GEOLOGIE EN MIJNBOUW VOLUME 51 (3), p. 337–345 1972

ORE MINERALS OF THE ZAMBIAN COPPERBELT

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ABSTRACT

In this paper, major and minor copper and cobalt ore minerals, presently known to occur in Copperbelt ores, are described briefly.

INTRODUCTION

A typical feature of the Copperbelt ore deposits is their stratiform character. Nine major mines are presently in operation (table 1), and a few other deposits where exploration is being carried out, are known. All orebodies occur stratigraphically in one group, called the Lower Roan Group, which is the lowest group of the Katanga System of metamorphosed sediments. The Katanga sediments were folded during the Lufilian Orogeny and regionally metamorphosed mainly under greenschist facies conditions. They occur now as synclinal structures within the Basement Complex. (See inset fig. 11, D r y s d a l l et al., this issue). The dip of the orebodies is related to the structural deformation and range from shallow to steep, and locally also overturned.

The major orebodies are associated with shaly and quartzitic facies, but conglomeratic and dolomitic associations also occur. The sulphide mineralisation is essentially the same in all sulphide orebodies: the major sulphide minerals are chalcopyrite, bornite, chalcocite and pyrite. Where the deposits are cobalt bearing, carrollite and cobaltiferous pyrite are the major cobalt minerals.

There is a zonal arrangement of the primary sulphides in most of the deposits, generally from barren through chalcocite, bornite, chalcopyrite and pyrite.

The relative proportions of the major sulphide minerals change from deposit to deposit. They are listed in table 1 for the mines presently in operation.

Near the surface, the primary sulphide orebodies are oxidised and leached. The depth of oxidation and leaching varies greatly, the average being 50-70 m. Locally, partial oxidation of the sulphides is found at depths of 800 m. In general, a zone of supergene enrichment exists between the primary sulphides and the oxide orebodies.

In the following mineral descriptions, the attention paid to each mineral is disproportionate to its relative abundance in the Copperbelt ore deposits. In general, more details are given on relatively rare ore minerals than on the common ore minerals, which have already been described in a number of papers on Copperbelt ore deposits.

SULPHIDE MINERALS

Chalcopyrite, $CuFeS_2$. – In most sulphide orebodies on the Copperbelt, chalcopyrite is the main source of copper and is almost without exception of primary origin. It occurs mainly as disseminated

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TABLE 1

Relative Abundances of the Major Copperbelt and Cobalt Minerals in the Copper-producing Mines on the Zambian Copperbelt.

Mineral	Baluba	Bwana Mkubwa	Chambishi	Chibuluma	Chilila-bombwe	Mufulira	Nchanga/ Chingola	Roan Antelope	Rokana/ Mindola
Chalcopyrite	XXXX	X	XX	XXXX	X	XXX	X	XXXX	XXX
Bornite	XX	XX	XXXXX	XX	XXX	XXXX	X	XX	XX
Chalcocite	X	XXX	XX	X	XXX	XX	XXX	XX	X
Cobaltiferous Pyrite	XX	-	-	XX	-	-	-	-	XXX
Carrollite	XX	-	-	X	X	-	X	-	XX
Malachite	XX	XXXX	XX	-	XX	X	XXXX	XX	X
Cuprite	X	X	X	-	X	X	X	X	-
Native Copper	trace	trace	-	-	X	X	X	trace	trace
Pseudomalachite	trace	X	X	-	X	-	XX	X	X
Chrysocolla	trace	X	trace	-	X	-	XX	X	trace

X = 1%-5% XX = 5% - 20% XXX = 20% - 40% XXXX = 40% - 70% XXXXX = > 70%

grains, the size of which is related to the grain size of the host rock. In some orebodies, where considerable migration and recrystallisation of the sulphides took place, chalcopyrite is found in vein-like masses (Rokana South Orebody, Baluba, Roan Antelope). The chalcopyrite in some orebodies shows complex growth twinning. The twinning lamellae have, on occasions, a typical oleander leaf shape, which appears to be an indication of relatively high temperature. More rarely translation twinning occurs near shear fractures. In the Rokana South Orebody chalcopyrite seldom contains exsolution lamellae of cubanite. In the Mindola, Baluba and Roan Antelope orebodies chalcopyrite is found as exsolution lamellae in bornite. Chalcopyrite frequently replaces carrollite as thin veins, following the parting and cracks in the latter. At Chambishi secondary chalcopyrite is found as transition rims, which occur at the contact between primary bornite and secondary chalcocite (photo 1).

