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# GEOLOGICAL BACKGROUND TO THE COPPER-BEARING STRATA OF SOUTHERN SHABA (ZAÏRE)

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## ABSTRACT

The Katangan (Katanga System or Sequence) is defined and a threefold division is adopted and justified. It is shown that each of the component supergroups is linked to a distinct uplift of the Kibaride Belt. The Upper Katangan or *Kundelungu Supergroup* is at least in part the result of the erosion of the Kibarides during uplift of the earlier belt under the influence of the *Lufilian orogeny*; the Middle Katangan or *Grand Conglomérat and Mwashya Supergroup* is mainly the result of uplift and erosion of the Kibarides caused by the *Lomamian orogeny* which affects the Lower Katangan in western and northern Shaba; the Lower Katangan or *Roan Supergroup* was deposited in part as a consequence of uplift and erosion ot the Kibarides during the late stages of the *Kibaran orogenic cycle* and in part as a platform deposit during the waning phases and cessation of this uplift.

Whereas in southern Shaba deformation is practically entirely due to the successive phases of the Lufilian orogeny connected with the Kundelungu Supergroup, the situation near the Kibaride Belt and on both sides of it is different: the Lufilian orogeny is weaker and in some areas non-existent; earlier tectonic movements are detectable and sometimes important.

Stratiform copper is known in minor quantities in beds of the Upper and Middle Katangan. The important stratiform deposits are in strata belonging to the Lower Katangan.

The Lower Katangan is known from several distinct areas in Shaba. Only the Bushimay Supergroup deposited in a basin immediately to the north-west of the Kibaride Belt and the Roan Supergroup of the Shaba basin to the south-east of the same belt are examined and compared to each other and to what is known of the uplift history of the Kibaride Belt.

It is concluded that in both basins of deposition each uplift of the Kibaride Belt is accompanied by deposition of arenaceous sediments, the terrigenous character of which decreases as the uplift slows down. Slight sinking of the belt brings in all basins decrease of arenaceous sedimentation, increase of pelites and introduction of a carbonate component: this is followed by a more or less stable period characterized by predominantly carbonate deposition; finally the early stages of the Lomamian orogeny are marked by a volcanic activity and an increase of pelitic and arenaceous sedimentation which heralds the advent of the Middle Katangan, consequence of the past-Lomamian uplift of the Kibarides.

The stratified mineralization in the Bushimay Supergroup and in the Roan Supergroup appears to occur at the same general level. For the areas immediately to the north-west and to the south-east of the Kibaride Belt, this is shown by the study of columnar stromatolites which yields results in keeping with the model age of the syngenetic lead mineralization in the Bushimay Supergroup.

The same may be said of the southeastern Shaba (and Zambian) Copperbelt in view of

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the striking parallelism between the depositional histories in all basins examined and the movements of the Kibaride Belt as deduced from the dating of various intrusive bodies.

The ore-bearing beds in all three areas are coeval with the top of the Middle Riphean of the U.S.S.R. (*circa* 1 100-1 050 m.yr.).

The mineralized groups appear at the close of the first uplift of the Kibaride Belt. The mineralization belongs to type 4 of Pelissonnier (1972) and thus conforms to this author's conclusion linking this type of mineral deposit to the post-orogenic stage of orogenic evolution.

The reader will find three appendices at the end of the paper: 1. Notes on radiometric age data; 2. Isotopic composition of common leads; 3. On the limit between Lower and Middle Katangan.

## 1. THE KATANGAN, DEFINITIONS AND FIRST ORDER SUBDIVISIONS

The Katangan (Cahen and Lepersonne, 1967; Katanga System of Van Doorninck, 1928) of Shaba (formerly Katanga) comprises over 10 000 m of metasediments which lie unconformably on various older units, the youngest of which is the Kibaran. In southern Shaba, it is folded by the phases (Cahen, 1970) of the Lufilian orogeny (Van Doorninck, 1928). In places it is overlain unconformably or disconformably by the late Palaeozoic beds of the base of the Lukuga Series (Lower Karroo).

Whereas in southern Shaba no unconformity is known to separate its component groups and disconformities are often difficult to observe, in other areas mainly to the North, in the vicinity of the Kibaride Belt, unconformities and disconformities are easily detected.

The traditional subdivisions of the Katangan unit are, in southern Shaba, mainly based on lithostratigraphical criteria. For reasons, natural, historical and personal, several schemes have been devised for the subdivision of this unit.

We adopt here a threefold division (Cahen and Mortelmans, 1947) which is fully justified elsewhere [Cahen and Dumont, in preparation (1)].

The *Upper Katangan* or *Kundelungu Supergroup* was deposited in conjunction with the different phases of the Lufilian orogeny (see below). In the north of Shaba, it is the result of the erosion of the foreland to the fold-belt known as the Lufilian Arc; thus it is at least in part the result of the erosion of the Kibarides during uplift of this earlier belt under the influence of the Lufilian orogeny (Cahen, 1970).

The *Middle Katangan*, or *Grand Conglomérat and Mwashya Supergroup*, is mainly the result of uplift and erosion of the Kibarides caused by an orogeny affecting the Lower Katangan in western and northern Shaba (see below).

The *Lower Katangan*, or *Roan Supergroup*, was deposited in part as a consequence of the uplift and erosion of the Kibarides during the late stages of the Kibaran orogenic cycle and in part as a platform deposit during the waning phases and eventually the cessation of this uplift (Cahen, 1970; and *op. cit.*).

Thus, each of the three supergroups which form the Katangan unit is linked to a distinct uplift of the Kibaride Belt. The effects of this dependency is naturally more marked in the vicinity of this belt than further out, towards the South-East. This dependency also becomes less exclusive from the bottom to the top of the

(1) In the present paper, this work is quoted as "*op. cit.*".

Katangan Unit. The first uplift has been described as "active," the other two are "passive" (Cahen, 1970).

Furthermore, the Middle Katangan was deposited under special climatic conditions (in part glacial) which further emphasize the threefold division.

Southern Katanga has often been considered to be a "geosyncline" (Robert, 1940) although knowledge of the area was insufficient (and still remains incomplete) to characterize such a feature. It is now however possible to confirm that a marked thickening of the sediments in a general North to South direction exists only in the Upper Katangan so that it is only the Kundelungu Supergroup that exhibits some characteristics of a "geosyncline" (Cahen, 1954; François, 1973; *op. cit.*).

For a long time the tectonic deformation of the Katangan was ascribed, explicitly or implicitly, to a single tectonic phase, the Lufilian folding ("Lufilische plooing" of Van Doorninck, 1928) or the Kundelungan folding ("plissement kundelungien" of Robert, 1940). During the last thirty years, awareness of a more complex situation arose (Robert, 1940; Cahen, 1954) and it is now certain that several folding phases have contributed to the complex tectonics of the Lufilian Arc (Demesmaeker *et al.*, 1963; Cahen, 1970; Drysdall *et al.*, 1972; François, 1973; *op. cit.*).

In the southern Shaba basin of deposition, what was originally called by Van Doorninck "de Lufilische plooing" is made up of at least six successive phases all connected with the Kundelungu Supergroup and which together constitute the Lufilian orogeny. The Middle and Lower Katangan in the same area do, perhaps, show some slight disconformities but in this area no important deformation is known prior to and distinct from the Lufilian orogeny (*op. cit.*).

The situation nearer the Kibaride Belt and on both sides of it is different. Here the Lufilian orogeny is weaker and in some areas, non-existent; earlier tectonic movements, on the other hand, are detectable and sometimes important.

The Lower Katangan is affected by at least three relatively important phases of deformation. The first, affecting the lowest group of the Lower Katangan is undated and is probably to be considered as a last phase of the Kibaran orogeny (Cahen, 1970; *op. cit.*) but the last two are distinct episodes of an orogeny the importance of which has been recognized only recently (Lepersonne, 1973; *op. cit.*). The local manifestations of this orogeny can be called the Lomamian orogeny and it is dated at about 940 million years (m.yr.) ([2]).

