

Abstract

The mildly acidic nature of rainwater, a result of atmospheric CO₂ concentrations, is a driving force responsible for the chemical weathering of continental silicate minerals. The release and transport of dissolved ions within the soil is a consequence of the weathering process. This includes cations such as Ca⁺² and Mg⁺² capable of precipitating carbonate minerals in the oceans. Thus, over geologic time scales, the weathering process facilitates the flux of CO₂ from the atmosphere to the lithosphere.

To observe the effect of atmospheric CO₂ concentration on weathering, three test areas measuring 4 feet by 8 feet each were established. Two of the areas were enclosed by plastic structures and one was left uncovered as a control. In the enclosed areas, CO₂ concentrations were held near 800 ppm in one and 2,000 ppm in the other. In the enclosed chambers, ambient air was bubbled through water in reservoirs until the CO₂ concentration reached equilibrium. The CO₂ equilibrated water used then applied to the soil to simulate rainfall. Custom-built suction lysimeters were installed at depths of 2, 4, and 8 feet in each test area to collect pore water samples during the experiment.

Major cation and dissolved silica concentrations from pore water samples are reported. Soil moisture and temperature were also monitored. Initial soil analysis indicated K⁺ and Ca⁺² were enriched over Na⁺ and Mg⁺² which is consistent with local mineralogy.

Background: The Carbonate-Silicate Geochemical Cycle

As continental silicate minerals react with the acidic equilibrium products of CO₂ (i.e. H₂CO₃ and HCO₃⁻), alkali cations are preferentially released from the mineral structure. When carbonate minerals precipitate from certain ions, and are stored via geological processes, CO₂ is transferred from the atmosphere to the lithosphere (Berner, 2004).

By Henry's Law, the concentration of CO₂ equilibrium products is proportional to the partial pressure; if CO₂ concentration increases, so must the equilibrium products. Therefore, chemical weathering is proposed as a negative feedback control on the concentration of atmospheric CO₂ (Berner, 2004).

Some authors hypothesize that changes in weathering rates may have influenced past climate trends. For example, it has been proposed that cooling during the Paleogene was influenced by the Himalayan uplift followed by weathering and sequestration of CO₂ (Drever & Zobrist, 1992; Berner et. al, 1983).

Primary Feldspar	Weathering Product
2KAlSi ₃ O ₈ (s) + 9H ₂ O (l) + 2H ⁺ (aq)	2K ⁺ (aq) + Al ₂ Si ₂ O ₅ (OH) ₄ (s) + 4H ₄ SiO ₄ (aq)
K-feldspar	Kaolinite
2NaAlSi ₃ O ₈ + 2H ₂ CO ₃ + 9H ₂ O	2Na ⁺ (aq) + 2HCO ₃ ⁻ + 4H ₄ SiO ₄ (aq) + Al ₂ Si ₂ O ₅ (OH) ₄ (s)
Albite	Kaolinite
CaAl ₂ Si ₂ O ₈ + H ₂ CO ₃ + 1/2O ₂	Ca ⁺² (aq) + Al ₂ Si ₂ O ₅ (OH) ₄ + CO ₃ ²⁻
Anorthite	Kaolinite

Fig. 1 Common mineral sources for ion products

Methods

- To enclose the soil area, two PVC structures were constructed measuring 4ft by 6ft and covered with a sheet plastic



Fig. 2 Sample area A (CO₂ added), area B (enclosed, but no added CO₂), and control

- Suction lysimeters** were installed at 2, 4, and 8ft depths at each of the three sample areas to retrieve pore water
- To collect a sample:** 25inHg vacuum is applied from a hand pump to draw pore water into the porous cup. Next, a valve releases 20psi of compressed air to drive the sample from the porous cup to the surface

