Journée d'étude – Studiedag
«Stone-lines»
(Bruxelles, 24.III.1987, Brussel)
Académie royale des Sciences d'Outre-Mer
Koninklijke Academie voor Overzeese Wetenschappen
pp. 37-59 (1989)

Geo-Eco-Trop.
11 (1987, n° 1-4) : 37-59
publ. 1989

PEDISEDIMENTS AND STONE-LINE COMPLEXES IN PENINSULAR MALAYSIA

BY

Morgan DE DAPPER *

SUMMARY. – In the hilly uplands of Peninsular Malaysia, pedisediments are found on widely developed degradational footslopes. The pedisediments are invariably composed of a stonelayer, possibly with a stone-line at the base and topped by a fine grained cover. Evidence is advanced to show that stone-line, stone-layer and cover are of allochtonous origin. A modified model of slopepedimentation (as defined by ROHDENBURG 1969) is put forward to explain the genesis of the pedisediments.

RÉSUMÉ. – *Le complexe de la stone-line dans les pédisédiments de la Malaisie péninsulaire.* – Dans la région des collines de la Malaisie péninsulaire, des pédisédiments ont été rencontrés sur de larges zones érosives de piémont. Les pédisédiments sont invariablement composés d'une "stone-layer" avec éventuellement une stone-line à la base et surmontés par des terrains de couverture assez fins. L'un et l'autre sont de toute évidence d'origine allochtone. Un modèle modifié de 'pédimentation de pente' (au sens de ROHDENBURG 1969) est proposé pour expliquer la genèse de ces pédisédiments.

SAMENVATTING. – *Het stone-line complex in de pedisedimenten van het Maleise Schiereiland.* – In het heuvelgebied van het Maleise Schiereiland werden pedisedimenten aangetroffen in brede zones van geërodeerde voethellingen. De pedisedimenten zijn onveranderlijk samengesteld uit een stone-layer met eventueel een stone-line aan de basis en bedekt met een bovenlaag met fijne textuur. Beide hebben zonder enige twijfel een allochtone oorsprong. Een gewijzigd model van "helling-pedimentatie" (volgens ROHDENBURG 1969) wordt voorgesteld om het onstaan van deze pedisedimenten te verklaren.

Introduction

Integrated in a soil mapping program, geomorphological field surveys were carried out in three testareas in the uplands of Peninsular Malaysia : (A)

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

Padang Terap (Kedah ; 6°15' N-100°35' E), (B) Kuala Pilah (Negeri Sembilan ; 2°45' N-102°20' E) and (C) Johor Bahru (Johor ; 1°30' N-103°30' E).

The following common chronosequence of landforms was found in decreasing order of age (Fig. 1) :

1. highland cores, considered as remnants of the Oldest Surface ;
2. low hills, considered as remnants of an Older Peneplain-Pediplain (R.O.P.), developed at the foot of the highland cores ;
3. a complex surface comprising :
   - a rock-cut river terrace level (T_2),
   - younger pediments (P_2), developed at the foot of highland cores and R.O.P. and grading into T_2.
4. younger T_1-terraces, cut-and-filled or covering T_2 and grading, where possible (A, C), in the coastal plain ;
5. the present riversystem (T_0), rock-cut or cut-and-filled in T_1.

Pediments

The footslopes in the test areas show the following common formelements :

1. They are developed at the foot of higher and steeper ground.
2. They have a typical transverse profile (i.e. normal to the hillfront) :
   a. The slope is at a low angle (less than or equal to 10°) relative to the steeper ground (15° to 30°) of which it is a footslope.
   b. The profile is smooth and in most cases concave, although rectilinear sections may be present.
   c. The nick between the footslope and upland is abrupt. However it is not necessarily perfectly angular and may comprise a short concavity in a nickzone.
3. They have a typical longitudinal profile (i.e. parallel to the hillfront) : it tends to be rectilinear and undulates only slightly where the footslope is dissected by streams having their head in the hillfront.
4. They have a typical shape when considered in three dimensions : they are generally planar low angle surfaces with a faint concavity.

Moreover, as will be further demonstrated, the footslopes are degradational landforms truncating lithological and tectonic variations and only covered by a thin veneer of loose superficial material.

The footslopes in the testareas therefore meet the requirements to be labelled pediments following the definition of WHITAKER (1979) : "A pedi-

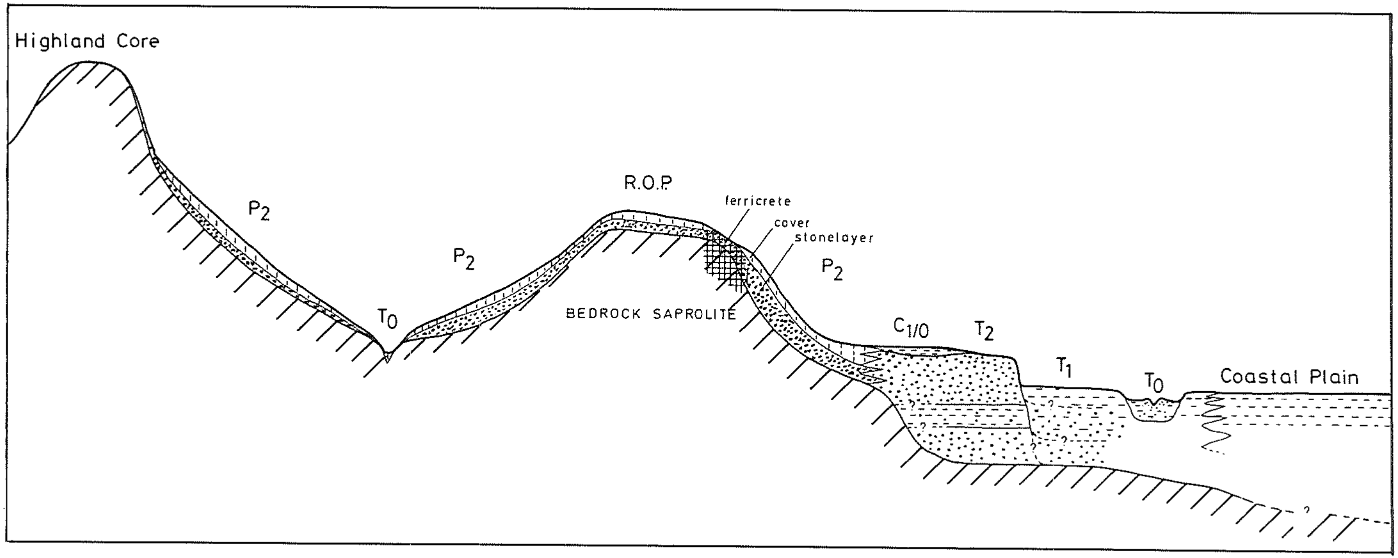

Fig. 1. – Chronosequence of landforms in the testareas.

ment is a terrestrial erosional footslope surface inclined at a low angle and lacking significant relief in all three dimensions. It usually meets the hillslope at an angular nickline, and may be covered by transported material". The definition given above is non-genetic, apart from the exclusion of purely depositional, non-terrestrial and tectonic landforms. The pediment, defined as such, is not restricted to any process, lithology, structural setting, climatic environment, or size.

Pedisediments

In almost all cases the subaerial pediment surface is only separated from the bedrock pediment surface by a veneer of loose unconsolidated material, with a thickness rarely exceeding 3 m and showing a typical twofold layering.

The first layer above the bedrock is composed of pebbles (as defined by FRIEDMAN & SANDERS 1978) with particle diameters usually ranging between 5 mm and 25 mm. In some cases the base of the first layer is marked by a pavement of cobbles, ranging in diameter size from 50 mm to 200 mm, and even rare boulders (Fig. 2). The gravel of the first layer is always imbedded in a fine earth matrix at varying proportions. The degree of packing ranges from sparse and matrix-supported to dense and clast-supported. The top layer is almost exclusively composed of fine grained matter. The boundary between gravel layer and top layer is always abrupt. The gravel is composed of weathering resistant elements such as vein quartz, metamorphic rock fragments and ironstone nodules (FAO 1977). The last are always present in very large quantities.

The above depicted build-up of the superficial layers on gentle slopes is very typical for intertropical areas and was described by many authors. In his review of the literature on stone-lines and related phenomena VOGT (1966) preferred the neutral expressions "stone-line complexe", "recouvrement argilo-sableux", "stone-line au sens large" and "stone-line au sens étroit" to designate the whole of the superficial layers, the top layer, the gravel layer and the pavement respectively. Another neutral but less detailed subdivision was proposed by VINCENT (1966) who identifies the layers as levels A (top) and B (gravel) overlying C, the bedrock. Following Vogt's proposition we will use the terms cover, stone-layer and stone-line to designate the top layer, the gravel layer and the pavement respectively.

