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Effect of water film on weathering of rock under unsaturated condition

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The pores in rocks near the Earth's surface often become unsaturated as the result of intermittent rainfall, drying, and drainage. There are several possible ways by which the weathering of rock progresses under unsaturated conditions: (1) The surfaces of the pores filled with air do not react at all. (2) Wetting (as water film) spreads to all the pore surfaces even for the pores filled with air, and reaction occurs as with the case of fully saturated condition. (3) Whether or not the wetting and reaction occur depends on pores. To understand the weathering of rocks near the Earth's surface, it is important to evaluate various factors under unsaturated conditions, such as the reactive surface area, the rates of dissolution, precipitation, and solute transport, and the thickness of water film. In this study, the effect of water film on water-rock reaction under unsaturated condition was studied.

A core was cut from a porous rhyolite (porosity 18%, mineral composition: glass 87%, plagioclase 9%, quartz 4%), and water was passed into the cores under a constant water head difference. Dissolution of Si occurred from the rock, and the solution containing dissolved Si was discharged from the rock. By measuring the concentration of Si in the solution discharged, the amount of dissolution was determined. To compare the amount of dissolution under unsaturated and saturated conditions, the experiments were conducted using both the saturated sample and dried sample. When water was passed into the dried rock, water saturation quickly increased with elapsed time and became 30% after 2 hour, but after that the increase was small, and the water saturation after 6 days was 41%. The relationship between the flow rate Q (cm^3/s), the concentration of Si in the solution discharged C (mol/cm^3), the mineral-water reactive surface area A (cm^2), and the dissolution rate of mineral R (mol/cm^2/s) is given by

$$Q_{sat}C_{sat} = A_{sat}R_{sat}$$

$$Q_{unsat}C_{unsat} = A_{unsat}R_{unsat}$$

Because R_{sat} is equal to R_{unsat} when the Si concentration is low, A_{unsat}/A_{sat} can be determined by measuring Q_{sat}, C_{sat}, Q_{unsat}, and C_{unsat}. The results of the experiment showed that A_{unsat}/A_{sat} was similar to the value of water saturation in the early period of the experiment but increased with elapsed time, and approached to 1 after 6 days passed. Similar results were obtained also for a sandstone (porosity 6%, quartz ~100%). For the case of the sandstone, A_{unsat}/A_{sat} was almost equal to 1 over the entire period of the experiment. These results showed that almost all the pore surfaces under unsaturated condition were covered with water film and dissolution occurs, even though the rhyolite and sandstone have different pore structure and mineral composition.

Keywords: weathering, dissolution, water film