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MAGNETIC SEPARATION IN ZAMBIA

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Abstract Magnetic separation facilities and research activities in Zambia are described.

INTRODUCTION

Zambia's economy depends for more than 95% on the export of raw materials. The main ones are copper (86%), cobalt (6%) and lead and zinc (4%). Copper and cobalt are mined in the main mining area, the Copperbelt, lead and zinc in Kabwe's Broken Hill Mine (see figure 1). The ore bodies of these mines will become less rich or completely exhausted during the next decennia. New techniques to concentrate ore minerals from poor and complex ores and low grade tailings have to be developed. One of these new techniques can be high gradient magnetic separation (HGMS).

At the Physics Department of the University of Zambia (UNZA), research on application of HGMS in Zambia has started recently. The magnetic separation research is part of a cooperation project with the Department of Applied Physics of the Twente University of Technology in the Netherlands. This project is initiated by Professor A.F. Fort (UNZA) and financed by the Netherlands University Foundation for International Cooperation. The Magnetic Separation Laboratory has been built up by the author and recently J.L. Top has joined the project. The present research consists of feasibility studies in various areas of the copper and cobalt production and in the near future of the lead and zinc production. Fields of interest are discussed with the Mining Industrial Technical Services of the Zambia Consolidated Copper Mines, who also provide the necessary samples.

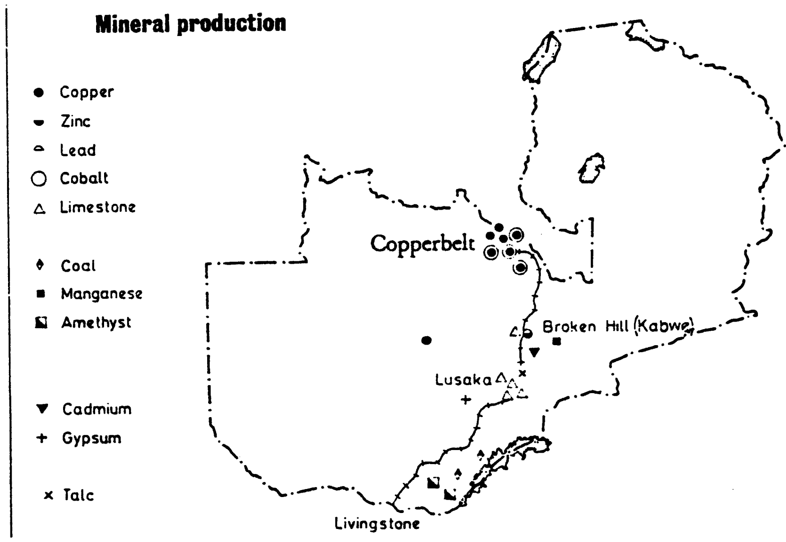

FIGURE 1 Mineral deposits in Zambia

MAGNETIC SEPARATION FACILITIES

The main interest of the magnetic separation project is high gradient magnetic separation of Zambian minerals in order to find alternative concentration methods. Conventional low intensity magnetic separators may be necessary for the removal of strongly magnetic iron oxides and hydroxides. For small samples a Frantz L-5 dry magnetic separator is used. At UNZA's School of Mines a rotating disc and a wet rotating drum magnetic separator are available. Dry and wet magnetic separability are tested with a Frantz isodynamic magnetic separator with a LH-3 particle elutriator. High gradient magnetic separation of small samples (15 grams) is performed on a Frantz CN-1 HGMS system (maximum background field 1.5T, filter dimensions 6 × 25 × 222mm), shown in figure 2.