The movements which affected the Middle Katangan as a whole are linked to the formation of the "geosyncline" and are therefore classified as the first phase of the Lufilian orogeny. This phase is probably dated at about 885 m.yr. or a little earlier (see appendix 1). The various fold phases of the Lufilian orogeny are distributed within the time range: *circa* 885 m.yr. to *circa* 620 m.yr. (Cahen, 1970*a*; *op. cit.*).

Stratiform copper is known in minor quantities in beds of the Upper and Middle Katangan. The important stratiform deposits both in southern Shaba and in the Zambia Copperbelt are however in strata belonging to the Lower Katangan.

Beds of Lower Katangan age are known not only in the basin of deposition situated to the south-east of the Kibaride Belt, e.g. southern Shaba which is continuous with the Copperbelt of Zambia, but also in several other basins: to the

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([2]) All radiometric ages are commented on in appendix 1.

TABLE 1. — *Stratigraphy of*

| | Bushimay-Luilu Area (eastern Kasai) (after RAUCQ, 1970, p. 61) | | |
|---|---|---|---|
| | Lava | | |
| B II Group (1 020 m) | B II*e*. | Zoned limestones and stromatolithic limestones . . . . . | 100 m |
| | B II*d*. | Dolomites and cherts . . . . . . . . . . . . . . . . . | 400 m |
| | B II*c*. | Stromatolithic dolomites and shales . . . . . . . . . . . | 291 m |
| | B II*b*. | Intraformational brecciae . . . . . . . . . . . . . . . . | 125 m |
| | B II*a*. | Stromatolithic dolomite . . . . . . . . . . . . . . . . . | 105 m |
| | Sharp sedimentological break ([a]) | | |
| B I Group (420 m) | B I*e*. | Dolomitic shales and silts, overlain by sandstones . . . . | 44 m |
| | B I*d*. | Micaceous sandstones, sometimes dolomitic . . . 58 m<br>Sandstones and micaceous sandstones . . . . . . 150 m | 208 m |
| | B I*c*. | Shales, micaceous shales sandstones, sandstones and conglomerates . . . . . . . . . . . . . . . . . . . . . . . . | 150 m |
| | B I*a*/*b*. | Conglomerates . . . . . . . . . . . . . . . . . . . . | 17 m |
| | UNCONFORMITY | | |
| | Pre-Katangan Basement. | | |

([a]) In the folded area, along the Lomami river, an important lava flow underlines this break.

| Lovoy Basin (Shaba) (modified after DUMONT, 1971) | | | | |
|---|---|---|---|---|
| *N. B.* | Formations B 0*a* to B 0*d* are described from the Makukulu Massif, B I*e* to B II from the Kiankodi Valley area. | | | B II Group (> 800 m) |
| B II. | Over 800 m of carbonate rocks observed in the Mwelwe Valley. In the Kiankodi Valley, all formations B I*a* to B I*e* are present, but their thickness is undetermined. | | | B II Group (> 800 m) |
| | Sharp sedimentological break ([a]) | | | |
| B I*e*. | Dolomitic shales and silts, sandstones and brecciae, silicified rocks | | 50 m | B I Group (c. 1 270 m) |
| B I*d*. | Kibudi sandstones and siltstones. Mauve, beige and dark red feldspathic micaceous sandstones and siltstones. | | 450 m | B I Group (c. 1 270 m) |
| B I*c*. | Mainly red sandstones and quartzites | | over 420 m | B I Group (c. 1 270 m) |
| | B I$c_2$. Red sandstones and quartzites with irregularly distributed lenses of pebbles | over 300 m | | B I Group (c. 1 270 m) |
| | B I$c_1$. Light-coloured quartzites, generally white or beige | 120 m | | B I Group (c. 1 270 m) |
| B I*a*/*b*. | Upper Lumafumbo conglomerates | | 350 m | B I Group (c. 1 270 m) |
| | B I$a/b_2$. Conglomerate with large clasts of red to orange sandstones (90 %) and quartz and light-coloured quartzite pebbles | 150 m | | B I Group (c. 1 270 m) |
| | B I$a/b_1$. Red to orange sandstone with interbedded conglomerates with quartz (50 %), quartzite and slate (50 %) pebbles | 200 m | | B I Group (c. 1 270 m) |
| | DISCONFORMITY | | | |
| B 0*b*. | Lower Lumafumbo conglomerates | | 660 m | B 0 Group (c. 1 260 m) |
| | B 0$b_4$. White to pink quartzite | 100 m | | B 0 Group (c. 1 260 m) |
| | B 0$b_3$. Red to orange sandstones | 160 m | | B 0 Group (c. 1 260 m) |
| | B 0$b_2$. Red conglomerate with millimeter-sized quartz grains dominant | 240 m | | B 0 Group (c. 1 260 m) |
| | B 0$b_1$. Conglomerate containing large quartz clasts (95 %) and light-coloured quartzites | 160 m | | B 0 Group (c. 1 260 m) |
| B 0*a*. | Mukebo quartzites. Red to orange fine-grained sandstones to siltstones, with interbedded shales; one bed of brownish red to mauve pink chert (less than 1 m thick). | | 500 to 600 m | B 0 Group (c. 1 260 m) |
| | UNCONFORMITY | | | |
| Pre-Katangan Basement. | | | | |

north-west of the Kibaride Belt (Bushimay Supergroup), in north-eastern Shaba (Marungu Supergroup) as also outside Shaba.

We are here concerned only with the Lower Katangan of the Bushimay basin of deposition and that of the Lufilian Arc in southern Shaba and of that portion of the Copperbelt which occurs in south-eastern Shaba.

## 2. THE LOWER KATANGAN (BUSHIMAY SUPERGROUP) OF THE BASIN OF DEPOSITION TO THE NORTH-WEST OF THE KIBARIDE BELT

The Bushimay Supergroup comprises over 3 000 m of metasediments subdivided into three groups designated by B 0, B I and B II (see table 1). It covers large areas of north-western Shaba and eastern Kasai (fig. 1).

Its stratigraphy has been well studied in the mainly flat-lying beds of western Shaba and eastern Kasai (Polinard, 1925; Cahen and Mortelmans, 1947; Raucq, 1957, 1970; Dumont, 1971). Only the western margin of an important folded area in north-western Shaba has been reconnoitred in the field (Cahen and Mortelmans, 1947); the rest of it has only been mapped by photogeology (Lepersonne, 1973) although some prospecting parties have traversed it (Reid in 1920 and Lombard in 1955).

The Bushimay Supergroup rests unconformably on pre-Kibaran units and on the Kibaran; in western Shaba it is disconformably overlain by the late Palaeozoic Lukuga Series (Lower Karroo). In the vicinity of the Kibaride Belt, the Bushimay Supergroup is older than the base of the Makonga Conglomeratic Complex which comprises pebbles of late- and post-Bushimay intrusives; its partial equivalent, the Nonda Group, is unconformably overlain by the Makonga Complex (Dumont, 1971; *op. cit.*). The lower subdivision of the Makonga Complex corresponds to the Mwashya Group (see appendix 3).

Group B I rests on Group B 0 with a marked disconformity whereas B I is separated from B II by a sharp change of sedimentation probably corresponding to a hiatus, locally underlined by an important lava flow in the Lomami river area. Cahen (1970) has shown that Group B 0 and probably part of the conglomeratic basal portion of B I, which are restricted to a relatively narrow trough alongside the Kibaride Belt, represent molasse of the latter belt (see also Cahen and Lepersonne, 1967; Raucq, 1970; *op. cit.*). The rest of B I and B II consist of deposits produced during the slowing down and cessation of the uplift of the Kibaride Belt (Cahen, 1970; *op. cit.*).

The top subdivision of B I, B I*e* should perhaps be separated as, like B II, it is of approximately uniform thickness from east to west whereas the rest of B I diminishes markedly in the same direction.

