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# Late Quaternary geomorphological evolution of the sand-covered plateaus near Kolwezi, Southern Shaba, Zaïre.

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**Abstract**

Plateaus are major elements in the macro-geomorphology of Southern Shaba (Zaïre). Large parts of them are covered by *a dilungu,* a thin sandy layer, reworked from Neogene (Kalahari System) to Plio-Pleistocene sand and covered with a steppic vegetation. A detailed study of a type-area, the complex of plateaus near Kolwezi, showed that the *dilungu* is marked by an extensive and varied microrelief that can be subdivided in a chronosequence of at least four generations.

The relatively oldest generation is composed of remnants of important longitudinal dunes that can be linked to the late Pleistocene ergs described for Zimbabwe, Zambia and Angola. There is evidence that after the modelling of the original aeolian landforms important radial tectonic movements took place that originated or accentuated the stepwise upbuilding of the complex of plateaus. The next generation consists of remnants of more local transverse dunes developed on the seif remnants. Both microrelief generations exclusively occur on the crest surfaces of the *dilungu.*

**A** third generation, the *mena,* occurs on the over-all *dilungu* and obliterates the two former ones. *Mena* form a very extensive network of small and shallow closed depressions. They are interpreted as resulting from the degeneration of a once open rill-system. Radiocarbon datings on correlated sandy sediments in the valley-heads permit to situate the rill phase before 2,000 y BP.

The last generation of microlandforms consists of belts of active forms that follow the rims of the plateaus and extend towards the centre, thus slowly consuming the fossil microrelief.

*Résumé*

*Dans le sud du Shaba (Zaïre), les éléments majeurs de la macro-géomorphologie sont les plateaux. De grandes parties de ceux-ci sont couverts par un dilungu, une mince couche sableuse remaniée à partir de sable d'âge néogène (Système du Kalahari) à plio pléistocène, occupée par une végétation steppique. Une étude détaillée d'une surface-type, le complexe de plateaux près de Kolwezi, a révélé que le dilungu est caractérisé par un microrelief varié qui peut être ubdivisé en une chronoséquence de quatre générations au moins. Le stade le plus ancien est composé de restes d'importantes dunes longitudinales qui peuvent être rattachées aux ergs du Pléistocène récent décrits au Zimbabwe, en Zambie et en Angola. Après que ces formes de relief éoliennes ont été construites, d'importants mouvements tectoniques radiaux ont créé ou accentué l'allure en gradins du complexe de plateaux. Le stade suivant consiste en vestiges de dunes transversales plus localisées, qui se sont développées sur les restes de seif. Ces deux générations de microrelief n'existent que sur les surfaces de crête des . Un troisième stade, les mena, peut oblitérer les deux précédents. Les mena sont de petites dépressions fermées, peu profondes, qui forment un réseau très vaste. On les interprète comme le résultat de la dégénérescence d'un réseau de ruisseaux. Des datations au $^{14}C$ faites sur des sédiments sableux des têtes de vallées permettent de situer la phase des ruisseaux à plus de 2 000 ans BP. La quatrième génération de microformes comprend des bandes de formes actives qui suivent les bords des plateaux et s'étendent vers le centre, en détruisant donc petit à petit le microrelief fossile.*

## I. INTRODUCTION

Plateaus are major elements in the macrogeomorphology of Southern Shaba (Zaïre) (ALEXANDRE and ALEXANDRE-PYRE, 1987). Important parts of them are covered with loose sandy deposits, reworked mainly from sand bodies of Neogene ("Kalahari supérieur : Série des sables ocre") to Plio-Pleistocene age. In situations where vegetation cover is sparse and/or low, varying from grass steppe to wooded steppe (MALAISSE, 1975), an extensive and varied microrelief can be detected on remote sensing images. This is especially the case for isolated features such as the Kundelungu, Marungu, Kibara, Biano and Manika plateaus (Fig. 1). The latter, situated near the mining town of Kolwezi (10°40'S-25° 30'E) is a typical example of the plateaus in southern Shaba and is

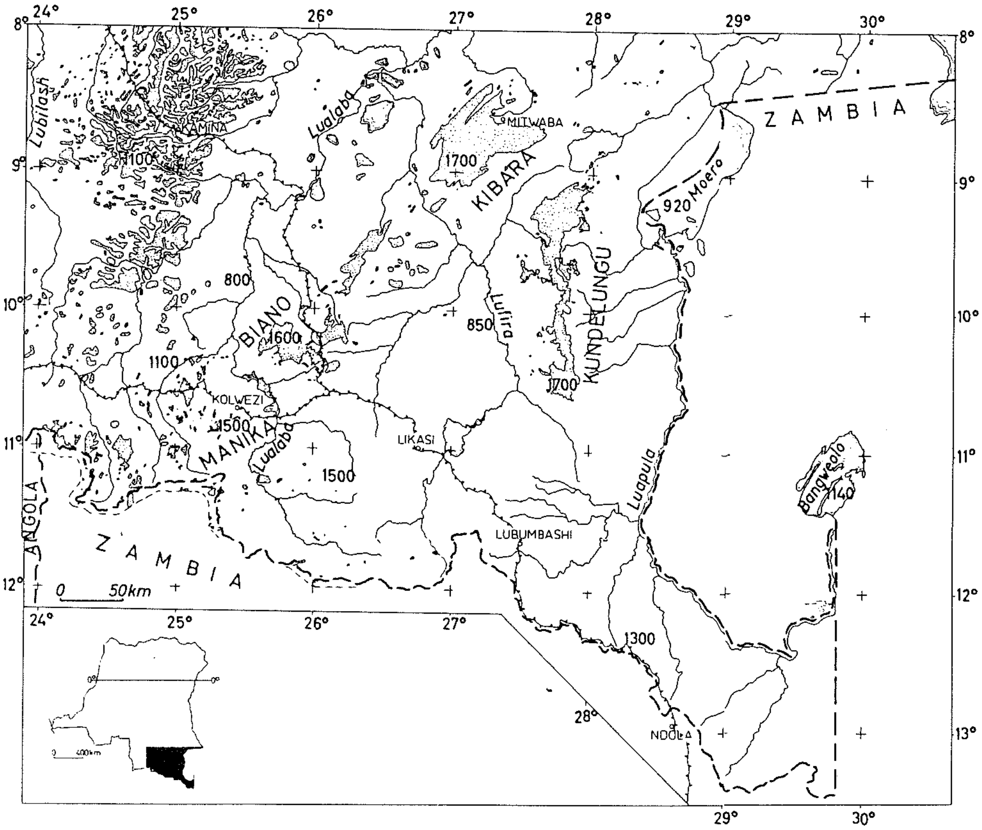


**Figure 1** : Zones (dotted) with dune-like features in Southern Shaba as detected on controlled airphoto-mosaics on scale 1/100,000 (based on the 1957 airphoto-coverage on scale 1/40,000-1/45,000 of the former Comité Spécial du Katanga concession). Altitudes are in meters a.m.s.l. The major high-plateaus are indicated (Kundelungu, ...).

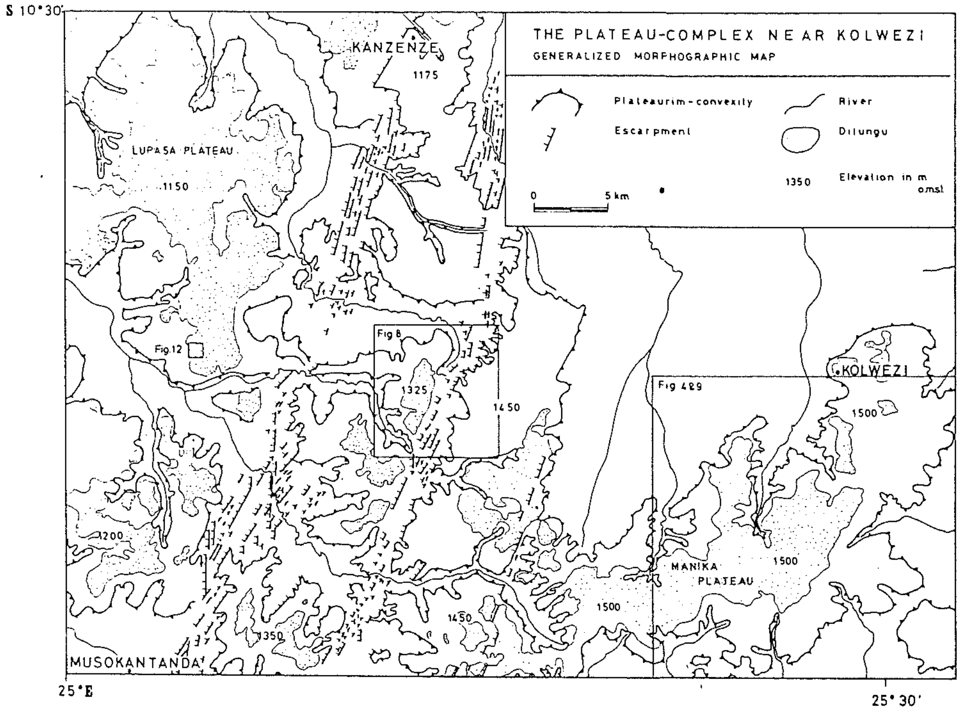


**Figure 2** : Generalized morphographic map of the complex of plateaus near Kolwezi (Shaba-Zaïre).

moreover reasonably accessible. It was therefore chosen for a detailed investigation combining airphoto interpretation and a dense network of field observations (DE DAPPER, 1975, 1977, 1978a, 1978b, 1979a, 1979b, 1980, 1981a, 1981b, 1981c, 1985, 1988; DE DAPPER and DE MOOR, 1980; DE DAPPER and MALAISSE, 1979; DE MOOR and DE DAPPER, 1979).

