Geo-Eco-Trop, 1979, 3 (1) 1-18

THE MICRORELIEF OF THE SANDCOVERED PLATEAUX NEAR KOLWEZI (SHABA, ZAIRE)

I. The microrelief of the over-all dilungu

M. DE DAPPER*

RESUME

Les plateaux des environs de Kolwezi sont couverts, en grande partie, d'un dilungu, un mince manteau de sables fins couvert d'une végétation steppique. Le microrelief du dilungu est très développé et très varié. On peut y distinguer des complexes de microrelief et des unités de microrelief isolées. Dans cette partie de l'article le microrelief du dilungu, couvrant le plateau indifféremment de sa macromorphologie, sera discuté. Des processus très divers comme la dégénération de rigoles, la micropédimentation, l'érosion sous forme de ruissellement et de rigoles, le piping, la suffosion et le compactage sont responsables pour la genèse de ce microrelief remarquable.

ABSTRACT

Great parts of the plateaux near Kolwezi are covered by a dilungu, a thin sandy layer with a steppic vegetation. The dilungu shows an extensive and varied microrelief that can be subdivided in complexes and separate features. In the present part of the article, the microrelief that occurs on the dilungu covering the plateau indifferently to his macromorphology -the over-all dilungu- is discussed. Several processes as rill-degeneration, micropedimentation, sheetwash- and rill-erosion, piping, suffosion and compaction are responsible for the genesis of this outstanding microrelief.

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* Laboratory for Physical Geography (Dir. Prof. Dr. R. TAVERNIER), State University Gent, Geological Institute, Krijgslaan 271, B-9000 Gent, (Belgium). Formerly collaborator of the Department of Geography, National University of Zaïre, Lubumbashi Campus.
The present study is part of a series of geomorphological investigations carried out in the field during the period 1972-1976 in S-Shaba and especially in the region between Kolwezi, Kanzenze and Musokantanda.

