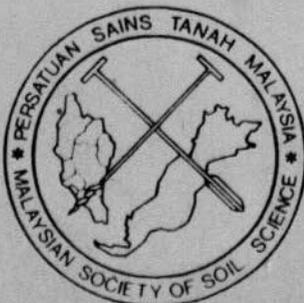
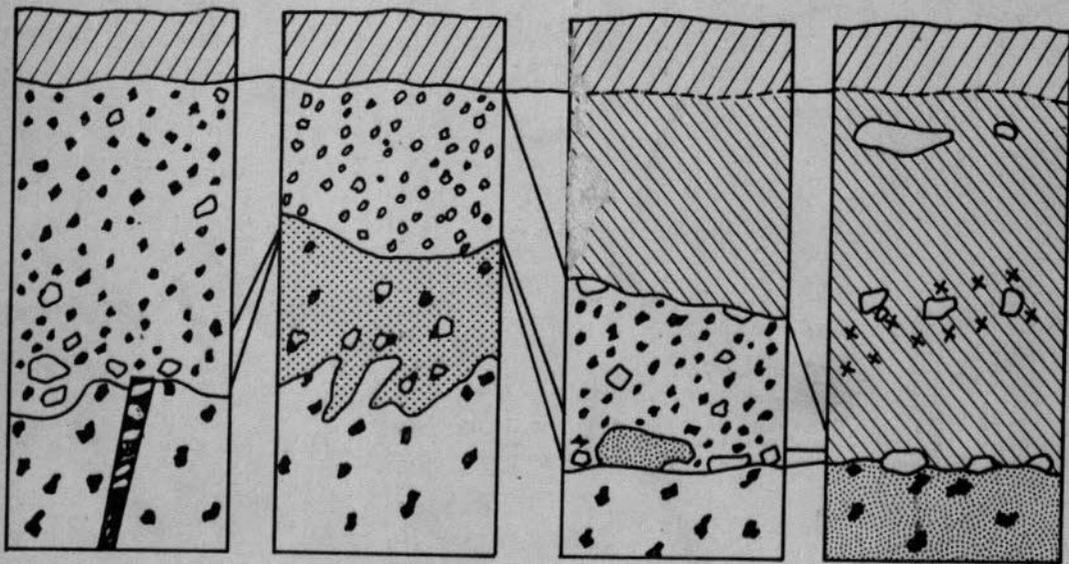


# CHARACTERISTICS OF SOME UPLAND SOILS IN KEDAH, PENINSULAR MALAYSIA



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Soil Correlation Tour to Kedah,  
9 - 11th September 1985

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IN KEDAH, PENINSULAR MALAYSIA

Compiled by  
ZAINOL EUSOF

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## PREFACE

Lateritic soils have been a constant source of discussions among soil scientists in terms of genesis, classification and management. The inland areas of Kedah, in particular, are dominantly lateritic and provide a clear illustration on the setting and development of such soils. This publication furnishes certain information available to date, on the setting and characteristics of some representative soils mapped in Kedah, with emphasis on lateritic soils, for the purpose of discussions during the correlation tour.

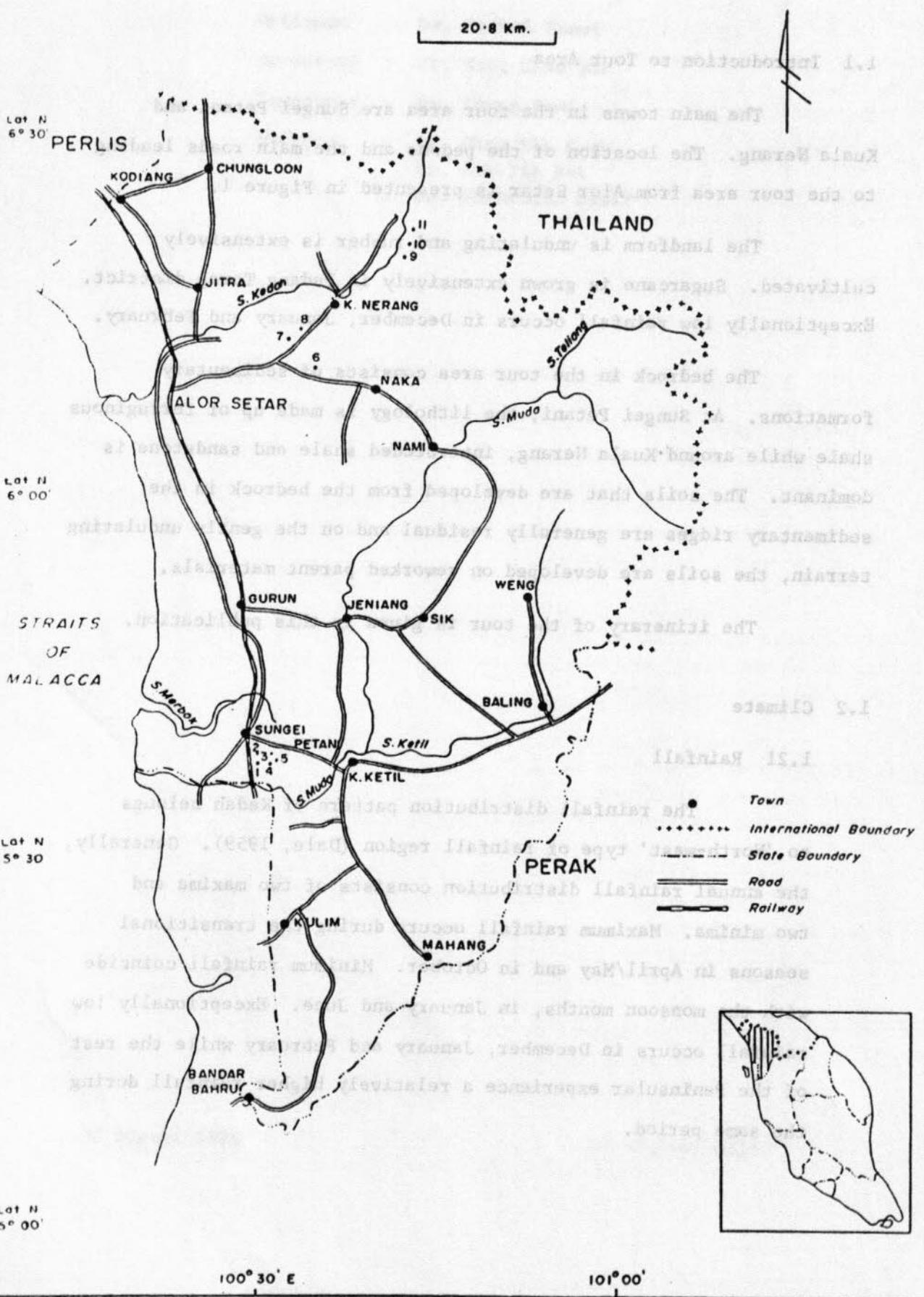
In this publication, no soil series names have been allotted to the soil profiles. This is to encourage participants to examine the soils objectively and relate them to their own experiences. This manner of presentation was done so as to generate discussions on the present regional soil classification system in Peninsular Malaysia. As a guide, the table on 'Keys to identification of soil series' originally prepared by Dr. Paramanathan are included in this publication. It is hoped that other aspects, especially on the genesis and management of the soils will be discussed to stimulate the interest on the part of the younger participants. In short, the objective of the correlation tour is to disseminate information such that knowledge gained will be shared among the soil scientists.

To appreciate the development the various soils, one has to consider the impact of landform evaluation which influences the nature of the parent materials. The profiles are deliberately selected to illustrate this point.

The soil information provided in this publication is essentially obtained from the Soil Survey and Land Use Group of the Rubber Research Institute of Malaysia (RRIM) and the Soil Management Branch of the Department of Agriculture. I am grateful to Messrs. Chuah Joo Hor (now with Sime Darby) R. Sathiyalingam, N. Selvarajah and Shahrudin Basir for their assistance in field mapping and soil sampling. The ever-willing cooperation of Mr. Lim Jit Sai of the Department of Agriculture is deeply appreciated. The laboratory staff of Analytical Chemistry Division (RRIM) is gratefully acknowledged for providing part of the soil analyses. I am deeply grateful to Mr. H.S. Chiah, Manager of Pinang Tunggal Estate for his assistance in providing the facilities for gathering the soil information.

Thanks are also due to Dato' Hj. (Dr.) Ani Arope, Director of RRIM, Dr. E. Pushparajah, Assistant Director (Biology) and Mr. Chan Heun Yin, Head of Soils and Crop Management Division for their unfailing support during the process of gathering the soil information.

FIG. 1 SOIL CORRELATION TOUR - KEDAH 1985  
LOCATION OF SOIL PEDONS



The annual rainfall of selected stations is shown in Table 1 and the annual rainfall distribution is shown in Figure 2. It can be seen that there is a decrease in annual rainfall from south to north Kedah; ranging from 2448 mm. at Sungei Patani to 2035 mm. at Kodiang. The pattern of rainfall distribution of the se stations are similar.

TABLE 1. MEAN ANNUAL RAINFALL OF SELECTED STATIONS IN KEDAH\*

Station	Rainfall (mm.)
Kodiang	2035
Sintok	2110
Alor Setar	2142
Pendang	2231
Kuala Nerang	2128
Sungei Patani	2448

\*Information obtained from the Malaysian Meteorological Service and the Drainage and Irrigation Department of Malaysia.

1.22 Air Temperature and Humidity

One of the characteristic features of the climate of Peninsular Malaysia is the uniform temperature. At Alor Setar the mean monthly temperature is generally between 26°C and 28°C. The annual variation in temperature rarely exceed 2°C. However, the diurnal variation is large, ranging from about 8°C to 12°C. High temperatures are reached during the first few months of the year. The highest temperature ever reached in Kedah is 38°C at Sungei Patani in 1931.

Mean relative humidity at Alor Setar varied from 72% to 87%. Low values of relative humidity coincide with the dry months, while high relative humidity occurs during the months of high rainfall, especially in September, October and November.

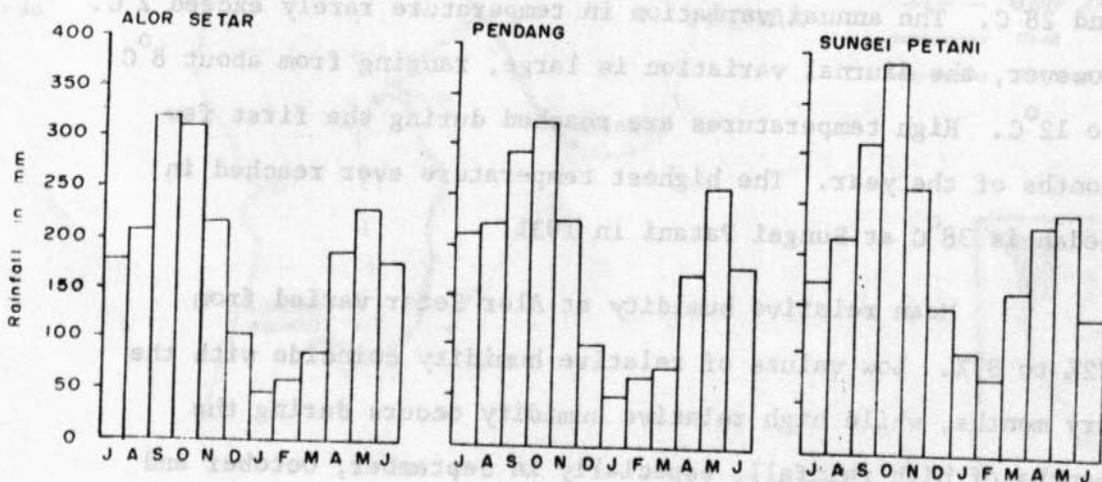
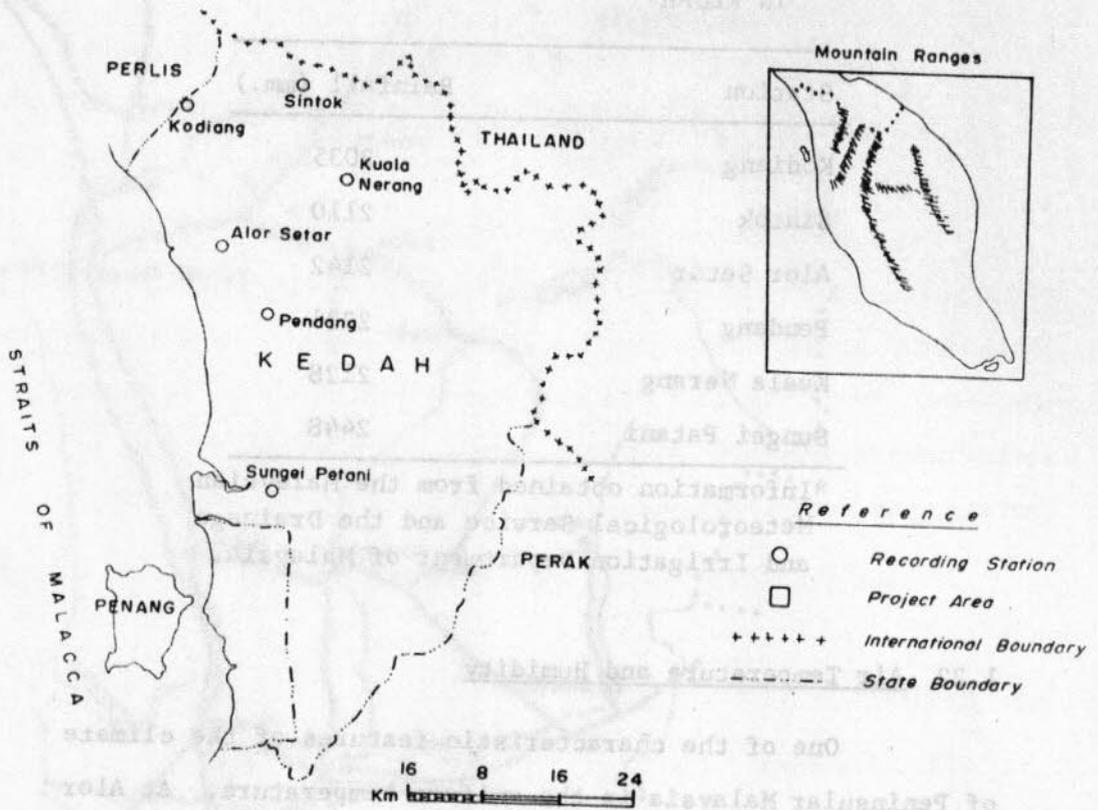
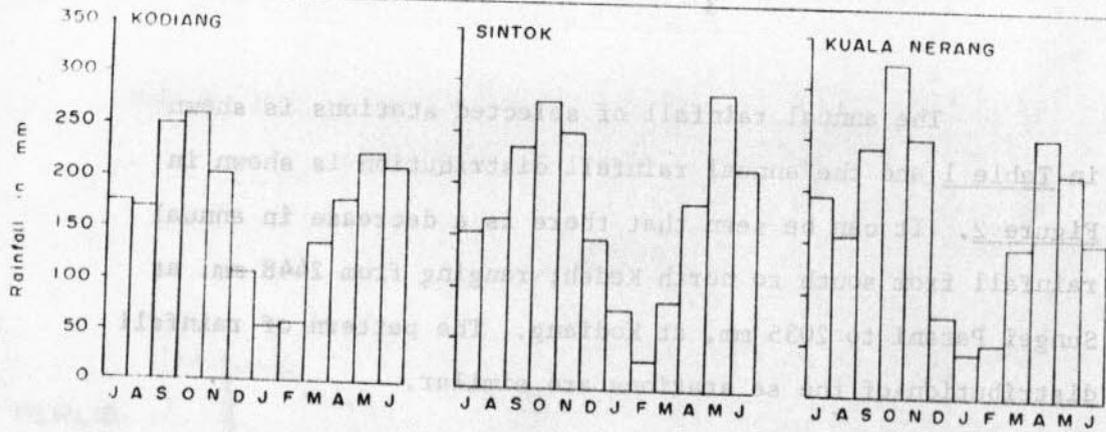