Bornite Cu_5FeS_4. – Bornite is the secondmost important primary sulphide copper mineral on the Copperbelt. It occurs as disseminations in the host-rock, often forming simple contacts with chalcopyrite and chalcocite. Chemical analyses of various types of bornite show that the iron content ranges from 8 to 11%. In polished sections the colour of the bornite varies from bright orange to dark pinkish brown. The orange bornite at Rokana apparently forms a metastable solid solution with chalcopyrite, which sometimes exsolves along polishing scratches during preparation of polished sections. Massive bornite from the 530-level in the Mindola Orebody is distinctly anisotropic and frequently shows polysynthetic twinning lamellae. Some of the bornite from Mindola and Baluba contains very regular exsolution lamellae of chalcopyrite along the (111)-planes.

Idaite, Cu_3FeS_4. – Idaite, originally described by Frenzel (1959) as an intermediate alteration product of bornite, has been found recently in several ore specimens from the Nchanga Mine. No previous mention of its occurrence in Copperbelt ores has been made. The idaite from Nchanga is similar to bornite in colour, but shows a distinct reflection pleochroism from brownish orange to greyish yellow. It is easily distinguished from bornite by its enormous anisotropism. Idaite occurs as small rounded inclusions in bornite, occasionally associated with minute specles of chalcopyrite. The bornite is being replaced by lamellar chalcocite and digenite. Textural relationships indicate that the idaite has been formed prior to the replacement of bornite by supergene sulphides.

Chalcocite, Cu_2S. – The most important chalcocite concentrations are found at Nchanga and Chililabombwe, where virtually all the chalcocite is of supergene origin, replacing the primary sulphides, thereby increasing the copper content (zone of supergene enrichment). Both primary and secondary chalcocite occur in the Roan-Muliashi Basin (Roan Antelope and Baluba) and Mufulira 'A'.

Carrollites, Co_2CuS_4. – In all cobalt-bearing orebodies on the Copperbelt, carrollite is the major source of cobalt. Numerous analyses of carrollites from several orebodies, carefully checked for any microscopically visible chalcopyrite, consistently give copper and cobalt percentages close to the theoretical values of respectively 20% and 38%. Electron microprobe studies on carrollite from Chibuluma (Darnley, 1962) confirm the formula Co_2CuS_4. Hills (1968) also confirms that at Chibuluma the predominant cobalt mineral is carrollite. Electron microprobe analyses on carrollites from the Rokana South Orebody by Richards (1965) show that the copper percentage in carrollite varies from 1.9% to 20.2%, but no data are given on the abundancy of the copper-poor carrollite, which should be classified as Cu-linnaeite. The average nickel content of the Rokana carrollite is 0.3%. Carrollite occurs mainly as disseminated anhedral to subhedral grains, frequently associated with chalcopyrite and/or bornite. Replacement of carrollite by chalcopyrite, digenite (photo 2) and bornite is common and takes place along the parting and fractures in the carrollite (Rokana, Mindola).

