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Soil landscapes in Peninsular Malaysia

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Abstract: Soil surveys have been carried out in Peninsular Malaysia since the latter part of the last century. Soil series have been mainly established in the past based on parent material and geomorphology. Recent studies have shown that parent material and geomorphology play very important roles in soil formation in Peninsular Malaysia.

The paper presents a series of cross-sections of landscapes showing the relationship between parent material, topography, geomorphology and soil type. These studies indicate that in the upland areas of *in situ* soils the parent material, elevation and position in the landscape are the dominant factors influencing soil formation. In the lowlands where alluvial soils dominate, the geomorphic surface and the groundwater table determine the soil type. These different landscapes greatly influence the use of these soils for agriculture.

INTRODUCTION

Soil surveys have long been used as basis for agricultural planning and development in Malaysia. Hence soil surveys have been carried out since the latter part of the nineteenth century in Malaysia. However, systematic soil surveys were only initiated in Peninsular Malaysia towards the middle of the twentieth century. The Soil Survey Division of the Department of Agriculture initiated a systematic reconnaissance soil survey of Peninsular Malaysia in 1955. This survey was completed in 1968. Since the completion of these surveys, semi-detailed soil surveys have been carried out. The different scales of soil surveys and the progress of these surveys in Peninsular Malaysia have been summarised by Paramananthan (1980).

During these early surveys, soil series were established and mapped both at the reconnaissance and semi-detailed scale (Leamy and Panton, 1966). The basis for the establishment of these soil series was the parent material (weathered rock) and geomorphology. Parent material differences were obvious criteria to be used in separating *in situ* soil types developed over weathered rocks. The differences in chemical and mineralogical composition of two widely different rock types are often reflected in the resultant soil types. Thus, for example, the Kuantan Series developed over basalts have clayey textures and brown colours whilst the Rengam Series developed over granites have coarse sandy clay textures and yellowish brown colours. The differences in colours were easily distinguishable and hence used often in establishing soil series. The differences in texture also often reflect the nature of the parent material. Another possible reason for the use of the parent material or geology to establish the soil series was the fact that many of the early soil scientists, both expatriate and local, were geologists.

In the case of alluvial soils, geomorphology and drainage class were often used to distinguish the various soil types. Thus for example, soils developed over riverine alluvia were grouped into three major groups—Older Alluvium, Sub-Recent

Alluvium and Recent Alluvium. It was generally implied that these deposits were different in age and this difference was reflected by the degree of dissection of the landscape. Within each group, soil series were separated based on other properties such as drainage class, texture etc.

While such early attempts to separate soils based on the parent materials and geomorphology were adequate for reconnaissance level mapping, more detailed mapping showed that within the so-called 'soil series', variation was great and a need to redefine and reexamine the criteria to be used in defining soil series was soon evident. Semi-detailed and detailed soil surveys carried out in recent years made it soon evident that the 'soil series' as defined during these early surveys were actually 'soil complexes'. In some cases the use of geology was overemphasised. Hence the distinction between the Prang Series and the Segamat Series was based on whether the rock was schist or andesite. In the field these two soils were often difficult to separate because morphologically and chemically they were identical. In a tropical environment weathering and leaching can be intensive resulting in certain soils from different parent materials appearing to be morphologically or micromorphologically identical.

The objective of this paper is to examine the influence of parent material and geomorphology in determining the soil landscapes found in Peninsular Malaysia.

INFLUENCE OF PARENT MATERIAL AND GEOMORPHOLOGY ON SOIL PROPERTIES

Detailed morphological, chemical, mineralogical and micromorphological studies of a wide range of soils have been carried out over the past few years in an effort to characterize and reclassify the major soils found in Peninsular Malaysia (Paramananthan, 1977; Lim, 1977; Loh, 1981; Zainuri, 1981; Halim, 1980; Noordin, 1980; Wong, 1981; Shamsuddin, 1982). These studies have illustrated the role of the parent material on the soil properties. These studies indicated that the parent material (geology) through its weatherability and chemical composition (particularly iron content) determine many of the soil properties of the soil. Paramananthan (1977), studying soils over a range of igneous rocks, has clearly indicated the influence of the parent material on the texture, colour, clay mineralogy, profile morphology, mineralogy and micromorphology of the soils. These differences are summarised in Table 1 for soils developed basalt, rhyolite and granite. It can be seen from this table that rocks such as basalt with a high proportion of weatherable minerals such as olivine and pyroxene weather readily to give soils which are clayey textured, iron-rich and that have a high proportion of sesquioxides in their clay fraction. On the other hand, acid igneous rocks generally weather to produce soils with less than 50% clay, are lighter coloured and are dominated by kaolinite in their clay fraction. Rhyolite, on the other hand, weathers much slower than granite possibly due to its more compact nature. The difference in grain size of the quartz in the parent materials is also reflected in the soil profiles. The soils with higher iron-content are better structured and hence better drained thereby enhancing leaching losses. It is obvious therefore that with *in situ* soils the parent mineral played a dominant role in determining soil formation and soil characteristics.

In the case of alluvial soils, the degree of dissection and geomorphology were used

TABLE 1

EFFECT OF PARENT MATERIAL ON SOIL PROPERTIES

CHARACTERISTICS OF PARENT MATERIAL			SOIL CHARACTERISTICS							
Type	Mineral Composition	Weatherability	Texture (% clay)	Colour	Diagnostic Horizon	Free Iron %	Cation Exchange Capacity meq/100g clay	Clay mineralogy		
								Kaolinite	Geothite	Gibbsite
Granite	Quartz Feldspar Mica	Moderate	Coarse sandy clay (40)	Yellowish Brown	Argillic	2	8-11	73	3	9
Basalt	Olivine Pyroxene Feldspar	High	Clay (85)	Dark brown	Oxic	13	2-3	57	21	14
Rhyolite	Quartz Feldspar Mica	Low	fine sandy clay (46)	Olive yellow	Argillic	3	8-11	50	Tr (Illite 30)	Tr (Chlorite 10)

to separate three groups of soils. The first group of soils was the so-called riverine alluvial soils. The soils which occurred on the more dissected terrain were termed Older Alluvial Soils (T_3) although in some cases these were not strictly terrace alluvia. The soils on the less dissected alluvial deposits were termed Sub-Recent Alluvial soils (T_2) while the alluvium associated with the present-day streams were referred to as Recent Alluvial Soils (T_1).

