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THE JOURNAL
OF MALAYSIA
TROPICAL GEOGRAPHY

VOLUME EIGHTEEN

AUGUST 1964

PUBLISHED BY THE DEPARTMENTS OF GEOGRAPHY
UNIVERSITY OF SINGAPORE AND
UNIVERSITY OF MALAYA

THE JOURNAL OF TROPICAL GEOGRAPHY
Formerly THE MALAYAN JOURNAL OF TROPICAL GEOGRAPHY

Correspondence concerning the Journal should be addressed either to the Editor or the Business Manager, whose addresses are as follows:—

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SUBSCRIPTIONS

The Journal is available, post free, on payment in advance at the rate of Malayan \$5, U.S. \$2.50, or 12s. 0d. sterling per copy.

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The maps and diagrams in this volume were
drawn by Messrs. J. Ngai, Poon Puay-kee,
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CHANGE OF EDITORSHIP

With the publication of Volume 18 of the *Journal of Tropical Geography*, Mr. W. L. Dale relinquishes his duties as Editor in order to take up a post at Monash University. The Editorial Board wishes to record its thanks and gratitude to Mr. Dale for his invaluable services to the Journal since its inception in 1953, in his capacities first as Advisor on Cartography, then as Associate Editor and finally as Editor.

Dr. Ooi Jin Bee takes over the editorship, with Dr. R. F. Kinloch as Assistant Editor.

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THE EVOLUTION OF LAND SUITABILITY MAPS IN THE FEDERATION OF MALAYA

By J.B. ALEXANDER

THE PROSPERITY of the Federation of Malaya is in large measure derived from the natural resources of the land, whether from the superficial soil, or from the underlying rock formations. In the agricultural and forestry sectors, the products of the soil include substantial quantities of rubber, palm oil, timber, pineapples, and coconut oil, while in the mining sector the extraction of tin ore and of iron ore, as well as useful amounts of bauxite, ilmenite, gold, columbite, copper sulphides (as by-products), tungsten ore, china clay, and monazite provide the bulk of the country's export revenues.

A review of land alienations in 1951 showed that the total area of land then held under mining leases amounted to 490,013 acres (1.54 per cent of the total area of the Federation), of which 230,781 acres were leased for tin mining. Acreages under agricultural crops and forest in the preceding year were: 485,000 acres for coconuts; 931,000 acres for padi; 3,464,000 acres for rubber; and 7,500,000 acres in Forest Reserve.

Whilst the importance of rubber and timber is obvious, the choice of land for these products is far greater than that for mining; on the other hand the revenue obtainable from mining is much greater per acre than that from agricultural crops or forestry. Assuming a tin price of M\$450 per pikul (133 1/3 lbs.) and a production of 250 pikuls of tin concentrates per acre, the export duty obtainable in 1950 from one acre alienated for tin mining amounted to approximately M\$12,500. Assuming a rubber price of M\$0.66 per pound, and a production of 750 lbs. per acre per year, the export duty obtainable per acre alienated to rubber would be M\$46. Average annual royalties in 1950 for regenerated forest land were about M\$3 per acre. In these terms, mining has a clear claim to first priority in land development policy.

REGIONAL MAPS FOR MINERAL DEVELOPMENT PLANNING

The first attempt to draw up maps as a basis for land development policy was made by the Geological Survey Department. In 1952 a regional map of the mineral development potential of the State of Perak was prepared and printed on a scale of 1:253,440. Eight more maps, covering the other ten States in the Federation, were subsequently prepared on various scales, with national coverage completed by 1959. These maps attempted to show the mineral development potentialities of land, according to the following categories:

- i) *Mining Areas*: comprising some old mining land, land currently alienated for mining, proved mining land not yet alienated, and areas closely surrounding mining land.
- ii) *Potential Mining Areas*: comprising possible extensions of mining land, i.e. areas in which the presence of exploitable mineral deposits was known from prospecting or had been indicated by geological survey.
- iii) *Possible Mining Areas*: comprising areas not surveyed in detail and areas in which reconnaissance geological surveys had indicated the possibility of economic mineral deposits.

- iv) *Other Areas*: comprising all land in the Federation not included in the previous three categories.

The regional maps took no account of quarries or pits for stone, limestone, gravel, sand, or clay. With the extension of geological surveys and prospecting it was hoped that the boundaries of mining areas would be periodically adjusted and kept up-to-date with the latest information. The ultimate aim was to divide the land of each State into only two categories: Mining Areas, and Other Areas. These regional maps were based on the records and work of the Geological Survey, in collaboration with the Department of Mines, and were originally plotted on scales from 1:63,360 to 1:253,440. Mineral Development Potentialities Maps for the whole Federation were printed on scales of 1:760,320 and 1:4,000,000. The latter, in which 'Potential Mining Areas' and 'Mining Areas' are grouped together, is reproduced here (see map on facing page).

THE LAND ADVISORY COMMITTEE AND THE NATIONAL LAND COUNCIL

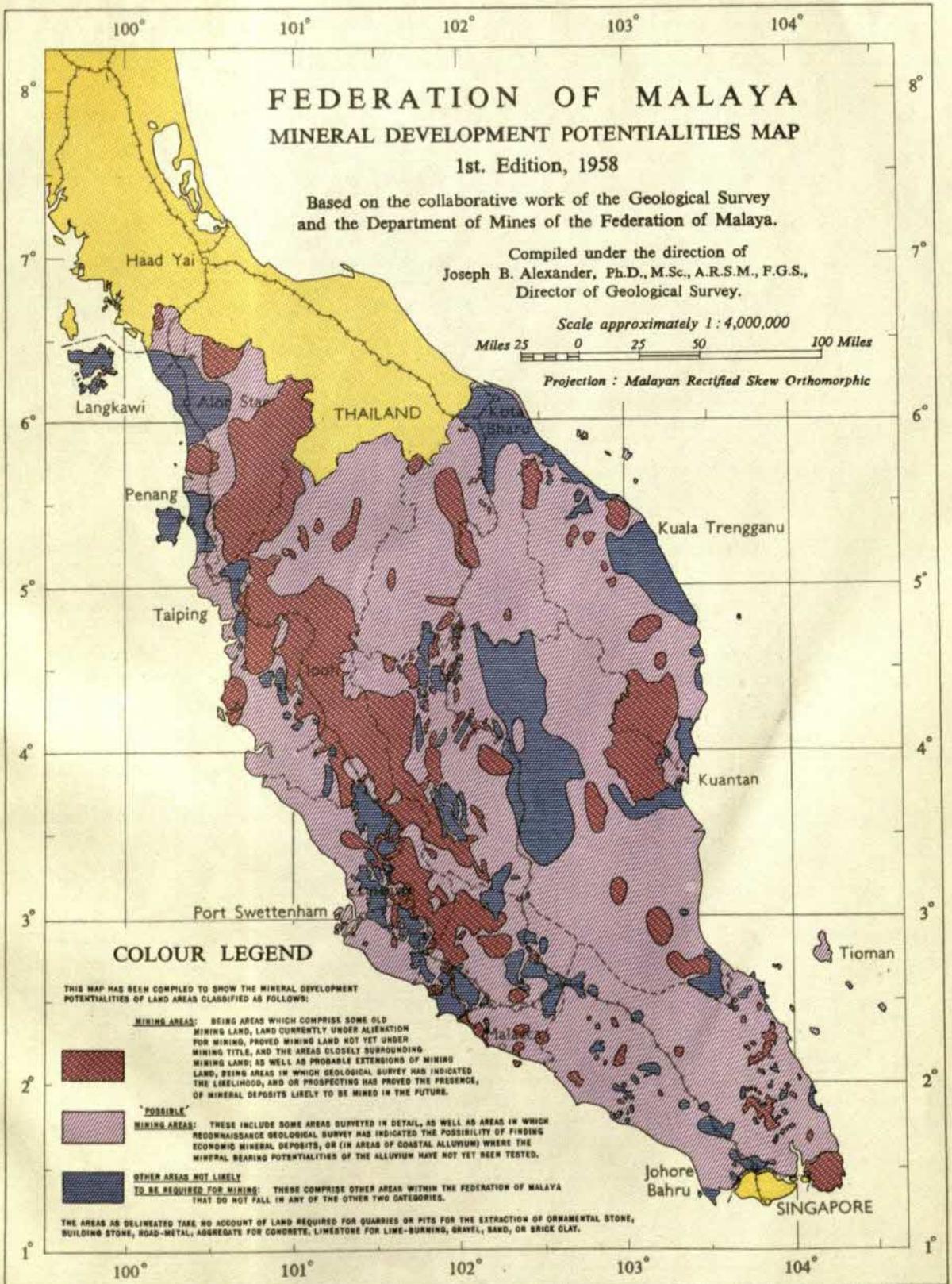
A Federal Land Advisory Committee was set up in Malaya in 1952, following the Ceylon meeting on Land Utilization in the Tropical Areas of Asia, the Far East, and the Islands of the Pacific, organized by F.A.O. in September 1951. The terms of reference of the Committee were: to consider the preparation of a comprehensive inventory of the basic natural resources of land, water, etc., in the Federation; to formulate principles for the utilization of these resources; to advise on planning for their integrated development; and to give advice on the best use of these resources in the light of the available information.

The Land Advisory Committee considered various matters connected with the principles of proper land use. Among its recommendations were that unterraced cultivation should not be allowed on slopes greater than 1 in 5, and that no cultivation other than protective forest should be allowed on slopes greater than 1 in 3. However, the Committee was never established on a permanent basis, and it ceased to hold meetings in 1954. Its place was taken by Natural Resources Boards in some States, but no co-ordinating body with federal powers existed until the establishment in 1957 of the National Land Council.

One of the early tasks of the National Land Council in 1958 was to consider a memorandum on the question of land use for mining. It was decided in 1959 that land alienation decisions should be made on the basis of (a) systematic mapping, (b) systematic classification of land, and (c) land use planned in accordance with that classification.

When a second edition of the regional Mineral Development Potentialities Maps became desirable, the Director of Geological Survey decided to use a more definitive classification than hitherto, as follows:

CATEGORY	RECOMMENDED USE
<i>CURRENT Mining Areas</i> (under current mining lease) <i>POTENTIAL Mining Areas</i> (prospected and showing payable mineral values at current prices)	Mining Reserve
<i>POSSIBLE Mining Areas</i> (prospected and showing payable mineral values at double current prices) <i>FAVOURABLE Mineral Areas</i> (examined by the Geological Survey and showing justification for scout prospecting)	Other Short-term Uses



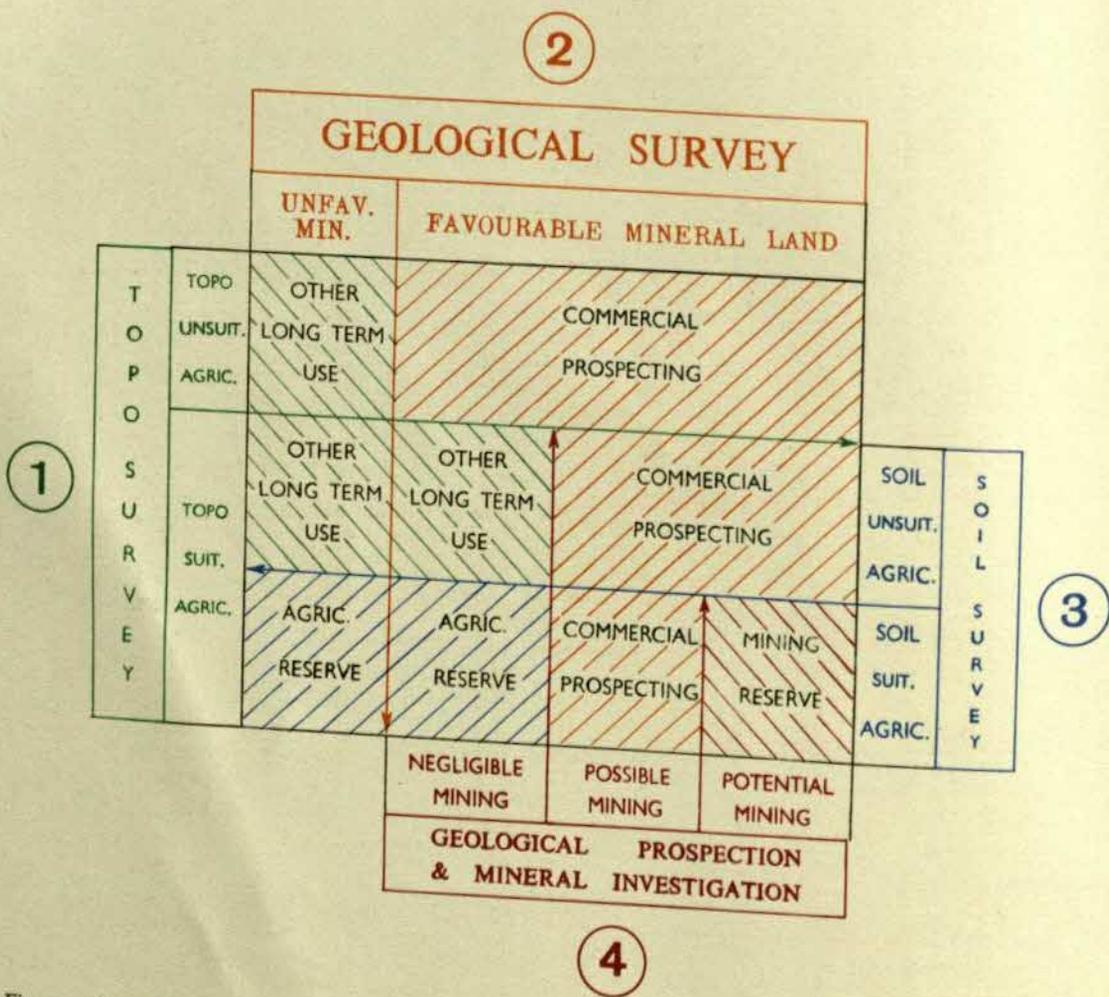


Fig. 1. Diagram to illustrate the functions of the various surveys in determining land suitability.

Soil Survey

This survey determines, in topographically suitable areas, the suitability or unsuitability of the soils for agricultural development. The Soils Division of the Department of Agriculture, in collaboration with the Geological Survey, inaugurated a series of State Schematic Soil Maps with the printing of the 1:500,000 soil map of Trengganu in 1959. A similar map for Kelantan was printed in 1961, and those for the remaining States are being compiled.

Mineral Development Potentiality Survey

This survey involves geological prospection and mineral investigation to determine, especially in favourable mineral areas with soil suitable for agricultural development, areas containing potential mining land which should be reserved for commercial prospecting, and the areas comprising land which can be given mineral clearance for agricultural development. This work is carried out by the Geological Survey, in collaboration with the Department of Mines, using the jointly controlled Mineral Investigation Drilling Unit for the testing of alluvial ground.

BASIC PRINCIPLES FOR THE UTILIZATION OF LAND RESOURCES

In considering the basic principles for the utilization of land, water, and other resources, the Geological Survey is primarily concerned with the formulation of a land policy which will ensure that valuable mineral deposits are not denied to the country by the alienation of mineral-bearing land to other types of development. Unoccupied land in any Potential Mining Area should therefore be automatically alienated for mining upon application, and priority should be given to all mining alienation applications for land in Possible Mining Areas. The Geological Survey and the Department of Mines should be consulted at an early stage in the planning of major development schemes in any Favourable, Unknown, Doubtful, or Inconclusive Mining Area. Land included in Unlikely or Negligible Mining Areas should be reserved for long-term surface development schemes.

While economic factors must be taken into consideration when deciding on the best utilization of land, it must be remembered that what is uneconomic today may become economic tomorrow. Tin ore and many other minerals may increase in value as they become scarce with the passage of time.

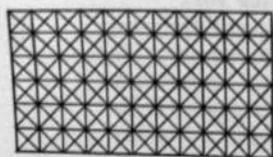
RURAL LAND DEVELOPMENT

The deliberations of the National Land Council prior to the initiation of the Rural Development Schemes in 1960 led to the conclusion that major new land settlement schemes should be of the order of 4,000 acres each. The Working Party on this problem agreed that the upper limit for group settlement schemes would be about 5,000 acres, although a lower limit of 1,000 acres would be feasible. Areas of only 300 acres could be developed on the fringes of existing villages. It was decided that within these limits group settlement areas should be as large as possible, on the grounds that the greater the concentration of population, the more efficient the provision of services and administration in the early stages.

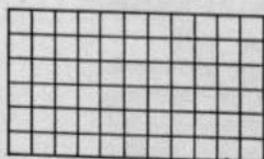
Land development by these methods therefore depended in essence on finding State land suitable for agricultural development, not required for mining or other purposes, and preferably in blocks of 2,500 to 5,000 acres.

A land area of 2,500 acres is represented by a half-inch square and a 300 acre plot is represented by a one-sixth inch square on a map of scale 1:253,440.

LEGEND

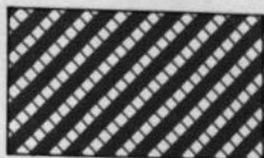


Areas already developed.



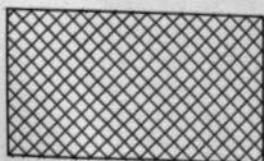
*Remaining areas not suitable
for agricultural development*

— some of these areas may be suitable for mining development.



*Remaining areas of potential
mining development*

— these areas should be reserved for mining development.



*Remaining areas of favourable mineral
potential and possible mining development*

— these areas should be reserved for commercial prospecting.



*Remaining areas of unknown, doubtful,
or inconclusive mineral potential*

*— these areas normally require further investigation
before mineral clearance can be given.*

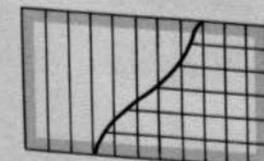


*Remaining areas available
for agricultural development*

*— these areas can be given mineral clearance
without further investigation.*



Gazetted Forest Reserves.



Gazetted Game Reserves.

The preliminary basic planning could therefore be done satisfactorily on the basis of the existing State maps on scales between 1:63,360 and 1:253,440. It was suggested by the Geological Survey Department that a practical and systematic method of initially selecting sites for land settlement schemes would be as follows:—

- a) for each State Government to prepare a copy of the State map on which everything except blocks of State land larger than half a square mile is blocked out;
- b) for the Department of Agriculture to mark on these maps the areas of steep slopes unsuitable for agricultural development;
- c) for the remaining parts of the maps to be marked by the Geological Survey Department, in consultation with the Department of Mines, with an indication of the mineral development potentialities, to the extent known;
- d) for the maps to be sent back to the State Governments to select group settlement areas. In most cases there would be little conflict of interest, and attention would be directed first to those areas not immediately requiring detailed soil survey or further geological investigation;
- e) in the few cases of conflict, an economic use of geological reconnaissance teams and the Mineral Investigation Drilling Unit could then be planned.

