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SCOPE OF STRATIGRAPHIC AND SEDIMENTOLOGIC ANALYSIS OF THE KATANGA SEQUENCE, ZAMBIA

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ABSTRACT

It is speculated that the Katanga Sequence of the Zambian Copperbelt may have been deposited in a large basin which extended to the southwest into South West Africa. This concept calls for improved regional correlation, particularly since many economic strata-bound deposits in these areas are found in identical stratigraphic sequences of similar age. The Great Conglomerate, partially glacial in origin, can be considered a deposit of the widespread Late Precambrian glaciation and can, therefore, provide a much needed time-stratigraphic marker. The association of the Copperbelt orebodies to particular sedimentary facies may help to delineate trends of mineralization on a local as well as on a more regional scale. The lowermost part of the Katanga Sequence is interpreted as deposited during a regional transgression of the sea which created similar environments along a northwest-southeast belt. Though much of the Copperbelt ore is considered syn-sedimentary in origin, some occurrences are better explained by secondary processes.

INTRODUCTION

The renowned copper deposits presently mined in Zambia were all found because of some surface expression of their mineralization. Deposits of this kind are now hard to find, and emphasis will have to be placed on detecting orebodies that do not surface. The search for "blind" orebodies will have to rely on more detailed geologic analysis of the ore environment. The Katanga Sequence of Zambia and the Damara System of South West Africa form an important metallogenic province (Clifford, 1964). These folded and weakly metamorphosed rocks form a sinuous orogenic belt, recognised as a major structural element of Southern Africa. The associated base metal mineralizations, however, are more directly related to the original sedimentary basin than to the orogenic event. The majority of economic base metal deposits in Zambia and Southern Katanga occur in one particular stratigraphic horizon, the Lower Roan Subgroup, and are controlled by the depositional environment (Mendelsohn, 1961). Thus, we feel that stratigraphic correlation and detailed study of the sedimentary features of the ore-bearing rocks are essential in the search for metal deposits in the region. In this paper we will outline some aspects of the regional geology and indicate the scope of stratigraphic and sedimentologic analysis by summarizing some recent studies of Copperbelt geology.

REGIONAL PERSPECTIVE

The metasediments of the Katanga Sequence extend from the Katanga province of Zaire to the Zambian Copperbelt and to the west and south over large areas of Zambia. Further to the southwest (fig. 1), the Katanga Sequence is covered by Karroo sediments, by Tertiary Kalahari beds and by Recent windblown and multicycled sands. Though Brock (1963) suggests a possible limit to the Katanga metasediments approximately at the margin of the cover sands, there is no geologic evidence to support

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this opinion. To the contrary, the Damara System of South West Africa has a similar stratigraphy and has yielded comparable isotopic ages (Cahen and Snelling, 1966), and a correlation with the Katanga Sequence is possible (Martin, 1961; Clifford, 1962). The rich mineral deposits of the Zambian Copperbelt occur in the Lower Roan Subgroup which is the lowest part of the Katanga Sequence.

In several prospecting areas west of the Copperbelt, copper is found disseminated and strata-bound in metamorphosed sandstones, argillites, and schists that can be tentatively correlated with the Lower Roan rocks of the Copperbelt. The best known of such deposits occurring around the Mombezhi Dome in the Lumwana area has been discussed by McGregor (1964) who treats it as Lower Roan on the basis of: sequential arrangement of lithologic units, relationships with older granites and with younger intrusives, and Lower Roan-type occurrence of copper sulphides. Although the sediments of Lumwana underwent a more severe degree of metamorphism, they are homotaxial, and probably correlative, with the Lower Roan of the Copperbelt and of Southern Katanga (Kinsenda, Lubembe). The rich copper deposit of Kalengwa, also west of the Copperbelt, is considered to be younger than the formations in which the Copperbelt orebodies occur (Ellis and McGregor, 1967). Kalengwa and other minor copper occurrences in the same area are replacement deposits, possibly associated with disseminated strata-bound mineralization of Lower Roan type.

In South West Africa, widespread copper mineralization occurs in the Nosib Formation, which forms the lowest part of the Damara System. The mineralization is strata-bound and probably syngenetic (Martin, 1965). Some copper-bearing pegmatites are also confined to the Nosib Formation or to its immediate vicinity (Smith, 1961).

