Chemical weathering in experimental ecosystems: bicarbonate patterns

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Experimental ecosystems within the Hubbard Brook Experimental Forest (New Hampshire, USA) are being used to investigate chemical weathering exports beneath different plant communities established on a sand substrate of granitic origin. The study area is located in a mountainous, humid continental environment that receives acid precipitation (pH 4.2). Average annual precipitation is 1300 mm, one-third of which falls as snow. The ecosystems are 7.5 m × 7.5 m × 1.5 m sand-filled lysimeters, lined with plastic on all sides and equipped with drainage pipe to collect all water exports. Different plant species were established in each lysimeter in 1984 to investigate N cycling (Bormann *et al.*, 1993).

We have monitored water and chemical fluxes from three of the experimental ecosystems planted with red pine (*Pinus resinosa*), bunchgrass (*Panicum virgatum*), and a non-vascular cover of bryophytes and lichen. Observed concentration patterns for bicarbonate ion vary among the systems and also differ from the patterns exhibited by base cations and dissolved silica. This study explores these patterns for what they may tell us about primary mineral wethering in an environment where sulphuric-acid precipitation inputs must be considered

Hydrology

Water export from the lysimeters is characterized by a steady, small discharge (~ 2 mm/day) during both the winter and growing seasons. During the spring and autumn, drainage discharges increase by 1-2 orders of magnitude for periods of days to weeks in response to snowmelt and high intensity, high volume rainstorms. Annual discharge varies with vegetative cover, being approximately twice as large from the bryophyte lysimeter as from the pine lysimeter.

The sand substrate has a low moisture retention capacity; ambient volumetric water contents throughout the year are 7% and 2% within the upper meter of the bryophyte and pine lysimeters, respectively. Assuming piston-type water movement in the absence of evapotranspiration, only about 100 mm of rainfall is needed to completely replace lysimeter porewater.

Concentration trends

Dissolved silica and base cation concentrations exhibit a seasonal, sinusoidal pattern in lysimeter discharge from all three ecosystems. The concentration trends are independent of water flux from the lysimeters and appear to be controlled by a temperature-dependent exchange complex within the sand (Berner *et al.*, 1998). In contrast, bicarbonate concentrations in lysimeter discharge do appear to vary with discharge magnitude. Well-defined concentration peaks observed in pine discharge during spring snowmelt have been attributed to wintertime primary mineral weathering beneath snow cover when acid-precipitation inputs are minimal (Berner and Rao, 1997). We have also observed bicarbonate concentration peaks in all three ecosystems during summer and autumn following large (> 40 mm) rainstorms.

Porewater samples were collected from three depths within the lysimeters using custom-manufactured, laterally-installed suction samplers that minimize the degassing of collected solutions. These samples confirm the discharge concentration trends and yield additional insight into the distribution of bicarbonate within the vadose zone. Throughout much of the year, bicarbonate concentrations in all lysimeters increase uniformly with depth. Concentrations at depth become 2–4 times larger during the early spring and during the growing season.

Increases in bicarbonate concentration correspond to observed seasonal increases in soil-gas CO_2 concentrations at depth. Carbon dioxide concentrations within the pine lysimeter are 3–5 times larger than those in the bryophyte lysimeter. Nonetheless, the byrophyte lysimeter shows elevated CO_2 concentrations (2 × greater than atmospheric) most of the year, presumably due to microbial respiration.

Chemical fluxes

On an annual basis larger bicarbonate concentrations in the lysimeter containing pine trees are counterbalanced by reduced discharges due to transpiration by the densely planted trees. As a result, the difference between drainage fluxes appears to be less than a factor of 5 between the pine and bryophyte lysimeters.

Bormann *et al.* (1998) report identical dissolved Ca and Mg fluxes from the pine and bryophyte lysimeters, which is consistent with the relatively small differences we estimate among bicarbonate (+ sulphate) fluxes. However their estimates of chemical weathering, which include the formation of secondary minerals as a weathering product, indicate that weathering rates in the pine lysimeter are 10–18 times larger than those for the bryophyte lysimeter. This illustrates the importance of higher plants in accelerating rock weathering.

References

Berner, R.A. and Rao, J.L. (1997) *Aquatic Geochemistry*, **2**, 301–12.

Berner, R.A., Rao, J.L., Keller, C.K. and O'Brien, R. (1998) *Aquatic Geochemistry*, in review.

Bormann, B.T. *et al.* (1993) *Ecology*, **74**, 583–98.

Bormann, B.T. *et al.* (1998) *Biogeochemistry*, in press.