As a rule, the stone-line is a thin deposit. On rocks providing coarse debris (e.g. from quartz veins) in sufficient quantity the stone-line forms a continuous, twodimensional pavement. On fine-grained rocks, like shales,

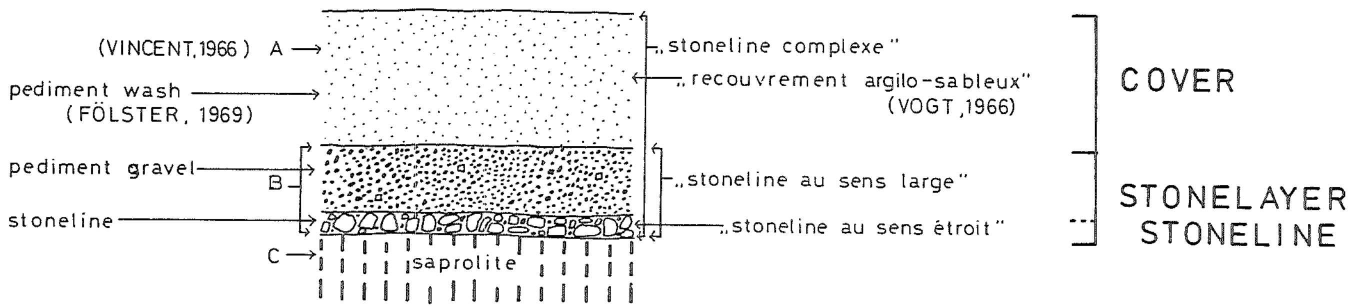

Fig. 2. – Nomenclature of the superficial layers on the pediments.

stone-lines are often discontinuous and may not be seen in individual profile pits or small exposures. The stone-layer and the cover run parallel to the surface, though with many minor irregularities. Undulations, irregular humps and runnel-like depressions of one to several tens of meters width characterize both the A/B- and the B/C-plane. As these irregularities do not conform on both planes, the thickness of A and B may vary considerably.

The bedrock is always weathered to a soft saprolite wherein original rock features such as bedding and quartz veins can still ne recognized to varying degrees. The top of the saprolite is very often duricrusted by varying degrees of laterite formation. As was showed by the soil surveys in the testareas, in many cases a close relationship exists between the saprolitic bedrock, the stone-layer matrix and the cover (DEBAVEYE & ABDUL RAHMAN 1983, BOUCKAERT *et al.* 1984) (Fig. 3). The cover however tends to possess a somewhat lower clay contents.

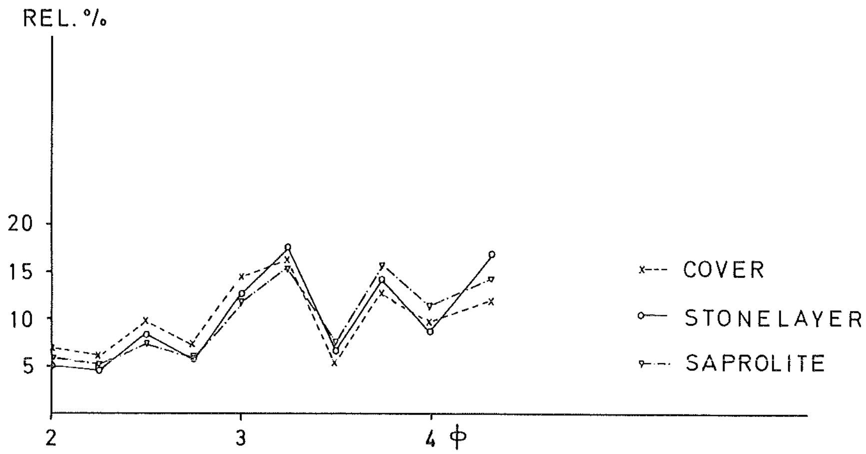

Fig. 3. – Typical particle size distribution of the 50-250 μm fraction of cover, stone-layer and saprolite.

Cover, stone-layer, stone-line

1. AUTOCHTONOUS OR ALLOCHTONOUS ORIGIN

Particularly within the tropics, stone-layers in weathering profiles have been the cause of considerable controversy. As they represent an obvious discontinuity separating the bedrock from the cover, the question arose whether the superficial layers are to be considered as the products of an autochtonous development, i.e. resulting from pedogenetic alteration of the bedrock *in situ*, or of an allochtonous one, i.e. resulting from erosional-depositional processes.

2. Application to the test areas

Individual soil profile pits or exposures provide a first approach to the study of the stone-layers on the pediments in the test areas. It reveals that, except for some vein quartz and bedrock fragments, the bulk of the stone-layer is composed of ironstone nodules of fine to coarse pebble size. Observations on the sorting, the macroscopic properties and the composition of the laterite gravel already gives several indications pointing to an allochtonous origin.

In a downslope sequence the ironstone nodules show a decrease in mean particle size and their shape changes from oblong to equidimensional and from angular and subangular to subrounded and rounded. For Padang Terap it was shown that,

1. the decrease in particle size is the result of physical desintegration initiated by shrinkage features following dehydratation of the iron oxihydrates,
2. as they become smaller, the nodules derived from weathering shale or sandstone rock, show an increased residual accumulation of iron oxihydrates and gradually loose the properties of the original material,
3. as the iron accumulation increases, the nodule colour becomes darker and its hardness and density increases (Debaveye & De Dapper 1987).

On the lower segments of the pediments the laterite nodules are a mixture of spherical, medium to fine, dark brown, moderately hard and fine, red, soft and black hard particles. It was shown for Padang Terap that the red nodules are plinthite (Soil Survey Staff 1975) or groundwater laterite (McFarlane 1983), derived from local weathering profiles. Micromorphologically they show an internal fabric similar to the fabric of the surrounding soil and clay coatings can be recognized. The dark brown and black nodules in some places have the internal fabric of shale or sandstone but more often they entirely consist of iron oxihydrates. They are derived from an older higher duricrusted weathering profile.

Stone-lines, indicating sorting of the gravel, are best developed on the middle and lower segments of the pediments (Fig. 4). All those observations point to the fact that transport by water took place and that the energy involved was proportional to the length of the downslope path.