Figure. 2 Mean annual rainfall distribution of selected stations in Kedah.

### 1.23 Sunshine and Radiation

The project areas appear to be the sunniest region in Peninsular Malaysia. At Alor Setar, the annual average of sunshine received is 2539 hours which is about 57% of the total possible (Dale, 1964). Considering the average number of sunshine hours on a daily basis, the period from January to April receive about 8 to 8.5 hours, the highest being in February. The months of September, October and November are characterised by low daily sunshine hours, the average being about 5.5. This period coincides with the season of maximum rainfall. Alor Setar has the least number of days with fog in the early hours of daylight and hence the sunniest part of the day occurs before noon. About 59% of the daily sunshine is received between 0930 and 1130 hours.

### 1.24 Koppen's Classification

Koppen's system of classification of climate are intended to correspond with principal vegetative groups. The climate of Kedah in general belongs to the A type i.e. tropical rainy climate where the temperature of the coolest month is more than  $18^{\circ}\text{C}$ . Within this climatic group, distinctions are made on the basis of rainfall distribution pattern. Three main types are recognised: (a) Af type which have minimum variation in temperature and precipitation and the rainfall of the driest month is at least 60 mm; (b) Aw type which have a distinct dry season during the winter months and at least one month has rainfall of less than 60 mm.; and (c) Am type which has a short dry season and the rainfall of the driest month is less than 60 mm. but the total rainfall is high so that the soil remains sufficiently moist throughout the year to support vegetation.

Am is intermediate between Af and Aw, resembling Af in amount of precipitation and Aw in seasonal distribution. The rainfall distribution from six station including one from Perlis, are given in Table 2.

TABLE 2. CLIMATIC TYPES OF STATIONS ACCORDING TO KOPPEN\*

Station	Rainfall of driest month (in)	Climatic Type
Kangar (Perlis)	1.69 (42.9 mm)	Ami
Kodiang	2.19 (55.6 mm)	Ami
Sintok	1.20 (30.5 mm)	Ami
Alor Setar	1.89 (48.0 mm)	Ami
Pendang	1.98 (50.3 mm)	Ami
Sungei Patani	2.95 (74.9 mm)	Afi

\*Information obtained from Drainage and Irrigation Department of Malaysia (DID) and Malaysian Meteorological Service (MMS)

The letter 'i' indicates that the difference in temperature between the hottest and coolest month is less than 5°C and hence isothermic. It can be seen that except for Sungei Patani, the rest of the areas fall into the Ami type of climate. So generally, the climate of north Kedah is marginal, between the tropical wet type which characterise the rest of the Peninsular and the tropical wet and dry climate which is more established in Thailand.

### 1.25 Soil Climate

The soil moisture regimes are defined on the basis of soil temperature conditions, the duration of dryness and its frequency over a period of time, existing in the control section. By employing the method of Franklin Newhall whereby the mean

is shown in Table 3. soil temperature was obtained. The importance of annual variation over long-term average is indicated. The soil moisture regime is considered as ustic in 3 out of 15 years. It can be seen that in 1977, the soil moisture control section is dry for as long as 62 days. Based on overall frequency, the soil moisture regime of the project areas is udic.

The marginal nature of the moisture regime in the project areas is apparent. It is a transition between udic and ustic. The moisture regime in Kedah is considered as dry tropudic. This regime is characterised by a bimodal rainfall distribution and the control section is moist for approximately 10 months.

### 1.3 General Geology of Kedah

The sedentary areas of Kedah is characterised by varying geology ranging from Lower Paleozoic to Tertiary in age (Figure 3). The Lower Paleozoic rocks generally, consist of sedimentary facies being deposited in a developing geosyncline. During this era, the succession comprises carbonaceous, siliceous and pyritic fine-grained sediments' mostly in the form of shale, siltstone and cherty rocks which contain planktonic organisms. This sequence differs from that of the extreme northwest part of the country i.e. in the Langkawi Islands and in Perlis where thick deltoic deposits and shelly limestone dominate the succession. In East Kedah, the sequence of rocks found in central and southern part of the state is again represented but they are interbedded with beds of coarse sandstone and lenses of limestone. The fine-grained sediments of central and south Kedah are the most widespread, being deposited in the deep basin of the Lower Paleozoic miogeosyncline. The succession in east Kedah originated on a genticline. During Devonian, localised upliftment due to folding took place in central Kedah. The uplifted area was eroded to produce

**TABLE 3.** DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : ALOR SETAR

YEAR	MEAN SOIL TEMPERATURE ANNUAL SUMMER	TEMPERATURE REGIME	CUMULATIVE DAYS MCS IN			SOIL TEMP > 5°C DRY M/D MOI	MAX. MOIST IN ONE YEAR	CONSECUTIVE DAYS THAT MCS IS		MOIST AFTER WINTER SOLST.	MOISTURE REGIME
			ONE YEAR IS DRY M/D MOI	SOIL TEMP > 5°C DRY M/D MOI	WHEN			IN SOME PARTS WHEN SOIL TEMP > 8°C	DRY AFTER SUMMER SOLST.		
1966	29.1	29.2	0	0	360	360	360	0	0	120	UDIC
1967	29.1	29.2	0	33	327	360	360	0	0	62	UDIC
1968	29.1	29.2	14	88	258	327	327	0	0	33	USTIC
1969	29.1	29.2	0	0	360	360	360	0	0	120	UDIC
1970	29.1	29.2	26	58	276	334	334	0	0	21	UDIC
1971	29.1	29.2	0	0	360	360	360	0	0	120	UDIC
1972	29.1	29.2	16	32	312	344	344	0	0	40	UDIC
1973	29.1	29.2	3	62	295	357	357	0	0	40	UDIC
1974	29.1	29.2	0	56	304	360	360	0	0	49	UDIC
1975	29.1	29.2	0	0	360	360	360	0	0	120	UDIC
1976	29.1	29.2	0	40	320	360	360	0	0	45	UDIC
1977	29.1	29.2	62	52	246	283	283	0	0	24	USTIC
1978	29.1	29.2	40	35	285	320	320	0	0	45	UDIC
1979	29.1	29.2	49	40	271	311	311	0	0	16	UDIC
1980	29.1	29.2	38	58	264	322	322	0	0	15	USTIC

(CORRECTIONS FOR TEMPERATURE IS 2.5°C SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)  
 COMPUTED BY FORTRAN PROGRAM VM18, NOV. 81

100°30' E

100°00'

### Geological Map Of Kedah

20.8 Km

Lat. N  
6° 30'

PERLIS

THAILAND

Lat. N  
6° 00'

STRAITS  
OF  
MALACCA

Lat. N  
5° 30'

PERAK



Source: Geological Map of West Malaysia 7<sup>th</sup> edition, 1973.

Refer to next page for the legend

L E G E N D

- QUATERNARY 1 Mainly Recent alluvium.
- TERTIARY 2 Minor - continental basin deposits of probable Upper Tertiary age: composed mainly of argillaceous and arenaceous beds in varying proportions; minor lignitic beds.
- JURASSIC-  
TRIASSIC 3 Sediments subdivisible into three facies, grading downward where found together from 'continental' (youngest) through 'mixed' to 'marine' (oldest).
- 4 Continental facies: areno-argillaceous with rudaceous and carbonaceous band; commonly red in colour.
- CARBONIFEROUS 5 Sediments: arenaceous and argillaceous beds predominate, the latter commonly carbonaceous in the east; minor calcareous interbeds.
- SILURIAN 6 Sediments: mainly interbedded calcareous and argillaceous strata, proportions varying from place to place, argillaceous component contains minor arenaceous interbeds.
- CAMBRIAN  
(Upper only) 7 Sediments: mainly arenaceous with minor argillaceous and rudaceous interbeds, and with a single calcareous bed at the top of the sequence.
- 8 Acid and undifferentiated granitic rocks.

R e f e r e n c e

- Faults.
- + + + + + International Boundary
- State Boundary.
- > River.



elastic material for carboniferous sediments. This sedimentation is the main feature of the Upper Paleozoic era. A typical formation of these sediments composed of thick-bedded quartz and felspathic sandstone, interbedded with mudstone.

The geosynchial phase ended in the Triassic period. This was followed by the Thai-Malayan Orogeny, that lasted throughout the Mesozoic period. During this era, considerable masses of post-orogenic sedimentary rocks were formed, being derived from the newly generated mountains. Middle to Upper Triassic sedimentary rocks occurred in south, central and north Kedah.

This formation is essentially of flysch facies made up of alternations of thin beds of varying lithology, ranging from conglomerate beds to the chert member of the formation. During the Cenozoic Era, the peninsula is stable. Geological activity was confined to uplift, tilting and fault movements Tertiary sedimentary rocks in Kedah occur near the Thai-Malaysian border. These sediments are basin deposits and are mainly of continental, lacustrine, paludal and fluvial origin. These are also widespread occurrences of weathered gravel, sand and clay, with plant remains. These deposits formed low hills and terraces and they are presumed to be formed during the Pleistocene. During this period, fluctuations of the sea-level shaped much of landform producing sediments found in valleys and on the broad coastal plains. An important geological activity in the northern part of the Peninsula is the Post-Cretaceous uplift. There is stronger uplift in the north relative to the south. The absence of Early Tertiary sediments was presumed to be due to the dry nature of the Peninsula which formed a part of emergent Sundaland.

### 1.31 Sungei Patani

The geology consists of sequence of sedimentary strata referred to as the Sungei Patani Formation (Bradford, 1972). This formation consists of a predominant argillaceous facies of

commonly ferrogenous shale and mudstone, and an arenaceous facies of sandstone and quartzite. The red shale of the argillaceous facies contains as much as 5 percent iron. Differing amounts of minor constituents such as pyrite, chlorite and carbonaceous matter give rise to a variety of colours in the other argillaceous beds which are of fairly common occurrence. Weathering of the red shale produce hematite and limonite-rich lateritic breccia which contain about 45 percent iron. Metamorphism due to the Gunong Jerai granite intrusion in the north-west is generally weak and is manifested in the form of indurated shale and mudstone, accompanied by quartz veins, and phyllitic shale which is fairly common. The arenaceous strata contain considerable amounts of iron oxides and in some places, they are cut by boxwork pattern of quartz veins.