## II. THE SAND-COVERED PLATEAUS IN THE KOLWEZI AREA

### A. Environmental setting

The major landforms in the vicinity of Kolwezi form a complex of plateaus situated on the transition of the peripheral plateaus that surround the Central Zaïre Basin and the high-plateaus that form the SW-extension of the western horst of the East African Rift system.

The macrorelief is developed in the folded schists and tillites of the *Katanga System* (Upper Precambrian). In a W-E topographic profile, elevations rise from 1,075 m to 1,515 m above sea level over a distance of 60 km. It shows a step-like form, resulting from three major series of fault scarps which transgress the area in a N-S to NE-SW direction (Fig. 2).

The climate is characterized by an alternation of a wet and a dry season which exceeds five months. The mean monthly air temperature is + 20° C, with the coldest month in June (below + 18° C). Diurnal temperature variations are important and during the dry season occasional night frost may occur. The mean annual precipitation reaches 1,200 mm. The onset of the rainy season often involves heavy storms, precipitation intensities of 50 mm/h being common.

The principal vegetation formation is the *miombo,* a woodland of the dry type eventually degraded to a savanna. Great parts of the plateaus are covered by the *dilungu* (see note 1), a steppic grassland formation. Strips of rainforest occur along the permanent rivers (MALAISSE, 1975).

### B. Morphography of the plateaus

The morphotype of the plateau in the Kolwezi region is built up as follows (Fig. 3). The plateau (I) is surrounded by a plateaurim (II), 25 m to 125 m high. The transition is sharply marked by a first major slope change line, the plateaurim convexity (III). The greatest part of the plateau itself is made up of an almost flat (slopes < 1.5°) crest surface (A), rising 20 in to 30 in above the plateaurim convexity. A few gently sloping crest hills (B) rise 25 m at maximum above the crest surface that is surrounded by a marginal surface (C). A second major break of slope, the crest surface edge convexity (D) marks the transition between crest- and marginal surface, two major morphological units. The marginal surface shows predominantly very gently inclined, rectilinear slopes. In some cases however a distinct concave slope change line delimits a marginal surface shoulder (E).

The *dilungu* is the dominant element on the plateaus. It forms an extensive flat, covered with fine Kalahari-type sands and occupied by a steppe vegetation of grasses and herbs. The term *crest dilungu* will be reserved for a *dilungu* that only covers the crest surface of a plateau. The term *over-all dilungu* will be used for the *dilungu* that covers both, crest and marginal surfaces.

In the region of Kolwezi the sandy cover of the *dilungu* is generally rather thin, between 0.5 and 4 m. Locally and especially around important valley heads, the thickness of the sandy layer may reach up to a few teps of meters. The sandy sediments lie discordantly over the weathered precambrian substratum that sustains a perched ground water table flooding great parts of the *malungu* during the rainy season.

### C. Ancient erg remnants on the crest *dilungu*

#### 1. Morphography

The microrelief on the crest *dilungu* is mainly composed of elongate forms (Fig. 4); other features that are associated with them have a more limited extent. The elongate forms can be subdivided into linear and sinuous microridges, and in linear microdepressions.

The linear microdepressions are very shallow (depths up to 30 cm) and narrow (maximum width of 40 m) but very long (lengths between 1 km and 3.6 km). Although difficult to survey on the field, they are easily discernible on aerial photographs. They show a remarkable constant E by S — W by N direction (Photo 1).

The linear microridges (Fig. 5) are low (maximum height of 50 cm), narrow (widths between 50 m and 100 m) and also very long (lengths between 1 km and 5 km). They are always associated with the linear microdepressions, running parallel and subparallel with them. In some cases ridges join and then form an Y-shaped fork with two long prongs and a short stem always pointed to the W by N. It should be noted that the linear microridges are not always evenly spaced.

The sinuous microridges are very low (average height of 20 cm), narrow (maximum width of 50 m) and long (lengths between 200 m and 1200 m). The direction of their long axis ranges between SSE-NNW and SE-NW. It is difficult to survey them on the field but they are also easily detectable on aerial photographs. Field measurements in the Kahilu test zone on the Lupasa plateau show a net asymmetrical cross-sectional form, with a more gentle slope facing ENE or NE. Drainage differences at the onset of the dry season are well translated in the airphoto image by tonality differences (Fig. 6, Photo 2).

Some pans occur in the linear microdepressions. These closed microforms are shallow (depths between 1 m and 3 m) and show a circular, elliptic or oval-shaped planform. Their diameter or axis varies in length from 50 in to 200 in.

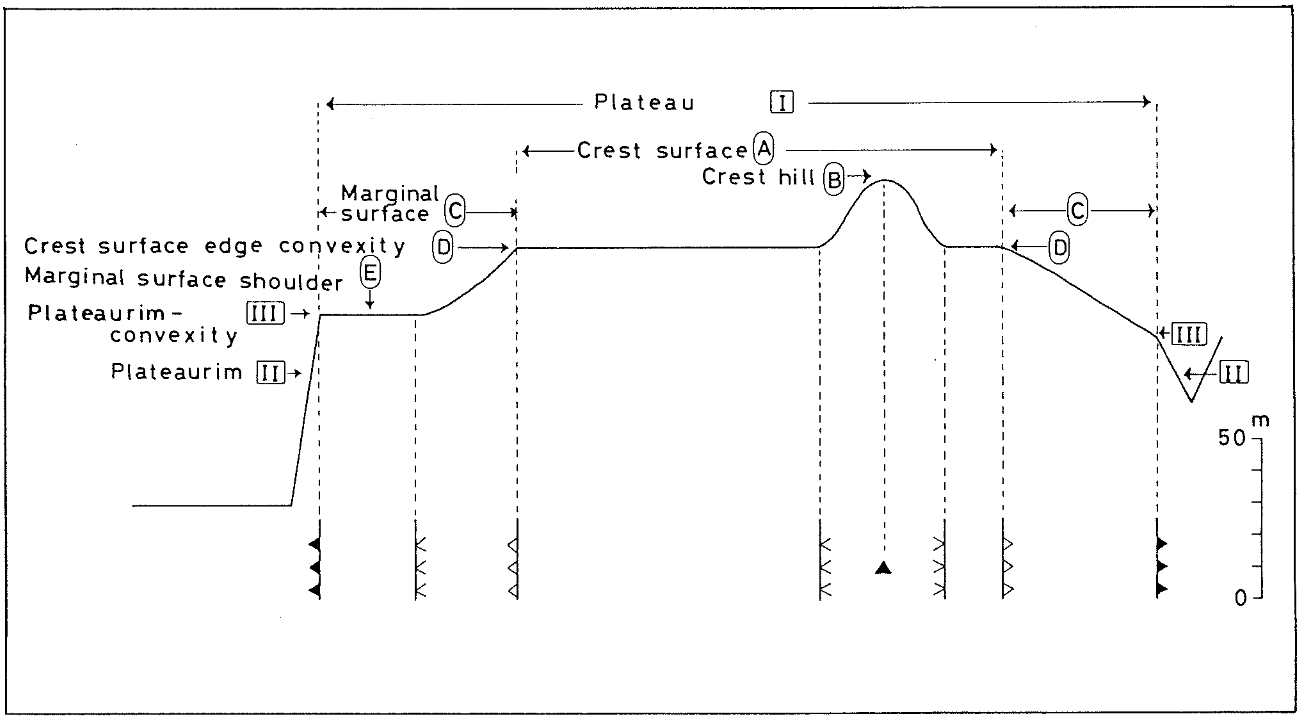


**Figure 3** : The morphotype of the plateau in the Kolwezi area.

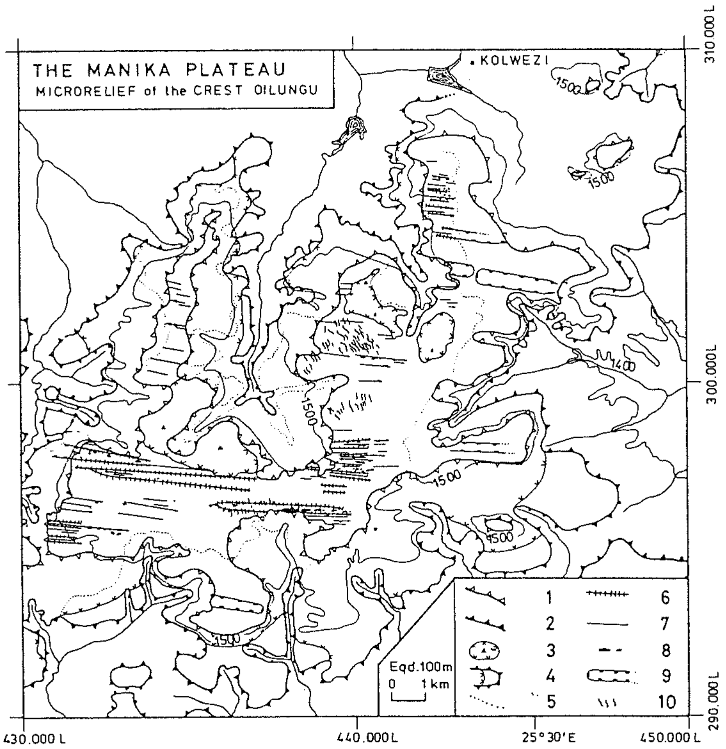


**Figure 4** : The microrelief of the crest *dilungu* on the Manika plateau (S of Kolwezi) (for situation, see Fig. 2). Legend : 1. Crest surface edge convexity; 2. Plateaurim convexity; 3. Crest-hill; 4. Marginal surface shoulder; 5. Extension of the *dilungu*; 6. Linear micro-ridge; 7. Linear micro-depression; 8. Depression-pan; 9. Dry trough shaped valley; 10. Sinuous microridge.

