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COPPER OREBODIES IN THE BASAL LOWER ROAN META-SEDIMENTS OF THE CHINGOLA OPEN PIT AREA ZAMBIAN COPPERBELT

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ABSTRACT

Lenticular copper concentrations in basal arenaceous and rudaceous members of the Katanga System occur in basins in Basement gneiss and schist in an area of rugged palaeotopography at the Chingola Open Pit sector of Nchanga Mine on the Zambian Copperbelt. The gneisses and schists, as well as the unconformably overlying Katanga meta-sediments with their stratiform orebodies, have been folded into overturned to recumbent structures in which the westerly to northwesterly trend of anticlinal and synclinal axes is closely controlled by the old ridges and valleys, respectively. The overfolding is in turn the result of the incompetent behaviour of the gneisses and schists which rode over the rigid buttress formed by the massive Nchanga Granite during orogenesis. Secondary redistribution of copper is believed to have taken place during the folding at one of the orebodies, which is located in the most intensely deformed area. Otherwise the present copper concentrations are still in their original stratigraphic positions.

The close spatial relationship between the palaeoridges, the meta-sediments and the associated copper concentrations, suggests a common origin of both sediment and copper from the old ridges. Pre-existing copper lodes in the Basement gneiss and schist are invoked as the source of the copper, which was reconcentrated, either by detrital or chemical means or a combination of these processes, into the sediments at no great distance from the original lodes some of which are still preserved directly under the cupriferous sediments.

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INTRODUCTION

The Chingola area is situated roughly in the centre of the Nchanga Mining Area and approximately 4 km west of the town of Chingola on the Zambian Copperbelt. A group of six copper orebodies, named Chingola 'A' to 'F', have been located in highly folded meta-sediments of the Katanga System. The Chingola 'A' deposit was mined between 1957 and 1971 in the Chingola Open Pit. The other deposits have not yet been exploited.

The area is virtually devoid of outcrop and surface mapping was carried out by prospect pitting, trenching and auger drilling. This work has been proceeding intermittently since the late 1920's but it was only in the period 1967 – 71 that detailed surface mapping was completed.

Diamond drilling, to intersect the known host rocks for copper mineralization below the zone of leaching, was started in 1930. In that year indications of the presence of the Chingola 'A', 'B', 'C' and 'D' deposits were found, but drilling to delineate their boundaries was delayed until the period 1955-71. Chingola 'E', 'F' and 'C' extension deposits were located only after the detailed surface mapping had started, viz. 'E' in 1967, 'F' and 'C' extension in 1969.

The views presented in this paper are based on broad spatial relationships outlined by the pitting and drilling. The main object of presenting the current interpretation is to draw attention to the close association of these rather small, lenticular, copper orebodies with the palaeohills and to offer a tentative

