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IR 72-60

BACTERIAL LEACHING OF COPPER ORE FROM MANITOU BARVUE MINES LIMITED VAL D'OR, QUEBEC

by

H.W. Parsons

EXTRACTION METALLURGY DIVISION

Mines Branch Investigation Report IR 72-60

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SUMMARY

Low grade copper ore from Manitou Barvue Mines Limited responds slowly to bacterial leaching in an acid-sulphate medium at pH 1.8. Only about 4% of the copper was leached in 26 weeks by the Thiobacillus ferrooxidans bacteria. The main copper mineral is chalcopyrite, which has often been found to be unresponsive to bacterial attack.

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INTRODUCTION

In mining their copper ore deposit, Manitou Barvue Mines Limited by-pass low-grade ore which is not suitable for their processing procedure. They requested aid from the Extraction Metallurgy Division, Mines Branch, Department of Energy, Mines and Resources, in determining whether or not the copper content of this ore could be extracted by bacterial leaching. A sample of the ore which contained chalcopyrite as the main copper mineral was submitted for testing.

To evaluate the leachability of a mineral sample with the aid of bacteria, the suitable environmental conditions for the bacteria must be created in the leaching tests. The porosity of the material is of utmost importance, since to attack the sulphides the solution must be able to reach them. Often, this problem can only be solved by reduction in particle size.

Most metallic sulphides of commercial importance - with the exception of lead sulphides - can be bacterially leached. The copper minerals bornite (Cu_3FeS_4), chalcocite (Cu_2S), covellite (CuS) and enargite ($3Cu_2S,As_2S_5$) generally respond well to bacterial leaching. The results obtained with chalcopyrite vary widely, and often only partial extraction is obtained[1].

The bacterium involved in the leaching of sulphide minerals is the species Thiobacillus ferrooxidans. Thiobacillus ferrooxidans cells are rod-shaped, and measure from 1.0 to 1.6 microns in length, and 0.6 to 1.0 microns in width. The

species is the chemosynthetic autotrophic type, and derives its energy from the oxidation of reduced sulphur compounds and ferrous iron. Nutrients needed for its metabolism include nitrogen (utilized from ammonium ions), phosphate, potassium, magnesium and calcium. A nutritive solution containing these salts, called Silverman 9K solution[2] is widely used as both a culture medium and as a leaching solution. An adequate supply of air is needed by the bacteria, as a source of oxygen and carbon dioxide. The bacteria obtain their carbon only from carbon dioxide. It has been reported that in the leaching of mineral sulphides with water containing nitrogen and phosphorus ions, in the presence of adequate oxygen and carbon dioxide, the gangue may supply the other necessary nutrients[3]. In leaching with these bacteria it has been determined that they perform best at a temperature of about 35°C, at a pH of from 1.5 to 3.5.

The Thiobacillus ferrooxidans bacteria used in the investigation of copper leaching were from a stock originally obtained from underground water of a uranium mine of the Elliot Lake area[4].

PROCEDURE

The ore, which had the analysis shown in Table 1, was crushed to minus 1/2 inch, and 500 grams were placed in the apparatus shown in Figure 1. The solution in the reservoir below the ore column was air-lifted at a rate of about 10 ml/minute to the top of the column and allowed to percolate through the ore back to the reservoir.