Two important basaltic amygdaloidal lava flows are known; the older approximately at the limit between B I and B II in the folded area, along the Lomami river, the younger, accompanied by dolerite necks, at the top of the sequence, just above subdivision B II*e* on which it rests disconformably in the flat-lying area of eastern Kasai. Gabbros with micropegmatites intrude the entire Bushimay succession (Raucq, 1957, 1970; Dumont, 1971; *op. cit.*).

*Chronology.* — Some radiometric data and a study of the Bushimay columnar stromatolites (Bertrand-Sarfati, 1972) yield concordant information on this subject (see table 2).

TABLE 2. — *Chronological data connected with the Bushimay Supergroup*

| Radiometric data in western Shaba | Radiometric data from Mauritania ([a]) correlation based on columnar stromatolites |
|---|---|
| At top of Bushimay Supergroup; just above B II*e*: amygdal. lava: 938 ± 15 m.yr. | |
| | B II*e*: a little younger than 909 ± 37 m.yr.<br>B II*c*: a little older than 909 ± 37 m.yr.<br>B II*a*: between 909 ± 37 and 1 019 ± 36 m.yr.<br>Base of stromatolite beds: 1 019 ± 36 m.yr. |
| B I*e*, top of B I Group, 20-30 m below the stromatolite beds: syngenetic lead: *c.* 1 055 m.yr. | |
| Base of B 0 Group, younger than syntectonic gneisses of the Kibaride Belt: *c.* 1 310 m.yr. | |

([a]) CLAUER (1973). CLAUER and BONHOMME (1972) (recalculated with $\lambda\ ^{87}Rb = 1.39 . 10^{-11} . yr.^{-1}$).

The Bushimay Supergroup is comprised between the age of the terminal lavas: 938 ± 15 m.yr. (Cahen and Snelling, in preparation) and the folding of the Kibaran which occurred at *circa* 1 310 m.yr. (Cahen, Delhal, Deutsch, 1972). An intermediate common-lead model age of 1 055 m.yr. on syngenetic galena is well substantiated by the results of the study of the stromatolites (appendices 1 and 2).

The stromatolites of formations B II*a*, B II*c* and B II*e* have been correlated with those of the Mauretanian Adrar by Bertrand-Sarfati (1972). Some of the beds of this Mauretanian group have been dated by Clauer and Bonhomme (1971) and Clauer (1973); Cahen (1973) has shown that the results obtained by radiometric and palaeontological methods are comparable (table 2).

On the basis of the age data and of direct comparison of the stromatolites (Bertrand-Sarfati and Raaben, 1970) it is concluded that Group B II corresponds to the lower part of the Upper Riphean of the U.S.S.R. whereas Groupe B I and B 0 correspond to the Middle Riphean (Cahen, 1973). The limit between Upper and Middle Riphean appears to be imperfectly dated but may be taken at about 1 050 m.yr. which corresponds to the contact between B II and B I*e*, the latter bearing the stratiform lead mineralization.

*Mineralization.* — Two areas have been assayed for their mineral content and found to be economically uninteresting: a little to the south of the Lubi-Lukula confluence (23° 20′ E-6° 00′ S) visible copper, zinc and lead are known (Polinard, 1929; Raucq, 1957, 1970) and near the confluence of the Luwishi and Luembe rivers (24° 15′ E-7° 00′ S) a second area contains iron (Raucq, 1970) and some lead.

The Lubi area has yielded some copper and zinc secondary mineralizations; pyrite is found in B I$e_1$ and B I$e_2$ as also locally in B I$c_1$. A more remarkable lead mineralization consists of stratiform galena in B I$e_1$. It has been shown to extend over several kilometers. Raucq (1957) shows this mineralization to be syngenetic.

In the Luembe area, drillings at Kafuku-Tshimboko have shown that pyrite (the name may cover other sulfides) has a stratiform habit and is specially to be found in B I$e_1$ and B I$e_2$ ; iron oxydes are found in B I*d* (Raucq, 1970). Although Raucq does not mention it, galena has been found in this area. It consists of irregular impregnations in carbonate rocks of B II; it is considered to be epigenetic (Timmerhans, personal communication).

Isotope studies of the two lead occurrences confirm Raucq's views for the Lubi galena and those of Timmerhans for the one from Kafuku-Tshimboko (Cahen and Snelling, 1966; see also appendix 2).

Occasionally pyrite and chalcopyrite have been met at various levels of Group B II (Raucq, 1957, p. 105). An idea of the distribution of several trace elements is also given by Raucq (1957, p. 51).

The non-economical primary mineralization in the Bushimay Supergroup is thus markedly stratiform. It is mostly concentrated in formations B I$e_1$ and B I$e_2$. In the former, a relatively important lead (galena) stratiform mineralization is syngenetic.

## 3. THE LOWER KATANGAN (ROAN SUPERGROUP) OF THE BASIN OF DEPOSITION TO THE SOUTH-EAST OF THE KIBARIDE BELT

The important copper-producing districts of South Shaba (between Lubumbashi and Kolwezi, Zaïre) and of the Copperbelt of Zambia and south-east Shaba (to the south-east of Lubumbashi) belong here. Usually these two districts have been considered separately as if they belonged to two separate basins of deposition, and indeed there are notable differences between the two areas. As examination of a geological map shows, the groups in each of these areas merge into each other and, rather than two distinct basins they belong to two portions of a single basin.

In each of the copper-producing districts, traditional nomenclature is on a purely lithological basis, the emphasis being placed on the ore-bearing strata, other strata being grouped as formations in relation with the former.

Furthermore the ore-bearing, footwall, and hangingwall formations have naturally been studied in more detail than formations with less economic importance. This, and certain natural differences and difficulties have precluded precise correlation between the stratigraphical columns of these districts.

Two hypotheses have been put forward by R. Oosterbosch (1962):

"Up to the present it has been thought that the mineralized horizons of Katanga are situated above those of the Copperbelt; it is however not excluded that they are at the same stratigraphical level."

The Roan Supergroup of the southern Shaba copper-district rests unconformably on rocks of the Kibaride belt in the vicinity of Kolwezi and further along the southeastern margin of this belt near latitude 9° S. It is overlain by the Mwashya with apparent conformity in southern Shaba and disconformably in Central Shaba (*op. cit.*, see appendix 3).

In the Copperbelt, the Roan Supergroup rests unconformably on basement rocks the youngest of which belong to the Muva unit which was folded during the Kibaran orogeny and is in part included in the Irumide Belt which is coeval with the Kibaride Belt. The Mwashya Group rests on the Roan Supergroup (Mendelsohn, 1961; *op. cit.*).

Thus, in both areas, the Roan is comprised within the same limits.

In table 3, the stratigraphical columns of the Lower Roan in these two areas are compared.

The first order subdivision differs in part from the traditional subdivision. Some formations also differ. The symbols used in southern Shaba mines for each formation and for some members are also given.

In each of the two districts, the Lower Katangan is subdivided in four groups, the lowest group being better known in the Copperbelt than in southern Shaba. On the other hand, the upper portions of the succession appear to be better known in the latter district.

*In the Copper belt of south-east Shaba*, the successions given are those of Musoshi and Kinsenda mines. They are easily compared to those of the more important Zambian portion of the Copperbelt. The succession of groups is, in ascending order: (1) Musoshi Group; (2) Ore-body Group; (3) Kinsenda Group; (4) "Silicified oolite" Group.

The Lower Katangan is deposited on an irregular topography with granitic hills. The Musoshi Group is the infilling of the hollows between these hills. The Ore-body Group rests with marked overlap on the Musoshi Group; its base, the Footwall Conglomerate rests either on the Musoshi Group or, as at Kinsenda, on Basement Granite which, as elsewhere on the Copperbelt (Mendelsohn, 1961, p. 48), has been abraded to form the Conglomerate.

At the top of the Ore-body Group, one finds alternating, silts, sandstones and quartzites with dolomites. These are shallow water deposits (see Van Eden and Binda, 1972). The base of the overlying Kinsenda Group consisting of arkoses or of feldspathic quartzites is in sharp contrast to the dolomitic higher levels of the Ore-body Group.

