

# Accelerated Weathering of Pyrite-bearing Rocks using Soxhlet Extractor

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## 1. Introduction

Pyrite is the most common and abundant sulfide mineral and its oxidation can generate acid drainage. Acid drainage is commonly perceived to have negative environmental effects as acidity promotes weathering of rocks, reduces slope stability, inhibits plant growth and increases the solubility of heavy metals. We collected three groups of core samples with different contents of pyrite ( $A \ll B < C$ ) from a mass of biotite banded gneiss. The mechanical and chemical change of rocks and the influence of pyrite oxidation on weathering were investigated using soxhlet extractor. In this paper, the chemical change of rocks and leachate during weathering were mainly discussed.

## 2. Method

### 2.1 Apparatus

The double soxhlet extractor consists of condenser, two flushing barrels and reservoir(Fig. 1). The reservoir at the base of the extractor was filled with 1L of deionized water. The water in the reservoir was heated to boiling point, the steam generated rose, was cooled, and condensed in the condenser, from which it dripped into the upper barrel. When the upper barrel was filled with water, it siphoned out to lower barrel, flushed the core samples in the lower barrel and promptly siphoned out to the reservoir. The weathering products from the core sample were concentrated in the solution in the reservoir. This type of soxhlet extractor were contrived to give the core sample a relatively uniform weathering.

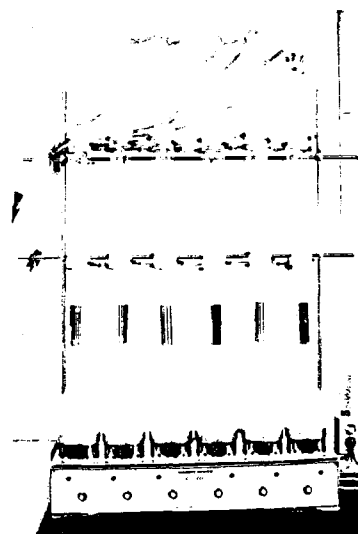


Fig. 1 Double soxhlet extractor.

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**Key words** : acid drainage, weathering, pyrite oxidation, soxhlet extractor

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Two core samples were piled up in each lower barrel and duplicated for each core group.

## 2.2 Analyses

The color and structural properties such as foliation and joint of core samples and mode of pyrite occurrence were closely investigated. We collected water samples from reservoirs after 2, 3, 4, 6, 9, 13, 22, 29 days of weathering. The temperature, pH, EC were immediately measured after filtering by 0.45 $\mu$ m membrane filter. The mineralogical compositions of core samples and residues on filter were analyzed by XRD. The morphology and chemistry of filtrates were examined by SEM/EDS. Major cations were analyzed by ICP-AES and anions by ion chromatography.

## 3. Results & discussions

The color of core samples were N 6/0 for group A, N 5/0 for B and N 6/0 for C, which showed little difference among core groups. The aspect of foliation was similar

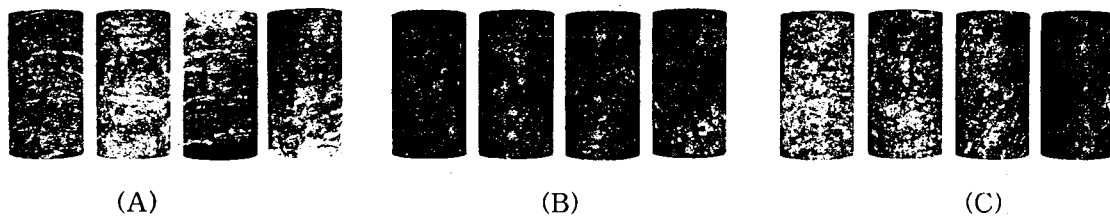


Fig. 2. Core samples before weathering.

in all core groups but several joints and small cracks are observed on the surface of cores from group C (Fig. 2).

Fig. 3 shows the x-ray diffraction patterns of core samples and filtrates. Quartz, feldspar, mica and chlorite were major mineral constituents. There was no significant mineralogical difference among core samples except pyrite content. The pyrite contents calculated by quantitative XRD analysis (Chung, 1976) were 0% for group A, 3.1% for group B and 5.65% for group C. The filtrates from group A and B are mainly composed of amorphous silica but hematite was found only in filtrate from group C. Fig. 4 is the SEM images and EDS spectra of filtrates. The aggregates of amorphous silica were found in filtrates of group A and B. Hematite with spherical form was observed in filtrates of group C.