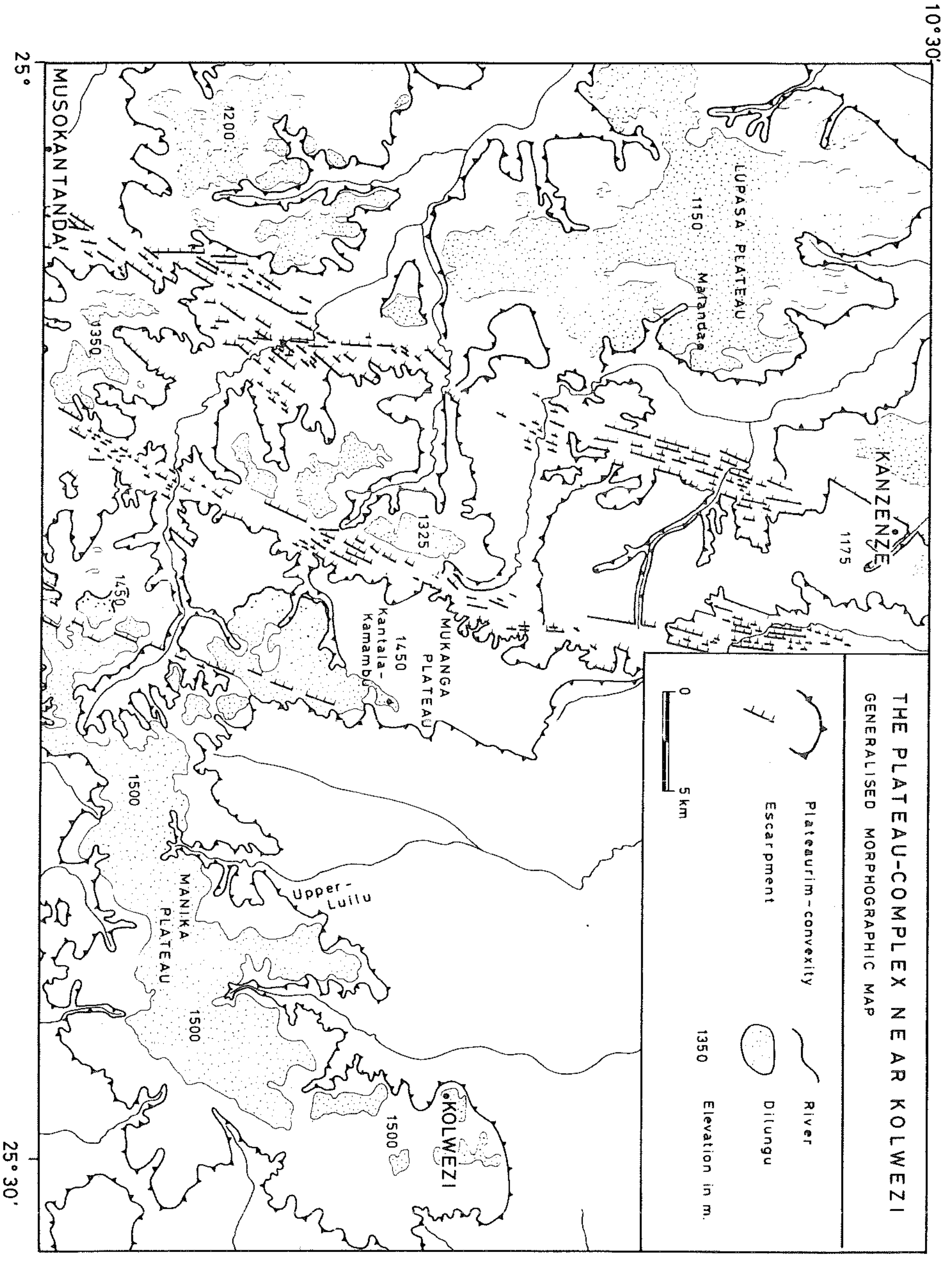

Fig. 1 : Generalised morphographic map of the Plateau-complex near Kolwezi.

GENERAL PHYSICAL GEOGRAPHICAL DATA

The relief of the region around Kolwezi consists mainly of a complex of plateaux situated on the transition of the peripheral plateaux that surround the Central Zaïre Basin and the high plateaux that form the SW-extension of the western horst of the East African Rift system.

The macrorelief is developed in the folded shales and tillites of the Katanga-system (Upper Precambrian). In a W-E topographic profile, elevations rise from 1,075 m to 1,515 m over a distance of 60 km. It shows a stairs-like form, due to three series of fault scarps (Fig. 1).

The climate is characterized by an alternation of a rainy and a dry season which exceeds five months. The mean monthly temperatures average +20°C, with a minimum in June (below +18°C). Diurnal temperature variations are important and during the dry season seldom 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 far from exceptional.

The principal vegetation formation is the *miombo*, a woodland of the dry type eventually degraded to a savanna. Great parts of the plateaux are covered by the *dilungu*, a steppic grasslandformation. Strips of rain forest occur along the permanent rivers (MALAISSE,1975).

THE MORPHOGRAPHY OF THE PLATEAUX

The morphotype of the plateau in the Kolwezi-region is built up as follows (Fig. 2). 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 *plateaurimconvexity* (III). The greatest part of the plateau itself is constituted by an almost flat (slopes < 1.5°) *crest surface* (A), rising 20 m to 30 m above the plateaurimconvexity. 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 slope change line, the *crest surface edge convexity* (D) marks the transition between crest- and marginal surface, two major

