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QUATERNARY ARIDITY IN THE TROPICS AS EVIDENCED FROM GEOMORPHOLOGICAL RESEARCH USING CONVENTIONAL PANCHROMATIC AERIAL PHOTOGRAPHS (EXAMPLES FROM PENINSULAR MALAYSIA AND ZAIRE)

by Morgan DE DAPPER (*).

ABSTRACT. - Geomorphological surveying and mapping, using conventional panchromatic aerial photographs combined with fieldwork, were carried out in Peninsular Malaysia and Zaïre (Shaba).
In West-Malaysia important pediments, developed under dry climatic conditions on soft saprolitic bedrock, were found. Tephrochronological datings on correlated alluvial terraces permit to situate the dry climatic shift in the Late Pleistocene.
In Zaïre, the geomorphological studies were focused on the sandcovered plateaux near Kolwezi (Shaba). Three distinct generations of microlandforms testifying to an environment, drier than the present day one, were found. They cover a timespan from Late Pleistocene to Late Holocene.

I. INTRODUCTION.

The study of the relief or landforms is a valuable aid in geological surveying and mapping (LADMIRANT, 1974).

In compact rocks, landforms reflect longterm degradation and hence provide information about lithostructure.

In loose rocks - bedrock saprolite or sediments - landforms result from shortterm degradation as well as aggradation. In that case the morphography of the landforms as well as their chronosequence provides useful information to the Quaternary geologist.

Landforms can be mapped in a variety of ways. In the past the representation of relief by contours or form-lines, has been a standard practice. Contours however, only provide partial information about surface form and the accuracy with which they display landforms is dependent on the contour interval. Other methods of landform mapping have therefore been developed, predominantly since 1950. Morphological maps provide information about the surface forms. Geomorphological maps in addition include an interpretation of the surface form.

In most intertropical countries the availability of reliable base topographical maps is problematic. Hence in those areas conventional panchromatic aerial photographs are an invaluable aid to geomorphological mapping. They may be employed at all stages of a geomorphological survey, from the planning and reconnaissance stage to the accurate compilation of the final map (DOORNKAMP, 1971).

In the following chapters, examples are discussed of mapping and surveying landforms developed on loose sediments in Zaïre (Shaba) and on loose bedrock saprolite in West-Malaysia.

(*) Dr. Sc.; Laboratory for Physical Geography,
Geological Institute of the State University, Krijgslaan 281, B-9000 Gent (Belgium).

2. GEOMORPHOLOGICAL RESEARCH IN PENINSULAR MALAYSIA.

On a megascale three landformunits can be distinguished in Peninsular Malaysia (Figs. 1 and 2). A central upland (I on Fig. 2), strongly dissected by narrow valleys, is roughley bounded by the 325 m contourline; elevations there range up to 2,391 m (Gunong Tahan in the National Park). The upland is surrounded by an inland lowland composed of upland cores, hills and broad riverplains (II on Fig. 2). Finally a coastal lowland or plain seams the whole (III on Fig. 2) (DE DAPPER, 1985a).

The geomorphological field surveys were focused on the inland lowland and carried out in well spread testareas (Fig. 1) :

(A) - the Padang Terap area (Kedah)
(B) - the Kuala Trengganu - Marang - Ulu Trengganu area (Trengganu)
(C) - the Kuala Pilah - Bahau area (Negeri Sembilan)
(D) - the Kulai - Pontian Kechil area (Johor).

In the four testareas the following common chronosequence of landforms was found in decreasing order of age (Fig. 3) :

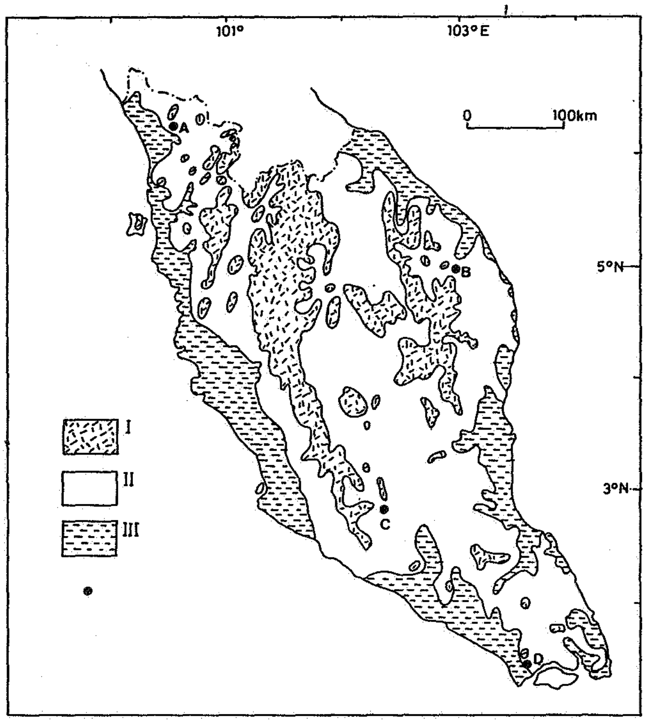

Fig. 1 - Megalandform-units in Peninsular Malaysia.
I Upland
II Inland lowland
III Coastal lowland
● Testareas for the geomorphological field survey.