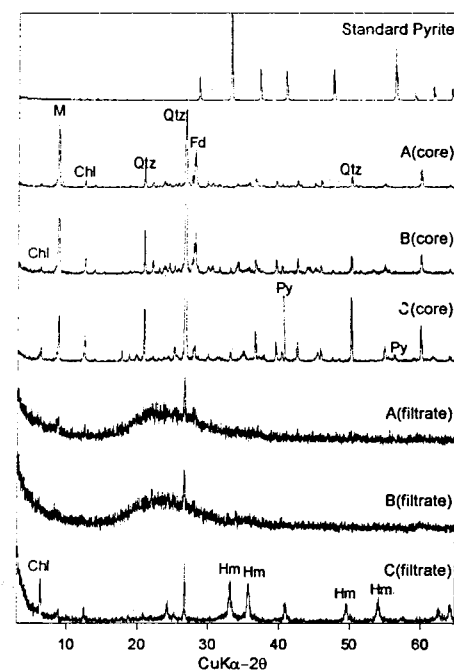


Fig. 3. X-ray diffraction patterns of core samples and filtrates.

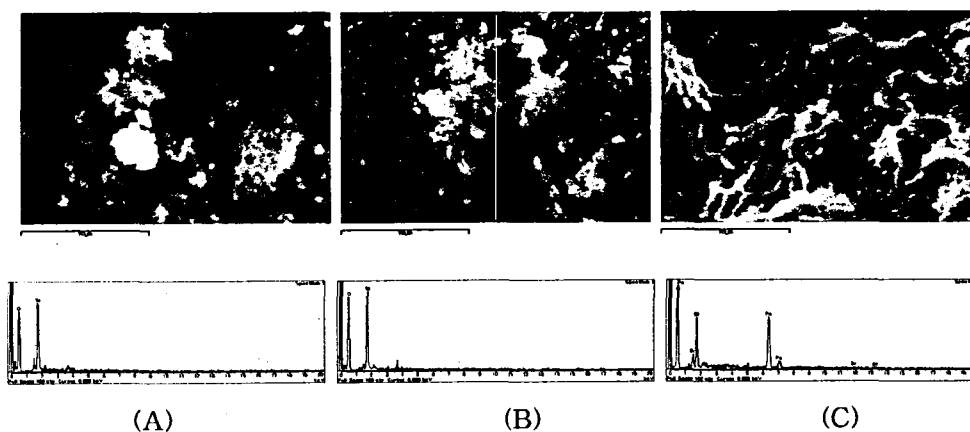


Fig. 4. SEM/EDS images of filtrates.

Fig. 5 showed the variations of Fe,  $\text{SO}_4^{2-}$  in solution during weathering. The Fe concentration in solution from group A was 0.1mg/l and showed little change. Although the content of pyrite of core group B and C were not significantly different, dissolved Fe from group C continuously increased to 98.6mg/l while Fe concentration in solution from group B increased to 0.19mg/l and became steady after 6 days of weathering (Fig. 5).

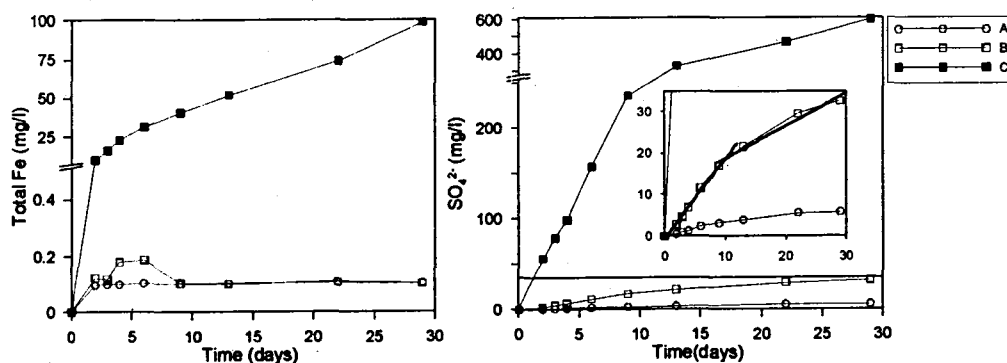


Fig. 5. Variations of Fe,  $\text{SO}_4^{2-}$  in water during weathering of 29 days.

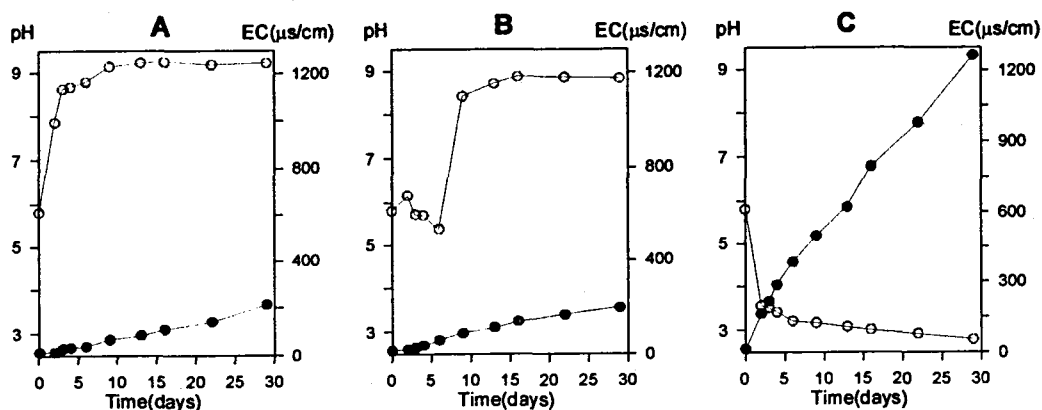


Fig. 6. Variations of pH, EC of water during weathering of 29 days.