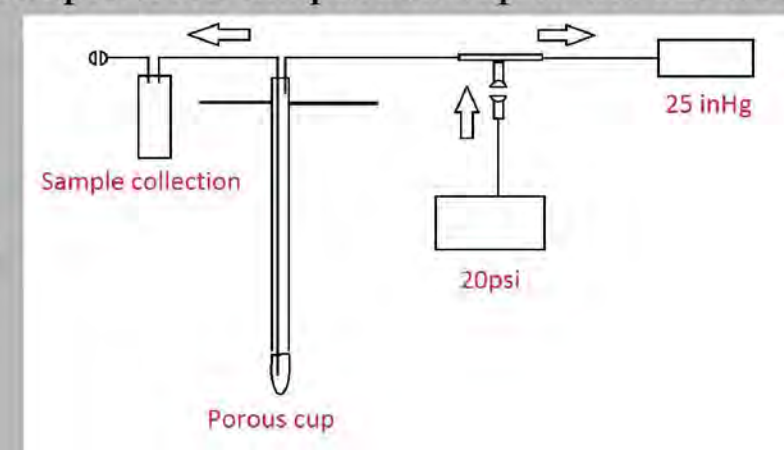


Fig. 3 Block diagram of suction lysimeters

- Controlling CO₂ concentration:** In area A, a CO₂ meter with a programable relay switch was used. The relay was programmed to open at concentrations above 2,000ppm and wired to a CO₂ tank with a solenoid valve regulator. This setup allowed CO₂ to flow into the enclosure only when concentration was below 2,000ppm



Fig. 4 Setting up Sample area A. Suction lysimeters (left), meter and relay (center), and solenoid valve (top right) can be seen.

- The theoretical pH of distilled water in equilibrium with sample area A was calculated to be ~5.2

- Irrigation:** In the enclosed chambers, ambient air was bubbled through 5gal water reservoir until reaching equilibrium. A total of 3in³ was applied per area per week.

- Pore water samples** were collected at each sample area during the course of the experiment. Temperature, soil moisture, and CO₂ flux were also monitored.