The 'Red Book' and Basic District Maps

The first Rural Development Directive was issued early in 1960. It called for the compilation in each District of a Rural Development Plan, known as a 'Red Book'. For each Red Book, a basic District Map was to be prepared, showing (a) areas already developed; (b) areas that could not be developed for agriculture because of relief, swamp, tin tailings, or other physical reasons; (c) gazetted Forest Reserves; (d) gazetted Game Reserves.

The purpose of the District Map was to show at a glance those areas which were immediately available for large-scale rural development. Three copies of the Red Book Basic Plan were required, one copy each for the District, State, and Federal Rural Development Committees. An additional copy of the Basic District Map was to be forwarded, via the Ministry of Rural Development, to the Geological Survey Department.

LAND DEVELOPMENT MAPS

The land suitability classification adopted by the Director of Geological Survey includes the following categories (Fig. 2):

- i) areas already developed;
- ii) remaining areas not suitable for agricultural development, some of which may be suitable for mining development;
- iii) remaining areas of potential mining development, which should be reserved for mining development;
- iv) remaining areas of favourable mineral potential and possible mining development, which should be reserved for commercial prospecting.
- v) remaining areas of unknown, doubtful, or inconclusive mineral potential, which would normally require further investigation before mineral clearance could be given;

- vi) remaining areas suitable for agricultural development, which can be given mineral clearance without further investigation;
- vii) gazetted Forest Reserves;
- viii) gazetted Game Reserves.

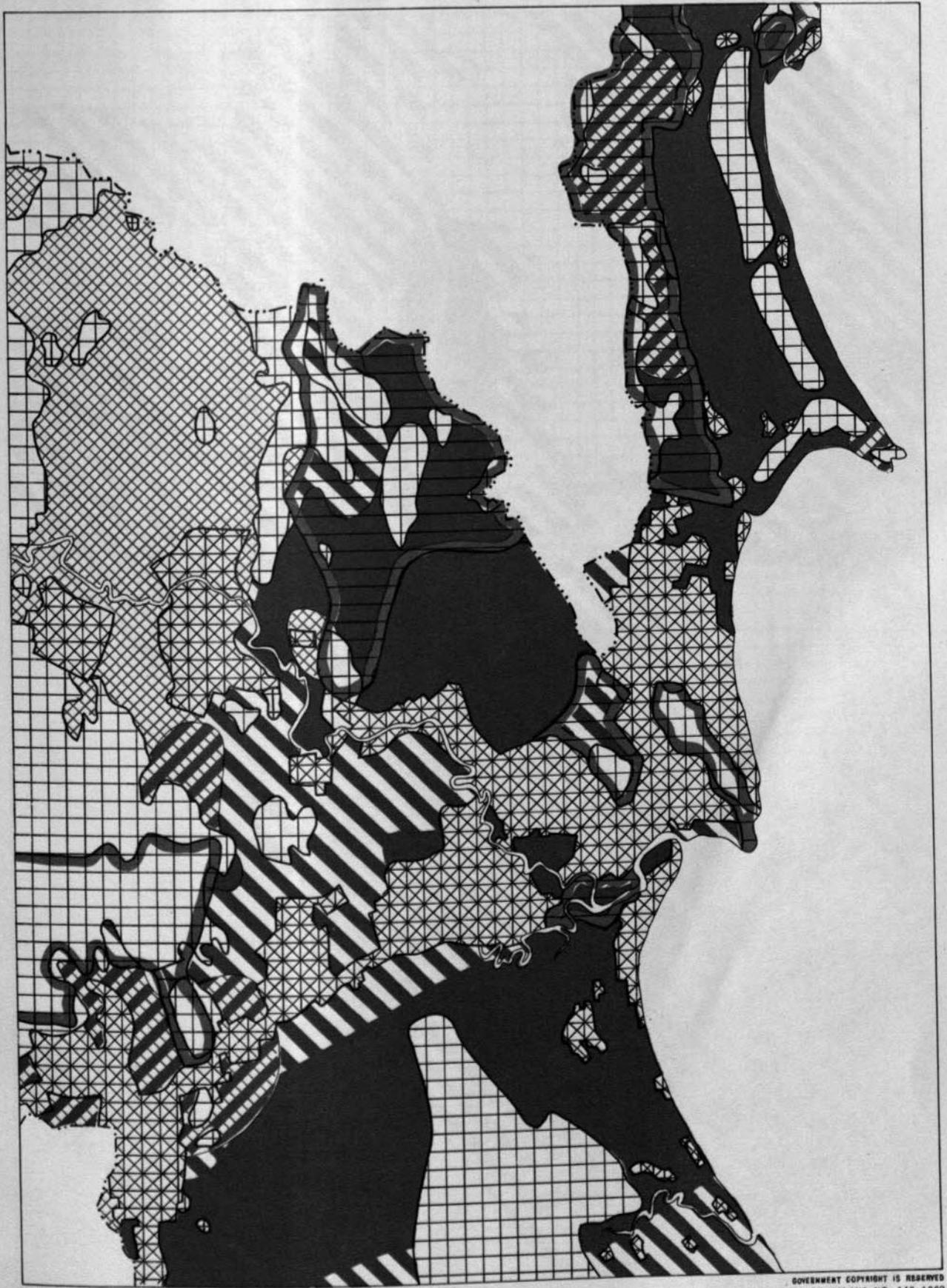
The legend for the various categories was chosen to indicate, in red, those areas most likely to be subject to mining development, and, in violet, those areas most likely to be suitable for agriculture, forestry, or other development.

The Basic District Maps provided by the District Offices showed only areas that had been developed by 1960 and some areas known to be unsuitable for agricultural development. These maps were therefore redrawn and passed to the Soils Division of the Department of Agriculture, which added other areas of known unsuitability for agriculture, whether on topographic or soil grounds. The Geological Survey and Mines Department next showed, in the remaining areas of these maps, the then known areas of potential mining development and of favourable mineral potential and possible mining development. The remaining land was then divided by the Geological Survey into areas of unknown, doubtful, or inconclusive mineral potential, and areas of unlikely or negligible mineral potential immediately available for agricultural development.

The whole of the Federation was depicted on 56 maps at various scales. Parts of the Land Development Map for Kuantan District, Pahang and for Kota Tinggi District, Johore, are shown in Figures 3 and 4. Work started in May 1960 and a limited edition of hand-coloured maps, with scales between 1:285,120 and 1:39,600 for the 72 Districts of the 11 States, was completed by June 1961 and distributed in atlas form to the appropriate Federal and State authorities. Additional copies were subsequently made available to the District authorities. Future editions of these maps will probably be on a common scale of 1:126,720, and will show the land settlement schemes initiated since the production of the first edition maps.

ACKNOWLEDGEMENTS

The writer records his appreciation of the helpful comments and constructive criticism offered by his colleagues in the Departments of Geological Survey, Mines, and Agriculture, and acknowledges the great help given by the members of the Geological Survey Cartographic Office in the preparation of the Mineral Potentiality and Land Development Maps mentioned in this paper.



DRAWN AT GEOLOGICAL SURVEY HQ., IPOH, 1963. DWG. 62-40

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Fig. 3. Land Development Map for part of Kuantan District, Pahang.

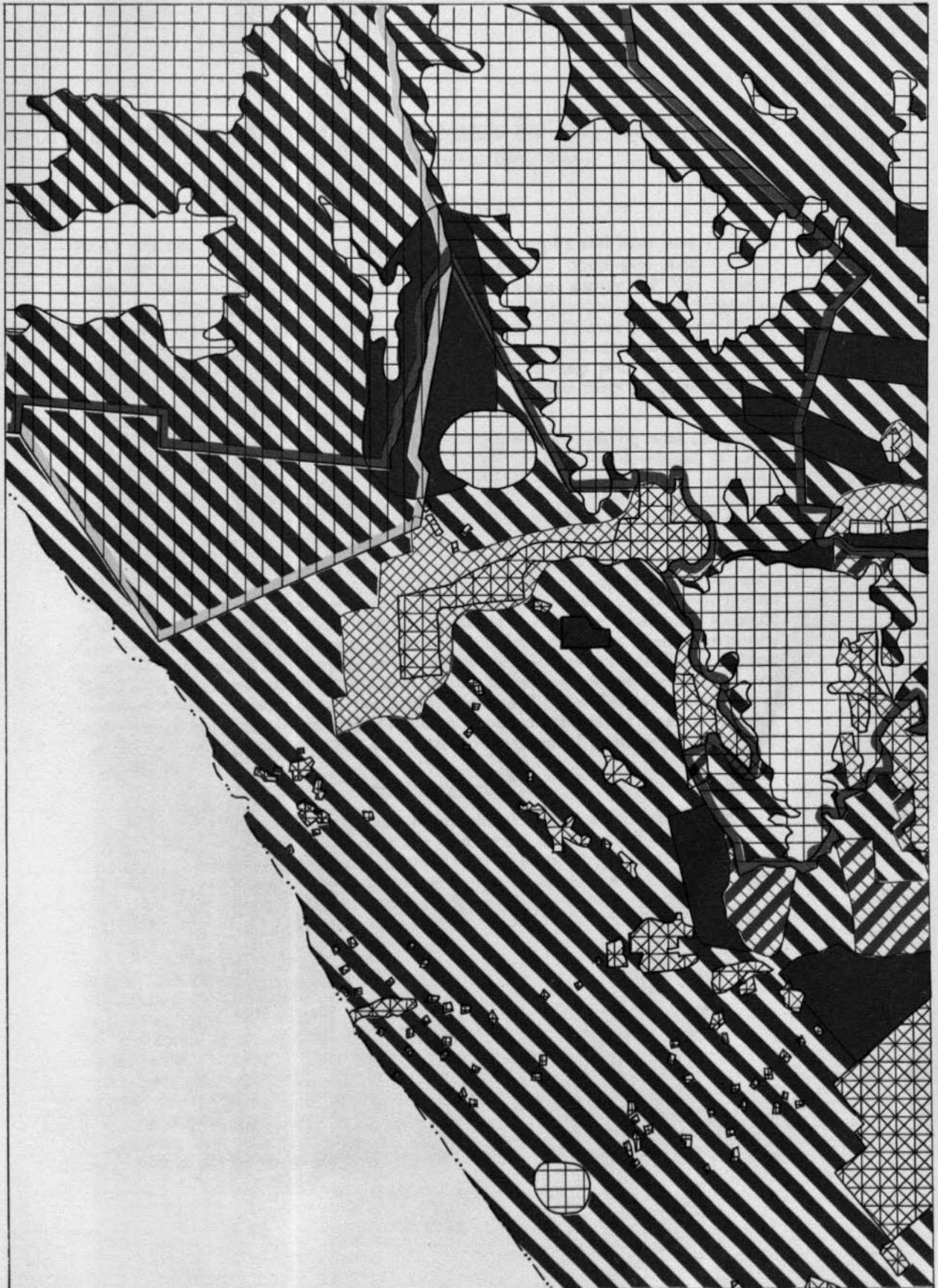


Fig. 4. Land Development Map for part of Kota Tinggi District, Johore.

THE STRUCTURE AND DEVELOPMENT OF THE PEAT SWAMPS OF SARAWAK AND BRUNEI

By J. A. R. ANDERSON

PEAT SWAMPS cover extensive areas in the humid tropics and have been recorded from the three main rainforest regions of the world: South-east Asia, tropical America and tropical Africa. In his comprehensive survey of the tropical rainforest, Richards (1) summarizes the available information on the vegetation and nature of peat swamps. Possibly the first person to discover peat in the humid tropics was Beccari (2), but the significance of these deposits was not realized until Potonie and Koorders (3) drew attention to the deep peat of Sumatra. In their paper, and in Tenison-Woods' description of Bornean peats (4), the emphasis is on the tropical origins of coal.

Fundamental studies of peats were made by Polak (5, 6, 7), who recognized two types, the ombrogenous and the topogenous. The first, developed in areas of high rainfall, are analogous to the raised bogs or *hochmoore* of temperate climates. Such formations are often lenticular in shape, with a bleached clay foundation; blackwater streams draining the peat are very acid, with pH values around 3.0. These soils are extremely oligotrophic. Topogenous peats usually evolve at high altitudes as well as along lakes and rivers at low altitudes; they are normally acid rather than alkaline, and therefore not directly equivalent to temperate fen peats. Richards (1) and van Steenis (8) state that topogenous peats cover greater areas than ombrogenous peats, but no comparative data are available. Recently Coulter (9, 10) has studied peat swamps in Malaya to assess their agricultural potential. He estimates that peat covers nearly two million acres in Malaya. Most formations there are relatively shallow, depths exceeding 18 feet being rare, and convex-surfaced formations are not highly developed. For Sarawak, accounts of peat swamps are given by Browne (11) in his book on the forest trees of Sarawak and Brunei; by the author (12, 13), and in the Annual Reports of the Forest Department (14, 15).

TERMINOLOGY

Subcommission 6 of the Second International Congress of Soil Science held in Russia in 1930 recommended that the term 'peat' be restricted to organic soils that are at least 0.5 metres (1.64 ft.) deep, one hectare (2.47 acres) in area, and ~~and Brunei by the author (12, 13), and in the Annual Reports of the Forest~~ with a maximum mineral matter content of 35 per cent. Where the mineral matter exceeds 35 per cent but does not exceed 65 per cent the soil is defined as 'muck'.

Peats and mucks may develop in freshwater or peat swamps. However, van Steenis' (8) definitions of freshwater swamp forest as developed on mineral or non-mineral soils and tolerant of climate, and of peat swamp forest as developed on peat and restricted to an ombrogenous climate are too imprecise to be satisfactory. On the basis of his studies in Malaya, Coulter (10) suggested the following classification of peats: (i) eutrophic peats, largely derived from marsh and grass, which have much mineral matter and are neutral or alkaline in reaction; these are basically the fen peats of the temperate zone and do not occur in Malaya or Borneo; (ii) oligotrophic peats, low in mineral content, especially in calcium, and acid in reaction; and (iii) a mesotrophic group, intermediate between the first two types, with a pH of about 5.0 and a rather high level of bases. Coulter proposed

that Malayan peats and mucks be termed 'bog soils', which may be convenient pedologically, but is ecologically confusing since it includes the freshwater and peat swamp habitats in a single group. The present writer's work indicates that the most important factors differentiating these two habitats are the surface structure of the swamp and the degree of flooding, which determine swamp drainage, and the mineral content of their soils (as determined by the percentage loss on ignition). The following terminology is proposed: (i) freshwater swamp, which is regularly or occasionally flooded, has peat or muck soils with pH values generally higher than 4.0, a loss on ignition below 75 per cent, and level or barely convex surfaces; (ii) peat swamp, which is not subject to flooding, has a peat soil with a pH value of less than 4.0, a loss on ignition above 75 per cent, and a markedly convex surface. Freshwater swamp may be oligotrophic, but more commonly approaches the mesotrophic group of Coulter, whereas peat swamp is always oligotrophic.

In Sarawak and Brunei, freshwater swamps are largely topogenous, forming along rivers where flooding is prevalent in the wet season. By comparison with peat swamps, they cover a negligible area. The margins of peat swamps, where flooding occurs, and where the soils have a relatively high mineral content may be considered as freshwater swamp. Similarly, a freshwater swamp in which the accumulation of organic matter has raised the soil above flood levels becomes a peat swamp.

CHARACTERISTICS OF THE PEAT SWAMPS OF SARAWAK AND BRUNEI

In Sarawak, peat swamps cover 5,660 square miles, or 12 per cent of its total area. The total area of peat swamps, as computed from the Land Use Map (16) is shown for each administrative division in Table 1:—

TABLE 1: SARAWAK: AREA OF PEAT SWAMPS, IN SQUARE MILES

1st Division	2nd Division	3rd Division	4th Division	5th Division	Total
576	1,072	2,322	1,624	66	5,660

In Brunei, the area of peat swamp is 380 square miles, representing 22.6 per cent of the area of that State. The distribution of peat swamps in both territories is shown in Figure 1.