In addition to these so-called river terraces, two groups of soils associated with the marine sediments were also identified and mapped. On the east coast where the open seas produced strong waves, sandy soils form a beach ridge and swale complex often just loosely referred to as the 'Bris Complex', were mapped. On the west coast, however the calm seas resulted in clayey deposits which have been drained by the construction of a coastal bund and cultivated. Organic soils occur in depressions which commonly are found between the *in situ* soils, the riverine alluvial soils and the coastal alluvium.

SOIL LANDSCAPE RELATIONSHIPS

Field mapping carried out during semi-detailed soil surveys soon emphasized the fact that the use of parent material alone was inadequate. During the reconnaissance soil surveys soil series or types were established without a proper understanding of the relationships between the various soils. Detailed surveys coupled with detailed profile descriptions and analytical data permitted a better understanding of the relationship between the soils. This paper attempts to synthesize the current knowledge of this relationship between the parent material, topography, geomorphology and soil type. It must be emphasized that the information presented here is only one possible interpretation and other interpretations particularly in respect to geomorphology can be made. More comprehensive data are currently being gathered to make such interpretations more meaningful.

SOIL LANDSCAPES ON GRANITE

Granites form one of the most important rock types in Peninsular Malaysia. This rock type occurs on the gently undulating to hilly and mountainous terrain of the Main Range. The Kuala Lumpur–Genting Highlands and the Tapah–Cameron Highlands roads provide an excellent access to areas with steep slopes and high altitudes on such parent materials. Paramananthan (1977) studied a number of soils from such areas and concluded that the high altitude and its consequent climatic characteristics dominate the soil types that occur on such areas. These findings are summarised in figure 1. In areas above 300 metres on the Main Range there is a perudic moisture regime (Soil Survey Staff, 1975) i.e. there is an excess of rainfall over evapotranspiration in all months of most years. This perudic moisture regime coupled with the low mean annual temperatures (isomesic temperature regime) of less than 18°C results in a very slow breakdown of the organic matter leading to the formation of highland peats. However, the excess rainfall coupled with the leaching of the organic acids results in the formation of spodic and placic horizons. A soil is considered to be an organic soil in Malaysia if the thickness of the organic soil layers taken cummulatively to a depth of 100 cm constitutes more than 50 cm in thickness (Paramananthan *et al.*, 1984). Thus soils such as the Brinchang Series is an organic soil. Such soils commonly occur at

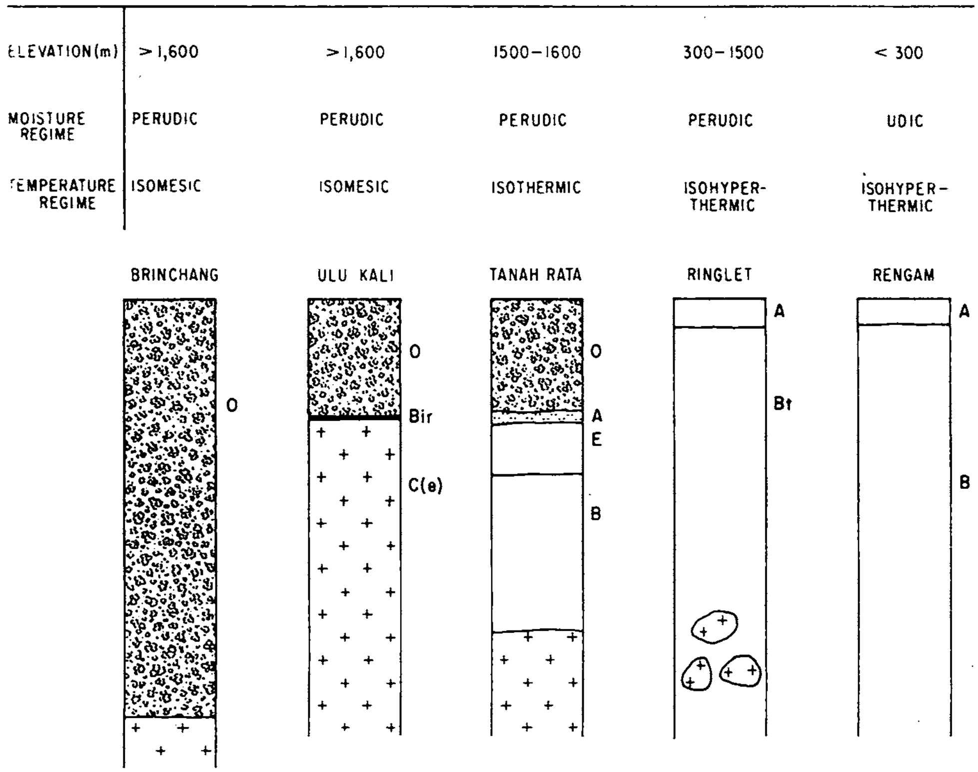


Fig. 1. Soil landscape in the Cameron Highlands (granite-high altitude).

altitudes of 1,600 m or more. At slightly lower altitudes the temperatures are somewhat warmer and the organic matter decomposes somewhat resulting in a mineral soil such as the Ulu Kali and Tanah Rata Series. However a study of the mineralogy of these soils and their weathered parent materials indicate the presence of gibbsite in large quantities. This is attributed to the intensive weathering by the organic acids transforming minerals such as feldspar to gibbsite.

At altitudes below 1,500 m the surface organic layer completely disappears due to the increased breakdown of the organic matter at the higher ambient temperatures. However, the decomposed organic matter (humus) is leached into the soil profile resulting in the soil having a high humus content in the subsoil. Often the weathering granite is also encountered at depths within 1.5 m of the soil surface. At lower altitudes where the mean annual temperature is higher than 22°C (isohyperthermic) and the moisture regime is udic the soils are much deeper with the solum commonly being more than 3 metres deep. Locally however, as in Pulau Langkawi (Figure 2) where the slopes are steep shallower soils are encountered. The main properties of the soils, climatic factors and classification of the soils over granite are summarised in Table 2.