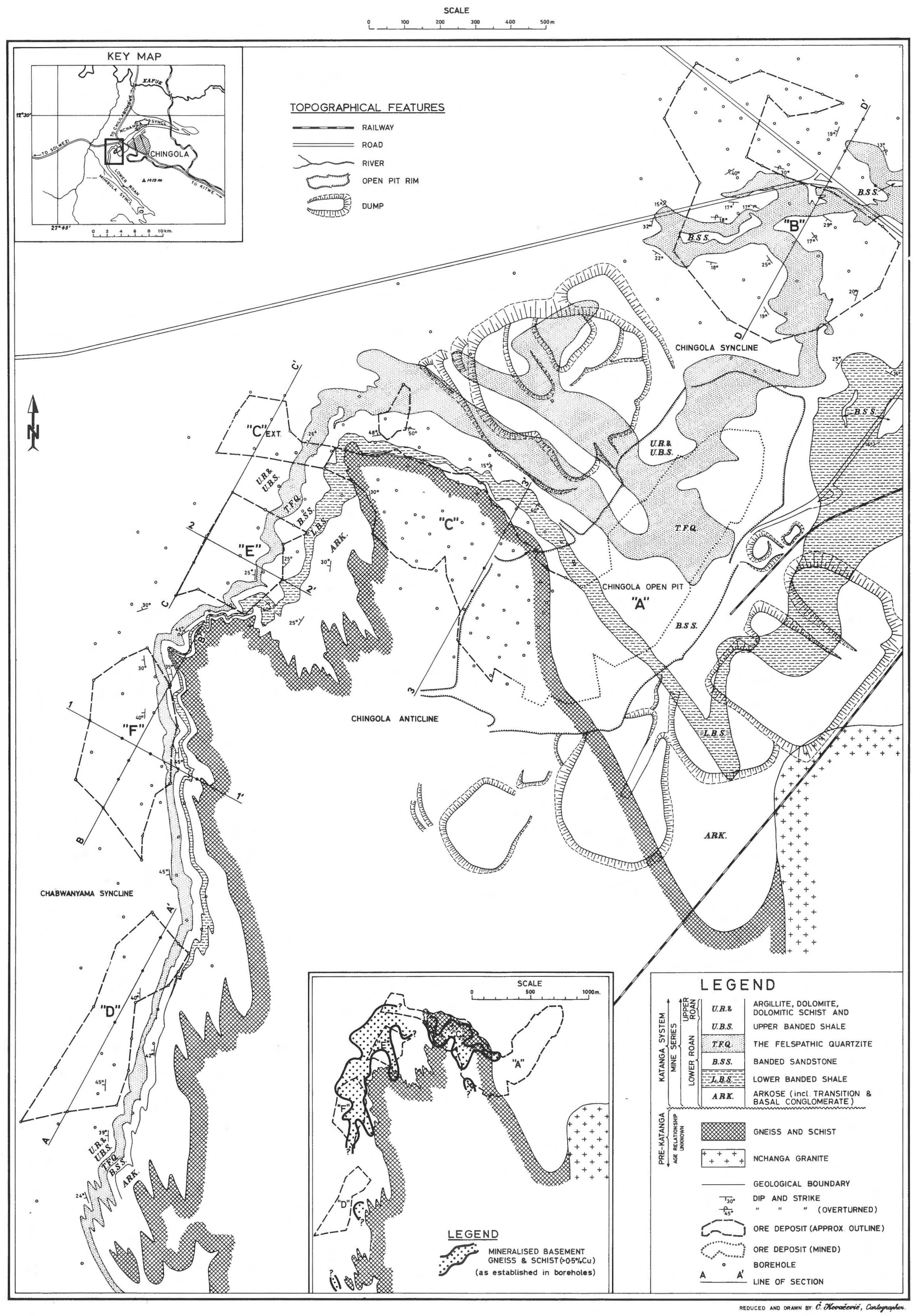

Fig. 1
Geological map of the Chingola Open Pit Area, Zambian Copperbelt.

hypothesis for the origin of the copper concentrations. Further rigorous geological study, both in the field and laboratory, will be needed to confirm or disprove these views. It is of interest to note, however, that exploration at Nchanga, guided by the association of palaeohills with copper concentrations, continues to outline new deposits. Furthermore, a recent paper in Economic Geology (W h y t e and G r e e n, 1971) describes a remarkably similar occurrence from the Zambian Copperbelt, at Chibuluma West near Kalulushi.

GEOLOGICAL SETTING

The major copper deposits at Nchanga are located

TABLE 1 A

	Kundelungu Supergroup	Lower Kundelungu Group
Katanga System	Mine Supergroup	Mwashia Group Upper Roan Group Lower Roan Group
—— Unconformity ——		
Basement Complex	Lufubu Gneiss and Schist Nchanga Granite	Age relationship unknown

TABLE 1 B

Group		
Upper Roan		Argillites, dolomites and dolomitic schist
Lower Roan	Upper Banded Shale	Multi-coloured banded phyllite
	The Fledspathic Quartzite	Beige to white massive feldspathic quartzite
	Banded Sandstone	Variable succession of quartz mica schists to arenites with thin interbeds of quartzite
	Lower Banded Shale	Light grey to blach carbonaceous phyllite and quartzite
	Transition	Decomposed sandstone or quartzite
	Arkose	Grey to pink arkose with local argillite and biotite schist
	Basal Conglomerate	Light to dark grey dolomitec pebble to boulder conglomerate
—— Unconformity ——		
Lufubu Gneiss and Schist Nchanga Granite	Basement Complex	

some 1.5 km to the east of the Chingola Open Pit area, along the gently dipping south limb of the Nchanga Syncline, and are underlain by the massive, competent Nchanga Granite. The copper occurs mainly in black carbonaceous shale, which is considered equivalent to the conventional Copperbelt "ore shale", and in the overlying feldspathic quartzite.