The coastal and deltaic peat swamps of Sarawak and Brunei have convex surfaces and are markedly oligotrophic. Five swamps in the Rajang delta were surveyed by the writer using a precise level and measuring peat depths with an extensible auger. The profiles obtained are shown in the upper part of Figure 2, where the vertical scale is 6.6 times exaggerated; the datum lines through the profiles indicate the levels of high tides or of river floods at the perimeter of the swamps. The convexity of the swamp surfaces becomes more pronounced with distance from the sea; on the island of Pulau Bruit at the coast, the maximum height of the swamp surface is 12.96 feet and the surface gradient is relatively gentle on both sides of the island. Maximum heights in the Daro Forest Reserve and along the two traverses in the Loba Kabang Protected Forest were 13.13, 15.40 and 13.13 feet respectively. Gradients in these swamps are steeper in the first 100 chains from their margins than at their centres, where the rise is only 1 - 1½ feet per mile. The swamp surface is like that of an inverted saucer, with an almost flat bog plain at the centre. The most remarkable profile is that from the Naman Forest Reserve upriver from the apex of the Rajang delta, and almost certainly the oldest

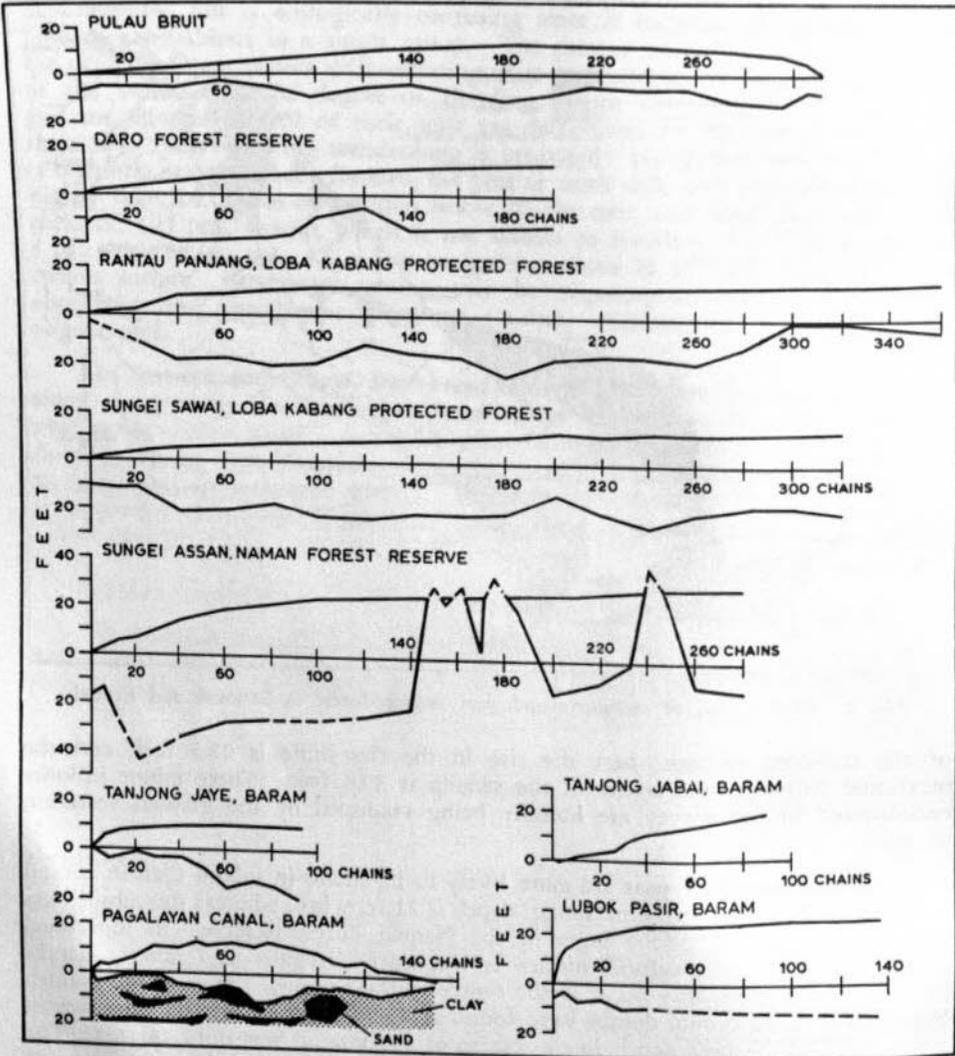


Fig. 2. Peat profiles in the Rajang delta and Baram river.

the swamp centre, the surface levels off to an almost flat bog plain. The greatest depth of peat recorded in the Baram swamps was 39 feet, found at the centre of the Lubok Pasir swamp. Subsoil levels are generally below the datum, but not as low as in the Rajang delta profiles.

Further light on the surfaces of swamps is derived from extensive level surveys across swamps from the Rajang delta to Lawas carried out by seismic parties of the Sarawak Shell Oilfields and Brunei Shell Petroleum Companies. These surveys are correlated with mean sea level, allowing accurate comparisons of swamp levels in different localities. Again, doming is more pronounced in the swamps further inland; in the centre of two swamps up the Baram river, maximum heights of 48 ft. 5 ins. and 45 ft. 7 ins. were recorded, whereas near the coast maximum

heights were only 22 ft. 9 ins. and 15 ft. 8 ins. It is interesting to note that the perimeters of inland swamps along the banks of streams are 16.4-19.7 feet above sea level, while the margins of coastal swamps are only 6.5-9.8 feet above sea level.

Three further swamp areas were surveyed by Sir Bruce White, Wolfe Barry and Partners in 1954-56 (17, 18, 19), in order to assess their suitability for padi cultivation. The swamp on the Nonok peninsula near Kuching has generally a uniform slope, the typical domed surface developing only near the inland margin. The large peat swamp in the Maludam peninsula between the Saribas and Batang Lupar rivers covers some 260 square miles and was traversed towards its seaward end along two lines of levels, 17.1 and 15.6 miles long. A bog plain was found to extend 9.5 and 6.8 miles along the two transects, with variations in height of less than 2.7 feet, except where the Maludam river forms a re-entrant. The third swamp, at the confluence of the Tinjar and Baram rivers upstream from Marudi, has a highly developed domed surface except in its southern portions where a flat bog plain occurs. The centre of the swamp reaches a maximum height of more than 60 feet above the arbitrary datum on the river bank. Two principal streams draining the swamp, the Sungai Majau and the Peking, form pronounced re-entrants into the peat formation. Unfortunately peat depths greater than 20 feet were not measured so it is not possible to compare structures here with those already described.

The domed surfaces of these peat swamps reduce the extent of flooding. Although precise data are lacking, tidal and river gauge observations made by the above-mentioned irrigation engineers show maximum river levels of 7.43, 10.68 and 11.2 feet above mean sea level at the Nonok and Maludam peninsulas and the Baram-Tinjar confluence respectively. When these levels are related to contoured maps and level surveys, the limit of maximum flooding in the Nonok swamp is seen to be less than half a mile from the margin; in the Maludam peninsula, flooding up to one mile may occur locally, but probably at spring tides only, while the steep doming of the swamp surface in the Baram-Tinjar area probably restricts flooding to less than a quarter of a mile except along streams. The degree of flooding is important when the development and agricultural potential of peat swamps are considered. Marginal floods deposit silt, forming an alluvial soil on river banks which grades into muck soil where flooding is less frequent. The distribution of soil types therefore indicates to some extent the degree of flooding. Wilford (20) notes that the alluvial strip along the Baram river is usually between 100 and 1,000 feet wide.

However, the watertable lies close to the swamp surface, even in highly domed bogs, and in the wet season it may be above the swamp surface, especially near the margins of swamps. The watertable itself was taken as the swamp surface in level transect No. 3 in the Rajang delta (Fig. 2) and in all subsequent surveys in the Baram. Variations in the watertable along Line No. 3 in the Loba Kabang Protected Forest (Fig. 2) were measured from April to October 1954 using graduated stakes. These measurements show that the smallest variation in height, 3.7-4.2 inches, occurs near the perimeter, gradually increasing to 7.5 ins. towards the centre of the swamp. Although the full annual height variation is not available since measurements were not made during the wet season, it is probable that the minimum variation observed near the swamp periphery reflects the high surface gradient and rapid runoff. In periods of comparative drought, the watertable at the periphery is maintained by a lowering of the watertable in the central zone.

The converse operates for the centre of the swamp, but further observations in a swamp in the Baram do not support this view entirely and the problem needs further study.

Swamp drainage is entirely at or close to the surface, since the heavily compacted masses of woody peat and the saucer-shaped alluvial subsoils probably prevent lateral drainage. The presence of undecomposed or semi-decomposed woody material at all levels in a peat swamp indicates complete stagnation of drainage. Excess water on the surface collects in minor depressions which tend to coalesce to form rivulets, and finally it drains to larger streams which may form marked depressions in the swamp surface and re-entrants into the bog plain. These streams of dark tea-coloured water provide channels through the larger swamps that are navigable by boats fitted with outboard engines.

Physically these peats are similar to the Malayan formations, consisting of a heavily compacted mass of semi-decomposed woody material. Roots and tree stumps are particularly abundant, but branches and trunks are also common. The centres of large pieces of timber may be quite undecomposed, and these frequently obstruct borings. The peat matrix is dark chocolate-brown in colour, soupy and amorphous; recognizable rootlets, leaves and twigs may be found in various stages of decomposition. The matrix is rich in pollen, and parts of bryophytes may often be identified. The surface peats found in the highly developed central bog plains of the Baram have a different texture, being formed under stunted open vegetation; these are heavily compacted and fibrous, light reddish-brown in colour and with many colourless rootlets. The normal dark fluid matrix is here replaced by a more watery liquid. This peat is more akin to that found in temperate regions.

These studies confirm and elaborate upon Polak's work on the peat swamps of Sumatra and south Borneo. As she points out, the structure of tropical peat swamps is similar to that of raised bogs in the temperate zone, and features of temperate raised bogs such as the lagg, rand and bog plain are repeated in the raised bogs of Borneo. The main differences seem to be the physical nature of the Bornean peats, their immense extent and mode of development.

DEVELOPMENT OF PEAT SWAMPS

The extensive peat swamps of the Rajang delta, Maludam peninsula and the Baram plain overlie a clay subsoil. The clay underneath the peats of the Rajang delta is almost certainly of mangrove origin; the report on the Maludam peninsula (18) states that 'the soil on the river banks is clay and clay underlies the peat deposits in the interior'. This clearly refutes the opinion of Kostermans (21) that peat will only develop on infertile, poorly drained sands; it supports the view of Bramao that reducing conditions, such as occur above clay subsoils associated with waterlogging, are essential (22). There is little evidence from Sarawak to support Wyatt-Smith's original hypothesis that estuarine peat swamps in Malaysia are always associated with coastal sites where a sandbank holds up drainage (22). However, local sandy subsoils have been found in the Baram and Lawas areas, and recent soil surveys report similar subsoils underneath coastal peats in the Mukah-Balingian area (26). The significance of these findings is discussed below.

The initial formation of peat overlying clay is a controversial problem that was discussed at some length in the UNESCO symposium on tropical vegetation (22). Richards supported the view of Mohr (23) that in the lowlands of the

humid tropics, a subsoil deficient in bases is as necessary as waterlogging. The fact that in Sarawak and Brunei the alluvium underneath peats originated from generally infertile parent materials from the interior tends to support this hypothesis. However, reports from irrigation engineers (17, 18, 19) indicate that the clay soils below peats may be relatively rich in bases. Mohr and van Baren (24) mention the possible existence of an impediment or poison in the soil flora which might not affect the macroflora; the ecological study carried out by the writer (12, 13) suggests that high sulphur and sodium contents of catclays may be toxic to microbiological activities, but not to the forest flora. It is perhaps significant that the initial accumulation of peat is relatively rapid.

This study also showed that vegetation communities form typical zonal patterns related to swamp structures, so that bogs in different stages of development can be mapped from aerial photographs (13). In addition, a palynological examination of a 42.65-foot core from the centre of a well developed bog at Lubok Pasir in the Baram swamp was undertaken with the cooperation of Mr. J. Muller of the Brunei Shell Petroleum Company. The unpublished results show clearly that the peat swamp there developed over a mangrove clay, and that the horizontal arrangement of vegetation communities represents the natural succession. Samples from cores taken in the same locality were carbon-14 dated by Prof. Hl. de Vries of the University of Groningen in Holland, whose results, shown in Table 2 below, were reported by Wilford (20, 25).

TABLE 2: RESULTS OF CARBON-14 DATING OF SARAWAK PEATS

DEPTH OF SAMPLE (feet)	AGE (years)	DEPTH (feet)	CALCULATED RATES OF PEAT ACCUMULATION (feet per 100 years)
16.40	2,255 ± 60	0.00 — 16.40	0.7271
32.81	3,850 ± 55	16.40 — 32.81	1.0285
39.37	4,270 ± 70	32.81 — 39.37	1.5634

These values show that the rate of peat accumulation decreases towards the surface. For bogs to evolve from the almost perfect convex-topped forms found near the coast, to the flat-topped structures with relatively steep margins typical of advanced bogs, either the rate of accumulation at the margins must increase or the rate of accumulation at the centre must decrease. The meagre evidence of the carbon-datings suggests that the second alternative is the more likely. The rate of accumulation decreases under the more advanced vegetation communities in the succession, hence the gradual flattening of the swamp surface as a bog plain towards the perimeter.

Thus the following phases in the evolution of peat swamps may be distinguished:—

- Phase 1:* Deposits of alluvium in bays, deltas or sheltered embayments along the coast are colonized by mangrove. With continued deposition further offshore the more inland mangrove is progressively replaced by transitional communities and a shallow peat, overlying mangrove clays, is formed.
- Phase 2:* With the continued deposition of alluvium on the seaward perimeter the swamps advance replacing mangrove. Consequently as the distance from the sea of the original swamp increases, rivers tend to back up and begin depositing alluvium along their banks, which consequently

are raised above the level of the original swamp subsoils. This is how the characteristic saucer-shaped foundations of peat swamps evolve. In this phase peat accretion proceeds rapidly and a shallow lenticular structure develops.

Phase 3: The rate of peat accumulation in the swamp centre falls and a typical flattened bog plain develops, usually occupied by a vegetation community dominated by *Shorea albida*.

Phase 4: This phase has only been found in the Baram and Belait rivers. As the rate of peat accumulation in the bog plain continues to diminish, the plain extends laterally. The radial distribution of vegetation communities tends to become restricted except on the bog plain itself. In this and the preceding phase, more alluvium may be deposited along the rivers as further backing-up of stream flow continues.

These phases may be modified by erosion. In 1961, nearly half a mile of peat swamp collapsed as a result of erosion undermining a levee in a meander of the Baram river. If such meanders are subsequently abandoned and a peat swamp is re-established, a succession of peat-clay/silt-peat may develop, as has been recorded by the seismic parties and by the irrigation engineers at Kuala Tinjar (19). Changes in offshore currents can also erode peats, as on the west coast of Pulau Bruit in the Rajang delta, where seven feet of peat have been exposed.

GEOMORPHOLOGICAL SIGNIFICANCE

This outline of the evolution of peat swamps helps in interpreting the post-glacial history of the Sarawak-Brunei coastline. Wilford (20) has shown from carbon-14 dating that the sea reached its present level 5,400 years ago, when the coastline may have followed the inland margins of the present peat swamps (Fig. 1). Since then, the Baram and Limbang floodplains have been extended seawards at an estimated rate of 30 feet per year. This seaward extension, and that of the associated peat swamps may not have occurred uniformly. The dominantly clay subsoils of the peat swamps indicate faster growth in bays or sheltered localities where offshore currents were slack and deposition faster.

The most developed swamps are found in the Baram upriver from Kuala Bakong. The high land on both sides of the Baram north of Marudi formed the mouth of the large bay which was rapidly filled in 5,400-4,000 years ago. This is suggested by the age of the peat at Lubok Pasir: $4,270 \pm 70$ years old (Table 2). When this bay was filled in, a second and larger embayment would have been formed between Miri and the high land east of Seria. It is likely that the coast at Seria then was a long spit of land running from the coast near the Lumut Hills. Evidence for this is provided by the highly developed bog immediately behind the littoral, the only place in the region where a bog dominated by *Shorea albida* occurs close to the coast. This bog must have originated on alluvium deposited 3,000-4,000 years ago. After this embayment had been filled in, changes in the smoothed coastline were small, and the present littoral fringe of marine sand colonized by *Casuarina* indicates relative stability.

In the immediate post-glacial period, the mouth of the Rajang river was close to the site of Sibu town. The wide estuary upriver from Sibu must have been rapidly filled in, as the deepest recorded peats (over 50 feet) occur there in the Naman Forest Reserve. A shallow embayment would then have been formed between the highlands in the Sarikei area and those between the Mukah and Balingian rivers. Here the most highly developed swamps are found in a wide

arc running through the Daro Forest Reserve, Lassa Protected Forest, the area south of Sungei Kut, and the Oya Mukah Protected Forest. Outside this arc, the structures of raised bogs in Pulau Bruit, Jemoreng Protected Forest and Matu Daro Protected Forest indicate relatively recent origins. Today the coastline between Tanjong Sirik and Bintulu is smooth, with parallel sandy beaches and offshore bars. Recent peat formation has occurred between the beach lines; a similar development occurs in the Mukah-Balingian area (26), where peats over 10 feet deep correspond closely to clay subsoils. Variations in peat depth of from 2 to 10 feet may occur within a horizontal distance of 300 to 400 feet.

The large peat swamps in the First Division and those between the Batang Lupar and Saribas rivers probably evolved fairly uniformly within the sheltered embayment between Tanjong Po and the high ground near Selalang. It is only in this region, especially in the Maludam and Nonok peninsulas, that the rapid seaward progression of mangroves on coastal silts or clays, followed by peat swamp, is taking place along the open sea coast today.

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CLASSIFICATION AND UTILIZATION OF SOME PHILIPPINE SOILS

By ALFREDO BARRERA

THE PHILIPPINE Archipelago of 7,100 islands, covering 115,707 square miles, extends from 116°55'E to 126°36'E, and from 4°30'N to 21°20'N. The largest island is Luzon (40,804 square miles) followed by Mindanao (36,906 square miles) (Fig. 1). The total population of the Republic in 1960 was 27,456,000 and the average density approximately 240 persons per square mile.

The Archipelago being situated in the volcanic belt that extends from New Zealand to Japan, numerous volcanic cones occur throughout the Philippines. Some are active, others are extinct or dormant. These volcanoes have contributed much material to the soils of surrounding areas.

As a result of marked tectonic instability, the islands are rugged, with sierras running from north to south and enclosing valleys such as the Central Plain and the Cagayan Valley in Luzon, the Agusan Valley and the Cotabato Plain in Mindanao. The plains in western Negros, Iloilo and Capiz, the eastern part of Leyte, Infanta and several smaller plains on the west coast of Luzon are other typical examples. Prosperous settlements have been established on the rich soils of some of these plains.

Annual temperatures throughout the lowlands are remarkably similar due to maritime influences. For example, the average annual temperatures at Jolo in the south and Aparri in the north differ by only 2°F. Thus vegetation types at sea level are practically the same everywhere in the Archipelago. Seasonal temperatures vary between 77.5°F and 79.7°F during the months from November to February, and between 80.6°F and 82.4°F from April to October. Diurnal temperatures range from a maximum of between 86.0°F and 91.4°F to a minimum of between 72.2°F and 69.8°F. The average diurnal variation is about 16°F.

Greater seasonal temperature variations occur with increasing altitude, so that vegetation types tend to change with altitude. Since temperature differences in the Archipelago are slight, rainfall differences due to the combined influence of topography and wind direction form the basis for the usual classification of Philippine climates into four types. These are based on the presence or absence of a dry season and the character of the rainy season (Fig. 2).

