Bacterial Acid Generation in Pyritic Shales and Remedial Measures[1]

by

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Abstract Since the isolation and identification of Thiobacillus ferrooxidans by Colmer and Hinkle in 1947, numerous investigators have tried to develop techniques to prevent bacterial acid generation within pyritic mine wastes. To date, none of the techniques developed have been completely successful. During the construction of a taxiway at Halifax International Airport in Nova Scotia in 1982, about 225,000 cubic meters of fractured waste pyritic slate material was disposed, on site, in a pile covering about 7 hectares. As a result of air and water infiltration and the presence of indigenous Thiobacillus ferrooxidans, this waste rock pile has been seeping a metal laden acidic effluent similar to acid mine drainage. As sufficient quantities of a relatively impermeable clay overburden were present on site , it was decided to apply a compacted clay cap to the pile to reduce air and water infiltration. From previous experience it was known that concentrations of sodium chloride, greater than 1% in the aqueous phase, were inhibitory to Thiobacillus ferrooxidans. Laboratory studies confirmed that the addition of a layer of highway salt beneath the clay layer not only prevented the formation of acid mine drainage, but also enhanced the sealing capacity of the clay. Capping of the waste rock pile was completed in 1987, and the results to date will be presented.

Additional Key Words: Thiobacillus ferrooxidans, clay covers, pyritic slate, rock salt.

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Introduction

Halifax International Airport is located on a band of highly mineralized pyritic bedrock. During airport expansion, 225,000 m^3 of waste rock was excavated and stockpiled over a 7 hectare area. Several months after disposal, an acidic effluent laden with metals began seeping from the waste rock pile and from the taxiway subdrains. A water collection system was built and all effluents were treated by lime addition at a water treatment plant. At the time, it was thought that the acidic drainage would subside with time.

When the acidic seepage continued, unabated, for five years, a decision was made to place an impermeable seal over the waste rock pile to prevent infiltration of air and water. An interdepartmental technical committee was struck to advise Transport Canada on the "state of the art" in the control of acid mine drainage. The committee charged the Canada Centre for Mineral and Energy Technology (CANMET) to investigate the feasibility of incorporating a salt layer between the clay cap and the pyritic waste slate. This paper describes the results of the laboratory investigations and the effect of the clay/salt capping of the pile to date.

Bacterial Acid Generation

Thiobacillus ferrooxidans is an autotrophic, acidophillic organism which grows in the pH range of 1.8 to 3.0. Cellular carbon is obtained from atmospheric carbon dioxide and the cell obtains all of its energy requirements from the oxidation of ferrous iron to ferric iron as well as the oxidation of sulphides to sulphate. The cells are rod shaped (0.5 um x 1 um), have a polar flagellum for locomotion in liquid media and produce pili (fimbriae) on the external cell wall for attachment to surfaces(Figure 1).

The microbiological oxidation of pyrite at pH 1.91 is represented by the following equation (Ahonen et al, 1986):

$$FeS_2 + 3.75\ O_2 + 0.5\ H_2O \rightarrow Fe^{3+} + SO_4^{2-} + HSO_4^-$$

Recent studies have shown that the organisms bind exclusively to the mineral sulphide phases of metal containing ores and totally ignore the non-sulphidic gangue material (Bennet and Tributsch, 1978; Sanmugasunderam et al, 1988).

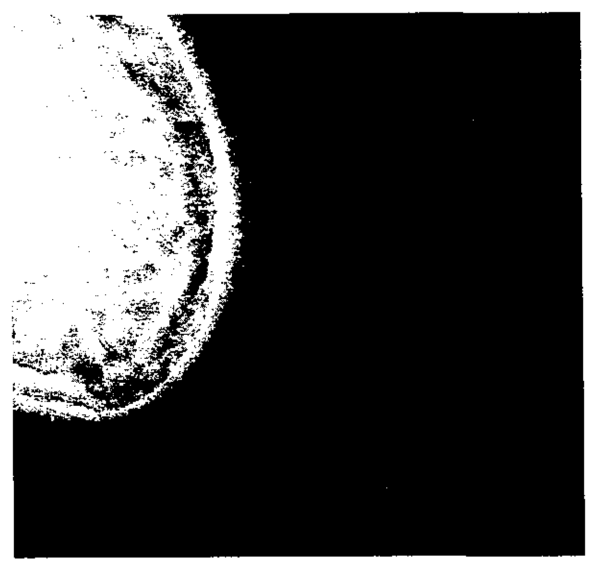

Figure 1: Electron micrograph of *Thiobacillus ferrooxidans* (x 170,000). Note the large polar flagellum and the hair-like pili on the cell surface.

During the oxidation of metal sulphides the organisms produce extensive pitting of the mineral sulphide crystals and often extensive chemical precipitates of ferric hydroxide or various ferric jarosites occurs within these bacterially produced pits (see Figures 2 and 3).

Figure 2: Pitting of a polished ore surface due to the bacterial leaching of sphalerite.

