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Physiographic Implications of Laterite in West Malaysia

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Abstract: A map of laterite-bearing soil associations is presented which illustrates the widespread but fragmentary location of laterite in the lowland areas of Malaya and the tendency for it to be most widespread in areas with relatively dry climates and argillaceous rocks.

Laterite commonly occurs in four positions in the landscape: flat alluvial land, foot slopes, gently undulating country, and hill summits. Laterites of two small sample areas are demonstrated, by measurement of soil properties (shear strength, infiltration capacity, percentage clay and aggregate stability) to be very resistant to erosion. This resistance has led to relief inversion with fossilization of laterite as summit caps in several parts of Malaya. The possibility of using these summit formations as marker levels in studies of denudation chronology is briefly discussed.

INTRODUCTION

A variety of definitions of laterite have appeared in scientific literature since Buchanan coined the term in 1807. One of the most comprehensive is that if Sivarajasingham, *et al.* (1962, p. 5) who define laterite as 'highly weathered material: (1) rich in secondary forms of iron, aluminium or both, (2) poor in humus, (3) depleted of bases and combined silica, (4) with or without non-diagnostic substances such as quartz, limited amounts of weatherable primary minerals or silicate clays, and (5) either hard or subject to hardening upon exposure to alternate wetting and drying'. Panton (1956, p. 419) gives a simple working definition of laterite, appropriate to Malayan field conditions, as including 'any iron rich mass which is normally harder than the surrounding soil, occurring in the soil profile where it appears to have resulted from the action of various tropical soil forming processes.'

DISTRIBUTION

Fig. 1 shows the location in West Malaysia of the main soil associations whose component series contain laterite. In aggregate these cover 5.9% of the surface area of the peninsula (Law & Selvadurai, 1968). A number of features are apparent from the map.

(1) The widespread distribution, Perak and Trengganu being the only major states without any mapped occurrences. Perhaps significantly, Perak contains relatively little rock of an argillaceous character and Trengganu is the state with the highest rainfall in Malaya.

(2) The often fragmentary nature of the distribution pattern, particularly in Southeast Pahang. This is often even more pronounced than depicted on the map;