The first type has two pronounced seasons: dry from November to April, and wet from May to October. The controlling factor here is topography. The localities with this type of climate are sheltered from the northerly winds and the north-east trades by mountain ranges, but are open to the south-west monsoon and cyclonic storms. The second type has no dry season, but a very pronounced rainy season from November to February. Areas with this rainfall regime are found along the east coast, where there is no shelter from the northerlies, the trades, the south-west monsoon or from cyclonic storms. The third type has no pronounced maximum rain period, but a short dry season lasting only from one to three months. This type is only partly sheltered from the northerlies and the north-east trades, and is open to the south-west monsoon, or at least to frequent cyclonic storms. The fourth type has no dry season and no pronounced maximum rainy

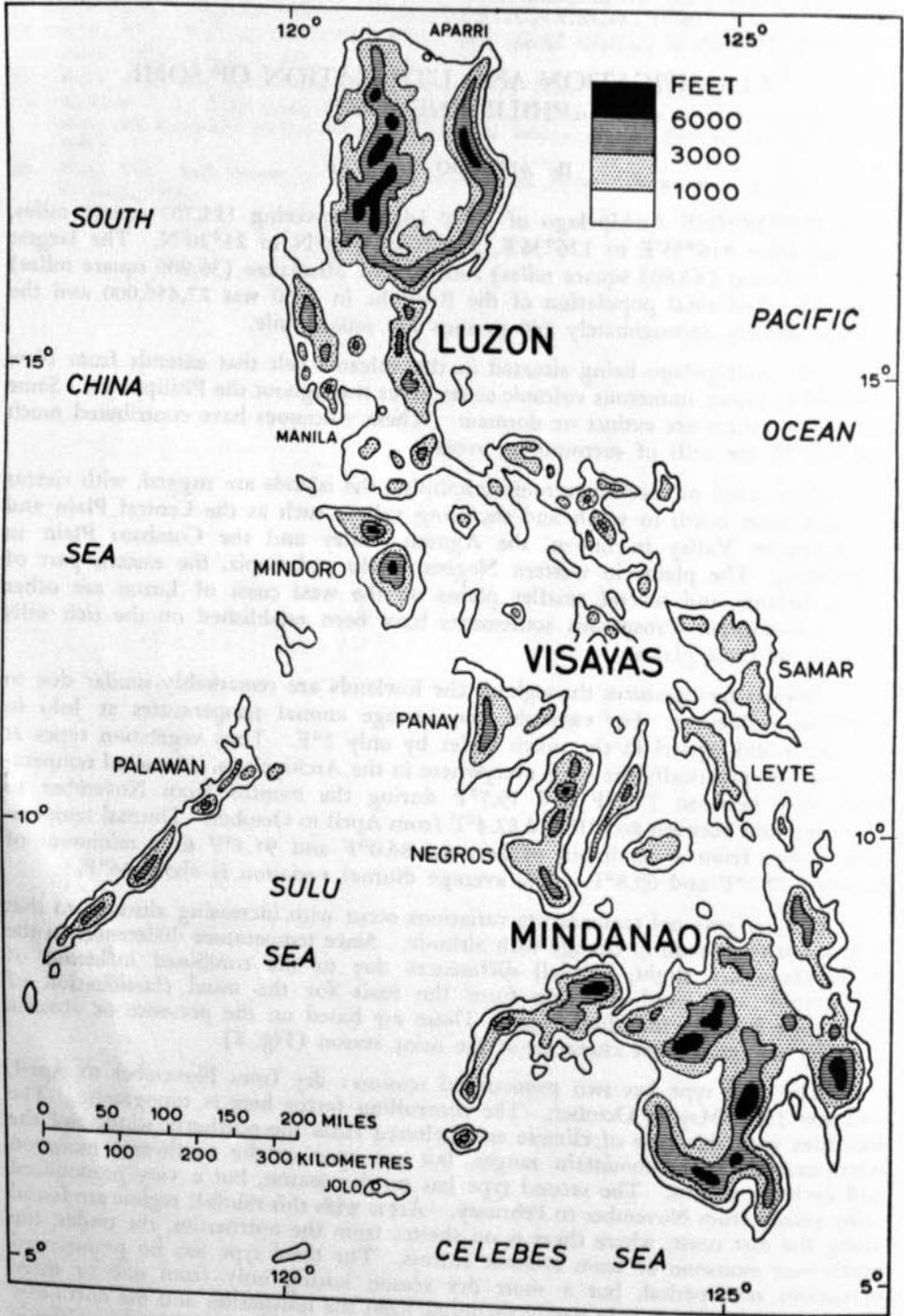


Fig. 1. Relief.

period. In the mountainous parts these climatic types are modified: temperatures decrease with altitude and rainfall tends to increase.

For the country as a whole rainfall is heavy, ranging from 90 to 120 inches per annum. As a result most soils are heavily leached and acidic in reaction. Deeply weathered latosols are found in Mountain Province, Laguna, Quezon, Negros, Leyte, Palawan and most areas of central Mindanao. Where rainfall suffices, dipterocarp forest is found, replaced by *molave* forest in drier areas. In still drier areas, particularly on soils of excessive drainage, *cogon* grasslands develop, and the driest areas of all have alkaline soils such as those in the southern part of Cotabato Province. In many dry areas with strong winds, sand dunes are formed, as in the northern and western regions of Luzon. In most parts of the country the combination of high rainfall and high temperature results in a rapid decomposition of organic matter and deep weathering of parent materials.

Brief reference must be made to the influence of typhoons. South of latitude 8°N , the Philippines are fairly free from typhoons. This is reflected in the high value attached to agricultural land in nearly the whole of Mindanao. From 8°N to 11°N , typhoons are slightly more frequent. This zone, some 180 miles wide, experiences about eight per cent of the more serious typhoons which affect the Archipelago. Thus the great sugar lands of Negros and southern Panay are fairly free from the more devastating storms. From 11°N to 13°N , typhoons are quite frequent and often destructive. Still further north there is a zone, more than 100 miles wide, which is a little less troubled by typhoons. Manila is located in this area. Finally, the northern part of the Archipelago is frequently traversed by typhoons.

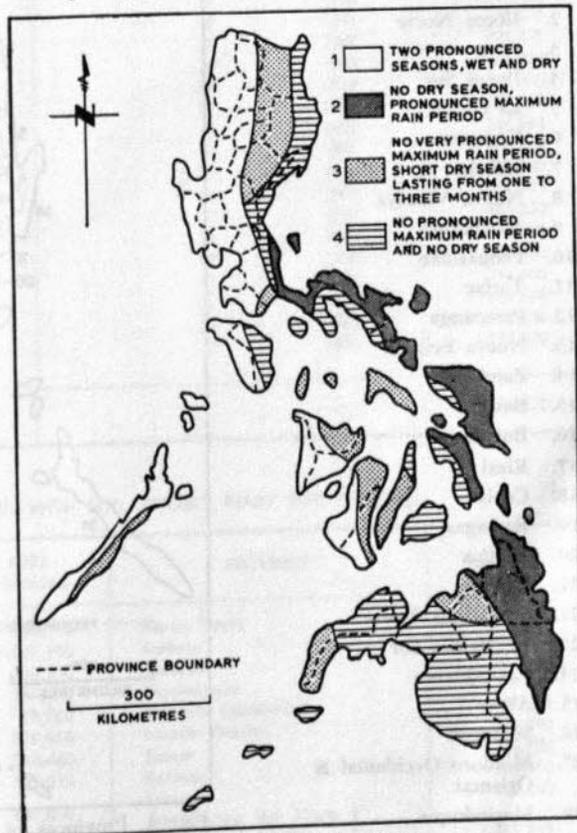


Fig. 2. Climatic types.

SOIL CLASSIFICATION

In the Philippines, as elsewhere, soils are classified into series and types. In addition, the phase of a soil type, defined on the basis of characteristics important for land use, is also considered. When two or more of these principal units form such an intimate or mixed pattern that they cannot be clearly shown on a soil map due to scale limitations, they are mapped as a complex. Areas not

covered by pure soils, such as river beds, coastal beaches, or bare rocky mountain sides, are classed as miscellaneous land types.

TYPES OF SOIL SURVEY

Reconnaissance soil surveys. The main objectives of reconnaissance soil surveys are to determine the characteristic properties of the soils and to establish the soil series for future detailed soil surveys.

Soil surveys in the Philippines began in 1934 and are essentially reconnaissance in nature, the scale of the published maps ranging from 1:75,000 to 1:250,000. The unit of survey is the province, which may range from 19,780 to 2,296,790 hectares in area.

1. Batanes
2. Ilocos Norte
3. Abra
4. Ilocos Sur
5. La Union
6. Cagayan
7. Isabela
8. Nueva Vizcaya
9. Mountain
10. Pangasinan
11. Tarlac
12. Pampanga
13. Nueva Ecija
14. Zambales
15. Bataan
16. Bulacan
17. Rizal
18. Cavite
19. Batangas
20. Laguna
21. Quezon
22. Camarines Norte
23. Camarines Sur
24. Catanduanes
25. Albay
26. Sorsogon
27. Mindoro Occidental & Oriental
28. Marinduque
29. Romblon
30. Masbate
31. Palawan
32. Capiz & Aklan
33. Antique
34. Iloilo
35. Negros Occidental
36. Negros Oriental
37. Cebu
38. Bohol
39. Leyte
40. Samar
41. Surigao
42. Agusan
43. Davao
44. Misamis Oriental
45. Bukidnon
46. Lanao Norte & Sur
47. Cotabato
48. Misamis Occidental
49. Zamboanga Norte & Sur
50. Sulu

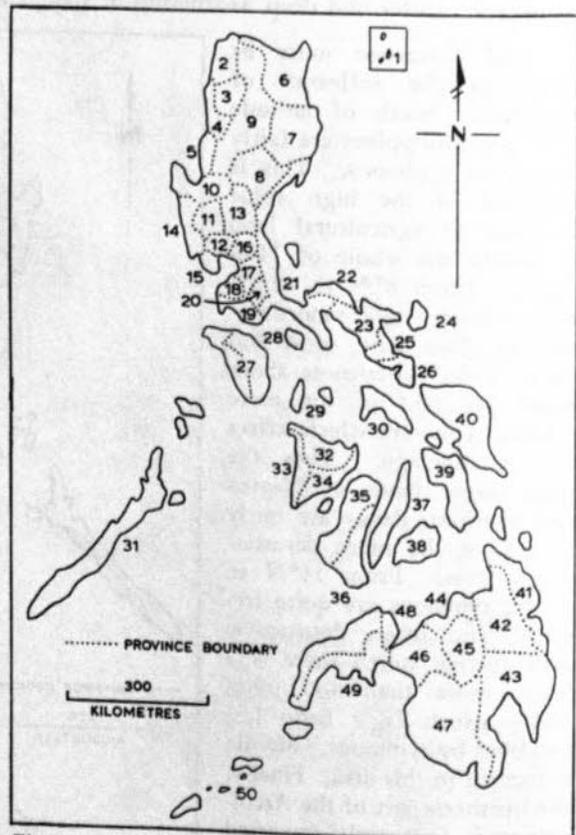


Fig. 3. Provinces of the Republic of the Philippines.

Figures 3 and 4 and Tables 1 and 2 show the progress made in such surveys by the end of 1961.

TABLE 1: PROVINCES WITH PUBLISHED SOIL SURVEYS

PROVINCE	SOIL REPORT NUMBER	YEAR PUBLISHED	AREA (Hectares)
	Technical Bulletin		
Bulacan	5	1935	264,440
Rizal	2	1936	208,570
Cavite	3	1937	128,860
Batangas	4	1938	308,580
Pampanga	5	1939	214,190
Tarlac	6	1940	304,230
Pangasinan	7	1940	523,380
Nueva Ecija	8	1941	549,170
Iloilo	9	1947	530,450
Laguna	10	1948	120,380
Bataan	11	1949	133,900
La Union	12	1950	137,290
Zambales	13	1951	364,560
Negros Occidental	14	1951	774,070
Bohol	15	1952	407,840
Davao	16	1953	1,949,900
Cebu	17	1954	486,850
Leyte	18	1954	798,690
Ilocos Sur	19	1954	268,540
Misamis Oriental	20	1954	391,680
Bukidnon	21	1955	803,840
Negros Oriental	26	1960	531,640
Palawan	27	1961	1,474,570
TOTAL			11,675,620

TABLE 2: PROVINCES WITH SOIL REPORTS READY FOR PRINTING

PROVINCE	AREA (Hectares)	PROVINCE	AREA (Hectares)
Abra	380,990	Ilocos Norte	338,680
Agusan	1,067,100	Isabela	1,053,990
Albay	256,230	Masbate	407,000
Antique	267,930	Marinduque	92,030
Batanes	19,760	Misamis Occidental	207,650
Cagayan	898,810	Nueva Vizcaya	680,390
Camarines Norte	214,660	Samar	1,375,100
Camarines Sur	533,610	Sorsogon	205,450
Capiz	441,010	Sulu	281,640
Akian		Zamboanga del Norte	1,687,920
Catanduanes	144,760	Zamboanga del Sur	
Cotabato	2,296,790		
TOTAL	6,521,650	TOTAL	6,329,850

Mindoro Occidental and Mindoro Oriental Provinces, totalling 1,007,790 hectares, were being surveyed in 1962. The total area covered by soil surveys is 24,527,120 hectares or 82.6 per cent of the Philippines.

TABLE 3: PROVINCES NOT SURVEYED BY 1962

PROVINCE	AREA (Hectares)	PROVINCE	AREA (Hectares)
Lanao del Norte } Lanao del Sur } Mountain Province	666,800 1,413,620	Quezon Romblon Surigao	1,195,660 132,700 797,580
TOTAL	2,080,420	TOTAL	2,125,940

Detailed soil surveys. Detailed soil surveys were started in 1939, and are undertaken only on special request. Their purpose is to give advice on the proper use of the land and to suggest better soil conservation methods. Such surveys employ plane tables to cover farms of up to 36,000 hectares, but it is intended to make greater use of aerial photographs in future. The scales of the finished maps range from 1:2,000 to 1:25,000. Soil samples are collected and analysed, and the farmers advised as to the amounts and types of fertilizer needed for the intended crops.

Semi-detailed soil surveys. These are undertaken for special purposes, such as dividing public lands prior to their alienation to farmers, or for forest reserves and wild life sanctuaries. Swampy areas are surveyed for possible conversion to fishponds.

Special investigations. Under this category 85,623.10 hectares have been surveyed to check soil types, and to determine the type of soil work required for development projects.

PARENT MATERIALS OF PHILIPPINE SOILS*

The Philippines are geologically very much younger than neighbouring islands. They are primarily volcanic, but Tertiary deposits of shale, sandstone and limestone exist, while small areas of metamorphic rocks are also found. The distribution of



Fig. 4. Progress in provincial soil surveys, 1961.

* Data as on 1 July 1959.

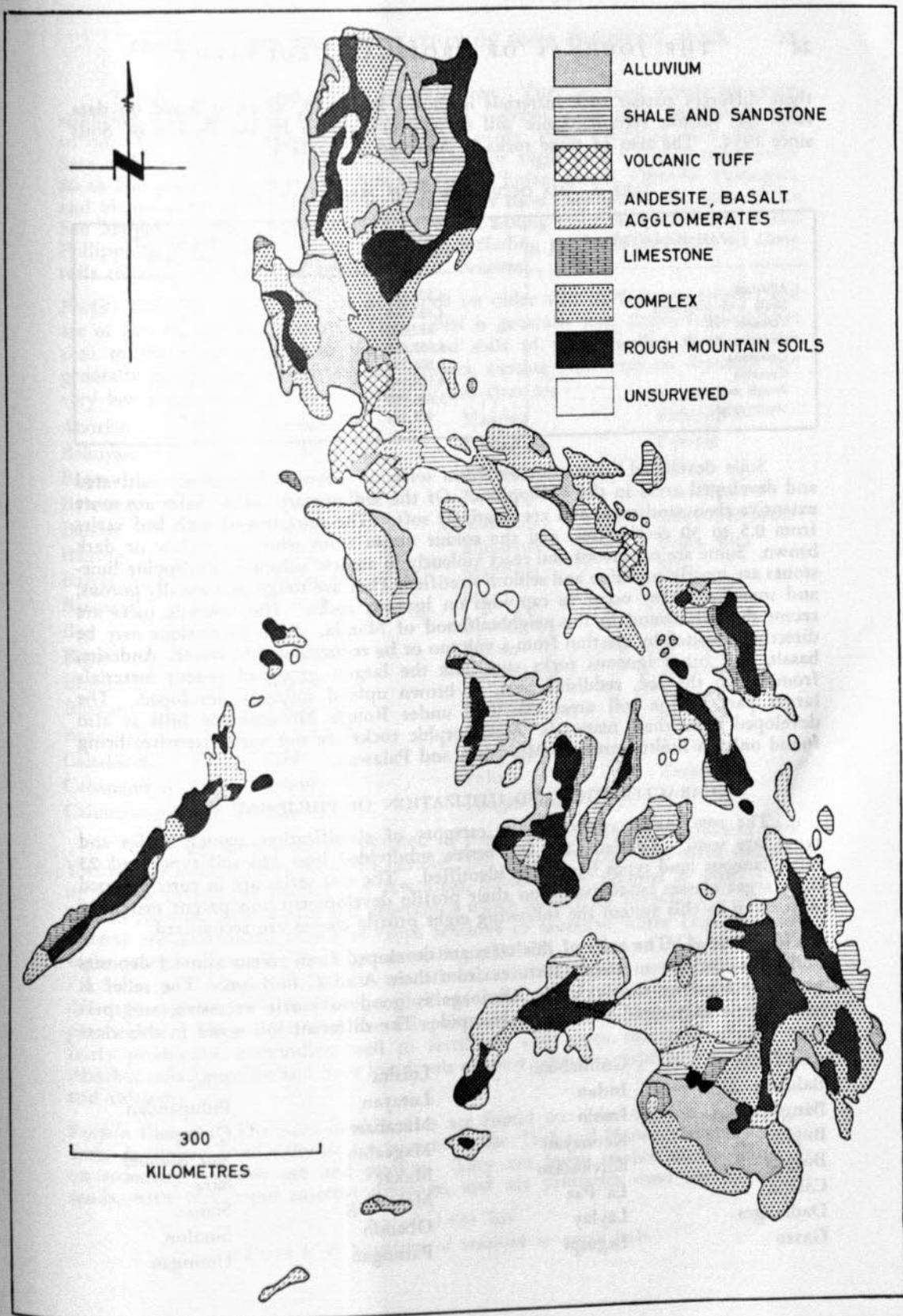


Fig. 5. Soil parent materials.

these different parent rock materials is shown in Fig. 5, which is based on data from the various reconnaissance soil surveys undertaken by the Bureau of Soils since 1934. The area of these rocks is indicated in Table 4.

