

THE CHEMISTRY OF WEATHERING OF A PLIOCENE VOLCANIC ASH DEPOSIT,
NATIONAL ELK REFUGE, WYOMING

R. C. Antweiler

J. I. Drever

Objectives

Precipitation falls to the earth basically as distilled water, except near population centers where atmospheric pollution contributes solutes and near the ocean which adds sodium and chloride. The waters of springs, however, contain varying amounts of Ca^{++} , Mg^{++} , K^+ , Na^+ , HCO_3^- and aqueous silica as major constituents, derived from bedrock. How rainwater changes its composition to springwater as it passes through soils and rocks is not well understood. The objectives of our project were to study the initial changes in water chemistry as moisture passed through a "reactive" bedrock and to compare our results with theoretical models (eg. Helgeson 1968, Helgeson et.al. 1969, 1970, Wood and Surdam, 1979).

We chose the National Elk Refuge for our study because atmospheric pollution is negligible and because suitable deposits of volcanic ash are located there. In addition, there is some data available on the water chemistry of the rivers and springs from the vicinity (Miller, 1974, Miller and Drever, 1977a, b) and on the geology (Love, 1957, 1968).

Methods

The ash deposit we are studying is located in the National Elk Refuge five miles north of Jackson. It is overlain by a thin (less than one meter) soil zone composed largely of clay minerals. The deposit is on top of a hill facing north. Vegetation in the study area is aspen and various grasses. The ash is a rhyolitic glass with less than five percent crystalline material. It is Pliocene in age (Love, 1957).

Rainwater was collected during storms, stored in polyvinyl chloride (PVC) bottles and frozen until analysis was possible. Snow was sampled on drifts occurring above the ash deposits and contributes the majority of the moisture which passed through the deposits. Moisture from the soil zone and the volcanic glass was removed using suction lysimeters (see Parizek and Lane, 1970). The lysimeters were sampled daily (if enough moisture was available) throughout May and June and biweekly thereafter for the duration of the summer. The pH of the samples was immediately taken; then the samples were frozen and stored in PVC bottles for future analysis. Samples of the volcanic glass were taken from each lysimeter station (there were 20) for x-ray and scanning electron microscope work. The lysimeter holes were dug with a 3-inch hand auger one to two meters deep. 400 samples were collected.

We plan to analyze each sample for aqueous silica, Ca^{++} , Mg^{++} , Na^+ , K^+ , alkalinity, PO_4^{3-} , CO_3^{2-} , and Cl^- . When there is sufficient quantity, we will also analyze for dissolved iron, aluminum, SO_4^{2-} , and NO_3^- . As of now, we have not analyzed the bulk of the samples.

Results

The moisture the lysimeters collected decreased by 95% from mid-May to mid-September. Rainstorms throughout the summer were observed to wet only the top tens of centimeters of the soil zone. This implies that the vast majority of moisture passing through the volcanic ash is derived from snow melt. Because the snowpack was gone before the middle of June, the movement of water through the glass is apparently slow. At the present time, we do not know how the water moves.

The pH of the waters collected was uniformly between 4.5 and 6.0 except in one lysimeter which averaged about 6.6. This lysimeter was the only one not overlain by vegetation and soil. Initial results on the alkalinity of the samples indicate that the pH is too low to be accounted for solely by carbon dioxide in the soil. We believe that the low pHs are due to organic acids (at present we do not know which ones) derived from the vegetation.

Initial results on the major cations (Ca^{++} , Mg^{++} , Na^+ and K^+) and aqueous silica indicate that there is a significant amount of dissolution of the glass which occurs rapidly. Stated another way, the water is picking up a substantial percentage (at this point, we do not care to clarify the work "substantial") of its solutes in the first few meters of contact with the glass. Aqueous silica and aluminum values are higher than springwater and are most likely due to organic complexation. It is proposed that these complexes break down deeper in the volcanic ash (compare Graustein 1975, 1976, Graustein et. al. 1977, Holdren et. al, 1977). As yet we do not know why.

Conclusions

From the preliminary results, we conclude that soil and ash moisture is largely due to snow melt. In addition, we conclude that vegetation exerts a major control on the chemistry of the water in the volcanic glass by the addition of organic ions. These ions serve to lower the pH and increase the rate of cation and silica release from the glass. More work is required before the organic ions can be identified and the trends typified.

Acknowledgements

We wish to thank the National Science Foundation for providing the financial support of this project. We also wish to thank the National Elk Refuge and the National Forest Service for their cooperation and assistance.

Literature Cited

- Graustein, W. C. (1975) On chemical weathering and forests. *Geol. Soc. Am. Abs.*, v. 7, p. 1090-1091.
- Graustein, W. C. (1976) Organic complexes and the mobility of iron and aluminum in soil profiles. *Geol. Soc. Am. Abs.*, v. 8, p. 891.
- Graustein, W. C., K. Cromack, Jr., and P. Sollins (1977) Calcium oxalate: occurrence in soils and effect on nutrient and geochemical cycles. *Science*, v. 198, p. 1252-1254.
- Helgeson, H. C. (1968) Evaluation of irreversible reactions in geochemical processes involving minerals and aqueous solutions - I. Thermodynamic relations. *Geochim. Cosmochim. Acta*, v. 32, p. 853-877.
- Helgeson, H. C., R. M. Garrels and F. T. Mackenzie (1969) Evaluation of irreversible reactions in geochemical processes involving minerals and aqueous solutions - II. Applications. *Geochim. Cosmochim. Acta*, v. 33, p. 455-481.
- Helgeson, H. C., T. H. Brown, A. Nigrini, and T. A. Jones (1970) Calculation of mass transfer in geochemical processes involving aqueous solutions, *Geochim. Cosmochim. Acta*, v. 34, p. 569-592.
- Holdren, G. R., W. C. Graustein, and R. A. Berner (1977) Chemical weathering in soils: evidence from surface compositions. *Geol. Soc. Am. Abs.*, v. 9, p. 1020-1021.
- Love, J. D. (1957) Cretaceous and Tertiary stratigraphy of the Jackson Hold area, northwestern Wyoming. In *Wyo. Geol. Assn. Guidebook*, 11th Ann. Field Conf. p. 76-94.
- Love, J. D. (1968) Geologic map of Teton County, Wyoming. *U. S. Geol. Survey*.
- Miller, W. R. (1974) Chemical weathering and related controls on the water chemistry in the Absaroka Mountains, Wyoming. Ph.D. thesis, University of Wyoming, 113 p.

- Miller, W. R. and J. I. Drever (1977a) Water chemistry of a stream following a storm, Absaroka Mountains, Wyoming. *Geol. Soc. Am. Bull.*, v. 88, p. 286-290.
- Miller, W. R. and J. I. Drever (1977b) Chemical weathering and related controls on the surface water chemistry in the Absaroka Mountains, Wyoming. *Geochim. Cosmochim. Acta*, v. 41, p. 1693-1702.
- Parizek, R. R. and B. E. Lane (1970) Soil-water sampling using pan and deep pressure-vacuum lysimeters. *J. Hydrology*, v. 11, p. 1-21.
- Wood, J. R. and R. C. Surdam (1979) Application of convective-diffusion models to diagenetic processes. in *Aspects of Diagenesis*, ed. by P. A. Schoole and P. R. Schluger. SEPM Special Pub. No. 26, p. 243-250.