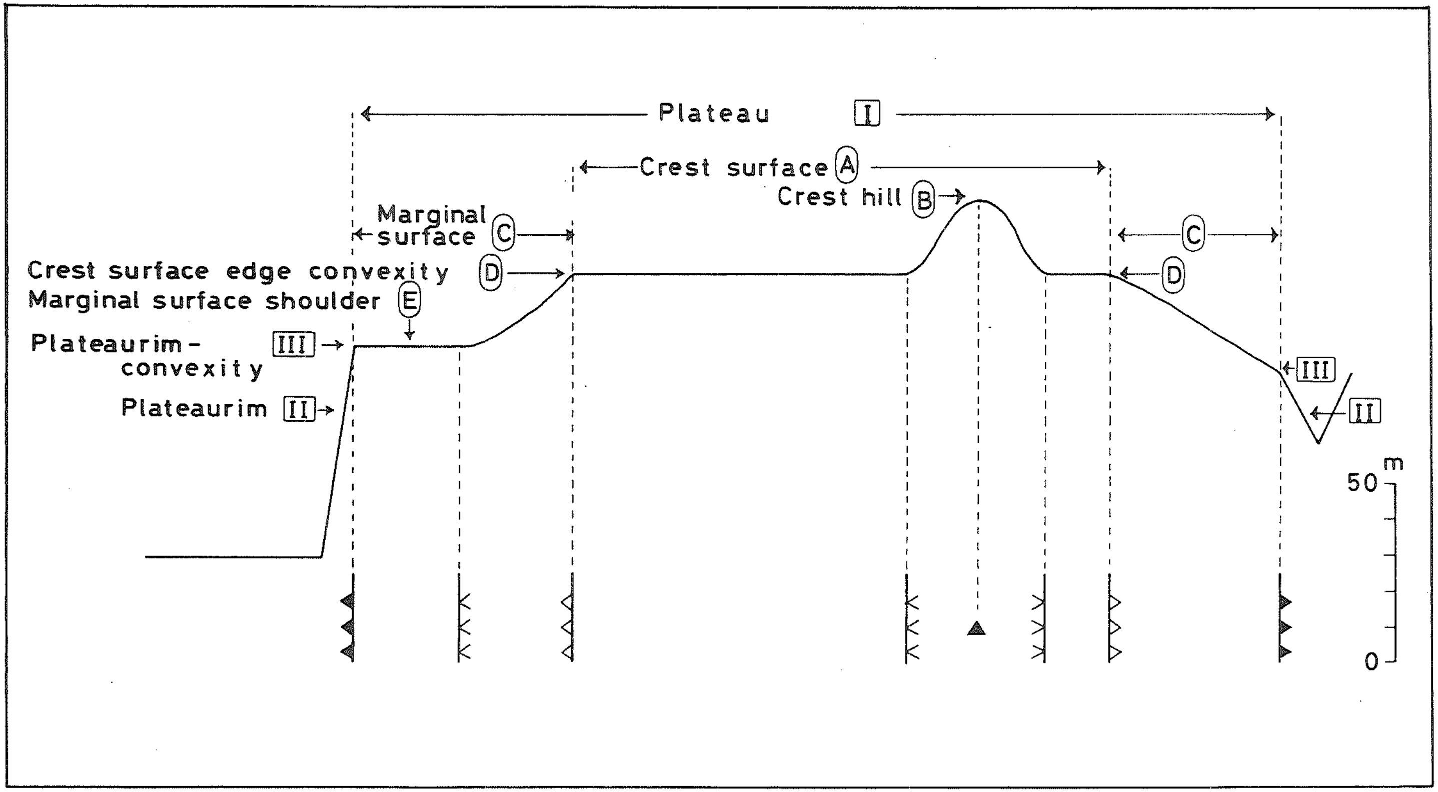

Fig. 2 : The morphotype of the plateau in the Kolwezi-region.

morphological units. The marginal surface shows predominantly gently inclined, rectilinear slopes. In some cases however a distinct concave slope change line delimits a *marginal surface shoulder* (E).

The *dilungu* (2) is the dominant element on the plateaux. 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 covers the crest surface of a plateau.

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

THE MORPHOLOGY OF THE MICRORELIEF ON THE OVER-ALL DILUNGU

Morphographic situation (Fig. 3)

The *dilungu* shows an extensive and varied microrelief. Some of the microrelief-units only occur on the crest *dilungu*. They will be discussed in the second part of this article. Other microrelief units are found on the whole *dilungu*, whatever his morphographic position on the plateau may be. They form the subject of the present part.

The over-all microrelief can be subdivided in complexes and separate features. The microrelief-complexes spread in distinctive zones with very regular spatial organisation. From the edge to the center of the plateau occur :

(1) a belt with sandy micro-fans

(2) a belt with spurs of active sheetwash- and rill- erosion

(3) a zone with *mena*-relief

The separate microrelief-units consist of circular shaped, shallow (depth up to 3 m) closed depressions (pans) filled with water during the rainy season. Generally they are related to slope change lines.

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(2) : *Di-lungu*, plural : *malungu*: term from the Luba language. Here the term is used in a morphological sense-including form, substratum and vegetation -that is slightly different from the mostly used botanical- geographical sense.