TABLE 4: AREA OCCUPIED BY CHIEF PARENT MATERIALS

PARENT MATERIAL	AREA (Hectares)	PERCENTAGE OF TOTAL AREA
Alluvium	4,528,368	15
Shale and sandstone	4,435,025	15
Volcanic tuff	622,588	2
Andesite, basalt, agglomerates	6,158,296	21
Limestone	3,805,790	13
Complex	4,154,995	14
Rough mountain soils	5,626,952	19
Unsurveyed	409,276	1

Soils developed from alluvium form some of the most intensively cultivated and developed areas in the Philippines. Of the sedimentary rocks shales are more extensive than sandstone, and are relatively soft. The thickness of each bed varies from 0.5 to 30 centimetres, and the colour varies from white to yellow or dark brown. Some are calcareous and react violently in an acid solution. Philippine limestones are mostly coralline and seldom stratified. They are rough and usually porous, and sometimes they occur as cappings on igneous rocks. The volcanic tuffs are recent deposits found in the neighbourhood of Manila. Such formations may be directly deposited by ejection from a volcano or be redistributed in water. Andesite, basalt, and other igneous rocks constitute the largest group of parent materials from which the red, reddish-brown, or brown upland soils are developed. The larger part of the soil areas classified under Rough Mountainous hills is also developed from these materials. Metamorphic rocks are not very extensive, being found only in limited areas in Mindanao and Palawan.

CHARACTERISTICS AND UTILIZATION OF PHILIPPINE SOILS

The two lowest orders in the category of classification, namely series and types, are used. To date, 210 soil series, subdivided into 726 soil types and 23 miscellaneous land types have been identified. The soil series are in turn grouped into larger classes based partly on their profile development and parent materials. According to this system the following eight profile classes are recognized.

Profile Class A. The soils of this class are developed from recent alluvial deposits and have medium to coarse textures from their A to C horizons. The relief is generally level or nearly level. Drainage is good to partly excessive, and permeability is very rapid to moderately rapid. The different soil series in this class are:—

Angeles	Guintabuan	Luisita	Pilar
Baluarte	Indan	Lutayan	Pulupandan
Banga	Irosin	Macabare	Quingua
Bugko	Kaunayan	Magcalon	San Manuel
Buguey	Kitchararo	Makar	Sara
Calape	La Paz	Malandag	Siaton
Dadiangas	Laylay	Obando	Sinolon
Gasán	Legaspi	Patungan	Umingan

The fertility of these soils is generally low. They are used mostly for crops requiring good drainage, such as sugar cane, coconut, fruit trees, vegetables and so on. The Angeles, Guintabuan, La Paz, Luisita, Pilar, Quingua, San Manuel, Sara and Umingan series are extensively used for sugar cane. Yields range from 80 to 200 pikuls* per hectare, while the Gasan, Indan, Irosin, Obando, Patungan, and Siaton series are mostly under coconut. Of those mentioned, the soils of the San Manuel, Quingua and Umingan series are among the most productive in the Philippines, being used for many purposes, including padi. In addition, all these soils respond well to fertilizers and green manures.

Profile Class B. These soils are developed on older alluvial fans or terraces, and are of fine to very fine texture. Their relief is generally flat, slopes varying from zero to three per cent. The fine-textured soils of the B and C horizons are generally sticky, slightly plastic, and compact, causing poor internal drainage and very low permeability. The soil series in this class are:

Aborlan	Candaba	Maapag	Patnongon
Babuyan	Candijay	Mailag	Pawing
Bago	Catubig	Makato	Pili
Balongay	Dagami	Maligaya	San Fernando
Bancal	Dalican	Mambajao	Santa Filomena
Bantog	Dauin	Mandawe	Santa Rita
Barcelona	Dolongan	Marikina	Silay
Bascaran	Donsol	Matina	Silliman
Bay	Glan	Matuya-tuya	Sinapangan
Bigaa	Hernani	Mayan	Sorsogon
Brooke's	Isabela	Maydolong	Tamontaka
Buayan	Kabacan	Mogpog	Timaga
Busuanga	La Carlota	Malinao	Tingib
Cabahuan	Libi	Palapag	Toran
Cabangan	Libon	Palo	Zaragoza
Calumpang	Ligao	Panganiran	

Nearly all these soils are devoted to the culture of irrigated lowland padi. Yields vary widely from 30 to 60 cavans*, but with fertilizers the yield increases up to 180 cavans per hectare. A few areas, however, are planted to other crops, such as coconut, upland padi and vegetables, which require no irrigation. Drainage systems are constructed whenever crops sensitive to excessive water (e.g. corn and sugar cane) are planted. For sugar cane, Bago, Isabela, La Carlota, Mandawe, Santa Filomena and Silay soils, which are all located in Negros, are provided with drainage systems. Yields of sugar in these soils range from 100 to 250 pikuls per hectare. These soils, with the exception of the Bago and Aborlan series, are fairly productive, responding well to fertilizers and green manures. Bago and Aborlan soils are acidic and have low levels of most nutrients, especially phosphorus and calcium.

Profile Class C. The soils in this class are found on older terraces and upland areas developed from volcanic ejectamenta. The Taal and Tupi series are formed on sedentary volcanic ash and pumice. They are loose friable sandy loams to sands, with very rapid internal drainage, and are primarily used for vegetables

* 1 pikul = 63 kgs.

* Cavan is 43 kilograms of unmilled or rough padi.

and fruit trees. In contrast, the water-laid volcanic products are hard and compact; in some urban areas the bedrock is cut into blocks for building purposes. From this bedrock the soils of the Guadalupe, Prensa, Buenavista and Novaliches series are developed. These soils are of very fine texture, shallow, plastic and sticky. Such physical properties make them suitable for wet padi. However, they are of relatively low fertility and deficient in phosphorus.

The series in this class are:—

Buenavista	Guinobatan	Mayon	San Jose
Carmona	Ibaan	Novaliches	Taal
Casiguran	Langkong	Pasil	Tagaytay
Castilla	Lipa	Prensa	Tupi
Guadalupe	Magallanes	San Fabian	

These soils occur in flat to rolling country. Padi is usually planted on level or undulating areas. When cultivated with upland crops, they are very susceptible to erosion and their fertility is quickly lost. The Tagaytay, Carmona, Magallanes, Taal, Lipa and Tupi series have good drainage and are fairly productive. Their calcium and phosphorus levels are adequate, but Tupi soils are rather acidic and low in calcium. They are used for many kinds of crops, but more extensively for citrus, papayas, various kinds of fruit trees and pineapples.

Profile Class D. This large class of soils is found in upland areas of hard igneous rocks, such as andesite and basalt. They are deeply weathered, fairly friable and reddish-brown, dark brown or red in colour. Internal drainage is good and permeability is moderate. Relief is usually rolling to steeply rolling, terminating sharply at the foot of mountain ranges. Most of these soils are latosols with low to very low calcium content and rather acidic reactions; their phosphorus content is also very low and the rate of phosphorus fixation very high.

The undulating or rolling areas support good stands of abaca, coffee, coconut, cacao or rubber; steep slopes are partly forested, mainly by dipterocarps. These softwoods grow mostly on deep friable soils with plenty of available moisture. Uncultivated areas are occupied by grass and are frequently used for pastures.

The soils in this class are:

Adtuyon	Basco	Cauayan	Legua	Paete	Tapul
Alaminos	Bayho	Cervantes	Luisiana	Parang	Tarug
Annam	Boac	Dolores	Macolod	Sabtang	Tigaon
Antipolo	Bulaoen	Guimaras	Malitbog	San Rafael	Timbo
Arayat	Baldun	Guimbalaon	Maranlig	Sapian	Tugbok
Baguio	Burgos	Jasaan	Manapla	Sigcay	Uyugan
Balanacan	Cadiz	Kamandag	Mauraro	Tacloban	Victorias
Banto	Calauaig	Kidapawan	Miral	Tagburos	Zamboanguita
Barotac	Camiguin	La Castellana	Nupol	Tagum	

Profile Class E. In this class are soils of upland areas of rolling to hilly relief, derived from shales. The solum developed is from fifteen to sixty centimetres thick, of a fine texture, sticky and plastic when wet and hardening on drying. Permeability is very slow, causing excessive runoff, especially on cleared areas. They are generally infertile and most are under grass or forest. The Sevilla and Lugo series, formed on calcareous shales, are relatively productive. On moderate

slopes, corn, padi, coconut and some tobacco may be grown. The soils of this class are :—

Alimodian	Cabantian	Dohinob	Maasin	Palompon
Bani	Camansa	Himayangan	Madunga	Sevilla
Bantay	Carig	Kudarangan	Montalongan	Ubay
Bauang	Catbalogan	Lugo	New Iloilo	

Profile Class F. This class includes soils of the older terraces or uplands developed through the weathering of limestone. Relief ranges from undulating, especially in the lower terraces, to steeply rolling. The soils in this profile class are :—

Binangonan	Cataingan	Medellin
Bolinao	Faraon	Sibul

The average profile is shallow, ranging from twenty to forty centimetres in depth. The A and B horizons may alone be present, followed immediately by limestone bedrock. Soil textures range from clay to clay loam, and when undisturbed they are friable and of moderate permeability. Both rendzina (black or dark grey friable clay) and red terra rossa soils are developed from coralline limestone. Large amounts of limestone gravel and stones and even solid rock outcrops are present, making cultivation difficult. Coconut, corn, fruit trees and some root crops are characteristic. These soils also support *molave* (*Vitex parviflora*), one of the hardest of Philippine timbers, reflecting the general rule that hardwoods in the Philippines are located on shallow, infertile and relatively dry or rocky soils.

Profile Class G. These soils are developed from sandstone, occupying older terraces or upland areas where the relief ranges from undulating to hilly. They are generally of poor to medium fertility. The solum developed is sandy clay with a compacted B horizon. Runoff is excessive, particularly on rolling areas, and soil erosion is a serious problem. The natural vegetation consists mainly of various grasses with widely scattered patches of low trees of no commercial value.

The soil series in this class are :—

Aroman	Batuan	Ilagan	Lourdes	Quilada	Tarlac
Balut	Bulusan	Inabanga	Matulas	Rugao	Villar
Banhigan	Culis	Libertad	Nangka	San Juan	

Profile Class H. Soils of this class are found on upland areas developed from metamorphic rocks, such as chert, gneiss and schist. Relief varies from rolling to steep and mountainous. The solum developed is very shallow, usually about fifty centimetres in depth and is immediately underlain by bedrock. Since there is only a very thin soil layer for the absorption of soil moisture, runoff is excessive and soil erosion is severe even under natural vegetation. There are only two soil series in this class, Coron and Malalag. They are mostly under forest or grass, the latter being useless even as grazing, and little or no crop cultivation is undertaken. One of the hardest timbers, the iron tree (*Xanthostemon verdugonianus* Naves), grows on these soils.

LAND CAPABILITY CLASSIFICATION

With a view to indicating in a general way the optimum use of land in the Philippines, nine classes of land are recognized. Each is based on differing physical factors, such as soil characteristics (physical, chemical and biological), slope, erosion hazards, groundwater and drainage. Table 5 shows the nine classes,

TABLE 5: LAND CAPABILITY CLASSES IN THE PHILIPPINES

	CLASS	DESCRIPTION	AREA (Hectares)	
CROPLAND	A	Land that can be cultivated intensively without deterioration.	2,370,063	8,931,839
	B	Land that can be cultivated with simple conservational methods.	2,331,554	
	C	Moderately good land suitable for most crops, but needing careful cultivation.	2,540,715	
	D	Fairly good land that can be cropped occasionally, but has inherent drawbacks of slope or drainage.	1,689,507	
PASTURE AND FOREST LAND	L	Land too wet or stony for crops, but suitable for pasture or forestry.	53,390	10,631,192
	M	Land suitable for pasture or forestry only.	3,528,385	
	N	Land suitable for forestry rather than pasture.	7,049,417	
NON-AGRICULTURAL LAND	X	Land suitable for fishponds or mangroves.	383,074	453,049
	Y	Land suitable only for wild life reserves.	69,975	
TOTAL				20,016,080

the cultural methods suggested, and the total area occupied by each class for thirty-eight of the fifty-six provinces in the country. Four classes are recommended as suitable for crops, three for pasture or forests and two for non-agricultural purposes such as game reserves or fishponds.

Class A land is sufficiently level to eliminate erosion as a problem. The soils are deep and dark, and are usually fertile or capable of being made fertile under good management. They are usually derived from alluvials, varying in texture from silts to sands. No special agricultural methods are necessary other than those needed to maintain productive capacity, and a wide range of crops may be grown.

Class B is also good land that may be cropped subject to simple conservational controls. Some areas in this class are located on slopes and require erosion control measures; others may need drainage, and sandy soils should be provided with organic matter in order to retain soil moisture.

Class C is moderately good land suitable for most crops, but the inherent limitations of slope, drainage and texture are more severe than in *Class B*, so that greater care and expense are necessary.

Class D land may be cropped occasionally under careful management, but over a large area the slopes are too steep for regular cultivation, and other areas are handicapped by seasonal aridity or sandy soils. In general, land of this class is better under pasture, or woodland where rainfall is adequate.

Class L has deep soils and level topography, but it is unsuitable for cultivation because of poor drainage, rock outcrops or unfavourable climatic conditions. Under good management this land is suitable for grazing or forestry.

Class M land is limited in its use by steep slopes or shallow soils. Grazing and forestry are possible with careful management. In addition, much of this class lies in areas with a marked dry season, where water for irrigation is in short supply.

Class N covers land which is steeper and rougher than *Class M*, and in places it is severely eroded. It also includes limited areas of deep loose sands. Both environments are near-marginal even for grass or forestry.

Class X includes the mangrove and freshwater swamps and other permanently wet areas that cannot be drained. This land may be utilized only for fishponds, sources of firewood or wild life reserves.

Class Y land is totally unsuited to agriculture, pasture or forestry, comprising highly eroded, rough, steep or stony ground, bare rock outcrops and coastal sand dunes. Such land may be used for natural parks, game reserves or as catchments.

THE OLDER ALLUVIUM OF JOHORE AND SINGAPORE

By C. K. BURTON

THE UNCONSOLIDATED clays, sands and gravels known as 'High Level' or 'Older Alluvium', form low hills in Johore and Singapore. These and related formations in other parts of Malaya range from 150 feet below to at least 230 feet above sea level, and were possibly deposited in an early Pleistocene sea standing about 250 feet above the present sea level. This paper reviews past work on the subject and gives some details of the lithology, structure, weathering, distribution, and geological relationships of the Johore and Singapore outcrops, using data obtained from nearly four and a half years of field work there. Further support for an early Pleistocene sea level at approximately 250 feet in Malaya and other parts of the world is discussed.

PREVIOUS WORK

The first published reference to these formations appears to have been made by Scrivenor, who in 1924 reported sand and clay hills between 50 and 100 feet high in the eastern part of Singapore Island (1a). He called these poorly consolidated sediments 'High Level Alluvium', because they were aggraded well above the Recent alluvials of the valleys and coastal flats. He also suggested that they might be old terraces of the Johore River, and G. R. Fulton, in an unpublished report of the Geological Survey, applied the term to similar formations in Johore State. Willbourn also used the same term in 1928, when he gave a brief account of the variable lithology in the formation, and suggested that it was fairly widespread in Johore even though exposures are relatively uncommon (2a). After 1928, Scrivenor continued to refer to these deposits (3, 4, 5) but no new information became available until 1950, when Mrs. Alexander elaborated on Scrivenor's description of the Singapore rocks (6a). She found that although the deposits extend to over 100 feet above present sea level, their base lies well below sea level. The term 'High Level' was therefore deemed inappropriate. She also had reservations about the validity of the term 'alluvium', but finally retained it, renaming the formation the 'Older Alluvium'. This change was adopted by the Malayan Geological Survey in 1954; the Director at that time deciding '... to discard the name High Level Alluvium in favour of Older Alluvium for all alluvial deposits in areas of Malaya where they can be distinguished from the more recent deposits' (7). A further note on the lithology and weathering of the Older Alluvium is found in a later publication by Mrs. Alexander (8a).

LITHOLOGY OF THE OLDER ALLUVIUM

Geologically, Johore and Singapore consist of a series of flysch-like Upper Triassic sandstones, shales and intercalated acid intermediate volcanics, intruded in later (Jurassic?) times by a granitic complex. All of these rocks have contributed, in varying proportions, material to the Older Alluvium whose lithological variability has been noted by both Willbourn and Alexander (2, 6). Because the formation is more often found in granite country there is an emphasis on the plutonic rather than the sedimentary source rocks. Thus the most common member of the Older Alluvium, a coarse felspathic sand or sandy clay with occasional rounded phenoclasts, closely resembles weathered granite in appearance. Its

phenoclasts include granite, granite porphyry, aplite, alaskite, vein quartz and quartz-tourmaline vein rock, conglomerate, various sandstones, quartzite, siltstone, shale, carbonaceous shale, hornfels, rhyodacite and crystal-lithic tuff. Heavy minerals also reflect the granitic provenance. Scrivenor (1) and Alexander (6) record staurolite, magnetite, ilmenite, zircon, cassiterite and monazite, in addition to which the writer has often seen topaz, tourmaline, pyrite, anatase and sphalerite.

Boulders in the Older Alluvium rarely exceed 12 inches in diameter, and are normally well rounded. Pebbles are often quite rounded, whilst granules and sand grains are as frequently angular (although on occasions they too are rounded or sub-rounded).

Bedding is often massive when sandy types predominate, but a thinly bedded succession of different lithological types is not uncommon. Current bedding occurs in some exposures, and graded or lenticular types of bedding are also known. Generally the formation as a whole is horizontal, dips rarely exceeding 15°. The depth of weathering and paucity of exposures prevent a detailed picture of the structure being obtained, but shallow anticlines and monoclines have been observed in several localities. When current-bedded, the strata may show a few degrees of original dip. In some areas, however, small but tight folds occur, with steeply inclined or even vertical beds over a distance of a few feet. Minor faulting, including step faulting, with displacements varying from a few inches to a few feet, is often associated with such folding. The largest observed fault is found in an exposure behind the English College in Johore Bahru, where a throw of 15 or 20 feet accompanied by drag folds was noted. Finally, an imperfect and rather massive type of block jointing is sometimes developed in those beds of the Older Alluvium which contain a high proportion of clay.

The Older Alluvium appears normally to be semi-consolidated, although Alexander stated categorically that '.....it is exceedingly hard' (8a). Some fresh exposures near Kampong Eunon in Singapore yield quite hard rock, but other samples from the same neighbourhood are rather soft, and it has not been established that the formation as a whole is uniformly hard when fresh.