By contrast, the Chingola orebodies are found below this "ore shale" in arenaceous and rudaceous meta-sediments of the Footwall Formation which overlies in most places incompetent gneiss and schist of the Basement. The "ore shale" in the Chingola area contains only pyrite, except in Chingola 'A' and 'C', where secondary copper minerals believed to be of supergene origin are found.

The distribution of the Chingola orebodies is shown in fig. 1.

STRATIGRAPHY AND LITHOLOGY

The regional stratigraphic succession in the Nchanga Mining Licence area is presented in table 1 A.

The stratigraphic range of rocks present in the Chingola area from the Basement Complex to the Upper Roan Group is shown in table 1 B.

All rock names are used in their local sense and the names are not specific.

Basement Complex

Nchanga Granite. – This is a massive coarsely crystalline biotite granite of an overall pink to white colour with abundant aplite and quartz veining. Locally skialiths of darker biotite-rich grey granite occur.

Lufubu Gneiss and Schist. – A well-foliated fine to coarse crystalline biotite "augen" gneiss of a dark grey colour with locally intercalated bands of dark brown to black biotite schist. The schist bands range in width from a few millimetres to several metres. These rocks are probably of sedimentary origin.

In the field the Lufubu Gneiss and Schist is found to overlie the Nchanga Granite. Unfortunately, in the Chingola area the contact between both rocks has not been seen. At the nose of the Nchanga Syncline, however, this contact is exposed in outcrops, but no definite conclusions could be made as to whether the granite is intrusive into the gneiss and schist.

Lower Roan Group

The sediments belonging to this Group were deposited on an irregular surface of Basement rocks and there is thus a considerable variation in thickness of the various members, especially the Basal Conglomerate and Arkose Formations.

Basal Conglomerate (0-50 m). – This conglomerate is quasi-basal and is developed locally, mainly on the slopes of some of the steeper gneiss and schist ridges suggesting a scree deposit. Its contact with the overlying Arkose Formation appears to be gradational. It is a very compact light to dark grey rock with a matrix mainly of quartz, feldspar and biotite with, locally, a high content of dolomite. The clasts range from pebble to boulder size and are generally angular to subrounded. The larger clasts are easily recognisable as fragments of the nearby gneiss and schist.

Arkose Formation (0-200 m). – This comprises a series of rock types which are considerably different on the two sides of the Chingola Anticline (see Structure).

North of the anticline, in the Chingola 'A', 'B' and 'C' areas, the Arkose comprises thickly bedded and poorly sorted medium to coarse grained feldspathic quartzite of a grey to pink colour. Only locally, mainly in Chingola 'A' and 'C', does biotite become a major constituent of the quartzites while here also beds of biotite schist may occur. The constituents of this Arkose consist largely of detritus from the Nchanga Granite with an increasing amount of Lufubu Gneiss and schist material towards the Chingola Anticline. South of the anticline, in the Chingola 'F' and 'D' areas, the feldspathic quartzite is more micaceous and dolomitic and in many places there are interbeds of biotite schists and argillites up to several tens of metres in thickness.

Transition (0-18 m). – The upper part of the Arkose Formation is generally composed of mica and limonite-rich silicified sandstone and argillite, marking the transition to the overlying Lower Banded Shales under quieter, possibly more off-shore conditions.

Lower Banded Shale (0-30 m). – This formation consists of light grey to black, well laminated carbonaceous and dolomitic phyllite to quartzite. It corresponds to the "ore shale" found elsewhere on the Copperbelt. Unlike the Basal Conglomerate and Arkose Formation, the Lower Banded Shale extends across the major Basement ridges. However, the shale is absent from parts of the troughs of the valleys as is the case at Chingola 'B', 'C' and 'D'. At the top of the Lower Banded Shale is an intermittently developed cherty limonite-rich quartzite, probably indicating a period of non-deposition.