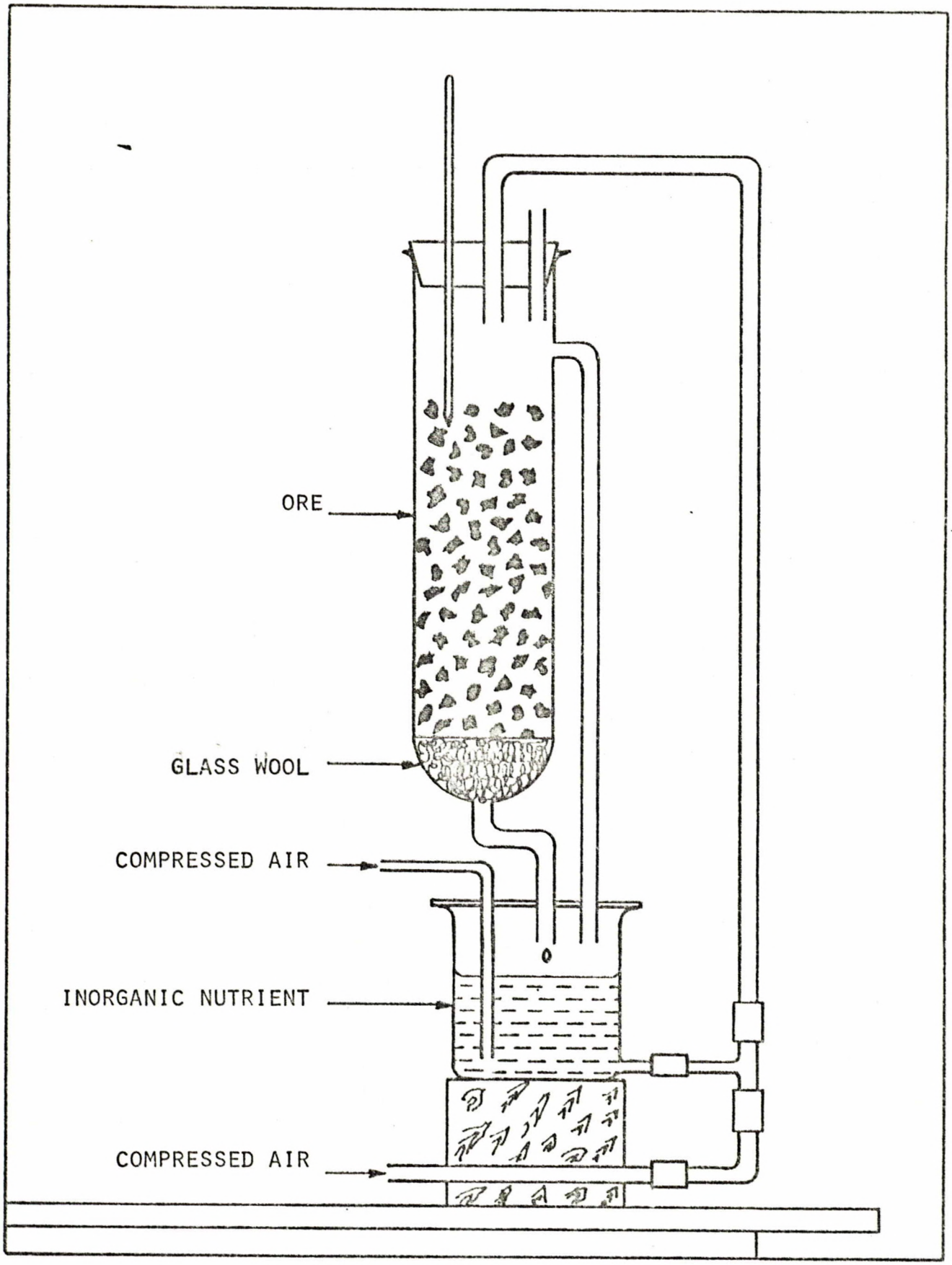

FIGURE 1: PERCOLATION LEACHING APPARATUS

This leaching medium was an aqueous solution of sulphuric acid, pH 1.8, which contained the salts shown in Table 2. This so-called 9K Medium was innoculated with 5 mls of Thiobacillus ferrooxidans serum concentrate. The bacteria were cultivated by aerating the solution at 35°C for five days; during which time the iron was oxidized from ferrous to ferric. The volume of solution used was 800 mls, maintained at pH 1.8 by the addition of sulphuric acid; loss by evaporation was compensated for.

TABLE 1

Chemical Analysis of Manitou Barvue Copper Ore

Cu	3.43	%
Zn	0.011	%
S	6.80	%

TABLE 2

Composition of 9K Medium*

Constituent	g/l
$FeSO_4 \cdot 7H_2O$	44.2
$(NH_4)_2SO_4$	3.0
K_2HPO_4	0.5
KCl	0.1
$MgSO_4 \cdot 7H_2O$	0.5
$Ca(NO_3)_2 \cdot 4H_2O$	0.02
H_2SO_4	0.5
pH	1.8

*after Silverman and Lundgren[2].

RESULTS AND OBSERVATIONS

The copper was leached slowly from the ore, with only about 3% being extracted after 20 weeks of leaching, as is shown by Figure 2. The copper in solution increased gradually to a value of 0.66 g/l, as is shown in Figure 3.