Results

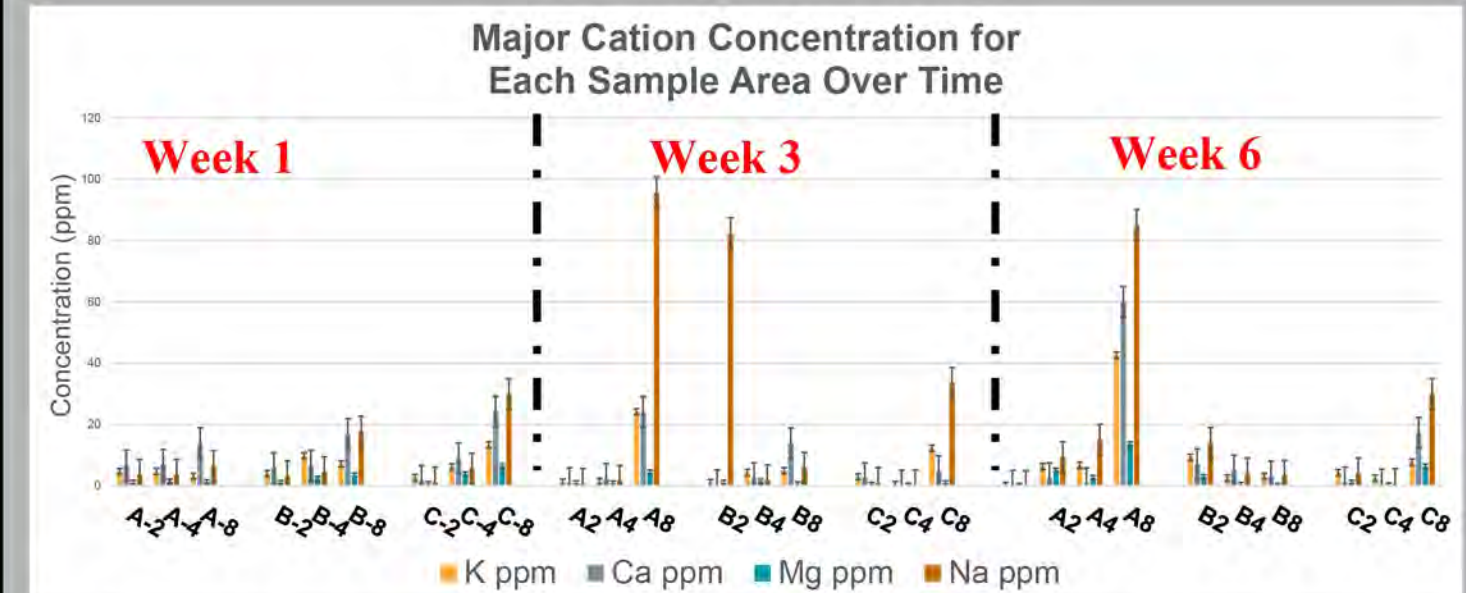


Fig. 5 Cation concentration (ppm) at each depth, for each sample area, over time

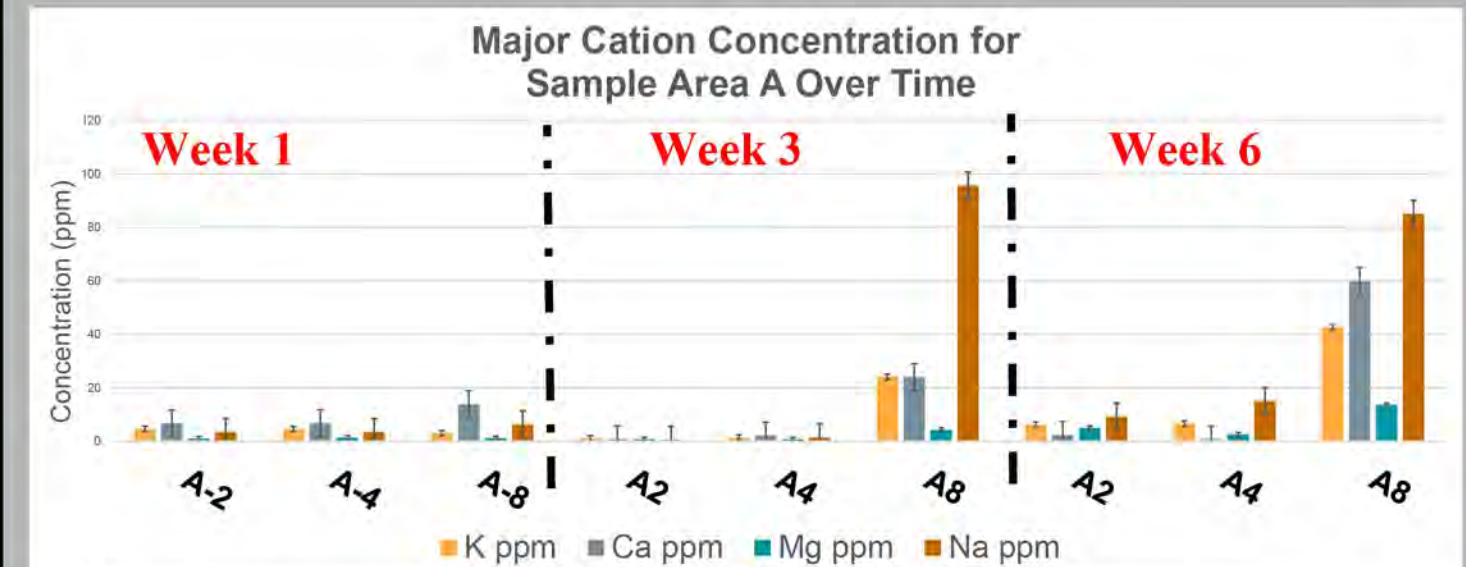


Fig. 6 Cation concentration (ppm) at each depth for area A (high CO₂) over time

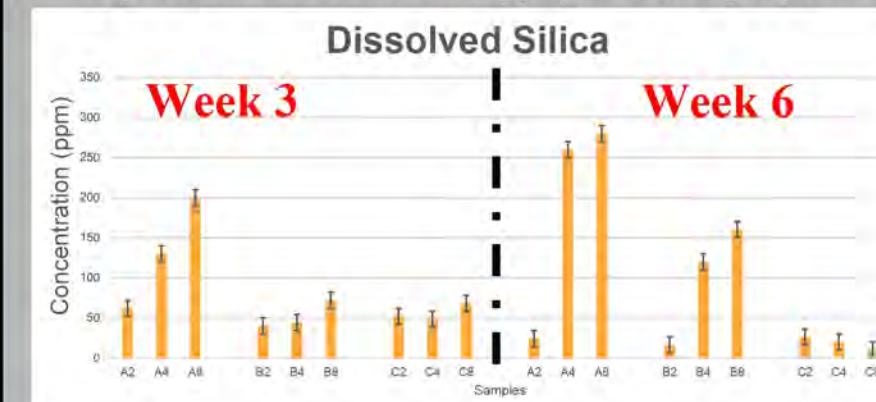


Fig. 8 Dissolved silica concentration (ppm) at each depth, for each sample area, measured at two periods

Conclusions

- Increase in pore water concentrations over time at area A (highest CO₂ levels) is consistent with hypothesis
- Initial condition concentrations of K⁺ and Ca⁺² were higher than Na⁺. A steady increase in Na⁺ with time infers increased weathering of Na⁺ minerals such as albite.
- Results imply concentrations of cations in surface and groundwater would increase with atmospheric CO₂

References

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