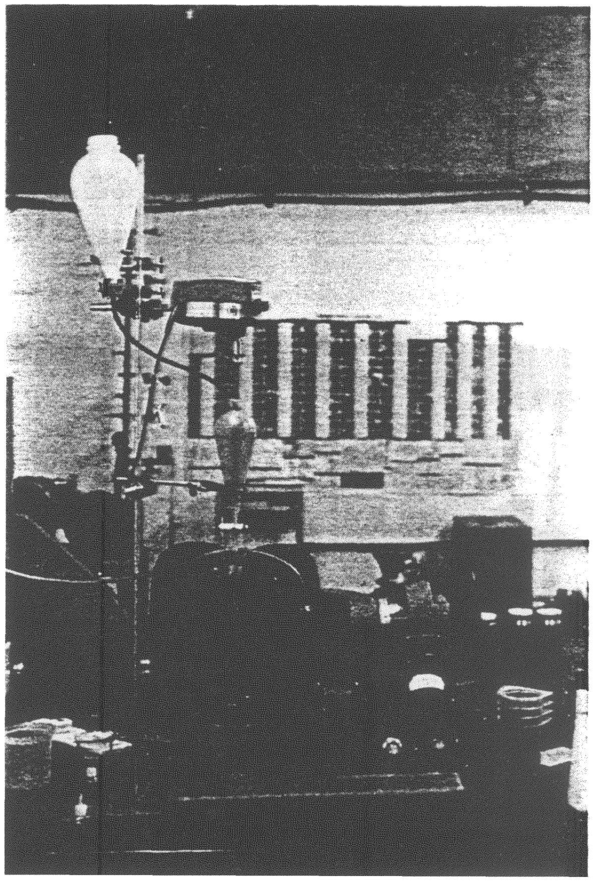

FIGURE 2 Frantz CN-1

In-house, a transverse HGMS system (maximum background field 2.0 T, filter dimensions 23 × 38 × 62mm) has been built, which is used for larger samples (see figure 3). The feed system of this set-up consists of a bulk tank from which the slurry is pumped into a constant level tank. Both tanks have bevels and are stirred. A three-way valve is placed in the output line so that the slurry can flow either back to the bulk tank or into the HGMS cannister. In this way, the slurry is in continuous motion to ensure a homogenous distribution of the solids. Flushing is provided by the general tap system. Soon the separator will be replaced by a Boxmag Laboratory Separator with a much larger filter volume and the valves by magnetic valves, controlled by a timing circuit. The change of the slurry density in the in-and output of the HGMS filter will be measured by a turbidity meter.

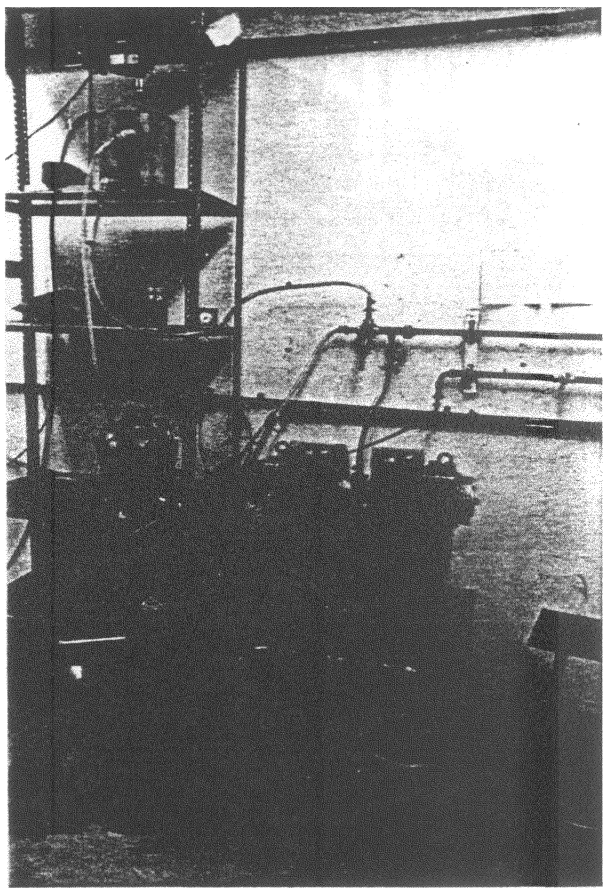

FIGURE 3 HGMS with feed system.

In the laboratory there are mineral dressing facilities such as grinding, wet and dry sieving, filtration and drying. Magnetic susceptibilities are measured by either a Gouy balance or an electronic mutual inductance bridge. The main technique used for qualitative and quantitative mineral analysis is reflected light ore microscopy, which gives reasonably reliable results. X-ray analysis, atomic absorption and chemical analysis can be done elsewhere at UNZA. Electron microprobe analysis has to be done abroad.

RESEARCH ACTIVITIES

Separation of Copper and Cobalt Minerals

In the Copperbelt, the main copper mineral is chalcopyrite and the second most important mineral is bornite. Both copper-iron-sulphides are weakly magnetic (see table 1). Further small amounts of diamagnetic chalcocite (Cu_2S) and other minor copper-sulphides are found. The distribution of these minerals varies from mine to mine. In some copper mines cobalt is found as well. The major cobalt source is carrollite and some cobalt can occur in pyrite. Both minerals are more weakly magnetic than the copper-iron-sulphides (see table 1).

MINERAL	CHEMICAL COMPOSITION	MASS SUSCEPTIBILITY $X \times 10^6 m^3/kg$
Chalcopyrite	$CuFeS_2$	0.04 - 0.1
Bornite	Cu_5FeS_4	0.1 - 0.2
Carrollite	Co_2CuS_4	0.01 - 0.04
Pyrite	FeS_2	0.01 - 0.02

TABLE 1 Main Copper and Cobalt Minerals.

