TECTONO-SEDIMENTARY EVOLUTION OF THE CENTRAL AFRICAN COPPERBELT

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Summary
The Neoproterozoic-Lower Palaeozoic Katangan sedimentary sequence records a complete Wilson Cycle. The sedimentary rocks rest unconformably upon granitic and metamorphic rocks of ages ranging from 2.0 Ga to 880 Ma. Rifting of a continental block and a major marine transgression led to the deposition of the Roan Supergroup continental and shallow marine clastics succeeded by platform carbonates in what is now Zambia. A northward shift of depocentre into present Congo followed by the development of a foreland basin associated with north-directeed thrusting are recorded by dolomitic shales, siltstones and sandstones of the Guba Supergroup. Two glaciogenic horizons occur within this unit: the Grand Conglomerat probably of Stuartian age (750 Ma) and the Petit Conglomerat tentatively correlated with Marinoan/Varangian glaciation (620-600 Ma). Intraplate tholeiitic and alkaline magmas mark stages of evolution from initial rifting to a mature continental rift, and mafic igneous rocks emplaced during the deposition of the Grand Conglomerat suggest opening of a young oceanic rift. The cycle terminated with the deposition of the Kundelungu Supergroup continental molasse of Lower Palaeozoic age.
The parautochthonous units represented by north-eastern proximal facies of the Roan Supergroup in Zambia host major stratiform-stratabound orebodies of early diagenetic Cu mineralisation. Their distal correlatives, originally deposited farther to the south, are Cu-Co-bearing mainly carbonate facies, which now occur in Congo as nappes thrust northwards onto the folded Guba Supergroup. They are associated with synorogenic deposits that include prominent olistostromes bodies with megablocks containing mineralised horizons. The Kundelungu Supergroup molasse consists of tabular to weakly folded barren continental clastic sediments, age of which extends into the Lower Palaeozoic. Metamorphic grade of the Katangan rocks decreases from high grade facies in the south to unmetamorphosed rocks in the northern region.

Introduction

The Neoproterozoic Katangan belt of Central Africa, also called the Lufilian Arc, straddles the national border between Zambia and the Democratic Republic of Congo (DRC) and is one of the richest metallogenic provinces. The sedimentary succession of the belt and associated intrusive igneous rocks were deformed during the Pan African orogenic cycle. They occur as autochthonous Cu-bearing units in Zambia and allochthonous thrust sheets/nappes with high-grade Cu-Co deposits in the Katanga Province of DRC. The thrust units were tectonically displaced to the north, towards the foreland region (Fig. 1). This paper presents an overview of the Katangan belt successions and tectonic controls on sedimentation and evolution of its basins.

Stratigraphy

The Katangan Sequence (Binda and Van Eden, 1972; Francois, 1973) of Zambia and Congo can be subdivided from base to top into three supergroups: Roan, Guba, and Kundelungu. The term Guba Supergroup, introduced by François (1995), is used here to denote the deformed "Kundelungu" of the Lufilian Arc, whereas the term Kundelungu Supergroup is restricted to the relatively undeformed rocks of the Kundelungu Plateau.

Extensive stratigraphic work carried out in Zambia and Congo under the aegis of IGCP Project 302 has resulted in detailed correlation of units within the Roan Supergroup (Cailteux *et al*., 1994). The Roan may be subdivided into four units from base to top.

1. A siliciclastic unit, consisting mainly of conglomerates and arenites deposited in alluvial fans, braided streams, and sand dunes, which rest unconformably on a basement of 1.0 Ga old granitic and metamorphic rocks and Neoproterozoic granitoids emplaced at ca. 0.88 Ga. In Congo, at least part of the Roches Argilo-Talqueuses (RAT) may be correlative with the siliciclastic unit of Zambia.
2. A mixed siliciclastic-carbonate unit consisting of argillites, arenites, dolostones with minor evaporites deposited in shallow marine and paralic environments as a result of transgressions and regressions.
3. A carbonate unit consisting of white dolostones with varying amounts of anhydrite. The dolostone is frequently brecciated and contains abundant irregular bodies of gabbroic rocks altered to amphibolite.
4. The Mwashya Group, in its turn is subdivided into a lower part consisting of a dolomitic unit with silicified ooids, black oncoids, jasper, pyroclastic, and haematitic layers, and an upper part consisting of shales and sandstones or black shales deposited in anoxic conditions.

Allochthonous units extend for 400 km along strike of the external fold-thrust belt of the Lufilian Arc (Fig. 1), from Mufulira in Zambia to Kolwezi in DRC (Cailteux *et al*., 1994). Their succession is subdivided into four groups: R.A.T. ('Roches Argilo-Talqueuses'), Mines, Dipeta and Mwashya. The R.A.T. and Dipeta form strongly fragmented and tectonised thrust sheets/nappes associated with prominent megabreccias containing megafragments of the Mines Group (Cailteux and Kampunzu, 1995). As a consequence of profound tectonic dismemberment, the stratigraphic record of the allochthonous units is fragmentary, rendering precise stratigraphic analysis difficult.

