

URG Final Report

Wu et al. established that ammonium was a major contributor to acid production through H^+ release due to charge balance. We hypothesized that fungi use a similar mechanism to produce acids that allow for chemical weathering of rocks and minerals. We designed an experiment in which fungi were grown with granite in four types of media: ammonium-rich with phosphate, ammonium-rich without phosphate, nitrate-rich with phosphate and nitrate-rich without phosphate. The difference between the NH_4^+ media and the NO_3^- media was the charge of the nitrogen source. We expected that the NH_4^+ media would result in H^+ production while the NO_3^- media would not. Therefore, we hypothesized that there would be more mineral weathering in the reactor containing NH_4^+ media and fungus compared to the reactor containing NO_3^- media and fungus. Phosphorus, a major component in biomass synthesis, is required for growth so we expected more acid production and weathering in phosphate-lacking media because the fungus would try to obtain phosphorus from the mineral.

We chose granite, a type of igneous rock, as our experimental mineral/rock to be weathered. By volume, granite contains 38.9% quartz, 29.1% plagioclase, 25.3% K-feldspar, 6.5% muscovite, 2.1% biotite, 0.30% apatite, 0.30% fluorite, and 0.20% calcite. The main elements found in granite are calcium, magnesium, iron, silica and aluminum. Therefore, we focused on these five elements when measuring elemental concentrations. Each of our four media conditions had two controls—media with only fungus and media with only granite—thereby giving us a total of twelve experimental reactors. We collected media samples every 48 hours for two weeks and measured elemental concentrations over time.

Our major hypothesis was the fungal weathering due to acid production would increase in the presence of ammonium versus nitrate because the positive charge on ammonium would result in H^+ release due to charge-balance. In general, we have evidence that NH_4^+ related acid production results in weathering of granite. Our second hypothesis was that fungus grown in phosphate-lacking media would produce more acid than fungus grown in phosphate-bearing media because it would have to weather surrounding minerals in order to obtain phosphate, a vital molecule for growth. In our nitrate samples, we see increased mineral dissolution in phosphate-lacking media compared to phosphate-bearing media, supporting our hypothesis. The calcium, iron, magnesium and silica media samples all show increased elemental concentrations in P-lacking media. Aluminum levels display no difference between the phosphate media types. This may be due to particular aspects of aluminum dissolution and should be a point of further review. In particular, iron and silica show relevant increases in dissolution rate when comparing P-bearing and P-lacking media.

In our ammonium samples, there is no evidence of increased dissolution due to fungal phosphate deficiency. In fact, granite placed in P-bearing media consistently shows a higher peak dissolution rate when compared to granite in P-lacking media. One explanation may be that the fungus grown in P-bearing media experiences rapid growth that the fungus grown in P-lacking media does not. Even if the fungus in the P-lacking media is producing more acid per

gram than the fungus in P-bearing media, it cannot compete with the acid production of the higher biomass P-bearing media fungus. This would account for the higher peak in dissolution yet relatively similar rate of dissolution around collection 5-6 of the P-bearing reactors compared to P-lacking reactors. The fungus in the P-lacking media simply grows slower than the fungus in the P-bearing media, but eventually produces a similar amount of acid for dissolution.

As expected, reactors containing only fungus or granite generally display lower levels of dissolution when compared to reactors containing fungus as well as granite. The reactors with only granite display a slow increase in dissolution followed by a flat-line in dissolution rate. This pattern is common to batch dissolution experiments and likely represents a combination of processes including the fluid's approach to saturation with respect to dissolving phases. In general, the fungus only reactors show less dissolution than the granite only reactors. This was expected because elemental release by fungus is less than elemental release by granite.

If this experiment is repeated, one important point to note is that the sample volume removed from each reactor should be measured carefully as the amount of remaining media has a large influence on concentration measurements. Additionally, reactor seals should be extremely tight to prevent evaporation of media and thereby artificial elevations in elemental concentrations. In our data, the concentrations of aluminum, iron and silica spike during collection 8. This is most likely due to the lack of media remaining in our reactors. 15 mL of media was collected eight times per 150 mL starting media reactor. Disregarding evaporation, this leaves 30 mL of media per reactor at the end of collections. However, the volume of granite in each reactor does not change. Therefore, by the last collection, there were artificially high elemental concentrations. While we tried to correct this using an equation, we were not able to correct for evaporation. Evaporation would have the greatest effect on the final collection.

The next step in measuring the weathering of rock/minerals by mycorrhizal fungi through acid production due to charge-balance would be to change the source of weathering and the material to be weathered. This study focuses specifically on one species of fungus and one rock type. In order to apply our findings to general geologic systems, we need to expand our study to include different fungal species and different rock types. The next logical step is to vary rock type as our experimental procedures can be used almost exactly. The following step would be to vary fungal species. This should be done after varying rock type because different fungi exhibit specific growth patterns and produce unique chemicals. Our experimental methods would have to be modified in order to be used with different fungi.

Our study demonstrates that charge-balance is a major component in fungal acid production and granite weathering. It bridges a critical gap between two fields that are often mutually exclusive, namely geochemistry and microbiology and provides insight into fungal acid production mechanisms that influence mineral weathering and the geochemical cycling of elements.