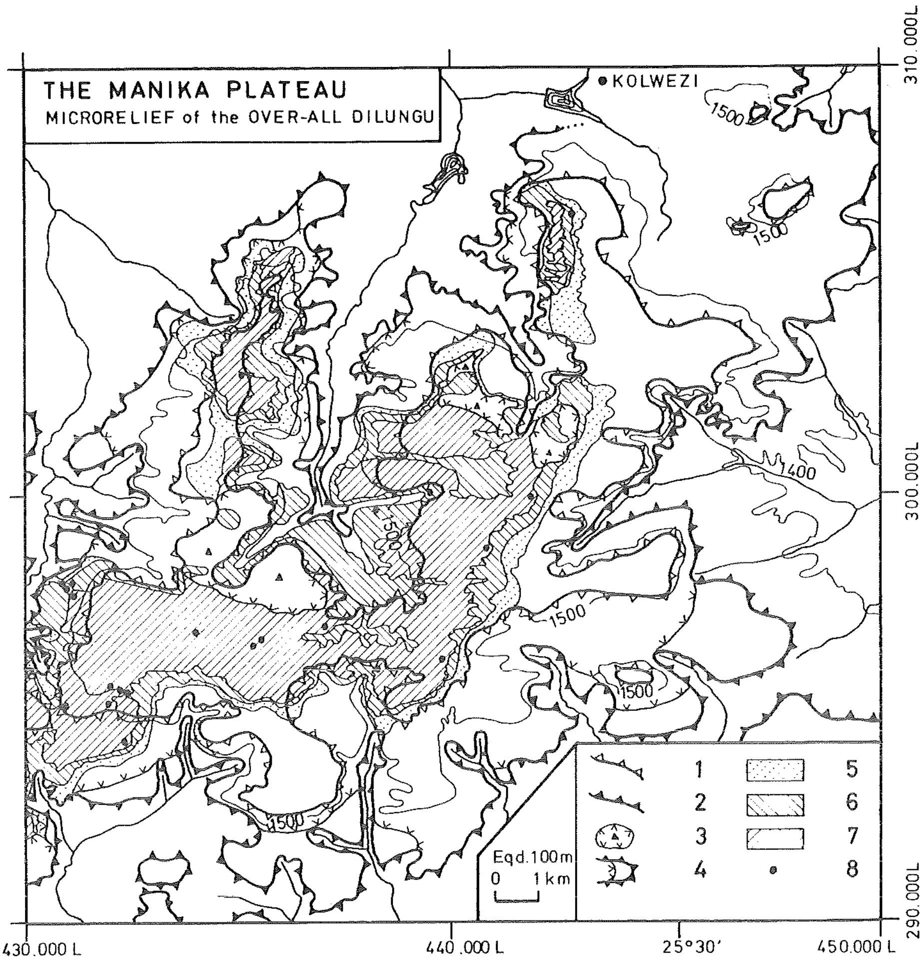

Fig. 3 : The microrelief of the over-all dilungu on the Manika plateau (S of Kolwezi).

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)

The microrelief-complexes

The belt with micro-fans

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 a morphological point of view, this belt corresponds to a relay-zone wherein fine sand supplied from the upward *dilungu* is temporarily stocked in microfans to be redistributed afterwards over the downward slope facets. The microfans are a few centimeters thick and have a planform up to 1 m^2, covering fallen leafs and branches, blades of grass etc ...

The belt with sheetwash- and rill- erosion

The joining microrelief-belt has a width of 100 m to 400 m, going up to 1500 m around valleys extending on the plateaux. The surface gradient averages 0.7° so that the transition to the microfan-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 centimeters high, retreating parallel to itself, thus showing a case of micropedimentation. 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* (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.

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(3) Numerous observations in profile pits and borings prove that the superficial sediments on the malungu show the typical tropical 3 layers built-up : fine cover - stone line - substratum.

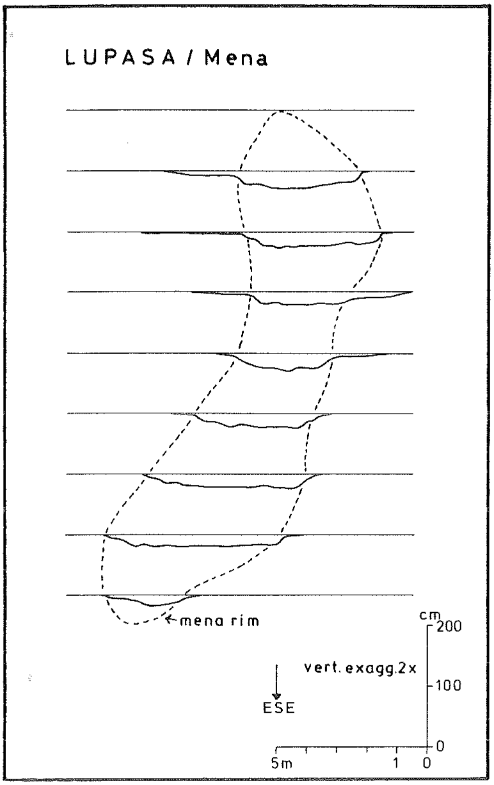

Fig. 4 : Planform and cross-sections of a wina; after field observations on the Lupasa plateau.