It is possible that at Musoshi a break exists in formation 2 (table 3) as a feldspathic conglomerate is interbedded in the mass of the feldspathic quartzites (Cailteux, 1972).

Cahen (1970) has shown that the basal beds of the Copperbelt Roan Supergroup were sediments derived from uplift and erosion of rocks which were elevated at the same time as the Kibaride and Irumide belts, these sediments were deposited in a transgressive sea (Van Eden and Binda, 1972). The terrigenous character of the sequence decreases upwards, but with some oscillations.

Gabbro sills, in what is here called the Kinsenda Group, are known in Zambia, sometimes occupying a high position in the Group (Mendelsohn, 1961, p. 51).

The "Silicified oolite" Group exists but is hardly ever mentioned being included either in the "Upper Roan" or in the Mwashya and having been very little studied, although rocks characteristic for the group are occasionally mentioned.

No post-Roan tectonic phase, independent of the Lufilian orogeny has been detected.

| | 1. Copper District of southern Shaba<br>Composite succession: OOSTERBOSCH (1962), FRANÇOIS (1973), LEFEBVRE (1973) | | |
|---|---|---|---|
| Kansuki Group (over 350 m) | R.4.1. | Black silicified oolites and associated jaspers (25 m); alternation of more or less magnesian limestone with micaceous silty phyllites; numerous hematite-bearing beds; locally, pyroclastic rocks (Dipoy pyroclastics) | c. 350 m |
| Dipeta Group (over 700 m) | | HIATUS | |
| | R.3.4.2. | Light-coloured dolomites with stromatolites (Dp. IV B) | over 40 m |
| | 1. | Mauve, hard micaceous silts (Dp. IV A) | c. 60 m |
| | R.3.3.2. | Light-coloured dolomites and marly dolomites; sandy ferruginous dolomites at base; oolitic horizons (Dp. III B) | c. 170 m |
| | 1. | Grey to violet, sometimes yellow to green silts (Dp. III A) | over 120 m |
| | R.3.2.2. | Dolomite with silts, stromatolites (Dp. II B) | c. 20 m |
| | 1. | Grey to violet silts (Dp. II A) | c. 30 m |
| | R.3.1.2. | Grey dolomites with stromatolites alternating with silts and shales (Dp. I B) | c. 120 m |
| | 1. | Coarse, medium or fine-grained feldspathic quartzites, with silty and dolomitic beds (R.G.S. or Dp. I A) | c. 35 m |
| Mines Group (100 to 300 m) | R.2.3. | Light coloured dolomite and coarse-grained dolomitic sandstones.<br>Grey and dark dolomites with black shales and feldspathic and conglomeratic sandstones (C.M.N.) | 50-125 m |
| | R.2.2. | Shales and siltstones, usually dolomitic, stromatolites (S.D.) | 35-90 m |
| | R.2.1.3. | Siliceous dolomite with micaceous shales stromatolites (R.S.C.) | 20 m |
| | 2. | Stratified siliceous dolomite (D. strat. R.S.F.) | 7-9 m |
| | 1. | Chloritic and dolomitic silts, locally with conglomerate at base (R.A.T. grises) | 0.5-3 m |
| | | OVERLAP? | |
| Lower Group (over 500 m) | R.1. | Reddish chloritic and dolomitic sandstones and siltstones (R.A.T. rouges) | 225 m |
| | | HIATUS | |
| | | Quartzites and silts.<br>Conglomeratic complex (Nzilo conglomerate) | c. 300 m |
| | | UNCONFORMITY | |
| | Kibaran | | |

*Column 1.* There are a certain number of gaps in the succession (*a*) in the Lower Group; (*b*) in the Dipeta Group, the exact position of what is here called R.3.3 relative to R.3.2 is uncertain, as also the relation between R.3.4 and the dolomites at the base of the Dipoy pyroclastics.

*Column 2.* GYSIN (1936) gives a general description, JAMOTTE (1946) gives a precise description of the 500 m

| Copper belt (south-east Shaba) | | |
|---|---|---|
| 2. *Kinsenda* [after GYSIN, 1936, Nos. 1-7; JAMOTTE, 1946, Nos. (1)-(9)] | 3. *Musoshi* (after VAES, 1962; SODIMIZA, *in* CAILTEUX, 1972) | |
| | | "Silicified oolite Group" |
| Top portion undescribed<br>7. (9) Observational gap *c.* 134 m<br>(8) Ferruginous dolomites . . . . . . 117 m<br>(7) Massive blue dolomites . . . . . . 46.5 m<br>(6) Marls with brown biotite . . . . . . 37 m<br>(5) White pyrite-bearing dolomite . . . 56.5 m<br>(4) Dolomites and dolomitic limestones with green biotite 23 m<br>6. (3) Grey siliceous dolomites . . . . . 54 m<br>(2) Graphitic shales . 8 m<br>(1) Talc-bearing white dolomites . . . . 24 m<br>Silts and dolomitic quartzites (total thickness of 6: *c.* 200 m) . *c.* 110 m<br><br>5. Feldspathic sandstones, more or less silty, in alternation with coarse arenaceus, and with dolomitic, beds . . . . . . . . . 130 m | "Dolomitic complex" 700-1 000 m<br><br>11. Silts, sandstones, with interbedded grits . . 60 m<br>10. Silts, dolomitic silts . 125 m<br><br>9. Arkosic complex II. Arkose, sandstone and silt . . . . . . 80 m | Kinsenda Group (950-1 250 m) |
| 4. Feldspathic and sericitic quartzites . . . . 7 m<br>3. Feldspathic and conglomeratic quartzites . 60 m | 8. Dolomitic sandstone (Little dolomite) . . 40 m<br>7. Arkosic complex I. Alternating arkoses and argillites or silts 75 m | Orebody Group (185 m) |
| 2. Feldspathic quartzites, sericitic silts . . . . . 29 m<br>1. Sericitic quartzites, feldspathic quartzites, conglomerates . . . . 42 m | 5/6. Sandy silts and silts (Ore formation) . . 25 m<br>4. Arkosic conglomerate (Footwall conglomerate) . . . . . 40 m | |
| UNCONFORMITY | DISCONFORMITY | |
| | 3. Sandstones and coarse sandy silts with argillaceous matrix . . . . . . . 290 m<br>2. Feldspathic quartzite, with sandstones and conglomerates . . . 450 m<br>1. Conglomeratic complex . . . . . . . . 300 m | Musoshi Group (1 040 m) |
| | UNCONFORMITY | |
| Kinsenda granite | Konkola granite | |

[formations (1) to (9)]. These correspond to subdivision 7 and the top of subdivision 6 of Gysin. The base of Jamotte's section in Kinsenda boreholes corresponds to the top of formation 11 of Musoshi.

*Column 3.* The thicknesses of the beds are variable. Those given here are taken from VAES (1962) in the western portion of Musoshi; the thicknesses given by CAILTEUX (1972) are very similar.

*The southern Shaba Copper district* follows the general trend of the Lufilian Arc from Lubumbashi to Kolwezi, to the north-west of the Copperbelt.

Owing to the intricate tectonics of this part of the Lufilian Arc, no complete succession of the rocks of the Lower Katangan Supergroup is known. The upper portion of the succession is, despite hiatuses in the sequence, fairly completely known but only a small portion of the lower part is seen either in outcrop or in drill holes. An interruption of unknown magnitude separates the base of the supergroup from the rest.

The base of the Roan rests unconformably on the Kibaride Belt. It consists of over 300 m of basal conglomerate, normally with a quartzitic matrix and is locally surmounted by quartzites and siltstones. The outcrops are overlain with slight unconformity by conglomeratic beds belonging to the Middle Katangan Luilu Complex *(op. cit.*; see appendix 3) and elsewhere probably by the Mwashya Group (François, 1973). When the basal or Nzilo Conglomerate is followed towards the north-east, areas are reached (latitude 9° S) where it is conformably surmounted by pelitic and carbonate rocks which together with the conglomerate, form the Kantanta Group (Cahen and Lepersonne, 1967; *op. cit.*) itself unconformably followed by the Kitondwe Group containing the well-known black silicified oolites or pisolites.