Occasionally large euhedral carrollite crystals up to 5 cm across are found at Chibuluma. In an ore specimen from the 790-level in the Rokana South Orebody euhedral to subhedral carrollite crystals contain exsolution lamellae of pyrrhotite along the (111)-planes (photo 3). At the contact of the

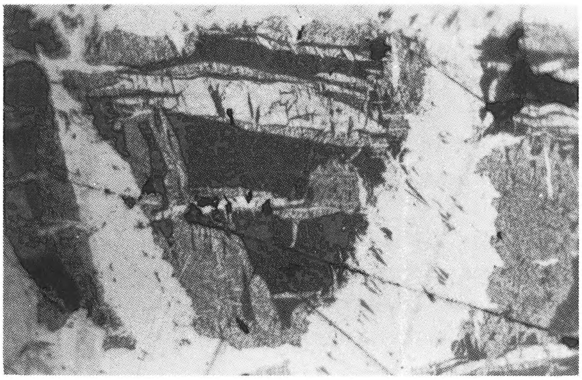

Photo 1
Secondary chalcopyrite (medium grey), partly as veins in primary bornite, and partly as rims around primary bornite at the contact with secondary chalcocite. Zone of supergene enrichment at Chambishi Mine. Magnification 400 x.

Photo 2
Subhedral carrolite veined by digenite and surrounded by bornite (medium grey). Nchanga Mine. Magnification 250 x.

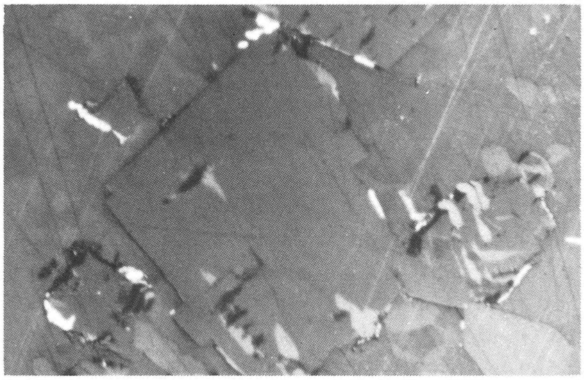

Photo 3
Euhedral carrollite containing exsolution lamellae of pyrrhotite. Concentrations of mackinawite (bright white) occur at the carrollite grain boundaries. The carrollite is surrounded by chalcopyrite. Part of a grain of cobalt pentlandite is visible (bottom right). Rokana South Orebody. Magnification 400 cx. Partially crossed nicols.

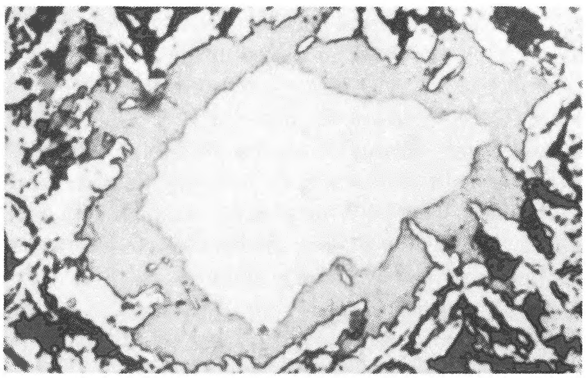

Photo 4
Digenite (medium grey) replacing carrollite and chalcopyrite (centre). Nchanga Mine. Magnification 250 x.

pyrrhotite lamellae and the carrollite with the surrounding chalcopyrite, concentrations of mackinawite occur. These are possibly formed as a reaction product between the chalcopyrite, pyrrhotite and carrollite. Also at Rokana carrollite is infrequently found as exolution lamellae in pyrrhotite, associated with cobalt-pentlandite. The majority of the carrollite is formed earlier than the chalcopyrite. However, in ore specimens from the 1970-level in the Rokana South Orebody a second generation of carrollite has been observed. This carrollite replaces chalcopyrite as irregular veins.

Linnaeite, Co_3S_4. – Etching tests on carrollite from Chibuluma (Hills, 1968) showed that some cobalt sulphide grains were composed of two phases, which have been identified as linnaeite and carrollite. Richards (1965) mentioned the occurrence of linnaeite, containing small quantities of copper, from the Rokana South Orebody.