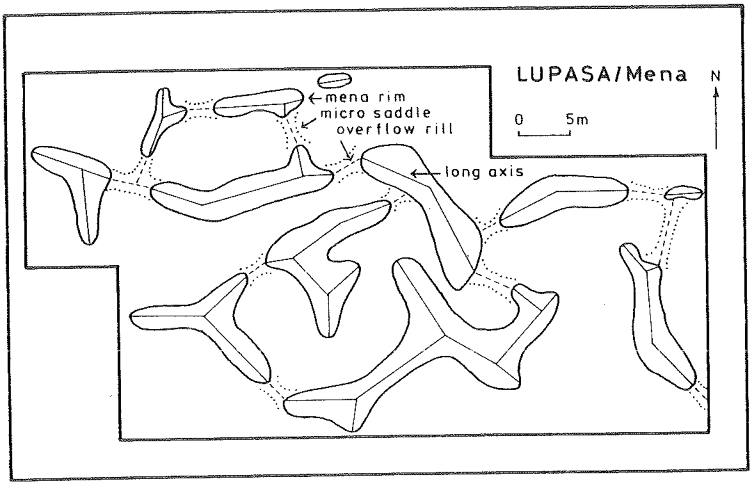

Fig. 5 : Planform of the mena network; after field observations on the Lupasa plateau.

The zone with mena-relief

Morphography of the *mena*.

Mena (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 2 m and 10 m, their width between 3 m and 5 m and their depth reaches 15 cm to 30 cm (Fig. 4). They never appear separately but in a dense pattern with long axes running parallel. In the Lupasa test zone the axial length averaged 1180 m/ha (Fig. 1, 5 and 6).

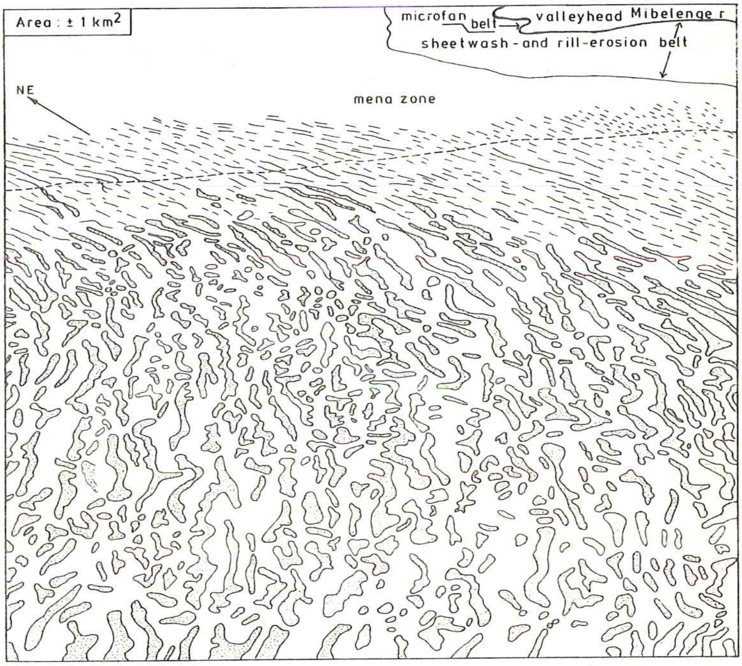

Fig. 6 : The different microrelief complexes as seen on an oblique low-altitude color-airphoto; taken on the Lupasa plateau during the dry season after a bushfire (05.07.76).

The *mena* rims always form subvertical micro-scarps. The sandy micro saddles between the *mena* are often crossed by short and narrow overflow rills. The rims show an undisturbed A_1 horizon, incised by the *mena* themselves, whose bottoms have only slight and probably more recent A_1 development.

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

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.

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*(5). Grass height varies between 10 cm and 250 cm; subshrub height averages 20 cm.

