Quantitative model of spheroidal weathering: Coupling of transport, reaction, and fracture in the transformation of rock to soil

RAYMOND C. FLETCHER, SUSAN L. BRANTLEY AND HEATHER L. BUSS

(rfletche@psu.edu, brantley@essc.psu.edu, buss@geosc.psu.edu)

In spheroidal weathering, successive rindlets of weakly weathered but sound rock separate from corestone along discrete fractures. We postulate that rindlet bounding fractures result from dilatation-induced stress associated with initial weathering. In the Rio Blanco Granite within the Rio Icacos watershed (Puerto Rico), sequences of 2 - 4 cm rindlets ~ 0.4 m in thickness separate unweathered corestone from saprolite. Sequences extend downward along joints and faults that serve as conduits for reactive fluid. Rindlet-bounding fractures and those cutting through them give reactive fluid rapid access to fresh rock, thus greatly increasing the rate of weathering relative to that by intergranular diffusive transport alone. We use first-order assumptions to build a conceptual and quantitative model of spheroidal weathering incorporating chemical transport, reaction kinetics, and macroscopic fracture. The model is calibrated by using field observations from the Rio Icacos watershed, El Yunque National Forest, Puerto Rico. We postulate that initial corestone weathering is dominated by the reaction of biotite to hydrobiotite + Fe-oxide. The criterion adopted for fracture is that the elastic strain energy in an incipient rindlet equal the fracture surface energy. Dilatation is not uniform and the elastic strain energy is integrated inward from the last-formed crack to the current position of a nucleation barrier for the Fe-oxide. Approximation of a stationary diffusion profile is used to obtain the rindlet thickness and the time between fracture events. Using plausible tuned parameter values, the predicted rindlet thickness is ~ 2 cm and the interval between fracture events is ~ 200a the value latter consistent with an observed weathering rate in the watershed of ≈ 1cm/100 a. Crack spacing and the time between cracking events are uniform, implying steady state weathering; in a no-fracture model, the reaction front moves inward at a rate $\propto 1/\sqrt{t}$.

Weathering and uptake of silicon in the Santa Cruz terraces: new evidence from silicon isotopes.

J.K. AGGARWAL[1], A.F.WHITE[2] AND T.D. BULLEN[2]

[1]Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, CA 95060, USA
[2]US Geological Survey, Menlo Park, CA 94025, USA

The Santa Cruz terraces along the Central Coast of California, USA, provide an excellent environment in which to examine the weathering cycle of silicon. The rainfall at Santa Cruz is limited to a few months in the winter during which plant growth is rapid. For the remainder of the year many plants are almost dormant. Since plants take up silicon from porewaters and groundwaters for the production of phytoliths, there is a seasonal variation in Si concentration of these waters.

A profile of Si concentration in groundwaters and soil porewaters show a rapid reduction in Si concentration with depth through the porewater profile followed by a steady increase with depth to groundwater. This pattern can be explained by the uptake of Si by the plants and concentration of the Si through tight cycling at shallow depths, while soil and rock weathering progressively dominates release of Si to waters at depth.

Data so far indicate that deep groundwaters have the heaviest Si isotope ratio with a δ^{30}Si of +5.8 per mil. δ^{30}Si values of the porewaters are lighter and more variable (1.7 to 2.4 per mil). Before the onset of the wet season the soil pore waters have the lightest δ^{30}Si values, indicating that during plant decomposition loss of Si due to phytolith dissolution results in the addition of light Si to the porewaters. Subsequently, at the peak of the growing season, the soil pore waters have greater δ^{30}Si suggesting that the phytoliths take up light Si from the porewaters, thus completing the cycle.