TABLE 2

SOILS DEVELOPED OVER GRANITIC PARENT MATERIALS

Altitude in metres	Climatic regime		Natural Vegetation Type	Soil characteristics		
	Temperature	Moisture		Soil Series	Soil Forming process	Classification
1,500–1,600	Isomestic	Perudic	Montane	Ulu Kali	Paludization Podzolisation	Lithic Placaquod
> 1600	Isomesic	Perudic	Montane	Brinchang	Paludization	Troposaprist
1,500–1,600	Isothermic	Perudic	Oak Laurel	Tanah Rata	Paludization Podzolisation	Ultic Tropaquod
300–1,500	Isohyper-thermic	Perudic	Hill Dipterocarp	Ringlet	Illuviation	Orthoxic: Tropohumult
< 300 (steep)	Isohyper-thermic	Udic	Lowland Dipterocarp	Bt. Temiang	Illuviation	Orthoxic Tropudult
< 300 (gentle)	Isohyper-thermic	Udic	Lowland Dipterocarp	Rengam	Illuviation	Typic Paleudult

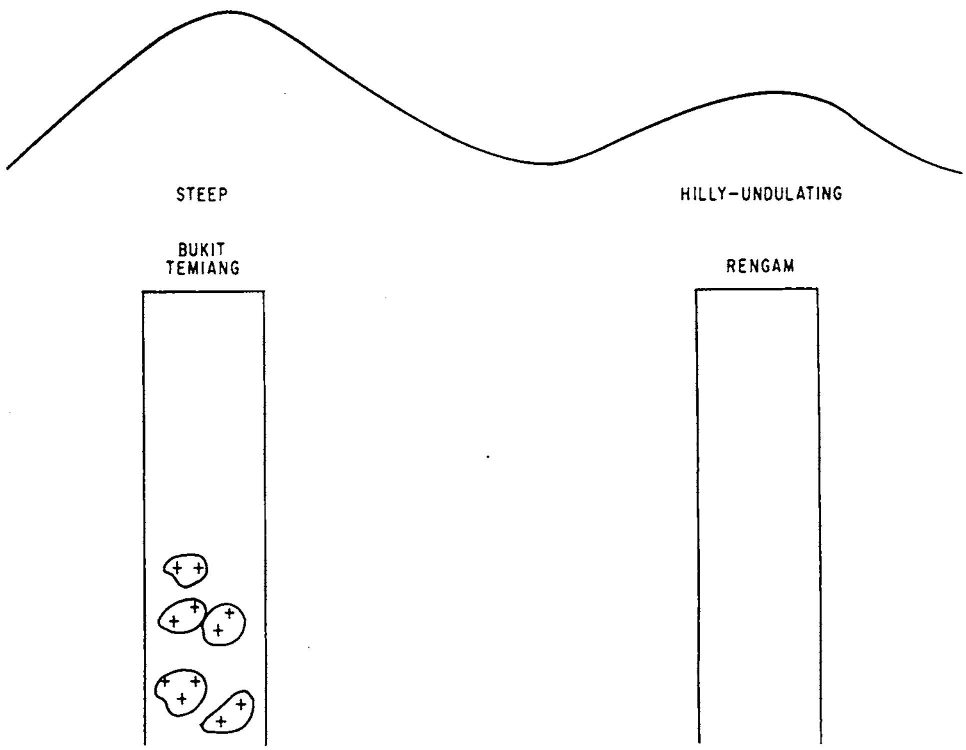


Fig. 2. Soil landscape in Gunong Raya, Langkawi (granite-low altitude).

SOIL LANDSCAPES ON SEDIMENTARY ROCKS

A large variety of sedimentary rocks occur in Peninsular Malaysia. These include limestones, sandstones and shales. Most of these rocks however have undergone at least a low grade of metamorphism. These rocks range in geologic age from Cambrian to Cretaceous. As in the case with soils developed over igneous rocks, the nature of these rocks and their chemical composition-iron content in particular appear to be the dominant factors which influence the genesis of soils on these rocks. The nature of the resultant soil type eg. whether sandstones or shales determines the texture of the resultant soil type. On the other hand the iron-content of the rock type to a large extent determines the rate of soil formation and other soil properties such as structure, colour, drainage class and mineralogy. The geomorphic position of the soil in the landscape often determines the depth of the soil and therefore its agricultural potential.

The influence of the parent material on the morphological, chemical and mineralogical properties of soils developed over sedimentary rocks is summarised in Tables 3 and 4. From these tables it is clear that the nature and chemical composition of the sedimentary rocks determined many of the soil properties. This is to be expected since under a tropical environment weathering and leaching are intense resulting in

TABLE 3

MORPHOLOGICAL PROPERTIES OF SOME SOILS DEVELOPED OVER SEDIMENTARY ROCKS

Parent Material	Example of Soil Series	Soil Characteristic					
		Texture	Colour	Structure	Consistence	Drainage Class	Diagnostic Horizon
Sandstone	Serdang	fine sandy clay loam	brownish yellow	weak medium subangular blocky	friable	well	argillic
Iron-rich Shale/schist	Prang	clay (pseudosands)	red	very weak medium subangular blocky	very friable	well to excessive	oxic
Iron-poor Shale/schist	Batu Anam	silty clay	light gray	strong coarse prisms	firm to very firm	imperfect to poor	argillic, cambic
Mixed sand-stone/shales	Bungor	fine sandy clay	strong brown	moderate, medium subangular blocky	friable to firm	well	argillic
Limestone	Langkawi	clay	red	weak medium subangular blocky	friable	well	argillic, oxic
Carbonaceous Shale	Kemuning	fine sandy clay-silty clay	Olive	moderate medium subangular blocky	friable to firm	moderately well	argillic

TABLE 4

CHEMICAL AND MINERALOGICAL PROPERTIES OF SOME SOILS DEVELOPED OVER SEDIMENTARY ROCKS

Parent Material	Example of Soil Series	Chemical			Mineralogy		
		Free Fe_2O_3	Cation Exchange Capacity meq/(100g soil)	Base Saturation	Geothite	Kaolinite	Others
Sandstone	Serdang	2–3%	3–6	15%	Tr	xxxx	—
Iron-rich shale/schist	Prang	13–18%	3–6	2–5%	xx	xxx	
Iron-poor shale/schist	Batu Anam	1%	6–8	5–10%	—	xxx	xx Mica
Mixed sand-stones/shales	Bungor	2–3%	2–4	5–10%	Tr	xxx	
Limestone	Langkawi	3–6%	3–6	15–45	xx	xx	—
Carbonaceous Shales	Kemuning	1–2%	4–6	5–10	—	xx	xx Mica Vermiculite