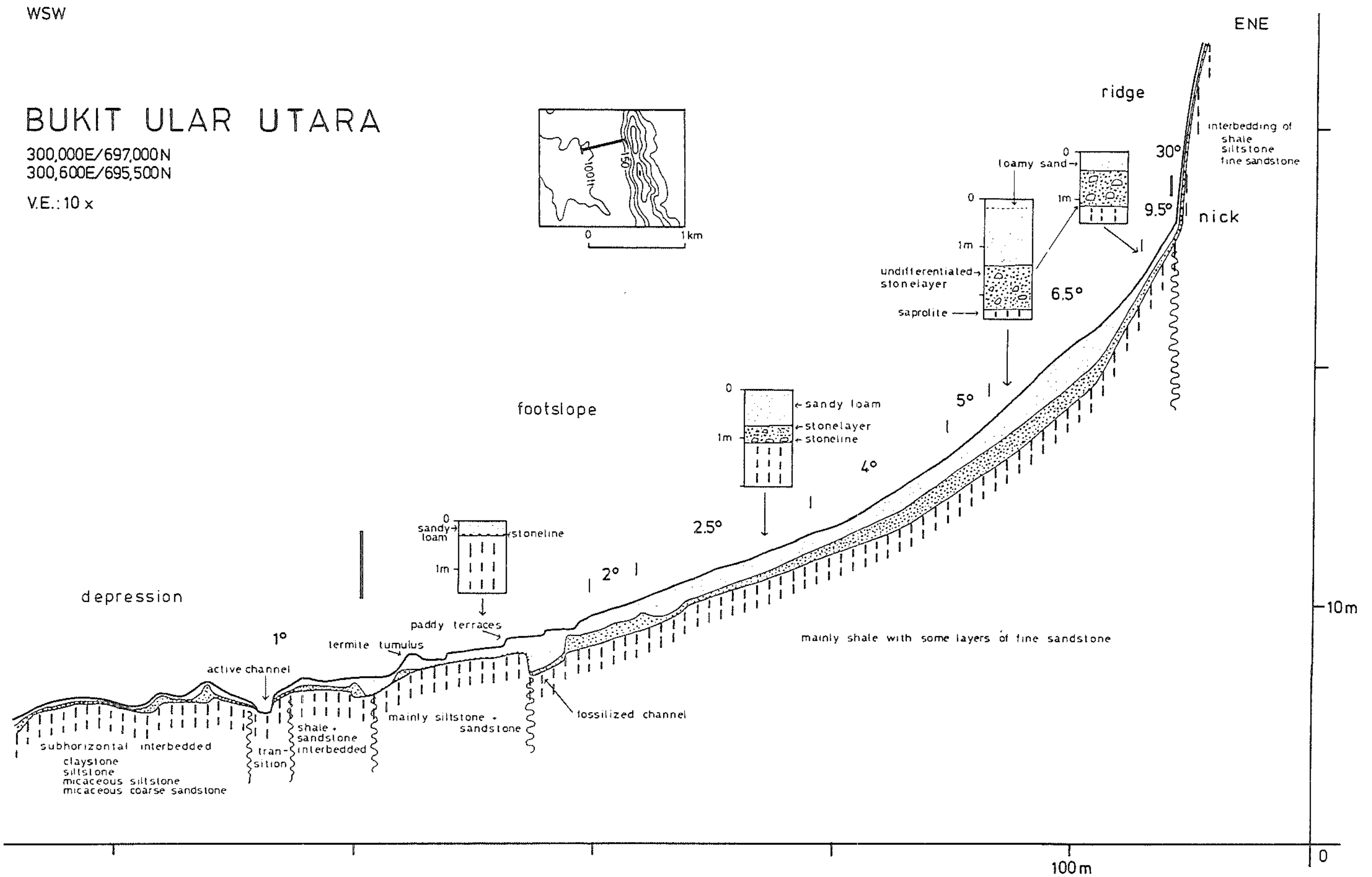

Fig. 4. – Transverse profile of a pediment developed at the foot of Bukit Ular Utara (Padang Terap). The co-ordinates refer to the RSO Grid (meters) of the topographical map on scale 1/63,360 of the Directorate of National Mapping, Malaysia.

Observations in long sections however permit to add some nuance to the picture sketched above. In long continuous exposures, the undulated aspect of the superficial layers is obvious. The nature of the undulations however, is dependent on the orientation of the sections. In exposures parallel to the hillfront, i.e. cutting the pediment longitudinally, the undulations are always more regular and show a shorter wavelength than it is the case in those oriented in other directions (Fig. 5 and 6). The 50 m long longitudinal section, illustrated in figure 5, for example shows a mean regular wavelength of 5 m and amplitudes varying between 25 cm and 75 cm.

The orientation dependent nature of the undulations excludes tree throw and termite extraction pits as exclusive cause, as they would result in irregular undulations independently from the orientation they are cut. For the same reason preferential chemical suffosion (as defined by TRICART 1965 and SEGALEN 1969), resulting in a kind of secondary irregular front of weathering (as defined by OLLIER 1974) can be excluded as exclusive cause for the undulations. In some cases, as is illustrated on figure 6, it is even very clear that the stone-layer does not follow the irregularities of the basal zone of weathering top.

The wavy aspect is obviously due to long stretching almost parallel channels running on the pediments following directions transverse to the hillfront. According to the size, those channels most probably are gullies.

The most regular undulations (considered in sections longitudinal with regard to the hillfront) are found in the upper middle segments of the pediments (Fig. 5). Rock features such as quartz veins are cut in the channels but they continue somewhat broken up in the interfluves, between channels, even if they are minor ones. The laterite pebbles in the channels mainly consist of subangular, medium, dark brown, moderately hard nodules quite similar to the nodules found in the interfluve stone-layer. It is obvious that the channel gravel is allochtonous but locally derived from an autochtonous stone-layer in the interfluves. The latter is very similar to STOOPS' (1967) β_2-layer ("grenaille latéritique" *in situ*).

On the lower middle segments of the pediments all minor rock features are cut by the stone-layer but larger rock features (e.g. sandstone beds and quartz veins with a thickness of 1 m and 0.5 m respectively, as illustrated on Fig. 7) continue in the interfluve stone-layer. In the centre of the channels a considerable thinning of the stone-layer is often observed.

On the lower segments of the pediments, all rock features are cut by the stone-layer, even the major ones (Fig. 8). Thinning of the stone-layer is often observed in the centre of the channels and sometimes the cover rests directly

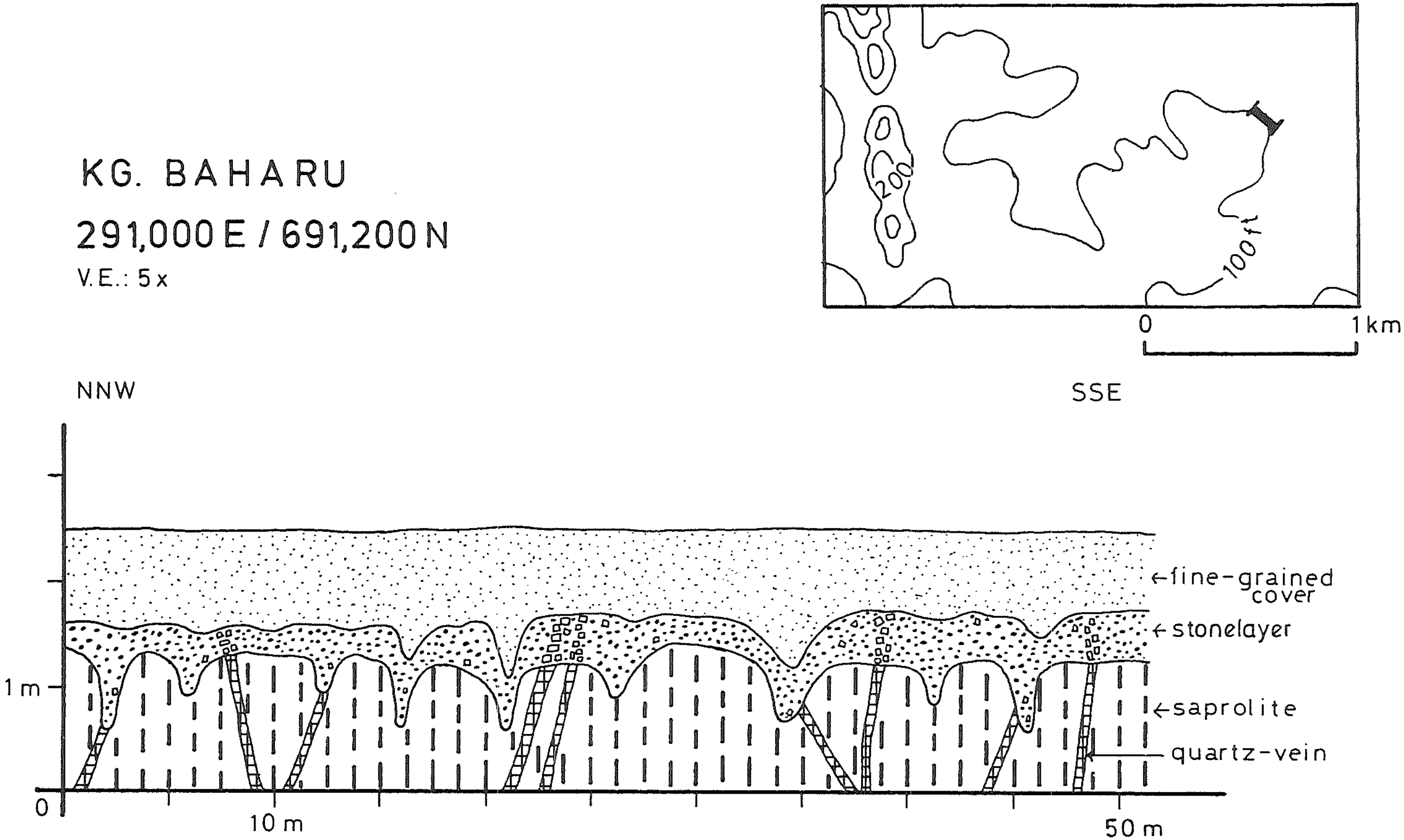

Fig. 5. – Longotudinal cross-section on the upper middle segment of a pediment near Kg. Baharu (Padang Terap).