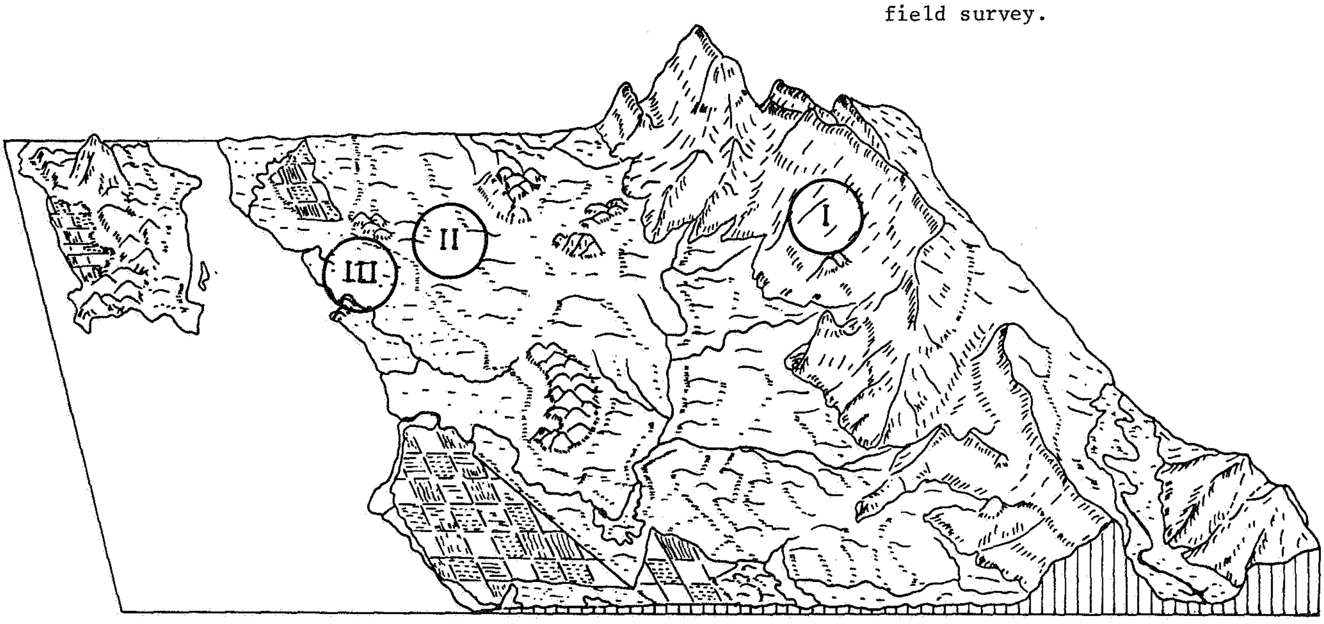

Fig. 2 - Blockdiagram representing the megalandform-units in Peninsular Malaysia (example from Kedah) (after MAHMOOD *et al.*, 1983).

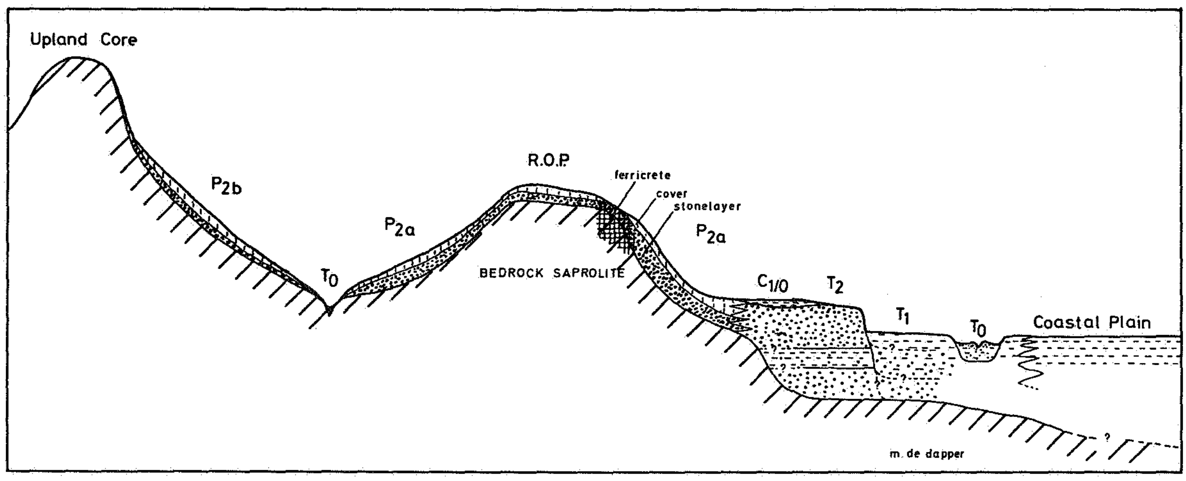

Fig. 3 - Model of the chronosequence of landforms in the inland lowland of Peninsular Malaysia (vertical scale exaggerated.