In southern Shaba, the beds that immediately overlie the conglomerate and associated beds are unknown. The succession is that of table 3 in which the formations are given the symbol by which they are known in the Gecamines concessions.

A subdivision in four groups is indicated, from the base upwards: (1) Lower Group; (2) Mines Group; (3) Dipeta Group; (4) Kansuki Group.

Of the Lower Group, only the base (*circa* 300 m) and the top 225 m are known. The latter 225 m are, in the mines, separated by a tectonic breccia from autochtonous Upper Kundelungu over which they are thrust (François, 1973).

A break in the sedimentation separates the Lower Group from the Mines Group, the base of which is taken at a possibly local coarse grained conglomerate, heralding shallow water deposits (Bartholomé, 1972).

The Mines Group, locally known as "Série des Mines," ends with the dolomitic "calcaire à minerai noir" which is succeeded by feldspathic sandstones, sometimes coarse-grained, more often medium-, sometimes fine-grained, which are taken as the base of the Dipeta Group. This group consists of repeated sequences of sandy and dolomitic pelitic rocks followed by silty dolomites.

The Dipeta Group is followed by the Kansuki Group which carries the characteristic silicified oolites or pisolites, similar to those met with in the "Silicified oolite" Group of the Copperbelt and in the Kitondwe Group of northern Shaba. Although the contact between the Dipeta and Kansuki Group is generally obscured by tectonic phenomena and is thus virtually unobserved in southern Shaba, the Kansuki Group is considered as a separate group because its northern equivalent, the Kitondwe Group overlaps on to the pre-Katangan basement. A complex of pyroclastic rocks has recently been described by Lefebvre (1973); it is situated in the Kansuki Group. This group is often called "Lower Mwashya" (see appendix 3); but the occurrence of these vulcanites which reach almost to the top, near the contact with the Mwashya Group, underlines the separation between Roan or Lower Katangan and Mwashya, base of the Middle Katangan.

The correlation between the two groups of successions of table 3 is not, at present, substantiated either by radiometric data or by palaeontology. Nevertheless it is thought that the correspondence is that indicated in table 3, for the following reasons:

1. The entire sequences are in both areas comprised between the same limits (Kibaran folding and Middle Katangan).

2. The basal beds are in both areas products of the erosion of the Kibarides, of the Irumides and of older rocks uplifted at the same time as these belts during the first stage of a transgression common to the entire south-eastern basin of deposition; the terrigenous character of the basal groups decreases upwards.

3. Each initial group is surmounted disconformably by a transitional group, comparatively thin, arenaceous and pelitic, marked by the appearance of carbonate which increases upwards. These transitional groups are mainly shallow water deposits.

4. The predominantly carbonate-bearing groups which follow (Dipeta and Kinsenda) are approximately the same thickness and are surmounted by the top groups carrying pelitic formations with some arenaceous beds, some dolomites, and the characteristic silicified oolites.

5. The successive sedimentary episodes correspond to each other as is normal in a single basin. This scheme corresponds to Oosterbosch's second hypothesis of 1962.

*Chronology.* — The Roan Supergroup is younger than the main phase of folding of the Kibaran, thus later than *circa* 1 310 m.yr. The radiometric data obtained on rocks and minerals in the Roan are linked with the Lufilian orogeny, connected with the Kundelungu Supergroup. The oldest is the age of microcline in veins at or near the base of the Roan Supergroup at Musoshi and at Roan Antelope, 888 m.yr. (see appendix 1). This age is connected with the development of the Lufilian "geosyncline" and thus distinctly postdates the Roan. Nevertheless it is the best radiometric "younger" limit available for the Roan Supergroup proper.

Stromatolites are known at various levels of the Copperbelt succession, but their systematics have not been studied. A preliminary study of the stromatolites in the Roan of the southern Shaba Copper district has been carried out by Raaben (*in* François, 1973). The results of this study have been compared by Cahen (1973*b*) to those of Bertrand-Sarfati (1972) on the Bushimay stromatolites. No detailed direct comparison can be made as yet but the result is nonetheless promising: the Mines Group carries stromatolites of the Middle Riphean of the U.S.S.R. whereas the Dipeta Group would belong to the Upper Riphean. In other words and taking into account the imprecision of the dating of the boundary between the Middle and Upper Riphean, the boundary between Mines Group and Dipeta Group is approximately dated at circa 1 050 m.yr.

*Mineralization.* — Several papers contributed to this symposium deal with the mineralization in the Copperbelt and in southern Shaba. It shall here simply be underlined that the main copper-cobalt stratiform mineralizations are, in the Copperbelt, found in the Ore-body Group and in southern Shaba, in the Mines Group. These groups, as a consequence of our correlation between the two areas, correspond to each other (see table 4), and each may be subdivided in two main units, the ore being concentrated in the lower unit. The mineralization is found in beds of shallow water origin, deposited in the vicinity of the coast (Oosterbosch, 1962; Bartholomé, 1972; Van Eden and Binda, 1972).

TABLE 4. — *The Lower Katangan compared tothe post-tectonic history of the Kibaride Belt*