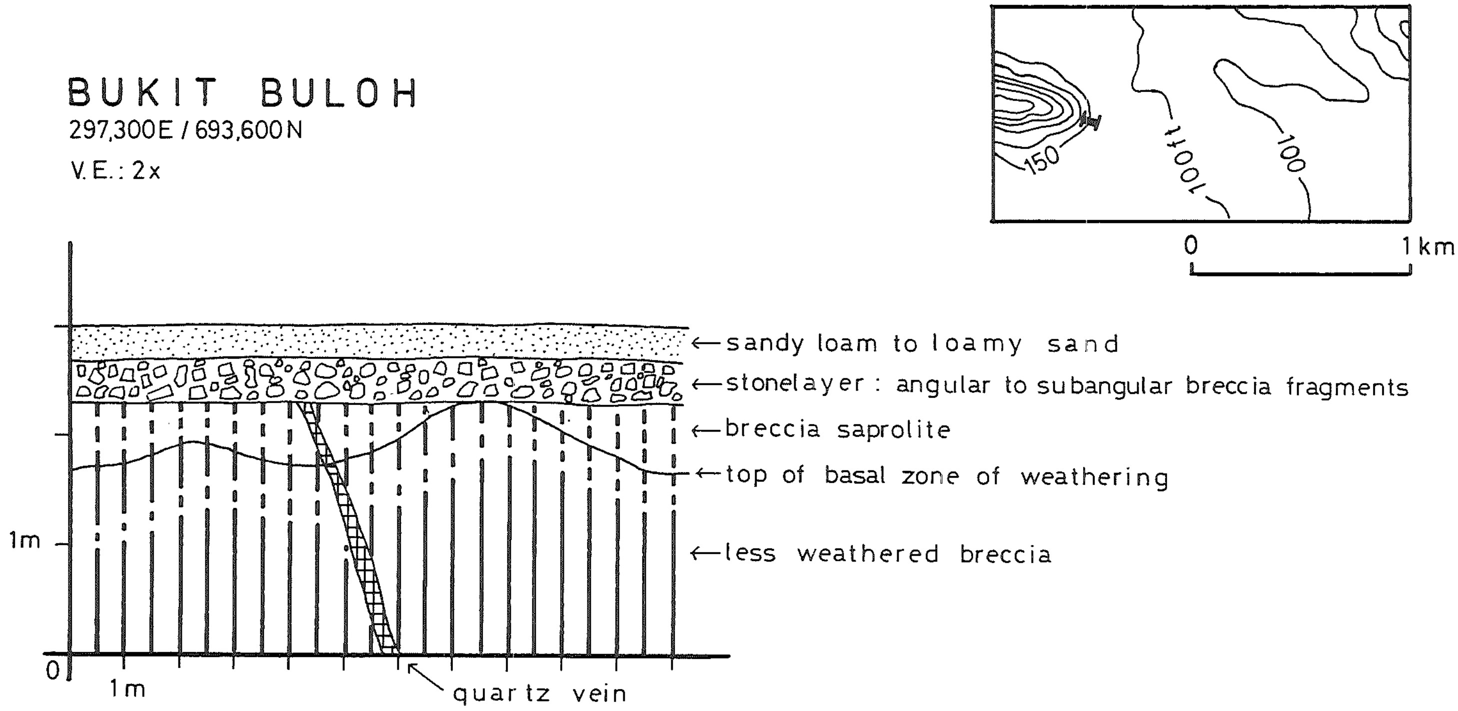

Fig. 6. – Transverse cross-section on the upper middle segment of a pediment developed at the foot of Bukit Buloh (Padang Terap).

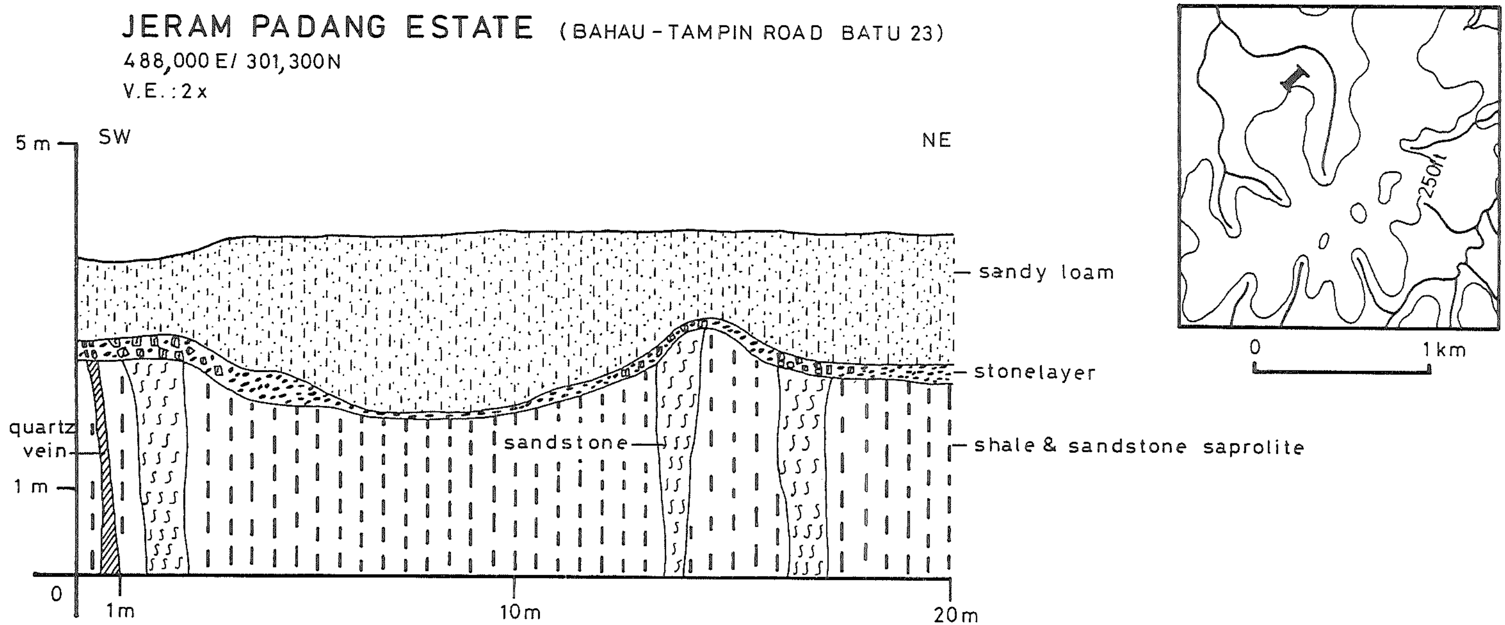

Fig. 7. – Longitudinal cross-section on the lower middle segment of a pediment in Jeram Padang Estate (Kuala Pilah).

