Effects of the coupling between weathering and erosion on reaction fronts and their transitions

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A model for the depth-dependent rate of mineral weathering was recently introduced and is used here to describe the steady states of the weathering zone in which a mineral reacts, starting at the bedrock-regolith interface. A boundary condition at that interface fixes the gradient of mineral concentration g_B. Two parameters describe the states of the weathering zone and of the full regolith: $q = g_B/g_R$, where, where g_R is the average gradient of mineral concentration in the regolith, and q_E, which is the ratio between denudation velocity v_E and the maximal weathering velocity v_c of mineral kinetics in far from equilibrium conditions. We define an intrinsic velocity v_I of the reaction front, which depends only on physical and chemical properties of the regolith and which controls the transition between a completely ($v_E \leq v_I$) and an incompletely ($v_E > v_I$) developed profile of mineral weathering. A second transition to an unstable state (in which the regolith is removed) occurs when $v_E \geq v_c$. For $q<<1$, which represents negligible weathering at the bedrock-regolith interface, results similar to other reactive transport models are obtained. In this case, v_I depends on the advection velocity and solubility, but not on dissolution rate constant nor specific area of the mineral. Thus the ratio between residence times of the mineral and of the fluid in the regolith can be used to characterize the state of the weathering process, in agreement with recent publications. In the cases $q \sim 1$ and $q>>1$, v_I also depends on dissolution kinetics. We apply this model to understand coupling between weathering and erosion.

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