The Role of Fungi in Rock and Mineral Weathering
Ekjyot Gill

Fungi are a kingdom of microorganisms including yeast and mold that likely play a critical role in rock and mineral weathering. It is increasingly recognized that biological processes are important for geochemical cycles. Fungi likely invaded land millions of years of before plants (Labandeira, 2005), yet most "bioweathering" studies have focused on plant-rock interactions. Few studies have focused on fungi, so my research will have important implications for understanding the co-evolution of Earth and life through time. Fungi weather rocks in two ways: mechanically by growing in rock pores, thereby tearing the rock apart; and chemically by lowering the pH of water, causing the rock to decompose. To quantify the rates and mechanisms of fungal weathering, I will collect and culture fungal samples and systematically pair them with rocks and minerals commonly found at the Earth's surface. I will focus on the characteristics of individual species regarding the mechanisms by which they regulate chemical weathering. This project will bridge a critical gap between two fields that are often mutually exclusive, namely geochemistry and microbiology. I will work jointly between Prof. Andrew Jacobson, a geochemist in the Department of Earth and Planetary Sciences, and Dr. Louise Egerton, a microbiologist at the Chicago Botanical Garden.

Fungi are a major source of biota in soils and mineral substrates. The ability of fungi to interact with minerals, metals, and organic compounds through biochemical and biomechanical processes makes them effective agents of rock and mineral weathering (Burford, 2003). Fungal mycelia growth allows fungi to exploit weak spots on rock and grain surfaces. The hyphae, long filamentous structures that allow fungi to grow and expand, respond to surface contours by following grooves and penetrating pores (Hoffland, 2004). At such spots, fungi begin the weathering process. Fungi are capable of generating osmotic pressures of 10-20 uN/uM^2, enough to penetrate bullet-proof material (Hoffland, 2004). However, in order to fully penetrate rock, fungi also use chemical processes (Hoffland, 2004). Fungi chemically weather rocks and minerals through proton-based and ligand-based agents (Hoffland, 2004). Proton-based agents include CO_2, which forms carbonic acid, and other acids produced in the areas directly surrounding the tips of the fungal hyphae (Hoffland, 2004). Ligand-based agents include lichen acids, organic acids, and other acid polysaccharides (Hoffland, 2004).

Previous studies on bacterial weathering have shown that nitrogen uptake results in acid formation (Wu et al, 2007; 2008). While most acid formation research focuses on the role of carbonic acid, Prof. Jacobson's research has demonstrated the new and important role of nitrogen utilization. When bacteria use nitrogen in the form of a positive ammonium ion (NH_4^+), the reaction yields protons (H^+) to maintain electroneutrality:

$$11C_6H_{12}O_6 + 24O_2 + 8NH_4^+ \rightarrow 8C_5H_8O_2N + 26CO_2 + 46H_2O + 8H^+$$

I hypothesize that fungi follow a similar reaction pathway as bacteria. To test this hypothesis, I will examine the effects of fungal acid production using a variety of fungal species and different rock and mineral specimens. I seek to answer the following questions: **What are the rates and mechanisms by which fungi weather rocks and minerals and how do they compare to abiotic weathering processes?** Specifically, I will grow fungi in the presence of rocks and minerals using glucose as a carbon source, and either ammonium or nitrate as a nitrogen source. I expect that pH will decrease when I supply ammonium but not when I supply nitrate. Following, Wu et al. (2007; 2008), I further hypothesize that other sources of acidity, such as gluconic acid and dissolved CO_2, are less important than ammonium uptake. To test this hypothesis, I will measure concentrations of gluconate, the conjugate base of gluconic acid, and I will measure solution alkalinity, which together with temperature and pH, will allow me to calculate dissolved CO_2 concentrations following the principles of carbonate equilibria. I will focus on fungi that form symbiotic relationships with oak trees because unlike the conventional decomposer (or saprophytic) fungi that are found in the soil and whose growth depends entirely on finding soluble carbon substrates, symbiotic fungi attack rocks to both break down mineral structures and release nutrients that are essential for plant growth.

I will first collect and grow fungal samples. Roots and soil from under oak trees will be collected from the Chicago Botanic Garden McDonald Woods area. Healthy roots with full fungal mantles, i.e., fungal sheathing around the root, will be removed from soil samples, washed in water to remove debris, surface-sterilized using 5% chlorine bleach (2 min) and two rinses of sterile deionized water (2 min each), and then allowed to surface dry under sterile conditions. Mantle tissue will be peeled from the roots and placed onto potato dextrose agar in petri dishes. The plates will be sealed and incubated at room temperature and examined for growth twice per week. Each successful culture will be plated onto 20 individual plates to produce sufficient material with which to test the capacity of the fungus to access nutrients from mineral substrates.

The next step is to analyze fungal-rock interactions by measuring the media for evidence of protons and chemical weathering byproducts, such as dissolved cations. One hundred ml of sterile growth medium containing glucose and nitrogen (ammonium or nitrate) will be placed into Erlenmeyer flasks along with a sterile, ground mineral source. Using a sterile blade, the fungal colony will be scraped from the agar medium and added to the liquid culture. Inoculated flasks will be incubated at room temperature on a shaker platform for two weeks, and checked daily for fungal growth and contamination. Solution pH will be measured with a high-precision benchtop meter. Cation concentrations will be measured by ICP-OES. Anion and gluconate concentrations will be measured by IC. Alkalinity will be measured by Gran titration.

As a senior Earth and Planetary Sciences and Biological Sciences double-major, I am well prepared for this interdisciplinary research focusing on the biology of fungi and the geochemistry of mineral weathering. I spent my 2011 spring break conducting fieldwork in the Yucatan Peninsula where I learned how to collect and analyze soil samples. For the past three years, I have conducted bench work in a biology laboratory. I am familiar with culturing and treating cells as well as maintaining and preparing biological samples. I plan to write a Senior Honors Thesis and have made arrangements to take three quarters of Earth 398. Spending this academic year on an independent project will allow me to appreciate the scope of the work and help me decide if laboratory research is something I would like to pursue as a career. This project will provide insight into fungal acid production mechanisms that influence mineral weathering and the geochemical cycling of the elements.

References

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