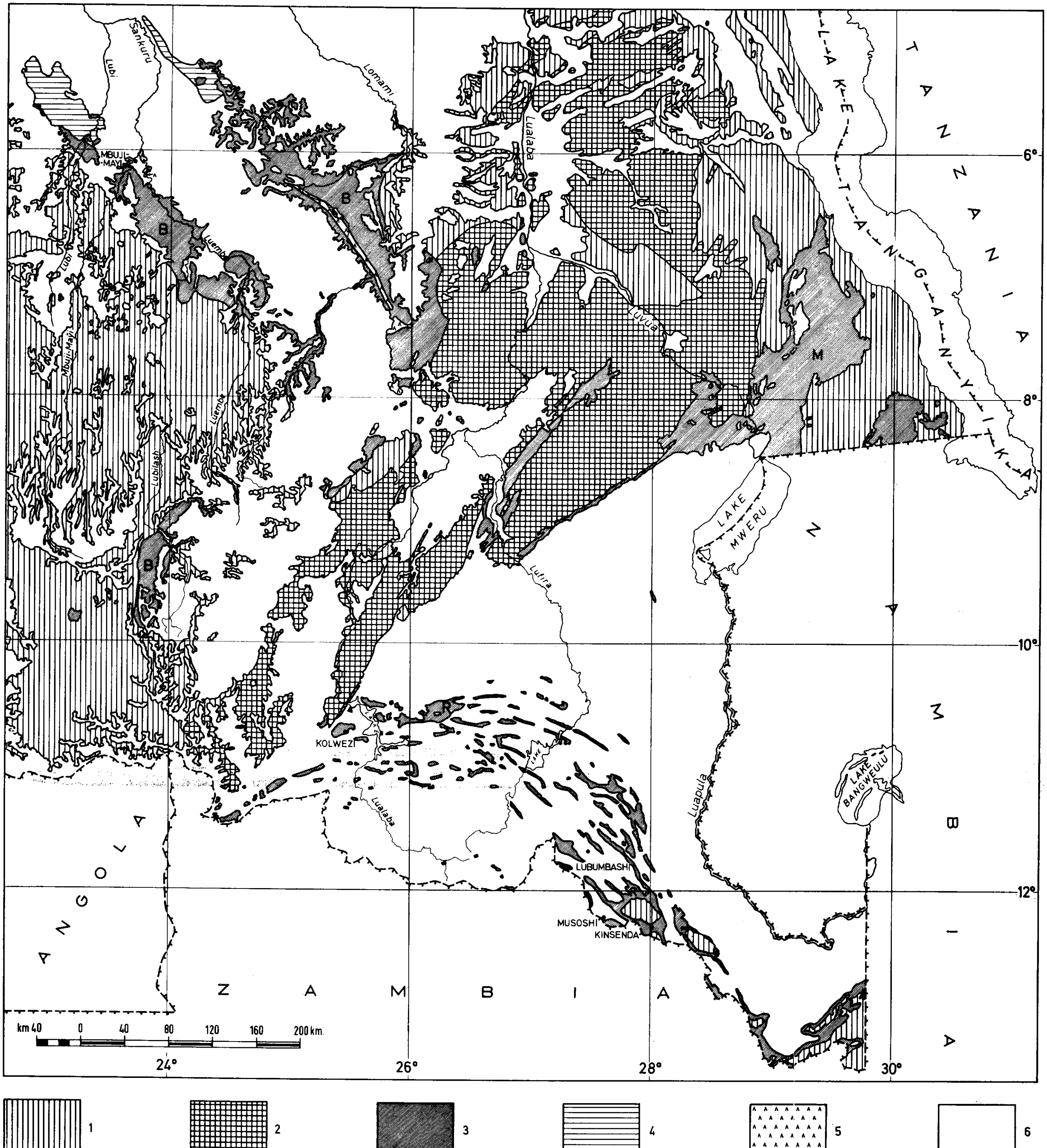
| Age (1) (million years) | North-west Shaba Bushimay Supergroup (2) | Kibaride Belt (3) | | Copper District of southern Shaba (4) | Copperbelt of south-east Shaba and Zambia (5) | Sedimentation (6) | Sub-division of Katangan (7) | U.S.S.R (8) |
|---|---|---|---|---|---|---|---|---|
| 800 | | 883m.yr. Isotopic blocking of biotites (Shaba) | uplift in relation to the Lufilian Orogeny | | 888m.yr microcline veins at base of Roan | | UPPER KATANGAN | UPPER RIPHEAN OF U.S.S.R. (strom) |
| 900 | | (905m.yr.) Veins (Shaba) | post-Lomamian uplift | | | | | |
| | Lomamian Orogeny<br>938m.yr. Amygdaloidal basalt | | oscillations | Grand Conglomérat Group<br>Mwashya Group | Grand Conglomérat Group<br>Mwashya Group | pelitic arenaceous (glacio-marine) | MIDDLE KATANGAN | |
| | | | | Mofya Group+Dipoy pyroclastics(strom) | "Silicified oolite" Group | transition | LOWER KATANGAN | |
| 1000 | B II Group c. 1020m: B II *e* (*Strom.*), B II *d*, B II *c* (*Strom.*), B II *b*, B II *a* (*Strom.*) | c.970 m.yr "tin" pegmatites and granites (Shaba) | sinking; stability | Dipeta Group (R.3) over 700m up to 1000?m: R.3.4 (strom), R.3.3, R.3.2 (strom), R.3.1 (strom) | Kinsenda Group c. 950 - 1250 m (strom) | predominantly carbonate sedimentation | | |
| | Amygdaloidal basalt<br>(1055 m.yr.) Syng Pb: B I *e* (Min.) *c.* 50m | 1048 m.yr. veins (Shaba and Kivu)<br>1082 m.yr. granite (Rwanda) | oscillations | Mines Group (R.2) (strom) 100 - 300m (Min.) | Ore-body Group (strom) c. 185 m (Min.) | transition nearshore | | MIDDLE RIPHEAN OF U.S.S.R. (strom) |
| | | | | overlap ? | overlap | | | |
| 1100 | B I Group c. 1270m: B I *d*, B I *c*, B I *a.b* } c.1220m | 1163 m.yr. pegmatite (Kivu) | sinking; decreasing uplift | Lower Group (R.1) over 500 m (top part: strom) | Musoshi Group c. 1040 m: 3, 2, 1 | Predominantly arenaceous sedimentation with some oscillations coarser → to finer | | |
| 1200 | disconformity | | | | | | | |
| | B0 Group c. 1260 m: B0 *b*, overlap, B0 *a* | 1212 m.yr. granite (Uganda) | rapid uplift | | | | | |
| 1300 | main tectonic | c.1310 m.yr. Syntectonic granite (Shaba etc.) | | phase of Kibaran | Orogeny | | | |

(*a*) Figures such as 938 which precede the indication of an intrusion (etc.) are ages expressed in million years.

## 4. CONCLUSION

Paradoxically, the correlation between the Bushimay Supergroup and the Roan Supergroup of the Copper district of southern Shaba (columns 2 and 4 of table 4), that is in two almost completely separate basins, is in some respects better established than that which has just been discussed between the two portions of the south-eastern basin of deposition (columns 4 and 5). Nevertheless it is difficult to escape from the latter correlation in view of the striking parallelism between the depositional histories of both basins north-west and south-east of the Kibaride Belt and the movements of this belt itself as deduced from the dating of various intrusive bodies (column 3).

The Bushimay succession begins with the deposition of Group B 0 which is not known to be represented in the Roan basin: it consists of the molassic infilling of the foredeep trough of the Kibaride Belt. This may also be the case for part of B I*a*/*b* but the remainder of the latter formation represents, as do the Nzilo Conglomerate at the base of the Lower Group of southern Shaba and the basal conglomerate of the Musoshi Group of the Copperbelt, the first stage of a trans-




*1, Pre-Kibaran basement; 2, Kibaride Belt; 3, Lower Katangan; 4, Lower Katangan under Cretaceous cover; 5, basalts linked with Lower Katangan; 6, all formations younger than Lower Katangan. B, Bushimay Supergroup; M, Marungu Supergroup; R, Roan Supergroup (after J. Lepersonne, 1974. Carte géologique du Zaïre au 1/2 000 000).*

gression, the age of which is unknown although, for reasons outside the scope of this paper, it is unlikely to be earlier than 1 230 m.yr. It is here arbitrarily placed at 1 200 m.yr.

Each uplift of the Kibaride Belt is accompanied by deposition of arenaceous sediments, the terrigenous character of which decreases as the uplift slows down. Slight sinking of the belt, marked by post-tectonic granites, brings, in all basins, decrease of arenaceous sedimentation, increase of pelites and introduction of a carbonate component; this is followed by a more or less stable period (see appendix 1) marked by predominantly carbonate deposition; finally the early stages of the Lomamian orogeny are marked by volcanic activity and an increase of pelitic and arenaceous sedimentation which heralds the advent of the Middle Katangan, consequence of the post-Lomamian uplift of the Kibaride Belt.

In each of columns 2, 4 and 5, the stratiform mineralization appears at the same general level. For the Bushimay Supergroup (column 2) and the Roan of the southern Shaba Copper district (column 4) this is shown by the study of columnar stromatolites which indicates that the boundary between the Upper and Middle Riphean of U.S.S.R. is situated in both cases just above the mineralized beds. This is in keeping with the model age of the syngenetic lead mineralization in the B I*e* Formation of the Bushimay Supergroup.

It can thus be stated that the beds carrying the important copper-cobalt mineralization of these areas (and those containing an economically unimportant copper, zinc, lead mineralization in the Bushimay) are about 1 050-1 100 m.yr. old, which is also the age of the latter lead mineralization.

The mineralization appears in groups (or formation in the Bushimay) in which pelitic sedimentation makes its appearance or increases in importance and carbonate sedimentation appears for the first time. The ore-bearing formations were deposited near the coast in shallow water.

The mineralized groups appear at the close of the uplift of the Kibaride Belt at the end of the Kibaran orogenic cycle. The mineralization, which belongs to type 4 of Pelissonnier (1972), thus conforms to this author's conclusion linking this type of mineral deposit to the post-orogenic stage of orogenic evolution.