The widespread copper occurrence in the lower parts of both the Katanga Sequence and the Damara System suggests that the Kalahari beds may overlie mineralized formations of economic potential. Detailed knowledge of stratigraphy and sedimentology of the Katanga Sequence will be invaluable in extracting maximum information from exploratory drillholes in the sand-covered areas.

STRATIGRAPHY

Stratigraphy relies heavily on correlation; and chronostratigraphic markers are scarce in Precambrian rocks. Some work is presently being carried out on fossil micro-organisms of the Katanga Sequence (Binda, this issue), but Precambrian biostratigraphy is still something of the future. Litho-stratigraphy alone, does not provide the necessary time frame in which the lithologic changes took place. Lithologic units that were deposited within a short lapse of time over a large area are not plentiful in the Katanga Sequence. Garlick (1960) reported the presence of a lava from drillholes near Ndola, but, to our knowledge, this bed has not been identified elsewhere and thus its usefulness in time-stratigraphy may be limited to local applications.

The Great Conglomerate (Kundelungu Tillite) that occurs in the upper portion of the Katanga Sequence in Zambia is a time-stratigraphic marker of regional significance (Binda and van Eden, 1971). The Great Conglomerate of Zaire and Zambia has been tentatively correlated with tillites or tilloids in central-west Africa, East Africa, and South West Africa, and has been considered as a deposit of the widespread Varangian glaciation (Harland, 1965). Schermerhorn and Stanton (1962), however, in a study of the tilloids of the West Congolian, which are said to be correlative with the Great Conglomerate, concluded that these deposits were in fact formed by mud-flows in a geosynclinal realm. The inference that the Great Conglomerate could also be regarded as a mud-flow deposit unrelated to glacial conditions cast some doubt on the paleo-climatic event. A recent investigation by Binda and van Eden (in press) has produced evidence that the concept of a glacial event is still valid; although the bulk of the Great Conglomerate in the Copperbelt is a pebbly mudstone deposited by spasmodic mud-flows in a marine milieu, a glacial component can be recognised. Interbedded with the pebbly mudstone, and laterally equivalent to it, are various types of finely bedded argillites that bear resemblance to glacial varves. Diamictic varves from drill-cores in Ndola East are virtually identical to varves described by Agterberg and Banerjee (1969) from the glacial Lake Barlow-Ojibway in Ontario. The occurrence in argillite of outsized clasts that penetrate the underlying laminae (photo 1) can only be

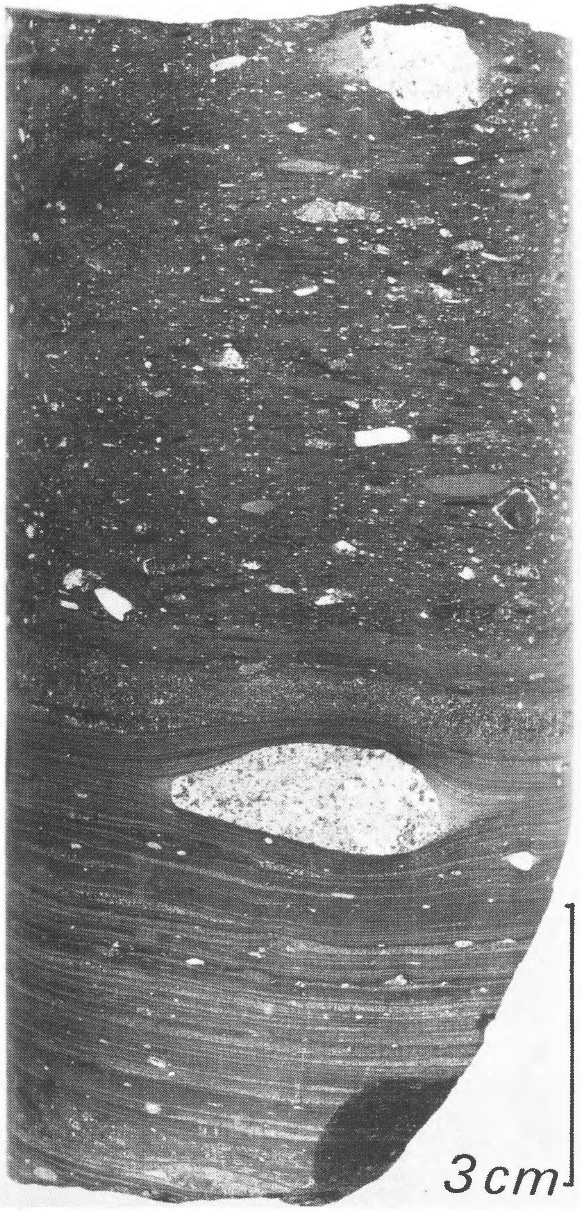

Plate 1
Drill core of the glacio-marine Great Conglomerate; pebbly mudstone (top) and laminated siltstone containing outsized clasts (bottom).

