(Paper No. 3103.)

“The Treatment of Oxy-chloride Copper Ores, Atacamite,
by Weak Solutions of Sulphuric Acid.

By JAMES WARNE CHENHALL, M. Inst. C.E.

IN the following Paper are given the results of a series of experiments carried out by the Author and Mr. G. H. Bulmer, Assoc. M. Inst. C.E., in Chili during 1896, to determine the practicability of treating the ores from the copper deposits in the Atacama Desert with a weak solution of sulphuric acid, for the extraction of the copper.

Analysis indicated that the copper existed in the ore experimented upon, chiefly in the form of atacamites, or oxy-chloride of copper, the composition of which Dana gives ¹ as—

	Per Cent.
Copper oxide	53·6
Copper chloride	30·2
(Chloride, 16·0; copper, 14·2.)	
Water	16·2
	<hr/> 100·0 <hr/>

It is evident, however, from the relative amounts of copper and chlorine in the ore, as well as from the presence of carbonic acid, that other copper compounds are present, of which azurite, an oxy-carbonate of copper, is most likely one, containing, according to the same authority:—

	Per Cent.
Carbonic acid	25·6
Copper oxide	69·2
Water	5·2

In all probability these ores are composed of azurite and atacamite, chiefly atacamite. The analysis of six samples of ore, which all contained carbonic acid, showed the average amount of copper contained to be 6·2 per cent. and of chlorine 0·873 per cent. The ores may be regarded as those of atacamite (hydrated cupric oxy-chloride, $\text{CuCl}_2, 3\text{CuH}_2\text{O}_2$). The pure mineral contains 59·48 per cent. of copper.

¹ “A System of Mineralogy,” London, 1868, p. 121.

The ores experimented upon may be described as very hard silicious rock, containing between 3 per cent. and 5 per cent. of oxide of iron, with atacamite infiltrated into the rock, either in flat leaves, spots or stains, but chiefly in flat leaves, taking every direction through the rock. Sometimes in the richest mineral it is more than $\frac{1}{16}$ inch and occasionally $\frac{1}{8}$ inch in thickness, but it principally occurs in very thin layers. The ores from the deposits which the Author had under consideration range between 1 per cent. and 6 or 6.5 per cent. of copper, but small quantities, which assayed between 10 per cent. and 14 per cent. of copper, were met with occasionally in the larger deposits. In such cases the gangue of the ore was a white silicious stone, of the same character as the other ore, but with very little iron in its composition. These richer ores are much softer than the poorer, but form a very small proportion of the whole. The copper portion of the mineral, where thick enough to be separated from the rock, was much softer than the gangue, but where very much diffused it was much harder.

The first series of experiments was performed on ores of different copper contents, to ascertain the percentage that would be obtained by sizing with different screens, the whole having first passed through a screen of nine holes to the square inch. Four series of experiments were conducted on ores containing 6.4 per cent. of copper, 5.3 per cent. of copper, 4.4 per cent. of copper, and 3.26 per cent. of copper. The ore on which the third series of experiments was conducted was selected on account of its extreme hardness. There was considerable concentration of the copper contents in the finely-crushed portions of the ore, due to the soft nature of the atacamite distributed through the ore in comparison with the rock in which it is embedded. In the first series of experiments, on ore with an average of 6.4 per cent. copper, the concentration reached to 13.44 per cent., and in another case to 10.53 per cent. There is a corresponding decrease in the rougher particles of ore, the largest grains falling as low as 3.54 per cent. in the first experiment, 4.5 per cent. in the second, 3.41 per cent. in the third, 2.7 per cent. in the fourth. In almost all cases, the lower the percentage of copper in the ore the harder will be the stone in which it is distributed.

Experiments were then conducted to ascertain the time required to dissolve out the copper contents from grains of ore of the various sizes, and how completely solution would be effected, with a solvent containing 5 per cent. of sulphuric acid of 1.8426 specific gravity. The first series consisted of nine experiments, with ore

that had passed through screens varying from 9 holes to the square inch to 2.5 holes to the square inch, and was continued from 6 hours to 90 hours. Eleven samples of liquor from each of the nine experiments were tested, with the result that in every case after the 90 hours practically all the copper was extracted. A second series of experiments was undertaken with a sample of ore, the chief feature of which was its extreme hardness, to ascertain if the hardness would affect the extraction of the copper contents. Experiments with nine samples of ore with grains of various sizes were conducted, and lasted over 72 hours, samples of the liquor being taken at the end of every 24 hours. Details of the experiments are given in the Appendix.

In the next series of experiments an ore containing 3.95 per cent. of copper, and ground to pass through a screen having 2,500 holes to the square inch, was treated with a solution containing 5 per cent. of sulphuric acid, the ore and acid-water being well agitated every hour. The experiments extended over a period of 24 hours, a sample of the liquors being taken every hour. The whole of the copper was extracted in 2 hours, but the amount of iron dissolved out continued steadily to increase with the number of hours that the ore remained in contact with the acid solution.

A further series of experiments was conducted with the concentrated fine ore obtained from the first experiments on the sizing of the ore. The finest portion contained 13.44 per cent. of copper, which was crushed to pass through a screen having 3,600 holes to the square inch, the solvent being of the same strength as in the other experiments. The experiments lasted 1 hour, samples of the liquors being taken at the end of 1 minute, and at every subsequent 10 minutes. The whole of the copper was extracted at the end of 40 minutes; the ore and solvent during the course of the experiments were agitated every 10 minutes. In this case also the iron dissolved increased during the whole of the time the ore was exposed to the action of the acid solution.