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# Appendix 1

## NOTES ON RADIOMETRIC AGE DATA

Note 1. — Constants used:

| | | |
|---|---|---|
| Potassium-Argon: | $\lambda_\beta$ | $= 4.72 \,.\, 10^{-10} \,.\, yr.^{-1}$ |
| | $\lambda_e$ | $= 0.584 \,.\, 10^{-10} \,.\, yr.^{-1}$ |
| | $^{40}K/K$ | $= 1.19 \,.\, 10^{-4}$ at % |
| Rubidium-Strontium: | $\lambda\ ^{87}Rb$ | $= 1.39 \,.\, 10^{-11} \,.\, yr.^{-1}$ |
| Uranium Lead: | $\lambda\ ^{238}U$ | $= 1.54 \,.\, 10^{-10} \,.\, yr.^{-1}$ |
| | $\lambda\ ^{235}U$ | $= 9.71 \,.\, 10^{-10} \,.\, yr.^{-1}$ |
| | $\lambda\ ^{232}Th$ | $= 4.99 \,.\, 10^{-10} \,.\, yr.^{-1}$ |

In most cases, rubidium-strontium ages were originally published with another constant: $\lambda\ ^{87}Rb = 1.47 \,.\, 10^{-11} \,.\, yr.^{-1}$. The original value is hereafter mentioned in brackets.

*Reviews of ages mentioned in the text and in table*

Note 2. — *c.* 1 310 m.yr. Provisional age of a syntectonic granitization in the Kibaride Belt. The best expression at present is 1 306 ± 35 m.yr. (zircons) (Cahen, Delhal, Deutsch, 1967; 1972).

Note 3. — 1 212 ± 42 m.yr. (1 146 ± 40) Rubidium-Strontium isochron age for the post-tectonic Chitwe granite southwestern Ankole (Uganda) (Vernon-Chamberlain and Snelling, 1972).

Note 4. — 1 163 ± 21 m.yr. (1 100 ± 20) Rubidium-Strontium age of microcline and muscovite from Lugusha pegmatite, southern Kivu (Zaire) (Monteyne-Poulaert *et al.*, 1962; Cahen, Delhal, Deutsch, 1972).

Note 5. — 1 118 m.yr. (1 023) Provisional Rubidium-Strontium isochron age for a post-tectonic granite (G 3 of Rwanda). Unpublished.

Note 6. — 1 055 m.yr. Model age of syngenetic lead mineralization (see appendix 2) in B I*e* (Bushimay); 1 048 m.yr. Uranium-lead age of priorite from Mitwaba, Shaba and of xenotime from Kaseti, Kivu; post-tectonic vein minerals in Kibaride Belt (Cahen, Delhal, Deutsch, 1972).

Note 7. — *c.* 970 m.yr. 970 ± 23 m.yr. (917 ± 22) Age, at the 95 % confidence level of three leucocratic "tin" granites (G 3 of Shaba) (Mwanza, Bia Mts, Bukena). At the 2 $\sigma$ level the ages are distinct: Mwanza: 1 032 ± 40 (976 ± 38), Bia Mts: 965 ± 4 (913 ± 4); Bukena: 961 ± 38 (909 ± 36) (Cahen, Delhal, Deutsch, 1967; 1971; 1972). The Kyabakonjo granite of Southwestern Uganda is 1 020 ± 60 (972 ± 57) m.yr. (Vernon-Chamberlain and Snelling 1972). Pending more precise determinations, it is uncertain wether these intrusions occurred over a single short period, around 970 ± 23 m.yr. or wether they constitute a succession of discrete events from 1 032 ± 40 m.yr. to 961 ± 38 m.yr. In the latter case it would seem that the period of stability of the Kibaride Belt between 1 048 m.yr. and *c.* 970 m.yr. was in reality a succession of relatively slight oscillations which could correspond to the sedimentological oscillations registered in the sedimentary sequences of the B II Group of the Bushimay Supergroup and the Dipeta Group of the Roan Supergroup.

The same figure conventionally expresses the age of tin pegmatites linked to the tin granites. Some measured ages are: Manono (Shaba), 978 ± 30 (925 ± 28) m.yr.; Sofwe (Shaba), 1 023 ± 32 (967 ± 30) m.yr.; Rweibango (Uganda), 1 041 ± 21 (985 ± 20) m.yr.; Rwemirio (Uganda), 999 ± 21 (945 ± 20) m.yr. Although the pegmatites are younger than their corresponding granite, the difference in age appears to be insignificant (Cahen, Delhal, Deutsch, 1967; Vernon-Chamberlain and Snelling, 1972).

Note 8. — 938 ± 15 m.yr. Potassium-Argon age of amygdaloidal basalts which end the Bushimay Supergroup. The age is the highest of three concordant or near concordant determinations, it is possible that the true age of the lavas is a little higher as one of the three specimens dated has suffered slight argon loss (Cahen and Snelling, in preparation; see also Cahen, 1970). The lava is in the flat-lying foreland of the Lomamian fold belt so that its relation to the folding is uncertain—Raucq (1957) suggests that the folding post-dates the lava. He gives evidence indicating that a disconformity exists below the lava. This disconformity is related to the Lomamian orogeny which folds the Bushimay Supergroup 100 km to the East. Evidence of syntectonic metamorphism of this age exists elsewhere in Central Africa. In West Nile and Northeast Zaire, the Mirian gneisses are 950 ± 50 m.yr. (Zircon, P. J. Leggo, 1973) and in the Rufunsa area of Zambia granites linked to an episode of folding are 945 m.yr. (Zircon, Barr and Ledent, unpublished).

Note 9. — 905 m.yr. Average model age of post-tectonic galena veins in the Kibaride Belt and of an epigenetic galena lead in the B II Group of the Bushimay Supergroup (Leads B 1 and B 2 in appendix 2). The veins are intrusive into the granites and pegmatites mentioned in note 6. Epigenetic sulfides accompany the gabbros with micropegmatites which are of post-Bushimay age. This evidence supports the average model age.

Note 10. — *c.* 885 m.yr. This figure represents (1) the average Rubidium-Strontium age of biotites in the Kibaride Belt of Shaba (883 m.yr.) (Cahen, Delhal, Deutsch, 1967) and (2) the age of microclines in veins of the Musoshi Group of the Roan in the Copperbelt: 888 ± 42 m.yr., 840 ± 40 m.yr. in Cahen *et al.*, 1970). The first represents the blocking age of the biotites during uplift of the Kibaride Belt following the Lomamian orogeny of *c.* 940 m.yr. (Cahen and Dumont, *op. cit.*). It has been shown that the age of terrigenous deposits such as molasse of a given belt is intermediate between that of the syntectonic events and the blocking age of biotites (Cahen, 1970). In this case the Middle Katangan which is, in northern Shaba, mainly the product of erosion of the Kibaride Belt during uplift following the Lomamian orogeny, is comprised between 940 m.yr. and 883 m.yr.

Whatever their origin (intrusive or metamorphic) the microclines in the veins at the base of the Musoshi Group of the Copperbelt were emplaced in their present setting at 888 ± 42 m.yr. This indicates a metamorphic environment caused by a relatively deep subsidence which can only have occurred during the early stages of the Lufilian orogeny. It is known (*op. cit*) that the earliest phase of this orogeny between the Middle Katangan and the Lower Kundelungu Group of the Upper Katangan caused (or started) the subsidence of the basin to the southeast of the Kibaride Belt and at the same time renewed the passive uplift of this belt (Cahen, 1970, *op. cit.*). The coincidence of the two ages is in keeping with these views.

This *c.* 885 m.yr. age is the earliest known relating to the Lufilian orogeny.

Note 11. — Other ages linked to this orogeny are: >706 m.yr.; 670 ± 20 m.yr.; 620 ± 10 m.yr.; younger ages such as 555 ± 10 m.yr.; 520 ± 10 m.yr.; etc., are post-tectonic. The Katangan Unit is entirely older than 620 m.yr. (Cahen, 1973).

Note 12. — The ages 909 ± 37 m.yr. (860 ± 35) and 1 019 ± 36 m.yr. (964 ± 36) are isochron ages by Clauer and Bonhomme (1972) and Clauer (1973), indicating respectively diagenesis of I 2 (Groupe du Char) and of I 5 (Groupe d'Atar of the Upper Precambrian of Mauretania). A comparison of columnar stromatolites of the Bushimay Supergroup and the Upper Precambrian of Mauretania has been carried out by J. Bertrand-Sarfati (1972) thus enabling correlations between the two groups (see Cahen, 1973).