### 1.32 Kuala Nerang

The dominant geology in this area consists of the sedimentary beds of the Middle to Upper Triassic Semanggol Formation (Burton, 1973). Generally, this formation is made up of the sedimentary sequence as described for Sungai Tiang. In this project area, however, the occurrence of chert beds is extensive. Due to its resistance to erosion, it dominates the landform as strike ridges, generally in the north-south direction. The chemical purity of the chert suggests it to be likely a chemical precipitate, the silica being originated from ash falls during contemporaneous volcanic activity in other parts of the country.

#### 1.4 Soil Information of Kedah

The earliest information pertaining to the inland soils of Kedah was obtained from Joseph (1965) who carried out a reconnaissance soil survey. Thirteen soil series and associations were presented in the first reconnaissance map of Kedah. Subsequent characterization of some representative soils was then done to evaluate its genesis (Paramanathan et. al., 1975). In this study, certain properties were observed to be different when compared to soils of the rest of Peninsular Malaysia. Aluminium and cation retention properties are higher and the development of argillans are more pronounced. The authors postulated that these properties are due to present and past climatic variations. Paramanathan and Lim (1978) first introduced the concept of the reworked nature of lateritic soils in Peninsular Malaysia. Later, field mapping of soils eventually provide more information on the genesis of these soils (Debaveye and Rahman, 1983; Zainol, 1984). Prior to this, the relationship between soil development and geomorphological evolution was by De Dapper (1981) in the Padang Terap area.

The overall genesis of lateritic soils and its relationship to geomorphic surfaces was then subsequently presented by Paramanathan and Tharmarajan (1983).

#### 1.5 Background Concept to Landform Evolution in Humid Tropical Areas

Generally, landforms have been classified into degradational and aggradational land surfaces (King, 1967). On a broad scale, over a lengthy geological time span, the uplifted land masses which is typical of Southeast Asia, undergo denudation and exhibit erosional characteristics while in certain areas the products of erosion have built up a constructional land mass as in the case of a coastal plain. The occurrence degradational and aggradational

surfaces reflects the tectonic history of the landmass. Alternations in the nature of the deposits within basins indicate the establishment or disruption of equilibrium states in the landscape (Thomas, 1974). The unstable phase (rhexistasy) condition sites and provide translocated parent materials while the stable phase (biostasy) allows weathering of parent rocks in-situ and soil formation to proceed.

### 1.51 Basic features of landscape denudation

One of the earliest ideas which have dominated geomorphic thought on denudation is the concept of downwearing which was proposed by W.M. Davis. Downwearing simply means the denudation of a landscape by subaerial processes in a humid environment. Penck (1953) objected to the Davisian concept of downwearing and instead proposed that slopes do not progressively reduce during subaerial erosion but they retreat parallel to themselves and such a process gives rise to a two-step landscape separated by a scarp. King (1967) applied the concept of Penck of African savanna regions and supported the idea of parallel retreat of slopes. At present geomorphologists agree that the two concepts work hand in hand and during certain periods the Davisian concept has a greater emphasise than the Penckian concept and vice versa. In a humid tropical area under natural forest, run off can be considered as of very low intensity and downwearing is the main process of denudation. However, where gullies are present, the process of slope retreat will be emphasised.

At a detail level, denudation is accounted by a combination of the processes of chemical weathering, mechanical eluviation, mass movement, slope wash and stream erosion (Thomas, 1974). On a broader scale, these processes are responsible in sculpturing the landscape which resulted in various landform types.

The total impact of these processes is realised in a humid tropical country like Peninsular Malaysia where Swan (1970) had reported on major hillslopes adjoining lower landsurfaces along a narrow zone of abrupt transition. The hillslopes and the lower landsurfaces which are pediments, form an erosion system. The essential feature of the landform is the scarp which retreat by backwearing and the rock-cut pavement which is the saprolite that is weathered basement rock. The accumulations which are termed as regolith include eroded saprolite and other translocated materials. The landform of Kedah is a good example of tropical planation. In this area, the overall process of pediplanation is well illustrated (De Dapper, 1981). Pediplanation is essentially the formation of pediplains by the process of pedimentation through backwearing. Scarp retreat which is made known by Penck is initiated by gully-head erosion and mass slipping of material. The most significant process related to scarp retreat is the phenomenon of slope pedimentation and micropedimentation (Rohdenburg, 1969). Backwearing of slopes provide debris with time and micropedimentation remove this debris working on debris slope and pediment. The resultant relief is a pediment below a retreating scarp.

#### 1.52 Pediplain soils

Soils developed on pediments were given much emphasis by geomorphologists working in tropical Africa (Thomas, 1974). These type of soils are appropriately termed as "pedi sediments" by Ruhe (1956). As such in humid areas, the pediments are naturally the sites of significant deposition. The main features of the depositional character of pedisediments are as follows (Folster, 1969).

- (a) The multiple stratification of the complex
- (b) The rather sharp boundaries between different layers unusual for pedogenetic horizons

- (c) Inclusion of allocthonous elements in the stone-line
- (d) Abrupt truncation of petrographic features, especially quartz veins at the stone-lines

The process of scarp retreat which explains such differentiation can be visualised in Figure 4. The figure explains schematically how coarse debris too heavy to be transported by water is deposited at the foot of the scarp or close to it, while the rest of the former soil mantle is removed and transported over the newly cut basal surface of erosion. During transport, some degree of sorting takes place and the gravel is dumped on to the stone pavement which covers the basal surface of erosion. The stone-line elements include vein quartz blocks, fragments of bedrock and laterised bedrock. The pediment gravel generally consists of quartz gravels and more commonly ferruginous gravels. In Kedah, these ferruginous gravels, commonly regarded as petroplinthites, are omnipresent in pedisediments.

## 1.6 Topography

On a regional scale, the inland areas of Kedah can be delimited into various landform units, each having its own morphological characteristics. For the purpose of the tour, the relevant topographic features are described below.

### 1.61 Dissected ridges

Steep, narrow-crested ridges and groups of elevated hills defined this landform unit. Summits are generally more than 100 meters above sea-level. Steep slopes of more than 30% flank the ridges. Though they do not assume greater heights as compared to the granitic Gumong Inas ridge in the south eastern part of Sungei Tiang, they are nevertheless prominent

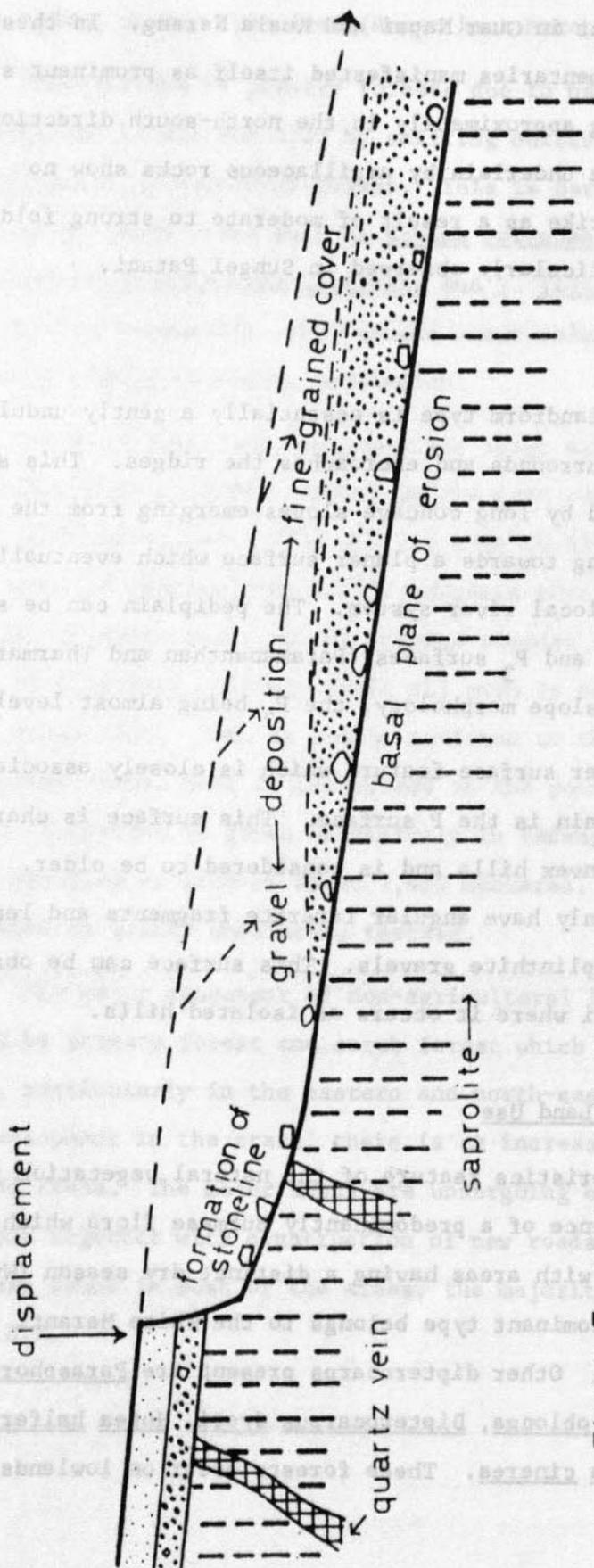


Figure 3. Model indicating the differentiation of stone-line, pediment gravel and pediment wash below a retreating scarp ( after Folster, 1969 )

topographic features in the inland areas. This type of terrain is most prominent in Guar Napai and Kuala Nerang. In these areas, arenaceous sedimentaries manifested itself as prominent strike ridges, aligning approximately in the north-south direction. The ridges which are underlain by argillaceous rocks show no preferential strike as a result of moderate to strong folding and this is particularly observed in Sungei Patani.

#### 1.62 Pediplain

This landform type is essentially a gently undulating surface which surrounds and encroaches the ridges. This surface is characterized by long concave slopes emerging from the foot slope and grading towards a planar surface which eventually terminate at a local river system. The pediplain can be subdivided into  $P_2$  and  $P_3$  surfaces (Paramanathan and Tharmarajan, 1983) based on slope morphology, the  $P_2$  being almost level.

Another surface feature which is closely associated with the pediplain is the P surface. This surface is characterized by low-lying convex hills and is considered to be older. The P surface commonly have angular laterite fragments and lesser amount of petroplinthite gravels. This surface can be observed at Sungei Patani where it occurs as isolated hills.

#### 2.8 Vegetation and Land Use

A characteristic feature of the natural vegetation in Kedah is the occurrence of a predominantly Burmese flora which is normally associated with areas having a distinct dry season (Wyatt-Smith, 1964). The dominant type belongs to the White Meranti group of the genus *Shorea*. Other dipterocarps present are Parasphorea Incida, Aricsoptera oblonga, Dipterocarpus dyeri, Hopea helferi, Hopea latifolia and Vatica cinerea. These forests occur on lowlands,

hillslopes and low ridges in north-west Kedah. In the foothills of South Kedah, *Shorea Kunstleri* (damar Laur Merah) is commonly found.

Destruction of primary forests due to natural disasters like storms and floods and also by shifting cultivation has given way to establishment of secondary forest. This is particularly evident in north Kedah where trees such as *Schima noronhae* and *Shorea talura* and the bamboos *Gigantochloa latifolia* and *G. ligulata* predominate. In the lowlands especially, the bamboos occur solely as scrubs or interspersed within secondary vegetation.

Agricultural land use comprises about 45% of the total area of Kedah. (Wong, 1979). Rubber is the main component accounting for 25%, followed by padi (15%) and oil palm (0.6%). Generally, rubber and oil palm are concentrated in the southern part of the state. Towards the northern part, rubber acreage becomes less and occurs in the form of scattered holdings while oil palm is negligible due to climatic constraint. Padi is mainly confined to the coastal plain. In the inland areas, padi is cultivated in the poorly-drained fluvial terraces. Sugarcane is grown extensively in Padang Terap district where it occupies an area of about 7,455 hectares. This crop is concentrated on gently undulating terrain.

The major component of non-agricultural land use is accounted by primary forest and scrub forest which make up about 46% of state, particularly in the eastern and north-eastern parts. With rapid development in the state, there is an increase in urban and associated areas. The major towns are undergoing extension urban development together with construction of new roads. Land settlement schemes are found in most of the areas, the majority of them belonging to F.E.L.D.A.

## METHODS OF LABORATORY ANALYSES

A. Physical Analyses

## 1. Particle-size Analyses

Clay, silt and sand fractions of the fine earth were determined by the pipette method after destruction of the organic matter by  $H_2O_2$  treatment and dispersion with Sodium Hexametaphosphate. Classification follows the ISSS system i.e. clay  $< 2 \mu m$ , silt is 2 to 20  $\mu m$  and sand is 20 to 2000  $\mu m$ . Fraction  $> 2 mm$  (gravels) was obtained as percent by weight.

## 2. Water Dispersible Clay

20 g soil sample in 1 l distilled water was subjected to end over end shaking for about 16 hours. Percentage clay was determined by the pipette method.

## 3. Bulk Density

Determined by dividing the weight of oven dry ( $105^\circ C$ ) soil core sample by their volume (100 cc).

