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SULPHIDE MINERAL ZONING IN THE BALUBA ORE BODY, ZAMBIA

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ABSTRACT

This paper describes the sulphide mineral zoning through the stratigraphic column in the Baluba copper-cobalt mine in the Zambian Copperbelt. This zoning is explained by changing Eh and pH conditions with time, due to fresh river and rain waters, entering a saline basin.

INTRODUCTION

The Baluba copper-cobalt ore body in the northern part of the Roan Basin in the Zambian Copperbelt (geological map Drysdall et al., this issue) is at an early stage of mining development. In 1970, a detailed sampling programme was carried out on the 120 and 240 m levels in the mine, where three crosscuts intersect the ore body. In each sample, the amounts of the various sulphide minerals were determined. In this paper, the zonal pattern of the sulphide minerals through the ore body is described, and a possible geochemical explanation is proposed by means of Eh-pH diagrams.

GENERAL

A stratigraphic column of the Baluba area is given in Table I, (after J.B. Lee-Potter, in Mendelsohn, 1961). The sediments of the Lower and Upper Roan Groups are folded and regionally metamorphosed to green schist facies. The dip is approximately 50° to the south, forming the northern limb of the E-W trending Baluba syncline. The oldest Lower Roan sediments, designated RL 7, were deposited in shallow water and in part as an aeolian continental facies. They were transgressed by shallow marine conditions, depositing the RL 6 sediments. The upper member of the RL 7 is a conglomerate, followed by calcareous and argillaceous RL 6 sediments. The ore body is stratiform, and mineralisation is confined to the lower 15 m of the RL 6 Formation. The ore horizon consists of two members,

TABLE 1
Stratigraphic section of the Baluba area.

System	Series	Group	Formation	Thickness
Katanga		Mwashia		Absent
		Upper Roan	RU 1	–
			RU 2	70 feet
			RL 3	370 feet
	Mine		RL 4	70 feet
		Lower Roan	RL 5	300 feet
			RL 6 Ore Formation	180 feet
			RL 7	500 feet+
Unconformity				
Muva				
Unconformity				
Granite (intrusive to the Lufubu System)				
Lufubu				

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at the base a calcareous schist overlain by partly calcareous argillite. In the calcschist, quartz, biotite and calcite are the predominant minerals, and K-feldspar, muscovite and tremolite occur in minor amounts. In the argillite, quartz, biotite and tremolite are the major constituents, whilst K-feldspar, calcite, muscovite, scapolite, epidote/clinozoisite and tourmaline are minor.

Most of the copper mineralisation occurs in the calcschist. The major sulphide minerals are chalcopyrite, bornite, chalcocite, pyrite and carrollite.

PROCEDURE

Chip samples were collected over each 30 cm distance in three crosscuts: 75 samples on Structure Section 44 (at the 120 m level), 65 samples on Structure Section 46 (at the 120 m level), and 90 samples in the shaft crosscut at the 240 m level. All samples were crushed to −2 mm (-10 mesh), and individually analysed for Cu, Co, S and acid-soluble Cu. In each crushed sample, the amounts of the different sulphide minerals were determined by microscopic point-count analysis, performed on polished briquettes. For each crosscut, these percentages were plotted against the sampling points through the crosscut. The graphic representation of the sulphide mineral distribution along the three crosscuts, based upon 2000 data, is given in fig. 1.

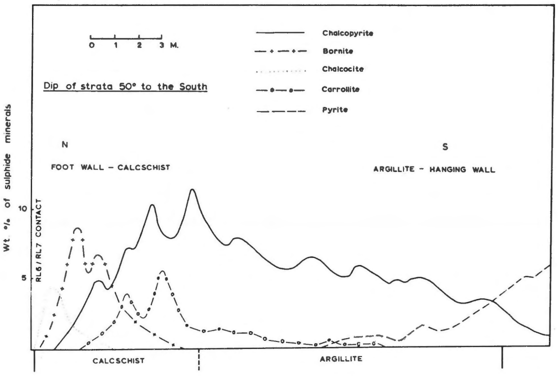

Fig. 1
Average section of sulphide mineral zoning in Baluba crosscuts.

SULPHIDE MINERAL ZONING

From the RL 7/RL 6 contact (footwall) to the hanging wall through the crosscuts, the following zones of mineralisation can be distinguished.

(a) A thin (> 2 m) zone of chalcocite, immediately above the RL 7/RL 6 contact.
(b) A thin (> 5 m) bornite zone.
(c) A thick (15-20 m) zone with mainly chalcopyrite.
(d) A zone with pyrite predominating, where the total copper value decreases to less than 1%.