However, the upper parts of the formation, from 2 to 10 feet below the surface, are almost always weathered and stained with ferric oxides. The colour of this zone is reddish-yellow or brownish-yellow, and the textures are usually sandy clay or clayey sand. Here the ferro-magnesian minerals have been destroyed, the feldspars altered to kaolin, and the quartz has probably undergone some solution; local reduction and/or eluviation, working along joints and roots, has sometimes produced veins and rod-shaped masses of pale-coloured materials.

This weathered zone may pass downwards fairly abruptly into a non-stained zone of partial staining or mottling, where the white, cream or pale grey colour of the fresh material is variegated by patches of red, pink, brown, purple and yellow that are normally associated with a fluctuating watertable. In extreme cases, this mottled zone may be 15 feet thick, and W.P. Panton in a personal communication to the author has suggested that it is unusual and possibly of diagnostic significance that the mottles are often in the form of elongated vertical streaks. The downward decrease in iron-staining is accompanied by a decrease in kaolinization of feldspars.

Normally the mottled zone merges gradually into uncoloured Older Alluvium, but the passage may be interrupted, retarded or partially repeated, particularly in

a thinly bedded formation, where the weathering processes work at different rates in different rock types. The overall effect of weathering, however, is to eliminate variations and promote uniformity. Bedding, faults, and other structural features besides lithological changes are largely obliterated in the upper stained zone; thus clay with sandy partings was seen to pass laterally into homogenous sandy clay in a pit near Layang Layang. However, well developed and persistent lithological features cannot be obscured by weathering. For example, an extensive clay bed at Pandan, 5 miles north of Johore Bahru, and a boulder bed near Tampoi, 4 miles north-west of Johore Bahru, are unequivocally expressed at the surface.

Weathered Older Alluvium is also characterized by a modest development of ferricrete within the stained zone, ranging from small discrete concretions averaging 0.4 to 0.8 inches in diameter to continuous layers of similar thickness; horizons of 12 inches are rarely attained. The attitude of these horizons is often demonstrably controlled by the original bedding of the Older Alluvium, and to a lesser extent by faults and joints, but elsewhere these horizons are parallel to the surface. In one instance, the abrupt U-shape of a ferricrete bed obviously describes a transverse section of a former stream. Occasionally concretions of iron oxides are found in the mottled zone. In the more clayey phases of the formation, numerous small gibbsite concretions occur. Concretions of MnO_2 are also recorded.

Another secondary feature of weathered Older Alluvium (and, incidentally, of weathered shale and quartzite in this area) consists of tabular layers of pebbles at depths varying from several inches to 10 feet (in an extreme example). These are aligned approximately parallel to the ground surface, and comprise broken pieces of ferricrete, rounded concretions of bauxite and ferricrete, and quartz and phenoclasts from the Older Alluvium. These layers appear to correspond to the carpedoliths of southern and central U.S.A., which are considered to be former surface aggregates buried by sheet wash and colluvials (9a, 10). These stone layers in south Johore correspond closely to the linear carpedoliths of the upper Georgia piedmont described by Parizek and Woodruff (9b), differing from them only in being formed mainly of ferricrete.

Mrs. Alexander described an early and not necessarily typical phase of weathering of the Older Alluvium, which on beaches 'has the curious property of being quite hard where it is undisturbed and out of reach of the air and rain water, but of weathering rapidly (in a few days) to unconsolidated gravel where it is exposed to the atmosphere' (6b). Elsewhere she relates that when the hard rock was broken by blasting for an airstrip the blocks crumbled to loose sand and gravel in two or three days. She suggested that this unique behaviour might be attributed to a cement of silica (8a).

The soils developed from Older Alluvium appear to be deficient in manganese; this deficiency has been noted by Panton and J. Bolton (in personal communications to the author) in a number of rubber estates in south Johore, all of which appear to be located within the Older Alluvial basin. That it is not due to the long history of exhaustive cropping to pineapples and gambier is shown by the fact that manganese deficiencies have also developed in rubber planted immediately after felling of virgin rainforest. In addition, the writer considers that surface morphology (dissected terrace of graduation plane) may be the crucial factor here, since it is upon this that the height of the watertable and the processes of eluviation depend. It is significant that on one estate studied, manganese deficiencies almost certainly extend from the Older Alluvium to granite country without change in the landforms.

TOPOGRAPHY AND DRAINAGE

The movement of groundwater, particularly in weathered Older Alluvium containing a high proportion of clay, is often very slow (11). In the more stratified formations, however, groundwater movement is considerable. In Singapore, engineers have found that the formation is saturated from a depth of 10 feet downwards (11a), and shallow wells in the Johore Bahru area seldom dry up completely.

At Majeedi, four miles north of Johore Bahru, the surface of the Older Alluvium exhibits a number of circular or oval depressions, 4 to 18 feet long and 3 to 9 feet deep. They normally occur on sloping ground, being deeper on the downhill side, and on the site of, or a short distance above, the source of a spring or stream. These depressions appear to result from the collapse of rock consequent upon undermining by subterranean water movement. Many streams in the Older Alluvium appear to have originated from such underground drainage, later appearing at the surface through collapse of the overlying strata, which may account for rapid headward sapping and for the formation of steep to vertical valley heads.

The poor resistance to erosion of the Older Alluvium results in rapid trenching by rivers, which cut deep, steep-sided, flat-bottomed valleys. Subaerial erosion produces low rounded hills, often with concordant summits. The lowering of the surface is sometimes halted temporarily when one of the ferricrete horizons is exposed, but as soon as it is undermined erosion resumes its rapid progress.

The top of the formation in Singapore is 50 to 100 feet above sea level. In Johore, however, the highest exposure lies at about 230 feet, the average height ranging from 100 to 200 feet; evidence will be mentioned later in this paper which suggests that the deposit may have been aggraded up to 200 feet or more *above* this level. Below 50 feet, the Older Alluvium is often overlain with Recent or Sub-Recent material. Owing to low elevation and subdued relief, exposures are uncommon, and even the best sections found in artificial cuttings rapidly deliquesce by weathering and erosion or are hidden by the growth of vegetation.

IDENTIFICATION OF THE OLDER ALLUVIUM

The distinction between the Older Alluvium and other geological formations is based on a number of field criteria. It can be differentiated from Recent alluvials on topographic grounds, as the low hills typical of the formation contrast markedly with the low-lying and flat relief of Recent deposits (1b). In addition, the younger alluvials are usually uncompacted and incoherent, with more pore space and higher moisture contents than the partly lithified Older Alluvium. Finally, the Recent material normally lacks the well developed weathering zones, concretions and occasional fine-bedding of the Older Alluvium.

The differentiation between the Older Alluvium and granite and granitic regoliths is much more difficult, since both weather into similar residues and related landforms. Field experience shows that the following criteria, in decreasing order of importance, distinguish the Older Alluvium from granites:—

- (i) The presence of phenoclasts, usually of quartz or quartzite, in the Older Alluvium.
- (ii) Rounding of the constituents, particularly the phenoclasts.
- (iii) Stratification and other sedimentary structures.

- (iv) Presence of lignitized vegetable matter (which, however, may be confused with decaying roots of modern vegetation).
- (v) Absence of veins. This is not absolutely reliable, as Alexander believes quartz veins to be forming in weathered materials today (8b), and the writer has met two examples of what might be weathered quartz veins in Older Alluvium.
- (vi) The absence of typical Older Alluvium above 230 feet; such boulder beds as are referred to this formation later (and which occur above this height) cannot possibly be confused with granite.
- (vii) The Older Alluvium contains very little mica.

In addition to these diagnostic features, Panton, in a personal communication to the author has suggested others, such as the presence of laterite; the greater susceptibility of Older Alluvium to erosion; the development of lighter yellow or almost white colours in the lower horizons of the developed soils in contrast to the pale red colours common in sedentary granitic soils; the presence of reddish mottling, often aligned in vertical streaks in the lower horizons; the pronounced prismatic blocky structure in contrast to the compact, rather structureless appearance of sedentary granitic soils; and the very loose consistency and friable nature of the upper horizons in contrast to the finer subangular blocky or crumb structure characteristic of sedentary granitic soils. Of these criteria, there are grounds for thinking that laterite is more common in Older Alluvium because of its heavier textures, banding and poorer drainage as compared with granitic soils. However, laterite does occur in granite soils, as Panton himself concedes (12). This, together with the occasional presence of vertical mottling in granitic profiles, reduces the usefulness of soil criteria as distinguishing factors.

The features which distinguish the Older Alluvium from Triassic sediments are as follows:—

- (i) Flat to gentle dips as against moderate to steep inclinations in the Triassic rocks. In addition, the Older Alluvium has no consistent strike, while the Triassic rocks strike more or less uniformly north-west to south-east.
- (ii) The only volcanic material is in the form of derived pebbles, while that in Triassic rocks is commonly intercalated lava and tuff.
- (iii) Lesser degree of induration and jointing.
- (iv) Absence of veins.
- (v) Presence of derived granitic material, particularly phenoclasts, in contrast to Triassic sediments, which in only six Malayan localities are known to carry granite pebbles.

DISTRIBUTION AND EXTENT OF OLDER ALLUVIUM

In Johore and Singapore the Older Alluvium seems to have been laid down in three separate basins. Detailed mapping shows that the outcrops in eastern Singapore and around Johore Bahru on the mainland cover forty-nine and seventy-three square miles respectively (Fig. 1). Reconnaissance mapping further east suggests that the same deposits extend from the Johore Bahru area along the Johore Strait, and up the west bank of the Sungei Johor beyond Kota Tinggi, some 20 miles inland (2b). Older Alluvium may also exist around Lombong in the Sungei Panti valley tributary to the Sungei Johor (locality 1, Fig. 1). The second basin in the low-lying region of central Johore is probably just as extensive

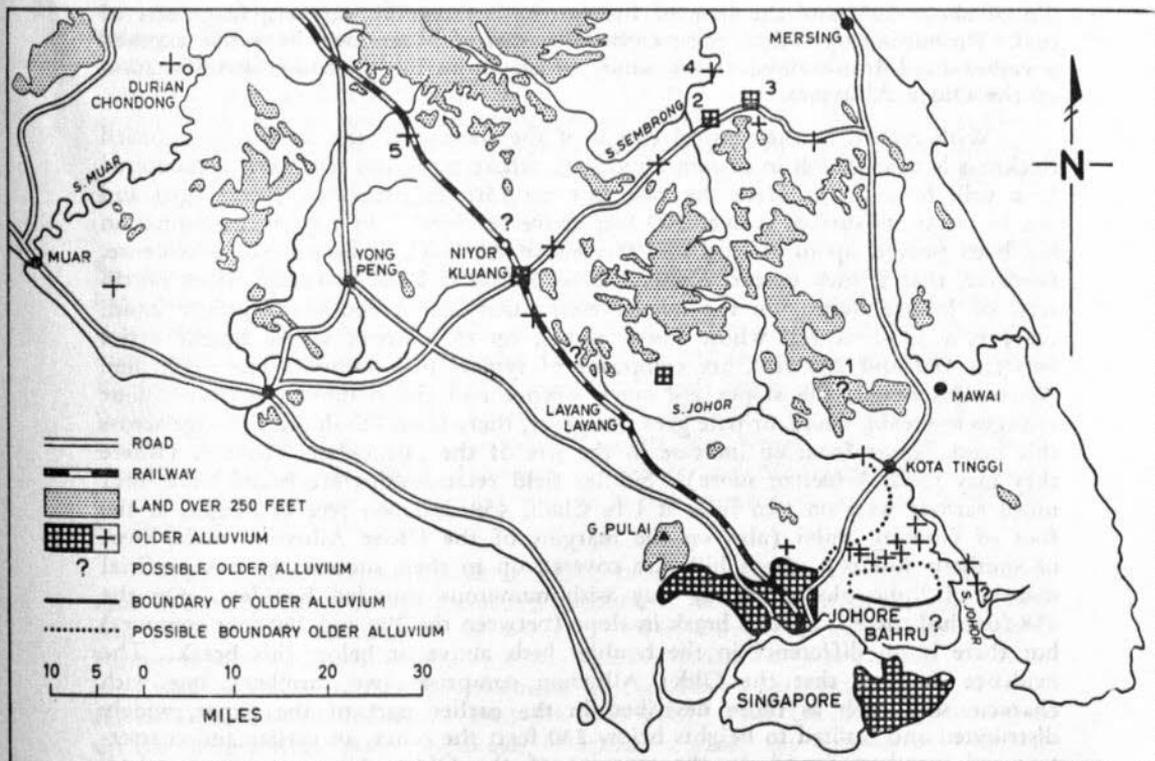


Fig. 1. Distribution of the Older Alluvium in Johore and Singapore.

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as the first. Older Alluvium is abundant around Kluang town, where it rises to 160 feet above sea level, and on the Kluang-Mersing road (localities 2 and 3). Further outcrops are found on the Sungei Sembrong (locality 4) and on the railway line (locality 5) between Bekok and Paloh (2c). Clayey sands and sandy clays of obvious granitic provenance and with slight indications of bedding occur near Layang Layang. This material, apart from the absence of rounded phenoclasts, is virtually identical to typical Older Alluvium, and occurs at least up to 200, possibly up to 250, feet above sea level. Underneath is a grey or grey-brown partly consolidated clay that has been referred to the Upper Tertiary on the grounds of lithological similarity to coal-bearing clay shales at Niyor and Durian Chondong. Well preserved plant remains are found in this rock, which D. Walker considers (in a personal communication) to be of Quaternary age. It is not yet certain whether or not the Layang Layang clay shale is an integral part of the Older Alluvium. Notwithstanding, it seems clear that the sands and clays above it are Older Alluvium. Its extent is probably considerable but it is difficult to define, owing to low relief, deep weathering, and dense forest cover. A similar clay shale is also exposed in a railway cutting south of Niyor, dipping at 10° to 15° , it also contains plant fossils similar to those at Layang Layang. The third Older Alluvial basin of Johore, which may in fact be continuous with the second, lies in the Muar River valley. At Durian Chondong, coal-bearing strata of possibly Upper Tertiary age (13) are overlain unconformably by Older Alluvium rising to at least 206 feet above sea level. Both the alluvium and the coal measures have a westerly

dip of about 20°, and the base of the former is irregular, carrying fragments of coal. Tin mining operations some eight miles east of Muar town have also exposed a rather hard iron-stained clayey sand, which is probably another manifestation of the Older Alluvium.

With regard to the vertical extent of the formation, the maximum recorded thickness is near Bedok in eastern Singapore, where some 180 feet were encountered in a drill hole (14). Here the base is some 150 feet below sea level (10) and not far away its surface is over 100 feet above sea level. In Johore the formation has been proved up to at least 230 feet above sea level. There is some evidence, however, that it may extend higher. Near Kangkar Pulai, fourteen miles north-west of Johore Bahru, on the north-western margins of the south Johore basin, there is a 343-foot hill whose lower slopes, up to a break whose height varies between 180 and 230 feet, are composed of typical iron-stained Older Alluvium. Above this height the slopes are much steeper and the dominant surface colour changes to cream, white, or pale grey. However, there is no lithological change across this break, apart from an increase in the size of the phenoclasts above it (where they may reach 3 feet or more). Similar field relationships are found some four miles further west on two hills at Ulu Choh, 458 and 363 feet in height, at the foot of Gunong Pulai (also on the margins of the Older Alluvium embayment of southern Johore). Both hills are covered up to their summits by a superficial mantle of light-coloured sandy clay with numerous rounded boulders. On the 458-foot hill there is again a break in slope (between the 200 and 250-foot contours) but there is no difference in the boulder beds above or below this break. The evidence suggests that the Older Alluvium comprises two members, one with characteristics such as those described in the earlier part of the paper, widely distributed and limited to heights below 230 feet; the other, an earlier and coarser-textured member, found on the margins of the Older Alluvium *sensu stricto*, but which is aggraded to higher levels.

The junction of the Older Alluvium with country rocks is usually uneven. The actual boundary is rarely visible and is almost impossible to pinpoint, since there is often no lithological break between the Older Alluvium and the weathered mantle of neighbouring and underlying rocks. Willbourn saw the margin in only one locality, where the Older Alluvium exhibits a vertical, faulted contact against granite (2d). In eastern Singapore, Mrs. Alexander describes tongues of Older Alluvium extending up granite valleys, and Older Alluvium beaches resting against vertical granitic cliffs (6c). The writer has seen only one boundary, where a pebble bed rests on a buried hill of gabbro.

THE OLDER ALLUVIUM IN MALAYA

Willbourn (2b) and Scrivenor (15) believed that the Older Alluvium might be correlated with the poorly consolidated Gopeng Beds of the Kinta tin-field in Perak. The Gopeng Beds, Western Boulder Clays (16) and Tekka Clays (17) of this area were grouped under the name 'Boulder Beds' by Walker, who shows that they form discontinuous strips along the valleys and fill in small valley heads. Contemporaneous with or slightly younger than the Boulder Beds are the sandy clays with sand and gravel laminae, or 'Old Alluvium' deposits, which occupy the main valleys (18a). Both the Boulder Beds and the 'Old Alluvium' resemble the Older Alluvium of southern Malaya in lithology, structure and surface expression. In addition, the Kinta 'Old Alluvium' is 'aggraded up to about 230 feet above M.S.L.' (18b). The highest points of aggradation are concordant and correspond with a horizontal terrace which may be cut in Boulder Beds or solid rock all the

way down the valleys. This obviously accords very closely with the position in Johore. However, it has not yet been proved that two separate rock groups occur there, although the morphology near Kangkar Pulau suggests that this may be so. Nor is it quite certain that the bulk of the Older Alluvium has been graded *up* to the 230-foot level rather than eroded *down* to this height. Elsewhere in Perak, Panton (personal communication) has noted what he considers to be Older Alluvium around Tapah, Bidor and Sungkai, extending up to 200 or 250 feet above sea level. The writer has confirmed these observations.

In Selangor, Tertiary coal measures at Batu Arang are unconformably overlain by unconsolidated Boulder Beds, generally undisturbed and horizontal, but with local minor faults and dips up to 40° (19). A thickness of more than 1,000 feet is attained by these Boulder Beds in the centre of the basin, and the geological map indicates that their highest surveyed point is 397 feet above sea level. These Boulder Beds have been tentatively correlated with those at Kangkar Pulau by Willbourn (19a) and with the Kinta valley Boulder Beds by Walker (18c). At Kajang, some 15 miles south of Kuala Lumpur, the writer has noted alluvium closely resembling the Older Alluvium of Johore and Singapore; this exposure in a tin mine showed boulders of this rock incorporated in a younger alluvial horizon.