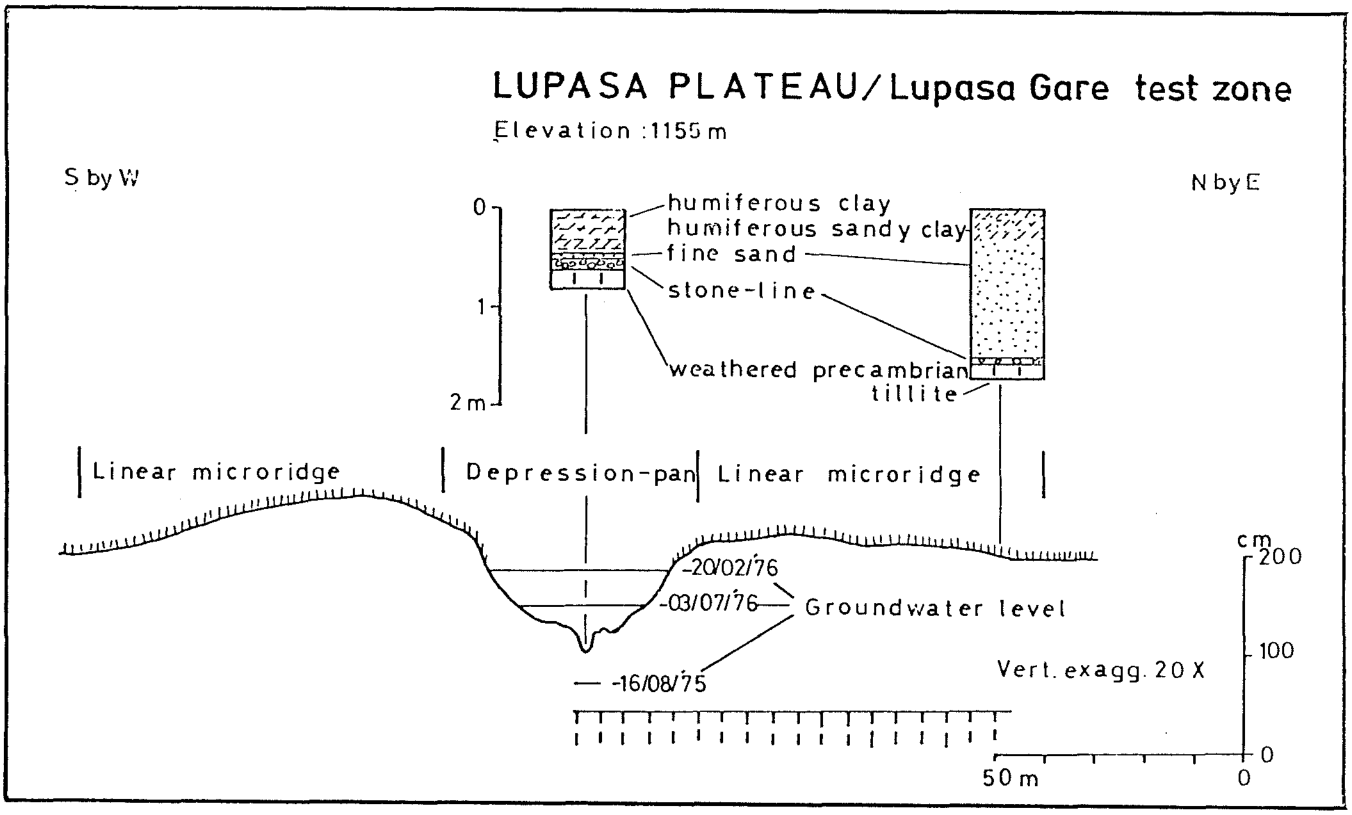


**Figure 5** : Cross-section in a set of two linear micro-ridges and a depression-pan in the Lupasa Gare test zone on the Lupasa plateau (for situation, see Fig. 2).

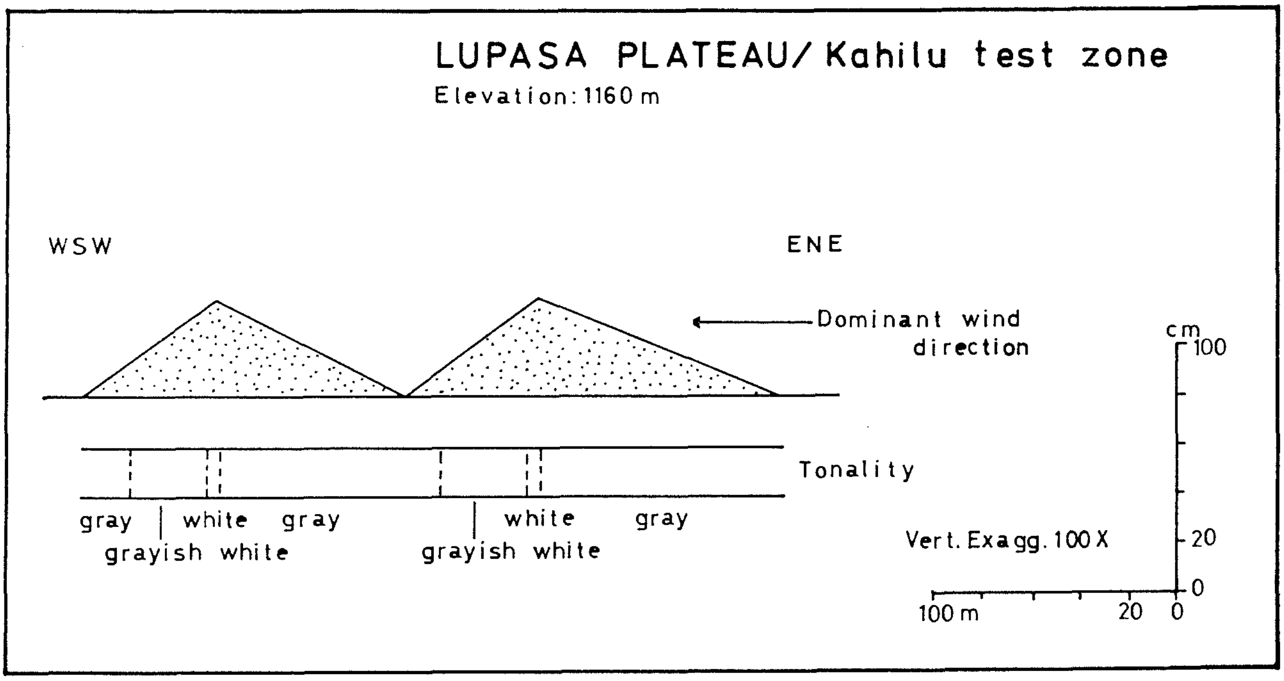


**Figure 6** : Asymmetrical cross-section of sinuous micro-ridges translated by tonality differences on the aerial photo image; as observed in the Kahilu test zone on the Lupasa plateau (for situation, see Fig. 2).

## 2. Morphogenesis

The linear microdepressions, linear microridges and depression pans constitute a landform association always situated on the peripheral zones of the crest *dilungu* (Fig. 4). On the contrary, sinuous microridges chiefly occur on the central zone where the sandcover is slightly thicker. In some cases sinuous microridges are developed on and affect the set of linear microdepression and microridges (photo 1).

Taking account of their remarkable constant direction and their important geographical extent, aeolian landforms are the most obvious origin of the linear microdepressions and microridges. Identical forms were observed on the Biano plateau by ALEXANDRE-PYRE (1971). We consider the linear microridges as fixed remnants of extensive longitudinal dunes. This interpretation particularly leans on the studies of dune sequences made by VERSTAPPEN (1968 and 1972) showing how longitudinal dunes, many kilometres long, irreversibly can be formed out of parabolic dunes. The same author insists on the fact that the great longitudinal dune ridges are not always evenly spaced and that they often join to form a fork the stem of which is always directed leeward. The depicted spatial arrangement perfectly fits with our observations in the Kolwezi area.

An aeolian origin supposes an arid climatic phase with very sparse or even lacking vegetation cover offering conditions in which the *dilungu* sand can easily be modelled and transported by the wind. Following the morphology of the ridges the dominant direction of the winds was E by S.

We suppose the linear microdepressions and the depression-pans are indirectly derived from the seif landscape. In our hypothesis (Fig. 7) the evolution of an arid phase to a semi- arid or steppic climatic phase involving some amount of precipitation led to a shrub vegetation able to fix the aeolian forms. Run-off concentrated in the *straats*, the parallel depressions between the dunes (GOUDIE, 1973).

In the case of a very thin sandcover as observed in the peripheral zones (Fig. 5) this water concentration initiated a drainage pattern running parallel to the longitudinal dunes. On the other hand, in the central zones where the sandcover was more important, concentrated water soaked entirely through the permeable sands impeding stream development.

During this first stage of evolution, dune ridges were already partially degraded by the attack of sheetwash erosion. In the peripheral zones the supplied sediments were evacuated by the streams. In the central zones on the contrary sheetwash led to aggradation in the *straats*.

In the long run, higher precipitation amounts led to a slow rise of the average water table perched on the relatively impervious precambrian bedrock, involving a growing seasonal hydromorphy in the peripheral zones. Under these conditions it is highly probable that the shrub vegetation was gradually replaced by a steppe vegetation of suffrutex and geofrutex, similar to the one that occupies the *malungu* nowadays (see note 2). In this second stage of the evolution, topsoil being less protected by vegetation, sheet- and rill-erosion became more important and accelerated the degradation of the dune ridges. Taking account of the very gentle sloping surface it is very possible that the growing sediment supply was not sufficiently evacuated any more, evolving a filling of the drainage network in the *straats.* The sketched evolution generated the linear microdepressions and depression pans that we consider as regression pans. Several authors (DE PLOEY, 1965; FLINT and BOND, 1968; VERBOOM and BRUNT, 1970; STERCKX, 1974) consider the pans as original blowouts. Nevertheless, it must be stated that their interpretation relies mainly on the sole morphographic aspects of this feature.

