate weathering by producing marine authigenic clays from dissolved silica and alkalinity. Recent models have postulated that rapid rates of reverse weathering maintained a high Precambrian atmospheric pCO_2 and were facilitated by elevated silica concentrations in the oceans before the rise of biosilicification. However, the fundamental geochemical controls on clay authigenesis under Precambrian ocean conditions remain poorly understood. To better understand the role of reverse weathering over this vast expanse of Earth's history, we provide new thermodynamic and kinetic parameterizations of authigenic clay mineral formation under relevant ocean chemistries. Solubility products calculated using the PyGeoChemCalc software package for 20 natural and synthesized clay minerals with Precambrian marine occurrences permit evaluation of the controls on reverse weathering. Generally, these results indicate that the thermodynamic drive for reverse weathering reactions more strongly depends on pH than marine silica concentrations over their plausible respective ranges. Building on this refined thermodynamic understanding, we performed laboratory experiments to investigate authigenic mineral growth rates. Synthetic Precambrian seawater solutions were reacted with kaolinite, a cation poor clay substrate, for one month to simulate the growth of magnesian clays (e.g., smectite-like phases). A ^{29}Si isotope doping method was used in two sequential experimental steps to first track the sorption of silica onto the kaolinite seed and subsequently observe coupled kaolinite dissolution and clay precipitation. The pH of the system was kept constant via autotitrator dosing of NaOH, which permitted direct examination of the role of solution pH on reverse weathering reactions while allowing for continual, direct monitoring of alkalinity consumption by mineral growth. Results show that silica sorption is kinetically favored and clay growth begins after initial sorption equilibrium. Clay growth rates then slow down as a second equilibrium is approached. Together, the data presented here strengthen understanding of the controls on reverse weathering reactions, which will, in turn, help to refine paleoclimatic models seeking to understand the history of Earth's habitability.