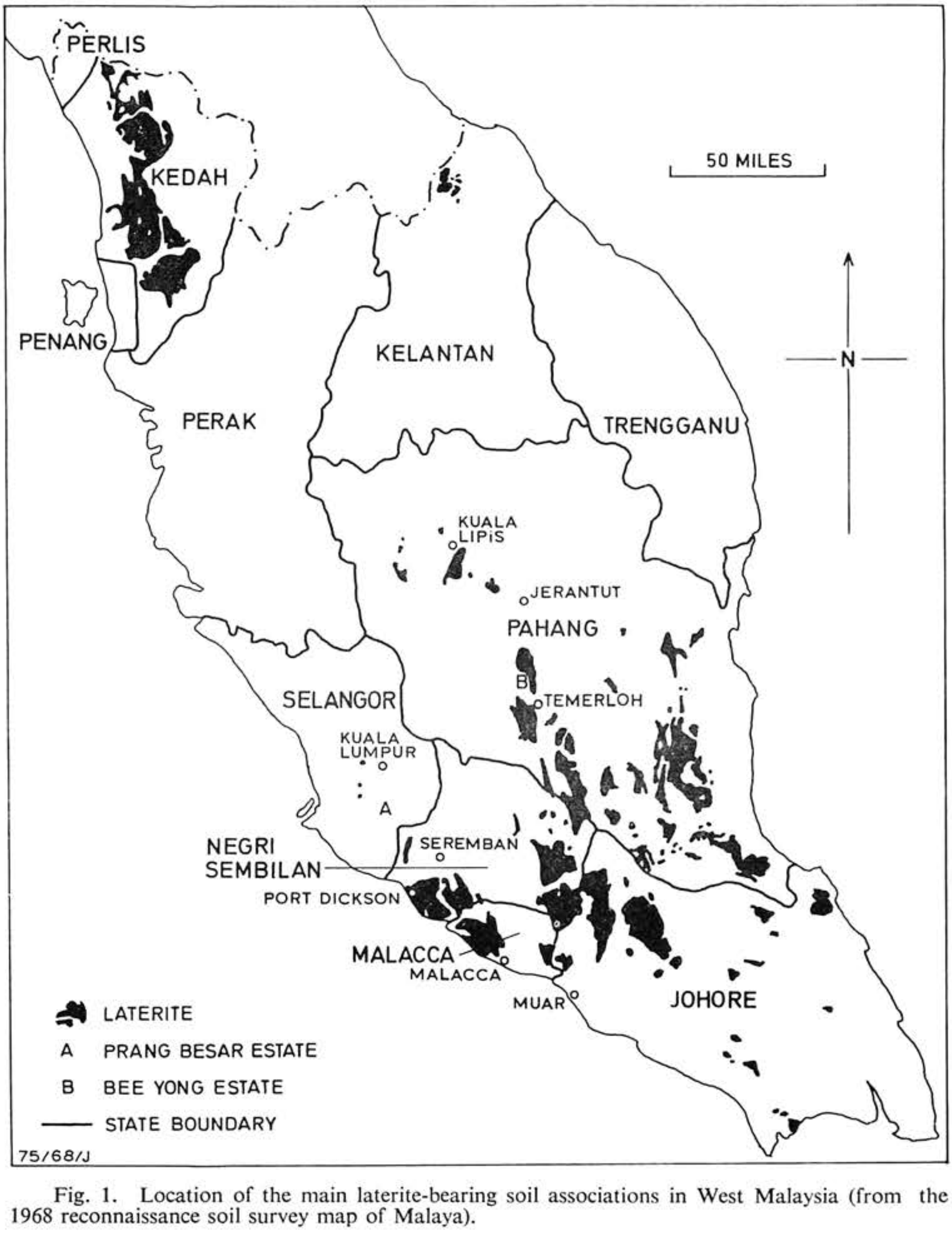

Fig. 1. Location of the main laterite-bearing soil associations in West Malaysia (from the 1968 reconnaissance soil survey map of Malaya).

for example, Dumanski and Ooi (1966, p. 29), speaking of the Temerloh–Gemas area, state that the Malacca Series soil (essentially laterite) 'occurs in association with all soils mapped in the region, although in most cases the sum total of the exposures constitutes less than 20% of any individual area.' Also, laterite is widely distributed in Selangor, but is in the form of small, discontinuous summit remnants which cannot be mapped at reconnaissance scale.

(3) The entirely lowland location: This may imply that high temperatures are necessary for laterite formation but is probably mostly because steep upland areas are mainly granitic and the high intensity of erosion makes it unlikely for there ever to be sufficient time for laterite to form.

(4) The largest areas of laterite (Kedah, the Port Dickson–Malacca coast and the Muar–Temerloh strip) are located in the portions of the peninsula with the smallest annual rainfall and/or the greatest susceptibility to dry periods (Dale, 1959, 1960; Wycherley, 1967).

(5) Reference to a geological map would show a tendency for laterites to develop on shale bedrock rather than on granite or arenaceous sedimentary rocks. This is probably because of the relatively low permeability and high natural iron content of shale.

Laterite can occupy four physiographic positions in the Malayan landscape (the first three are mentioned by Panton, 1956).

(i) flat alluvial land
(ii) the foot of slopes close to the boundary between dry land soils and alluvial soils
(iii) gently undulating country
(iv) summit caps on hills.

The sites are listed in an order which corresponds to a rough sequence of morphological development of the representative laterites. Flat alluvial land gives rise to widespread occurrences of soils which can be classed as rather imperfectly developed ground-water laterites (Panton, 1956). An example is the Briah Series developed over fine textured riverine deposits in Selangor. 'The top soil horizon generally varies from 2 to 6 inches... The second horizon of light brownish grey or light grey clay contains abundant strong brown and yellowish brown mottles... which tend to dominate the soil colour to a depth of 24″. ...The mottled horizon is under-lain by grey to light grey clay' (Acton, 1966, p. 463).