The shrub vegetation probably lasted longer in the central zones, the average water table laying deeper in this part of the crest *dilungu* . In these zones the combination of degradation of dune ridges and aggradation of *straats* oblitarered the original aeolian microrelief almost completely. There also the evolution finally ended in hydromorphic conditions forcing the shrubs to be replaced by a less protective steppe vegetation and leading to further general degradation.

In the scope of the hypothesis on the evolution of the most important part of the microrelief on the crest *dilungu* , as sketched above, only the peripheral zones show remains of the original longitudinal dunes and *straats* under the form of linear microridges, linear microdepressions and depression-pans. On the central zones the original aeolian landforms were completely destroyed.

Several field observations indicate the existence of an obliterated drainage pattern on the origin of the linear microdepressions. Where the crest surface edge convexity cuts a linear microdepression frequently water seep zones can be observed, often forming the source of small intermittent streams on the marginal surface. Possibly the *straats* drainage pattern here and there cut into the weathered precambrian bedrock so that these former thalwegs now serve as collecting channels for the perched ground water. The occurrence of linear dry through shaped valleys (Fig. 4) parallel to the linear microrelief, on the parts of the crest surface no longer covered by a *dilungu* , corroborates this view. Though the drainage network is very sparse on the sandcovered crest surfaces, it shows a remarkable preferential E by S — W by N direction emphasizing the axes of the *crest dilungu* microrelief.

In some cases, e.g. on the Ilunga plateau (Fig. 8), the set of linear microlandforms hits the basal concavity of the fault escarpments (Fig. 2). With respect to these morphographic observations one can conclude that the formation of the original longitudinal dunes must be situated before

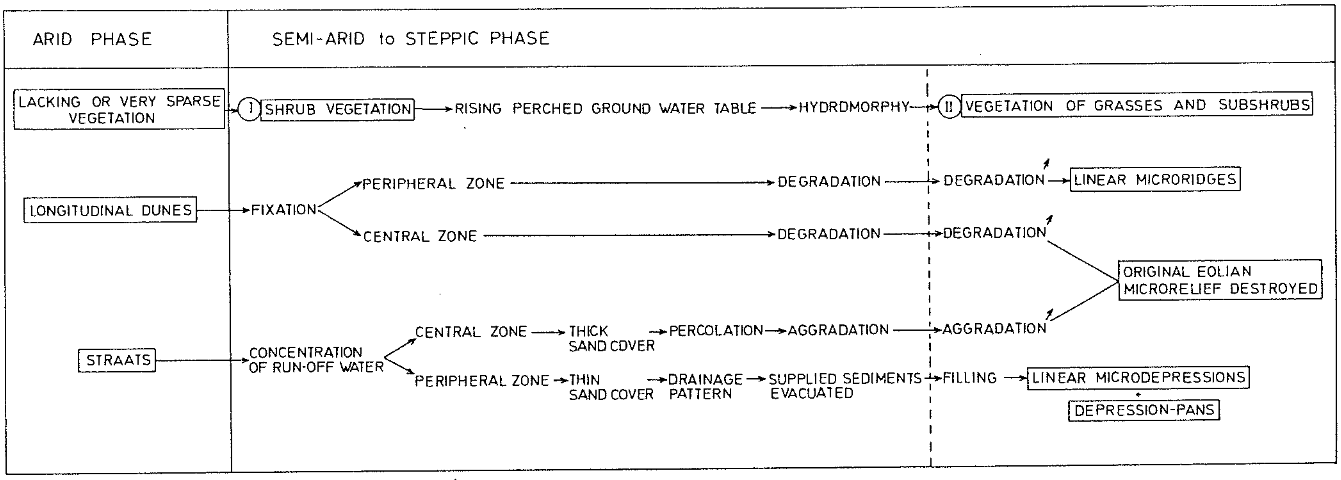


**Figure 7** : Scheme of the evolution of the original longitudinal dune landscape.

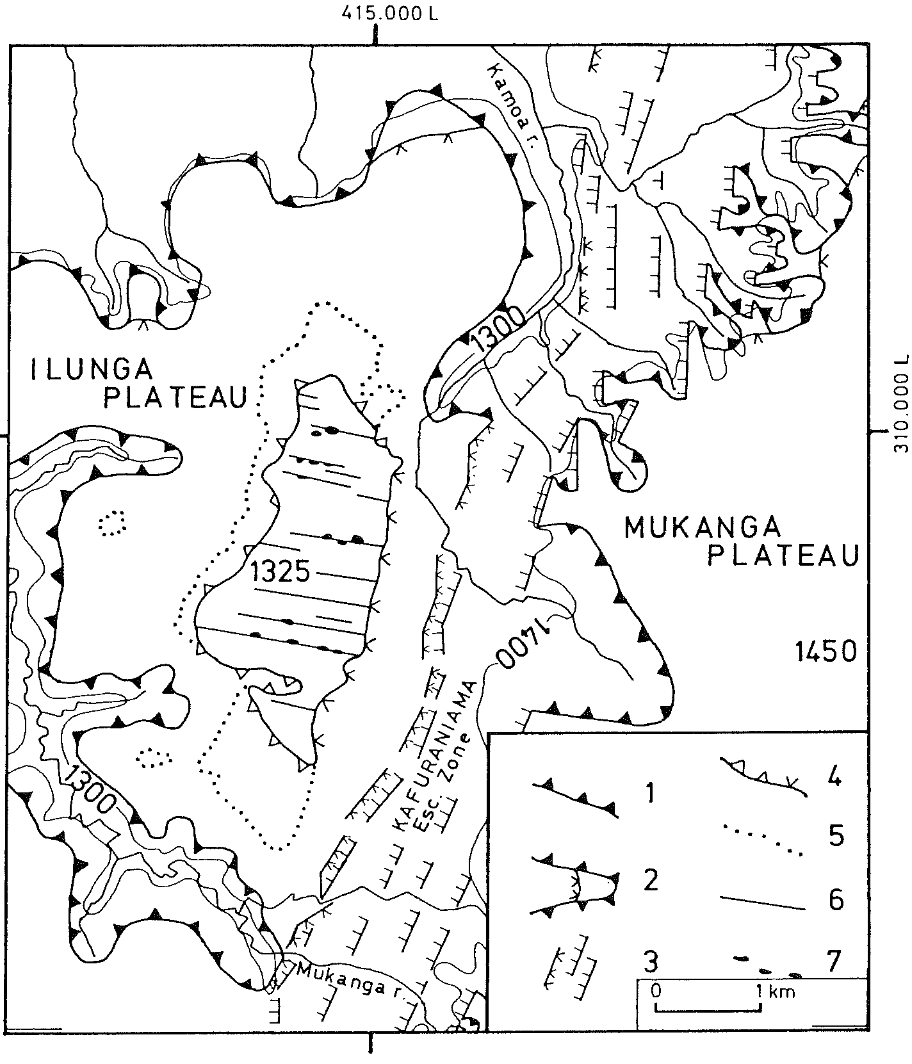


**Figure 8** : Simplified morphographic map of the Ilunga plateau. The linear micro-ridges hit the basal concavity of the Kafuraniama escarpment zone (for situation, see Fig. 2).

Legend: 1. Plateaurim convexity; 2. Marginal surface shoulder; 3. Escarpment zone; 4. Crest surface edge convexity and basal concavity; 5. Extension of the *dilungu*; 6. Linear microridge; 7. Depression-pan.

the escarpment formation. If not, the very regular longitudinal aspect would be perturbed at the proximity of the escarpments, the more as the derived dominant wind direction was approximately perpendicular to the escarpment fines.

With respect to their morphographic characteristics and distribution, an aeolian origin also can be postulated for the sinuous microridges. From their rather scattered distribution as compared to the seif remnants, one can conclude that they are not obligatory formed under arid conditions but that they are merely seasonal forms issued from a climatic phase with long and accentuated dry seasons. The asymmetric cross-section as observed on the field and on aerial photographs and the sinuous wavy crest fines fit in with the morphography of fixed transverse dunes stretching approximately perpendicular to a dominant ENE wind direction.

The origin of transverse dunes has usually been associated with low or decreasing wind speed. However, the crucial factor in the formation of transverse dunes, according to VERSTAPPEN (1972), is rather the decrease in dune speed velocity. They can be formed from parabolic dunes and from barchans alike. If either of these two dune types starts to move at a slower rate, the upwind dunes can catch up with the ones further downwind and thus form transverse ridges. In the case of the *crest dilungu* decreasing dune speed can result from a growth in size of the dunes approaching the more important source of sand in the central zones. Since the speed of the dunes is inversely proportional to their size, the upwind dunes under such conditions will more readily catch up with the ones further on the central zones which increased in size when reaching the area with thicker sand cover. Eventually also shrub vegetation on the central zones under drier climatic conditions could be responsible for the decrease of the dune velocity.

