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Tectonic Modulation of Seafloor Weathering: Constraints on Climate Sensitivity on Ocean Worlds

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Silicate weathering is thought to regulate atmospheric CO_2 on Earth and may similarly stabilize climates on rocky planets [1]. On ocean-dominated planets, seafloor weathering may be the primary long-term carbon sink, yet its controlling factors and climate feedback strength remain poorly constrained [2-4]. We extend the Maher–Chamberlain weathering framework [5] to the upper oceanic crust and constrain key parameters using Pacific drill-core data [3] within a time-dependent box model. The framework reproduces the observed age-dependent CO_2 content of Cenozoic crust [3] and indicates a transition from kinetically limited weathering during the first 10 Myr after crust formation to a predominantly supply-limited regime thereafter. Climatic forcing alone cannot account for elevated Late Mesozoic crustal CO_2 inventories: plausible variations in bottom-water temperature and carbonate chemistry enhance weathering rates by at most ~3x, insufficient to explain the nearly 5x higher CO_2 contents [3]. Reproducing these inventories requires enhanced exposure of reactive basalt in young crust, corresponding to ~2× greater strain-driven fracturing and fluid pathways in our model [4]. Combined with younger Late Mesozoic seafloor age distributions [6], global seafloor weathering rates may have been ~8× higher than at present (~4 Tmol C yr^{-1} versus ~0.5 Tmol C yr^{-1}), comparable to modern continental weathering rates. Our results indicate that the direct climate sensitivity of seafloor weathering is limited, and its long-term sequestration capacity may depend on tectonic processes that generate and maintain sufficient kinetically limited surfaces to balance outgassing. Tectonic modulation of seafloor weathering may thus be a key control on atmospheric evolution and climate stability on ocean-dominated rocky planets and early Earth–like worlds.

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[6] Becker, Conrad, Buffett & Müller (2009), EPSL 278, 233-242.