(1) - upland cores, such as ridges and high hills, dominantly controlled in their distribution and forms by the bedrock lithostructure,
(2) - low hills, considered as Remnants of an Older Pediplain (R.O.P.),
(3) - a complex surface comprising :
- a rock-cut river terrace level (T_2) along the main rivers,
- younger pediments (P_2) developed in saprolitic bedrock at the feet of upland cores and R.O.P. and grading into T_2,
(4) - younger T_1-terraces, cut-and-filled in or covering T_2 and grading, where possible (A, B, D), in the coastal plain,
(5) - the present riversystem (T_0), rock-cut or cut-and-filled in T_1 and then exhibiting an active morphology of riverbanks, levees and backswamps.

The relative importance of the landforms is different from one area to another. In Kedah (A) f.i., the younger pediments occupy most of the area and river-terraces are confined to narrow stretches (DE DAPPER and DEBAVEYE, 1985) (Fig. 4). In the Kuala-Pilah - Bahau area (C), the T_2-terrace forms a huge plain of some 100 sq km, whereas the younger pediments are rather short (BOUCKAERT *et al.*, 1984) (Fig. 5).

The superficial deposits of the younger pediments, testify to extensive slope pedimentation, operating on a dense gully system. The process must have taken place under a fairly open vegetation, such as a tree or grass savanna (DE DAPPER, 1981a, 1983, 1985b).

In granite terrains (B, C, D), the T_2-sediments are strikingly different from the T_1-sediments. The former are almost exclusively composed of granite grus derived coarse sand and fine gravel, whereas the T_1-alluvia are clayey and sometimes very organic. In the Padang Terap area the difference is not so clear as the bedrock is mainly composed of shales. The T_2-deposits reflect an environment marked by rather unprotected slopes and rivers of the braided type; the same environment wherein the P_2 developed. The T_1-deposits are correlated with slopes well protected by a dense forest cover - still prevailing at present day - whereon clay illuviation was a dominant process.

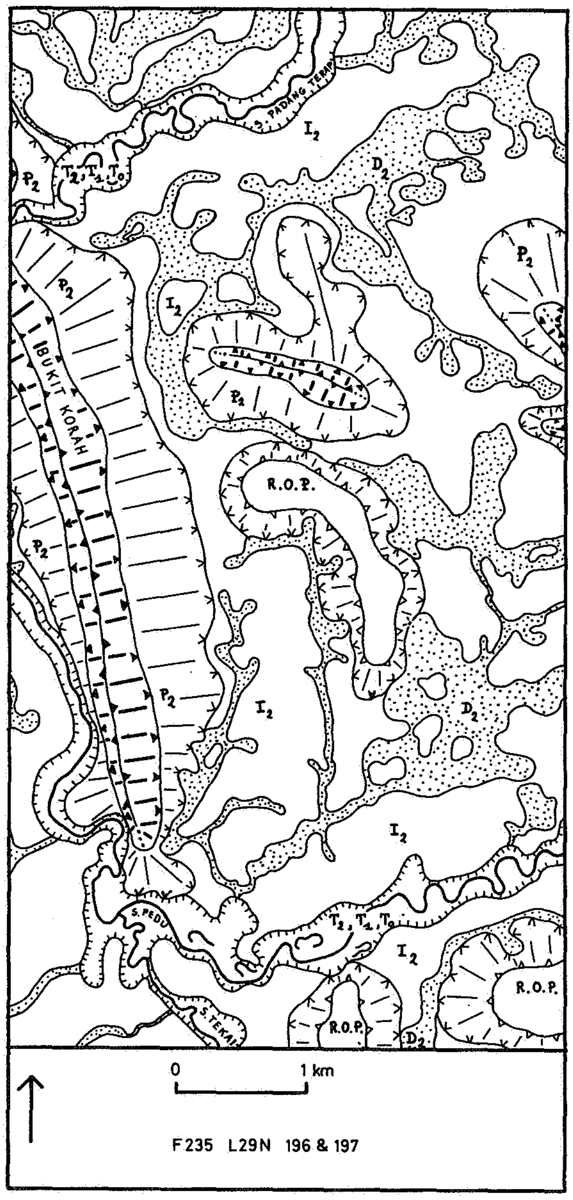

Fig. 4 - Map of the landforms near Korah Hill in the Padang Terap District of Kedah State. Based on aerial photographs L235 L29N 196-197 (approximate scale 1/25,000). I_2 en D_2 represent local variations of P_2 and T_2 respectively.