Between the thirteenth and sixteenth milestones on the Kuala Lipis-Benta road in Pahang State, Savage identified 'incoherent but graded beds of sand, gravel and pebbles... at an altitude of about 250 feet above present sea level' (20). Panton reports (personal communication) that his field surveys in Pahang '... indicate very extensive terrace development in the Maran-Temerloh region, but as far as I can see all are below your 230-foot limit. One exception, however, is up the Sungei Klau valley south-east of Raub... where the terraces over several hundred acres are at about 300+ feet level'.

Further field work will undoubtedly reveal other areas of Older Alluvium in Malaya. However, it may be that occurrences have been overlooked or wrongly identified hitherto, owing to their unconsolidated nature and restriction to low ground where extreme developments of eluvium and colluvium are the rule, and because of their resemblance to weathered phases of older rocks.

EVOLUTION OF THE OLDER ALLUVIUM

Mrs. Alexander thought that the Older Alluvium in Singapore represents 'a mixture of the characteristics of shallow-water marine deposits and river deposits and it is probable that they were laid down in a wide tidal estuary' (6d). In support she drew attention to the existence of two beaches and of irregular lenticular clay seams which apparently represent infilled meanders or tidal-scoured channels. The current bedding, graded bedding, plant remains, and marine fossils such as echinoid spines and possible otoliths, also point to an estuarine or littoral marine environment in southern Johore.

Mrs. Alexander also stated that deposition commenced when the land stood much higher than it does today, and ended when it was much lower (6c); this assumes a constant sea level which is rather unlikely, since we appear to be dealing with the Quaternary era, in which glacio-eustatism was a continuing process. However, it may be that absolute movement of the land was a contributory, if not major, factor. It has been noted above that the base of the formation is apparently at about 150 feet below the present sea level. This corresponds closely with the altimetric position of the Sunda Shelf, some 130 to 150 feet (seldom more than

165 feet) below the Java Sea (21). This Sunda Land peneplain was probably at or near sea level at the end of the Pliocene (22, 23). To this apparent depression of 150 feet must be added an overall decline of sea level during the Quaternary of about 300 feet or more, indicating a net (relative) subsidence of the Sunda surface of at least 450 feet (24a). Since the Pleistocene decline of sea level is supposed to have been continuous (25), Sunda Land must have subsided at an early stage to allow the accumulation of a minimum of 380 feet of sediments on its (Pliocene) surface (Fig. 2). For the same reason the deposition of the Older Alluvium must have taken place fairly early in the era to allow aggradation up to some 230 feet above present sea level. An early subsidence of Sunda Land would also 'dampen' the effect of the depressed glacial sea levels and, to some extent, account for the fact that its surface was apparently but little modified in the glacial stages.

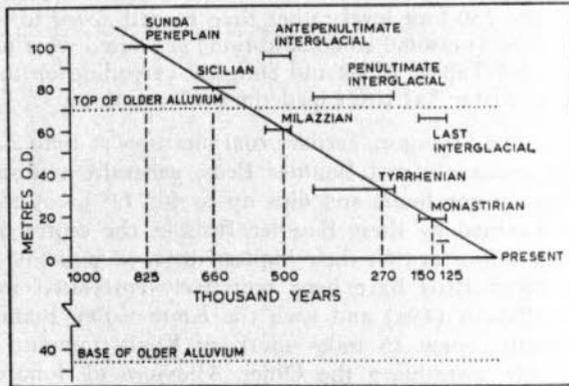


Fig. 2. Diagram showing the relation of altitude to time for the high sea levels of the Pleistocene. The horizontals representing the Monastrian, Tyrrhenian and Milazzian levels have the length of the corresponding interglacials on the time scale. (Adapted from Zeuner (24b).

The Boulder Beds at Kangkar Pulai, referred to above, may represent either a discrete early stage in the deposition of the Older Alluvium or, less probably, a final phase of a period of sedimentation. In the former case, they may be torrential fanglomerates, not necessarily indicative of the position of the contemporary sea level, which, delimited by the Older Alluvium *sensu stricto*, probably lay near the present 250-foot contour. Alternatively, if the Boulder Beds follow conformably above the Older Alluvium proper, the degree of inundation must have been more severe, and the extensive 250-foot level would then be related to a stillstand during regression from a higher level, or to a subsequent ingressions.

The Older Alluvium is not, of course, always present below 250 feet. A sea level 250 feet higher than the present would flood about 80 per cent of Johore State, and would in places erode rather than deposit. This higher base level acted as a plane up to which the Older Alluvium was deposited, and down to which the more ancient exposed rocks were eroded.

The break in slope between 50 and 75 feet indicated by R. Ho (in a personal communication) in his hypsometric analysis of Singapore doubtless relates to a temporary stand of a Pleistocene sea regressing from the 230-foot level. To this level may be attributed the loose, virtually unconsolidated but occasionally podsolized sand found in many places around Johore Bahru and which is aggraded up to the 50-foot contour. This sand is manifestly derived from the Older Alluvium. The same formation forms a terrace just above 50 feet some 30 miles distant near Mawai in Kota Tinggi District. The carpedoliths described above may, in this sequence of events, have originated during a period of lowered sea levels, when extreme dissection by rejuvenated streams produced extensive surfaces carpeted with stones. This was followed by a period of relatively higher sea levels, when

the deposits were buried by alluvials. These events almost certainly occurred subsequent to the high level at 230 feet, but they cannot yet be related to lower breaks of slope.

The literature includes a number of references to terraces, benches, and similar surfaces at about 250 feet in various parts of the world. In west Sarawak Allen mentions uplifted levels between 200 and 350 feet (26), from which Fitch singles out a wave-eroded platform at 250 feet in the Tanjong Datu area (27). G.E. Wilford (personal communication), doubts the existence of this level. Wilford also describes a sand-covered terrace at 260 feet above sea level from Miri in east Sarawak, but advises caution in attempting correlations with Pleistocene levels in view of late Quaternary warping (28). Berry reports a surface at 230 feet in Hong Kong '... believed to have evolved from a gently sloping wave-cut platform of which only remnants remain' (29). In the Australian area Zeuner records that Tindale noted a level at 250 feet in south-east South Australia, and Gill mentions surfaces ranging from 240 to 270 feet in Tasmania (24, 30). Levels of this height are mentioned by Cooke, Mabbut and Hey for Cape Province, Good Hope and Cyrenaica respectively, and in the Hawaiian Islands Stearns has studied the Olowalu shoreline at 260+ feet altitude (31, 32, 33, 34). Along the Atlantic seaboard of the United States, Pleistocene terraces rise to 215 and 263 feet (31); and Davies includes, among his many Irish erosion surfaces, one at 260-280 feet (35). Zeuner's worldwide survey of Pleistocene sea levels suggests that while the classical Sicilian lies at 328 feet (100 metres), in many parts of the world somewhat lower heights, between 262 and 328 feet (80-100 metres), are the rule; these lower heights are indicated in Figure 2 (36, 24b). Considerably more work will have to be done before it can be determined whether or not all the above levels around 250 feet are contemporaneous. Their very existence, however, does suggest that the approximately 250-foot stand of the Older Alluvium sea *may* be eustatic in nature.

AGE OF THE OLDER ALLUVIUM

Fossils in the Older Alluvium are rare and undiagnostic. Fragments of lignitized wood and rounded pieces of damar have been found in several places. Fossil logs in the formation at Tanjong Penyabong, near the eastern bank of the Johore River estuary, were identified in the Singapore Botanic Gardens as 'dicotyledonous wood, representative of the flora of recent times' (2a). Micro-palaeontological research has revealed a few shell fragments, echinoid spines and doubtful otoliths.

The lithological character of the Older Alluvium indicates that it is not of very great age. Its stratigraphical relationship to other rocks in Malaya, together with the fact that it was apparently deposited on the Sunda peneplain, points to a Quaternary (or at most a late Pliocene) date, to be related to a (eustatic) high sea level of about 250 feet. Workers who have recorded ancient shorelines and surfaces at this altitude have rarely assigned ages to them. An exception is Cooke, who tentatively dates his 265-foot terrace as pre-Nebraskan and that at 215 feet as Aftonian (31). Doering, however, has contested the reality of these shorelines (37).

The 250-foot (76 metre) sea level of Malaya falls between the Sicilian (295 to 330 feet, 90 to 100 metres) and Milazzian (180 to 200 feet, 55 to 60 metres) levels of Deperet's classification of four major terraces in the Mediterranean and Atlantic (36). This discrepancy may be due, according to Zeuner, to the presence of several Sicilian shorelines, the lowest of which at 262 feet (80 metres) is shown to date immediately before the glacial age (24a); this is supported by Cooke's own

dating scale (31). Arambourg offers a different explanation for those levels which do not coincide with Deperet's data (38). Apparent lowering of the ocean throughout the Quaternary (on which eustatic changes of sea level would have been superimposed) may be explained by progressive isostatic compensation. Arambourg calculates that, on an average, 360 feet (110 metres) are eroded from the continents every million years, causing isostatic uplift of some 295 feet (90 metres), thus accounting for the Sicilian levels at 295 to 330 feet (90 to 100 metres) early in the Pleistocene era. He adds, 'Mais il est évident que la valeur et la vitesse de l'usure des surfaces continentales par l'érosion sont essentiellement variables et dépendent du climat, de la latitude et surtout du relief' (38). As Malaya has a tropical climate, the rate of erosion and of consequent isostatic compensation may well be above that suggested by Arambourg, so that the 250-foot level may represent the Milazzian of First Interglacial age or an even lower terrace (24, 25). The Old Alluvium of Perak, almost certainly homologous with that of southern Malaya, has been considered to be of First Interglacial age by Walker (18c), and is correlated with Smit Sibinga's earliest and highest interglacial alluvia in Indonesia, which lie from 230 to 330 feet (70 to 100 metres) above river levels (39, 40). Smit Sibinga's chronology has, however, been criticised by van Bemmelen (41) and Rutten (42).

The evidence suggests that the Older Alluvium is related to a 250-foot sea level of pre-glacial or First Interglacial (Gunz-Mindel or Aftonian) age; this is Lower Pleistocene, but it is not impossible that the formation may date even further back to the late Pliocene.

ACKNOWLEDGEMENTS

The writer is indebted to Mr. W. P. Panton, Senior Soil Scientist of the Malayan Department of Agriculture, for valuable information and useful discussion on topics dealt with in this paper, especially those concerning weathering and soil formation. Thanks are due to the following for their observations: Dr. G. E. Wilford, Geological Survey, Brunei; Professor R. Ho, University of Malaya; Mr. C. R. Jones, Geological Survey, Malaya; and Mr. J. Bolton and Dr. G. Watson of the Rubber Research Institute of Malaya. The writer also records his appreciation of the cartographic assistance, comments and constructive criticisms of his colleagues, particularly during the editing of the manuscript by the staff of the Geological Survey, Malaya, and subsequently by Professor R. Ho and Mr. W. L. Dale. Thanks are due to Dr. J. B. Alexander, Director, Geological Survey, for permission to publish this paper in its revised form.

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STANDARD CATCHMENTS IN THE ESTIMATION OF FLOOD FLOWS

By F. G. CHARLTON

THE NEED for accurate hydrological data in connection with national development planning in the Federation of Malaya has prompted the Drainage and Irrigation Division of the Ministry of Agriculture and Cooperatives, in the absence of adequate long-term hydrological records, to investigate methods of estimating river discharge. Many Malayan streams have few tributaries, and have small catchment areas of the order of 50 square miles. Some catchments are 200 or more square miles in area, but there are very few as large as 3,000 square miles. The measurement of river discharge in the larger catchments requires the establishment of permanent flow gauge stations. It is not feasible, however, to gauge the smaller streams at all points where development is likely to occur in the future. To overcome this difficulty, the Division has started a research programme which aims to determine from short-term observations in a number of specially selected catchments, the relationships between rainfall, runoff and river flow. It is hoped that the data derived from these standard catchments will make possible reliable estimates of both volumes and rates of flood discharges from rainfall in other unknown small catchments.

SELECTION OF STANDARD CATCHMENTS

After a successful pilot study, of which details are presented below, it was decided that the following variables alone required to be taken into account in the selection of standard catchments:—

1. Type of rainfall: (A) West coast; (B) East Coast.
2. Topography: (S) Steep; (F) Flat.
3. Vegetation: (I) Jungle trees; (II) Light vegetation;
(III) No vegetation; (IV) Rubber trees.
4. Amount of precipitation.
5. Intensity of precipitation.
6. Distribution of precipitation.

The size of the catchment is taken into account in estimating the volume of precipitation. The geological factor is not included: its omission might possibly limit the application of the estimation method to other catchments.

In the first stages of the investigation, attention is focussed on western Malaya, giving scope for eight catchment studies. The catchment types, and those catchments already selected, are given below:—

- ASI — Sungei Lui (Selangor).
- ASII — not yet selected.
- ASIII — no catchment selected, as this type is rare.
- ASIV — Sungei Kayu Ara or Sungei Mantua (Negri Sembilan).

- AFI — not yet selected.
 AFII — not yet selected.
 AFIII — Sungei Johan (Perak).
 AFIV — not yet selected.

OPERATION OF STANDARD CATCHMENTS

The equipment required consists of rain gauges (autographic and daily), float-type water level recorders, stick gauges and current meters. The density of the rain gauges should be about one per square mile. Rainfall stations should be uniformly distributed, and should conform to Divisional standards (1, 2). Frequent and careful river discharge observations are needed to cover all stages of flow. The same current meter should be used for all observations.

The following information will then be available: rainfall recorder charts, check observations on the amount of rainfall received; water level recorder charts; check observations on the operation of the water level recorder; current meter observations, with notes on the state of the river,

METHOD OF ESTIMATING RIVER DISCHARGE

Observation indicates that a certain amount of rainfall is required before runoff occurs. This, the base loss, may be defined as the amount of rainfall required to satisfy interception, subsoil storage and surface storage losses. The base loss depends upon the antecedent rainfall conditions, the rates of soil saturation and infiltration, the intensity of rainfall, and the nature of the vegetation. In Malaya, with storms of high intensity and short duration, and with few periods without rainfall, it is possible that the base loss may, for particular catchment characteristics, assume fairly constant values, depending on the antecedent rainfall conditions. The effect of area has probably been overemphasised in the past, and it is considered that the distance of flow before a channel is reached is of greater importance. The duration of such overland flow affects the period of concentration, and hence the water losses.

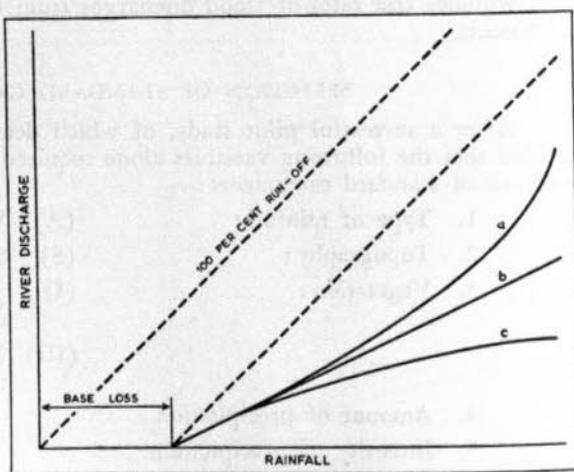


Fig. 1. Possible relations between rainfall and runoff.

Once runoff begins, infiltration losses will continue, but at a slower rate. These variable losses may be dependent upon the duration of runoff in a given catchment, but they should be much the same and relatively unaffected by the antecedent rainfall conditions. Accordingly, the graphs relating rainfall and runoff would follow one of the forms shown in Figure 1. It may be possible, therefore, to represent the relation between rainfall and runoff as

$$Q = R - f(R) - L$$

rather than $Q = B.R$

- where Q = runoff
- B = constant
- R = rainfall
- L = base loss for any given antecedent rainfall condition
- $f(R)$ = variable loss occurring during runoff.

The variable loss depends mainly on the duration of runoff, the permeability of the soil, and the intensity of the storm (Fig. 2). The actual shape of the flood runoff hydrograph after the base loss has been satisfied will depend on the interrelation of these factors, but once the rate of infiltration assumes near-constant values, then the relation between rate of runoff and $(R - L)$ may be approximately linear, i.e. $f(R) = J(R - L)$, where J is a constant.

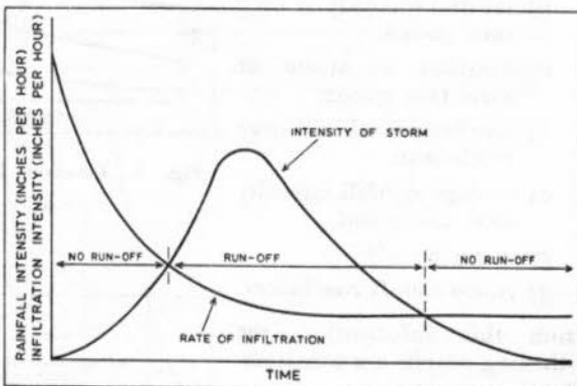


Fig. 2. Relation between runoff and infiltration.

The equation relating rate of infiltration and time is:

$$f = f_c - (f_o - f_c) e^{-\beta t}$$

- where f = rate of infiltration at time t
- f_o = rate of infiltration at time $t = 0$
- f_c = value of infiltration rate to which f becomes asymptotic
- β = constant.

Hence the equation $f(R) = J(R - L)$ will only be true when the rate of decrease of infiltration is rapid and reaches the value f_c at about the same time as the base loss is satisfied.

Then the equations

$$Q = R - f(R) - L$$

$$f(R) = J(R - L)$$

may be written as

$$Q = (1 - J)R - (1 - J)L$$

$$= K.R$$

$$\text{where } K = 1 - \frac{f(R)}{R} - \frac{L}{R}$$

$$\text{or } K = (1 - J) \frac{R - L}{R}$$

ANALYSIS OF OBSERVATIONS

Areal rainfall depths are calculated by means of the Thiessen polygon method. The data is then analysed to provide the following information:

- a) total storm rainfall at each rain gauge;
- b) rainfall intensity at each rain gauge;
- c) duration of storm at each rain gauge;
- d) areal storm rainfall over catchment;
- e) average rainfall intensity over catchment;
- f) storm runoff;
- g) storm runoff coefficient.