Banded Sandstone (15-45 m). – This formation consists of a series of feldspathic and dolomitic quartzites, quartzitic schists, schists and phyllites. It is the lowermost persistent formation in the area. The mica in the micaceous members often carries considerable quantities of copper trapped in its lattice.

The Feldspathic Quartzite (5-30 m). – The Banded Sandstone grades upwards into a succession of micaceous arkose and feldspathic quartzite which is persistent throughout the area. The arkose and feldspathic quartzite is similar to that found within the Banded Sandstone and is generally white to pinkish in colour, medium to coarse grained and well-sorted. Current bedding is a common feature.

Upper Banded Shale (3-35 m). – The Feldspathic Quartzite grades rather abruptly into a series of multi-coloured laminated argillites. Both these members are hosts to the important Upper Orebody mined at Nchanga Open Pit on the main Nchanga syncline to the east.

Upper Roan Group

The sediments of this group appear to have been deposited in deeper water than those of the Lower Roan Group. They consist mainly of an assemblage of argillites with the lower part interbedded with dolomite and dolomitic schist.

STRUCTURE

The structure in the Nchanga Mining Area is dominated by the Nchanga Granite which occurs in a dome-like body elongated in a north-westerly direction. Lufubu Gneiss and Schist form a mantle around the Granite. This complex of Basement rocks had been eroded into a mountainous area of considerable relief at the start of the deposition of the Katanga sediments and local elevational differences of up to 300 m were attained. The ridges and valleys controlled not only the sedimentation of the basal Katanga rocks but subsequently also the configuration of the main structures during the Lufilian (post-Katanga) Orogeny. Three principal sedimentary basins, which in turn become the loci of three main synclines, are recognised from north to south, namely, the Nchanga, Chingola and Mimbula Synclines. The northern portion of the large and complex Mimbula Syncline is referred to as the Chabwanyama Syncline. The Chingola area dealt with in this paper comprises the southern part of the Chingola Syncline and the northern part of the Chabwanyama Syncline, which are separated by the Chingola Anticline.

The Chingola 'A', 'B', 'C' and 'C' Extension ore deposists are located in the Chingola Syncline which like all the folds in the area, is characterised by a steep to overturned southern limb. The axis of the fold plunges west or northwest at an average of 10°.

The Chingola 'E' deposit is located on the Chingola Anticline which is in fact a complex northwest trending ridge of Lufubu Gneiss and Schist, comprising two subsidiary ridges with a saddle between (fig. 2).

The northeastern ridge corresponds with the overturned limb of the Chingola Syncline described above while the southwestern ridge, also overturned to the northeast, forms part of the northeastern limb of the Chabwanyama Syncline. The ore deposit occupies the saddle between the two ridges which plunges 25° – 30° to the northwest. Down-dip, the Basement rocks culminate in a northerly-trending ridge against which the copper mineralization terminates (fig. 3). Thus the Chingola 'E' deposit occupies an enclosed sedimentary Arkose basin.

The Chingola 'F' and 'D' deposits are found on the northeast limb of the Chabwanyama Syncline (fig. 2). The Syncline is still largely unexplored but it seems that the Katanga meta-sediments are everywhere underlain by Lufubu Gneiss and Schist. The pre-Katanga topography was very rugged and in the area described are a number of west to northwest trending ridges and valleys. There is also evidence for the presence of north trending ridges roughly parallel to the present sub-outcrop. The general dip of the sediments is 30 – 45° to the west. As elsewhere in the Chingola area, the disposition of fold axes in the Katanga sediments and their attitude is closely controlled by the grain of the original palaeotopography.

COPPER MINERALIZATION

In the Chingola Area, copper concentrations of economic significance occur predominantly in various levels of the Basal Conglomerate/Arkose Formations. Locally ore is also developed in the Lower Banded Shale and Banded Sandstone (In Chingola 'A' and 'C') and in the Feldspathic Quartzite (Chingola 'B').