## Appendix 2

## ISOTOPE COMPOSITION OF COMMON LEADS

Leads of four different isotopic compositions are linked to the Katangan Unit. The data in tables A, B and C are taken from Cahen and Snelling (1966).

TABLE A. — *Leads from epigenetic mineralizations linked to the last phases of the Lufilian Orogeny and post-Lufilian leads*

| | 204 Pb | 206 Pb | 207 Pb | 208 Pb |
|---|---|---|---|---|
| A 1 1 Kipushi | 1 000 | 18.35 | 15.83 | 38.51 |
| 2*a* Kiseba | 1 000 | 18.36 | 15.83 | 38.59 |
| 2*b* Kiseba | 1 000 | 18.38 | 15.81 | 38.45 |
| 3 Ndola | 1 000 | 18.38 | 15.77 | 38.72 |
| Average | 1 000 | 18.37 | 15.81 | 38.57 |
| A 2 4*a* Kengere | 1 000 | 18.13 | 15.78 | 38.17 |
| 4*b* Kengere | 1 000 | 18.12 | 15.79 | 37.98 |
| 5 Mulungwishi | 1 000 | 18.19 | 15.80 | 38.23 |
| 6 Mazabuka | 1 000 | 18.13 | 15.76 | 38.12 |
| 7 Kapiri Mposhi | 1 000 | 18.15 | 15.83 | 38.59 |
| 8 Broken Hill | 1 000 | 18.12 | 15.83 | 38.62 |
| 9 Chiwanda | 1 000 | 18.12 | 15.89 | 38.64 |
| Average | 1 000 | 18.15 | 15.81 | 38.34 |

TABLE B. — *Leads from a post-Lower Katangan (Lomamian) epigenetic mineralization and leads of similar composition in the Kibaride Belt*

| | 204 Pb | 206 Pb | 207 Pb | 208 Pb |
|---|---|---|---|---|
| B 1 1*a* Kafuku Tshimboko | 1 000 | 17.73 | 15.85 | 37.85 |
| 1*b* Kafuku Tsimboko | 1 000 | 17.71 | 15.88 | 37.51 |
| Average | 1 000 | 17.72 | 15.86 | 37.68 |
| B 2 2 Lupopo | 1 000 | 17.75 | 15.80 | 37.36 |
| 3 Mitwaba | 1 000 | 17.76 | 15.88 | 37.58 |
| 4 Little Mobale | 1 000 | 17.70 | 15.77 | 37.21 |
| 5 Mwendakombo | 1 000 | 17.56 | 15.78 | 37.51 |
| Average | 1 000 | 17.66 | 15.81 | 37.43 |

TABLE C. — *Leads from a syngenetic mineralization in the Lower Katangan (Bushimay)*

| | 204 Pb | 206 Pb | 207 Pb | 208 Pb |
|---|---|---|---|---|
| C. 1 Lubi Camp | 1 000 | 17.43 | 15.78 | 37.47 |
| 2 Senga Senga | 1 000 | 17.32 | 15.70 | 37.25 |
| 3 Gandajika | 1 000 | 17.37 | 15.81 | 37.20 |
| Average | 1 000 | 17.37 | 15.76 | 37.31 |

Calculated as single-stage leads, the model ages of leads A 1 are about 425 m.yr. old, of leads A 2, about 600 m.yr. old. These model ages are in keeping with the epigenetic nature of the galenas the majority of which are emplaced in post-tectonic veins in the Katangan; Kengere and Kipushi are in the Lower Kundelungu Group.

Lead B 1 is epigenetic (replacement in the B II Group of the Bushimay Supergroup, Lower Katangan) whereas leads B 2 are in post-Kibaran veins. The average model age is 905 m.yr. which is a little younger than pegmatite Rb-Sr ages in the same setting.

Leads C are from the syngenetic galena mineralization in B I*e* of the Bushimay Supergroup, the model age is about 1 055 m.yr. and is supported by the study of the stromatolites (see p. 63).

Without placing too much weight on these model ages, it must be noted that they are in keeping with the geological setting of the mineralizations.

It is more important to note that the lead ores found in the Lower Kundelungu Group are not remobilized from syngenetic ores such as those in the Bushimay, which are (see p. 71) about the same age as the copper-cobalt mineralization of southern Shaba.

## Appendix 3

## ON THE LIMIT BETWEEN LOWER AND MIDDLE KATANGAN

*a*) The exact correlation of the terminal beds of the Lower Katangan on either side of the Kibaride Belt is difficult to establish.

Unnecessary confusion has been introduced by various usages for the term "Mwashya." At present, two usages remain in use in southern Shaba. The mines geologists distinguish an Upper Mwashya (R.4.2) and a Lower Mwashya (R.4.1). The latter is here called the Kansuki Group, the former is the Mwashya Group in this paper.

A discontinuity between the two groups is evidenced by the presence, in the Mwashya mixtite, in the lower portion of the Mwashya Group, of pebbles belonging to the Kansuki Group. In northeastern Shaba the two groups are more distinctly separated, as the Mwashya Group rests disconformably of the Katangan Group which belongs to the lower part of the Roan Supergroup.

The contact between the Kansuki Group and the Mwashya Group is, in the southern Shaba basin of deposition, taken as the limit between Lower and Middle Katangan although the disconformity is here difficult to observe. It corresponds to an important disconformity and locally to an unconformity in northern and northeastern Shaba (*op. cit.*).

To the north-west of the Kibarides, no beds similar to the Kansuki Group are known (see *c*).

*b*) It is shown elsewhere (*op. cit.*) that the Mwashya Group is younger than the top of the Bushimay. Only a summary of this demonstration is given here. Along the southeastern margin of the Kibaride Belt lies an important complex of mixtites and greywackes, from near Kolwezi to halfway between Mitwaba and Pweto. The basal portions of these conglomeratic complexes carry pebbles and cobbles of (*a*) lava of the same type as the end Bushimay lavas; (*b*) gabbros with micropegmatites which are intrusive into the entire Bushimay Supergroup and in the Kibaran; (*c*) "tin" granites and pegmatites, *c.* 970 m.yr. old; and (*d*) silicified oolites from the Kansuki Group. The basal portions of these complexes are thus younger than the entire Bushimay and Roan Supergroups. They are also younger than the Lomamian folding, some of the underlying Lower Katangan Groups being distinctly folded or faulted prior to deposition of this complex.

The two lower formations (Lower Mixtite and Lower Greywacke) of the "Makonga Conglomeratic Complex" which can be taken as the type of these complexes, having been better studied (Dumont, 1971) than the others, correspond to the Mwashya Group; the Middle Mixtite corresponds to the Grand Conglomérat Group. This is shown by a series of sections drawn through the southern Shaba basin of deposition towards the West, the Northwest and the North. The Lower Katangan Supergroup is thus, in all regions studied here, older than the Mwashya Group.

*c*) In table 4, the end-Bushimay lavas have been tentatively correlated with the Kansuki Group because of the presence of volcanogene formations in the latter group (Lefebvre, 1973). The Kansuki Group, with a sedimentation of transitional character (Lefebvre, 1973), may well be linked to the first stages of the Lomamian orogeny as is the end of the Bushimay (Raucq, 1957; 1970) and the amygdaloidal lava which caps it.

*d)* In 1961 (Cahen *et al.*, p. 13) and in 1970 (Cahen) it was thought that the Katangan had been folded by the successive phases of a single orogeny, the Katangan Orogeny. The newly recognized fact that the Lower Katangan is, outside the type area of the Katangan, deformed by an orogeny independent of the one which affected the type area leads to the discarding of this single orogeny concept and to the replacement of the Katangan orogeny by the Lomamian orogeny (post-Lower Katangan, pre-Middle Katangan) and the Lufilian orogeny, linked to the deposition of and consecutive to the Upper Katangan.

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