## 4. Moisture Retention

Soil moisture determination was carried out on aluminium core samples at 1/10 and 1/3 bar pressures using a pressure plate (ceramic) extractor while the 15 bar pressure extraction was done on loose soil aggregates on rubber retaining rings by a pressure membrane extractor. The moisture retained was then obtained by percent weight of the soil. However, the results are expressed as percent volume by multiplying the percent by weight with the bulk density values.

B. Chemical Analyses

## 5. Organic Carbon

Rapid oxidation method of Walkley and Black (1934)

## 6. Nitrogen

Kjeldahl digestion method followed by semi-micro-distillation in a Markham apparatus.

### 7. Soil pH

Soil pH was measured with a pH meter on 20 g soil in 20 ml  $H_2O$  or 1N KCl solution. Soil suspensions were shaken periodically and left overnight before determination.

### 8. Extractable Iron

Method of Mehra and Jackson (1960). The free iron extracted was determined by atomic absorption spectrophotometer (AAS).

### 9. Cation Exchange Capacity and Extractable Bases

The method used involved continuous leaching of 10 g sample for 6 hours with 1N neutral  $NH_4OAc$  in a batch system. Acid-washed sand was added to soils which are rich in clay to increase and standardise the rate of leaching. The extractable bases were determined by (EEL) Flame photometer (K, Na) and atomic absorption spectrophotometer (Ca, Mg). The saturating ammonium was displaced by 10% 1N KCl which was adjusted to pH 2.5 for the purpose of estimating CEC.

### 10. Extractable Aluminium

Extraction by leaching with 1N KCl solution. Aluminium was determined by atomic absorption spectrophotometer.

### 11. Acid Extractable P and Mn

Total P and Mn were determined colorimetrically on sulphuric acid-perchloric acid digest. Phosphorus is measured by the 'phosphovanadomolybdate complex' of Jackson (1958). Manganese was determined by oxidation with periodate to permanganic acid.

### 12. Available P

Extracted by a mixture of 0.1N HCl and 0.03N  $NH_4F$ . P is determined colorimetrically.

### 13. 6N HCl Extractable Cations

Acid extractable cations were determined by digesting 2 g soil in 20 ml 6N hydrochloric acid. The cations were determined as for the extractable bases by  $NH_4OAc$ .

## Pedon 1

Information on the site

Profile number: C4-12; date: 13 September 1979; authors: Zainol E. and J.H. Chuah; location and grid reference: Field 3, Division 3, Pinang Tunggal Estate - Toposheet 16 and 17, 197818; elevation: 132 m a.s.l.; surrounding landform: Hilly, physiographic position: near the summit of a steep hill; slope: 40%; vegetation and land-use: mature Hevea.

General information on the soil

Parent material: ferruginous shale of the Sungei Patani formation; drainage: well-drained; depth of ground water-table: not observed; erosion: strongly eroded; presence of rock outcrop and other features: exposed shale outcrops on the ridge; human-influence: Hevea is planted in contour terraces.

Classification

Soil Taxonomy: Lithic Dystropeptic Orthoxic Tropudult, clayey, mixed, isohyperthermic  
FAO : Ferric Acrisols.

Horizon description

- Ap 0-9 cm Yellowish brown (10YR 5.4) fine sandy clay; moderate fine and medium subangular blocky structure; friable, slightly plastic; many coarse pores; abundant fine roots; clear smooth boundary.
- Bt 3-13 cm Brownish yellow (10YR 6/6) clay; moderate coarse and very coarse subangular blocky structure breaking to moderate coarse and medium subangular blocky structure; slightly firm, slightly plastic; many coarse pores; many fine roots; organic acid coatings on ped surfaces and along pores; abrupt wavy boundary.
- BC 13-33 cm Brownish yellow (10YR 6/8) clay; presence of about 50% shaly (30-60 mm) and gravelly (10-20 mm) shale fragments with internal colours of dark red (10R 3/6), weak red (10YR 4/4) and dusky red (10R 3/4) clay matrix is compact; clear wavy boundary.
- CR 33-168 cm A layer of fragmented red (10R 4/6) ferruginous shale; cavities within fractures are filled with brown (7.5YR 6/6) clay matrix; shale becomes less fragmented and more continuous with depth; gradual wavy boundary.
- R 168-183 cm A somewhat continuous layer of weak red (10R 5/3) consolidated unweathered ferruginous shale.

Micromorphological DescriptionMicrostructure and Porosity Pattern

The B<sub>2</sub> and C horizons are vughy cavities comprising macro and megapores. Fissures and irregular joints are occasionally present in B<sub>2</sub> but in the C horizon they are common. Pedotubules are occasionally present in the B<sub>2</sub> with inclusions of quartz grains and semi-decomposed roots.

Coarse Material ( > 5μ )

Dominantly fine to coarse sand-sized, angular to subangular grains of quartz. In the B<sub>2</sub> muscovite is very rare and of fine sand-sized, feldspars which are rarely observed, commonly show a dotted pattern of alteration. Fine sand-sized tourmaline is rare in both horizons. Phytoliths of fine to medium sand-size are frequent in B<sub>2</sub> and are common in C. Lithorelicts of ferruginous shale are present in both horizons. In B<sub>2</sub>, they are of 0.5 to 1 mm diameter. In the C horizon, they are commonly present and of gravel-size.

Fine Material ( < 5μ )

Brownish-yellow clay, dotted, with dominantly random striated b-fabric. Locally, b-fabric is weakly-developed granostriated and porostriated. The fine material consists of clay, sericite, iron oxihydrates and organic matter especially in the B horizon.

Coarse/Fine Related Distribution

Open-spaced porphyric with coarse/fine ration of 1:2.

Organic Matter

Organic matter is composed essentially of semi-decomposed roots with fecal pellets and are common in the B horizon.

Special Features

Illuviation cutans are very rare and of irregular thickness. They are yellowish consisting of hyaline clay showing sharp to rather diffuse extinction. Papules are very rare, consisting of yellowish

hyaline clay. They are fragments of clay cutans having strong to weak orientation.

Parent Rock

The parent rock is the most characteristic and wide-spread rock type of the Sungai Petani formation. Generally, it is reddish shale, fissile and micaceous. The ferruginous shale is composed of a very fine-grained mixture of clay minerals, iron oxide, quartz together with laths of mica. Bands of quartz are common.

## Analytical data

Depth cm.	Horizon	Size class and particle diameter (um)				2mm %	Water dispersible clay %
		% fine earth					
		clay 2	silt 2-20	fine sand 20-200	coarse sand 200-2000		
0-3	Ap	47.3	33.3	10.3	9.1	-	10.3
3-13	B2	52.1	29.7	7.2	11.0	-	14.2
13-33	BC	58.8	29.7	5.2	11.3	60	21.7

Depth cm.	Bulk den. g/cc	% porosity		Moist. Retent. % V/V			Avail. Water mm/m		Org. N %	N %	C/N
		Total	Air filled	1/10 bar	1/3 bar	15 bar	1/10 -15	1/3 -15			
0-3	-	-	-	-	-	-	-	-	2.57	0.259	10
3-13	-	-	-	-	-	-	-	-	1.19	0.165	7
13-33	-	-	-	-	-	-	-	-	0.90	0.156	6

Depth (cm.)	pH (1:1)		Ext. Fe <sub>2</sub> O <sub>3</sub> %	Extractable bases* by amm. acetate				Sum* of bases	KCl* ext. Al	ECEC
	KCl	H <sub>2</sub> O		Ca	Mg	Na	K			
0-3	3.4	4.1	6.16	0.36	0.26	0.06	0.36	1.04	4.31	5.35
3-13	3.4	4.0	2.04	0.13	0.10	0.05	0.20	0.48	6.13	6.61
13-33	3.5	4.2	2.97	0.11	0.07	0.04	0.18	0.40	5.56	5.96



## Pedon 2

Information on the site

Profile number: C4-5; date: 9 August 1979; authors: Zainol E. and J.H. Chuah; location and grid reference: Field 7, Div. 5, Pinang Tunggal Estate - Toposheet 16 and 17, 191847; elevation: 18 m a.s.l.; surrounding landform: gently undulating pediplain; physiographic position: upper slope of the pediplain; slope: 1-3%; vegetation and landuse: mature Hevea.

General information on the soil

Parent material: reworked material of the Sungei Patani formation of ferruginous shale composition; drainage: well-drained; depth of ground water-table: not observed; erosion: slightly eroded; presence of rock outcrop and other features: few lateritic boulders and termite hills; human influence: Hevea is planted in straight rows.

Classification

Soil Taxonomy: Tropeptic Haplorthox, clayey-skeletal, kaolinitic, isohyperthermic

FAO: Orthic Ferralsols

Horizon description

- Ap<sub>1</sub>** 0-3 cm Yellowish brown (10YR 5/6) to dark yellowish brown (10YR 4/6) clay; moderately strong medium subangular blocky breaking into moderate fine subangular blocky and crumbs; slightly hard, friable non sticky; non plastic; few coarse and very coarse pores; abundant fine and coarse lateral roots; clear smooth boundary.
- Ap<sub>2</sub>** 3-15 cm Yellowish brown (10YR 5/6) to strong brown (7.5YR 6/6) clay; moderate medium subangular blocky breaking into moderate weak fine subangular blocky; very friable; slightly sticky; many medium and coarse pores; abundant fine and coarse lateral roots; clear smooth boundary.
- Bo<sub>1</sub>** 15-28 cm Strong brown (7.5YR 5/6) clay; moderately weak medium and coarse subangular blocky breaking into moderately weak medium and fine subangular; very friable; non sticky; abundant fine pores; many medium root; patchy organic acid coating along some root channel; gradual smooth boundary.

- Bo<sub>2</sub> 28-58 cm Strong brown (7.5YR 5/8) clay; weak coarse subangular blocky breaking into moderately weak medium and some fine subangular and crumbs; very friable to somewhat loose; non sticky; abundant fine and medium pores; many fine and medium roots; about 2%, fine 2.5 mm dusky red (10YR 3/2) petroplinthite; abrupt and smooth boundary.
- 2Bo<sub>3</sub>cs 58-109 cm Yellowish red (5 YR 5/8) clay; non sticky with about 50% gravelly (5-20 mm) and few coarse gravelly (20-40 mm) petroplinthite; petroplinthite colours are dark reddish brown (2.5YR 3/4) and (2.5YR 3/2) petroplinthites are loosely packed in place and easily removed; clear smooth boundary.
- 3Bo<sub>4</sub>cs 109-132 cm Yellowish red (5YR 5/8) and red (2.5YR 5/6) Yellow (10YR 7/8) sandy clay; non sticky; about 40% gravelly (5-15 mm) and coarse gravelly (about 20-30 mm) dark reddish brown (2.5YR 3/4) petroplinthite; petroplinthite are somewhat compact in place but loose when removed; gradual smooth boundary.
- Bo<sub>5</sub>cs 132-163 cm Red (2.5YR 5/8) and (4/8) and some yellow (10YR 7/8) sandy clay; non sticky; about 40% mainly gravelly (5-15 mm) dusky red (2.5YR 3/2) dark reddish brown (2.5YR 3/4), dark red (2.5YR 3/6) petroplinthites; petroplinthites are somewhat subrounded and angular; petroplinthites are compact in place, somewhat loose when removed.

## Micromorphological Description

### Microstructure and Porosity Pattern

In the upper three horizons, the microstructure is essentially complete irregularly jointed grading to crumbly. Individual crumbs have a vughy cavitated intrapedal microstructure comprising macro and megavughs. In the lower horizons, the microstructure is spongy but locally developed jointed microstructure is also present possibly due to the pressure induced by drought stress. The intrapedal microstructure of the complete cleavage peds is similar to the upper horizons. Pedotubules are rare and found in the Ap layer having a diameter of about 1 mm. In the B<sub>21</sub> horizon, channels and chambers with smooth surface indicating active biological influence are common.

### Coarse Material

Dominantly, the coarse material is made up of fine to coarse sand-sized, angular to subrounded grains of quartz (F). Funiquartz is common where the fractures of the quartz grains are filled with iron oxihydrate material. Silt to fine sand-sized phytoliths are commonly found in the upper horizons.

### Fine Materials

The upper three horizons have a brownish-yellow fine material due to the influence of organic stains. In the horizons with ferrugenous gravels, the colour of the fine material is stronger expressed with depth and it is reddish yellow. The B<sub>23</sub> horizon is somewhat transitional in colour. The fine material is dotted, composed of clay, humus especially in the upper horizons, and iron oxihydrate in the lower horizons. The plasmic fabric grades from dotted to circular striated. The latter fabric is more pronounced with depth.

### Coarse/Fine Related Distribution Patterns

The proportion of coarse to fine material is reflected in its open-spaced porphyric distribution. The dominance of the fine material is reduced in the stone-line layers. The apparent larger

proportion of ferruginous nodules in the stone-line layers is largely due to difficulty in sampling. In actual conditions, the fine material is dominant in these layers. Generally the coarse/fine ration decreases from 1:3 in the upper horizons to 1:2 in the stone-line layers.

### Organic Matter

Organic matter is present in the upper horizons as slightly humified roots (C), as well as fecal pellets (O).