In Chingola 'F', 'E' and 'C' economic copper concentrations occur immediately below mineralized meta-sediments in the top of the Lufubu Gneiss and Schist. Copper minerals in both meta-sediments and the gneisses are identical. Very fine copper minerals which are macroscopically invisible, have given high copper values in chemical analyses. The visible ore minerals are concentrated in stringers parallel to the foliation of the gneiss. The grade of the copper in the

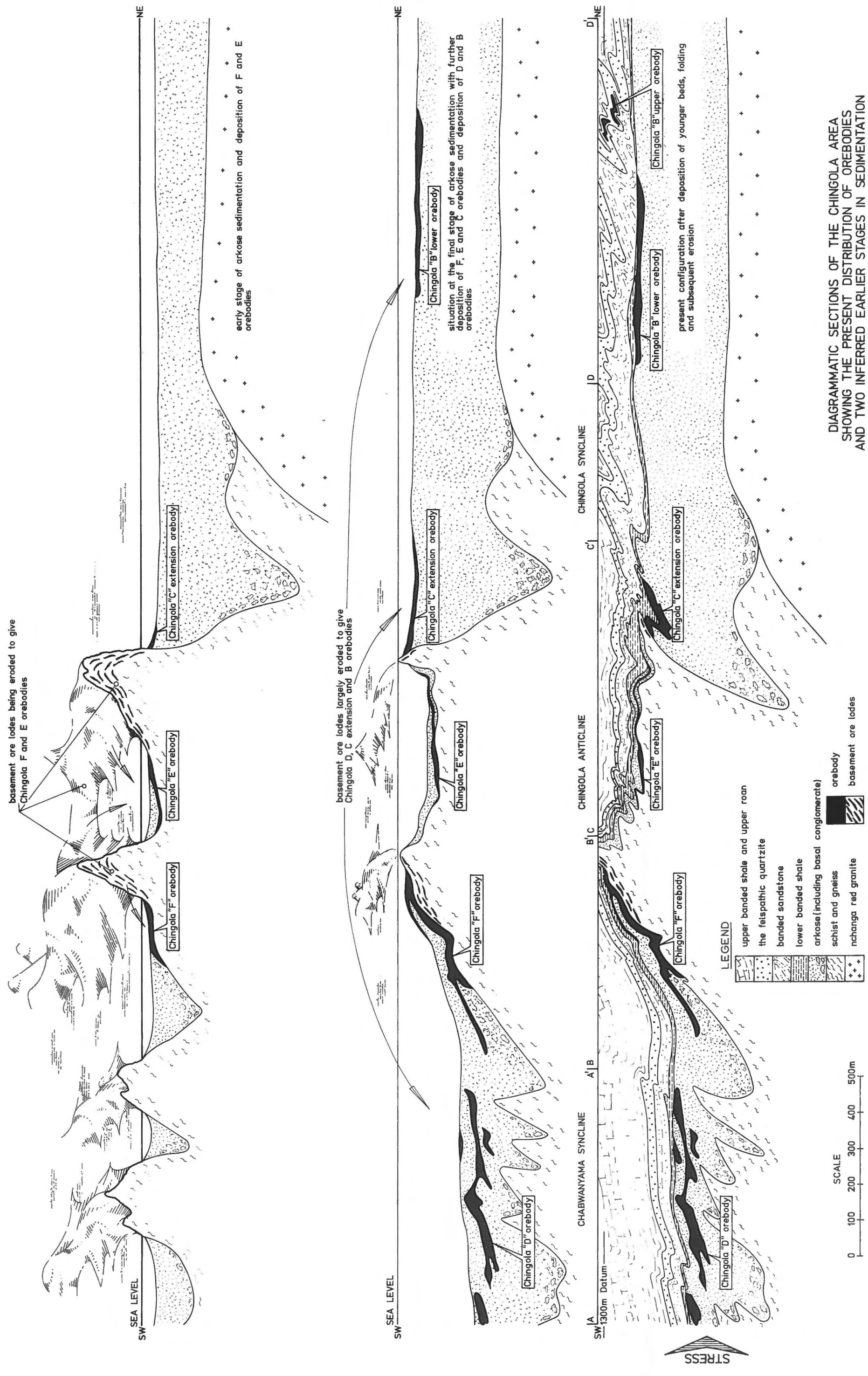

Fig. 2
Diagrammatic sections of the Chingola Area showing the present distribution of orebodies and two inferred earlier stages in sedimentation.

