REVERSE WEATHERING AS A LONG-TERM STABILIZER OF MARINE PH AND PLANETARY CLIMATE

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For the first four billion years of Earth's history, climate was marked by apparent stability and warmth despite the Sun having lower luminosity. Proposed mechanisms for maintaining an elevated partial pressure of carbon dioxide in the atmosphere (pCO_2) centre on a reduction in the weatherability of Earth's crust and therefore in the efficiency of carbon dioxide removal from the atmosphere. However, the effectiveness of these mechanisms remains debated. Here we use a global carbon cycle model to explore the evolution of processes that govern marine pH, a factor that regulates the partitioning of carbon between the ocean and the atmosphere. We find that elevated rates of 'reverse weathering'—that is, the consumption of alkalinity and generation of acidity during marine authigenic clay formation—enhanced the retention of carbon within the ocean–atmosphere system, leading to an elevated pCO_2 baseline. Although this process is dampened by sluggish kinetics today, we propose that more prolific rates of reverse weathering would have persisted under the pervasively silica-rich conditions that dominated Earth's early oceans. This distinct ocean and coupled carbon–silicon cycle state would have successfully maintained the equable and ice-free environment that characterized most of the Precambrian period. Further, we propose that during this time, the establishment of a strong negative feedback between marine pH and authigenic clay formation would have also enhanced climate stability by mitigating large swings in pCO_2—a critical component of Earth's natural thermostat that would have been dominant for most of Earth's history. We speculate that the late ecological rise of siliceous organisms and a resulting decline in silica-rich conditions dampened the reverse weathering buffer, destabilizing Earth's climate system and lowering baseline pCO_2.