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A Model Describing Differential Rates of Feldspar Weathering in Granitic Regoliths

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Differential plagioclase and K-feldspar weathering rates in bedrock and soil/saprolite environments are modelled in terms of hydrologic, kinetic and solubility controls. In the Panola watershed in the Piedmont Province of Georgia, USA, elemental balances indicate that plagioclase is being converted to kaolinite to depths of 6 m in the granitic bedrock during iso-volumetric weathering. Such weathering is contrasted to stable bedrock K-feldspar, which subsequently weathers at the overlying saprolite/bedrock interface. Sr is much less mobile than Ca due to comparable Sr concentrations in the plagioclase and K-feldspar. $^{87}Sr/^{86}Sr$ ratios in the bedrock correlate with the quantitative removal of plagioclase. K-feldspar, but not plagioclase, is thermodynamically saturated in ground water within the Panola granite but is under-saturated in the overlying saprolite. In contrast to Panola, plagioclase remains stable in granitic bedrocks elsewhere in Piedmont Province, such as Davis Run, Virginia where both plagioclase and K-feldspar weather concurrently in an overlying thick saprolite sequence. The propagation rates of the weathering fronts, based on cosmogenic isotope dating, are similar in the two watersheds, 10 m per million years for the Panola regolith and 6 m per million years for the Davis Run regolith (Bierman et al., 1995; Pavich et al., 1996) Kinetic rate constants, mineral surface areas and primary and secondary hydraulic conductivities are fitted to plagioclase and K-feldspar loses with depth in the Panola and Davis Run regoliths using a time-depth spreadsheet model. Best fits indicate that the kinetic rate constants for plagioclase are 2 to 3 times faster than K-feldspar, which is in agreement with experimental findings. However, the range for individual rate constants (log k = -16 to -15 moles/m^2/s) is 3-4 orders of magnitude slower than for comparable minerals in experimental studies. Rates of feldspar weathering in bedrock are more dependent on relative mineral solubilities than on kinetic reaction rates. Weathering is very sensitive to primary and secondary hydraulic conductivities (qp and qs), which control both the fluid volumes passing through the regoliths and the thermodynamic saturation of the feldspars. Bedrock permeability is primarily intra-granular, created by internal weathering of the cores of plagioclase phenocrysts. Saprolite permeability is principally inter-granular, formed by dissolution of silicate phases during iso-volumetric weathering. A ratio of qs/qp = 150 in the Panola bedrock results in kinetically-controlled plagioclase dissolution but thermodynamically-inhibited K-feldspar reaction, which is in agreement with calculated saturation states of the groundwater. In contrast, greater secondary permeability in the Davis Run saprolite, qs/qp = 800, produces both kinetically controlled plagioclase and K-feldspar weathering. Faster plagioclase reaction, leading to bedrock weathering in the Panola Granite but not at Davis Run, is attributed to a higher anorthite component, a wetter and warmer climate and greater amounts of disseminated calcite, the reaction of which also leads to a greater bedrock permeability.

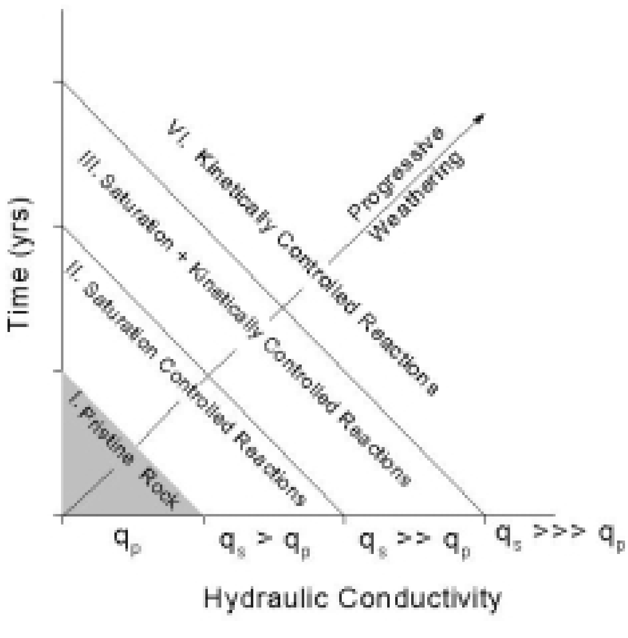

Figure 1: The relationship between the progression of iso-volumetric weathering in granites and increases in time and primary qp and secondary hydraulic qs conductivities.

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