The *malungu* are colonised by humivorous termite species (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 I).

	interfluve	bottom
mean density	1.2 calies /m^2	2.4 calies/m^2
heigth min.	6 cm	8 cm
max.	25 cm	25 cm
average	13 cm	17 cm
diameter min.	1.3 cm	3.0 cm
max.	7.5 cm	8.5 cm
average	3.4 cm	5.3 cm
mean weight of calies material	98 g/m^2	506 g/m^2

Tabl. I : Occurrence of candle-shaped termite calies

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

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(5) Determinations by Prof. Dr. F. MALAISSE, National University of Zaïre, Lubumbashi Campus.

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

differences between interfluve and bottom calies as to their clay and organic matter content. Clay content in both cases varies about 42% and organic C content about 9.2%.

Morphological processes in the mena.

Fluctuations of the perched groundwater table mainly control nowadays morphological processes. After a slow rise during the rainy season, a maximum level of water table is reached at the end of February. All *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 all termite activity concentrated towards 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. Runoff transport from the interfluves to the bottoms is greatly impeded by the subshrubs and by the lack of microslumping. That material consists only of silt, clay and organic matter and it also settles on the *mena* bottoms. This reconstruction supports the evidence of the colluvial nature of the material on the *mena* bottoms.

As the *dilungu* surface slopes slightly down towards the plateau edge, a distinct water overflow starts between successive aligned *mena* as soon as the groundwater 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 groundwater level drops and overflow finishes. The *mena* transform into pans wherein silt, clay and organic matter settle from suspension. Later dessication by evaporation and drop of the groundwater level occurs. At the end of the dry season, this sediment layer forms a hard skin with a thickness of several millimeters, covering most of the *mena* bottoms. The bottom grasses very quickly wither. Shortly afterwards they are completely burned by early bushfires, by contrast the green leaves of the subshrubs do not suffer. Towards the end of the dry season all vegetation becomes withered and late bushfires also destroy the leaves of the subshrubs.

At the onset of the rainy season heavy storm rains fall, but erosion only affects the interfluves. The interfluve surface shows intense sheet wash onto the *wina* bottoms where sedimentation in micro-fans occur buth neither flooding nor run off is initiated. Moreover the layer of sediment and the weak slope protect the bottoms against splash erosion.

Morphogenesis of the mena.

Field observations and airphotointerpretation clearly show the *mena* long axes directed to the *dilungu* edges. Profile pits crossing the *mena* did 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* corresponds 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° seem to weak to allow sufficient runoff velocity to induce severe soil erosion. However treshold slope values ought not to be generalised. Indeed, precipitation surplus, soil 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 generalised rills could be generated during a climatic period with precipitation characteristics somewhat different from those occuring 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 dessication cracks affecting the structure of the A_1 horizon. Increase of rainfall variability induces higher runoff agressiveness especially by higher precipitation intensities at the onset of the rainy season and shifting of the onset itself.

The onset of generalised bushfire practising in the study region could also be imputed for the rill-phase generation. These practices can lead to a small scale pseudo-rhexistasic 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 temporarily thinning of the cover.

A slight climatic change to the present-day type could provoke a generalised rising of the groundwater table so that his seasonal fluctuations could 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*. Sedimentological and palynological (7) investigations in the correlative valley bottom sediments of the Upper-Luilu (Fig. 1) indicate such subrecent climatic shift. Based on radiocarbon dates (8) the transition-phase can be situated after 2,000 years B.P.

The establishment of the bushfires as an ever-recurring practice could 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*.

The transition mechanism can also be explained by the vegetation-hydrology relationship. The development of an extensive rill system could provoke a generalised drop of the groundwater 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 soil patches. In both cases clumps cover about 22% of the surface. In the *mena* bottoms their number averages $56/m^2$, on the *mena* interfluves only $32/m^2$ (test plots of 4 m^2). This clearly shows that the average

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(7) A first palynological survey was made 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).

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 distincly 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 develop at a critical level of their extension ushering in a new cycle.

The separate microrelief-units

As already mentioned, the pans are almost always related to slope change lines. According to their position on the slope change, distinction can be made between *topslope-pans* and *footslope-pans*.

The topslope-pans

The topslope-pans mostly occur nearby valleyheads stretching on the plateau. They will be discussed on the hand of a typical example from the Malanda-testplot on the Lupasa-plateau (Fig. 1).

The Malanda topslope-pan takes part of the headwatersystem of the Kapafu-river and is situated at the top of an outspoken convex slope change (Fig. 7). The closed depression has an oval to ovoid planform with a long axis of 29 m perpendicular to the slope change line and a short axis of 17 m. The depth from the highest water level measures 1 m.

