Three billion years of continental weathering and implications for marine biogeochemistry

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Biogeochemical models have often relied on assumptions about changes in terrestrial weathering through Earth's history and linked weathering to continental fluxes, changes in seawater chemistry, and biological evolutions. While this problem has been tackled indirectly by looking at the evolution of continental crust or shales, quantitative constraints on the actual continental weathering products through time have typically not been incorporated, leaving room for incorrect assumptions to affect model results. A compilation of paleosol geochemistry (n= ~3400) through time fills this data gap, quantifying the concentrations of elements in continental weathering products that would have been transported to the oceans. This three-billion-year history shows remarkably steady continental weathering using multiple proxies, suggesting that despite major perturbances (climate changes, paleogeography, crustal evolution, biological evolution), the degree of continental weathering may be similar throughout Earth's history. Preservation bias and the emergence of subaerial continents need to be considered in interpreting this record; paleosols prior to 2.9 Ga are scarce, so the record of Earth's earliest weathering and highest $p\text{CO}_2$ is largely absent. However, the oldest weathering profiles tend to preserve only higher weathering values, with essentially all CIA values plotting above the long-term mean, which would be consistent with models and data that have suggested very high atmospheric $p\text{CO}_2$ prior to 2.5 Ga. Weathering profile thicknesses generally decrease through time, reflecting a change in dominant weathering style and geomorphological processes (*i.e.*, transition from bedrock weathering to fluvial weathering).

While the delivery from weathering of some elements relevant for understanding seawater chemistry are quantitatively reflected by shales' compositions, others are not when indexed to crustal values. As a result, assuming that weathering and nutrient fluxes are either the bulk crustal or shale value is incorrect. Instead, values in the weathering product should be considered as sources for fluxes to oceans. Interpretations of apparent changes in ancient seawater chemistry should consider explanations beyond variability in the composition of continentally-derived fluxes, such as subaerial landmass extent and changes in weathering style.