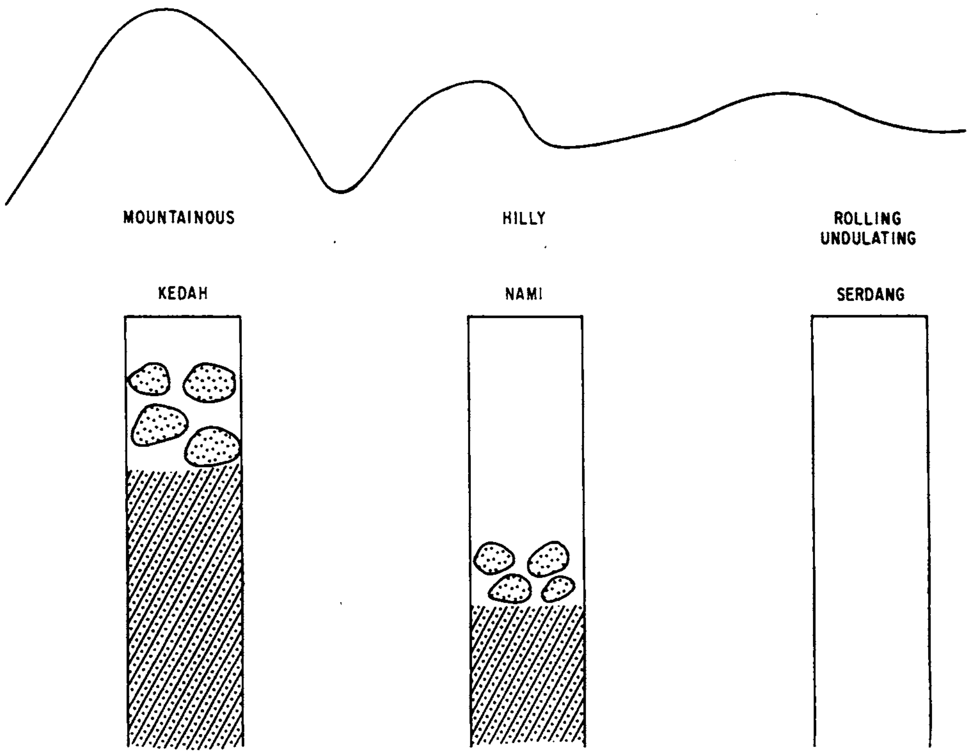


Fig. 3. Soil landscape in the Nami area, Kedah (sandstones).

many soils moving quickly into the intermediate or advanced stage of soil formation. Even the soils such as the Batu Anam Series which are less weathered as indicated by their silty clay textures, has a low cation exchange capacity and low base saturation. The intensity of weathering of the rock depends largely on its iron-content. Rocks with high iron content weather more readily, resulting in soils which have low silt content and which are rich in oxides of iron and aluminium. These soils have an oxic horizon and often the clay particles may be aggregated to form pseudo-sands and pseudo-silts. Iron-poor parent materials weather much slower and soils over such rocks tend to have high silt/clay ratio, some micas and vermiculite in their clay and silt fractions, and have coarse angular blocky or prismatic structures.

The position in the landscape and the types of slopes on which the soil is situated determines to a large extent the depth of the soil. The influence of the landscape on the different sedimentary parent materials is illustrated in figures 3–5. The slope of the land determines the depth of the soil in most cases. On the steep mountainous topography soil erosion often exceeds weathering and soil formation resulting in shallow soils while on the gentler slopes and on foot of hills weathering exceeds soil erosion resulting in deeper soils. Such a relationship has been observed extensively in Peninsular Malaysia

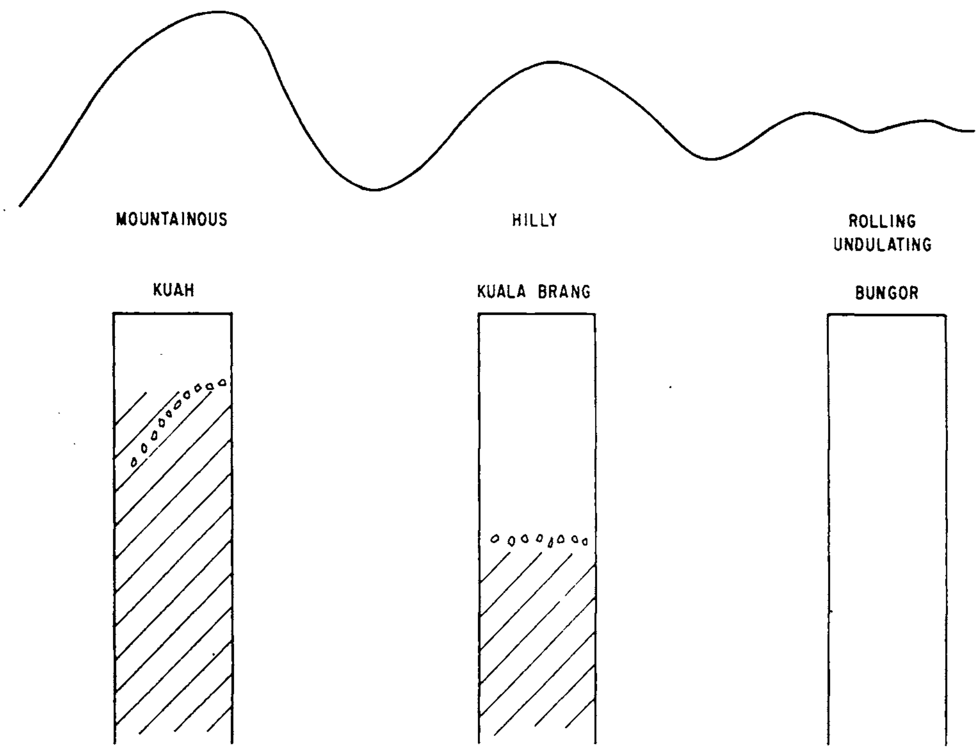


Fig. 4. Soil landscape in the Kemaman area, Terengganu (iron-poor sandy shales).