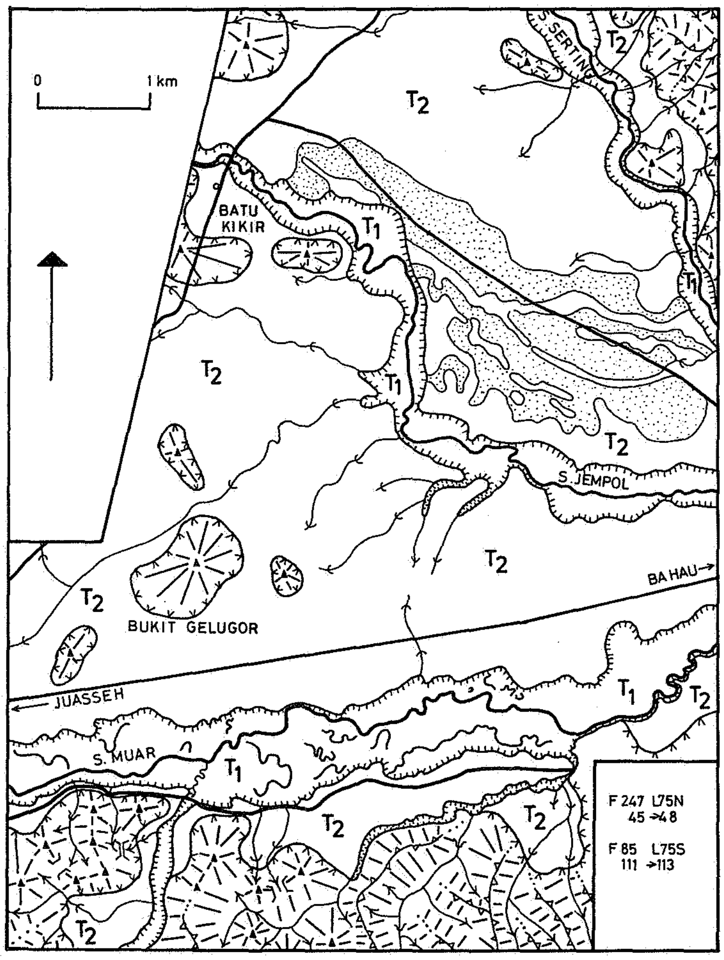

Fig. 5 - Map of the landforms in an around part of the Juasseh riverplain west of Bahau in Negeri Sembilan State. Based on aerial photographs F247 L75N 45-48 and F-85 L75S 111-113 (approximate scale 1/25,000).

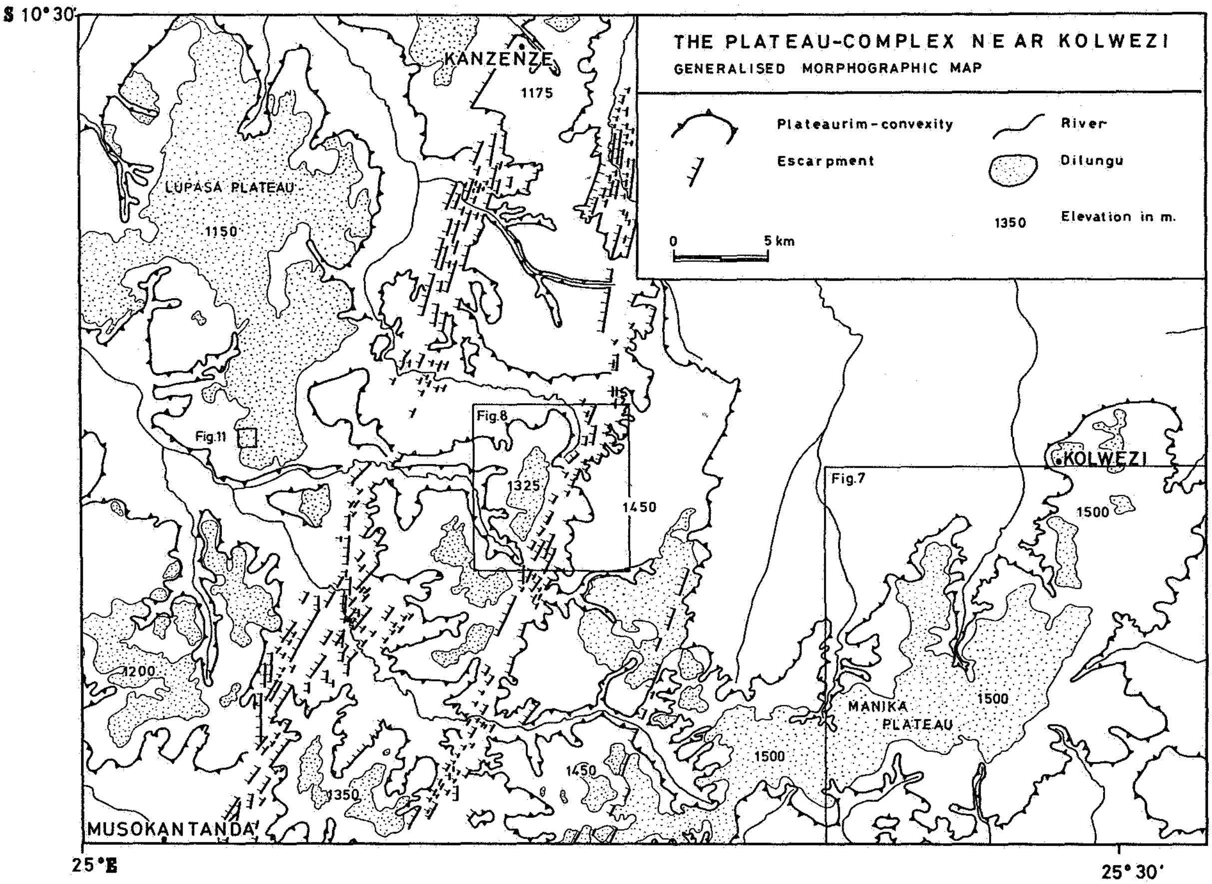

Fig. 6 - Generalised morphographic map of the complex of plateaux near Kolwezi (Shaba-Zaïre).