After 130 days, the recycling was stopped, and the column was allowed to drain. The procedure was then repeated, using fresh leach solution, with recycling for 44 additional days. As is shown by Figure 2, only an additional extraction of about 1% was obtained. In the second leach the copper in solution increased gradually to a value of 0.16 g/l.

The rate of extraction of the copper was slow, and varied between 0.048 lb Cu/ton of ore/day and 0.007 lb Cu/ton of ore/day as is shown in Table 4.

The values of the redox potential of the solutions in Figure 4, fluctuated between 500 mV and 600 mV. The iron content of the leach solution decreased from 8.0 g/l to about 2.5 g/l, as is shown in Figure 5.

DISCUSSION

As was noted in the introduction, the results obtained in bacterial leaching of chalcopyrite vary widely. For example, in percolation leaching tests,[5] Bryner and Anderson[6] extracted 20% of the copper in 63 days, Razzel,[7] 25% of the copper in 60 days, and Malouf and Prater[8] 60% in 480 days. Bruynesteyn[3] found that some chalcopyrite samples were leached rapidly to completion, while others were difficult to leach and gave only

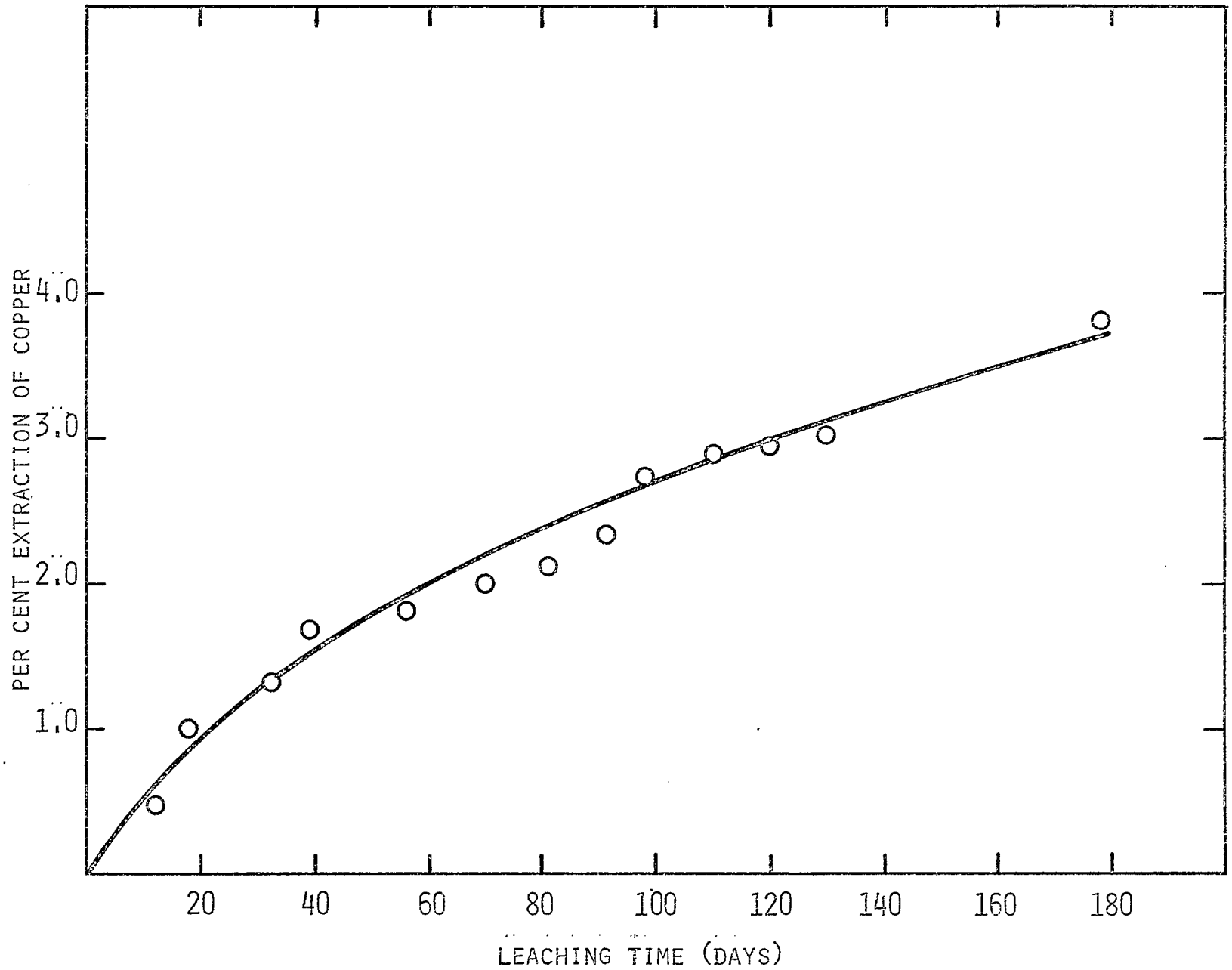

FIGURE 2: ACCUMULATIVE PER CENT EXTRACTION OF COPPER