explained by ice-rafting and is strong evidence in favour of a glaciation, as pointed out by Harland et al. (1966) and by others. These pebbles are restricted to the Great Conglomerate and do not occur in laminated horizons either above or below it.

On the basis of this evidence, the Great Conglomerate of the Zambian Copperbelt is regarded as the glacio-marine facies of the Late Precambrian continental glacial deposits of Katanga (Zaire), and its use as a time-marker in regional stratigraphic correlation is justified.

The Damara System of South West Africa has been interpreted as the deposit of eugeosynclinal and miogeosynclinal basins on the basis of typical sedimentary and volcanic facies (Martin, 1965). The Damara geosyncline is part of a large belt that follows the western rim of the African continent. In South West Africa it branches off into the interior in a northeastern direction, and its trend is apparently continued into the Katanga – Lufilian belt of Zambia (Cahen and Snelling, 1966).

The Katanga Sequence and the miogeosynclinal facies of the Damara are remarkably homotaxial in their development and it is possible to speculate on their continuity. Both have coarse clastics of continental origin at the base, filling hollows in the basement topography, followed by quartzites and silty argillites, overlain by dominant dolomites and shales. Both sequences contain at least one glacial conglomerate in approximately the same stratigraphic position, and each can be considered as a major transgressive cycle with minor regression-transgression fluctuations.

In the Zambian Copperbelt, the basal part of the Katanga Sequence was probably formed as the sea was encroaching on the old land area (Basement Complex) in a northeasterly direction. The trend of a coastline has been interpreted in Luanshya, Chambishi (Garlick, 1961) and Mufulira (van Eden, 1970) in an approximately northwest to southeast direction. A transgressive front along this direction would explain the parallel alignment of orebodies that also have a similar sedimentary facies (fig. 1). At a particular stage of development of the sedimentary basin, similar depositional environments would exist at a number of locations along the coast, controlled by the tectonic mobility of the area, rate of depostion, etc. Thus, there is no need to invoke fundamental faults in the Basement (Brock, 1961) to explain the alignment of the Copperbelt deposits.

SEDIMENTOLOGY

The relationship between the occurrence of copper sulphides and particular sedimentary facies has been