### Special Features

Iron oxihydrate nodules are present throughout the profile. Above the stone-line layers, nodules are occasionally present and their diameter ranges from 0.3 to 1 mm. However in the stone-line layers they are common to frequent and the dimensions of the nodules are larger, reaching up to 4 mm. in diameter at the scale of microscopic observation and even more at field observations. Generally, they are rounded, have sharp boundaries, are compact to porous, and have inclusions of fragmented quartz grains and soil matrix. The colour is dark red and is dominantly hematitic in composition.

Gibbsite (O) in the main neoformed mineral and characterises absolute accumulation. Mineralisation sites of gibbsite are variable. Generally, gibbsite crystallises as infilling material within the interstitial spaces between the soil crumbs. In this case, silt-sized crystals arrange themselves normally to the soil crumbs and the rest of the space is occupied by clay-sized crystals. In the lowest horizon, gibbsite also crystallises as infilling material but it shows a cutanic relationship to ferriargillans.

Ferriargillans (C) are only encountered in the lowest horizon. They are generally thin reddish yellow with sharp boundary and having strong continuous orientation. Most of ferriargillans are discontinuous.

Depth cm	Horizon	Size class and particle diameter (um)				2 mm %	Water dispersible clay %
		% fine earth					
		clay 2	silt 2-20	fine sand 20-200	coarse sand 200-2000		
0-3	Ap1	70.6	13.0	10.2	6.2	-	10.9
3-15	Ap2	64.2	15.5	13.8	6.5	-	8.7
15-28	Bo1	80.6	7.6	7.4	4.4	-	0.6
28-58	Bo2	74.3	12.4	7.9	5.4	3	0.4
58-109	2Bo3cs	81.9	6.4	6.9	4.8	83	0.5
109-132	3Bo4cs	52.5	13.6	14.9	19.0	85	0.4
132-163	3Bo5cs	47.7	16.1	17.1	19.1	80	tr

Depth cm.	Bulk den. g/cc	% porosity		Moist. Retent. % V/V			Avail. Water mm/m		Org. N %	N %	C/N
		Total	Air filled	1/10 bar	1/3 bar	15 bar	1/10 -15	1/3 -15			
0-3	-	-	-	-	-	-	-	-	3.00	0.313	10
3-15	0.88	67	35	32.5	31.0	26.3	62	47	1.47	0.195	8
15-28	0.90	66	30	36.4	35.0	28.9	75	61	1.04	0.131	8
28-58	0.89	66	30	36.3	34.5	28.2	81	63	0.34	0.069	5
58-109	-	-	-	-	-	-	-	-	0.74	0.099	7
109-132	-	-	-	-	-	-	-	-	0.20	0.050	4
132-163	-	-	-	-	-	-	-	-	0.12	0.040	3

Depth cm.	pH (1:1)		Ext. Fe <sub>2</sub> O <sub>3</sub> %	Extractable bases* by amm. acetate				Sum* of bases	KCl ext. Al	ECEC
	KCl	H <sub>2</sub> O		Ca	Mg	Na	K			
0-3	3.6	4.2	3.96	0.43	0.20	0.06	0.47	1.16	3.58	4.74
3-15	3.8	4.4	4.16	0.11	0.06	0.03	0.19	0.39	2.92	3.31
15-28	3.8	4.4	4.16	0.11	0.05	0.03	0.18	0.37	2.71	3.08
28-58	4.0	4.4	4.16	0.12	0.04	0.03	0.19	0.38	1.57	1.95
58-109	3.8	4.3	5.03	0.08	0.02	0.04	0.24	0.38	1.45	1.83
109-132	4.0	4.5	5.66	0.08	0.02	0.04	0.24	0.38	1.45	1.83
132-163	4.1	4.6	6.51	0.35	0.09	0.03	0.10	0.57	-	-

\*meq/100 g soil - not determined

Depth cm.	CEC* by NH <sub>4</sub> OAc	Base Satn. %		Al Satn. %	Acid ext. ppm		Avail. P ppm	6N HCl ext*			Sum* of total cations
		NH <sub>4</sub> OAc	ECEC		P	Mn		Ca	Mg	K	
0-3	16.4	7	24	76	714	101	85	1.61	3.58	3.94	9.13
3-15	13.7	3	12	88	322	110	7	0.39	3.83	4.17	8.39
15-28	10.0	4	12	88	236	128	5	0.52	4.14	3.86	8.52
28-58	7.0	5	19	81	215	136	6	0.34	3.70	4.60	8.64
58-109	7.8	4	10	90	222	123	4	0.34	4.59	5.42	10.35
109-132	6.0	6	21	79	213	160	5	0.38	3.77	7.45	11.60
132-163	6.4	9	-	-	215	129	5	0.39	1.98	4.39	6.76

Pedon 3

Information on the site

Profile Number: C4-6; date: 9 August 1979; authors: Zainol E. and J.H. Chuah; location and grid reference: Field 7, Div. 5, Pinang Tunggal Estate - Toposheet 16 and 17, 193841; elevation: 15 m a.s.l.; surrounding landform: gently-undulating pediplain; physiographic position: near the edge of the pediplain, adjacent to recent alluvial tract; slope: 1-3%; vegetation and land-use: mature Hevea

General information on the soil

Parent material: reworked material of the Sungei Patani formation of ferruginous shale composition; drainage: well-drained; depth of ground water table: not observed; erosion: slightly eroded; presence of rock outcrop and other features: few lateritic boulders and termite hills; human influence: Hevea is planted in straight rows.

Classification

Soil Taxonomy: Tropeptic Haplorthox, clayey, mixed isohyperthermic

FAO : Orthic Ferralsols

Horizon description

- Ap 0-8 cm Brown to dark brown (7.5YR 4/4) and strong brown (7.5YR 5/8); clay, moderately strong, medium and coarse subangular blocky breaking into moderately strong fine subangular blocky and crumbs; friable, non sticky; many coarse and very coarse pores; abundant fine, medium and coarse root; some termite cast; clear, smooth boundary.
- Bo<sub>1</sub> 8-38 cm Yellowish red (5YR 5/8) to strong brown (7.5YR 5/8) clay; moderately weak, coarse subangular blocky breaking into moderate medium and fine subangular and few crumbs; slightly firm in place, friable when removed; non sticky; abundant fine and very fine pores; many medium roots; very patchy organic acid coatings; some termite cast; about 2-5% gravelly (2-5 mm) red (2.5YR 4/6) petroplinthite; clear, somewhat wavy boundary.
- Bo<sub>2</sub> 38-69 cm Yellowish red (5YR 5/8) clay; weak, coarse and very coarse subangular blocky breaking into weak medium and fine subangular blocky and crumbs; very friable to somewhat loose, non sticky; abundant fine and medium pores; many medium and fine roots; about 5% gravelly petroplinthite as above; clear smooth boundary.

- Bo<sub>3</sub>** 69-110 cm Yellowish red (5YR 5/8) clay; weak coarse subangular blocky breaking into weak, medium and fine subangular blocky and crumbs; very friable to loose; non sticky; many fine pores; many fine and medium roots; about 2-5% gravelly petroplinthite similar to 2nd. and 3rd. horizons; abrupt, wavy boundary.
- 2Bo<sub>4</sub>cs** 110-147 cm Yellowish red (5YR 5/8) clay; non sticky; with about 40% coarse gravelly (5-30 mm), mostly subrounded and some well rounded petroplinthite; petroplinthite colours are mainly reddish brown (5YR 4/3, 4/4) with some yellow (10YR 7/8) clay fillings in cavities and some are dark red (10R 3/6); diffuse boundary.
- Bo<sub>5</sub>cs** 147-185 cm Clay; non sticky; as above but with some angular gravelly and more coarse gravelly petroplinthites.

## Micromorphological Description

### Microstructure and Porosity Pattern

The upper two horizons are incompletely jointed to crumbly. Similar microstructure are observed in the B<sub>22</sub> and B<sub>23</sub> horizons but they are more expressed as reflected in the macrostructure being completely jointed. The individual crumbs have a vughy cavities intrepedal microstructure comprising mega and macrovughs. Pedotubules are rare with diameter ranging from 0.5 to 1mm.

### Coarse Material ( > 5 $\mu$ )

Fine to coarse sand-sized angular to subangular grains of quartz dominate the coarse material. Runiquartz is common throughout the profile. Fine sand-sized tourmaline and mica (muscovite) are present in the upper two horizons but they are very rare. Silt-sized phytoliths are common in the upper horizons and decrease with depth.

### Fine Material ( < 5 $\mu$ )

The fine material is brownish, dotted, composed of clay, iron oxihydrates and very fine mica (sericite). The most common fabric is dotted together with grano fabric. An interesting feature is the development of circular striated fabric which is better expressed with depth.

### Coarse/Fine Related Distribution Pattern

The high proportion of fine material is reflected in an open-spaced porphyric distribution. Difficulties in sampling of the stone-line layers do not give the true distribution of coarse and fine. Based on field observations, the fine material still dominate the size distribution. Generally, the coarse/fine ratio decreases from 1:3 to 1:2 in the stone-line layers.

### Organic Matter

Slightly humified roots are common the A horizon. Fecal pellets (O)\* are observed in the upper two horizons. Organic matter is absent in the rest of the profile.

### Special Features

Iron oxihydrate nodules are generally present in all horizons. These nodules are dark red and dominantly hematitic in composition. They are occasionally present in the layers above the stone-line and are irregular to rounded with sharp boundary with a diameter of about 1 to 2 mm. Some of the nodules are relatively dense. Within the stone-line, the nodules are gravel-sized and even reaching up to 4 cm. (field observation). They show a high porosity and yellow, dark red to black patches. Inclusions of quartz characterise the nodules and they show some form of disintegration as indicated by angular grains.

Apart from quartz inclusions, gibbsite mineralization is an important phenomenon within the iron oxihydrate nodules. Gibbsite crystallizes on quartz grains and in voids as gibbsan and crystal chambers. Inclusions of very fine mica (sericite) are often observed in the gibbsite.

- \* (VF) - very frequent  
 (F) - frequent  
 (C) - common  
 (O) - occasional  
 (R) - rare  
 (VR) - very rare

Depth cm.	Horizon	Size class and particle diameter (um)				2 mm %	Water dispersible clay %
		% fine earth					
		clay 2	silt 2-20	fine sand 20-200	coarse sand 200-2000		
0-8	Ap	50.9	23.3	9.9	15.9	4	11.4
8-38	Bo1	68.1	12.9	8.8	10.2	4	0.5
38-69	Bo2	65.5	15.0	8.5	11.0	2	0.3
69-110	Bo3	52.9	24.1	11.7	7.5	8	0.3
110-147	2Bo4cs	63.8	17.3	8.4	10.5	79	tr
147-185	Bo5cs	52.1	20.8	12.1	15.0	79	tr

Depth cm.	Bulk den. g/cc	% porosity		Moist. Retent. % V/V			Avail. Water mm/m		Org.		C/N
		Total	Air filled	1/10 bar	1/3 bar	15 bar	1/10 -15	1/3 -15	C %	N %	
0-8	1.00	62	27	35.2	34.2	27.1	81	71	2.02	0.282	7
8-38	1.03	61	26	35.3	34.0	28.8	65	52	0.86	0.122	7
38-69	0.97	63	26	37.0	34.5	29.7	73	48	0.50	0.090	6
69-110	0.98	63	24	39.2	36.1	31.5	77	46	0.34	0.070	5
110-147	-	-	-	-	-	-	-	-	0.23	0.077	3
147-185	-	-	-	-	-	-	-	-	0.16	0.092	3

Depth cm.	pH (1:1)		Ext. Fe <sub>2</sub> O <sub>3</sub> %	Extractable bases*				Sum* of bases	KCl* ext. Al	ECEC
	KCl	H <sub>2</sub> O		by amm. acetate						
			Ca	Mg	Na	K				
0-8	4.0	4.6	4.58	1.12	0.18	0.03	0.28	1.61	1.17	2.78
8-38	4.0	4.2	5.55	0.34	0.09	0.02	0.08	0.53	1.70	2.23
38-69	4.0	4.5	5.22	0.29	0.08	0.03	0.05	0.45	1.31	1.76
69-110	4.2	4.6	5.66	0.54	0.15	0.03	0.04	0.76	0.50	1.26
110-147	4.2	5.0	5.45	0.23	0.07	0.03	0.04	0.37	0.74	1.11
147-185	4.2	5.0	4.89	0.25	0.05	0.04	0.06	0.40	0.89	1.29

Depth cm.	CEC* by NH <sub>4</sub> OAc	Base Satn. %		Al Satn. %	Acid ext. ppm		Avail. P	6N HCl ext*			Sum* of total cations
		NH <sub>4</sub> OAc	ECEC		P	Mn		Ca	Mg	K	
0-8	13.5	12.7	58.8	42.7	363.4	611.8	7.7	2.02	4.10	3.42	9.54
8-38	8.7	6.2	24.8	76.8	293.4	553.3	3.0	0.66	4.36	3.58	8.60
8-69	8.4	5.8	26.7	74.9	249.4	560.7	4.0	0.60	4.87	3.50	8.97
9-110	8.7	9.6	60.7	40.1	222.8	967.3	4.1	1.06	4.53	3.01	8.60
0-147	8.0	5.0	33.0	67.0	216.0	971.0	4.0	0.53	4.10	3.50	8.13
7-185	7.4	5.0	31.0	69.0	216.0	674.0	5.0	0.67	3.85	3.00	7.52

Pedon 4

Soil Series:

Information on the site

Profile number: S-1; date: 16th. August 1985; authors: Zainol E. and Shahrudin B; location and grid reference: Field 1, Division 7, Pinang Tunggal Estate - Toposheet 16 and 17, 194868; elevation: 34 m.a.s.l; surrounding landform: gently undulating pediplain; physiographic position: mid-slope of the pediplain; slope: 3-4 %; vegetation and land-use: mature Hevea.