Pyrite, FeS_2 – *Cattierite*, CoS_2. – Pyrite occurs widespread in most sulphide orebodies. An interesting and economically important feature of some Copperbelt pyrites is their cobalt content. The cobaltiferous pyrites belong to the isomorphous series pyrite-cattierite. It appears that cobalt and iron are interchangeable over the whole range of compositions from FeS_2 to CoS_2. The pure endmember cattierite from Shinkolobwe in Katanga has been described by Kerr (1945). O'Meara (1961) mentioned the occurrence of cattierite from the 890-level in the Rokana South Orebody. At Baluba and Rokana the cobalt percentages of most pyrites vary from 0 to 8%. Intermediate members of the pyrite-cattierite series have been reported from Chibuluma (Riley, 1968). In polished sections some pyrites from the Rokana South Orebody show distinct, irregular colour zones, varying from creamy white to pinkish brown, and showing slight differences in polishing hardness and reflectance. Electron microprobe analysis (Richards, 1965) showed that the brown coloured zones contain more cobalt than the white zones.

Hills (1968) carried out a detailed study on Chibuluma cobaltiferous pyrites and found that both the magnetic susceptibility and reflectance of the pyrite decrease with increasing cobalt content. There appears to be no significant relationship between the cobalt percentage and the microhardness. X-ray diffraction studies on pyrites with different amounts of cobalt (Riley, 1968) revealed a linear relationship between the d(511)-spacing and the cobalt content of the pyrite. A linear relationship probably also exists between the length of the pyrite unit cell edge and its cobalt content.

Pyrite occurs mainly as disseminated, subhedral to euhedral crystals up to 3 cm. in diameter. In the Rokana South Orebody octahedral pyrite crystals, having a distinct brownish tint in a polished section, are often associated with small amounts of native bismuth and bismuthinite. Textural observations clearly indicate that pyrite normally is the first crystallized sulphide, followed by carrollite and chalcopyrite, although overlapping occurs to a variable extent. It appears that the high-cobalt pyrite is usually formed later than the cobalt-poor pyrite. Graphic intergrowths of pyrite and carrollite occur at Chibuluma, and were probably formed as a result of replacement of pyrite by carrollite along the crystallographic directions of the pyrite.

Covellite, CuS. – Covellite is a common, though very minor mineral in most sulphide orebodies. The bulk of the covellite is of supergene origin and replaces chalcopyrite, bornite and chalcocite.

Digenite, $Cu_{1.8}S$. – Digenite is found in minor quantities in ores from the Roan-Muliashi Basin, the Chambishi-Nkana Basin, Nchanga and Chililabombwe. Most of it appears to be of secondary origin and is associated with chalcocite, carrollite and bornite. Digenite, replacing carrollite from the centre, is relatively common at Nchanga and Chililabombwe (photo 4).

Pyrrhotite, $Fe_{1-x}S$. – Pyrrhotite is an accessory sulphide in the vein ores of the Rokana South Orebody. It occurs as disseminated grains and aggregates of grains, associated with chalcopyrite, cobalt-pentlandite, pyrite, carrollite and mackinawite. Occasionally pyrrhotite is found as stringers, following the chalcopyrite grain boundaries. Very rarely it is enclosed as orientated lamellae in carrollite. Small quantities of pyrrhotite are found in the Basement rocks at Roan Antelope.

The pyrrhotite from Rokana frequently contains exsolution lamellae of pentlandite parallel to the basal plane marked by the pyrrhotite parting. Etching shows that the pyrrhotite is composed of a light coloured hexagonal form, which contains dark coloured monoclinic lamellae. The proportions of the two pyrrhotite modifications vary from grain to grain, but it appears that on the average the hexagonal form is slightly more abundant than the monoclinic form.