The variation trend of  $\text{SO}_4^{2-}$  concentration was analogous to that of Fe. The concentration of  $\text{SO}_4^{2-}$  in solution from group C increased to 600mg/l and the rate of increase was constant. The  $\text{SO}_4^{2-}$  concentration in solution from group B sharply increased to 11.44mg/l until 6days with the slope of 1.92 but after that, the increasing rate became lower with the slope of 0.7. The solution pH was dropped to 5.3 until 6 days and then increased and kept a steady state at 8.9(Fig. 6). The electrical conductivity was continuously increased during the weathering experiment(Fig. 6). The changes in Fe and  $\text{SO}_4^{2-}$  concentration, pH and EC of the solution indicated that the pyrite oxidation was limited on the core surface of group B.

Fig. 7 shows the profiles of core fragments after uniaxial compression test. After 29 days of weathering the surfaces of cores from group B and C became covered by iron oxide precipitation while core from group A showed little change. The cross sections of core from group A and B remained unweathered but on the fragmented surface of core from group C, pyrite oxidation progressed along a joint was observed. After 6

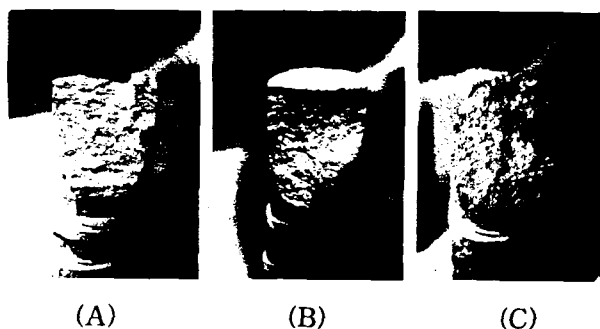


Fig. 7. Profiles of core fragments after uniaxial compression test.

days of experiment the precipitation of iron oxide on the surface of core from group B and C could be observed. Thereafter pyrite oxidation of core from group B might be limited. For group C the oxidation of pyrite in joints or cracks promoted the water and dissolved oxygen to infiltrate into inner part of the core. Consequently the pyrite oxidation could continue after precipitation of iron oxide on the surface of core from group C. The concentrations of other metals in solutions are plotted in Fig. 8. The concentrations of Mn, Zn and Ni in solution from group C increased to 930, 2020 and 1332 $\mu\text{g/l}$ , respectively, which exceeded the standards for ground water quality (Ministry

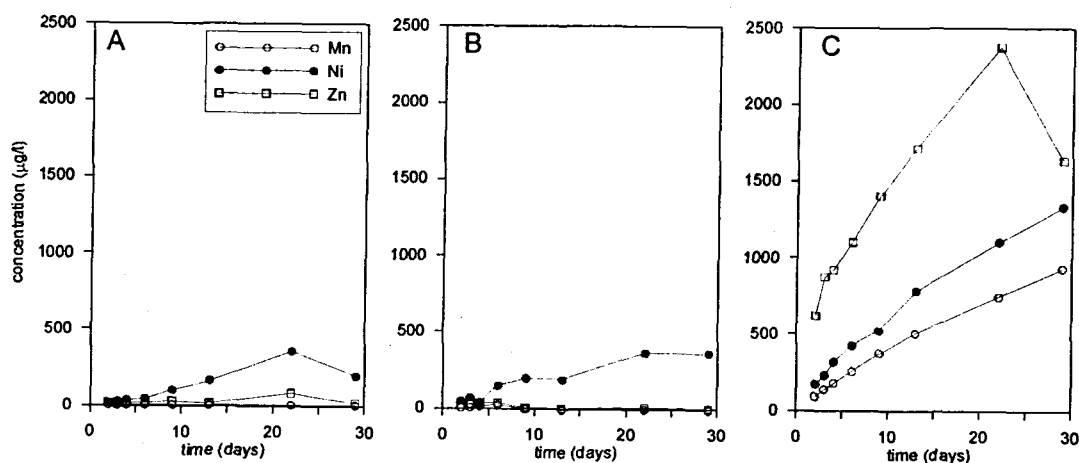


Fig. 8. The concentrations of heavy metals in solutions.

of Environment, 2003). Therefore, the weathering of pyrite-bearing rocks can be an environmental problem as the acid produced by pyrite oxidation remarkably increased the solubility of other toxic heavy metals.

#### **4. Conclusions**

- 1) The pyrite oxidation promotes the weathering of rocks.
- 2) When a pyrite-bearing rock is weathered, the amount and mode of occurrence of pyrite in rocks regulate the chemical characteristics of weathering.
- 3) The pyrite oxidation increased the solubility of other toxic heavy metals during weathering.

#### **5. Acknowledgement**

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