General information on the soil

Parent material: reworked material of Sungei Petani formation of interbedded shale composition; drainage: well drained; depth of ground water-table: not observed; erosion: moderately eroded; presence of rock outcrop and other features: few lateritic boulders observed at upper slopes; human influence: Hevea is planted in straight rows.

Classification

Soil Taxonomy: Tropeptic Haplorthox, clay skeletal, kaolinitic, isohyperthermic.

FAO : Orthic Ferralsol.

Horizon description

- |                     |   |
|---------------------|---|
| Ap                  | 0-3 cm Brown to dark brown (7.5YR 4/4); clay; moderate fine and medium subangular blocky structure and medium crumbs; friable; sticky and plastic; many coarse pores; many medium and fine roots; clear smooth boundary.  |
| Bo <sub>1</sub>     | 3-18 cm Strong brown (7.5YR 4/6); clay; moderately strong; medium and coarse subangular blocky structure; friable; sticky and plastic; many coarse pores; few medium roots; some scattered pebbly laterites; abrupt and wavy boundary.  |
| 2Bo <sub>2</sub> cs | 18-91 cm Yellowish red (5YR 5/6 to 5/8); clay; weak coarse and massive structure; slightly firm; sticky and plastic; many coarse pores; rare fine roots; presence of about 50-60 % somewhat loosely to moderately packed pebbly and gravelly laterites with some stony lateritic boulders; diffuse wavy boundary. |
| BC                  | 91-160 cm Yellowish red (5YR 5/8); clay; weak coarse and massive structure; firm; sticky and plastic; common coarse pores; presence of about 50 % platy and stony laterite and laterised material somewhat compactly packed.  |

Depth (cm)	Horizon	Clay	Silt	Fine Sand	Coarse Sand	Wt.% gravels	Percent		C/N	Avail.P (ppm)	Total Mn (ppm)
							O.C	N			
0-3	Ap	64.8	15.3	10.0	9.9	-	3.08	.32	10	7	178
3-18	Bo <sub>1</sub>	65.1	11.9	9.9	13.1	-	1.79	.20	9	6	117
18-91	2Bo <sub>2</sub> cs	74.7	10.6	6.8	7.9	68	.48	.08	6	8	139
91-160	BC	57.1	12.2	11.6	19.1	52	.27	.06	5	7	106

Depth (cm)	pH (1:1) H <sub>2</sub> O	Ext. bases			CEC (NH <sub>4</sub> OAc) meq/100 g soil	Base Saturation
		K	Ca	Mg		
0-3	4.3	3.9	.25	.39	.30	4
3-18	4.4	3.9	.12	.20	.11	2
18-91	4.4	4.0	.07	.15	.06	2
91-160	4.6	4.2	.08	.22	.06	3

Depth (cm)	KCl ext. Al meq/100 g soil	Free Fe <sub>2</sub> O <sub>3</sub>		ECEC meq/100 g soil
0-3	3.14			4.1
3-18	3.00			3.4
18-91	1.91			2.2
91-160	.89			1.3

Pedon 5

Soil Series:

Information on the site

Profile number: S-2; date: 16th. August 1985; authors: Zainol E and Shahrudin B; location and grid reference: Field 1, Division 7, Pinang Tunggal Estate - Toposheet 16 and 17, 194868; elevation: 34 m.a.s.l.; surrounding landform: gently undulating pediplain; physiographic positions: mid-slope of the pediplain; slope: 3-8%; vegetation and land-use: under mature Hevea.

General information of the soil

Parent material: reworked material of Sungei Petani formation of interbedded shale; drainage: well drained; depth of ground water-table: not observed; erosion: moderately eroded: presence of rock outcrop and other features: few lateritic boulders observed at upper slopes; human influence: Hevea is planted in straight rows.

Classification

Soil Taxonomy: Tropeptic Haplorthox; clayey skeletal; kaolinitic; isohyperthermic.  
FAO : Orthic Ferralsol.

Horizon description

- Ap 0-3 cm Dark yellowish brown (10YR 4/4); clay; moderately strong, medium and fine subangular blocky structure with coarse crumbs; friable; sticky and plastic; many coarse pores; few medium roots; clear and smooth boundary.
- Bo<sub>1</sub> 3-33 cm Strong brown (7.5YR 5/6); clay; moderately strong medium and coarse subangular blocky structure; friable; sticky and plastic; many coarse pores; few fine roots; some humic acid coatings and some root channels; diffuse wavy boundary.
- Bo<sub>2</sub> 33-72 cm Strong brown (7.5YR 5/6 to 5/8); clay; moderate coarse and very coarse subangular blocky structure breaking to medium and coarse subangular blocky structure; friable; sticky and plastic; many coarse pores; few fine roots; some patchy humic acid coatings; abrupt wavy boundary.
- 2Bo<sub>3</sub>cs 72-130 cm Strong brown (7.5YR 5/8); clay; weak coarse and massive structure; slightly firm; sticky; many coarse pores; rare roots; presence of about 50-60 % somewhat moderate to loosely packed gravelly and pebbly laterites, some stony lateritic boulders were also observed; gradual irregular boundary.
- BC 130-140 cm Strong brown (7.5YR 5/8) and reddish yellow (7.5YR 6/8) clay; weak and massive; firm; slightly sticky; few coarse pores; nil roots; presence of about 50 % somewhat compactly packed gravelly laterite and some laterised material.

Depth (cm)	Horizon	Clay	Silt	Fine Sand	Coarse Sand	Wt. % gravels	Percent O.C	Percent N	C/N	Avail. P (ppm)	Total Mn (ppm)
0-3	Ap	57.0	15.3	15.7	12.0	-	3.09	.31	10	9	90
3-33	Bo <sub>1</sub>	69.9	11.2	10.3	8.6	-	1.01	.13	8	7	70
33-72	Bo <sub>2</sub>	73.3	11.1	8.9	6.7	-	.65	.10	7	8	51
72-130	2Bo <sub>3</sub> cs	66.6	11.4	9.8	12.2	78	.32	.07	5	10	66
130-140	BC	55.0	13.3	12.6	19.1	50	.24	.07	3	7	58

Depth (cm)	pH (1:1) H <sub>2</sub> O	Ext. bases			CEC (NH <sub>4</sub> OAc) meq/100 g soil	Base Saturation
		K INKCl	Ca	Mg		
0-3	4.7	3.8	.39	.32	26.5	4
3-33	4.4	3.9	.10	.07	22.1	2
33-72	4.4	3.9	.07	.04	16.6	1
72-130	4.6	4.1	.07	.05	15.5	2
130-140	4.6	4.2	.07	.06	11.4	3

Depth (cm)	KCl ext. Al meq/100 g soil	Free Fe <sub>2</sub> O <sub>3</sub>	ECEC meq/100 g soil
3-33	3.92	4.3	
33-72	3.61	3.8	
72-130	2.28	2.6	
130-140	1.58	1.9	

## Pedon 6

Location: : Mango plot of soils management branch,  
Gajah Mati Station, Kedah

Described by : J.S. Lim

Date : 11/6/83

Topography : Flat to undulating

Physiographic position: Lower part of concave slope

Parent materials : Reworked materials

Vegetation : Mango and grass cover

Drainage : Moderately well-drained

Classification : Loamy over clayey skeletal, agric Tropudult

Profile Description

Ap <sub>1</sub>	0-12 cm	Dark yellowish brown (10YR 4/6); fine sandy clay loam; friable; many crumbs and some weak to moderate fine subangular structures; few lateritic nodules (about 5 mm)- many fine roots; few fine charcoal pieces; gradual smooth boundary.
Ap <sub>2</sub>	12-35 cm	Dark brown (10YR 4/3); fine sandy clay loam, friable but slightly firmer than above horizon (indication of plough sole); moderate, medium and coarse subangular blocky structures which break down to fine subangular blocky structures; many fine roots many charcoal fragments; abrupt smooth boundary.
2Btcs <sub>1</sub>	35-79 cm	Yellowish brown (7.5YR 5/6); gravelly clay; gravels consist predominantly of rounded and sub rounded sizes ranging from 5 to 1.5 mm, some angular and platy laterites of the same size are also present; lateritic gravels constitute about 50% of the soil volume; weak to moderate, medium and coarse subangular blocky structures; thin patchy clayskin on ped faces; few fine roots; gradual wavy boundary.
2Btcs <sub>2</sub>	79-105 cm	Reddish Yellow (5YR 5/6) to Red (2.5YR 4/8); clay; about 15% of gravels; weak, fine and medium subangular blocky structures; friable, patchy clayskins; few fine roots.

## ANALYTICAL DATA

Pedon 6

Depth (cm)	Horizon	Granulometric Composition (%)				
		Clay	Silt	Fine sand	Coarse sand	Gravel
0-12	Ap1	17.91	10.83	60.70	10.54	8.0
12-35	AP2	18.43	12.94	59.25	9.34	4.4
35-79	2Btcs1	48.66	8.16	35.10	8.06	76.5
79-105	2Btcs2	36.25	12.27	39.86	11.57	30.4

Depth (cm)	Horizon	(I N NH <sub>4</sub> Ac at pH <sub>7</sub> (me/100 g soil))					Base saturation	Available P (ppm)
		CEC	Exchangeable cations					
			Ca	Mg	K	Na		
0-12	Ap1	9.4	0.96	0.30	0.28	N	16.4	
12-35	Ap2	6.9	1.14	0.24	0.12	N	21.7	
35-75	2Btcs1	4.4	0.95	0.29	0.26	N	34.0	
75-105	2Btcs2	5.0	0.32	0.12	0.79	N	24.6	

Depth (cm)	Horizon	C %	N %	C/N ratio	pH H <sub>2</sub> O	pH KCL	Free Iron %	Exch. Al (meq/100 g)
0-12	Ap1	1.21	0.12	10.08	4.8	4.8		
12-35	Ap2	1.24	0.10	12.40	5.1	4.7		
35-79	2Btcs1	0.62	0.08	7.75	5.3	4.8		
79-105	2Btcs2	0.46	0.07	6.57	4.7	4.4		

N = Negligible

Pedon 7

Information on the site

Profile number: S2-18; date: 15 June 1980; authors: Zainol E. and R. Sathiyalingam; location: Felcra Bkt. Tampoi; elevation: about 15 m a.s.l.; surrounding landform: pediplain; physiographic position: on a raised part of pediplain adjacent to alluvial tract; slope: 1-3%; vegetation and land-use: mature Hevea

General information on the soil

Parent material: reworked material of the Semanggol formation of interbedded shale/sandstone composition; drainage: moderately well-drained; presence of rock outcrops and other features: few termite hills; human influence: Hevea plantation

Horizon description

- Ap<sub>1</sub> 0-9 cm Brown (10YR 5/3) loamy fine sand; weak, coarse and medium subangular blocky structure; friable; many pores; many fine and medium roots; 15% channels; 3% termite activity; 5% charcoal inclusion; gradual smooth boundary.
- Ap<sub>2</sub> 9-16 cm Brownish yellow (10YR 6/6) to yellowish brown (10YR 5/6) fine sandy loam; weak coarse subangular blocky structure; friable; many pores; common fine roots; 15% channels; with common fine distinct pale yellow (2.5Y 8/4) blotches; 3% termite activity; 2% charcoal inclusion; abrupt slightly wavy boundary.
- Bt<sub>1cs</sub> 16-29 cm Yellow (10YR 7/6) gravelly fine sandy loam with about 50-60% gravelly fine sandy loam with about 50-60% gravelly (3-30 mm) reddish brown (5YR 4/4) and dark reddish brown (2.5YR 3/4) which are somewhat loosely packed; common pores; few roots; gradual smooth boundary.
- 2Bt<sub>2cs</sub> 29-64 cm Strongly variegated red (2.5YR 5/8), pale yellow (2.5Y 7/4) gravelly fine sandy clay loam with about 40% gravelly fine sandy clay loam with about 40% gravelly and nodular (3-25 mm) dusky red (10YR 3/4) and very dusky red (10R 2.5/2) petroplinthic material which are moderately compact in place, gravels decrease with depth; common pores; rare roots; clear smooth boundary.

BC<sub>1</sub> 64-89 cm Strongly variegated reddish yellow (5YR 6/8), yellow (10YR 7/6), fine sandy clay with about 15% nodular and gravelly (2-10 mm) dusky red (10R 3/4) petroplinthic material; moderately weak, coarse and medium subangular blocky structure; friable; common pores; gradual smooth boundary.

BC<sub>2</sub> 89-139 cm Strongly variegated white (10YR 8/2), yellow (10YR 8/6), reddish yellow (7.5YR 6/6), yellowish red (5YR 5/6), fine sandy clay with about 5% gravelly (15-30 mm) dusky red (10R 3/4) petroplinthic material and 30-40% plinthic material; moderate, coarse subangular blocky structure; friable; common pores; 10% channels.