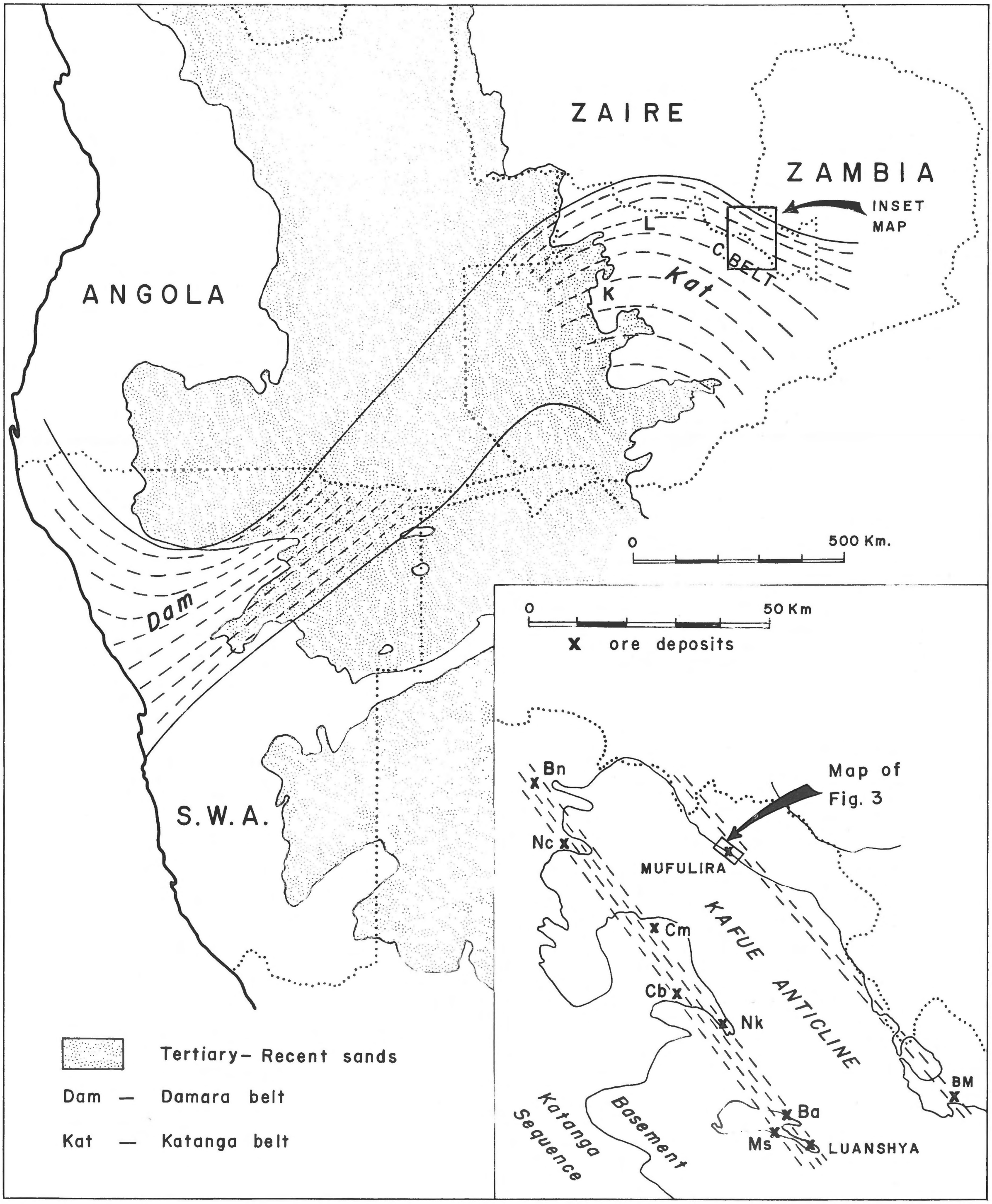

Fig. 1
Map showing Damaran and Katangan-Lufilian orogenic belts (modified after Cahen and Snelling, 1966). Indicated are the following ore deposits: Lumwana (L), Kalengwa (K). Inset map shows lineament of Copperbelt ore deposits: Bancroft (Bn), Nchanga (Nc), Chambishi (Cm), Chibuluma (Cb), Nkana (Nk), Baluba (Ba), Muliashi (Ms), Bwana Mkubwa (BM).

recognized long ago, but it has been interpreted differently by different authors.

Thus, Garlick and other "syngeneticists" provide strong evidence for a direct relationship between copper sulphides and the depositional environment, whereas authors of the "epigenetic" school (e.g. Darnley, 1960) accept that some sedimentary facies were more favourable than others to trap copper introduced in the rocks through metasomatic processes. Whatever the final answer to the problem of ore genesis may be, the mere existence of such relationship stresses the importance of sedimentologic analysis in the Katanga Sequence. Detailed sedimentologic analyses have recently been carried out in the Copperbelt, and the depositional environment of the copper-bearing formations is becoming better known, particularly since mining development is providing an ever increasing number of rock exposures.

The pre-Katanga Basement consists largely of granite which were long considered to be intrusive in the Katanga metasediments until Garlick and Brummer (1951) showed the contacts to be erosional unconformities. Isotopic age determinations (Cahen and Snelling, 1966) confirmed that the granites are older than the Katanga metasediments. The only granite that consistently yielded an anomalously young age is the Nchanga granite (Cahen et al., 1970). However, recently, a study of zircon populations of the Nchanga granite and of the overlying sediments has confirmed that the Katanga sediments at Nchanga were partially derived from the granite and are, therefore, younger than the latter (Binda, 1971).

