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Silicate weathering balances across marine sedimentary environments

GERRIT TRAPP-MÜLLER[1], ROBERT C. ALLER[1], APPY SLUIJS[2] AND JACK J MIDDELBURG[2]

[1]Stony Brook University

[2]Utrecht University

Silicate weathering is a major process in marine sediments and comprises a spectrum of reaction balances, ranging from alkalinity consumption (‘reverse’) to alkalinity release (‘forward’ weathering). The direction and magnitude of weathering fluxes vary across depositional environments and with depth and time at individual locations, governed by sediment composition (reactants) and sedimentation patterns that determine ambient biogeochemistry and authigenic mineral assemblages (products). Based on reaction balance modelling combined with mechanistic constraints and mineral distributions maps, we discuss weathering balances in a range of idealized endmember environments from the coast to the deep sea (Figure).

Highly energetic nearshore environments, such as river deltas and beaches, are modern weathering hotspots. High reaction rates are sustained by physical disturbance and rapid organic matter degradation, but differences in grain sorting and reworking timescales drive contrasting reaction balances, with dominantly reverse weathering in suboxic deltaic muds and alkalinity-neutral to forward weathering in beaches.

Steadier, anoxic shelf and slope sediments vary between forward and reverse weathering at moderate rates, depending on volcanogenic and lithogenic vs pedogenic and biogenic inputs. However, the direct influence of such deep-seated, anoxic weathering on the water column is reduced by internal recycling during upward diffusion through suboxic and oxygenated zones.

Deep-sea clays tend to slow reverse weathering distributed over a wide areas, but reaction balances are highly sensitive to the distribution of volcanic ashes, biogenic silica and metal (oxy-)hydroxides. Silicate weathering balances in mafic beaches, deep-sea ashes and biogenic sediments remain to be assessed in detail.

Overall, we find (I) prominent as well as distributed roles of different marine weathering environments in the major biogeochemical cycles, (II) an intimate coupling between land and ocean, silicate and non-silicate processes (e.g., organic matter degradation, carbonate and sulfide precipitation), and (II) extensive exchange of biogenic and lithogenic silica within most marine sediments. A novel perspective on the role of silicate weathering in the Earth system emerges from the consideration of multiple, fundamentally different marine weathering environments whose reaction balances vary with terrestrial weathering and erosion, marine productivity and sedimentation dynamics, alteration of oceanic crust, and hydrothermal processes.