Pentlandite, $(Fe, Ni)_9S_8$, Cobaltpentlandite, $(Co, Ni, Fe)_9S_8$. – Small quantities of cobaltpentlandite are found in the sulphide veins of the Rokana South Orebody. It occurs as small irregular masses enclosed in chalcopyrite and as minute exsolution lamellae in pyrrhotite. A quantitative electron microprobe analysis on two cobaltpentlandite samples from the Rokana South Orebody by Richards (1965) showed that they contained 63% Co. The cobaltpentlandite is replaced by mackinawite and chalcopyrite. Replacement of pentlandite by mackinawite takes place along the grain boundaries and occasionally along the cleavage directions.

Mackinawite, FeS, *with variable amounts of* Co, Ni. – Recently the occurrence of mackinawite in the Rokana South Orebody was confirmed by X-ray diffraction (Notebaart, 1970). Mackinawite is found mainly as small worm-like inclusions in chalcopyrite. Some ore specimens contain rectilinear veinlets of mackinawite, which frequently cross the chalcopyrite grain boundaries. This indicates that the mackinawite replaces the chalcopyrite and is not an exsolution product.

Millerite, NiS. – Millerite is found very rarely as exsolution lamellae in carrollite. Small exsolution blebs of millerite are occasionally found in pyrrhotite from the Rokana South Orebody.

Bismuth and Bismuthinite, Bi_2S_3. – Trace amounts of native bismuth, invariably associated with bismuthinite have been found in ore specimens from the Rokana South Orebody. The bismuth minerals are often associated with octahedral pyrite (probably with high Co-content) in which they occur as small, irregular inclusions with or without chalcopyrite.

Bismuth is a harmful impurity in refined copper. It makes the metal brittle and thus unsuitable for wire-drawing.

Tellurobismuthite, Bi_2Te_3. – Recent studies of massive bornite specimens from the 530-level at Mindola revealed the presence of small inclusions and veinlets, composed of a high reflectant, strongly anisotropic mineral, which was identified as tellurobismuthite by X-ray diffraction. This mineral has not been reported previously from the Copperbelt. It occurs principally as small rounded masses, surrounded by a greenish, strongly anisotropic mineral which has not yet been identified (tetradymite?). The Latter mineral associated with tellurobismuthite also forms thin, irregular veins in the bornite (photo 5) frequently crossing the chalcopyrite exsolution lamellae. The tellurobismuthite from Mindola undoubtedly replaces the bornite.

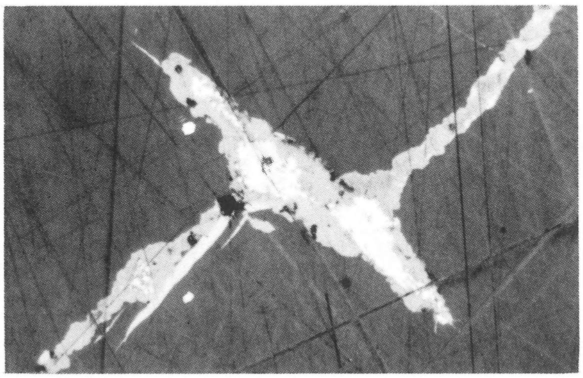

Photo 5
Bornite (dark grey) containing a vein composed of tellurobismuthite (bright white) and a greenish strongly anisotropic mineral (tetradymite?). Chalcopyrite (white) occurs as exsolution lamellae. Mindola Mine. Magnification 250 x.

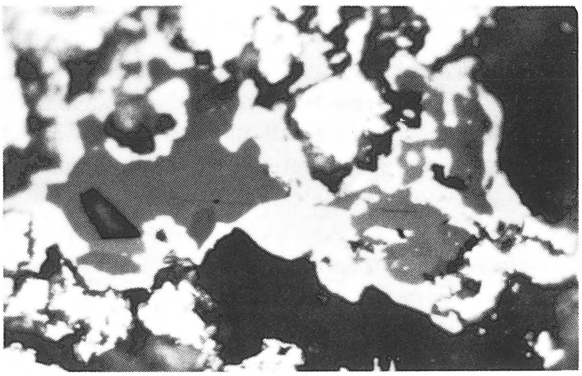

Photo 6
Rickardite (medium grey), surrounded by weissite (light grey) and melonite (white). Mindola Mine. Magnification 300 x.