*(Faint, mirrored text from reverse side of page)*

## Pedon 7

Depth (cm)	Horizon	GRANULOMETRY					Percentage			P (p.p.m.)	
		Clay	Silt	Fine sand	Coarse sand	Wt. % Gravels	O.C.	N	C/N	Total	Avail
0-9	Ap1	10.6	8.0	66.2	15.2	2.0	.52	.093	5.59	50	6
9-16	Ap2	13.2	8.1	63.5	15.3	13.8	.33	.040	8.25	45	5
16-29	Bt1cs	17.5	9.8	57.5	15.2	75.0	.19	.039	4.87	45	4
29-64	2Bt2cs	45.2	7.8	36.3	10.7	72.2	.18	.047	3.83	65	6
64-89	Bc1	37.6	11.5	40.0	10.9	39.1	.12	.024	5.00	53	5
89-135	Bc2	34.1	12.9	39.5	13.5	32.0	.10	.025	4.00	55	5

Depth (cm)	pH (1:1)		Ext. bases				CEC (NH <sub>4</sub> OAC) meq/100 g soil	Base saturation
	H <sub>2</sub> O	IN Kcl	Ca meq/100 g soil	Mg meq/100 g soil	Na	K		
0-9	4.5	3.8	.36	.23	.02	.15	3.06	25
0-16	4.6	3.8	.22	.14	.02	.16	3.31	16
16-29	4.8	3.8	.18	.18	.02	.20	3.84	15
29-64	4.8	3.7	.13	.20	.02	.24	8.36	7
64-89	4.6	3.7	.09	.10	.03	.13	6.29	6
89-135	4.5	3.8	.13	.06	.04	.08	10.00	3

Depth (cm)	6 N HCl Ext.				Mn (p.p.m.)	Free Fe %
	K	Ca	Mg			
0-9	1.12	.39	1.55		10	0.76
9-16	1.07	.26	1.71		11	0.87
16-29	1.40	.24	2.18		11	1.13
29-64	2.82	.21	5.19		20	2.85
64-89	2.60	.14	4.15		15	2.99
89-135	2.32	.15	3.12		14	3.02

## Pedon 8

Information on the site

Profile number: S2-39; date: 20 June 1980; authors: Zainol E. and R. Sathiyalingam; location: Kg. Bakong, 19th milestone, Kuala Nerang; elevation: 20 m a.s.l.; surrounding landform: pediplain; physiographic position: on a slightly raised part of the pediplain; Slope: 1-3%; vegetation and land-use: mature Hevea.

General information on the soil

Parent material: reworked material of the Semanggol formation of sandstone composition; drainage: moderately well-drained; presence of rock outcrop and other features: none; human influence; Hevea smallholding.

Horizon description

- Ap<sub>1</sub> 0-10 cm Brown (10YR 4/3) loamy fine sand; moderate, coarse and medium subangular blocky and few angular blocky structure; very friable; abundant pores; abundant fine, medium and coarse roots; 3-4% termite activity; 2-3% charcoal inclusion; 20% channels; gradual smooth boundary.
- Ap<sub>2</sub> 10-25 cm Dark yellowish brown (10YR 4/4) loamy fine sand; moderately weak, coarse and few medium subangular blocky structure; very friable; abundant pores; many fine and medium and few coarse roots; 15% channels; 5% termite activity; gradual smooth boundary.
- Bt<sub>1</sub> 25-49 cm Yellowish brown (10YR 5/6) loamy fine sand; weak, coarse and few medium subangular blocky structure; very friable; many pores; common medium and fine roots; 20% channels; 6% termite activity; few patchy clay-skin; gradual smooth boundary.
- Bt<sub>2</sub> 49-76 cm Reddish yellow (7.5YR 6/6) fine sandy loam; moderately weak, coarse subangular blocky structure; friable; many pores; few medium and fine roots; 20% channels; 10% termite activity; with few medium and fine faint yellow (10YR 6/6) blotches of mottles; few patchy clay-skins; gradual smooth boundary.
- Bt<sub>3</sub> 76-127 cm Strongly variegated yellow (10YR 7/6), yellowish red (5YR 5/6), white (10YR 8/1), fine sandy loam with about 2-3% gravelly and nodular (3-4 mm) brown to dark brown (7.5YR 4/4) petroplinthic material; moderately weak, coarse and few very coarse and medium subangular blocky structure; friable, slightly sticky, slightly compact; many pores; common medium and fine roots; 15% channels; few patchy clay-skin; abrupt irregular boundary.



## Pedon 8

Depth (cm)	Horizon	Clay	Silt	Fine sand	Coarse sand	Wt. % Gravels	Percent.		C/N	P (ppm)	
							O.C.	N		Total	Avail.
0-10	Ap 1	8.6	5.4	68.6	17.4		.95	.151	6	73	8
10-25	AP 2	8.2	5.8	64.9	21.1		.47	.112	4	51	6
25-49	Bt 1	8.6	5.1	65.7	20.6		.28	.100	3	40	4
49-76	Bt 2	12.9	4.4	61.2	21.5		.21	.092	2	40	4
76-127	Bt 3	14.7	4.6	59.6	21.1		.15	.069	2	45	5
127-140	BC	18.5	6.5	53.0	22.0		.21	.044	5	73	5

Depth (cm)	pH (1:1)		Na	Ext. bases			CEC (NH OAC) meq/100 g soil	Base saturation
	H <sub>2</sub> O	IN KCL		K (meq/100 g soil)	Ca	Mg		
0-10	4.8	4.0	.03	.18	.10	.10	4.0	10
10-25	4.9	4.1	.01	.07	.08	.03	2.8	6
25-49	4.8	4.1	.02	.07	.09	.02	2.9	6
49-76	4.7	3.8	.01	.05	.07	.02	3.2	4
76-127	4.8	3.8	.01	.04	.08	.03	2.4	6
127-140	5.0	3.9	.01	.05	.10	.05	3.9	5

Depth (cm)	6N HCl Ext.			Mn (ppm)	Free Fe <sub>2</sub> O <sub>3</sub>
	K	Ca meq/100 g soil	Mg		
0-10	1.01	.18	1.40	18	.34
10-25	.72	.13	1.24	11	.40
25-49	.82	.10	1.32	9	.44
49-76	1.21	.09	1.97	9	.59
76-127	1.14	.08	2.00	9	.54
127-140	1.29	.13	2.10	11	1.83

Pedon : 9

## 1. General information on the site and the soil

Profile Number : 295.2

### Higher Category Classification

FAO : Plinthic Acrisol

Soil Taxonomy : Clayey skeletal over clayey, kaolinitic, isohyperthermic plinthudult.

Date of Examination : 25.03.81

Author : J. Debaveye and H. Mahmud

Location : 6° 20' 54" Lat. N, 100° 42' 08" Long. E

Elevation : 48 m

### Land form

Physiographic position: : situated on the lower concave slopes of the dissected pediplain.

Surrounding land form : slightly undulating to flat

Slope of the site : flat

Vegetation or land use : bamboo and shrub

Parent material : reworked material derived from interbedded shale and sandstone.

Drainage : somewhat imperfectly drained

## 2. Profile Description

Ap 0-16 cm : Dark brown to brown (10YR 4/3) fine sandy loam; weak medium crumb; non sticky, non plastic; friable; no cutans; many fine and medium roots and few coarse roots; abrupt, smooth boundary.

Bt<sub>1</sub>cs 16-29 cm : Yellowish brown (10YR 5/6), very gravelly fine sandy clay loam; very frequent (60% v/v) small (1 cm) blocky and spherical, brown and black iron stone nodules; moderately weak coarse subangular blocky; slightly sticky, slightly plastic; friable; no cutans; few fine and medium roots; clear, wavy boundary.



## ANALYTICAL DATA

Depth (cm)	Horizon	Granulometric Composition (%)				
		Clay	Silt	Fine sand	Coarse sand	Gravel
0-16	Ap	18.5	19.4	52.3	9.7	-
16-29	Bt 1 cs	27.2	17.3	36.2	19.3	64.6
29-40	Bt 2 cs	41.2	17.6	29.2	12.0	65.9
40-80+	C cs	46.2	22.9	27.6	3.3	9.6

Depth (cm)	Horizon	(1 N NH Ac at pH (meq/100 g soil))				Base Saturation	Available P (ppm)	
		CEC	Exchangeable cations					
			Ca	Mg	K			Na
0-16	Ap	6.50	0.11	0.37	0.22	0.11	12.5	
16-29	Bt 1 cs	5.00	0.04	0.22	0.21	0.11	11.6	
29-40	Bt 2 cs	6.10	0.02	0.16	0.18	0.09	7.4	
40-80+	C cs	7.10	0.02	0.14	0.19	0.09	6.2	

Depth (cm)	Horizon	C %	N %	C/N ratio	pH H <sub>2</sub> O	pH KCL	Free Iron %	Exch. Al (meq/100 g)
0-16	Ap	1.9	0.15	12.6	4.5	4.0	1.56	2.42
16-29	Bt 1 cs	0.95	0.10	9.5	4.8	3.7	2.90	3.32
29-40	Bt 2 cs	0.68	0.08	8.1	4.8	3.5	5.65	4.64
40-80+	C cs	0.47	0.04	11.8	4.7	3.5	10.87	6.30

## Pedon 10

1. General information on the site and the soil

Profile Number : 380.7

Soil Name :

## Higher Category Classification

FAO : Orthic Ferralsol

Soil Taxonomy : Loamy skeletal, mixed, isohyperthermic  
Typic Haplorthox.

Date of Examination : 26.04.82

Author : J. Debaveye

Location : 6° 16' 47" Lat.N, 100° 40' 32" Long.E  
GPT estate, G Division.

Elevation : 31 m

## Land form

Physiographic position: situated on the convex upper slope  
of a low hill in the upper section  
of the pediplain landscape

Surrounding land form: slightly undulating

Slope of the site : nearly level

Vegetation or land use: sugar cane

Parent material : reworked material derived from sandstone  
and shale

Drainage : Well drained

2. Profile Description

Ap 0-12 cm

Dark yellowish brown (10YR 4/4) fine and medium loamy sand  
weak very coarse subangular blocky; non sticky, non plastic; friable;  
no cutans, important termite activity; many fine and common medium  
roots; clear and smooth boundary.

BA1 12-30 cm

Yellowish brown (10YR 5/6) to strong brown (7.5YR 5/6)  
fine and medium loamy sand weak very coarse and coarse subangular  
blocky; slightly sticky; slightly plastic; firm; no cutan; important  
termite activity; many fine and few medium roots; clear and smooth  
boundary.



## ANALYTICAL DATA

## Pedon 10

Depth (cm)	Horizon	Granulometric Composition (%)				
		Clay	Silt	Fine sand	Coarse sand	Gravels Stones
0-12	Ap	12.1	7.0	61.0	19.8	1.48
12-30	BA 1	13.5	6.8	59.6	20.1	2.50
30-42	BA 2 cs	19.8	7.1	54.6	18.5	51.70
42-76	BOX 1 cs	39.7	4.3	42.0	14.0	77.40
76-105+	BOX 2 cs	45.1	5.3	39.0	10.6	62.0

Depth (cm)	Horizon	IN NH Ac at pH (meq/100 g soil)					Base Satur- ation	Available P (ppm)
		CEC	Exchangeable Cations					
			Ca	Mg	K			
0-12	Ap	3.3	<0.05	0.60	0.08	27.3	5.50	
12-30	BA 1	2.5	<0.05	0.60	0.06	18.5	4.50	
30-42	BA 2 cs	-	-	-	-	7.6	4.50	
42-76	BOX 1 cs	3.0	<0.05	0.35	0.06	5.1	14.50	
76-105+	BOX 2 cs	2.3	<0.05	0.40	0.08	-	3.0	

Depth (cm)	Horizon	% C	% N	C/N ratio	pH H <sub>2</sub> O	pH KCL	% Free Iron	Exch. Al meq
0-12	Ap	0.71	0.04	18.0	4.3	3.8	0.76	0.12
12-30	BA 1	0.47	0.07	7.0	4.7	3.6	0.89	0.28
30-42	BA 2 cs	0.39	0.08	5.0	4.6	3.5	-	-
42-76	BOX 1 cs	0.39	0.08	5.0	4.5	3.5	2.24	1.39
76-105+	BOX 2 cs	0.30	0.08	4.0	4.3	3.6	3.20	1.56

Pedon 11

Soil Profile Description1. General Information on the site and the soil

Profile Number : 389.1

Soil Name :

Higher Category Classification

FAO : Orthic Ferralsol

Soil Taxonomy : Fine loamy over clayey skeletal, mixed, isohyperthermic, Typic Haplorthox.

Date of Examination: 25.04.82

Author : J. Debaveye

Location : 6° 16' 55" Lat.N, 100° 40' 23" long. E  
GPT estate, G. Division

Elevation : 32 m

Land form

Physiographic position : situated on the convex top of a low hill in the upper section of the pediplain landscape.