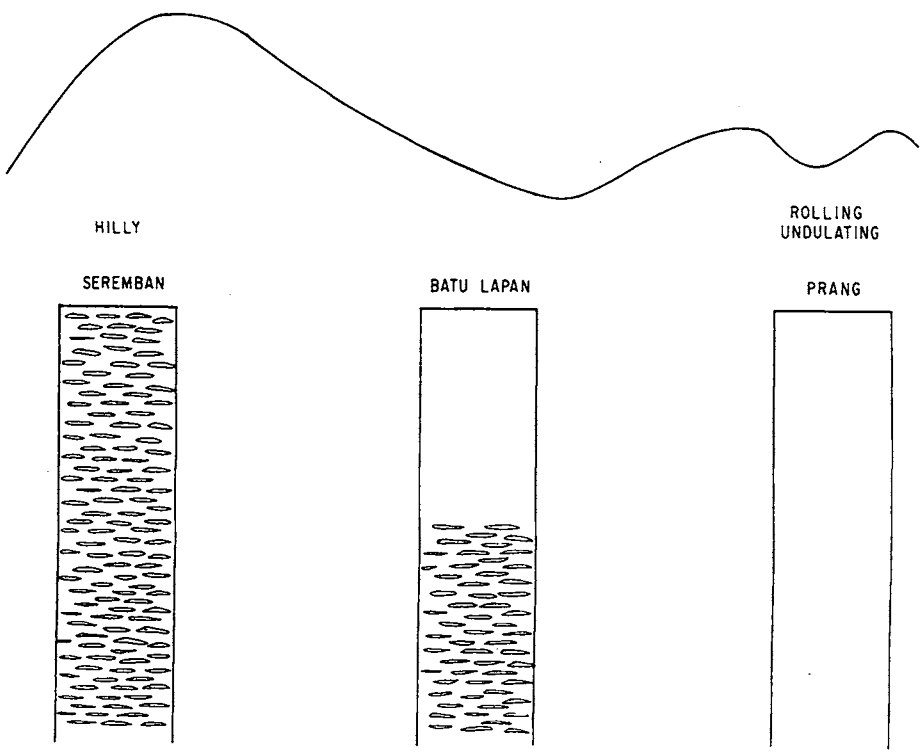


Fig. 5. Soil landscape in the Seremban area (ferruginous shales/schists).

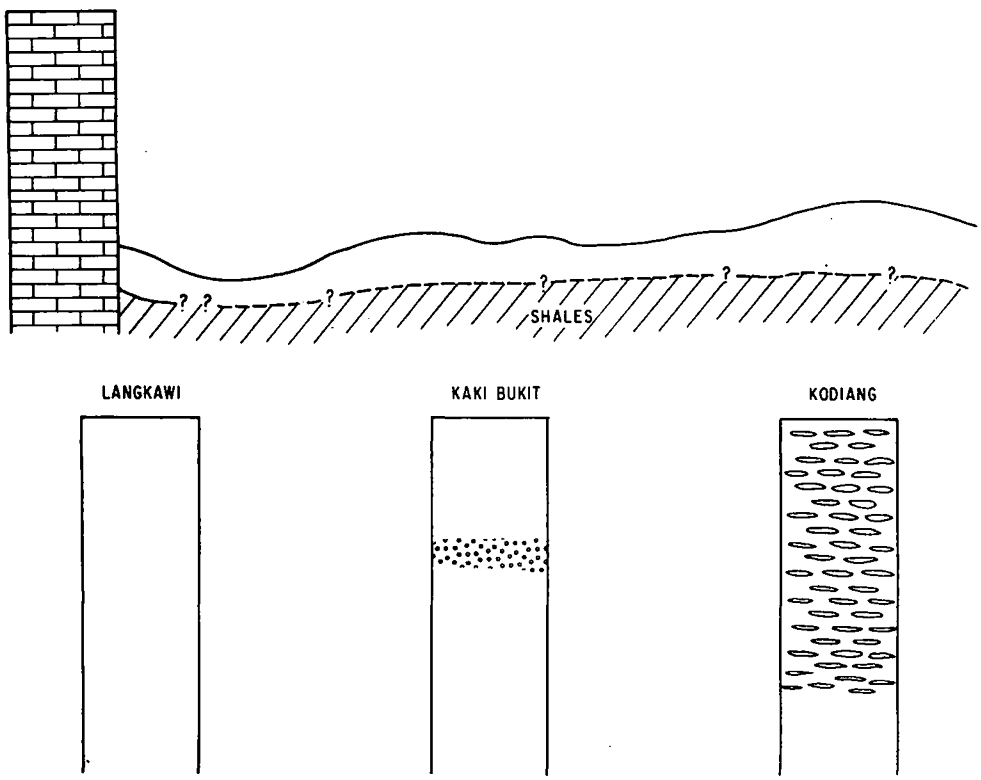


Fig. 6. Soil landscape in the Kodiang area (limestone and shales).

on sandstones and shales. In the case of ferruginous shales or schists weathering releases the iron which then coats the shale fragments. This results in soils having platy iron-coated fragments (figure 5). Consequent erosion results in inversion of relief resulting in the iron-coated materials occuring at the tops of hills. On the middle and lower slopes these iron-coated materials are often overlain by a thin or thick soil cover which was probably transported by soil creep or pedimentation to the lower slopes.

Limestone in Peninsular Malaysia forms the typical tower karst topography. Between the limestone hills, level or gently undulating terrain may occur depending on whether sedimentary rocks or alluvium is present. Reddish clay textured soil which has developed over limestone occur as a very narrow belt adjacent to these limestone hills. Further away from the hills the influence of the shale is more important and the soils such as the Kaki Bukit and Kodiang Series occur. However, these soils tend to have manganese concretions in their profile—a feature probably inherited from the limestone parent material. In areas such as Gua Musang where the limestone is continuous between the hills but alluvium has filled the valleys (figure 7), soils such as the Terah and Merapoh are found. Here again, manganese concretions may occur in these soils.