Basement concentrations can be as high as 4% over 4 metres.

When the sedimentary ore beds crop out copper minerals are commonly completely leached out. The depth of this zone of leaching is approximately 25-40 m. Below is a zone of copper oxides mainly malachite, chysocolla and cuprite with or without chalcocite which is considered to be a supergene sulphide. The depth of the zone of oxidation is extremely variable, depending on the type of host rock and its degree of deformation. Thus, in Chingola 'A' and 'C' where extreme folding occurs oxidation is evident throughout the entire orebody except for local remnants of the primary sulphides (bornite and chalcopyrite), in the shale. In Chingola 'F' on the other hand, where simple structures prevail and the host rock is extremely compact and solid, practically no oxidation occurs below 50 m and the ore minerals are mainly bornite and chalcopyrite with locally associated native copper. The Chingola 'B', 'E' and 'D' deposits, which are moderately deformed and in compact host rocks, show a gradual increase in bornite and chalcopyrite downwards, although the deepest intersections still contain an appreciable amount of oxide and chalcocite.

A similar pattern of leaching and oxidation applies to the Basement mineralization in the Lufubu gneiss and schist.

DISTRIBUTION OF OREBODIES

1. *Chingola 'A'*

This orebody has been mined in the Chingola Open Pit in the period 1957 to 1971, during which some 8 million tonnes of ore grading about 5% copper was extracted. The orebody occupies both the normal lower limb and the overturned upper limb in the nose of the Chingola Syncline. The bulk of the ore is in the Transition and Lower Banded Shale members but in places extends into the Banded Sandstone and Arkose.

2. *Chingola 'B'*

Two orebodies have been defined, a larger lower orebody in the Arkose and Transition, and a small upper orebody in the Feldspathic Quartzite.

The structure of the tabular lower orebody is relatively simple and it occupies part of the normal northern limb of the Chingola Syncline which dips northwest at less than 20°. There are only gentle subsidiary undulations along the orebody.

3. *Chingola 'C' and 'C' Extension*

The Chingola 'C' orebodies are situated in the overturned south limb of the Chingola Syncline and are down-plunge extensions of the Chingola 'A' deposit. The copper minerals occur as lenticular bodies in highly folded Arkose, Transition and Lower Banded Shale. The copper lenses are fairly persistent down the plunge but have limited lateral extent. Isolated lenses are also found in the Basement Gneiss and Schist.

A feature of the distribution of the copper mineralization at the southeastern part of Chingola 'C' and in Chingola 'A' is the transgression of ore across geological boundaries. In contrast, as the orebody is traced down plunge into 'C' extension the ore is restricted to the Arkose.

4. *Chingola 'D'*

This orebody is found in the Chabwanyama Syncline. The copper concentration occurs near the top of a thick Arkose Formation underlain by a complex of overturned ridges of Basement Gneiss and Schists. The pre-Katanga topography at Chingola 'D' was extremely diversified with steep ridges up to 300 m high separated by narrow valleys. The Katanga rocks are much less severely folded than at Chingola 'C', and it is suspected that this is due to their situation at a greater distance from the Nchanga Granite buttress where the most severe deformation took place. The axes of the folds plunge 40° to 50° to the northwest which is much steeper than at 'A', 'B', 'C' or 'E'.

5. *Chingola 'E'*

The Chingola 'E' deposit occurs in a basin of Arkose preserved in a saddle overlying the Chingola anticlinal ridge which divides the major Chingola and Chabwanyama Synclines. The body plunges gently in a westerly direction. A feature is the occurrence of copper minerals in the Basement Gneiss on the downdip side of the orebody (fig. 3).

INTERPRETATION OF EVENTS

From the general data presented on the disposition of ore and the structure, the following inferences are made regarding the original setting of the sedimentary basin and subsequent tectonic events:

Contours of the top of the Basement Complex, established by pitting and diamond drilling, show that at the onset of the deposition of the Lower Roan rocks, the Basement was deeply eroded into a series of mainly west to northwest-trending ridges and valleys.