The stratigraphic sequence of the overlying Lower Roan Subgroup has a similar development over the whole of the Zambian Copperbelt. The Basement is covered by conglomerates and sandstones that mark the initial transgression of the Katanga sea over the continent. Sediments of alluvial, littoral and nearshore marine facies reflect periods of minor transgression and regression. The association of mineralization to particular beds in the stratigraphic sequence is particularly clear at Mufulira where three superimposed orebodies are contained in a repeating sedimentary cycle. The lowest Footwall sandstones are truncated by a disconformity that marks a minor regression of the sea, after which the transgression proceeded at a slow pace forming the continuous sedimentary succession of the Upper Footwall and 'C' Orebody (van Eden, 1969; Hodgson, 1969). The high energy environment of the Footwall formation evolved to the quieter conditions in which the 'C' Orebody was deposited. Main characteristic of this evolution is the diminishing rate of sedimentation, forming a sequence that ended with the finely laminated Mudseam, which overlies the 'C' Orebody. A similar succession of conglomeratic sandstone to argillite and dolomite is repeated twice to form the 'B' and 'A' orebodies.

The study of the Upper Footwall has provided a firm basis for interpretation of the paleogeography of the immediately overlying 'C' Orebody rocks. The Upper Footwall contains alluvial fan deposits in the western area, which are laterally transitional into shallow marine deposits towards the east (van Eden, 1970). The alluvial deposits have strongly unimodal current directions, while the coastal marine sandstones show characteristically long-shore and off-shore directions (fig. 2). The relationship between the paleocurrents and the topography of the partially buried Basement indicates a strong influence of the latter on the paleogeography. The main features of the paleogeography were preserved for considerable time after burial of the Basement, because of the compaction of the thick sedimentary sequence over the old valleys. Thus, shallow water environments persisted over buried Basement hills during the time of deposition of the ore-bearing sediments. Within the coastal area fine sandstones with abundant clayey matrix formed in quiet, slightly deeper parts while coarser and cleaner sandstones were deposited on the shoals above wave base. Carbon-rich sediments ("Graywacke") were laid down in parts of the coastal area that were sheltered from the open sea by shoals or off-shore barriers. In these sheltered areas anaerobic conditions favourable for sulphide precipitation were likely to exist due to stagnating bottom waters. The fine-grained wackes of Mufulira are lithologically not much different from the silty or fine sandy "Oreshale" that forms the hostrock of orebodies southwest of the Kafue anticline, and similar syngenetic-diagenetic conditions may well be valid for both types of mineral occurrences in the Copperbelt.

In the past, great emphasis has been placed on the occurrence of aeolian sandstones in the footwall of nearly all the Copperbelt deposits (Mendelsohn, 1961). We feel, however, that there is no need to

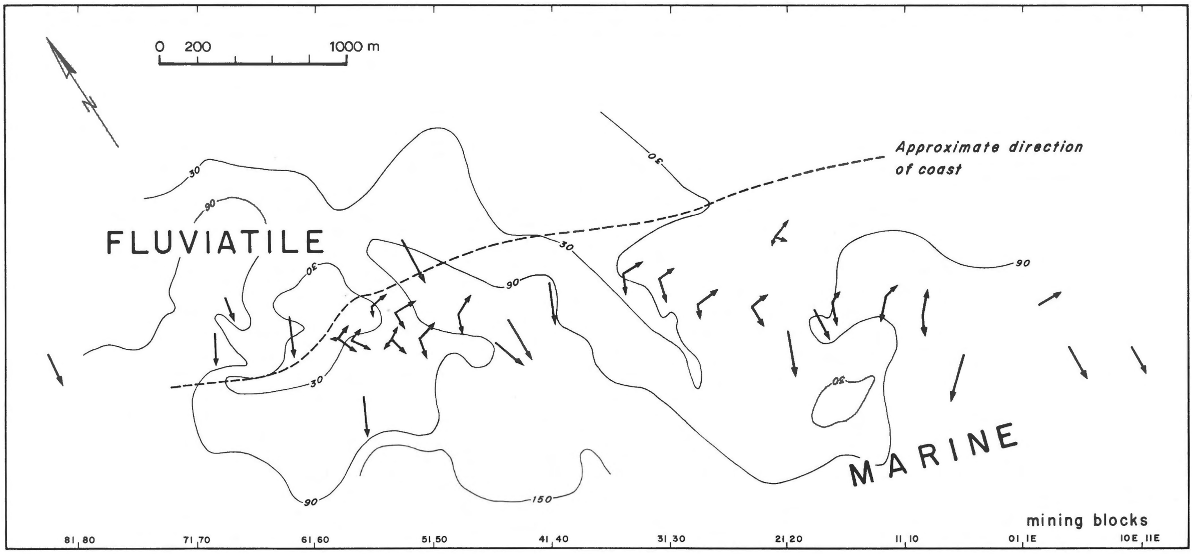

Fig. 2
Unrolled plan of Mufulira showing Basement paleotopography (indicated by isopachs in metres of Footwall plus 'C' Orebody) and paleocurrent directions in Upper Footwall.