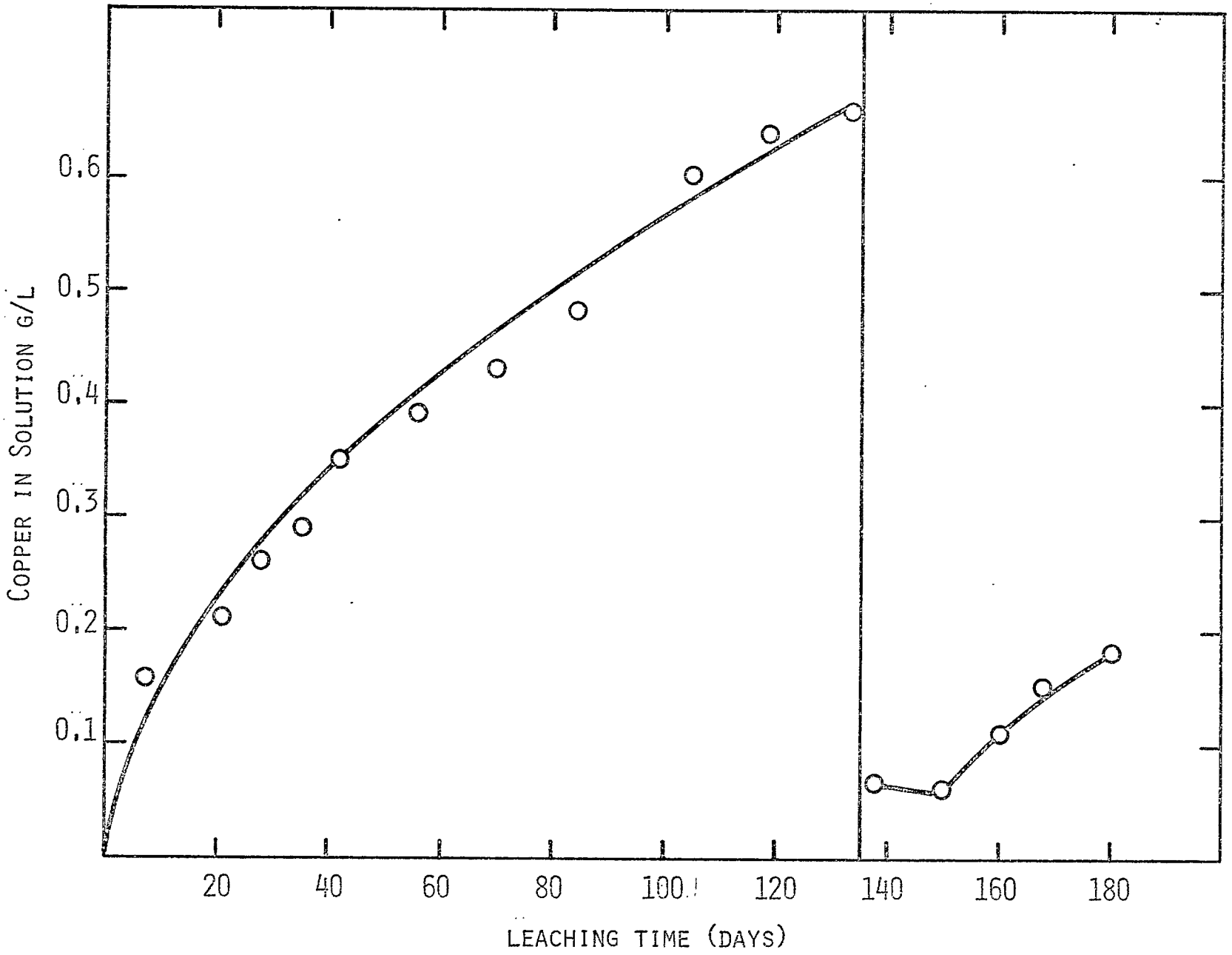

FIGURE 3: COPPER CONTENT OF LEACH SOLUTIONS

TABLE 4

RATE OF EXTRACTION OF COPPER

Leach Period Day-to-Day	Cu Extraction lb Cu/day/ton	Total Per Cent Extraction At end of Period
First Leach		
0- 14	0.048	0.98
14- 28	0.012	1.23
28- 42	0.020	1.63
42- 56	0.009	1.82
56- 70	0.008	1.99
70- 84	0.012	2.23
84- 98	0.025	2.74
98-112	0.011	2.97
112-126	0.010	3.03
126-140	0.020	3.20
Second Leach		
0-14	0.020	3.48
14-28	0.007	3.68
28-42	0.013	4.03

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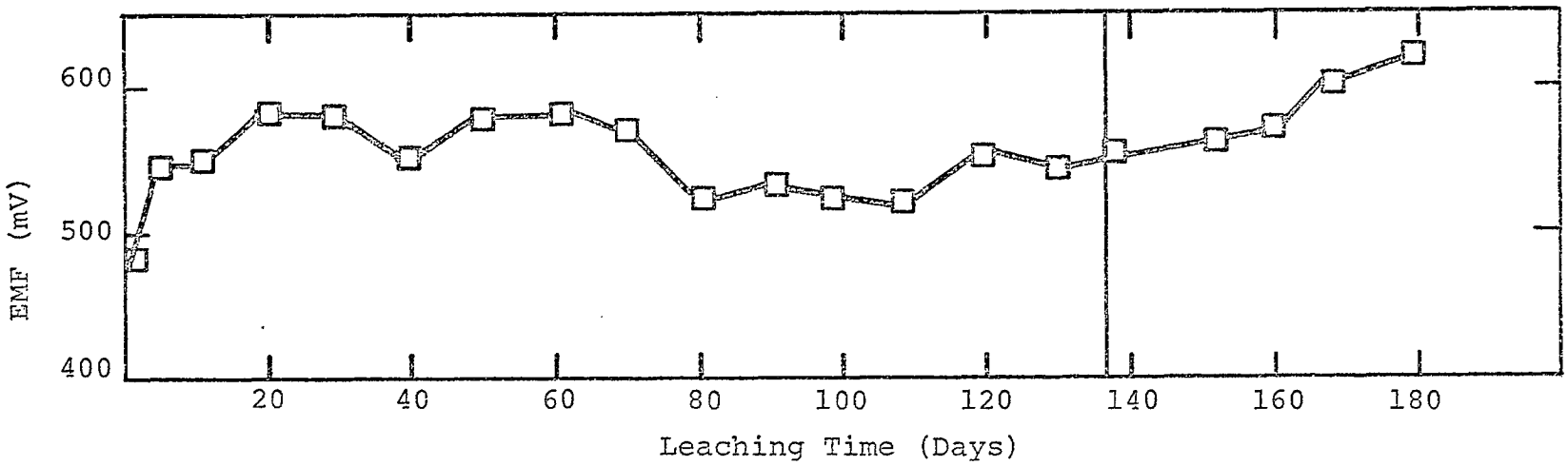
FIGURE 4: ELECTROMOTIVE FORCE OF LEACH SOLUTIONS



