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Weathering of granite and associated changes in reaction-transport characteristics

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In granitic regions, weathering profiles often develop from deep underground toward the surface. We examined borehole cores of Hiroshima granite drilled to a depth of 20 m below the surface, exhibiting a distinct weathering profile extending from the whitish, hard, unweathered section underground to the yellowish-brown, brittle, extensively weathered section near the surface. Five samples with varying degrees of weathering (depths from the surface: 9.3 m, 7.6 m, 6.2 m, 5.2 m, 2.8 m) were extracted from the cores, and their porosity, diffusion coefficient, and permeability were determined. From the unweathered to the extensively weathered sections, the porosity increased approximately 40-fold, the apparent diffusion coefficient increased approximately 3-fold, and the permeability increased by approximately 8 orders of magnitude. The flow velocity within the pores at each depth was determined based on the hydraulic gradient estimated from the water level measurements in the borehole. Using these values, the Peclet number (Pe), a measure of the relative significance of diffusion versus advection in solute transport, was calculated for each depth, assuming a rock block approximately 30 cm in size. The results showed that below a depth of approximately 6–7 m, solute transport was dominated by diffusion ($Pe < 1$) on the subsurface side and advection ($Pe > 1$) on the surface side. As the porosity increases from 1% and exceeds approximately 3%, the primary transport mode appears to shift from diffusion to advection. The Damköhler number (Da), a measure of the relative significance of reaction versus transport, was also calculated for each depth, assuming the rock is composed solely of plagioclase. Below a depth of approximately 5–6 m, the reaction becomes dominant ($Da > 1$), and most of the pore water within the rock block reaches equilibrium with respect to plagioclase dissolution. Conversely, on the surface side, transport became dominant ($Da < 1$), maintaining a relatively low saturation index for plagioclase and enabling efficient dissolution.