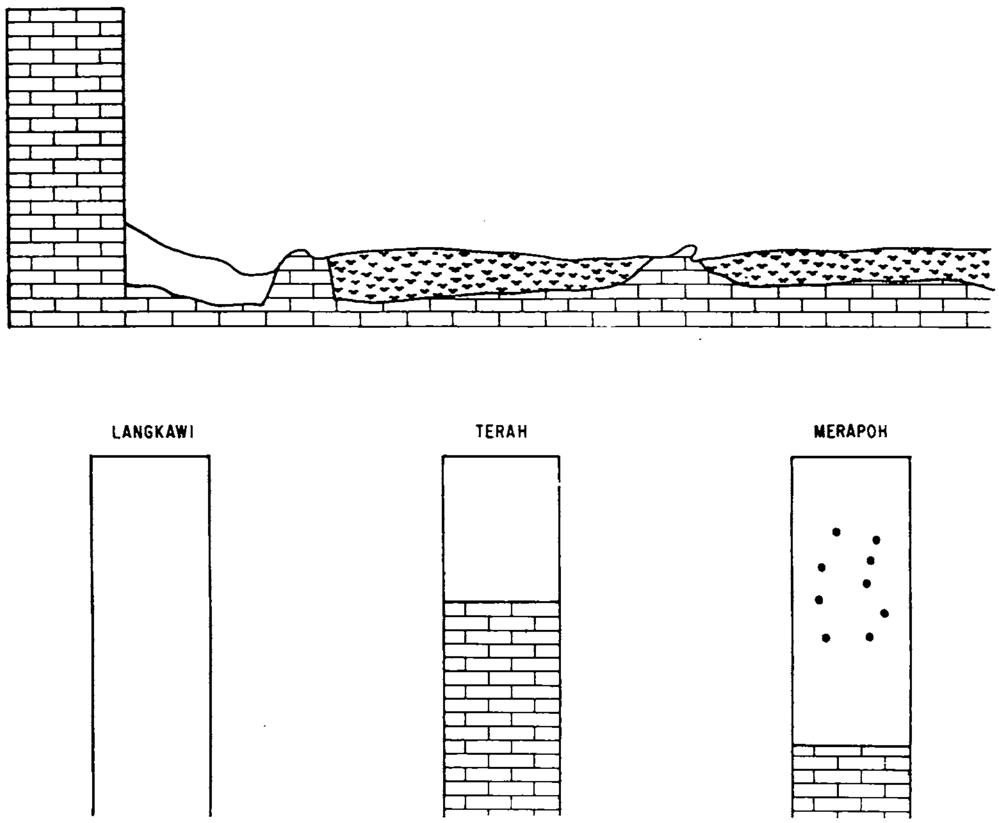


Fig. 7. Soil landscape in the Gua Musang area (limestone and alluvium).

Soils which have lateritic or petroplinthite gravels occur extensively in Peninsular Malaysia. The genesis these soils has been discussed by Paramananthan and Tharmarajan (1983). Contrary to earlier ideas it is now believed that most of these lateritic soils have been transported or they are reworked deposits. The reworking has been by soil creep or pedimentation processes. Paramananthan and Lim (1978) recognized three levels of peneplains with these lateritic soils. During each reworking the lateritic gravels become smaller, more dense and are better rounded (figure 8). These gravels are often pedimented over weathered shale saprolite. In some areas where dissection of the lateritic peneplain has exposed the underlying saprolite new soils have formed over them. Where only the plinthite or variegated material is exposed, soils such as the Durian Series with about 2–4% free iron are formed while where the dissection exposes the underlying pallid zone, pale coloured soils such as the Batu Anam Series are formed (figure 9). The high silt/clay ratios and the presence of illite and vermiculite in these soils supports the fact that these soils are only in their intermediate stage of weathering compared to the lateritic soils of the Malacca Series which occurs as cappings on the peneplains.

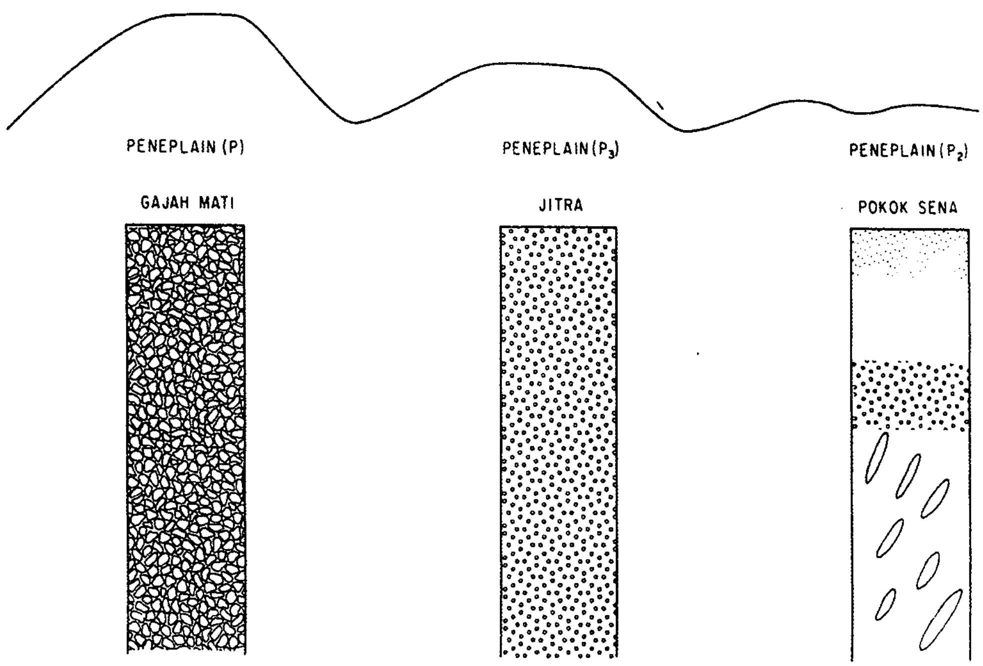


Fig. 8. Soil landscape in the Padang Terap area, Kedah (reworked lateritic gravels).