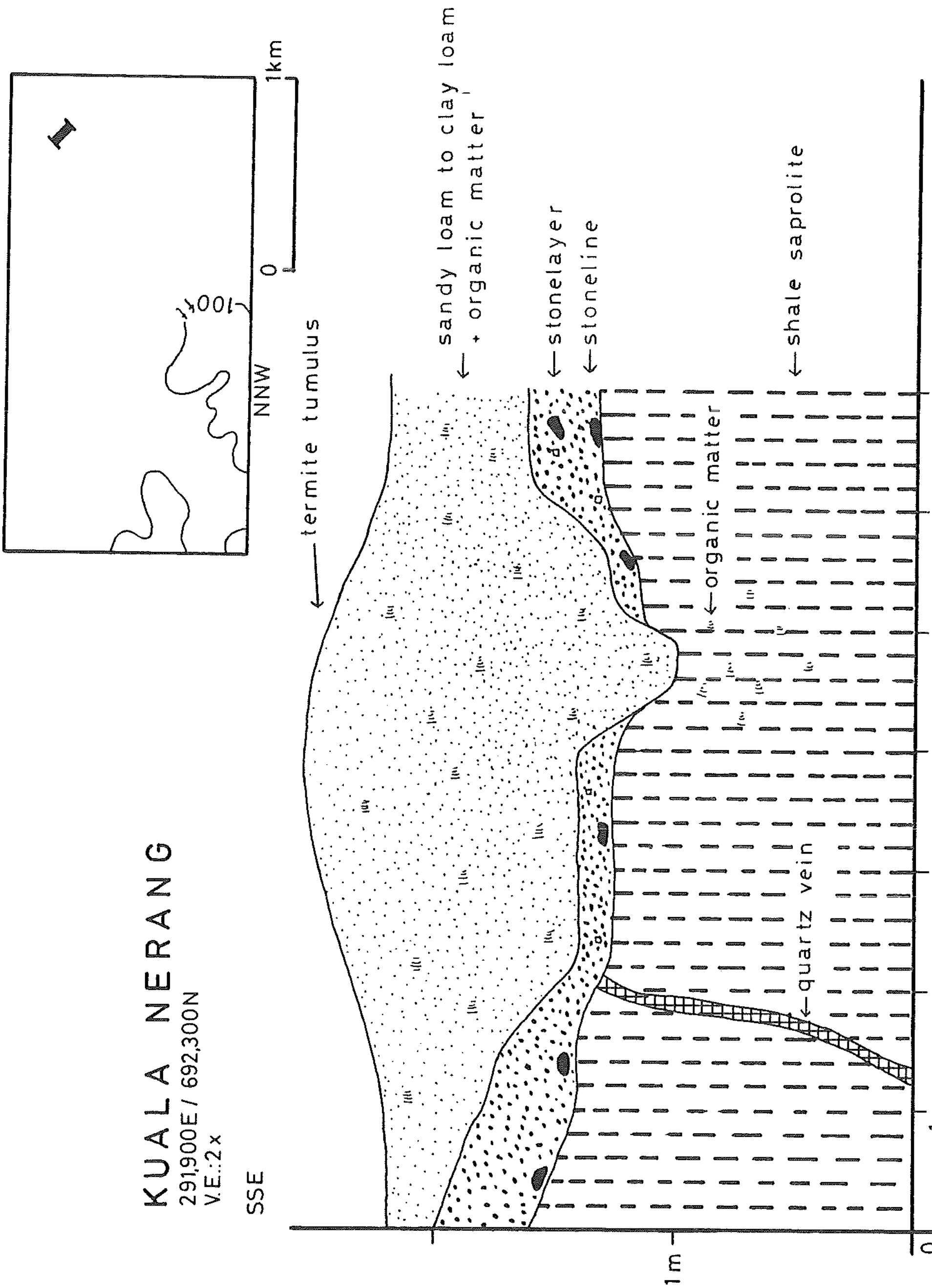

Fig. 8. — Longitudinal cross-section on the lower segment of a pediment near Kuala Nerang (Padang Terap).

on the saprolite. Stone-lines are often developed and in some cases concentrated in the major channels (Fig. 9). Sorting is also indicated by the concentration of fine black hard nodules on top of the stone-layer. It is obvious that here the whole stone-layer is an allochtonous deposit, a fact that is corroborated by the mixed nature of the laterite nodules. The fossilized gully nature of the channels is occasionally illustrated by the preferential outflow of groundwater perched on the saprolite even after a long dry period (e.g. Fig. 10, observations of the beginning of May 1981 after a relatively dry period lasting from December to March).

In most cases the top of the cover, i.e. the subaerial pediment surface, hardly reflects the undulations of the stone-layer. The cover evens out the irregularities of the bedrock pediment surface. The presence of solifluction lobes affecting the stone-layer and leaving cover features undisturbed (e.g. on Fig. 11, a secondary stone-line is not affected) show that the stone-layer was exposed to the air for some time. In a micromorphological study ZAUYAH & BISDOM (1983) observed features, interpreted as iron encrusted fungal hyphae in ironstone nodules from Kedah. This finding may imply that the nodules at some time occurred at or close to the surface. Those observations lead to the conclusion that the cover was deposited after the stone-layer formation or that it was at least locally reworked after its deposition. The reworked nature is corroborated by the occasional presence of a secondary stone-line in the cover (Fig. 9 and 11). It represents a thin lag layer mainly composed of very fine to fine quartz pebbles and clearly derived from the underlying cover material. Unconcentrated runoff and splash may be responsible for their formation. However, the close genetical relationship between cover and stone-layer is indicated by the fact that secondary stone-lines in most cases follow the undulations of the latter (e.g. Fig. 9).

Geomorphologically important termite activity was mainly observed in the Padang Terap testarea. Termite tumulus densities of 16 to 30 ha^{-1} were observed, tumuli cover 4 to 17% of the surface and take up total volumes of 176 to 596 $m^3.ha^{-1}$ (DE DAPPER 1981). In most cases termite tumuli are located on top of the stone-layer channels (Fig. 8). This observation may lead to the false impression that they are termite extraction pits. It is plausible however that the termites chose the fossilized gullies to locate their nests because of the local better soil moisture conditions. Similar observations were made by DE DAPPER (1978) in Zaire. In some cases however the reworking and removal of stone-layer material is obvious (Fig. 12). For the Padang Terap area one can conclude that the role of termites in bringing up and mixing cover material may be important but that they are not the exclusive cause of the wavy aspect of the stone-layer.

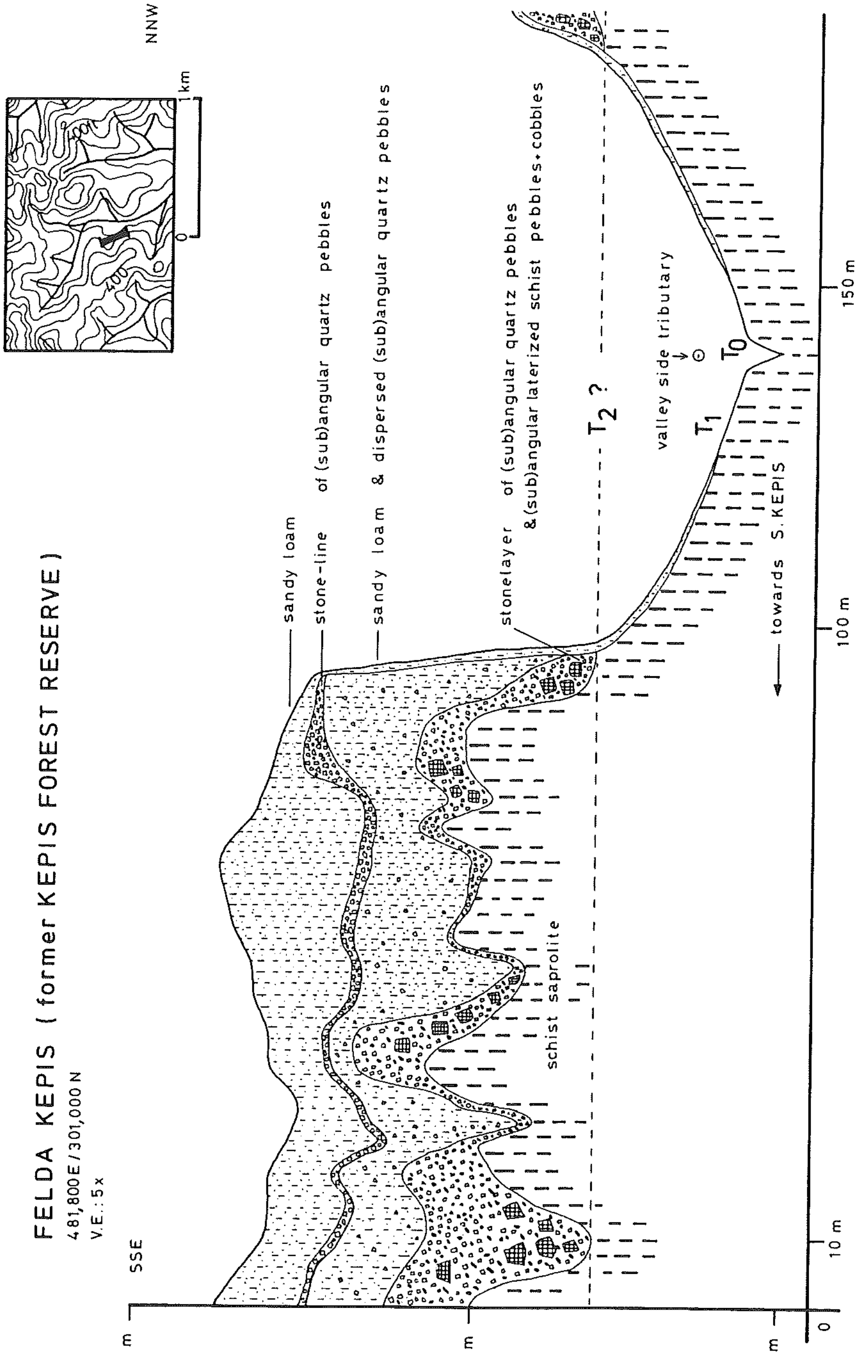

Fig. 9. — Longitudinal cross-section on the lower segment of a pediment in FELDA Kepis (Kuala Pilah).