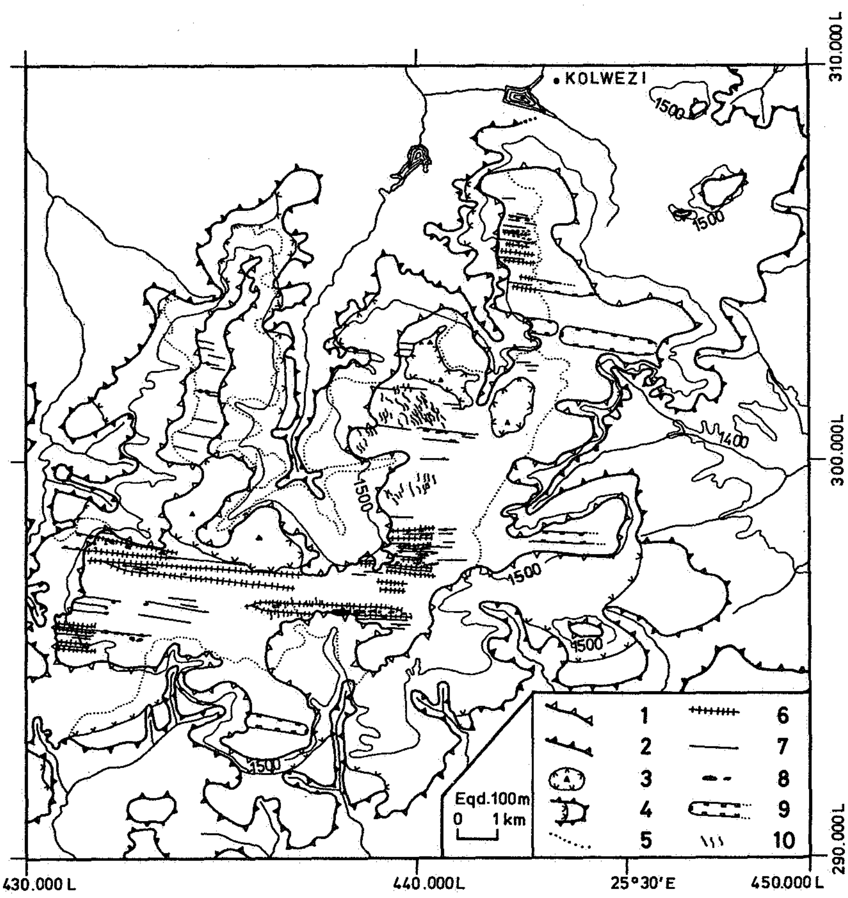

Fig. 7 - Microlandforms on the dilungu of the Manika plateau (S of Kolwezi, for situation see Fig. 6).

1. Crest surface edge convexity.
2. Plateaurim convexity.
3. Crest hill.
4. Marginal surface shoulder.
5. Extension of the dilungu and the mena.
6. Linear microridge.
7. Linear microdepression.
8. Pan.
9. Dry valley derived from longitudinal dunes.
10. Sinuous microridge.

In Kedah and Negeri Sembilan, the T_2-surface was found to be locally covered by volcanic ashes. The ashes never occur on the T_1-surface and are even locally covered by the T_1-alluvia. Electronprobe X-ray microanalyses on glass shards showed the ashes originated from an explosion of the Toba volcano on Sumatra (DEBAVEYE *et al.*, 1985). Similar ashes were dated 75,000 y BP by some authors and 30,000 y BP by others.

The geomorphic position of the volcanic ashes permits us to situate the complex of P_2-younger pediments and T_2-river terraces in a Late Pleistocene environment. The landforms and the nature of the superficial deposits allow us to suppose that this environment was markedly drier than the present day one.

3. GEOMORPHOLOGICAL RESEARCH IN ZAIRE (SHABA).

In Shaba, the geomorphological mapping was focused on the Kolwezi region. Due to three series of fault scarps the generally flat area forms a complex of plateaux with a 1,075 m to 1,515 m elevation range (Fig. 6). Great parts of the plateaux are covered by a dilungu, a thin sandy layer with a steppic vegetation. The dilungu shows an extensive and varied microrelief. At least three microlandformgenerations testifying to drier climatic conditions can be distinguished : longitudinal dunes, transverse dunes, mena (DE DAPPER, 1981c) (Fig. 7).