Surrounding land form : undulating

Slope of the site : nearly level

Vegetation or land use: secondary succession of shrubs and low trees

Parent material : reworked material derived from sandstone and shale.

Drainage : Well to somewhat excessively drained

2. Profile Description

A 0-20 cm

Dark brown (10YR 4/3), fine and medium sandy loam, weak very coarse and coarse subangular blocky; non sticky, non plastic; friable; no cutans; common fine roots; clear, smooth boundary.

BA 20-40 cm

Strong brown (7.5YR 5/6), fine and medium sandy loam to sandy clay loam; weak to moderate coarse subangular blocky; sl sticky, non plastic; friable; no cutans; important, termite activity; common to few fine roots and few medium roots; clear and smooth boundary.



## ANALYTICAL DATA

## Pedon 11

Depth (cm)	Horizon	Granulometric composition (%)					
		Clay	Silt	Fine sand	Coarse sand	Gravels	Stones
0-20	A	14.2	8.2	60.9	16.8	-	
20-40	BA	19.6	8.3	56.4	15.7	1.66	
40-51	BOX 1	22.7	5.6	48.7	13.0	9.86	
51-78	BOX 2 cs	48.6	7.9	34.6	9.9	79.4	
78-125	BOX 3 cs	37.5	8.6	42.7	11.3	86.1	

Depth (cm)	Horizon	IN NH Ac at pH (meq/100 g soil)					Base Saturation	Available P (ppm)
		CEC	Exchangeable cations					
			Ca	Mg	K			
0-20	A	3.8	0.20	0.30	0.04	15	5.00	
20-40	BA	3.2	0.20	0.15	0.03	10	2.00	
40-51	BOX 1	2.5	0.15	0.25	0.05	13	2.50	
51-78	BOX 2 cs	2.5	<0.05	0.25	0.08	12	2.00	
78-125	BOX 3 cs	-	-	-	-	-	2.50	

Depth (cm)	Horizon	% C	% N	C/N ratio	pH H <sub>2</sub> O	pH KCL	% Free Iron	Exch. Al meq
0-20	A	0.88	0.11	8.00	4.20	3.60	1.06	1.39
20-40	BA	0.34	0.05	7.00	4.30	3.50	1.48	1.56
40-51	BOX 1	0.45	0.07	6.00	4.25	3.40	1.90	1.87
51-78	BOX 2 cs	0.43	0.08	5.00	4.50	3.50	3.94	1.83
78-125	BOX 3 cs	0.26	0.06	4.00	4.45	3.60	-	-

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Padan 6 - Dr. Sharifuddin Hj. Abd. Hamid

Padan 7 - Mr. Wong Han Chong

Padan 8 - Mr. Goh Cheng Hock

Padan 9 - Prof. Dr. K.T. Joseph

Padan 10 & 11 - Mr. Lim Jit Sai

**SOIL CORRELATION TOUR - KEDAH**  
**(9-12th September 1985)**

Soil Name

Pokok Sana Series

Higher category classification:

YAG

Moderators

- |               |   |                                |
|---------------|---|--------------------------------|
| Soil Pedon 1  | - | Dr. Zainol Eusof               |
| Pedon 2       | - | Dr. S. Paramanathan            |
| Pedon 3       | - | Mr. Chang Ah Kow               |
| Pedon 4       | - | Mr. Chan Heun Yin              |
| Pedon 5       | - | Dr. Zainol Eusof               |
| Pedon 6       | - | Dr. Sharifuddin Hj. Abd. Hamid |
| Pedon 7       | - | Mr. Wong Nan Chong             |
| Pedon 8       | - | Mr. Ooi Cheng Hock             |
| Pedon 9       | - | Prof. Dr. K.T. Joseph          |
| Pedon 10 & 11 | - | Mr. Lim Jit Sai                |

Bt<sub>1</sub>

12-34 cm

Light gray (10YR 7/2) with common to few fine distinct clear red (2.5YR 5/8) and many coarse and medium distinct diffuse reddish yellow (7.5YR 7/8) mottles, fine sandy clay; moderate, medium and coarse subangular blocky; sticky, plastic; firm; no cutans; many fine and medium roots and common coarse roots; abrupt smooth boundary.

Bt<sub>2</sub> ss

34-41 cm

Yellow (10YR 7/6) with many prominent sharp red (2.5YR 4/6), very gravelly clay; frequent (40% w/v) black spherical ironstone nodules; structureless massive; sticky, plastic; firm;

BC ss

41-70 cm

White (10YR 8/1) with many prominent sharp red (2.5YR 4/6), very gravelly clay; frequent (45% w/v) small (0.2-0.5 cm) black spherical ironstone nodules; structureless massive; sticky, plastic; no roots gradual to clear boundary.

Pedon 9

1. General information on the site and the soil

Soil Name : Pokok Sena Series

Higher category classification:

FAO : Plinthic Acrisol

Soil Taxonomy : Clayey skeletal over clayey,  
kaolinitic, isohyperthermic  
plinthudult

Slope of the site : flat

Vegetation or landuse : secondary succession of shrubs

Parent Material : reworked material derived from shale

Drainage : somewhat imperfect

2. Profile Description

A 0-12 cm : Brown (10YR 5/3), clay loam;  
moderate to weak medium subangular  
blocky; slightly sticky, slightly  
plastic; firm; no cutans; abundant  
fine, and common medium and coarse  
roots; clear smooth boundary.

Bt<sub>1</sub> 12-34 cm : Light gray (10YR 7/2) with common to  
few fine distinct clear red (2.5YR 5/8)  
and many coarse and medium distinct  
diffuse reddish yellow (7.5YR 7/8)  
mottles, fine sandy clay; moderate,  
medium and coarse subangular blocky;  
sticky, plastic; firm; no cutans;  
many fine and medium roots and  
common coarse roots; abrupt smooth  
boundary.

Bt<sub>2cs</sub> 34-43 cm : Yellow (10YR 7/6) with many prominent  
sharp red (2.5YR 4/6), very gravelly  
clay; frequent (40% v/v) black spherical  
ironstone nodules; structureless massive;  
sticky, plastic; firm;

BC cs 43-70 cm : White (10YR 8/1) with many prominent  
sharp red (2.5 YR 4/6), very gravelly  
clay; frequent (45% v/v) small (0.2-  
0.5 cm) black spherical ironstone  
nodules; structureless massive; sticky,  
plastic; no roots gradual to clear  
boundary.

C

70-90<sup>+</sup> cm

:

White (10YR 8/1), with many prominent sharp, red (2.5YR 4/6) slightly hardened continuous plinthite, very gravelly clay.

Field legend

P. Cf. C. A - 0. - 51.5

L - 1 Le, 4A - A1, C1

Profile Description	Soil Taxonomy	Slope of the site	Vegetation or Landuse	Parent Material	Drainage
<p>A</p> <p>0-12 cm</p> <p>Brown (10YR 5/3), clay loam; moderate to weak medium subangular blocky; slightly sticky, slightly plastic; firm; no roots, moderate fine, and common medium and coarse roots; clear smooth boundary.</p>					
<p>B<sub>1</sub></p> <p>12-34 cm</p> <p>Light gray (10YR 7/2) with common to few fine distinct clear red (2.5YR 5/8) and many coarse and medium distinct diffuse reddish yellow (7.5YR 7/8) mottles; fine sandy clay; moderate medium and coarse angular blocky; sticky, plastic; firm; no roots; many fine and medium roots and common coarse roots; sharp smooth boundary.</p>					
<p>B<sub>2</sub> ca</p> <p>34-43 cm</p> <p>Yellow (10YR 7/6) with many prominent sharp red (2.5YR 4/6), very gravelly clay; resistant (40% v/v) black subangular ironstone nodules; accumulation massive; sticky, plastic; firm.</p>					
<p>B<sub>3</sub> ca</p> <p>43-70 cm</p> <p>White (10YR 8/1) with many prominent sharp red (2.5YR 4/6), very gravelly clay; ironstone (40% v/v) nodules 0.5 cm) black spherical ironstone nodules; accumulation massive; sticky; plastic; no roots graded to clear boundary.</p>					

SOIL CORRELATION TOUR - KEDAH  
(9-12th September 1985)

ITINERARY

- 9th September (Monday) 8.00 p.m. Registration of participants at Alor Setar Rest House.
- 8.30 p.m. Briefing by Dr. Zainol Eusof on 'Characteristics and Classification of Upland Soils in Kedah'.
- 10th September (Tuesday) 8.30 a.m. Assemble at Soil Management Office, Department of Agriculture, Teluk Chengai. Opening address by President, MSSS - Tuan Hj. Dr. Noordin Wan Daud)
- 8.45 a.m. Address by Director of Agriculture, Kedah - Tuan Haji Hassan Lebai Mat
- 9.00 a.m. Tea
- 9.15 a.m. Leave Telok Chengai
- 10.30 a.m. Examine Pedon 1
- 12.00 p.m. Examine Pedon 2
- 1.00 p.m. Lunch at Sungei Patani
- 2.30 p.m. Examine Pedon 3
- 3.15 p.m. Examine Pedon 4
- 4.00 p.m. Examine Pedon 5
- 4.30 p.m. Summing up by Dr. Zainol Eusof
- 8.00 p.m. Dinner at Kuala Kedah
- 11th September (Wednesday) 8.15 a.m. Assemble at Rest House
- 8.30 a.m. Depart for Gajah Mati Station, Department of Agriculture
- 9.00 a.m. Examine Pedon 6
- 10.00 a.m. Depart to Felcra Tampoi
- 10.30 a.m. Examine Pedon 7
- 11.30 a.m. Depart fro Kg. Bakong
- 11.45 a.m. Examine Pedon 8
- 12.45 p.m. Depart for Gula Padang Terap Plantation
- 1.15 p.m. Lunch break at Gula Padang Terap Plantation Canteen
- 2.30 p.m. Examine Pedon 9
- 3.40 p.m. Examine Pedon 10  
Examine Pedon 11
- 4.40 p.m. Summing up by En. Lim Jit Sai

END OF TOUR

SOME CRITERIA FOR THE SEPARATION OF THE LATERITIC PENEPLAIN SOILS.

Characteristic	Peneplain Level	
	P	P <sub>1</sub>
1. Terrain Class		P
2. Height Above Valleys (Approximate)	C <sub>1</sub> 7-8 m	C <sub>2</sub> -C <sub>3</sub> 4-5 m
3. Gravel Layer		C <sub>2</sub> 1 m
a. Depth		
b. Thickness	All stonelines occur at shallow or moderate depths. Soils with a deep gravel layer are rather exceptions. The moderately deep soils occur at somewhat lower slope position, surrounding the shallow groups. 30-40 cm	40-70 cm (Shallow soils) 20-30 cm (Moderately deep soils) 10-40 cm 35-45
c. Gravel Content % Volume/Volume	30-35	
d. Composition of Gravels	0.2-0.5 cm in diameter Many	0.2 to 0.5 cm in diameter Very few to none 2-3 cm
i. Rounded Laterite Gravels		
ii. Laterised Parent Material		
iii. Manganese Gravels		
4. Horizon Symbol of Gravel Layer	B <sub>2</sub> t B <sub>2</sub> ox	BC (B <sub>2</sub> t)
5. Nature of Horizon Underlying Gravel Layer	2.5YR 5,6 or 5YR 5,6 Clay to heavy clay; no gley; fresh shale fragments.	10YR 8,1 or 8/0 gley colours, common coarse sharp 10R 4,6 or 10R 3,6 clay to silty clay. Material is massive and impervious
6. Nature of Horizon Overlying Gravel Layer	2.5YR, 5YR or 7.5YR clay to heavy	10YR 7,2 Gley, 10YR 6,8, 7.5YR 5,8 and 5YR 5,8 with mottles Sandy clay to clay Loamy to clayey
7. Drainage Class	8	6, 5, 4, 3
8. Other Features	Reccementation of gravels to form larger blocks common. Ferricrete at break of slope.	

PROBABLE GEOMORPHIC PROCESSES FORMING LATERITIC SOILS

Geologic Age	Geomorphic Process	Result
Tertiary	Intensive chemical weathering under tropical conditions.	Reddish coloured ferruginous soils with iron coated materials and formation of plinthite. <i>Soils:</i> Padang Besar, Batu Lapan, Seremban.
Pleistocene	i) Physical weathering and transport or micropedimentation.	Inversion of relief and hardening of plinthite to petroplinthite during erosion and transport forming peneplain (P) <i>Soils:</i> Malacca, Gajah Mati, Tavy and Tandak
	ii) Dissection of petroplinthite 'cap' and either micropedimentation or transport and removal of laterite exposing plinthite 'cap' and either micropedimentation or transport and removal of laterite exposing plinthite and/or pallid zone.	Erosion and transport forming P, geomorphic surface. <i>Soils:</i> Pedu, Terap. <i>In areas where erosion is dominant:</i> Soil formation on pallid and/or plinthite. <i>Soils:</i> Durian, Asahan, Batu Anam, Lokyang
	iii) Further dissection and transport of older geomorphic surfaces.	Erosion and transport forming P, geomorphic surface. <i>Soils:</i> Pokok Sena, Chungloon Further soil formation on plinthite and/or pallid zone. <i>Soils:</i> Durian, Asahan, Batu Anam, Lokyang