### D. Microrelief on the over-all dilungu

The over-all microrelief can be subdivided into several complexes, spread in distinctive zones with very regular spatial organisation. From the edge to the centre of the plateau the following sequence is observed (Fig. 9) :

1°) a belt with active sandy micro-fans

2°) a belt with forms due to active sheetwash — and rill — erosion

3°) a zone with mena-relief

#### 1. Belts with active forms

A narrow, 40 m to 200 m wide, belt forms the transition between the *dilungu* and the surrounding areas without sandy cover, generally occupied by *miombo* and savanna. This outermost belt is characterized by a typical vegetation of small trees with domination of *Philippia benguelensis* and *Uapaca robijnsii* (MALAISSE, 1975). The general surface gradient varies between 1° and 1.5°. From the morphological point of view, this belt corresponds to a transit zone wherein fine sands supplied from the upward *dilungu* is temporarily stocked in micro-fans to be redistributed afterwards over the downward slope facets. The micro-fans are a few centimetres thick and have a planform up to 1 sq.m, covering fallen leaves and branches, blades of grass etc.

The adjoining microrelief belt has a width of 100 m to 400 m, going up to 1,500 m around valley heads extending on the plateaus. The surface gradient averages 0.7°so that the transition to the micro-fan belt is marked by a convex slope change line. Although slope values are small, this belt is dissected by a great number of rills. The rill-interfluves are subjected to intense sheetwash during the rainy season storms. The upward end of the belt consists of a micro-scarp, a few tens of centimetres high, retreating parallel to itself, thus showing a case of micro-pedimentation. This process is very active during the rainy season as shows the denudation of roots and subsoil stems of grasses and subshrubs. As a result, part of the sediments covering the stone-line (see note 3) are affected and sorted. The fine fractions are transported in the rills to form the micro-fans of the outer belt. The soft nuclei of iron oxide accumulations in the podzol-like soil are washed out and harden as soon as they are exposed to the air. They form angular concretions with a rough surface that are concentrated and covered with fine material supplied by subsequent micropedimentation processes, thus forming a new embryonic stone-line.

#### 2. Zone with mena-relief

##### a. Morphography of the *mena*

*Mena* (see note 4) are small and shallow closed depressions with the rim at slightly lower elevation where two *mena* are joined by a saddle. Mostly they are elongated and ramified. Their length varies between 3 m and 10 m, their width between 2 m and 5 m and their depth reaches 15 cm to 30 cm (Fig. 10). They never appear separately but in a dense pattern with long axes running parallel (Photo 3). In the Lupasa test zone the axial length averages 1,180 m/ha (Fig. 2, 11 and 12).

The *mena* rims always form subvertical micro-scarps. The sandy microsaddles between the *mena* are often crossed by short and narrow overflow rills. The rims show an undisturbed Al horizon, incised by the *mena* themselves, whose bottoms have only slight and probably more recent Al development.

The *mena* interfluves consist of mainly sandy material which continues over at least 2 m depth. In the *mena* bottoms, by contrast, occurs a superficial layer of a more clayey and silty texture, but resting upon the same *dilungu* sands as the interfluves.

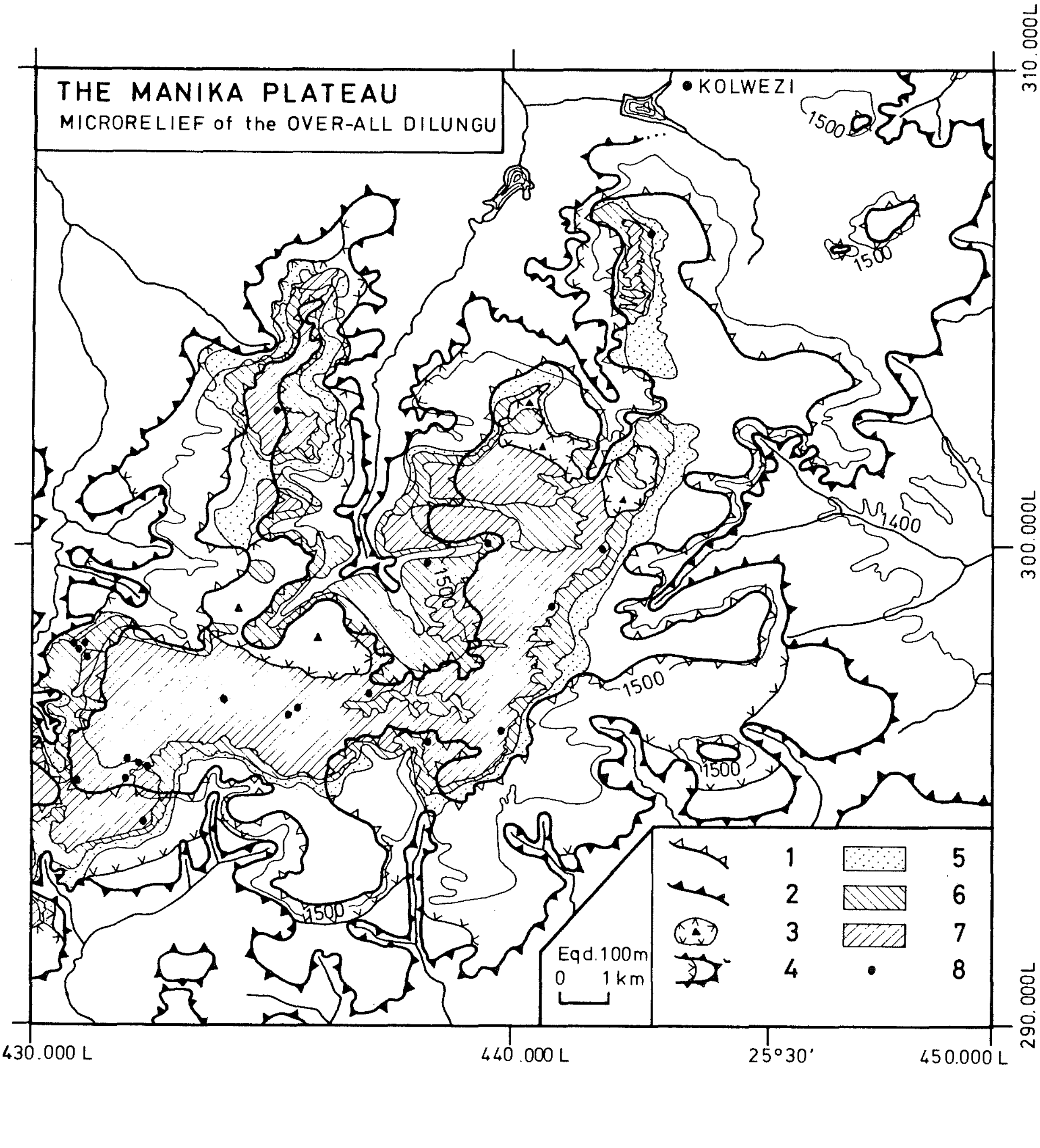


**Figure 9** : The microrelief of the over-all *dilungu* on the Manika plateau (S of Kolwezi) (for situation, see Fig. 2). Legend : 1. Crest surface edge convexity ; 2. Plateaurim convexity ; 3. Crest-hill ; 4. Marginal surface shoulder ; 5. Belt with micro-fans ; 6. Belt with spurs of sheetwash- and rill-erosion ; 7. Zone with *mena*-relief ; 8. Closed depression (pan).

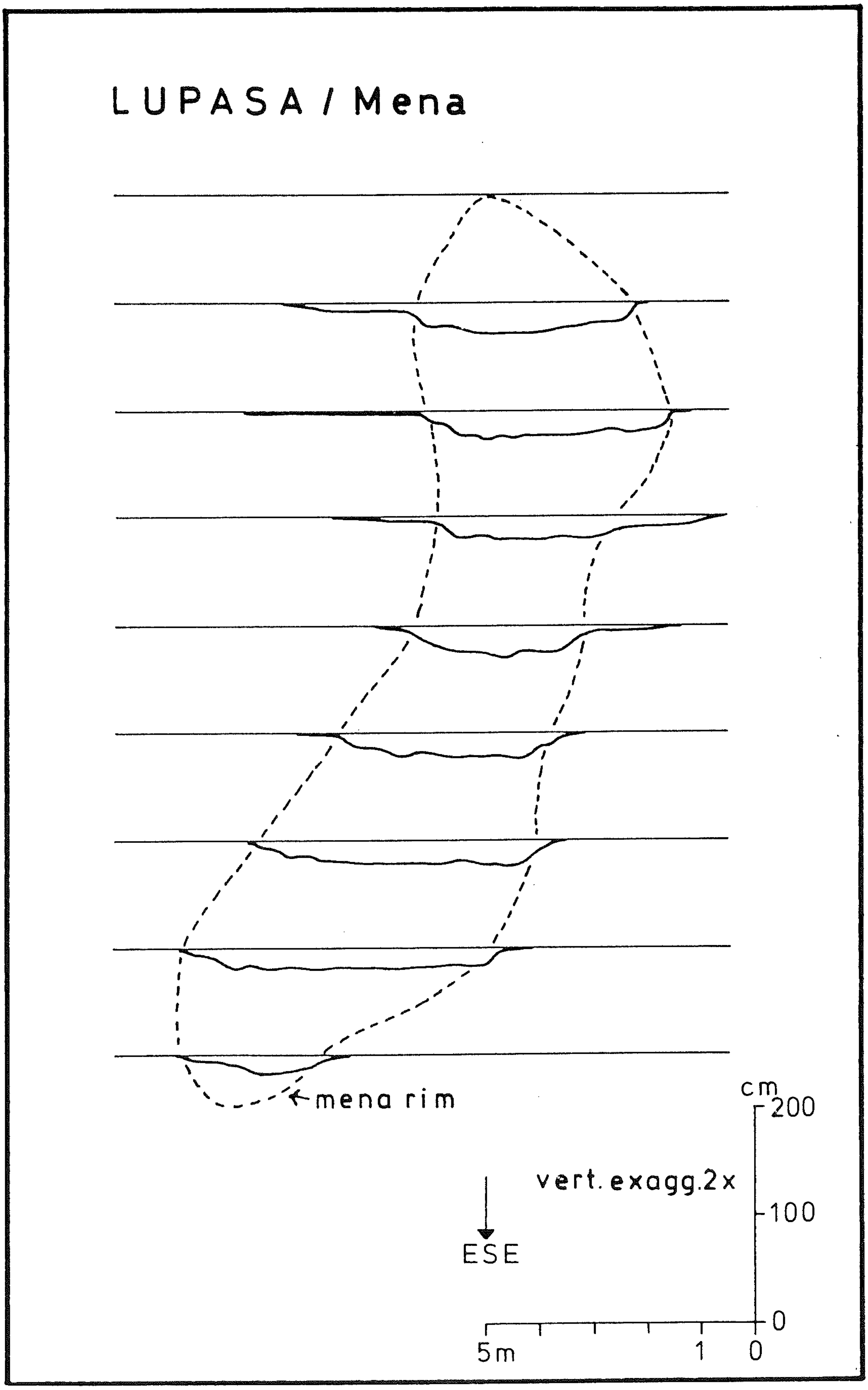


**Figure 10** : Planform and cross-sections of a *wina*; after field observations on the Lupasa plateau (for situation, see Fig. 2).