Melonite, $NiTe_2$. – In the uranium ore deposit at Mindola, melonite is found as small disseminations and as irregular veins transversing subhedral uraninite crystals.

Rickardite, Cu_7Te_5, *Weissite*, $Cu_{2-x}Te$ *and Vulcanite*, CuTe. – Rickardite, with its characteristic purplish red and violet colours, occurs at Mindola, as irregular masses, surrounded by weissite and melonite (photo 6). The coppertellurides replace melonite and have been formed probably by reaction between melonite and later chalcopyrite and digenite. Small inclusions in rickardite and weissite, with enormous bireflectance from white to greyish blue, are probably vulcanite.

Wittichenite, Cu_3BiS_3. – This mineral was identified by H i l l s (1968) in ore samples from Chibuluma, where it occurs as radially segmented inclusions in bornite. A n n e l s (1969) mentions wittichenite from the Nkana North Limb Prospect, where it is found as lath-shaped inclusions in bornite.

Cubanite, $CuFe_2S_3$. – Cubanite is found as exsolution laths in chalcopyrite from the Rokana South Orebody, and is associated with mackinawite and cobaltpentlandite.

Cobaltite, CoAsS. – Cobaltite, being replaced by chalcopyrite has been found by R i c h a r d s (1965) in the carbonaceous shales in the Rokana South Orebody, and was identified by electron microprobe analysis.

Molybdenite, MoS_2. – In the Rokana South Orebody molybdenite is found as irregular masses, replacing chalcopyrite. Small amounts of lath-shaped molybdenite were also reported from Chibuluma and the Nkana North Limb Prospect.

Galena, PbS *and Sphalerite*, ZnS. – Both minerals are extremely rare.

Uranium Minerals. – A small uranium deposit was located at Mindola in the 4-shaft barren gap. The predominant radio-active mineral is uraninite, UO_2, which is associated with minor amounts of brannerite, (U, Th, Ca,) [$(Ti, Fe)_2O_6$] and coffinite, $U(SiO_4)_{1-x}(OH)_x$. The uranium minerals occur as small disseminations and as larger masses throughout the host rock. Under the action of ground-water these minerals have been altered to uranophane, $Ca(HO_3)_2 (UO_2/SiO_4)_2 \cdot 5H_2O$ and gummite, which is an oxidation and hydration product of uraninite. Meta-torbernite, $Cu(UO_2/PO_4)_2 \cdot 8H_2O$ is found as small, well developed tabular crystals in vugs and lining rock fractures at Nchanga, Chililabombwe and Bwana Mkubwa. B o w i e (1960) reports the presence of meta-autunite, $Ca [(UO_2/PO_4)]_2\ 6H_2O$ and phosphuranylite, $Ca [(UO_2)_4/(PO_4)_2] (OH)_4 \cdot 9H_2O$ at Chibuluma. Small amounts of the hydrated and hydroxylated uranyl sulphates zippeite and johannite are reported from Roan Antelope, where they occur as efflorescences on the walls of mine workings.

OXIDE COPPER MINERALS

General

Near the surface the sulphide orebodies are oxidised and leached by meteoric water. In this zone, the sulphide minerals are in general completely altered. From descending copper containing solutions, new copper minerals are deposited in lower levels. Below the groundwater level secondary sulphides, mainly chalcocite, are formed, with minor cuprite and native copper, resulting in an increase of the copper content in this zone, and thus forming the zone of supergene enrichment. Lowering of the groundwater level resulted in renewed oxidation of primary and supergene sulphides, thus forming a zone of mixed primary and secondary sulphides with cuprite and native copper.

The depth of leaching is a function of the resistance of the host rock to weathering processes. The more resistant rocks have sulphides even in the outcrop. In general, however, the orebodies are completely leached at or near the surface with only trace amounts of copper. In the case of the Chibuluma ore deposit, this totally leached zone is represented by a gossan extending to a depth of over 40 m.