According to the traditional definition, the R.A.T. Group is considered as the oldest unit of the allochthonous succession in Congo. It consists of continental red siltstones and sandstones, with chlorite matrix and dolomitic cement, associated with minor evaporites and presumed to have undergone intense diagenetic transformation (Cailteux, 1994). The succeeding Mines Group begins with the first Cu-Co mineralisation, hosted in clastic rocks of mineral composition the same as the underlying red R.A.T., but devoid of evaporites and hematite, grey in colour, thus deposited in subaqueous anoxic environment. The R.A.T. is thought to be followed by shallow marine carbonate clastic facies, stromatolite bioherms and dolomitic shales deposited in increasingly oxygen-rich conditions and hosting another mineralised horizon (Cailteux, 1994). The Dipeta Group is defined by cycles of argillaceous evaporites, siltstones or sandstones and carbonates, with the proportion of carbonate component increasing up the succession. The Mwashya Group represents a transgressive trend of intertidal oolithic and stromatolitic facies grading to an association of

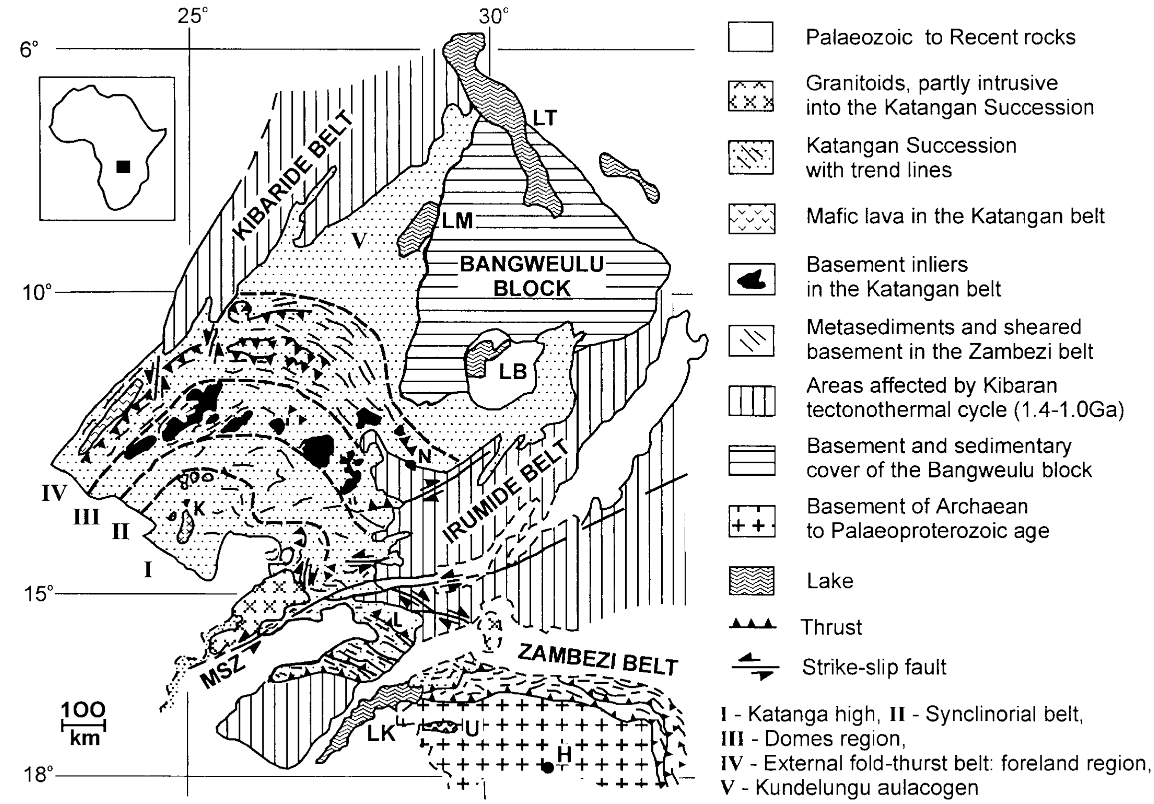

Fig. 1. Geological map of the Katangan belt and a part of the Zambezi belt; modified from Binda and Porada (1995). H – Harare, L – Lusaka, N – Ndola; U – Urungwe Klippe, MSZ – Mwembeshi Shear Zone, LK – Lake Kariba, LB – Lake Bangweulu, LM – Lake Mweru Wantipa, LT – Lake Tanganyika

shales, lagoonal black shales and sandstones deposited in increasingly anoxic conditions.

