

Influence of mineral liberation on metal leaching and dissolution rates in ore material and associated host rock Gerrit VanderWaal and Christian Schardt

Introduction

Current methods of sulfide ore comminution produce harmful waste in the form of leached metals and acidic runoff. Ore minerals in tailings piles oxidize when exposed to air and water to form sulfate and free H+ ions, lowering the pH of the system and accelerating sulfide oxidation and the release of metals, a phenomenon known as "acid rock drainage" (Lapakko et. al, 2013; Nicholson et al., 1990). A technology that has recently become commercially available, electric pulse disaggregation (EPD), breaks apart rock at mineral grain boundaries, void spaces, and other cavities within the rock. By breaking the rock apart into individual mineral grains, the surface area of both sulfides and silicates is drastically increased, improving the recovery of ore minerals and increasing the buffering capacity of silicates, thereby limiting the potential production of acidic runoff. EPD should increase ore recovery efficiency while simultaneously decreasing the amount of waste released into the environment by separating ore minerals from the gangue at grain boundaries.

Methods

Source

The ore material used in this project is a Duluth Complex phaneritic gabbro (Fig. 1) hosting disseminated Cu-sulfides. The mineralogy is typical of gabbros, containing (observable) plagioclase and biotite in addition to chalcopyrite and pyrite. The plagioclase crystals form elongated ~5 mm laths uniformly distributed throughout the rock, while the sulfide grains range from 1-5 mm.



Processing

The material to be processed via EPD was first processed in a Selfrag Lab unit with an electrode gap of 40 mm, 10 pulses, 5.0 Hz pulse frequency, and 120 kV to break it up into 3-4 cm chunks. It then was processed with an electrode gap of 35 mm, 100 pulses, 5.0 Hz pulse frequency, and 200 pulses to break it into 1 mm pieces. It was processed one last time with same settings with little effect on grain size (Figs. 2a-c). The rock portion to be mechanically crushed was first processed using a jaw crusher and was ran through the machine five times until a grain size of around 1 cm was reached. The material was then ran through a rotary pulverizer until the average grain size was 2-3 mm (Figs. 2d-f). Both the material processed mechanically and via EPD were baked for one hour at 200°C. All material was sieved using 8-inch sieves for approximately 10 minutes.





Set-up

All glass beakers, disposable plastic syringes, and high density polyethylene (HDPE) sample bottles were rinsed twice with deionized water then submerged (filled in the case of the beakers) in 10 parts deionized water, 1 part 12.1 N HCl and left to sit for 2-3 hours. The solution was then drained and the beakers, syringes, and bottles were rinsed twice with deionized water and left to dry in a laminar flow hood. The beakers were split into three stations: room temperature, heat (50°C), and acid (pH ~4). Two beakers were present at each station, one to be filled with material processed by EPD and another to be filled with mechanically processed material. Each beaker was filled with 150.1 g of material, ~900 g deionized water, and sealed with aluminum foil and a glass cover. The room temperature beakers were placed under a laminar flow hood (Fig. 4), the heated beakers were placed in a continuously running oven (Fig. 5), and the acid beakers were placed in a fume hood (Fig. 6).





Sampling

Weekly mass, conductivity, pH, and temperature measurements (Figs. 3a-h) were taken from each vessel in the following order: mass, temperature, conductivity, pH. Samples of the aqueous solution were taken on 3/04/2016, 4/04/2016, and 4/11/2016. A 0.2 μm nylon syringe filter was affixed to a syringe and approximately 10 mL of solution was extracted from each beaker. The solution was then injected into a sample bottle and 125 μ L of 12.1 N HCl was added to prepare the samples for analysis. Each bottle was then labeled and placed in a refrigerator for storage. Samples were then sent to the Research Analytical Laboratory at the University of Minnesota for ICP-MS analysis.

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Results

The pH for the different environments and processing methods initially started out at differing pH values but eventually normalized to around 7, both around the same time. Conductivity steadily increased throughout the duraction of this experiment, but the room temperature and heated environments containing EPD-processed material eventually began reading very similar values in the final third of the project. However, the mechanically processed material did not exhibit this phenomenon and the heated environment consistently displayed higher conductivity values. As expected, mass decreased at a steady rate (deviations caused by solution extraction) and temperature remained more or less constant.

A 15-element ICP-MS analysis revealed material processed by EPD had consistently higher Ca, Cu, K, Ni, and Zn (albeit inconsistently) concentrations, while mechanically processed material had higher Al (acidic EPD/acidic mech.), Fe, Mg, Mn, and Na concentrations than the EPD material. However, Al, Cu, Fe, Mn (acidic EPD/acidic mech., heat EPD/heat mech. only), Ni (acidic EPD/acidic mech., heat EPD/heat mech. only), and Zn decreased in concentration over time. Oddly, the amount of Ca in the acidic environments was nearly 3-7 times the amounts in the other environments. B, Cd, P, and Pb were not present in any significant amounts.

Conclusions

It is difficult to draw strong conclusions from the results from this experiment given the weekly readings and odd ICP-MS results. Because EPD breaks up rock based on grain boundaries, one would expect more and smaller grains of exclusively chalcopyrite or anorthite. Therefore, based on the small grain size and "pure" grains, there is more surface area for the water to react with, and thus one would expect higher concentrations of elements in the EPD beakers than in the mechanically processed beakers (containing larger grains composed of mixed minerals). One would expect the EPD portions of the experiment to exhibit higher conductivities and lower pH values. This, however, has not observed.

Some of this behavior may have explanations. Weathering feldspars would create a buffering effect, negating the effect of the acidified water in the acid environment and generally preventing the pH from dipping below neutral levels. A coating of orange oxides were observed in the acidic mechanically processed environment which could explain why some elements decreased in concentration over time.



References

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