

## **DRA-23. WEATHERING AND TRANSPORT OF IRON IN COLUMN STUDIES**

Weathering and Transport Investigations of Waste-Rock Material from the Questa Molybdenum Mine using Column Studies to Investigate the Roles and Formation of Secondary Iron-bearing Mineral Phases

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### **1. STATEMENT OF THE PROBLEM**

What is the sequence of weathering reactions of a polymineralic mine-waste rock material and the paragenesis of Fe-bearing secondary mineral phases?

### **2. PREVIOUS WORK**

There are several controls on the weathering of pyrite and other minerals found with in a mining environment. Obviously, the availability of oxygen is a key control on the oxidation rate of pyrite (Morth and Smith, 1966). However, a variety of interrelated factors probably influences the rates of these processes. For example, Malmstrom et al. (2006) discuss the importance of bio-geochemical kinetics, the rate of supply of reactants (i.e. dissolved oxygen), and geochemical equilibrium in conjunction with flow rates and the transfer of components between mobile-immobile water interfaces.

### **3. TECHNICAL APPROACH**

The kinetics, controls, and products of pyrite oxidation in bulk rock matrices will be investigated using five sequentially connected borosilicate glass columns with an internal diameter of 2.7 cm and a length of 100 cm. A multi-channel peristaltic pump will be used to pump and control flow rates from one column to the next. The degree of unsaturation in the columns will increase from the first to the final column. The first column will be completely saturated with respect to water, and the last column will be completely unsaturated. Figure 1 (Appendix 1) is a schematic representation of the experimental design layout described above.

A series of chemical extractions are to be used to determine the distribution and speciation of iron and other major elements within the samples. The speciation will be distributed into the following categories: 1) ion exchangeable ferrous and ferric iron, 2) iron in acid volatile sulfides, 3) pyrite, 4) ferric oxides and oxyhydroxides, and 5) poorly crystalline oxides described further by Heron (1994). BET N<sub>2</sub> adsorption isotherms will be used to measure the surface area and density of the samples (Brunauer S. et al., 1938). Electron microprobe and electron microscopy techniques will be used to examine surface coatings and composition of the samples used.

The column packing characteristics are to be determined by modeling the breakthrough of a lithium non-reactive tracer. The hydraulic conductivity is measured before the experiments begin. The porosity is measured empirically and compared against values found in the literature. Samples are to be collected and analyzed on consistent intervals. Samples are collected between each column. The pH, conductivity, dissolved oxygen concentration and the oxidation-reduction potential is measured on every sample

upon collection. The samples will be analyzed for total iron and ferrous iron where appropriate. Major anions and cations are also measured for a sufficient ion balance. All samples are collected via 12 mL HDPE syringe and immediately filtered through a 0.2  $\mu\text{m}$  syringe filter and preserved for further analyses.

The above experiments and analyses are to be used for modeling of the iron chemistry within the columns and compared to field data. PHREEQC for Windows will be used for modeling the chemical and transport reactions (Parkhurst and Appelo, 1999). Initially 1-D reactive transport models will be used to determine transport controls. Geochemical equilibrium and kinetic models will be used to elicit the pertinent chemical reactions and transport phenomena described above of the iron chemistry of the system.

#### **4. CONCEPTUAL MODEL**

The formation of ferric iron-bearing secondary minerals form is directly proportional to the degree of unsaturation of the system. This relationship between iron-bearing secondary minerals and the degree of unsaturation is caused by the increasing availability of oxygen with increasing degree of unsaturation. Transport controlled rate limiting steps will predominate as controls on weathering and the formation of iron-bearing secondary minerals with increased levels of unsaturated flow.

#### **5. STATUS OF THE COMPONENTS**

The experimental design is finished and the columns are in operation. The column packing characterizations have an initial hydraulic conductivity of  $5.96 \times 10^{-2} \pm 23\%$   $\text{cm}\cdot\text{sec}^{-1}$  and an initial average porosity of the 5 columns was  $0.40 \pm 2.2\%$ . The non-reactive tracer study has yet to be performed. The apparatus needed to perform chemical extractions of the solid samples is being assembled. The BET isotherms on several fractions of the initial column packing samples to determine the particle size distribution heterogeneity of the column packing procedure are currently being performed. Sampling and monitoring of the column eluents continues. Modeling parameters are being compiled as they become available and input files are then created.