The Guba Supergroup is a more than 4000 m thick heterogeneous unit, which is better represented in Congo than in Zambia. It contains two distinct diamictites: the Grand Conglomerat at the base of the unit and the Petit Conglomerat approximately 1700 m above the base (François, 1973). Each of these glaciogenic units is overlain by its cap carbonate, the Kakontwe Limestone and Calcaire Rose respectively. The Grand Conglomerat is a glaciogenic deposit (Binda and Van Eden, 1972), probably correlatable with the approximately 750 Ma old Stuartian glacials. The Petit Conglomerat is probably also of glacial origin and could represent a deposit of the approximately 620-600 Ma Marinoan/Varangian glaciation, but, owing to the dearth of reliable radiometric dates and to the apparent absence of Ediacaran fossils, its correlation is uncertain.

The mainly undeformed siliciclastic rocks of the Kundelungu Supergroup mark the end of Katangan sedimentation. While some authors consider these rocks as Neoproterozoic, Kampunzu and Cailteux (1999) suggested that they are early Palaeozoic, and the occurrence of Ordovician microfossils in shales correlated with rocks of the Kundelungu Plateau (Vavrdova and Utting, 1972) would extend the sedimentation of the Katangan molasse well into the Palaeozoic.

Metamorphic grade of the Katangan rocks decreases across the Katangan belt from high grade facies (eclogite and amphibolite) in the south through very low grade (pumpellyite-prehnite) to unmetamorphosed rocks in the northern region.

Tectonics and sedimentation

The Katanga Sequence is the sedimentary record of a complete Wilson Cycle. At this stage, our knowledge of the details of each part of the cycle is incomplete. However, the record indicates rifting of a continental block associated with outpouring of continental tholeiites, followed by a major marine transgression, development of a carbonate platform on a rifted margin and emplacement of tholeiitic and alkaline mafic igneous rocks marking a mature continental and a proto-oceanic rift (Kampunzu *et al.*, 1993; Tembo *et al.*, 1999). The closure of the basin started during deposition of the upper units of the Guba Supergroup and was marked by north-directed thrusts and minor south-verging back-thrusts (Kampunzu and Cailteux, 1999). The depocentre shifted from the passive margin to a foreland basin north of the present Zambia-Congo border. The cycle ended with deposition of the Kundelungu molasse.

Good evidence for the tectono-sedimentary setting of the Roan Supergroup is available in Zambia, where the rocks of this unit unconformably overlie the pre-Katangan basement and where in more than six decades of mineral exploration and exploitation, a wealth of sedimentological data have been collected. Several lines of evidence attest to the breakup of a mature continental block at the onset of Katangan sedimentation and to the development of a rifted margin.

The sediments below the Ore Formation were deposited on a rugged palaeotopography of steep hills and valleys. Cycles of fining-upward fan conglomerate (Clemmey, 1976) suggest a horst-and-graben setting with renewed movement along the faults, which is typical of early stage rifts. Mineralogical and petrological composition of the siliciclastic rocks indicate a granitic and metamorphic source. Point-count microscopic analysis of arenites from the top of the siliciclastic unit and from the Ore Formation, clearly shows a continental block provenance. Measurements of current direction from cross-bedding and clasts size indicate that the palaeostreams were flowing from NE to SW (Van Eden and Binda, 1972).

The base of the Ore Formation records a major marine transgression from SW to NE. The Ore Formation of Zambia displays a gradual facies change from arenite/wacke in the NE to carbonaceous shale in the SW (Binda, 1994). Above the Ore Formation, transgressions and regressions of the shoreline (Binda and Mulgrew, 1974; Maree, 1962) suggest fluctuations of the sea level, possibly influenced by rift tectonism.

A carbonate platform transgressed from the south where rift-related mafic tholeiitic and alkaline magmas were emplaced. The facies transition between rocks of the mixed unit and carbonates to the south is obscured by tectonic complications evidenced by carbonate/amphibolite breccias (Binda and Porada, 1995).

The stratigraphic succession and lateral changes of thickness and facies in the Guba Supergroup, apparent from strip logs published by François (1973), imply a northward shift of the source zone of detrital material. At this stage, the source was located near the northern boundary of the belt in what is now Congo, where the basal conglomerate rests unconformably upon the Kibaran basement. It is followed by the Mwashya Group, the glaciogenic tillite and associated conglomerates (Grand Conglomerat), overlain in turn by granule and coarse grained sandstones and subordinate siltstones with an interbed of Petit Conglomerat. Distally, towards the south, the total thickness of the Guba Supergroup increases while the tillites become markedly thinner and sandstones grade to siltstones, dolomitic siltstones and carbonate rocks.