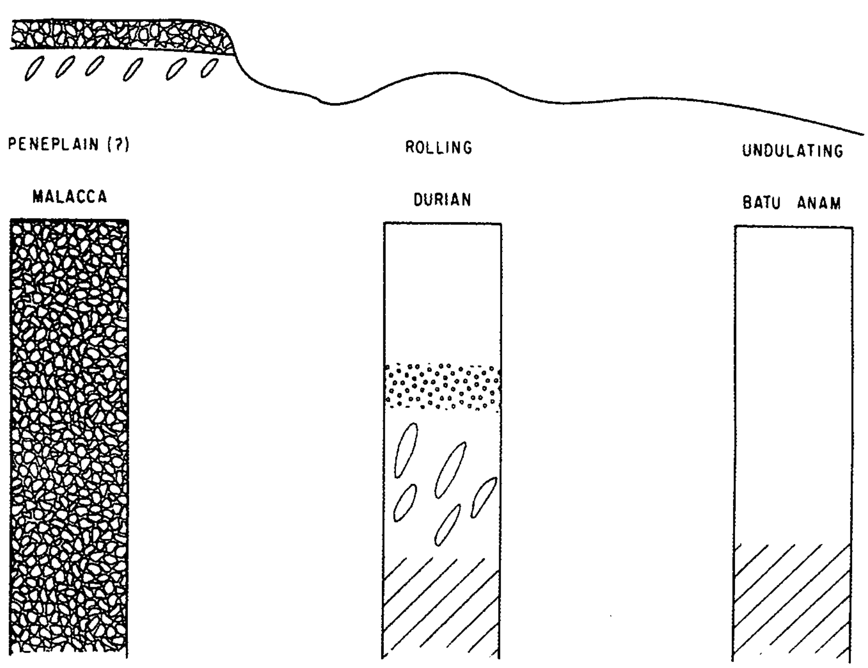


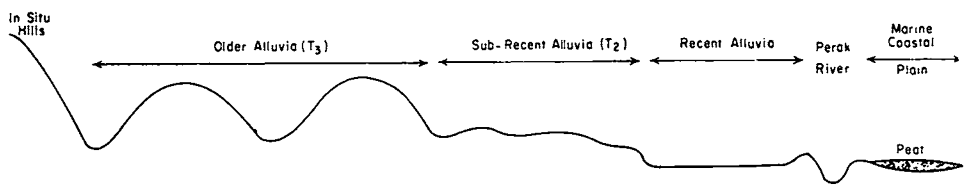
Fig. 9. Soil landscape in the Gemas area (iron-poor shales).

ALLUVIAL SOIL LANDSCAPES

Alluvial soils occur extensively both along the east and west coast of Peninsular Malaysia. In Peninsular Malaysia, two broad groups of alluvial deposits have been identified viz. riverine and related deposits and the marine, estuarine and brackish water deposits. The riverine deposits which include colluvial and hill wash sediments are further sub-divided into three groups known as the Older Alluvia, Sub-Recent Alluvia and Recent Alluvia (figure 10). The criteria used to separate these three groups is geomorphology. It is also generally implied that there is an age difference between these deposits. The difference between these deposits and their general relationship in the landscape is summarised in figure 10.

The Older Alluvia are mainly alluvial fan and wash deposits. They tend to form low hills adjacent to the *in situ* soils. Areas with such soils have a rolling terrain and are well drained. Occasionally, few petroplinthite gravels may be present in the soils. These soils are in the intermediate to advanced stage of soil formation. Mineralogy in these alluvial soils cannot be used as a criteria to determine the weathering stage as the minerals may have been transported in their weathered state.

Soils on the Sub-Recent Alluvia generally tend to occur on gently undulating to level terrain which has a relief amplitude of less than 5 metres. These soils have a range in texture and drainage class. A characteristic feature of soils on these deposits is the fluctuation in groundwater table. During the rainy seasons these soils may be flooded but in the dry season they are dry with watertables below one metre. This fluctuation in watertable encourages the formation of plinthite. Soils on this landscape have a low silt/clay ratio and little or no weatherable minerals. It appears that these soils were probably formed by a much earlier river system as a levee and floodplain deposit but has been subsequently dissected by the present-day river system.



CHARACTERISTIC	OLDER ALLUVIA	SUB-RECENT ALLUVIA	RECENT ALLUVIA
TERRAIN	Rolling	Undulating to level	Level to depressional
RELIEF AMPLITUDE	5 – 15m	2 – 5m	< 2m
WATER-TABLE	> 2m	0.5 – 2 m	< 1 m
DRAINAGE CLASS	Well	Poor to well	Very poor to well
SOIL FORMATION STAGE	Argillic – Oxic	Argillic – Cambic	Cambic – Argillic
SPECIAL FEATURES	Fe-gravels Low silt/clay ratio No weatherable minerals	Soft Plinthite Low silt/clay ratio No weatherable minerials	Mn Concretions High silt/clay ratio Micas abundant

Fig. 10. Soil landscape across coastal plain, Perak.

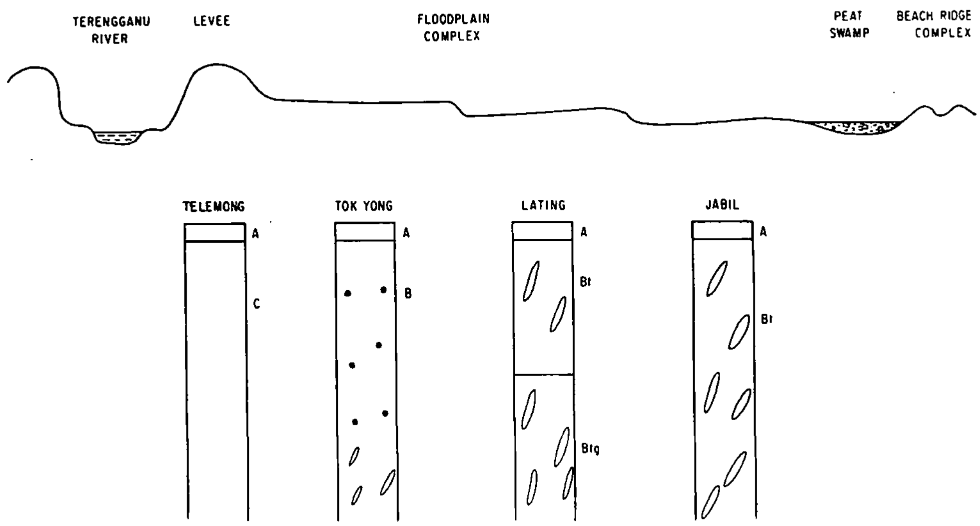


Fig. 11. Soil landscape in the Terengganu plain.

Recent alluvial deposits occur along the banks of most of the larger present-day rivers. These soils form a sequence from the levee to the floodplain. These soils are characterized by level landscapes with a relief of less than 2 metres. Watertables are high throughout the year. The soils are characterized by high silt/clay ratios, the presence of manganese concretions and mica flakes. Drainage in these soils is somewhat excessive on the levees and this grades to very poor in the backswamps. The textures range from sandy loams and sandy clay loams on the levee to clays and heavy clays in the backswamps. Since the watertable fluctuates with position in the landscape the drainage class is used to define the various soil types on this landscape. Some of the important soils mapped are illustrated in figure 11. This recent alluvial plain often grades into peat swamps and then on to the marine coastal plain nearer the coast.