The copper "oxide" minerals include Cu-carbonates, Cu-oxides, Cu-phosphates, Cu-silicates, Cu-sulphates and native copper.

Copper Carbonates

1. *Malachite*, $Cu_2(OH)_2CO_3$. – Malachite is the major source of copper in the oxide orebodies on the Copperbelt. The main occurrences are Nchanga, Chililabombwe and Chambishi.

The well-known ornamental malachite is common in Katanga, but virtually absent on the Zambian Copperbelt, although specimens of high quality malachite, ranging up to 15 cm across, have been found at Mindola, Chambishi and Bwana Mkubwa.

At Mindola malachite occurs rarely as well developed twinned crystals in vugs. In the Nchanga open pit malachite is sporadically found as pseudomorphs after azurite.

Alteration of sulphides to malachite is a relatively fast process. This was suggested by the observation of the weathering of fresh Baluba sulphide ore, containing 0.035% acid-soluble copper, present as malachite. After 18 months exposure to atmospheric conditions, the same ore contains 0.18% acid-soluble copper, again in the form of malachite, occurring as distinct grains, up to 100 microns across.

2. *Azurite*, $Cu_3(OH)_2(CO_3)_2$. – The main occurrence of azurite is in the Chingola Open Pit, where it is found as rounded compact masses of radiating crystals, frequently containing a core of malachite. It is possible that the rounded masses of azurite retain moisture over a long period, permitting the core to alter to malachite. Azurite is occasionally observed as idiomorphic, short prismatic crystals.

Native Copper, Cu

Native copper is locally abundant in the partially oxidised zones of supergene enrichment. It is associated with chalcocite, cuprite and malachite. At Nchanga and Mufulira masses of native copper, weighing over 100 kg, have been recovered. Native copper, occurring as large solid masses, is most unwelcome in milling practice, because it will not crush, due to its ductility.

Copper Oxides

1. *Cuprite*, Cu_2O. – Cuprite is common in all oxide orebodies and can be abundant locally. An example is Muliashi South, the western extension of Roan Antelope, where cuprite accounts for approximately 75% of the total copper in the oxide zone. It is mainly found in the lower part of the oxidation zones and occurs as earthy masses, intergrown with malachite, and Fe-oxides. At Nchanga occasionally octahedral crystals and felty growths of minute crystals (chalcotrichite) are found.

2. *Tenorite*, CuO. – This is a very minor copper mineral in most of the oxide orebodies. Normally it occurs as fine grained earthy material, intimately intergrown with cuprite, Fe-oxides and/or wad. Very rarely coarse grained, polysynthetically twinned tenorite forms a crystalline crust around malachite grains (Nchanga).

Copper Phosphates

1. *Pseudomalachite*, $Cu_5(PO_4)_2(OH)_4$. – In oxide orebodies, the mineralisation can change abruptly over short distances. A typical example is the occurrence of pseudomalachite. This mineral, although widespread in most oxide orebodies, is often concentrated in some beds, and can be virtually absent in directly overlying or underlying beds, (Roan-Muliashi Basin, Chingola Open Pit). As the name indicates, pseudomalachite is, in appearance, very similar to malachite, but it displays a distinct bluish green tint, compared with malachite. In the Chambishi Open Pit it is found in the same banded and botryoidal structures as malachite.

Breccias composed of malachite fragments cemented by later pseudomalachite are commonly found at Chambishi. In the Chingola and Mindola Open Pits, pseudomalachite occurs as small globules, lining cavities in the host rock. Pseudomorphs of pseudomalachite after libethenite are occasionally observed at Chingola.

2. *Libethenite*, Cu_2PO_4OH. – Libethenite occurs in small amounts in most oxide orebodies, associated with pseudomalachite and malachite, mainly as well-developed rhombic crystals, up to 1 cm. In the Mindola Open Pit fibrous varieties are frequently found.