In the lower 7 m of the ore body (calcschist), carrollite is a major sulphide mineral, whereas in the argillite it occurs in very small amounts. The zonal pattern, as shown in fig. 1, is the same in all three crosscuts, although the absolute amounts of the sulphides and the widths of the sulphide zones vary slightly from crosscut to crosscut, affecting mostly the width of the bornite zone.

ORIGIN OF THE ORES

Discussions on the origin of the ores from the Zambian Copperbelt have been manifold in the past. In the following discussion a geochemical model is presented, explaining the sulphide mineral zoning at Baluba with the use of Eh-pH diagrams. In this type of diagram, the Eh represents the redox potential, indicating whether and to what extent the conditions in the system under consideration are oxidizing or reducing. In the diagram, these conditions are related to the alkalinity, expressed as pH.

Eh-pH diagrams are calculated by means of the tabulated standard thermodynamical data at 298°K (Gibbs free energies). Calculation methods for Eh-pH diagrams are given by Garrels and Christ (1965) and Pourbaix (1949). The Eh-pH diagram for the system under consideration is given in fig. 2, (after Garrels and Christ, 1965), at 25°C and 1 atm. pressure, with sulphur concentration 10^{-4} molal. The systems under consideration consist of the various sulphides and water. The elements determining the systems are Cu-Fe-S-O-H. Fig. 2 shows under which conditions of Eh and pH the different oxides and sulphides of Cu and/or Fe are stable in water.

The important role of Eh and pH as controlling factors in syngenetic ore deposition has been mentioned by a number of authors, in publications concerning the genesis of the Copperbelt ores (Garlick, 1965; Mendelsohn, 1961). But to date, as far as the present author is aware, sulphide mineral zoning has not yet been explained with the aid of the available Eh-pH diagrams. It is presumed that the marine sediments from the mineralised members of the RL 6 Formation were deposited in shallow and isolated saline basins, rich in organic material and sulphur-producing bacteria (Mendelsohn, 1961). In such a basin the pH can range up to 10, whereas Eh is very negative down to –0.5 mVolt, (Garrels and Christ, 1965, p. 381). During the deposition of the RL 6 sediments a continuous supply of river and rain waters caused a change in Eh and pH conditions in the basins, since the average pH of river waters is approximately 6 and the average Eh is strongly positive. Therefore, the pH in the basin will decrease and the Eh will increase with time.

In fig. 2 the line A-B has been constructed, marking the sulphide mineral zoning at Baluba with time. The environmental conditions at starting point A are more extreme than the average Eh and pH for saline waters, mentioned above. Fig. 2 is constructed for a sulphurmolality 10^{-4}. At a lower sulphurmolality, for instance 10^{-6}, all stability fields shift about 2 pH units to the left, bringing point A in the area with pH about 10 and Eh –0.5 mVolt, which is the desired condition of the model.

The first supply of copper bearing solutions during deposition of the calcschist sediments resulted in the precipitation of chalcocite at point A in fig. 2. A very small decrease in pH and increase of Eh from point A to point A1 in fig. 2, caused the precipitation of bornite. Further decrease of pH and increase of Eh is marked by the trajectory A1-A2-B, passing respectively the stability fields of chalcopyrite and chalcopyrite/pyrite.

As a result, the theory might explain why the chalcocite and bornite zones are thin, (the required small decrease in pH and increase in Eh could have taken place in a relatively short deposition period), and the chalcopyrite and pyrite zones are wider, (a larger decrease in pH and increase in Eh should have required a longer deposition period).

At the points A, A1 and A2, magnetite would be expected to precipitate with respectively chalcocite, bornite and chalcopyrite, whereas in the stability field of point B, not magnetite but pyrite is the expected stable phase. In fact, this is what is observed: in the calcschist magnetite is a common accessory, whereas pyrite is virtually limited to the hanging wall argillite and upper members of the RL 6 Formation.

The overlap of the various sulphide mineral zones is probably caused by small fluctuations in Eh and pH, c.q. fluctuations in sulphurmolality.

It is not yet possible to include in this theory the geological history of the carrollite. Carrollite is the major source of cobalt in the Copperbelt, but its standard thermodynamical data are not yet known. Its distribution through the Baluba ore body can not yet be discussed in the terms of the proposed model, due to a lack of the Eh-pH diagram of the system Cu-Co-Fe-S-O-H.

