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A Lithology-based Silicate Weathering Model for Earth-like Planets

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Silicate weathering is a key step in the carbonate-silicate cycle (carbon cycle) that draws down

CO2 from the atmosphere for eventual burial and long-term storage in the planetary interior. This process is thought to provide an essential negative feedback to the carbon cycle to maintain temperate climates on Earth and Earth-like. We implement thermodynamics to determine weathering rates as a function of surface lithology (rock type). These rates provide upper limits that allow estimating the maximum rate of weathering in regulating climate. We model chemical kinetics and thermodynamics to determine weathering rates for three types of rocks inspired by the lithologies of Earth's continental and oceanic crust, and its upper mantle. We find that thermodynamic weathering rates of a continental crust-like lithology are about one to two orders of magnitude lower than those of a lithology characteristic of the oceanic crust. Our results show that the weathering of mineral assemblages in a given rock, rather than individual minerals, is crucial to determine weathering rates at planetary surfaces. We show that when the CO2 partial pressure decreases or surface temperature increases, thermodynamics rather than kinetics exerts a strong control on weathering. The kinetically- and thermodynamically-limited regimes of weathering depend on lithology, whereas, the supply-limited weathering is independent of lithology. Our results imply that the temperature-sensitivity of thermodynamically-limited silicate weathering may instigate positive feedback to the carbon cycle, in which the weathering rate decreases as the surface temperature increases.