The thrust sheets of the external fold-thrust belt are associated with prominent megabreccias, which form tabular and wedge-shaped bodies underlying, and sometimes intruding, the allochthonous sheets above. They are composed of subangular to rounded fragments of Katangan provenance, including huge blocks with mineralised units of the Mines Group, set in an abundant sandy to clayey matrix with dolomitic cement. In the past publications, summarised by Cailteux and Kampunzu (1995), the Katangan megabreccias were considered as tectonic friction breccias. However, they were recently reinterpreted in selected localities as sedimentary bodies of olistostromes resulting from subaqueous redeposition by mass gravity flows of clastic materials supplied from the emergent fronts and tops of the advancing thrust sheets (Wendorff, 1995, 1997; Wendorff, in press-a). This interpretation is based upon the provenance of clasts, unroofing sequences, sedimentary textures and structures, vertical and lateral trends of facies, injections of breccia into the overlying units and an absence of pervasive shearing. The deposition of each individual olistostrome body was blocked when the advancing thrust sheet overrode it. Upwards-projecting injections of the unconsolidated olistostrome materials were formed at this stage. The Katangan olistostromes belong to a broader spectrum of synorogenic subaqueous and subaerial deposits unconformably overlying the Guba Supergroup.

Poorly deformed to undeformed shales and arkoses of the Kundelungu Supergroup represent a continental molasse and the closing stage of the Katangan tectono-sedimentary cycle.

Mineral deposits

Comprehensive treatments of the mineral deposits of the Central African Copperbelt can be found in volumes edited by Mendelsohn (1961), Bartholomé (1974) and Boyle et al. (1989). Three types of ore deposits are, or have been, exploited: (1) stratiform Cu-Co, (2) stratiform U and (3) discordant polymetallic. Of these, the economically most important are the first type which occur in the lower part of the Roan Supergroup.

One of the main achievements of IGCP Project 302 has been to establish that the allochthonous Cu-Co-rich orebodies of Congo belong to a carbonate heteropic facies of the autochthonous Ore Formation of Zambia. The latter shows a regional, as well as local zonation from chalcocite in nearshore facies to bornite, chalcopyrite, pyrite into basinal mudstones (Binda, 1994). Arenite/wacke orebodies of the Ore Formation, such as at Mufulira, tend to be richer (>3 % Cu) but Co-poor. Silty argillite and carbonate schist orebodies, such as Chambishi and Baluba respectively, may have relatively high Co values.

Copper concentrations of ore grade, with or without Co, are not confined to the Ore Formation but occur also, locally, in arenites and argillites stratigraphically below or above the Ore Formation, in contact with the latter (e.g. Muliashi South) or as discrete bodies (e.g. Chibuluma and Nchanga). Details of the stratigraphic distribution of copper deposits in the Zambian Copperbelt can be found in Binda and Mulgrew (1974) and in Binda (1994).

Several and diverse theories of ore genesis have been proposed in the past six decades for the Zambian Copperbelt orebodies. A review and assessment of the various genetic models by Sweeney *et al.* (1991) concluded that an early diagenetic origin with derivation of metals from weathering and leaching of a mineralised pre-Katangan basement is the one that satisfies most observations.

In the allochthonous Cu-Co deposits of Congo, the primary copper-cobalt sulphides (chalcocite-digenite, bornite, chalcopyrite, carrollite) and pyrite occur as disseminated stratiform ores conformable with primary bedding of the host rock. They form two orebodies within the lower part of the Mines Group, the lower and the upper orebody, separated by barren stromatolitic bioherms. Less important occurrences of Cu-Co mineralisation occur in similar lithofacies of younger formations in the Mines and Mwashya Groups (Cailteux, 1994). The distribution of the sulphides shows the following vertical repetitive, 'transgressive' - 'regressive', zonation (Cailteux, 1994): chalcocite (digenite)-bornite to bornite-chalcopyrite to carrollite-chalcopyrite to pyrite-chalcopyrite-carrollite. A laterally similar zonation of the sulphides expresses the decreasing content of Cu associated with an increase in Co within the deposits, with no change of sedimentary facies.

Conclusions

The past IGCP Project 302 demonstrated that the allochthonous units of the Mines Group in Congo are correlatives of the autochthonous ore-bearing section of the Roan Supergroup in Zambia. The recently conducted IGCP 419 brings forward new ideas, e.g. on synorogenic sedimentation and stratigraphy in the Katangan foreland region (Wendorff, in press-a, b) or tectonic interpretations of igneous activity (Kampunzu *et al.*, in press). Such approaches provide new focus and new research targets, which should enable to refine our comprehensive understanding of the Katangan belt.

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