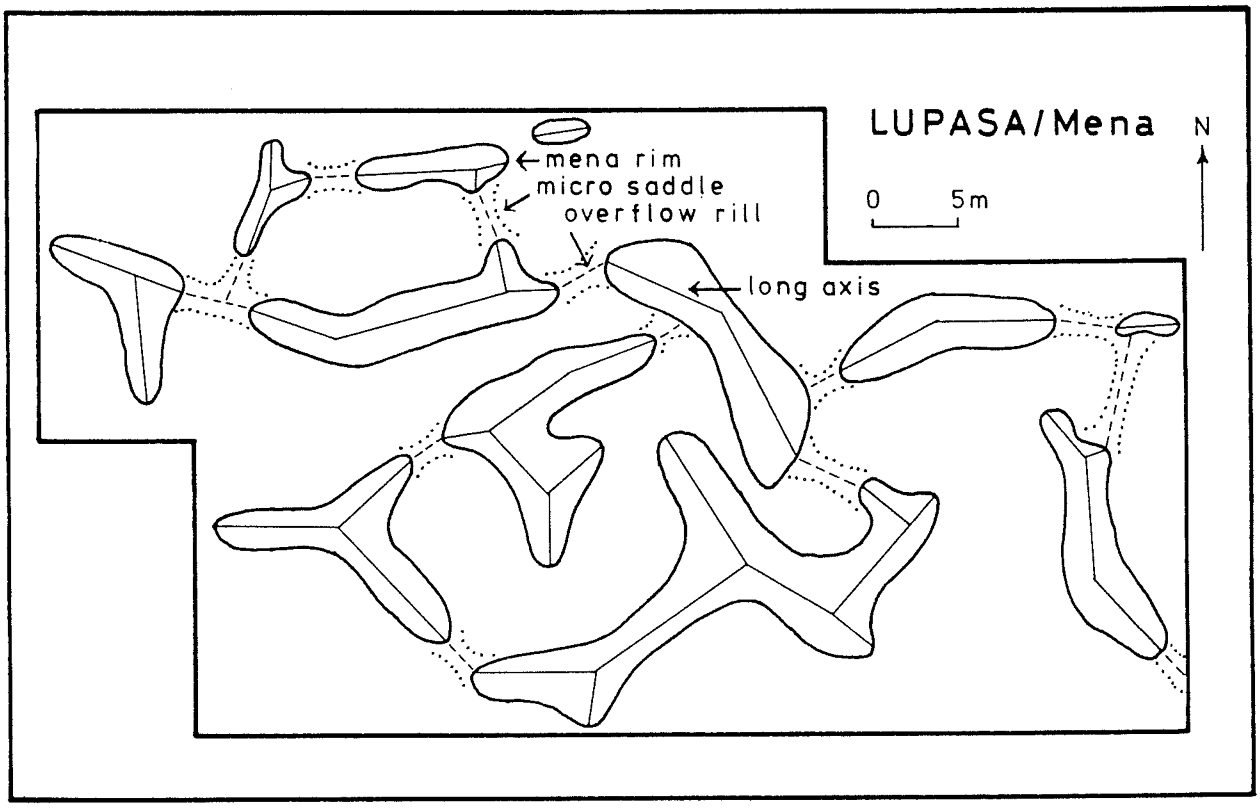


**Figure 11** : Planform of the *mena* network; after field observations on the Lupasa plateau (for situation, see Fig. 2).

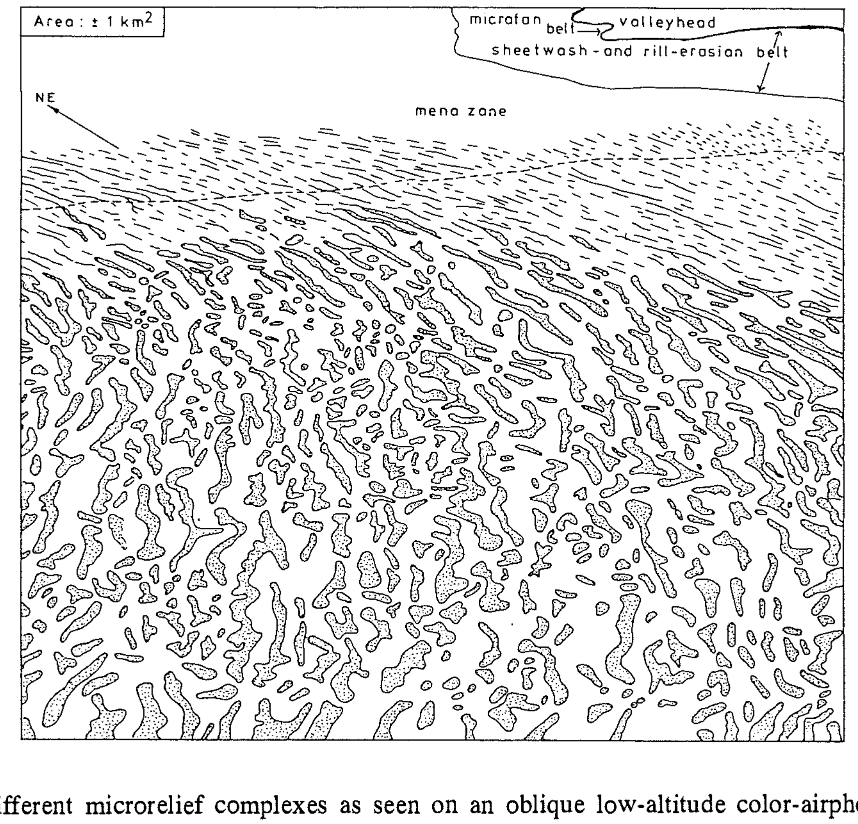


**Figure 12** : The different microrelief complexes as seen on an oblique low-altitude color-airphoto; taken on the Lupasa plateau during the dry season after a bushfire (beginning of July; for situation, see Fig. 2).

The *mena* bottoms and *mena* interfluves show definite contrasts in vegetation and termite activity. The *mena* bottoms are covered with grass species, mainly hemicryptophytic *Gramineae* and *Cyperaceae.* The vegetation on the *mena* interfluves, on the other hand, besides a few grass species (mainly *Gramineae)* is dominated by subshrubs, especially *Syzygium guineense subsp. huillense* and *Parinari capensis subsp. latifolia* (see note 5). Grass height varies beween 10 cm and 250 cm; subshrub height averages 20 cm.

The *malungu* are colonised by humivorous termite species (see note 6) constructing candle-shaped calies.

Despite intense termite activity the amount of reworked substratum is quite restricted. Termite activity is distinctly higher on the *mena* bottoms as compared to the interfluves (Table 1).

**Table I**

Occurrence of candle-shaped termite calies

| | Interfluve | Bottom |
|---|---|---|
| Mean density | 1.2 calies/sq.m | 2.4 calies/sq.m |
| Height min. | 6.0 cm | 8.0 cm |
| Height max. | 25.0 cm | 25.0 cm |
| Height average | 13.0 cm | 17.0 cm |
| Diameter min. | 1.3 cm | 3.0 cm |
| Diameter max. | 7.5 cm | 8.5 cm |
| Diameter average | 3.4 cm | 5.3 cm |
| Mean weight of calies material | 98.0 g/sq.m | 506.0 g/sq.m |

The calies consist mainly of silt and clay as the humus on which the termites feed is attached to these fractions. There are however few differences between interfluve and bottom calies as to their clay and organic matter content. Clay content in both cases averages about 42 % and organic C content about 9.2 %.

b. Morphological processes in the *mena*

Fluctuations of the perched ground water table mainly control present-day morphological processes. Alter a slow rise during the rainy season, a maximum level of water table is reached at the end of February. Ail *mena* bottoms are then flooded but interfluves remain dry. These contrasts in drainage account for differences in vegetation and an even more complex termite activity. In the *mena* bottoms, some of the termite calies become completely flooded and therefore abandoned; the others have ail termite activity concentrated toward the top.

As soon as the *mena* are flooded, cohesion of material at the depressions rims and at the base of the termite calies is lost. This decrease starts a general microslumping, a slow retreat of the rims and some aggradation on the *mena* bottoms. Collapse of calies by narrowing at their base promotes their breakdown. Meanwhile the interfluves know little erosion, as runoff transport is greatly impeded by the subshrubs. The transported material consists only of silt, clay and organic matter and it also settles on the *mena* bottoms. This reconstruction corroborates the colluvial nature of the material on the *mena* bottoms.