In the case of cobalt-bearing copper ores, copper and cobalt concentrates are produced by flotation in different stages. Unfortunately too much cobalt comes into the copper concentrate and gets lost. The feasibility of producing a better copper and cobalt concentrate from a copper-cobalt concentrate (from which most of the gangue has already been removed) by high gradient magnetic separation is being studied presently.

The composition of a typical copper-cobalt concentrate is given in Table 2a. Magnetic separation is applied to a 53-75 μm fraction, since more than 90% of the minerals are free in this fraction. Firstly, the strongly magnetic iron minerals like magnetite (Fe_3O_4) and goethite (FeOOH) are removed by the Frantz L-5 separator. This separator gives better results than the Frantz CN-1 HGMS system at low field control because less weakly magnetic particles are entrained by the strongly magnetic particles. The less strongly magnetic particles like hematite (Fe_2O_3) are separated with the Frantz CN-1 with a background magnetic field strength of 0.25T. Two weakly magnetic products are obtained at a magnetic field of 1.0T and 1.2T. The magnetic separation is applied to 15 gram feed mixed with 250 ml water and 0.5 ml Calgonite per cycle. The matrix consists of 50-100 μm steelwork filaments (5 volume %). The slurry flow velocity is about 2 cm/s, while the flushing velocity is four times higher. The relative distribution of the minerals over the separated fractions m1, m2 and nm is given in Table 2b. m1 is the sum of the mags up to a magnetic field of 1.0T, m2 is the magnetic fraction obtained at 1.2T and nm is the final nonmagnetic fraction.

In order to improve the separation of chalcopyrite, a higher magnetic field is necessary, but this leads to a higher amount of carrollite in the copper concentrate. The results also show that at higher magnetic fields, bornite can be well separated and indicate that bornite, chalcopyrite and carrollite can be separated from the gangue. It is observed that there is a high dispersion in magnetic susceptibility values of chalcopyrite and carrollite due to composition differences and intergrowth. Probably the selectivity between weak and weaker magnetic particles will improve by increasing the flow velocity, but then a higher magnetic field is necessary.

TABLE 2a.

MINERAL	FEED DISTRIBUTION IN %
Chalcopyrite	50
Bornite	13
Carrollite	3
Pyrite	3
Gangue	30
Iron (hydr) oxides	0.5
Others	0.5

TABLE 2a. Mineral distribution in Copper-Cobalt Concentrate

TABLE 2b.

MINERAL	TOTAL IS 100% PER MINERAL		
	m1(B=1.0T)	m2(B=1.2T)	nm
Chalcopyrite	22	14	64
Bornite	32	41	27
Carrollite	13	29	58
Pyrite	6	5	89
Gangue	6	3	91
Iron (hydr) oxides	96	4	0
Others			

TABLE 2b. Distribution per mineral over separated fractions.

From these results, it can be seen that a separation between the copper-iron-sulphides and the carrollite, pyrite and gangue is not achieved completely.

SEPARATION OF COPPER AND COBALT MINERALS AND GANGUE

Most copper and cobalt orebodies are getting poorer and more complex, which leads to smaller free particle sizes of the different minerals. Separation of these mineral particles by flotation will become more difficult. Further, there are large stockpiles of various types of low grade copper-cobalt tailings, which have been accumulated during the last 30 years. Separation of the copper and cobalt minerals involves handling of large amounts of material. In both cases concentration means separation of weakly magnetic copper and cobalt minerals from nonmagnetic gangue. Possibly high gradient magnetic separation will be more effective and economical than flotation. Preliminary magnetic separation results obtained by the Frantz CN-1 (maximum background magnetic fieldstrength 1.5T) look promising.

SEPARATION OF CUPRIFEROUS MICAS

In the Copperbelt there are large stockpiles of sandstones and shales that contain a high amount of cupriferous micas which are weakly magnetic (mass susceptibility $0.15 \times 10^{6} m^3/kg$). These micas like vermiculite, contain up to 6% copper. Presently, the feasibility of high gradient magnetic separation of these micas is studied. HGMS on a 53-75 μm fraction of a sandstone sample on the Frantz CN-1 (maximum background magnetic field-strength 1.5T) gives a magnetic product that contains 5.5% copper from a feed that contains 3.0% copper. This means that the magnetic fraction has a very high mica grade.

BENEFICATION OF LEAD AND ZINC MINERALS

In Kabwe's Lead and Zinc mines there are some interesting possible applications of high gradient magnetic separation, which will be looked into in the near future. These are the separation of iron-stained lead and zinc minerals from the clean ones and the concentration of lead and zinc minerals from slimes.