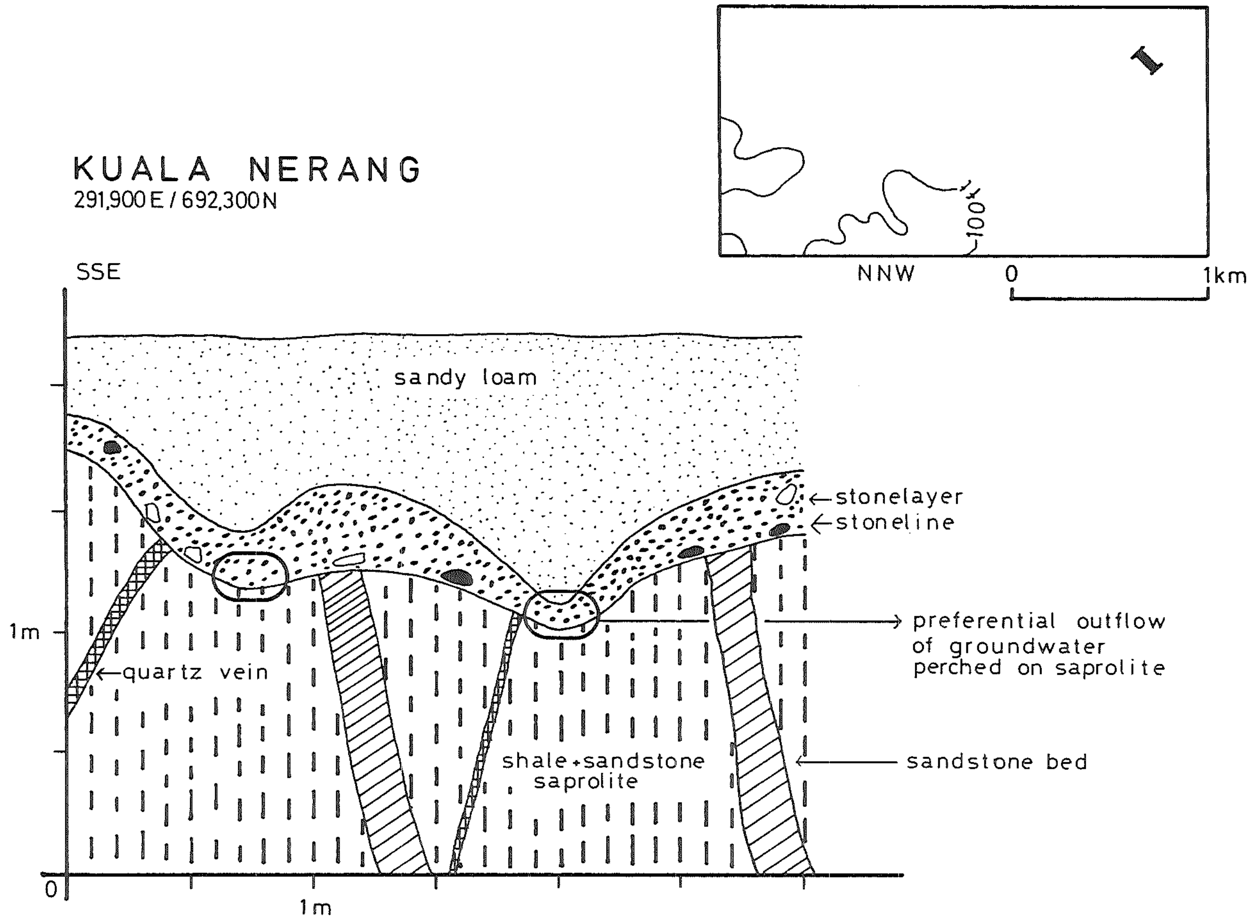

Fig. 10. – Longitudinal cross-section (detail) on the lower segment of a pediment near Kuala Nerang (Padang Terap).

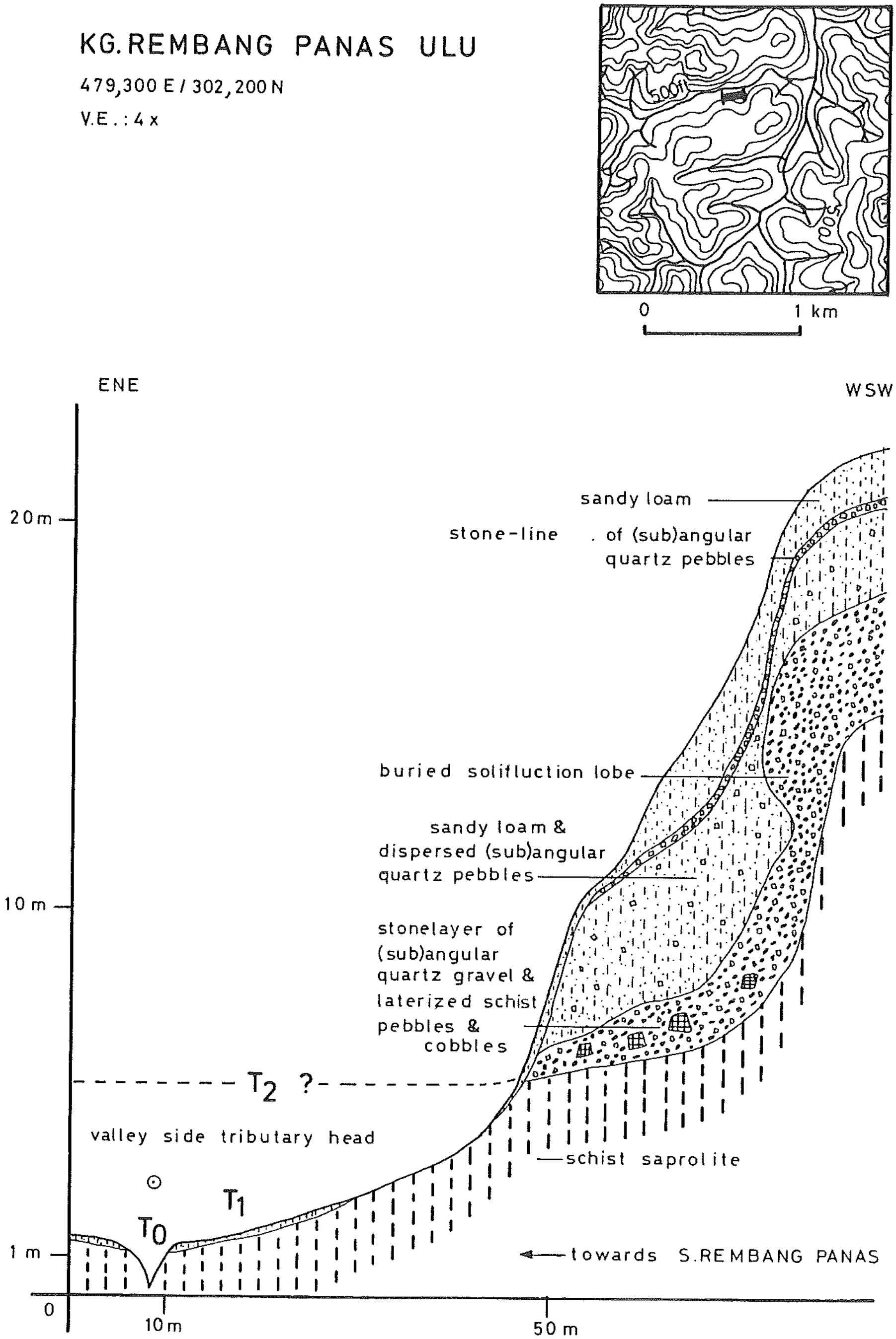

Fig. 11. – Longitudinal cross-section on the lower segment of a pediment near Kg. Rembang Panas Ulu (Kuala Pilah).