As the *dilungu* surface slopes slightly towards the plateau edge, a distinct water overflow starts between successive aligned *mena* as soon as the ground water level rises sufficiently and floods the bottoms. This overflow transports silt and clay in suspension while some fine sand is dragged for a short distance along the overflow rills.

At the end of the rainy season the ground water level drops and overflow stops. The *mena* transform into pans wherein silt, clay and organic matter settle from suspension. Later dessication by evaporation and drop of the ground water level occurs. At the end of the dry season, this sediment layer forms a hard skin with a thickness of several millimetres, covering most of the *mena* bottoms. The bottom grasses wither very quickly. Shortly afterwards they are completely burnt by early bushfires; by contrast the green leaves of the subshrubs do not suffer (Photo 4). Towards the end of the dry season all vegetation becomes withered and Tate bushfires also destroy the leaves of the subshrubs.

At the onset of the rainy season heavy stormrains fall, but erosion only affects the interfluves. The interfluve surface shows intense sheet wash onto the *mena* bottoms where sedimentation in micro-fans occurs but neither flooding nor runoff is initiated. Moreover the clayey skin and the weak slope protect the bottoms against splash erosion.

c. Morphogenesis of the *mena*

Field observations and airphoto interpretation clearly show the *mena* long axes directed to the *dilungu* edges. Profile pits crossing the *mena* do not show any collapse structure in the sands, showing that the formation of the depressions cannot be imputed to solution mechanisms. These arguments make it obvious that the *mena* correspond to a phase of degeneration of a once-extensive open rill system, dating from a period of severe soil erosion.

Three phases can be discerned in the morphogenesis of the *mena :*

1°) a rill-phase,

2°) a transition-phase,

3°) a mena-phase.

Concerning the rill-phase, objections arise as to the value of the overall slope which is mostly below 0.5° in the mena zone. According to several authors, slopes below 2° are too weak to allow sufficient runoff velocity to induce severe soil erosion. However threshold slope values ought not to be generalized. Indeed, soi roughness, vegetation type and cover also condition the erosive power of the runoff. Moreover changes in these factors may at the same time affect soil erodibility.

The generalized rills could be generated during a climatic period with precipitation characteristics somewhat different from those occurring now : a lower mean annual precipitation amount, a longer dry season and a higher rainfall variability. Decrease of the annual precipitation amount results in a thinning of the vegetation cover. Increase of the length of the dry season intensifies withering of the vegetation and provokes the development of a denser network of desication cracks affecting the structure of the Al horizon. Increase of rainfall variability induces higher runoff aggressiveness especially by higher precipitation intensities at the onset of the rainy season and shifting of the onset itself.

The onset of the generalized bushfire practising in the region can also be imputed to the rill-phase generation. These practices can lead to a small-scale pseudorhexistasic situation resulting in increased soil erodibility and subsequent rill formation. Bushfires consume the protective litter cover that weakens the raindrop impact, favours percolation and attenuates runoff concentration. Besides, vegetation has to adapt to the new situation leading to temporary thinning of the cover.

Several causes can be imputed to explain the transition of the rills into *mena.*

1°) A slight climatic change to the present-day type can provoke a generalized rising of the ground water table so that the seasonal fluctuations can play a morphodynamical role on the *dilungu* surface. Liquefaction of the sandy material at the rims of the rills at more or less regular distances and subsequent colmatation induces the transition of rills to *mena.*

2°) The establishment of the bushfires as an ever-recurring practice can result in an increased sediment supply from the rill-interfluves to the rill-bottoms. Because of the very low slope values, a situation can be reached whereby sediment evacuation cannot follow supply, resulting in colmatation of the rills and transition to *mena.*

3°) The transition mechanism can also be explained by the vegetation-hydrology relationship. The development of an extensive rill system can provoke a generalized drop of the ground water table, resulting in an extension of the subshrubs that occur exclusively on the dry parts of the *mena* zone at present day. As field observations prove, soil roughness of *mena* bottoms and *mena* interfluves shows clear-cut differences at the end of the dry season. The overall surface consists of a mosaic of clumps, 2-6 cm high and of an almost circular shape, alternating with barren soi patches. In both cases clumps cover about 22 % of the surface. In the *mena* bottoms their number averages 56/sq.m, on the *mena* interfluves only 32/sq.m (test plots of 4 sq.m). This clearly shows that the average diameter of the clumps is much higher on the interfluves, increasing concentration and aggressiveness of runoff. That process can clearly be observed at the outer rim of the *mena* zone, where part of the *mena* are opened by the micropedimentation processes already mentioned above. Because of the slow adaptation, *mena* vegetation still remains unchanged here despite lack of flooding. Because of the lack of pan formation, no skin of silt-clay organic matter can develop. Here rill erosion affects the bottoms as well as the interfluves, but is distinctly more severe on the latter. In this case too, increased sediment supply can result in a transition to the *mena* phase. Once the *mena* formed, flooding and widening by microslumping can take place, leading to the extension of the grasses to the detriment of the subshrubs. Because of the vulnerability of the grasses to bushfires, a new rill-phase can eventually develop at a critical level of their extension ushering in a new cycle.

## III. MORPHOCHRONOLOGY

Direct absolute datings on the microlandforms of the sand-covered plateaus near Kolwezi are not available. Despite this inconvenience it is however possible to establish a relative geomorphological chronosequence and to frame that sequence in a general climatological evolution scheme for the area (Fig. 13). Such a scheme is worked out for the Late Quaternary of Southern Shaba by ROCHE (1979), ROCHE and MBENZA (1980) and MBENZA *et al.* (1984). It is based on palynological evidence for several sites of the area.

The relatively oldest recognizable generation of landforms is the major complex of longitudinal dunes. They very probably belong to the important fixed aeolian landform remnants surveyed in the former arid zones of Zimbabwe, Zambia and Angola by THOMAS (1984, 1985). Although no dates have yet been obtained for the formation of those ergs, LANCASTER (1981) and REINE (1982) suggest periods of stronger anticyclonic circulation coinciding with glacial maxima during the Late Pleistocene. In the Shaba context, the formation of the longitudinal dunes may be situated during the arid maximum around 20,000 years BP. This view is in contradiction with the one of ALEXANDRE-PYRE (1971) who associates the formation of the Biano-ergs with other arid phenomena (such as desert varnishes) that were formed during the End-Tertiary. The transverse dunes form a second generation as they are developed on the remnants of the longitudinal dunes. Their formation can also be situated during the same major arid phase. The fact however that the longitudinal dunes were already degraded before the formation of the transverse dunes may imply that the curve based on palynological evidence is more complex. A second possibility is however that the longitudinal dunes predate the more humid *Kalambo* interstadial, that they were degraded during that humid transition and subsequently affected by the transverse dunes then formed during the arid *Mount Kenya* hypothermal.

The formation or more probably reactivation of fault scarps after the erg formation could lead to river incision that had a repercussion on the degradation of hillslopes

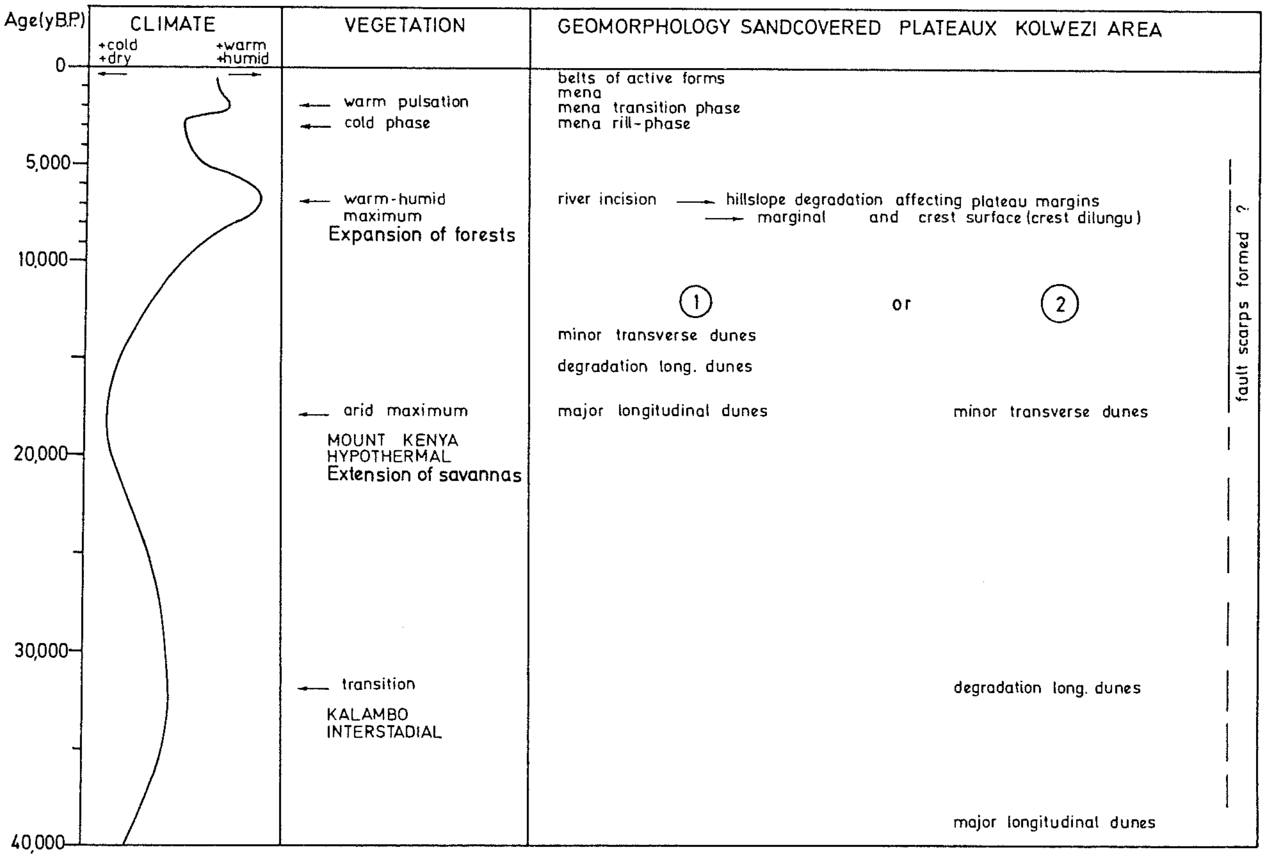


**Figure 13** : Chronosequence of landforms on the sandcovered plateaus of the Kolwezi area and tentative correlation to the climatic and environmental evolution during the Late Quaternary of Southern Shaba (climate and vegetation after ROCHE (1979), ROCHE and MBENZA (1980) and MBENZA *et al.* (1984)).

extending into the plateau margins. A similar N-S faulting is mentioned for the western border of the Lufira valley South of Likasi by ALEXANDRE and ALEXANDRE-PYRE (1987).