A series of handborings and profile pits following longitudinal and transverse cross-sections (Fig. 8) show the convexity also reproduced in the highly weathered tillite substratum. The pan however is worked out exclusively in the loose sandy *dilungu*-sediments. The stone-line follows the cross-section of the pan and lays on the tillite in the deepest part. In the centre of the depression occurs a funnel-shaped shaft with a diameter of 0.5 m.

The topslope-pan is the result of a process of piping. Hereby surface water penetrates on a given spot and percolates vertically into the

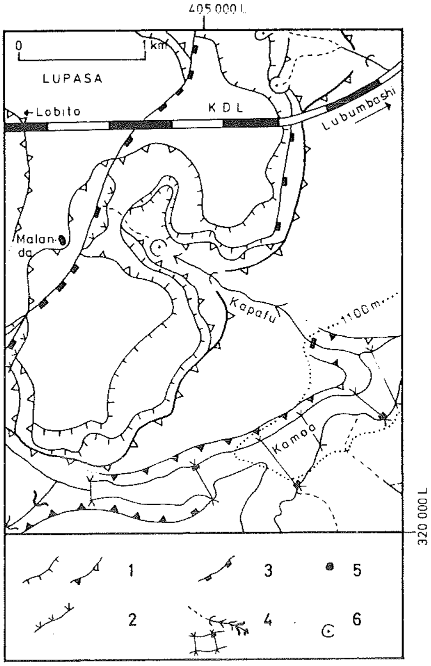

Fig. 7 : Morphological position of the Malanda topslope-pan.

Legend : 1. Convexity
2. Concavity
3. Terrace
4. Valley
5. Topslope-pan
6. Spring-amphitheatre

ground over a certain distance. An impervious layer catches the water that continues his subterranean way in a more or less concentrated manner in a subhorizontal direction. On the *malungu* of the study-region penetration spots are mostly provided with holes of burrowing animals, especially bushrats. The heavy rainstorms during the rainy season and the storage of a water-mass in the depression around the penetration spot allow an abundant and strong percolation of surface water. The subterranean flow is enabled by the sloping almost impervious weathered tillite substratum and a permanent evacuation of the water through the valleyhead of the Kapafu.

Nearby the pan, the footslope area of the convexity is marked by a marshy zone even at the end of the dry season, clearly showing preferential outflow of subsurface water at this spot. The level of the free water surface in the pan itself is regulated by a small overflow channel. The maximum water level in the pan stands somewhat 60 cm lower than the corresponding water-table level in the surrounding *dilungu* sands. This