3. *Cornetite*, $Cu_3PO_4(OH)_3$. – This rare copper phosphate was first reported from Bwana Mkubwa. Later small quantities have been found at Nchanga. Cornetite is a common mineral at Kalengwa, a copper deposit, 320 km west of the Copperbelt, where it occurs as dark blue, minute crystals, lining rock fractures.

Copper Silicates

1. *Chrysocolla*, $CuSiO_3 .nH_2O$. – Chrysocolla is locally abundant and particularly well known from Nchanga. It occurs as solid masses, up to 40 cm across, varying in colour from pale green to sky blue, depending on the hydration state. It is sometimes found as veins, containing a central part of chalcedony (Nchanga), clearly indicating its deposition from a silica gel.

2-5 *Bisbeeite*, $CuSiO_3 .H_2O$
Dioptase, $Cu_6(Si_6O_{18}). 6H_2O$
Shattuckites, $(Cu, Ca)_3Si_3O_9 . 1½H_2O$
Plancheite, $(Cu, Ca)_3Si_3O_9 . 1½H_2O$. – These copper silicates are rarely found in the Copperbelt orebodies. Bisbeeite and shattuckite were reported from the oxidation zone of the Chililabombwe Mine, where they are associated with chrysocolla.

Shattuckite is found as pale blue aggregates of radiating crystals (Nchanga). Dioptase has been reported only from Nchanga, plancheite from Nchanga and Mufulira.

Copper Sulphates

1-3 *Chalcanthite*, $CuSO_4 .5H_2O$
Brochantite, $Cu_4SO_4 .(OH)_6$
Antlerite, $Cu_3SO_4(OH)_4$. – Chalcanthite is present as a secondary formation in underground mine workings. Antlerite is found in association with sphaerocobaltite at Nchanga. Brochantite occurs in trace amounts in most oxide orebodies.

Cupriferous Wad

Wad is a common oxidation product in most oxide deposits. It occurs as earthy black masses, in fissures and often inter-leaved in mica flakes. Purified wad concentrates from Baluba contain up to 20% Mn, 10% Co and 20% Cu. X-ray diffraction shows that all these materials are amorphous. The Cu/Co/Mn ratios change over very short distances, sometimes within a few centimeters.

Cupriferous Micas

In virtually all Copperbelt oxide orebodies, low-grade micaceous copper ores, from which the copper is difficult to extract by conventional methods are present in large quantities. The cupriferous micas are generally termed vermiculite. Basset (1958) concluded that the copper is firmly fixed in the exchange position of the intersilicate layers of the vermiculite. A later thorough investigation on cupriferous micas from Anglo-American Mines (Jebson 1970), using X-ray diffraction, TGA and DTA techniques, showed that these micas are composed of regularly interstratified layers of biotite and cupriferous chlorite. All Copperbelt cupriferous micas show exfoliation properties. Jebson attributed the exfoliation to the Cu-OH bond, which is weaker than the corresponding Mg-OH bond in normal non-exfoliating chlorites. Exfoliation appears to take place in two stages, corresponding to the major water losses during heating, as shown by TGA curves. The considerably lower cation exchange capacity of cupriferous micas, compared with that of the normal Mg-vermiculite, indicates that the copper bonding is different from that in a normal vermiculite. This can be explained by the fact that the Cu-OH bond in a chlorite is stronger than the $Cu\text{-}H_2O$ bond in a Cu-vermiculite. From Bassett's and Jebson's investigation and from other unpublished company reports it appears that the Copperbelt cupriferous micas form a mineralogically heterogeneous group, including vermiculite, hydrobiotite and cupriferous chlorite. These micas occur often as mixed layer silicates, as, for instance, Jebson's mixed layer biotite-cupriferous chlorite.

ACKNOWLEDGEMENTS

The authors wish to thank the Managements of Nchanga Consolidated Copper Mines Limited, Anglo American Corporation Limited and Roan Consolidated Mines Limited for their permission to publish this paper.

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