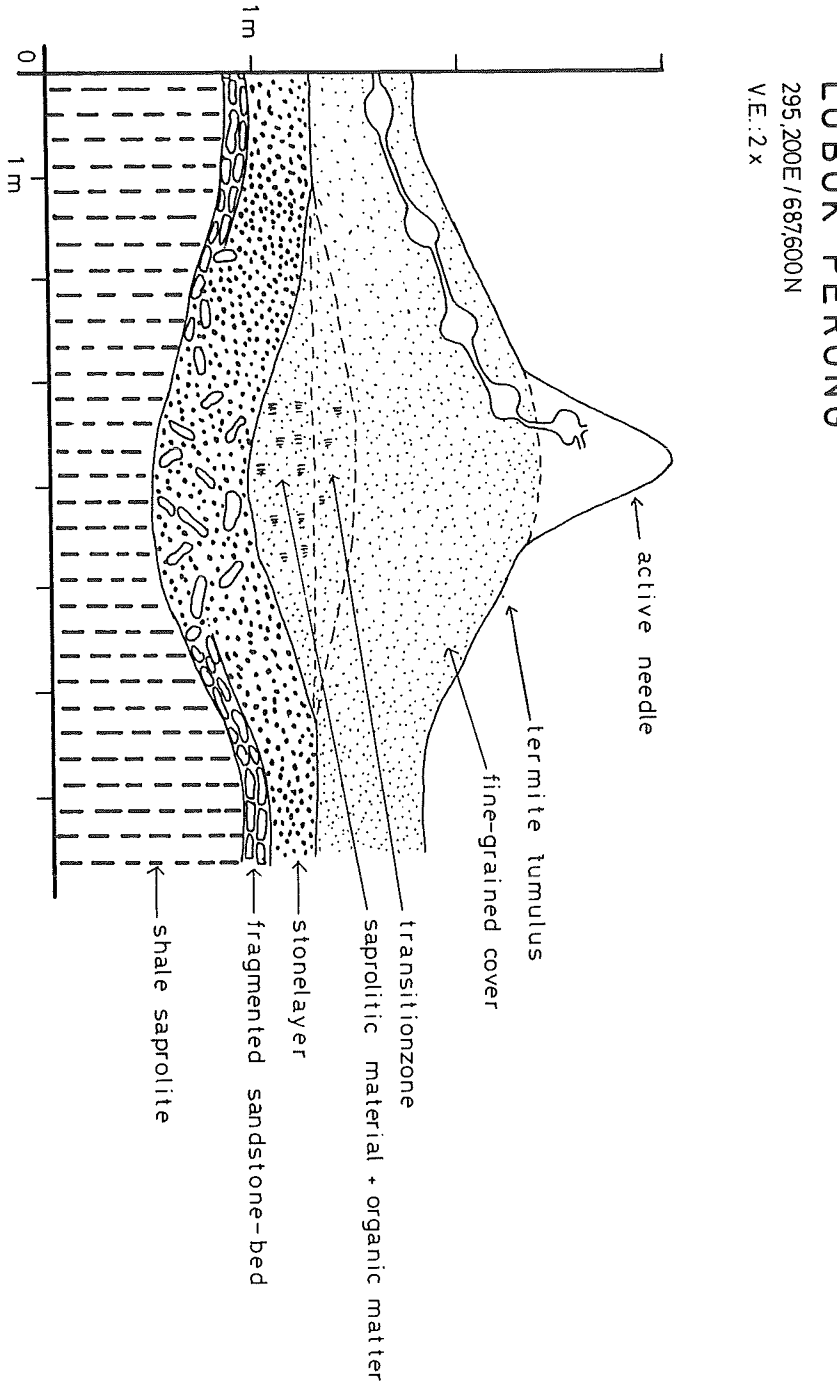

Fig. 12. – Termite activity on a stone-layer near Lubok Perong (Padang Terap).

None of the classical models can fully account for the fieldobservations in the testareas. Especially the presence of conjointed allochtonous and autochtonous stone-layers in the middle segment of the pediments is not explained. An adapted form of ROHDENBURG's (1969) slope pedimentation model may however provide the best explanation for the observed phenomena (Fig. 13).

In the eo-stage of an unstable morphogenic phase, sheet and rill erosion on the upper segments of the footslopes initiates a dense network of parallel gullies running down the middle and lower segments and evacuating into the main drainage lines. The gully sides are steep and can act as pedimentation scarps. The saprolitic bedrock, lateritisized to some degree, is exposed on the gully scarps. By local lowering of the groundwater table, due to the incision, processes of irreversible hardening can start or are accelerated on the exposed ironstone nodules. The side scarps of the gullies remain relatively stable but the headscarps are undercut and move rapidly backwards parallel to themselves.

During the pleni-stage, as runoff increases, also the side scarps of the gullies become unstable. The gullies widen and grow close to each other until only a narrow interfluve remains. In the upper middle segments those interfluves are conserved because of lack of erosive runoff, due to a reduced and insignificant catchment area. On the top of the interfluves fine material can be removed mainly by splash and throughflow (WILLIAMS 1978, ROOSE 1980) that is easily evacuated by the gullies. As a result the laterite nodules are packed and local lithosomes such as quartz veinz are broken but conserved as recognisable features. The stone-layer on these small interfluves can be considered as a "stone-line de type éluvial" (as defined by VINCENT 1966). On the lower middle and lower segments of the pediments, greater amounts of runoff water are involved and there even the interfluves are eroded, except where they are sustained by very thick resistant rock features.

As a result of the gully scarp retreat saprolite is eroded. On the upper middle segments, due to the low capacity of the waterflow, almost no transport takes place. The fine matter however is washed out, resulting in a relative accumulation of ironstone nodules. That stone-layer material is very similar to the one on the interfluves and forms a transition between VINCENT's "stone-line de type éluvial" and "stone-line de type colluvial". On the lower middle and lower segments transport and sorting are more important. Coarse debris such as cobble and boulder size vein quartz, fragments of ironcemented or metamorphic bedrock, too heavy to be transported by water, are dumped close to the foot of the gully scarps and form a stone-line. Relatively

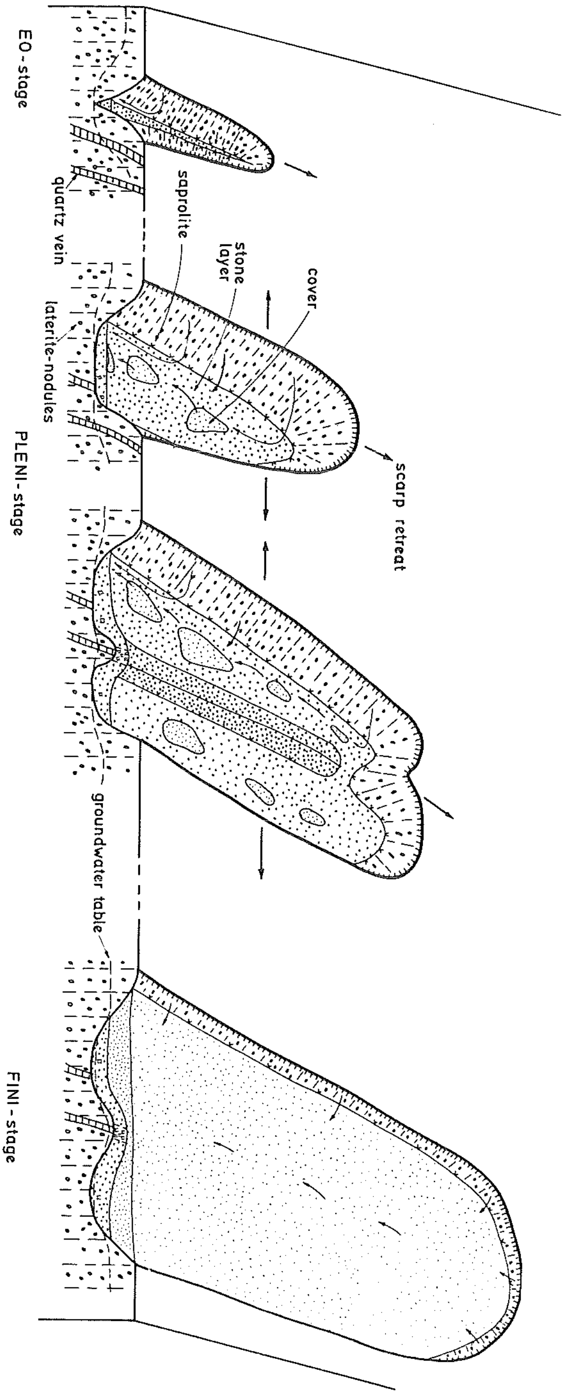

Fig. 13. – Model of slope pedimentation in the testareas.

fine gravel of vein quartz and large amounts of hardened ironstone nodules, together with fine matter, are susceptible to short bedload transport by running water. As a result they are mixed, broken and their shape becomes somewhat rounded. As the gully scarps retreat, the finer gravel is deposited on top of the already present stone-line. The finest gravel and the fine earth however will be partly sorted out of the stone-layer. The former will be deposited in local lenses at the top of the pediment gravel, the latter can undergo a relatively long transport as suspended load. Part of it is evacuated to the rivers, part of it is temporarily deposited, probably under the form of microfans, on the already deposited stone-layer and fills the voids between the coarse fragments in the stone-layer top. During the transport of the fine material a further sorting takes place. Silt and clay particles will be more easily evacuated, resulting in a relative enrichment in sand particles.