3.1. LONGITUDINAL DUNES.

Remnants of longitudinal dunes - linear microdepressions and microridges - are restricted to the sandcovered crest surfaces of the plateaux (DE DAPPER, 1979a, 1981b). They are difficulty surveyable on the field but easily discernable on aerial photographs by differences in tonality, translating drainage differences at the onset of the dry season (Photo 1). The linear microdepressions are very shallow (depths up to 30 cm) and narrow (maximum width of 40 m) but very long (lenghts between 1 km and 3.6 km). They show a remarkable constant E by S-W by N direction. In the linear microdepressions occur some pans. They are shallow (depths between 1 m and 3 m) and show a circular, eliptic or oval-shaped planform. Their diameter or axis varies in length from 40 m to 200 m. The linear microridges are low (maximum height of 50 cm), narrow (widths between 50 and 100 m) and also very long (lengths between 1 km and 5 km). They are always associated with the linear microdepressions, running parallely or subparallely with them.

The landform assemblage of linear microdepressions, linear microridges and pans, has an important geographical extent. Identical forms were observed on the Biano plateau (ALEXANDRE-PYRE, 1971) and on the Kundelungu plateau (DE DAPPER *et al.*, 1985). Taking account of their remarkable constant direction, they most probably originate from longitudinal dunes (VERSTAPPEN, 1968 and 1972; McKEE, 1979).

That origin supposes an arid climatic phase with very sparse or even lacking vegetation cover, offering conditions in which the dilungu sands could easily be modelled and transported by the wind.

In many cases the ridges join and then form an Y-shaped fork with two long prongs and a short stem always pointed to the W by N. Such a pattern reveals an E by S resultant drift direction of the winds.

Comparison with fixed eolian landform remnants surveyed in the former arid zones of Zimbabwe, Zambia and Angola by THOMAS (1984), shows the longitudinal dune remnants of Shaba to belong to the same ancient ergs.

Although no dates have yet been obtained for the formation of the ergs, HEINE (1982) and LANCASTER (1981) suggest periods of stronger anticyclonic circulation coinciding with glacial maxima during the Late Pleistocene.

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. 6). With respect to these morphographic observations one can conclude that the formation of the original longitudinal dunes must be situated before the escarpment formation. If not, the very regular longitudinal aspect would be perturbed at the proximity of the escarpments, the more so as the derived dominant wind direction was approximately perpendicular to the escarpment lines.

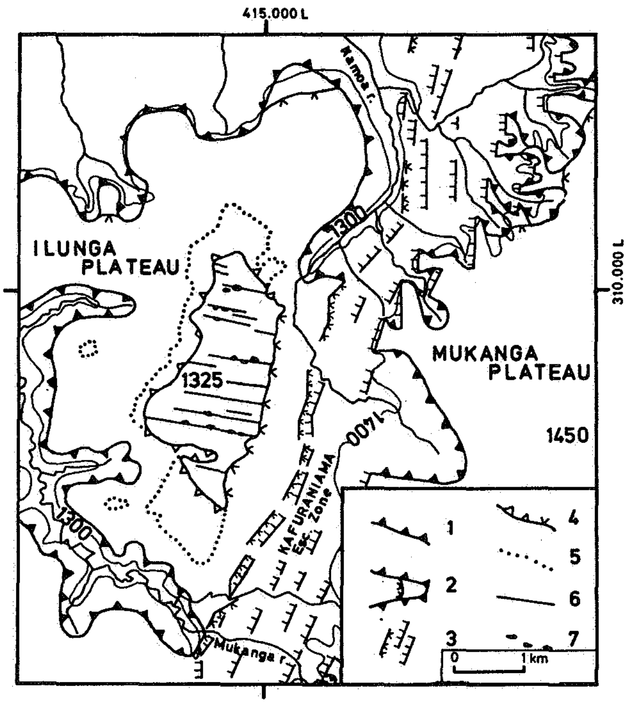

Fig. 8 - Simplified morphographic map of the Ilunga plateau (for situation see fig. 6). The linear microridges hit the basal concavity of the Kafuraniama tectonic escarpment zone.
1. Plateaurim convexity.
2. Marginal surface shoulder.
3. Tectonic escarpments.
4. Crest surface edge convexity and basal concavity.
5. Extension of the dilungu.
6. Linear microridge.
7. Pan.

Taking into account the probable age of the longitudinal dunes, one can suggest that at least part of the tectonic movements took place during or after the Late Pleistocene. This suggestion adds a nuance to the vision of leading authors as CAHEN (1954) and ROBERT (1956) situating the movements in the Early Pleistocene.

3. 2. TRANSVERSE DUNES.

Restricted to the sandcovered crest surfaces of the plateaux also occur remnants of transverse dunes. They form sinuous microridges that 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. Field measurements on the Lupasa plateau show a net asymmetrical crossform with a more gentle windward slope facing ENE or NE. This configuration is well translated in the photo image by tonality differences. The very well drained crests show a white tonality whereas the well drained leeward slopes and more badly drained windward slopes show grayish white and gray tonalities respectively (Photo 2, Fig. 9).

