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Modeling depletion zones in weathering profiles and comparison with field data

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As reactive fluids permeate through weathering rock, minerals dissolve leaving weathered zones characterized by concentrations of primary minerals that are lower than the parent rock. These depletion zones are also characterized by the formation of secondary alteration products. Eventually, the regolith becomes completely depleted in the weathering mineral, defining the outer boundary of the depletion zone. Depletion zones defined at the bedrock-saprolite interface can vary substantially in their nature and thickness. For example, in basalt clasts weathering in Costa Rica, the depletion zone over which plagioclase completely dissolves from the parent basalt is less than 3 mm thick. In a Puerto Rican granite, the plagioclase depletion zone occurs over a 50-cm thick reaction zone. Depletion zones occurring in weathering alluvial material in temperate climates can be many meters in thickness. Model calculations incorporating fluid infiltration, diffusion, porosity, and weathering rates are used to predict the thickness of depletion zones for different rock types and the results are compared with field observations.

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Rate rontrols on chemical weathering under unsaturated flow

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Source term modelling is a critical part of environmental risk assessment for mine water pollution. Such modelling requires the prediction of mineral weathering rates that generate and attenuate the load of dissolved metals in mine water discharges. A longstanding discrepancy in observed weathering rates between laboratory and catchment scale is also observed for mine sites [1]. The study reported here addresses how differences in hydraulic conditions may contribute to the observed discrepancy.

Hydraulically unsaturated column experiments were carried out on 8 different polymineralic geological materials from mine waste deposits and used to quantify the chemical weathering rates of individual minerals and possible rate-controlling mechanisms. Transport characteristics for each experimental condition were characterised by tracer tests using inert solutes. These tests generally demonstrated significant mass of immobile water within each column.

Element release rates were 1-2 orders-of-magnitude slower than those observed for the same geological materials weathered in batch reactors under hydraulic saturation. Where batch reactor solutions were far from equilibrium, concentration versus time plots indicated that surface chemical reaction kinetics provided the rate controlling step for mineral weathering. Mineral weathering rates determined for the batch reactors were within 2σ of rates reported in the literature. The geological materials were prepared identically for the two types of experiments and differences in rates are assigned to differing rate-controlling mechanisms in the two reaction environments.

Results from the column studies are consistent with diffusion controlled release kinetics. Intraparticle diffusion is is considered but is not consistent with the calculated characteristic diffusion length scales. The slow weathering rates are consistent with the hypothesis of slow diffusive transfer of solutes from immobile water to flow paths within the columns. This suggests that rate-controlling mechanisms may vary with hydraulic saturation and that relatively concentrated solutions may be present within stagnant zones above the water table in mine waste deposits.

References

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