During the fini-stage runoff weakens again until it reaches stable phase conditions. Only fine-grained material can be transported and also the pediment gravel becomes fixed. Redistribution of the temporarily deposited fine earth and continued supply of wash material from the backing upland, results in a covering by fine sediments and a levelling of the microrelief resulting in a very gently undulating subaerial pediment surface that is stabilized during the following stable morphogenetic phase.

The above sketched process also accounts for the fact that the cover, although very similar to the saprolite, is, in most cases somewhat sandier than the latter. This trend sometimes lasts into the upper part of the stone-layer matrix. Other processes such as pedogenetic clay eluviation (LEOW 1979), lateral removal of clays by subsurface wash or throughflow (SWAN 1970, MORGAN 1973) and soil fauna activity (STOOPS 1967) are not excluded but only contribute to the same effect.

REFERENCES

BOUCKAERT, W., DE DAPPER, M. & ALIES, R. 1984. Soils and landscape in inland Peninsular Malaysia. – In : Proceedings of the 5th ASEAN Soil Conference (Bangkok, 10-23 June 1984) : C8.1-C8.25.

DEBAVEYE, J. & ABDUL RAHMAN, A. B. 1983. Semi-Detailed Soil Survey of the Padang Terap District, Kedah. – Soil Survey Report 21, Division of Agriculture, Soils and Analytical Services Branch, Ministry of Agriculture, Government of Malaysia, Kuala Lumpur, 415 pp.

DEBAVEYE, J., DE DAPPER, M., DE PAEPE, P. & GIJBELS, R. 1986. Quaternary volcanic ash deposits in the Padang Terap District, Kedah State, Peninsular

Malaysia. – In : GEOSEA V Proceedings (Kuala Lumpur, 9-13 April 1984) : Vol. **1**, *Geological Society of Malaysia, Bulletin,* 19 : 533-549.

DEBAVEYE, J. & DE DAPPER, M. 1987. – Laterite, soil and landform development in Kedah, Peninsular Malaysia. – *Z. Geomorph.* N.F., Suppl. Bd. **64** : 145-161.

DE DAPPER, M. 1978. Couvertures limono-sableuses, stone-line, indurations ferrugineuses et action des termites sur le plateau de la Manika (Kolwezi-Shaba-Zaïre). – *Geo-Eco-Trop.*, **2** : 265-278.

DE DAPPER, M. 1981. – Geomorphology of the Padang Terap District, Kedah State, Peninsular Malaysia. – Ministry of Foreign Affairs and Foreign Trade of Belgium, Department of Development Co-operation, report, 83 pp.

DE DAPPER, M. 1983. Geomorphology of the Kuala Pilah-Bahau area, Negeri Sembilan, Peninsular Malaysia. – Ministry of Foreign Affairs and Foreign Trade of Belgium, Department of Development Co-operation, report, 114 pp.

DE DAPPER, M., 1985a. Geomorphological surveying for mapping soils in Peninsular Malaysia. – *De Aardrijkskunde,* **1** : 51-68.

DE DAPPER, M. 1985b. Pleistocene geomorphological evolution in northwest Peninsular Malaysia. – In : VAN MOLLE, M. (ed.), Recent trends in physical geography in Belgium. *Study Series of the Vrije Univ. Brussel,* New Ser., No. 20 : 117-142.

DE DAPPER, M. 1987. Landform development during the Late Quaternary in the Upland Area of Peninsular Malaysia. – *In* : WEZEL, F. W. & RAU, J. L. (eds.). Progress in Quaternary Geology of East- and Southeast-Asia. CCOP Technical Secretariat, Bangkok, CCOP/TP18 : 109-139.

DE DAPPER, M. 1989. Late Quaternary geomorphological evolution in the uplands of Peninsular Malaysia. – *Verh. K. Acad. overzeese Wet.*, Kl. nat. geneesk. Wet., nieuwe reeks in-8°, **22** (3).

DE DAPPER, M. & BIOT, Y. 1987. Geomorphology for soil survey : a case study from the humid tropics (Trengganu, Peninsular Malaysia). – Proceedings of the Spanish Meeting of the I.G.U. Working Group on Geomorphological Survey and Mapping (Barcelona, 24-30 August 1986), *Acta geol. hispan.* (in press).

DE DAPPER, M., BIOT, Y., BOUCKAERT, W. & DEBAVEYE, J. 1988. Geomorphology for soil survey : a case study from the humid tropics (Peninsular Malaysia). – *Z. Geomorph.*, N.F., Suppl. Bd. **68** : 21-56.

DE DAPPER, M. & DEBAVEYE, J. 1986. Geomorphology and Soils of Padang Terap District, Kedah State, Peninsular Malaysia. – In : GEOSEA V Proceedings (Kuala Lumpur, 9-13 April 1984) : Vol. 2, *Geological Society of Malaysia, Bulletin,* **20** (in press).

ERHART, H. 1955. Biostasie et rhexistasie : Esquisse d'une théorie sur le rôle de la pédogenèse en tant que phénomène géologique. – *C.R. Acad. Sci.* (Paris), **241** : 1218-1220.

FAO, 1977. *Guidelines for soil description.* – FAO, Rome, 66 pp.

FRIEDLAN, G. M. & SANDERS, J. E. 1978. *Principles of Sedimentology.* – John Wiley & Sons, New-York, 792 pp.

LEOW, K. S. 1979. Differences in particle size distribution and mineralogy in soil catenas in Singapore. – *Geo-Eco-Trop.*, 3 (4) : 231-252.

MCFARLANE, M. J. 1983. Laterites. – In : GOUDIE, A. S. & PYE, K. (eds.), Chemical sediments and geomorphology. Academic Press, London, pp. 7-58.

MORGAN, R. P. C. 1973. Soil-slope relationships in the lowlands of Selangor and Negri Sembilan, West Malaysia. – *Z. Geomorph.* N.F.; **17** (2) : 139-155.

OLLIER, C. D. 1974. Weathering. – Longman, London, 304 pp.

ROHDENBURG, H. 1969. Handpedimentation und Klimawechsel als wichtigste Faktoren der Flächen- und Stufenbildung in den wechselfeuchten Tropen an Beispielen aus Westafrika, besonders aus dem Schichtstufenland Südost-Nigerias. – *Göttinger Bodenkundl. Ber.*, 10 : 57-152.

ROOSE, E. J. 1980. Dynamique actuelle de quelques types de sols en Afrique de l'Ouest. – *Z. Geomorph.*, N.F., Suppl.-Bd. **35** : 32-39.

SEGALEN, P. 1969. Le remaniement des sols et la mise en place de la stone-line en Afrique. – *Cah. ORSTOM, Sér. pédol.*, **7** (1) : 113-131.

Soil Survey Staff. 1975. *Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys.* – U.S. Dep. Agr., Agriculture Handbook No. 436, 754 pp.

STOOPS, G. 1967. Le profil d'altération au Bas-Congo (Kinshasa). – *Pédologie,* **17** (1) : 60-105.

SWAN, S. B. St. C., 1970. Relationships between regolith, lithology and slope in a humid tropical region : Johor, Malaya. – *Trans. Inst. British Geogr.*, **51** : 189-200.

TRICART, J. 1965. Traité de Géomorphologie. Tome **5** : Le modélé des régions chaudes : forêts et savanes. – SEDES, Paris, 322 pp.

VINCENT, P. L. 1966. Les formations meubles superficielles au Sud du Congo et au Gabon. – *Bull. Bureau Rech. géologiques et minières,* **4** : 53-111.

VOGT, J. 1966. Le complexe de la stone-line. – *Bull. Bureau Rech. géologiques et minières,* **4** : 3-52.

WHITAKER, C. R. 1979. The use of the term "pediment" and related terminology. – *Z. Geomorph.* N.F., **23** (4) : 427-439.

WILLIAMS, M. A. J. 1978. Termites, soils and landscape equilibrium in the Northern Territory of Australia. – In : DAVIES, J. L. & WILLIAMS, M. A. J. (eds.), Landscape Evolution in Australia. ANU, Canberra, pp. 128-141.

ZAUYAH, S. & BISDOM, E. B. A. 1983. SEM-EDXRA investigations of tubular features and iron nodules in laterite soils from Malaysia. – *Geoderma,* **30** : 219-232.