interpret all these occurrences as aeolian. The large scale of crossbedded units, up to 2 metres thick, is no direct evidence for an aeolian origin; cross-bedding of an even large scale is frequently reported from recent fluviatile or marine shelf environments. Steeply dipping foresets that have occasionally been observed and interpreted as aeolian are also no reliable criterion in these folded Precambrian rocks. Though some may correct the effects of tectonic tilt and axial plunge (Ramsay, 1961), and obtain accurate current directions, internal deformation of the beds and its influence on the inclination of foresets is difficult to assess. At Mufulira, measurements of maximum angles of foresets show no significant difference between the so-called aeolian and aqueous cross-bedding (van Eden, 1969). Most of the "aeolian" cross-bedded units at Mufilira are tabular single sets sandwiched between horizontally bedded layers and are, thus, much different from the intricate cross-bedded cosets that are typical of modern aeolian dunes. Some of the "aeolian" sandstones examined in thin section show poor sorting and contain up to 15 percent fine matrix, which would exclude an aeolian origin. Internal organization, type of cross-bedding, and textural parameters show that at least some of the "aeolian" sandstones both at Mufulira and Luanshya must be attributed to a subaqueous environment (Binda and van Eden, 1968; van Eden, 1970). Thus, the marine transgression that marks the beginning of the Katanga Sequence formed a marine succession that, at places, directly overlies the Basement Complex. The analogy of the sedimentary succession of the Copperbelt with that of the Kupferschiefer of Germany, as stressed by Garlick (1961, this issue), may still be valid. A detailed sedimentologic analysis by Pryor (1971) has recently shown that the sandstones underlying the Kupferschiefer is marine in origin and not aeolian as previously thought.

Though the association of sedimentary facies and copper sulphide mineralization suggests a syngenetic origin for most of the Copperbelt orebodies, at least some of the copper concentrations is better explained by secondary processes. At Mufulira, mineralization in cross-bedded arenites that form the lowest part of the orebodies and in fluviatile conglomeratic sandstones forming the Footwall at Mufulira West is probably not syngenetic. Some features, such as the irregular lower boundaries of the copper mineralization indicate infiltration of copper-bearing pore-fluids (Garlick, 1967, p. 114). At Muliashi South, in the western part of the Luanshya basin, up to ten metres of the footwall, immediately underlying the carbonate schist lower orebody, are mineralized with a total copper content well above one percent. The copper minerals, mostly chalcocite and acid-soluble copper, but at places also chalcopyrite and bornite, occur in sandstones and conglomerates of fluviatile origin (Binda, 1969a). The richest mineralization is in the coarser lithologic types that are interpreted as occupying the central and fastest flowing part of the paleoriver. Occurrences of this type cannot easily be explained by Garlick's (1961) syngenetic theory of ore genesis requiring quiet anaerobic conditions and low rates of sedimentation. A detrital origin for the copper minerals in the footwall is also difficult to envisage.

Field relationships suggest migration of copper-bearing solutions from the overlying carbonate schist as the most likely mechanism for the emplacement of the footwall mineralization at Muliashi South (Binda, 1969b). Migration may have occurred during diagenesis, especially at a late stage when the inter-layer water of the clay was squeezed out by compaction, into the porous footwall. A similar mechanism has been suggested by Bogdanov (1967) for copper deposits in sediments of lagoonal-deltaic type, and by Beales and Jackson (1968) for the lead and zinc deposit of Pine Point.

Further remobilization of copper occurred during metamorphism, as indicated by the post-tectonic veins studied by Jolly (this issue), and at even later stage when circulating groundwaters brought about a deep supergene enrichment. The processes that formed the Copperbelt orebodies are certainly complex and no single mechanism can be expected to explain all the observable features.

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