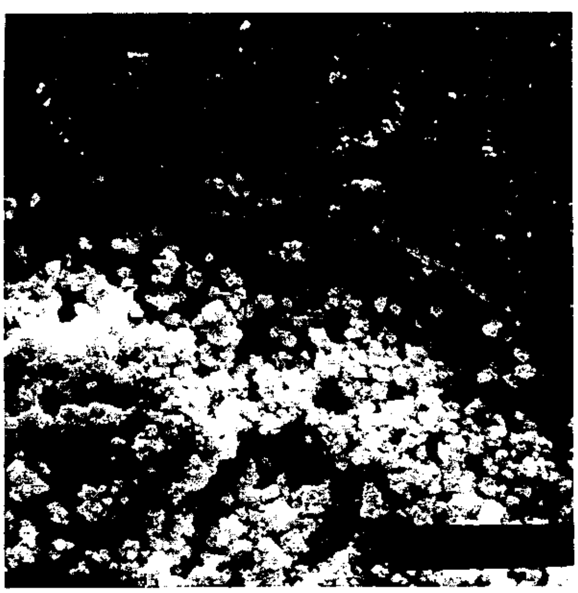

Figure 3: Scanning electron micrograph of the chemical precipitates seen in the pits produced by bacterial leaching of mineral sulphides.

Laboratory and Field Tests on Capping

CANMET set up laboratory leaching columns (6cm in diameter and 50cm long) to test the effects of a clay/salt cap, a clay cap and a control column.For this study, 1kg of clay was used which was tightly compacted and 250ml of distilled water was added to the columns to assess the percolation rate through the clay. The clay used in these studies and at the airport is described by the Unified Soil Classification System (USCS) as Silty, Sandy Clay and Sandy, Silty Clay. Its measured permeability was 4×10^{-7} cm/sec. Highway rock salt addition was based on assumed pore space within the pile being 40% void volume.

Sufficient salt(approx. 5g) was added as a layer between the waste slate and the clay cap to produce a 1.5% w/v solution of sodium chloride in the interstitial water if a rupture in the clay seal allowed the infiltration of water (McCready and Krouse, 1982,1982a)

Table 1 Metal content of the Halifax Slate (Murray et al.,1988)

Element	Percentage	mg/g
Aluminum	9-13	
Iron	3-6	
Manganese	0.01-0.04	
Cobalt		10-80
Nickel		40-270
Lead		10-48
Arsenic		4-19
Copper		18-46
Zinc		70-21

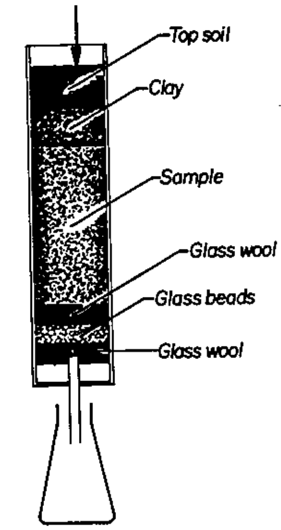

Figure 4: Schematic drawing of a laboratory test column.

From the column study, the iron content of the seepage in the clay and salt capped column declined from 292 mg/L to 34 mg/L and the pH of the interstitial water remained at 2.51. Over a period of three months, although a head of water was applied to the column, no water penetrated through the clay/salt cap. When the cap was allowed to dry out, horizontal cracking was observed, rather than the vertical cracking observed in the clay only cap.

After drying the caps out, water was reintroduced and 4.9L. percolated through the clay only capped column over a four month period. However, on rewetting the clay/salt cap, it immediately resealed itself and no water penetration into the column was observed over a four month period.

Due to the success of the laboratory study, the waste rock pile at the Halifax Airport was recontoured to allow all precipitation to flow off the surface, a layer of road salt was spread over the surface and subsequently sealed with two lifts of 300 mm of compacted clay. The clay cap was then covered with 150 mm of top soil and seeded to grass and the slopes were sodded. The total cost for the 7 hectares was $800,000.

Prior to capping, the waste rock pile produced a constant drainage of about 200 gpm, with acidities as high as 7800 mg of acidity/L, ferric iron concentrations of 1200 mg/L and aluminum contents as high as 700 mg/L. At the end of 1988 the volume of drainage varied from 25 to 50 gpm, the acidity is consistently below 900 mg/L, and the metal contents have declined substantially. Iron is consistently below 40 mg/L and Aluminum is generally <50 mg/L. Because of the low pH and the high heavy metal content the water was treated in a Lime neutralization plant to precipitate the heavy metals and adjust the pH before releasing the water to the environment.

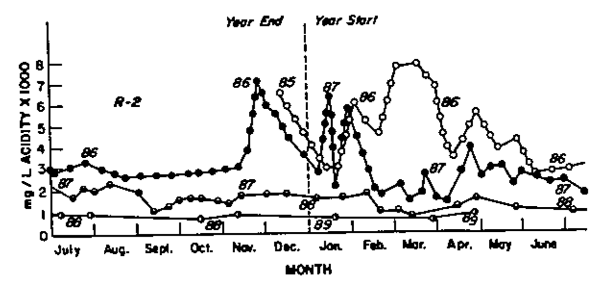

Figure 5: Acidity of influent to water treatment plant vs. time.

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