There was no difficulty in absorbing all the sulphuric acid in the solutions; the method employed being simply to pass the nearly-spent acid solution over tanks of newly-crushed ore, and to treat the nearly-spent ore with fresh solutions of acid. Very little sulphuric acid is consumed beyond the equivalent necessary to take up the copper, and whatever iron may be dissolved during the extraction of the copper. The small loss is due to presence of carbonic acid. Nitric or hydrochloric acids in weak solutions will also dissolve out the copper contents of these ores, but sulphuric acid is preferable on account of its being more

easily manufactured, and a large portion of it may be recovered and sold as sulphate of iron, metallic iron being used as the reagent for precipitating the copper from the solutions as well as the acid used in dissolving some of the iron contents of the ores. If the local circumstances are such that the manufacture of sulphate of iron would not be profitable, the waste liquors may be collected in ponds and evaporated by sun-heat, and the residue, crude sulphate of iron, calcined for the production of sulphurous acid for the manufacture of sulphuric acid. The oxide of iron residue, from the calcining of the crude sulphate of iron, can be sold as red paint. The copper dissolved was four times that of iron. The acid liquors filtered through the ore with ease, even in the case of those grains which would pass through a screen having 900 holes to the square inch, and not through a screen having 1,600 holes to the square inch. In all cases the grains of ore were free from fine dust or slimes. The larger grains of ore naturally required longer time to yield their copper contents than the smaller grains, but the extraction was as perfect from grains of about $\frac{5}{8}$ -inch cube as from the very fine grains. When the grains were larger than $\frac{1}{2}$ -inch to $\frac{5}{8}$ -inch cube, the time taken for the total extraction of the copper was much too long for the use of the tank filtering process.

The production of copper sulphate from these solutions has received the Author's attention, but the number of times the crude sulphate of copper crystals require redissolving and crystallizing makes the operation too expensive, in a district such as that in which these experiments were conducted.

A large number of experiments was made with solutions of higher and lower strength than 5 per cent., and it was found, that when higher more iron was dissolved out; when lower there was the difficulty of having a much larger volume of liquor to deal with. A 5-per-cent. solution gave the best results, therefore the experiments were conducted with it.

In conclusion, the experiments indicate that these ores can be treated with ease and profit by the use of weak solutions of sulphuric acid for the extraction of their copper contents, provided that sulphur can be obtained at a reasonable cost for the production of the sulphuric acid required, and that the ore can be mined at small cost.

The Paper is accompanied by Tables giving the results of the experiments in detail.

[APPENDIX.

APPENDIX.

EXPERIMENTS TO ASCERTAIN THE PERCENTAGE OF COPPER AND IRON DISSOLVED FROM DIFFERENTLY SIZED GRAINS OF AN EXTREMELY HARD CHILI ORE, IN A GIVEN TIME, BY A 5-PER-CENT. SOLUTION OF SULPHURIC ACID AND WATER.

Solvent added 10 A.M., March 9th, 1897.

No.	Screen passed through.	Screen not passed through.	Time at which Sample Taken.	Hours Exposed to Solvent.	Copper Per cent.	Iron Per cent.
1	9	16	10 Mar., 10 A.M.	24	3.20	0.17
			11 " 10 "	48	3.30	0.42
			12 " 10 "	72	4.40	..
			Residues		0.20	..
2	16	36	10 Mar., 10 A.M.	24	3.17	0.165
			11 " 10 "	48	3.50	0.420
			12 " 10 "	72	3.55	0.650
			Residues		0.04	..
3	36	64	10 Mar., 10 A.M.	24	3.20	0.185
			11 " 10 "	48	3.50	0.400
			12 " 10 "	72	3.75	0.600
			Residues		0.04	..
4	64	100	10 Mar., 10 A.M.	24	3.57	0.200
			11 " 10 "	48	3.95	0.380
			12 " 10 "	72	4.05	0.750
			Residues		0.03	..
5	100	225	10 Mar., 10 A.M.	24	3.70	0.20
			11 " 10 "	48	4.05	0.37
			12 " 10 "	72	4.05	0.70
			Residues		0.03	..
6	225	400	10 Mar., 10 A.M.	24	4.20	0.20
			11 " 10 "	48	4.70	0.45
			12 " 10 "	72	5.50	0.91
			Residues		0.19	..
7	400	900	10 Mar., 10 A.M.	24	4.63	0.23
			11 " 10 "	48	4.95	0.48
			12 " 10 "	72	5.45	0.91
			Residues		0.02	..
8	900	1,600	10 Mar., 10 A.M.	24	4.90	0.21
			11 " 10 "	48	5.70	0.44
			12 " 10 "	72	7.00	0.85
			Residues		0.02	..
9	1,600	2,500	10 Mar., 10 A.M.	24	5.60	0.23
			11 " 10 "	48	6.40	0.55
			12 " 10 "	72	7.70	0.70
			Residues		0.02	..
10	2,500	3,600	10 Mar., 10 A.M.	24	6.30	0.25
			11 " 10 "	48	7.00	0.35
			12 " 10 "	72	8.10	0.45
			Residues		0.03	..