In some places transverse dune remnants are developed on linear microridges. This observation proves the former to be posterior to the longitudinal dunes. They form a second generation of eolian landforms. From their rather scattered distribution with regard to the sand ridges, one can suppose they are not obligatory formed under perarid conditions but that they are merely seasonal forms issued from a climatic phase with long and accentuated dry seasons.

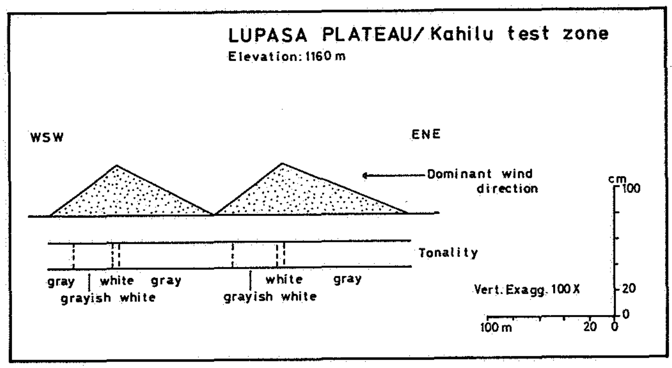

Fig. 9 - Asymmetrical cross-section of sinuous microridges translated by tonality differences on the aerial photo image; as observed in the Kahilu test zone on the Lupasa plateau.

3. 3. MENA.

Mena occur on the over-all dilungu, regardless of its morphographic position on the plateaux (DE DAPPER, 1979b). They are small (lengths between 2 m and 10 m; widths between 3 m and 5 m) and shallow (depths between 15 cm and 30 cm) closed depressions. Mena are elongated and ramified and appear in a dense pattern with long axes running parallely. In a test zone on the Lupasa plateau the axial length averaged 1180 m/ha (DE MOOR and DE DAPPER, 1979) (DE DAPPER and DE MOOR, 1980) (Figs. 10 and 11).

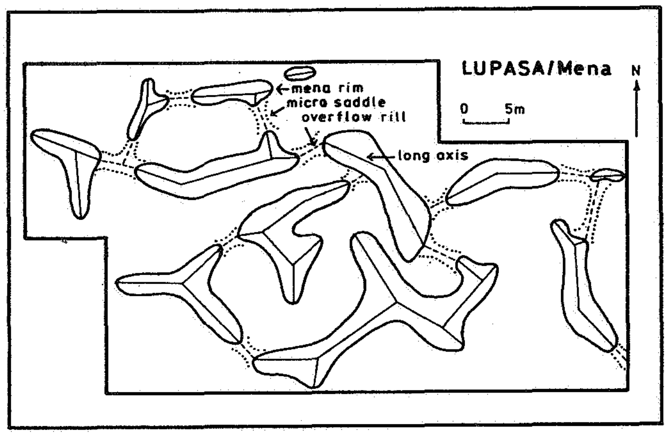

Fig. 10 - Planform of the mena network; after field observations on the Lupasa plateau.

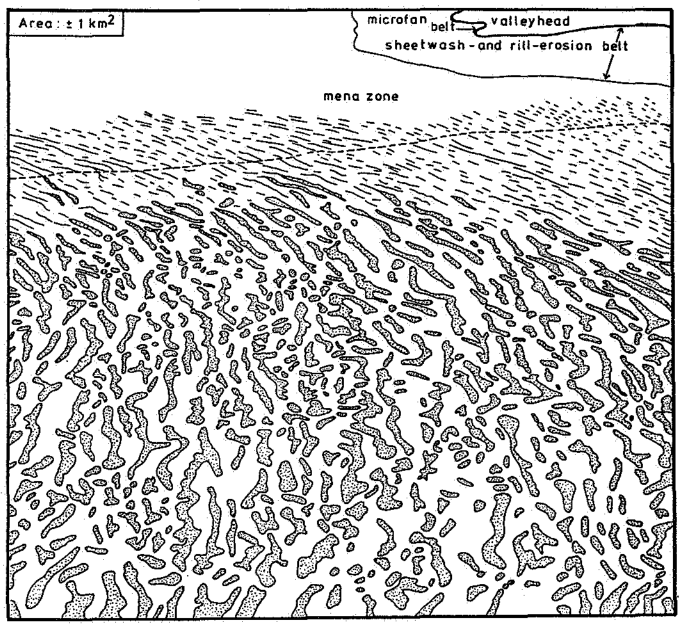

Fig. 11 - The mena network as derived from an oblique low-altitude color-airphoto. Taken near the valleyhead of the Kabilenge river on the Lupasa plateau during the dry season, after a bushfire (05.07.76) (for situation see Fig. 6).

The mena bottoms and mena interfluves show definite contrasts in vegetation. The mena bottoms are flooded during the rainy season and are therefore covered with grass species. The mena interfluves on the other hand remain dry the whole year through. Their vegetation, besides a few grass species, is dominated by subshrubs. At the end of the dry season the perched groundwatertable drops rapidly and bottom grasses very quickly wither, wheras interfluve subshrubs do not suffer yet. Those differences at the onset of the dry season makes the mena visible on aerial photographs (Photo 3).