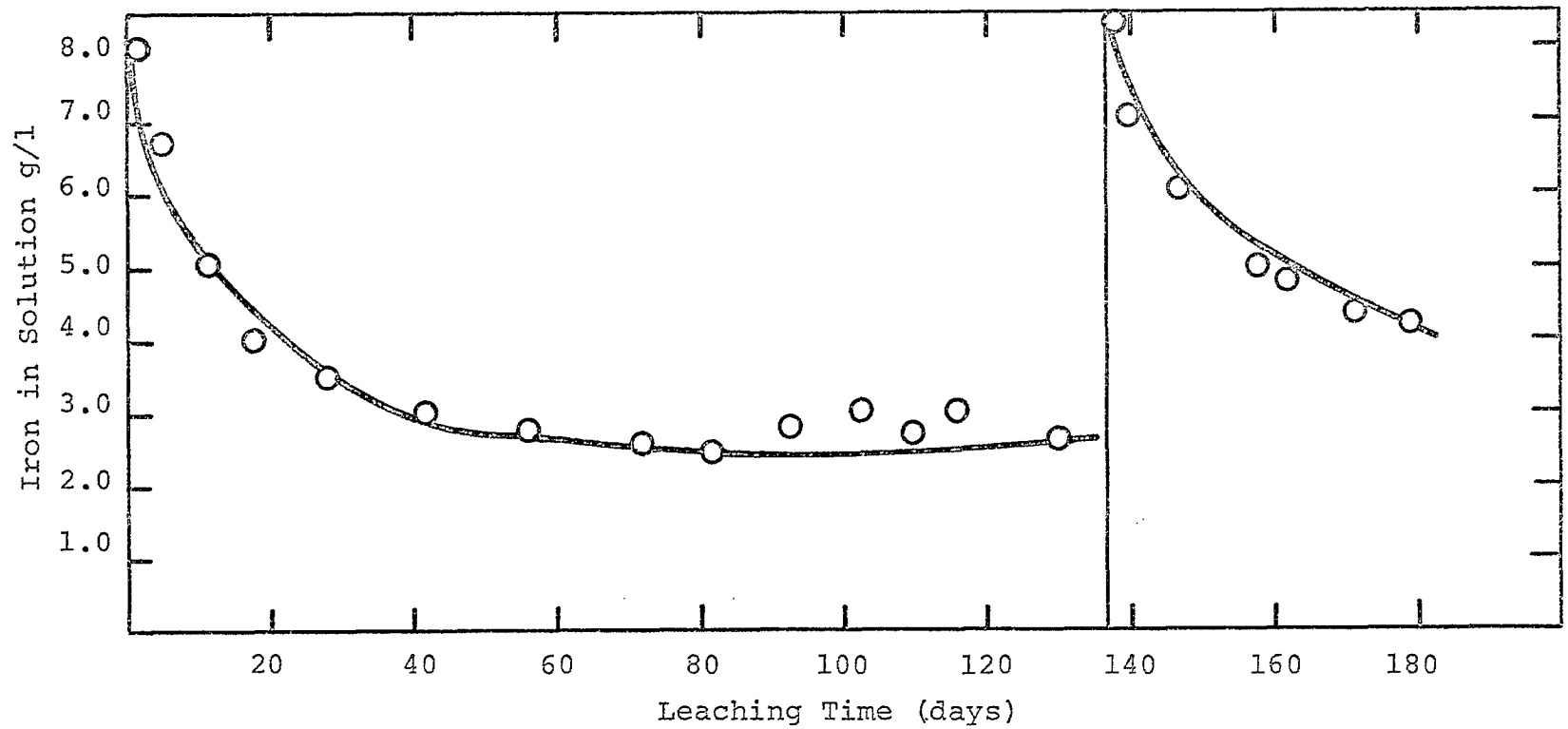


FIGURE 5: IRON CONTENT OF LEACH SOLUTION

low extractions of copper. Bruynesteyn and Duncan[1] state that, with partially leached chalcopyrite, a secondary extraction can be obtained after regrinding the residue. Duncan et al[9] showed that the rate of copper release from chalcopyrite increases with decreasing particle size, down to sizes below 400 mesh. It has been shown also that the addition of a surfactant increases the rate of leaching of copper from some specimens of chalcopyrite[10].

Bruynesteyn[3] reports that research is continuing in an attempt to explain why erratic and unpredictable results are obtained in the bacterial leaching of chalcopyrite.

In the experimental work the slow extraction rate obtained is from minus ½-inch ore; from coarse minus 8-inch ore at the mine the copper would possibly be extracted at too slow a rate to be economically practical.

CONCLUSIONS

The low grade copper ore from Manitou Barvue Mines Limited responds slowly to bacterial leaching, as only about 4% of the copper was extracted after 6 months leaching with solution containing Thiobacillus ferrooxidans bacteria at a pH 1.8. This represents 2.75 lbs of copper extracted per ton of ore treated.

ACKNOWLEDGEMENTS

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