Along the coastal plain, marine, estuarine and brackish water deposits occur in Peninsular Malaysia. The nature of the deposits and the landscape on the west coast differs from that on the east coast. On the west coast, thhe presence of Sumatra off the coast results in calm seas and consequently clayey material are deposited. On the other hand the open sea off the east coast results in strong waves and hence a series of beach ridges occur.

On the coastal plain of the west coast (figure 12) water tables are high and these areas can only be used after the areas are drained and a coastal bund built to prevent inundation by sea water. Two major types of deposits occur on this coastal plain. Near the coast where mainly marine sediments occur these are relatively low in organic matter and consequently the soils are gray to light gray in colour, structures are angular blocky to prismatic and the consistence is sticky. In addition to this some areas also tend to develop acid sulfate conditions through the oxidation of the pyrite in these soils to jarosite. The depth of the underlying marine clay also varies with the intensity

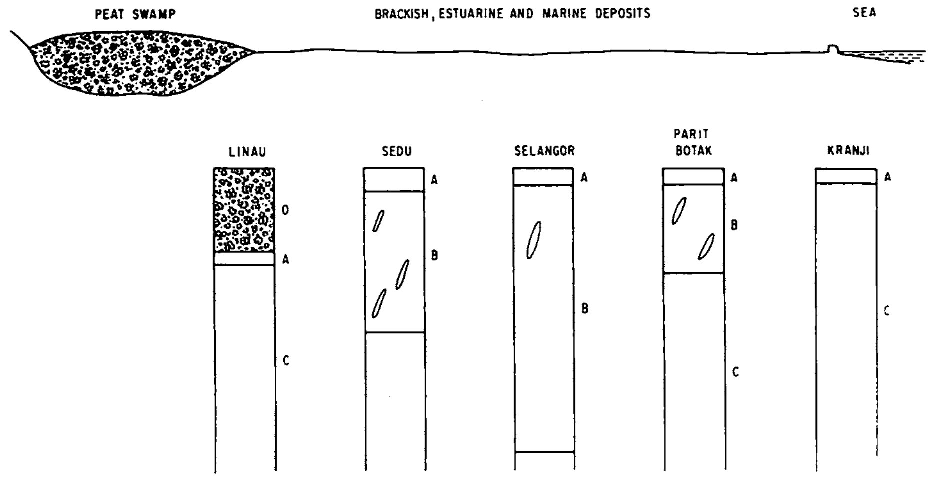


Fig. 12. Soil landscape in the Parit Botak area, Johore.

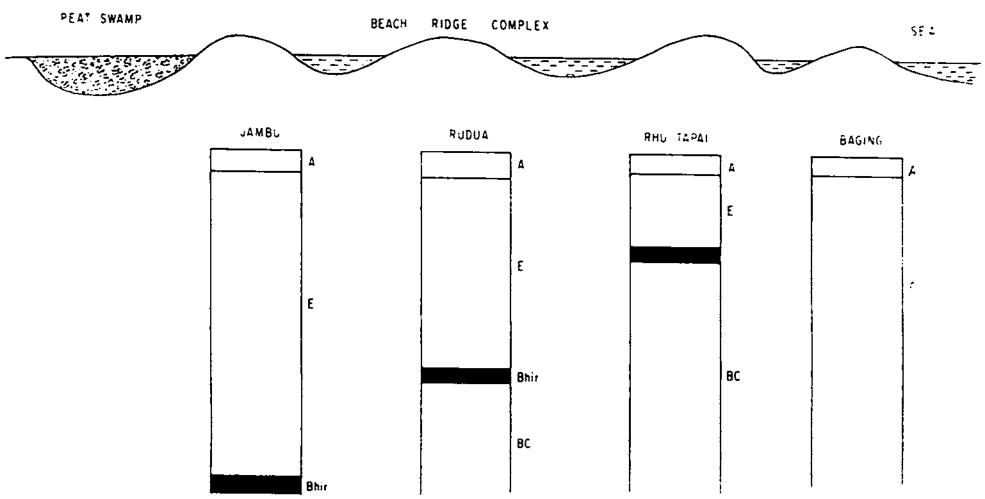


Fig. 13. Soil landscape in the Besut area, Terengganu.

of drainage and the distance from the sea. Near the peat swamps further inland, brackish water deposits rich in organic matter are common. On drainage the organic matter decomposes and the soils have a brown colour, are fine structured and are more friable. Again acid sulfate conditions may be present and the depth of the marine clay varies depending on the intensity of the drainage.

On the east coast, a series of beach ridges with its interwining swales occur (figure 13). The ridges are made up of sands while the swales are extremely variable. These ridges grade further inland into peat swamps. The swales are underwater throughout the year while the ridges suffer from moisture stress due to their high porosity. Leaching of humus, iron and aluminium from the surface horizons forming a bleached or albic horizon (Soil Survey Staff, 1975) and the deposition of these materials near the watertable through a process of podzolization is the major soil forming process on these ridges. Depending on the position of the ridge the spodic horizon (Soil Survey Staff, 1975) occurs at different depths. Since the spodic horizon coincides with the depth of the watertable it determines largely the use of the soils. Soils which have the spodic horizon within 50 cm are mainly used for tobacco cultivation while where the spodic horizon occurs between 50 to 100 cm the soils are used for cashew nut cultivation. When the spodic horizon is more than 100 cm from the surface the albic horizon is thick, then these soils give poor yields but the bleached sand of the albic horizon can be mined for glass manufacture.

CONCLUSION

Recent studies of the soils and soil landscapes in Peninsular Malaysia have shown that the the nature of the parent material determines to a large extent many of the important properties of the soil developed from it. The soil texture, colour, structure, consistence and soil formation stage are largely dependent on the nature of the parent material. At high altitudes however, the low temperatures are more important. At the low elevations the steepness of the slope and position of the slope are important factors which determine the soil properties particularly soil depth.

This relationship between the soil properties and the landscape characteristics determines largely the use of these soils for agriculture. A clearer understanding of such relationships can be used to help in field mapping and land evaluation.

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