Geochemical and ecological models of plant-driven chemical weathering: Insights into the sinks for atmospheric CO_2

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It is generally agreed that rhizospheric acidification of the shallow subsurface – the vascular-plant 'acid pump' – accelerates weathering and the loading of soil and drainage waters with base cations, thereby also promoting drainage losses of weathering products (chemical denudation) and lowering atmospheric CO_2 levels on geologic timescales [e.g. 1, 2]. Mass-balance tests of this model, in comparative studies of watersheds with different plant covers, report scattered results.

In our experimental mesocosm studies employing the same approach, a single ecosystem exhibits order-of-magnitude variations in chemical weathering and denudation rates over decadal timescales. Our results also show that the silicate-derived Ca+Mg denudation flux, i.e. the lithospheric CO_2 sink, is not equivalent to the alkalinity flux, i.e. the hydrospheric sink, because of disturbance-driven strong-acid generation. These results underline the idea that the efficacy of the plant-driven lithospheric CO_2 sink, and perhaps associated long-term climate control, may depend on the planet's geophysical, biological and ecological disturbance regime. It is true that the weathering power of vascular plant systems dwarfs that of nonvascular systems; but the vascular systems also have correspondingly great capacity to conserve the nutrients generated by weathering, by localizing water and nutrient cycles both during growth and following perturbations.

Our findings are consistent with an ecological model in which mechanisms of biologically mediated weathering are adaptive functions of ecosystem state. In this paradigm, which emphasizes the plant as chemical sink and builder of soil and ecosystem nutrient capital, vascular systems are likely to deploy varying portfolios of weathering and nutrient uptake strategies, involving a range of plant physiologies, rhizospheric symbioses, and mass transfer and transport mechanisms with a range of hydrochemical consequences.

[1] Keller & Wood (1993) *Nature* **364**, 223–225. [2] Berner (1997) *Science* **276**, 544–546.

Beyond the closure temperature concept: when does $^{40}Ar/^{39}Ar$ dating constrain exhumation?

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$^{40}Ar/^{39}Ar$ ages determined on metamorphic minerals are commonly assumed to reflect cooling and exhumation, but recently reported experimental results on muscovite suggest a significant pressure dependence of argon diffusion in muscovite, which acts to decrease argon diffusion rates at high pressure. Using numerical diffusion models, which include a pressure correction, we systematically interrogate the assumptions associated with $^{40}Ar/^{39}Ar$ dating of muscovite in such rocks. We show the pressure-temperature regions in which $^{40}Ar/^{39}Ar$ dating could constrain the timing of exhumation in an open system, and suggest a method for checking that the rock being dated has behaved as an open system during exhumation. The link between apparent $^{40}Ar/^{39}Ar$ age and traditional 'closure temperature' is shown to be valid only when muscovite crystallized under, or subsequently reached, high temperature and relatively low pressure conditions. Our modelling data suggest that HP and UHP rocks, particularly those that have experienced short orogenic cycles are unlikely to yield cooling and exhumation ages. The results and discussion presented here for muscovite are equally applicable to other metamorphic minerals commonly dated using the $^{40}Ar/^{39}Ar$ system.