Photosynthate carbon-energy flux to the rhizosphere as a unifying concept for understanding biological mineral weathering

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The evolution of mycorrhizal fungi in partnership with early land plants over 410 million years ago led to the greening of the continents by plants of increasing biomass, rooting depth, nutrient demand and capacity to alter soil minerals, culminating in modern forested ecosystems. The co-evolution of tree rooting systems initially with arbuscular mycorrhizal fungi, and later with ectomycorrhizal fungi, is thought to constitute one of the most important biotic feedbacks on the geochemical carbon cycle to emerge during the Phanerozoic, accelerating land-to-ocean transfers of calcium. This concept fundamentally rests on the intensifying effect of trees and their root-associating mycorrhizal fungal partners on mineral weathering processes to meet mineral nutrient demands.

Here I synthesise experimental and field evidence linking the evolution of land plants and their mycorrhizal fungal partners to a mechanistic framework of plant-driven mineral weathering in the "mycorrhizosphere" at the interface between mineral grains and growing root and fungal hyphal tips. This is underpinned by the unifying concept that delivery of photosynthate carbon-energy belowground via roots and mycorrhizal fungal partners into the mycorrhizosphere drives plant-soil interactions and biologically mediated weathering. Evidence will be presented to address the following hypotheses that follow from this unifying concept: (1) as plants evolved in stature, biomass, and rooting depth, their mycorrhizal fungal partnerships received increasing amounts of plant photosynthate; (2) this enabled intensification of plant-driven fungal weathering of rocks to release growth-limiting nutrients; (3) in turn, this is likely to have increased land-to-ocean export of calcium and phosphorus and enhanced ocean carbonate precipitation affecting the global carbon cycle and biosphere-geosphere-ocean-atmosphere interactions over the past 410 Ma. Our findings support an over-arching hypothesis that evolution has selected plant and mycorrhizal partnerships that have intensified mineral weathering and altered global biogeochemical cycles.