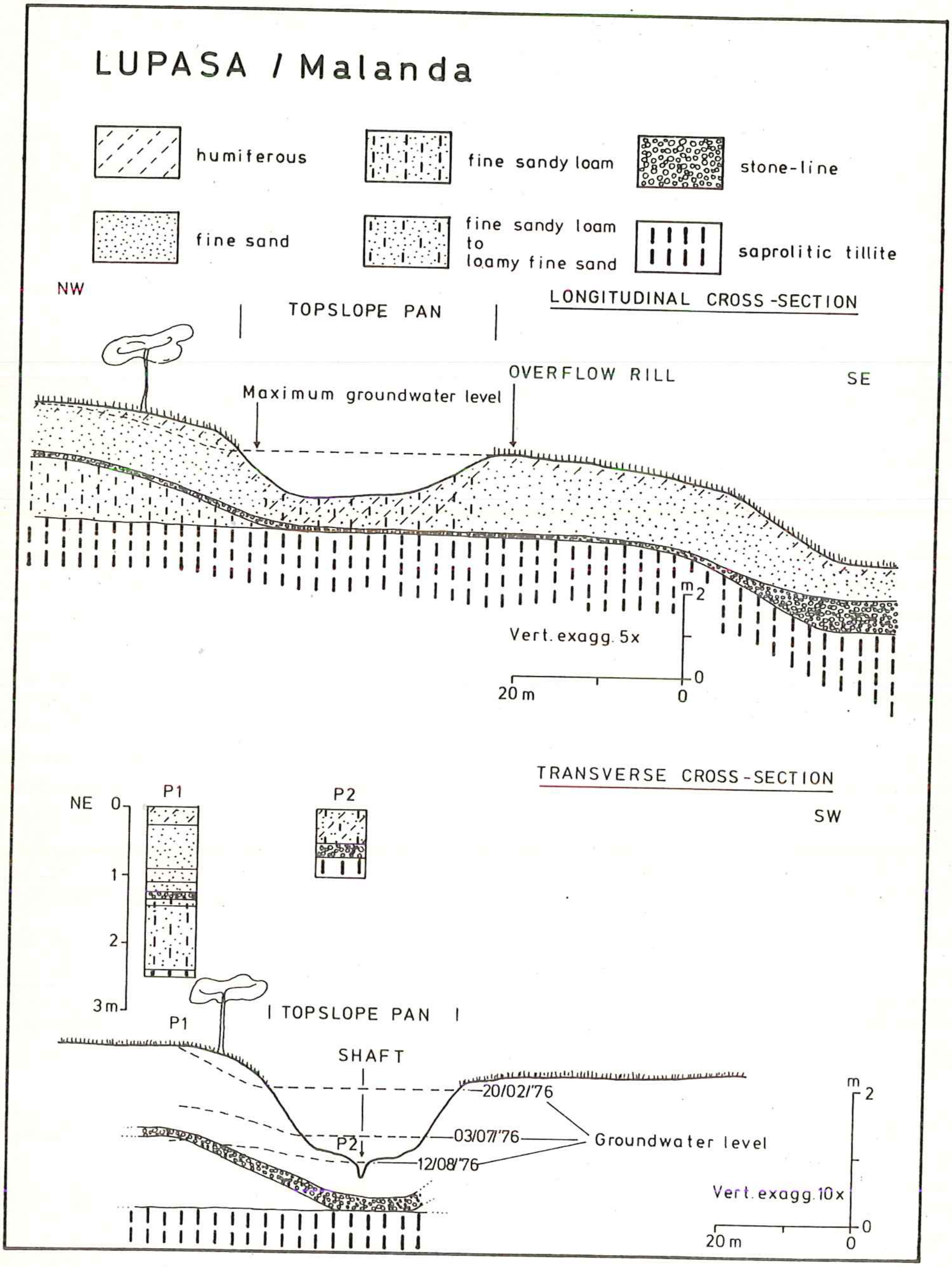

Fig. 8 : Cross-sections of a topslope-pan; after field observations in the Malanda-testplot on the Lupasa plateau.

level difference causes a narrow drainage trough around the pan. The more favourable hydrological conditions in this belt are sharply marked by the presence of shrub-vegetation.

As could be stated from a great number of field observations, the gradually lowering of the overflow-channel, the subsequent lowering of the free water surface and extension of the drainage trough and shrub-vegetation belt, results in the evolution of topslope-pans to spring-amphitheatres, a landform that frequently occurs on the *malungu*.

The footslope-pans

The footslope-pans mostly occur in headwatersystems stretching on the plateau and on marginal surface shoulders.

Most of them are worked out in thin (average thickness : 1 m) ferricrete caps developed at the foot of slope facets where iron is accumulated by the groundwater movement and cements parts of the sandy cover, the stone-line and the saprolitic precambrian substratum. The lower friable horizons beneath the ferricrete cap are attacked by suffosion, a pseudo-karstic process of combined chemical and mechanical erosion resulting in the development of caverns and underground channels beneath the duricrust. Because of the underground removal of material, ferricrete caps are undermined and collapse resulting in closed depressions repercuted on the *dilungu* surface. In the Kantala-Kamambu testplot on the Mukanga-plateau (Fig. 1) several steps in the evolution of the pans were recognized (DE DAPPER and MALAISSE, 1979), whereby the width/depth dimensions of the pans vary between 20 m/0.15 m and 90 m/1.8 m.

A few of the footslope-pans are not supported by ferricrete caps and are entirely worked out in loose sandy sediments. The origin of this kind of pans is not clear but a process of compaction of the sands on preferential wet spots could play an important role. Comparable phenomena were noted by MACKEL (1974) for the dambo-zones of the plateau region of Zambia.

ACKNOWLEDGMENTS

The author is greatly indebted to Prof. Dr. J. ALEXANDRE, Prof. Dr. J. ALONI, Prof. Dr. G. DE MOOR, Dr. A. FRANCOIS, Prof. Dr. F. MALAISSE, Prof. Dr. J. SOYER and Prof. Dr. R. TAVERNIER, for their varied help in the field and in the laboratory.

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