There is wide variation in the morphology of laterites formed in footslope positions and over gently undulating country in response to variations in the structure, permeability and age of the soil, and the availability of iron. The range is from loose pisolitic concretions in the Pokok Sena Series (Joseph, 1965), through a dense layer of pisolitic nodules which increase in abundance and compaction with depth in the Gajah Mati Series (Law and Selvadurai, 1968), and a massive horizon of laterite in one phase of the Chungloon Series (Joseph, 1965), to laterite of the classical Buchanan type which exists as a spongy mass over, particularly, phyllites in Malacca and which hardens on exposure sufficiently to allow blocks to be used for building purposes (Scrivenor, 1927).

Laterites capping hill summits are the most highly developed of Malayan laterites and are mostly classified as Malacca Series which is described by Law and Selvadurai (1968, p. 7) in the following terms: 'Laterite boulders may litter the surface, but more commonly the laterite which occurs in the form of well rounded nodules in the top portion rapidly increases in size and becomes very irregularly shaped at depth. Laterite boulders of varying sizes may be scattered throughout the profile.'

PHYSICAL PROPERTIES

The remainder of this paper is concerned with the physical properties of summit laterites, particularly those occurring in two small sample areas: Bee Yong Estate, 10 miles northwest of Temerloh, and Prang Besar Estate, 14 miles south of Kuala Lumpur (fig. 1). Results of field surveys of Bee Yong Estate conducted by the author and students from the University of Malaya have been reported elsewhere (Eyles, 1967) and will not be repeated here in detail. The portion of Bee Yong Estate studied contained a catenary (ridge-crest to valley floor) sequence of soils with Malacca Series soils outcropping at the surface of conical hill summits, Durian Series soils on the lower slopes and Batu Anam soils occupying the alluvial valley bottoms. Measurements of shear strength and infiltration capacity were made with a shear vane and a home-made infiltrometer at a series of points in the three soils.

Table 1. Average Values of Shear Strength and Infiltration Capacity, Bee Yong Estate

Soil Series	Shear Strength (lbs/sq. inch)	Infiltration Capacity (inch/hour)	No. of determinations
Batu Anam	20.8	0.48	5
Durian	15.5	1.71	6
Malacca	41.2	5.78	15

Table 1 shows the high average values for the Malacca Series. Infiltration capacities are such that surface runoff will seldom, if ever, occur and the high values of shear strength mean that Malacca soils are not subject to slumping. The summit laterite formations are therefore extremely resistant to erosion and are capable of persisting in the landscape for long periods of time.

The pattern of soils and topography in Prang Besar Estate is complex. 'The area is predominantly shales and quartzites... but the pattern of rock and consequently of the overlying soil has been complicated by the intrusion of amphibolite (or similar basic igneous rock) and the alteration by heat and pressure of the country rock adjacent to this intrusion... Topography varies from gently to steeply undulating' (Shearing, 1962, p. 2 & 6). The soil on 44 of the 100 summits included in the random field survey contained laterite nodules or fragments of varying sizes. In general, the higher summits were found to be capped with more massive laterites. Some of the laterite observed in the estate occupied footslope positions, but most of it was in the form of summit residuals. It was estimated that soils containing laterite within the top 30 inches of the profile occupied 7% of the estate area. The survey was designed to study the relationship between valley-side morphometry and properties of the soil. The range of variables measured can be seen in Table 2.

Aggregate stability was defined as the percentage by weight of an initial sample of a given size range which remained on a sieve after exposure to running water under controlled conditions. Laboratory procedure followed closely the method of Keraitis and Ferguson (1957). The values of shear strength and infiltration capacity

Table 2. Mean Values of morphometric and soil properties for summits with and without laterite in Prang Besar Estate, Selangor.