The valleys were filled with the detrital components of the Basal Conglomerate and Arkose Formations derived from the nearby ridges.

The basal Katanga meta-sediments, comprising the Basal Conglomerate and the Arkose Formation, show characteristic features of rapid erosion and transport over short distances as there is considerable variation in composition both laterally and downdip and between the different basins. Where these rocks are confined to small local sedimentary basins, it seems reasonable to assume that they are the products of the erosion of the nearest ridges of Basement rock. In a similar way, since the copper concentrations are strata-bound, it would appear reasonable to assume that the copper also was derived from the nearby Basement rocks either as a detritus with the other sediment components or that it was transported and precipitated chemically.

In the Chingola 'E' and 'F' orebodies the Basement gneiss and schist is mineralized where it is contiguous with the ore horizon in the overlying sediments and this intimate spatial relationship is taken to indicate that the copper was redistributed directly from the gneiss and schist into the sediments. This view is contrary to that expressed in the paper by Garlick and Fleischer (this issue) where Basement mineralization is stated to have originated by downward migration of copper in selected areas where mineralized sedimentary beds abut into the old land surface. At the 'C', 'C' Extension and 'D' orebodies, where the main copper concentrations are at the top of the arkose, there are also smaller lenses of ore in the lower part of the arkose in close proximity to mineralized Basement. The general distribution of the mineralized Basement is shown on the inset in fig. 1. It should be noted that all the sedimentary copper concentrations occur along the outer edge of the cupriferous Basement away from the core of the Chingola Anticline.

If the copper in the sediments was derived from the erosion of cupriferous Basement, it is to be expected that on the slopes of the Basement ridges copper concentrations would be found in the lowest beds of the Basal Conglomerate/Arkose, and that further into the basins copper minerals would be restricted to the higher beds. Evidence of such a distribution is indeed present in the Chingola area.

For example, in the Chingola Anticline the ore deposit at Chingola 'E' is located in a basin of Basal Conglomerate/Arkose completely enclosed by subsidiary ridges of the major Chingola anticlinal ridge. In this case the lowest copper-bearing bed is the Basal Conglomerate which rests directly on cupriferous Basement schist whereas increasingly younger rocks are mineralized away from the ridge (fig. 3).

The apparent exceptions to this relationship are the Chingola 'A' and 'C' deposits where the bulk of the ore is in the younger Transition, Lower Banded Shale and even the Banded Sandstone, whereas the older Arkose is only erratically mineralized. If a local Basement gneiss and schist source is postulated for the copper then it is anomalous to find the main copper concentrations in stratigraphically young beds at Chingola 'A' and 'C', which are close to the source, whereas at Chingola 'B' which is further away, the copper is in the older Footwall Arkose Formation, as in all the other deposits. This situation can perhaps be accounted for by postulating a redistribution of copper from its original position in the Arkose during the severe deformation which took place at Chingola 'A' and 'C'. It is significant that both these deposits are in the overturned and intensely folded southern limb of the Chingola Syncline, which is located directly over the buttress between the weak Lufubu schists and strong Nchanga Granite. In all the other deposits, where deformation is less severe, the ore is always in the Footwall Formations below the "ore shale" and in the expected position with relation to a local source. It is also of interest to note that the major copper minerals at both Chingola 'A' and 'C', are chalcocite, malachite and azurite, which could all be of secondary origin. It is assumed that the copper