Stripping of the bedrock saprolite starting from the plateaurim-convexity (Fig. 3) could split the plateau surface into a marginal and a crest surface. Hereby the crest *dilungu* conserved the original microlandforms that were destroyed on the marginal surface. The expansion of the forest during the warm-humid maximum around 7,000 years BP could also activate river incision and its morphological consequences.

The *mena* rill-phase may be linked to the cold phase around 3,000 years BP. Sedimentological and palynological (see note 7) investigations in the correlative valley bottom sediments of the Upper-Luilu (Fig. 2) indicate that the transition-phase took place before 2,000 years BP (see note 8). It can most probably be linked to the warm pulsation around 2,000 years BP.

Finally, the belts with sandy micro-fans and forms related to sheetwash- and rill-erosion are active phenomena.

**Notes**

1. *Dilungu,* plural : *malungu; a* term from the Luba language. Here the term is used in a morphological sense (including foret, substratum and vegetation) that is slightly different from the commonly used botanical-geographical sense.

2. Following MA LAISSE (1975) the inverse process can be observed nowadays on the sandcovered plateaux : "La steppe sèche se caractérise principalement par l'abondance des géofrutex qui lui donne son aspect caractéristique... Dès que le niveau de la nappe phréatique s'abaisse quelque peu, cette formation évolue en steppe sèche arbustive ou arborée, formation végétale différente, mais à composition fioristique très voisine." (p. 20).

3. Numerous observations in profile pits and borings proue that the superficial sediments on the *malungu* show the typical intertropical 3 layer build-up : fine cover — atone-line — substratum.

4. *Wina,* plural : *mena;* term from the Chokwe language.

5. Determination by Prof. Dr. F. Malaisse, University of Lubumbashi (Zaïre) and Agronomical Faculty of Gembloux (Belgium).

6. Determination by Dr. G. Goffinet, State University Liège (Belgium).

7. A palynological survey was done by Dr. E. Roche of the Royal Museum for Central Africa at Tervuren (Belgium).

8. GrN7682 and 7683 by Dr. W. Mook of the Groningen University (The Netherlands).

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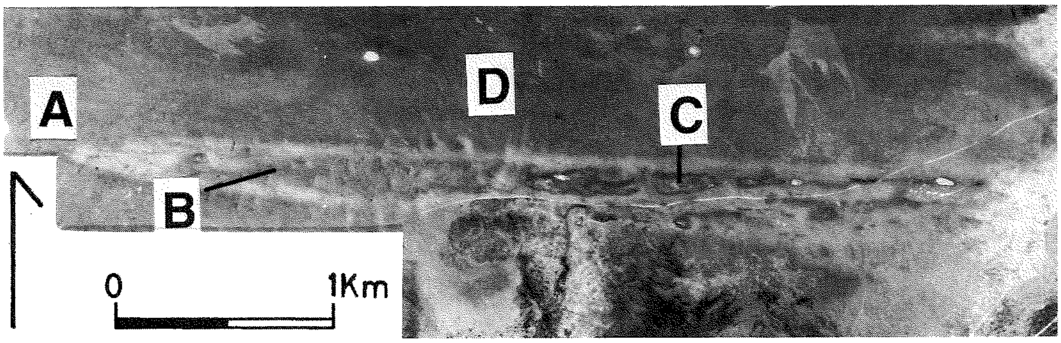


**Photo 1.** Extract from aerial photograph C.S.K. 3124 RUWE (original scale 1/45,000). Two linear microridges (A) join in the W by N and enclose a linear microdepression (B) in which some pans (C) occur. A few transverse dunes (D) are developed on the longitudinal dune remnants. Where possible the track (white line) runs over the microridge to avoid flooding during the rainy season.

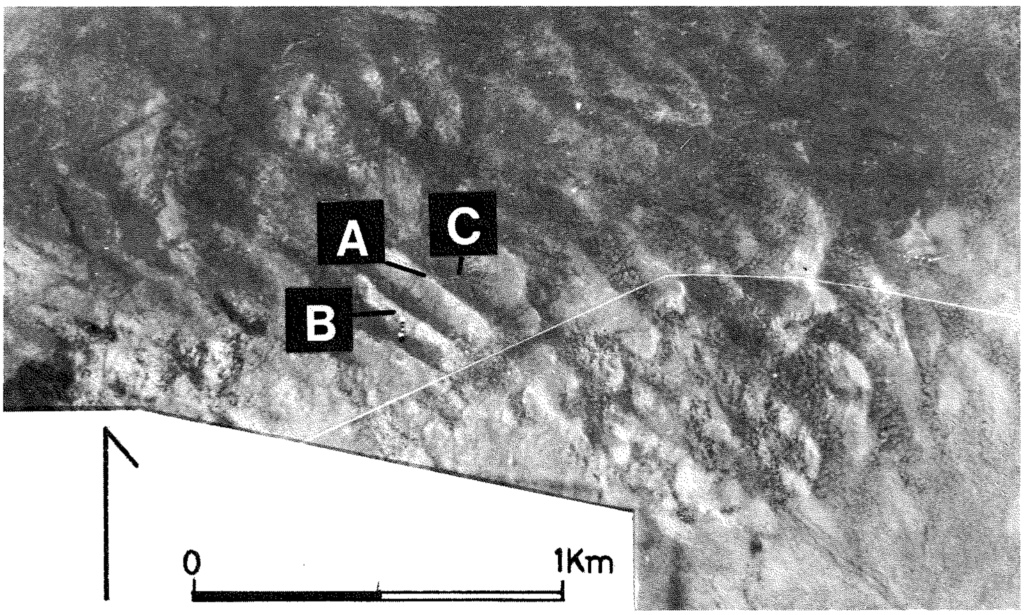


**Photo 2.** Extract from aerial photograph C.S.K. 1903 RUWE (original scale 1/45,000). A field of asymmetrical transverse dune remnants is visible by tonality differences. The narrow crests (A) show as a white line, whereas the steeper leeward slopes (B) and the more gentle windward slopes (C) show grayish white and gray tonalities respectively.

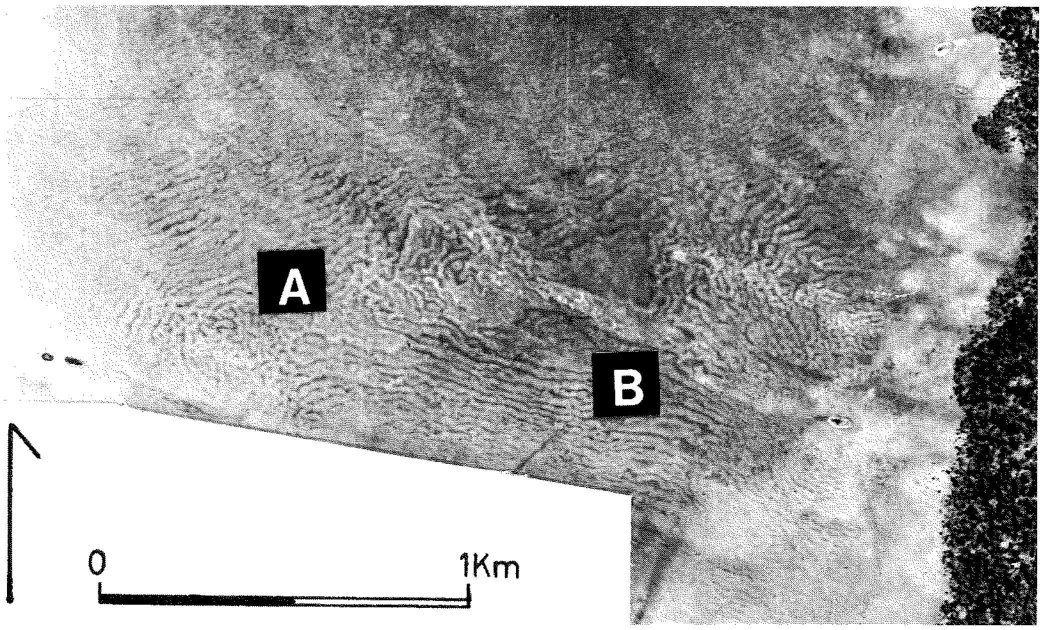


**Photo 3**. Dense network of *mena* (A) developed on the over-all *dilungu* . They issued from the degeneration of an extensive once open gully system. In places they partly obliterate remnants of longitudinal dunes (B).


**Photo 4**. Vegetation on the *mena* network in the beginning of August. The grasses in the *mena*-bottoms (A) are already withered and partly destroyed by early bushfires. The *mena*-interfluves (B) are covered with still green subshrubs.