Property	Mean Valve for Summits	
	Containing laterite (44 summits)	Without laterite (56 summits)
Altitude (ft)	200	153.5
Radius of curvature (ft)	415	609
Steepest slope of valley side profile (degrees)	20.8	15.3
Clay (%)	38.3	48.2
Shear strength (lbs/sq. inch)	22.6	13.7
Infiltration capacity (inch/hour)	82.9	55.4
Aggregate stability (%)	70.6	56.7

in Table 2 cannot be compared with those in Table 1. To eliminate the effect of changes in soil moisture content with time and with soil type, shear strength readings in Prang Besar Estate were taken under saturated conditions. Again, to eliminate the influence of the surface organic horizon, infiltration capacity readings were taken in the subsoil. A very much smaller cylinder was also used to conserve water and the consequent greater disturbance of the soil within the cylinder as it was inserted partly explains the excessively high values in Table 2. While these in no way approximate to actual infiltration capacities they can be used for comparisons within the estate.

The percentage of clay was thought to give a gross indication of the susceptibility of the soil to processes of creep, aggregate stability to be a measure of the cohesion of soil particles under conditions approximating to ground-water movement, infiltration capacity to be inversely proportional to surface runoff, and shear strength to measure susceptibility of the soil to slumping. Taken together, the four properties were assumed to provide an overall measure of the resistance of the soil to erosion.

The differences between mean values of the soil properties for summits with and without laterite are all judged to be significant at the 5% level by a 'Student's t' test (Brookes and Dick, 1960, p. 216). The presence of laterite on summits in Prang Besar Estate is therefore associated with high summit altitudes, low radii of curvature and high values of steepest slope and with soils having low clay percentages, high shear strength, high infiltration capacity and high aggregate stability. The relationship is stronger than mere association as these pedological and morphometric properties are in large measure caused by the summit laterites. Thus, for example, areas which in the absence of laterite would probably consist of low convex hills developed on the clay-rich Munchong and Prang Besar Series soils are in fact composed of steep high hills capped by resistant surficial laterite.

DISCUSSION

It is clear, then, that laterite, as it develops from a zone of mottling through the formation of concretions, induration into nodules, and cementation into more massive aggregates, acquires properties of increasing resistance to erosion. This is to be expected as laterite is itself a product of the process of tropical weathering and erosion. Summit laterite residuals possess many of the properties of gravel which, as long ago as 1911, Rich demonstrated to be very resistant to most forms of erosion. The change in physical properties is often accompanied by a change in physiographic status. Laterite which initially forms in lowlying alluvial or footslope positions under the influence of vertical and/or lateral movement of iron-bearing ground water, can become more resistant to erosion than surrounding areas and eventually remain perched, out of reach of the water table and fossilized, on summits in the landscape. This represents an inversion of relief (Bonnault, 1938).

In addition to those studied in this paper, a number of summit-top laterites have been reported in Malaya: Ives (1966) mentions the existance of Malacca Series soils as 'cappings on broad, flat ridges' in the Bt. Ibam area of southeast Pahang, Dumanski and Ooi (1966, p. 10) note the presence, in the Temerloh–Gemas area, of 'numerous steep hills protected by fossil caps of laterite', Law and Leamy (1966, p. 107) quote reports of laterite on the tops of generally rolling to hilly and steep terrain in the Jerantut area and in the vicinity of Kuala Lipis. The present author has observed similar ridge-top residuals in the Pasoh Forest Reserve of Negri Sembilan. Laterite is also reported to occur on steeply sloping low hill country in Kelantan (Panton, 1960) and Southern Johore (Null, *et al.*, 1965).

Leamy (Law and Leamy, 1966) suggested that these high level laterites represent remnants of a Cretaceous peneplain, and Eyles (1967) associated the altitude of the Bee Yong Estate summit laterites with the proposed early Pleistocene (Burton, 1964) marine transgression to about 250 feet, but at present one can do little more than speculate on the geological significance of the formations. Now that the existence of fossil laterite remnants has been recognised in Malaya the next step is to plot their location and altitude. It may be expected that no simple pattern will emerge; for example, summit laterite on Prang Besar Estate ranges from 90 to 310 feet above sea level. Laterite can form on slopes as steep as 10 degrees (Playford, 1954); over a large area this can lead to significant differences in the altitude of laterites of the same age. Again, laterites of differing age can coexist in the landscape. Chemical analysis may, however, enable estimates of relative age to be made because of differential leaching. Aluminium migrates much more slowly than iron and older deposits are therefore likely to have a higher alumina content (Maignien, 1966).

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