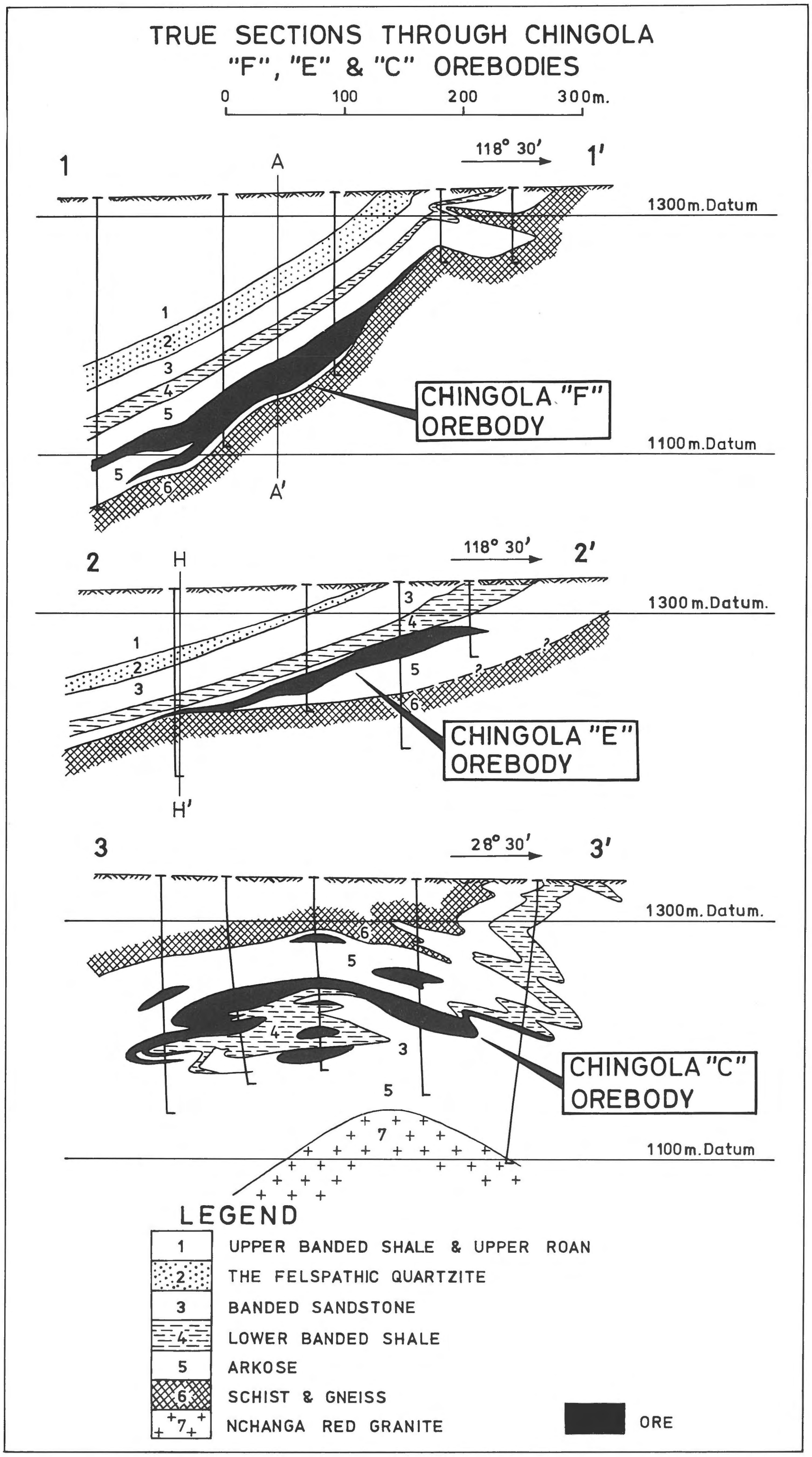

Fig. 3
True sections through Chingola 'F', 'E' and 'C' orebodies.

migrated from its original position in the Arkose and was reconcentrated along shear planes associated with the axial planes of the tight folds.

The relationship between the source of supply and distribution of copper is well illustrated in the northeastern limb of the Chabwanyama Syncline where the 'D' and 'F' deposits are located. In the northern part of the Chingola 'F', underlain by cupriferous Basement, the ore occupies the entire thickness of Basal Conglomerate (figs. 2 and 3). Traced to the south and west away from the Basement only the higher beds of the Basal Conglomerate are copper-bearing. Still further to the south in Chingola 'D' copper is concentrated only in the upper beds of the Arkose.

As has been mentioned earlier, evidence for Basement lodes is present all the way along the crest of the Chingola Anticline where remnants of the lodes are preserved under the Katanga Sediments. In the exposed core of the anticline no traces of the lodes have been observed. It is postulated that they were removed by erosion and the copper was recycled either by detrital or chemical agencies to produce the stratiform Chingola copper orebodies.

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