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Modeling the impact of mineral armoring on chemical weathering rates

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Weathering rates are slowed by the build-up of insoluble coatings on primary mineral phases, a process that is termed armoring. Such coatings often form as the result of coupled dissolution-precipitation reactions that occur during weathering. While the role of armoring in reducing dissolution rates is widely recognized, a quantitative mechanistic description of the way it impacts mineral weathering rates has not yet been developed. In this study, a diffusion boundary layer model is developed that simulates the effect of a porous secondary mineral layer on the rate of primary mineral dissolution under acidic conditions. The rates are affected by 3 parameters: layer thickness, the ratio of porosity to tortuosity, and the Biot number, which defines the ratio of dissolution to diffusion. Numerical solutions to the equations show that when the porosity/tortuosity ratio is low (~0.01), dissolution rates can be reduced by several orders of magnitude relative to armor-free minerals. Biot numbers greater than 1 were also found to lead to a significant reduction in the dissolution rate. Moreover, comparison with reported experimental data shows that the model can accurately simulate the change in thickness of the secondary mineral coating with time. The results suggest that mineral armoring can account for the several orders of magnitude difference between the dissolution rates associated with coating-free minerals measured in laboratory experiments and those determined for naturally coated minerals under field conditions.