The Eh-pH model indicates that the sulphide mineral zoning at Baluba is a primary sedimentary feature, and therefore, the original sulphide mineral zoning is still present at Baluba. It is concluded therefore, that during metamorphism of the sediments no substantial transport of the ore constituents has taken place, but only recrystallisation and segregation of the sulphides, together with very small scale exsolution of mainly chalcopyrite and bornite. Exsolution has been observed but it is rare. Some local redistribution of the sulphides at Baluba is also indicated by mineralised dolomite veins. The veins in the calcschist contain chalcopyrite, bornite and/or carrollite, the veins in the argillite contain chalcopyrite and/or pyrite. The Eh-pH theory also explains why covellite and digenite can not be present as primary sulphide phases. Covellite is a minor sulphide and digenite an accessory at Baluba, but both minerals occur always as secondary replacements of the primary sulphides.

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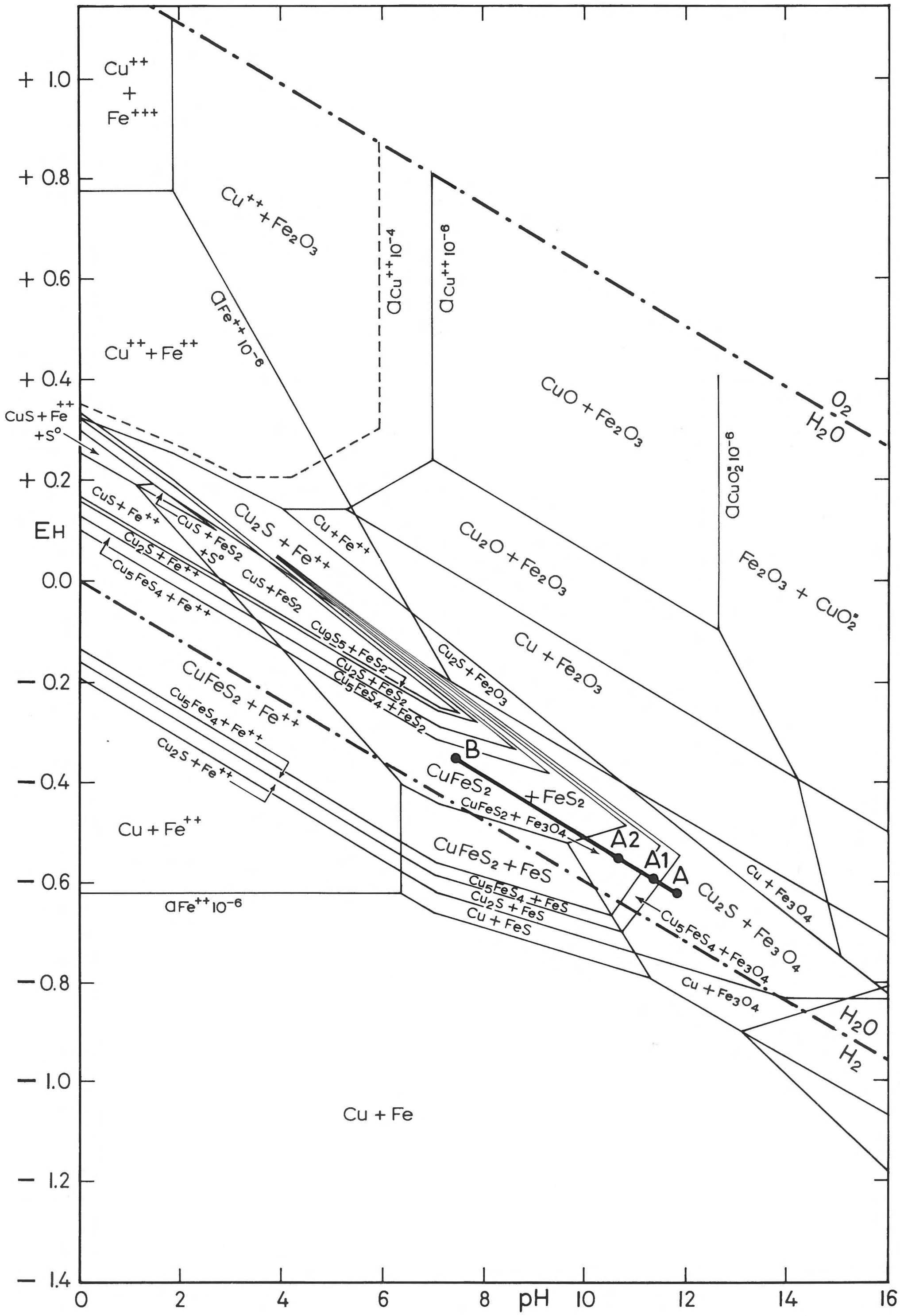

Fig. 2
The system Cu-Fe-S-O-H (in part) at 25°C and 1 atmosphere total pressure. Total dissolved sulfur = 10^{-4} m.
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this paper, and to the Geology Department, Luanshya Division for collecting the samples.

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