#### **6. RELIABILITY ANALYSIS**

Laboratory-measured chemical weathering rates are usually orders of magnitude faster than those experienced under field conditions. White and Brantley (2003) attribute these increases to both intrinsic (i.e. increases of surface area with increased weathering duration, progressive depletion of energetically reactive surfaces and accumulation of leached layers and secondary mineral formation) and extrinsic (i.e. low permeability, high mineral/fluid ratios and increased solute concentrations) factors that produce weathering reaction rates close to thermodynamic equilibrium under field conditions compared to highly unsaturated conditions during experimental reaction of fresh and weathered minerals. Considering these and other factors will reliably allow extrapolation to field conditions. BET  $\text{N}_2$  adsorption isotherms for determining surface area comes with a few caveats: 1) all areas including fractures that  $\text{N}_2(\text{g})$  can adsorb to are measured, often over-estimating reactive surface area, 2) assumes a monolayer of  $\text{N}_2(\text{g})$  adsorbs to the surface

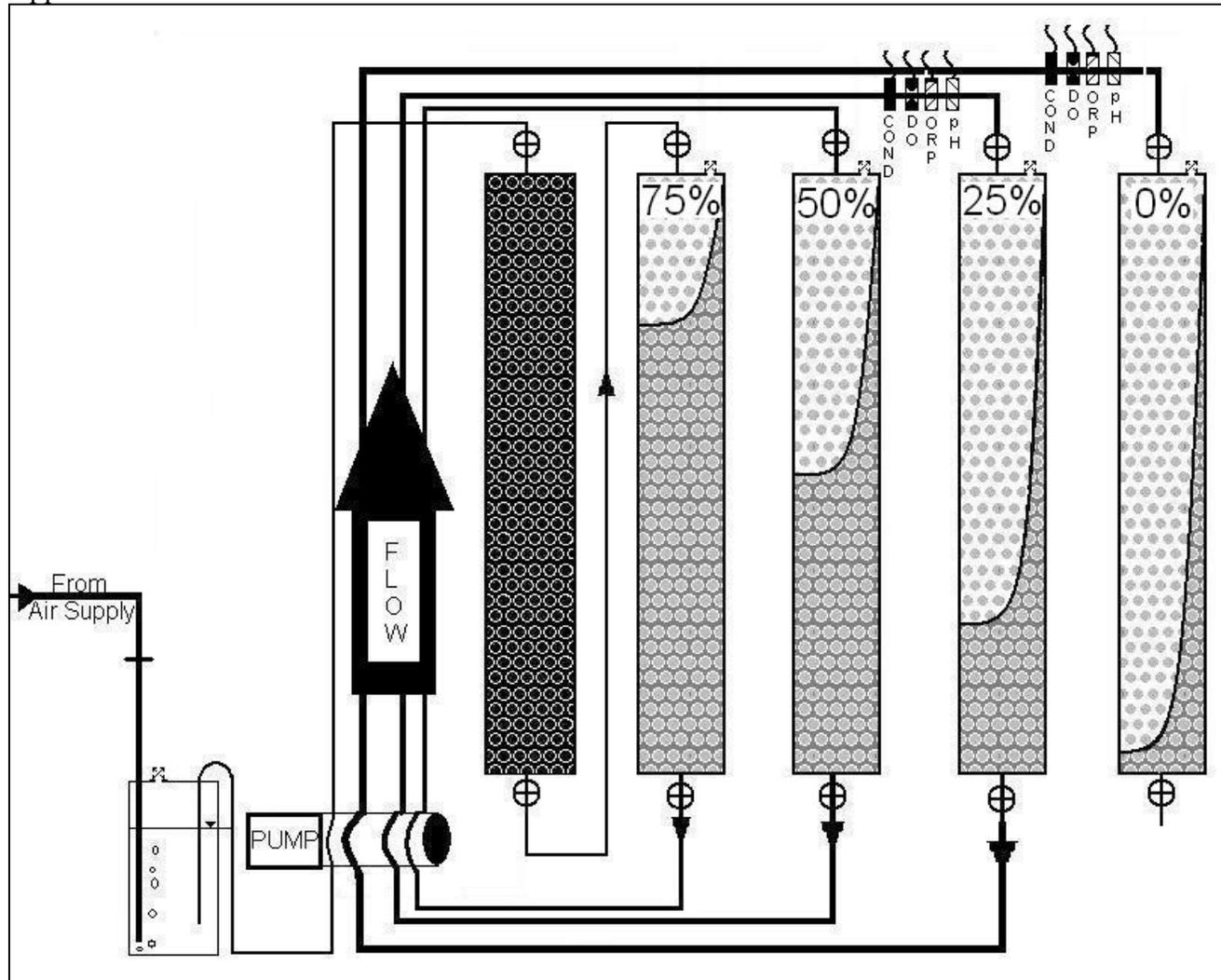
## **7. CURRENT CONCLUSION OF THE COMPONENTS**

There are currently no conclusions at this time. The column leaching experiments will be stopped in October and the material inside will be characterized.

## **8. REFERENCES CITED**

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- Morth A. and Smith E., 1966, Kinetics of the sulfide-to-sulfate reaction: American Chemical Society Division of Fuel Chemistry Preprints, v. 10, p. 83.
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Appendix 1



**Figure 1:** Conceptual Design of Experimental Setup