Mena are no eolian forms but are the result of the degeneration of a once extensive rill-system operating on the

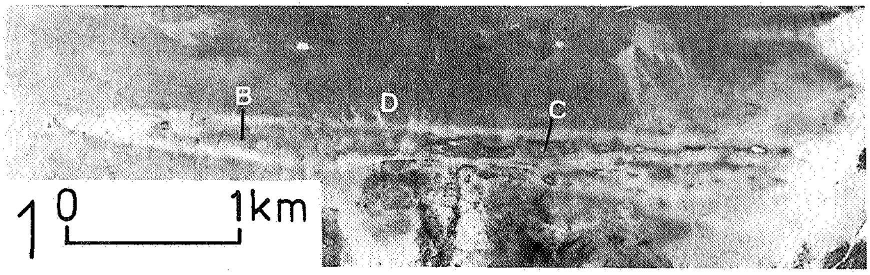

PHOTO 1.

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 occur some pans (C). 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.

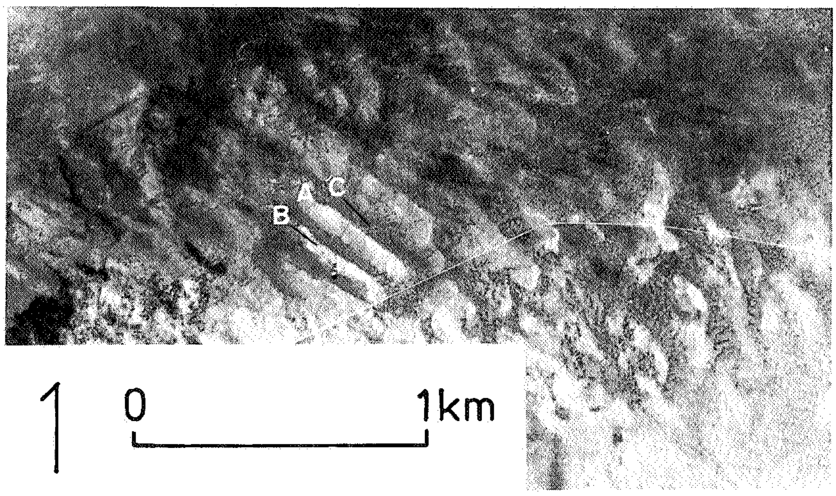

PHOTO 2.

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.

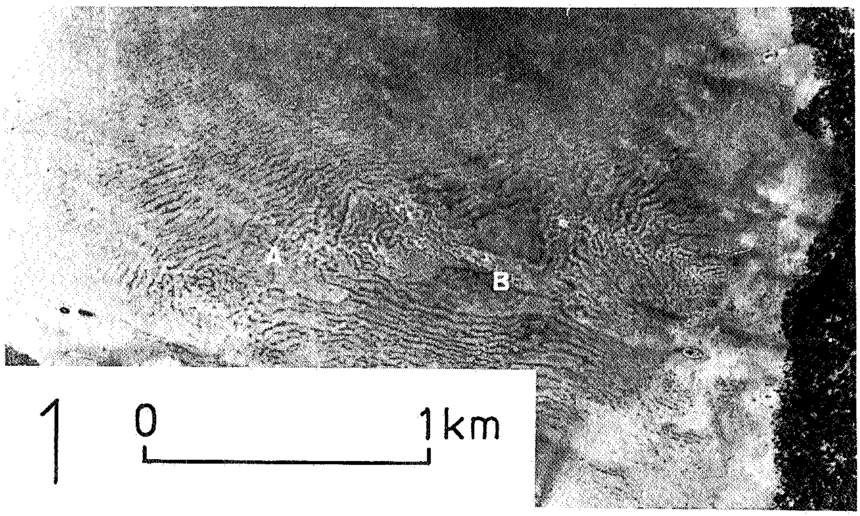

PHOTO 3.

A dense network of mena (A) is developed on the over-all dilungu. They issued from the degeneration of an extensive gully system. In places they partly obliterate remnants of longitudinal dunes (B).

dilungu under climatic conditions somewhat drier than the present day ones. Radiocarbon dates on correlated sediments in valley heads permit to situate the rill-phase around 2,000 BP.

4. CONCLUSION.

Conventional panchromatic aerial photographs are a helpful instrument in surveying and mapping landforms, especially in tropical areas where the availability of reliable topographic maps is problematic. In cases where the vertical dimensions of the landforms are below the contour interval, the use of aerial photographs is even indispensable.

In Peninsular Malaysia, where nowadays natural vegetation consists of a dense rainforest, as well as in southern Zaîre, where the natural vegetation corresponds to a savanna climate, geomorphological indicators point to a much drier Late Pleistocene environment. Those findings add to the accumulating evidence of severe aridity throughout most of the tropical savanna and forest zones during the Late Pleistocene (THOMAS, 1978), (STREET, 1981).

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