From this information the following graphs are constructed:

- i) a graph relating the rainfall and coefficient of runoff for each catchment characteristic, with the assumption $Q = K.R$ (Fig. 3);
- ii) a graph relating the rainfall in excess of base loss and the variable loss for the catchment, as shown in Figure 4. The base loss and antecedent rainfall condition should also be tabulated. This assumes that $Q = R - f(R) - L$;
- iii) the ratio of the rainfall intensity over an area to that at a point as in Figure 5;
- iv) the rainfall intensity duration curves, as in Figure 6;
- v) the relationship between C and $K.R'$, as in Figure 7(3).

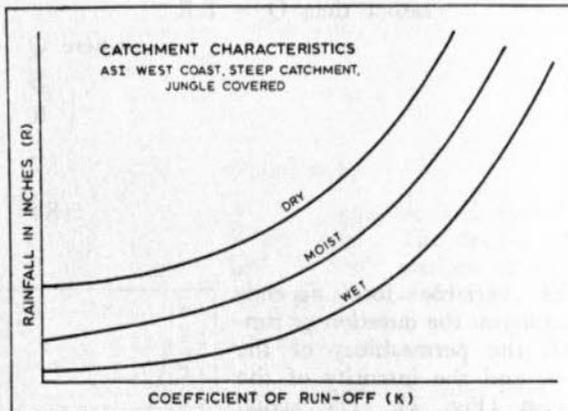


Fig. 3. Relation between coefficient of runoff and rainfall.

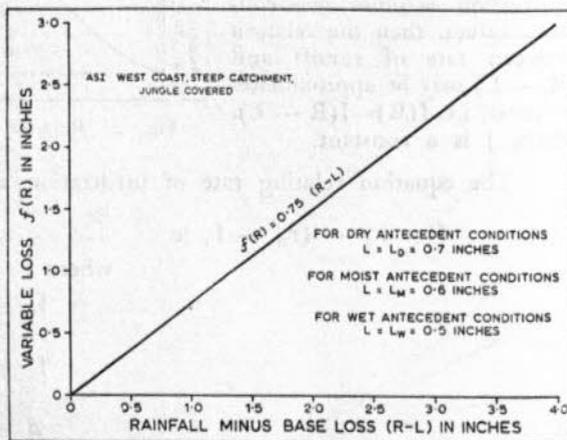


Fig. 4. Variable losses in a catchment of type ASI.

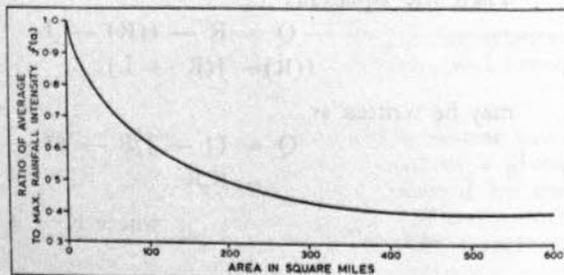


Fig. 5. Relation between area and rainfall intensity.

ESTIMATION OF RUNOFF IN AN UNKNOWN CATCHMENT

When the runoff is to be estimated for a catchment which can be directly related to one of the standard catchments, the following method is simple and its application is quick.

Computation of volume of runoff.

A map of the catchment showing the position of rain gauges, the Thiessen polygon for each gauge and the boundaries of each type of catchment sub-area is prepared. Assuming a uniform distribution of rainfall within each polygon, the rainfall for each sub-area is calculated from the rain gauge observations selected. Using graphs of the type of Figure 3, the base losses and coefficients for the required catchment characteristics and antecedent rainfall conditions are obtained, and hence the runoff from each sub-area is computed. The sum of the volumes from each sub-area is then the total volume of runoff from the selected storm.

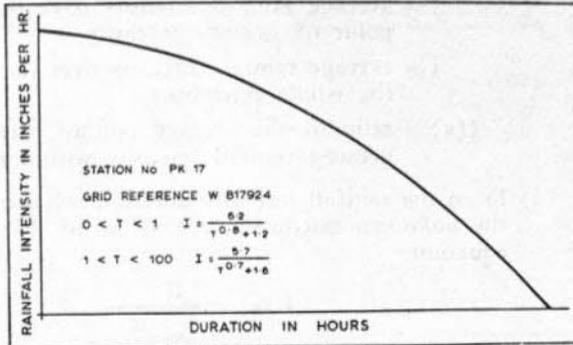


Fig. 6. Relation between rainfall intensity and duration.

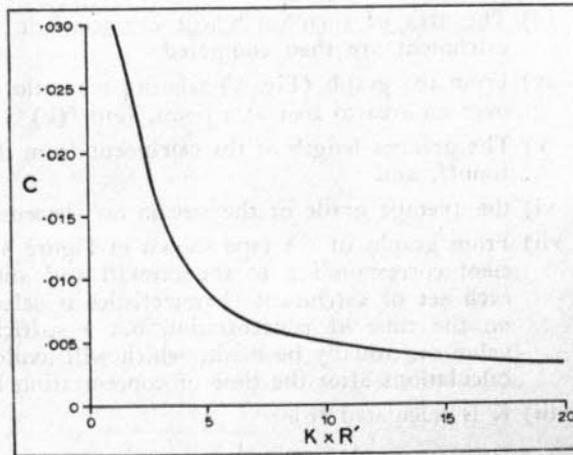


Fig. 7. Relation between C and K.R'.

Computation of rate of runoff.

In order to compute the maximum rate of runoff from an unknown catchment, the following method, based on that described by Richards (3), may be used.

- t = time of concentration in the unknown catchment
- T = duration of the storm
- R' = rainfall coefficient
- m = rainfall intensity exponent
- c = rainfall intensity constant
- K = runoff coefficient
- K₁, K₂, K₃ = runoff coefficients for each type of catchment characteristic
- A = area of unknown catchment
- A₁, A₂, A₃ = area of each portion of the catchment with particular catchment characteristics
- C = coefficient dependent on K and R
- L = length of catchment
- s = average slope of catchment

I = average rainfall intensity over the duration of the storm at the point of greatest intensity

i = average rainfall intensity over the duration of the storm and over the whole catchment

$f(a)$ = ratio of the average rainfall intensity over a given area to the greatest rainfall intensity within the area.

- i) From the rainfall intensity duration relations for the rainfall station nearest the unknown catchment, the values of R , m , and c are obtained from the equation

$$I = \frac{R}{T^m + c}$$

- ii) The occurrence of different catchment characteristics (ASI, ASII, etc.) is plotted on the map of the unknown catchment.
- iii) The area of each catchment characteristic type and the total area of the catchment are then computed.
- iv) From the graph (Fig. 5) relating the ratio of the average rainfall intensity over an area to that at a point, find $f(a)$.
- v) The greatest length of the catchment from the point of concentration of the runoff, and
- vi) the average grade of the stream are determined.
- vii) From graphs of the type shown in Figure 3 the value of the runoff coefficient corresponding to the rainfall and antecedent rainfall conditions for each set of catchment characteristics is selected. The rainfall will depend on the time of concentration but a sufficiently accurate estimate of the value can usually be made, which will avoid the necessity of repeating the calculations after the time of concentration has been computed.
- viii) K is calculated from

$$K = \frac{A_1}{A} K_1 + \frac{A_2}{A} K_2 + \frac{A_3}{A} K_3$$

- ix) The value of $K.R'$ is calculated, and from the graph of $K.R'$ plotted against C (Fig. 7), the value of C is obtained.
- x) The following equation is solved for t

$$\frac{t^3}{t^m + c} = \frac{C.L^2}{K.s. R'. f(a)}$$

- xi) For the condition $t = T$ the value of I is computed from equation

$$I = \frac{R'}{T^m + c}$$

- xii) i is computed from

$$i = I.f(a)$$

- xiii) The peak instantaneous discharge Q_m is computed from $Q_m = K. i. 640$ cusecs/square mile.

If it is necessary to compute the greatest sustained runoff over any given period of time corresponding to a particular storm intensity, then the procedure after (x) above is as follows:

- (xa) A value of T is selected.

(xia) I is computed from the equation

$$I = \frac{R'}{T^m + c}$$

(xiiia) i is computed from $I = i.f(a)$

(xiiia) t is computed from $t^3 = \frac{C.L^2}{K.s.i}$

(xiva) The duration of the flood runoff is then equal to $T - t$.

(xva) The greatest runoff sustained for the above period is then equal to

$$Q_s = K.i. 640 \text{ cusecs/square mile.}$$

The computation of average sustained rates of runoff resulting from specified rainfall intensities and durations for catchments which are directly related to a particular standard catchment follows the same procedure as has been given above. The procedure can, however, be simplified as follows:

i) The values of R' , m and c are obtained from equation $I = \frac{R'}{T^m + c}$

ii) It is ascertained that the unknown and standard catchments correspond with respect to topography, vegetation, shape, geology and location.

iii) The area of the unknown catchment is calculated.

iv) $f(a)$ is calculated from the graph relating $f(a)$ and the catchment area (Fig. 5).

v) The greatest length of the catchment is measured from the point of concentration of the runoff, and the average grade of the stream is calculated.

vi) From the graph (Fig. 3) a value of K is selected to correspond to the rainfall and antecedent rainfall conditions in the standard catchment.

vii) $K.R'$ is calculated, and from the graph of $K.R'$ against C , the value of C is obtained.

viii) The following equation is solved for t

$$\frac{t^3}{t^m + c} = \frac{C.L}{K.S.R'. f(a)}$$

ix) For the condition $t = T$, the value of I is obtained from

$$I = \frac{R'}{T^m + C}$$

x) i is computed from the equation $i = I.f(a)$

xi) The peak instantaneous discharge Q_m is computed from $Q_m = K.i. 640$ cusecs/square mile.

The computation of the sustained runoff over any given period of time corresponding to a given storm intensity follows steps (xa) to (xva) above.

The computation of the rate of runoff can alternatively be based on the determination from the standard catchment observations of the factors in Snyder's synthetic unit-hydrograph method (4).

RESULTS OF PILOT INVESTIGATION

A conveniently located and representative area, the catchment of the Sungei Kemansah (Selangor) was chosen for the pilot investigation (Fig. 8). The catchment, of type ASI, covers approximately 5 square miles, with a maximum length

of 3½ miles and maximum breadth of 2 miles. The river flows in a south-westerly direction, breaching a transverse limestone ridge of about 900 feet maximum height. The elevation of the catchment varies from about 170 feet to more than 1,500 feet above sea level in the extreme north-east corner. Aerial photographs indicated that the vegetation cover was about 90 per cent jungle, the remaining 10 per cent composed of grass, barren ground, and a small patch of rubber. The latter were

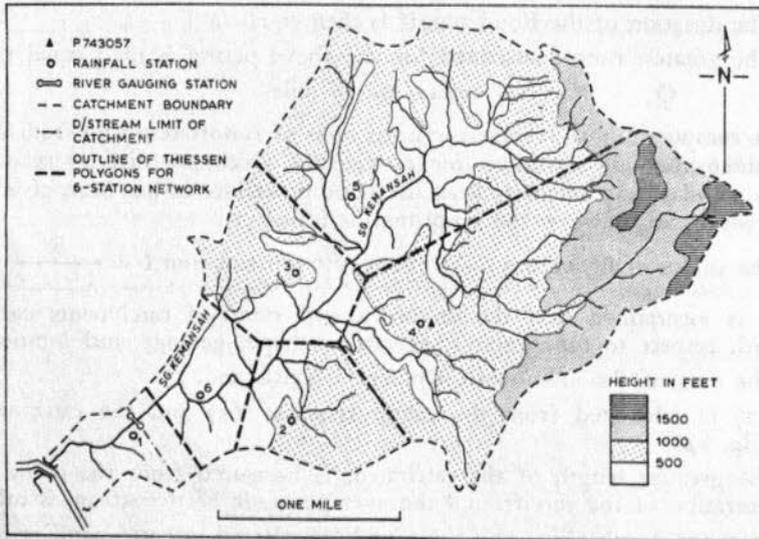


Fig. 8. Sungei Kemansah catchment.

located mainly at the lower end of the catchment and near the limestone ridge. The bed of the stream was mainly gravel, with some sand below the gauging site and in some flatter upstream reaches. Towards the head of the catchment the stream bed was boulder strewn, with several waterfalls of up to 30 feet in height.

The instruments used were: 8-inch rain gauges, 5-inch weekly rainfall recorders, a float-type water level recorder, and Amsler and Watts current meters. It was not possible, in the time available, to instal equipment for the measurement of interception losses, or water level recorders of the pressure bulb type. In two cases modifications of the rainfall recorders were made to permit their installation at tree-top level.

TABLE 1: PILOT CATCHMENT RAINFALL STATION COVERAGE

Station No.	Thiessen Polygon Areas (square miles)
1	0.08
2	0.47
3	0.54
4	2.04
5	1.68
6	0.33

Six rainfall stations were set up, but difficulties of access made it impossible to conform to the planned uniform distribution. The Thiessen polygon areas of the individual stations are shown in Table 1 and Figure 8.

The catchment was operating on a 'full equipment' basis on 17 December 1958. Observations were made daily at station 1, weekly at the others. Discharge measurements were made for as wide a range of water levels as possible. An attempt was made to anticipate high stages by reference to the D.I.D. Research Station five miles distant, but this was unsuccessful, as the differences in rainfall between the two were great, and the duration of high discharge in the standard catchment was short.

Several difficulties were encountered in maintaining the accuracy of the clocks, and various faults occurred in the instruments. Together with the effect of the non-uniform station distribution and the marked differences in rainfall recorded between stations, these defects meant that many storm records were incomplete. Data for about 50 per cent of the storms had to be rejected for these reasons.

It was immediately obvious from the results that all rainfall was subject to an initial base loss, with little or no runoff occurring below a certain threshold rainfall amount. As it appeared likely that this base loss varied with antecedent conditions of wetness in the catchment, criteria were developed to denote 'dry', 'moist' and 'wet' conditions. Although these criteria were arbitrary in nature, they served to indicate a range of base losses, from 0.7 inches for 'dry', to 0.5 inches for 'wet' conditions.

A graph was plotted of $(R - L)$ against $f(R)$, where $f(R) = R - Q - L$, deducting the value of L indicated by antecedent catchment conditions. This graph showed most points lying on a straight line, which is expressed as the 'Normal' relationship between R and $f(R)$, and certain points above this line giving higher runoff values, which are classed as 'Maximum Observed' conditions. From the line containing the 'Maximum Observed' points, the relationship was obtained for $R/f(R)$, and by using this in the formula

$$\frac{Q}{R} = K - 1 - \frac{f(R)}{R} - L$$

values of K were determined for corresponding depths of rainfall and antecedent catchment conditions. Runoff could now be deduced (as $Q = K.R$) for the 'maximum' conditions recorded during observation in the catchment. A point for consideration is that in the $R/f(R)$ relationship although the conditions appeared to indicate a straight line over the range of observations, i.e. up to $R = 3$ inches, it seems probable that higher values of R may result in a smaller increase in $f(R)$, thus decreasing the proportion of variable loss and increasing the runoff.

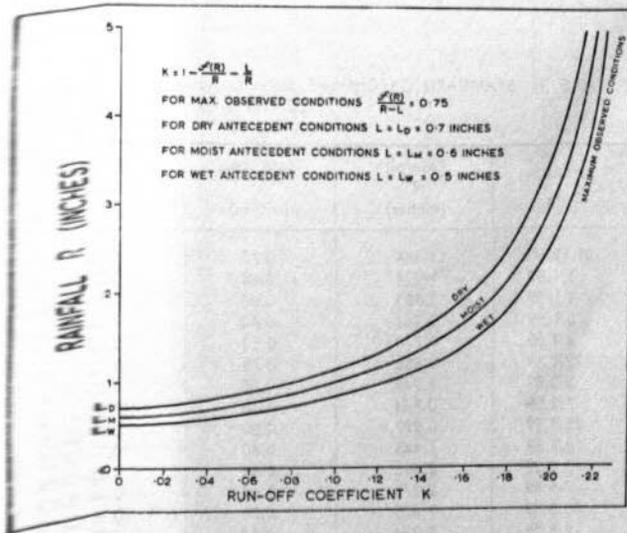


FIG. 9. Rainfall-runoff coefficient for catchments of type ASI.

After a study of the observed rainfall and stream flow data, criteria for antecedent rainfall were deduced, as in Table 2.

TABLE 2: CRITERIA FOR ESTIMATING ANTECEDENT RAINFALL CONDITIONS

Period Prior to Storm Considered	Total Rainfall in Inches for Conditions		
	Dry	Moist	Wet
1	0.0 — 0.5	0.5 — 1.5	1.5+
2	0.0 — 1.5	1.5 — 2.5	2.5+
3	0.0 — 2.5	2.5 — 3.5	3.5+
4	0.0 — 3.5	3.5 — 4.5	4.5+
5	0.0 — 4.5	4.5 — 5.5	5.5+
6	0.0 — 5.5	5.5 — 6.5	6.5+

The shape of the flood discharge hydrograph was such that it was normally several days or weeks before the stream flow returned to the base flow level at the beginning of the storm under consideration. Thus the determination of the maximum duration of surface runoff was difficult. After a study of the discharge hydrographs, it was decided that the area under the curve after reaching peak flow should be computed, and a graph of area against time plotted. This graph was found to have a peak value, and the time at which the peak occurred was taken as the limit of the discharge hydrograph.

Tables 3 and 4, and Figures 4 and 9 summarize the results obtained from the Sungei Kemansah standard catchment.

TABLE 3: STANDARD CATCHMENT SUNGEI KEMANSAH: VALUES OF RAINFALL, RUNOFF & LOSSES PLOTTED ON $R/f(R)$ AND $(R-L)/f(R)$ CURVES

Storm Date	Rainfall R (inches)	Base Loss L (inches)	Runoff Q (inches)	R-L (inches)	$R-L-Q = f(R)$ (inches)
31.12.58	1.436	0.70	0.051	0.736	0.685
1.1.59	1.226	0.60	0.048	0.626	0.578
2.1.59	0.982	0.60	0.049	0.382	0.333
3.1.59	2.251	0.60	0.154	1.651	1.497
4.1.59	0.723	0.50	0.047	0.223	0.176
12.1.59	0.856	0.70	0.010	0.156	0.146
3.2.59	1.949	0.70	0.071	1.249	1.178
7.3.59	0.844	0.70	0.013	0.144	0.131
25.3.59	0.927	0.50	0.061	0.427	0.366
28.3.59	1.446	0.60	0.105	0.846	0.741
12.4.59	2.695	0.60	0.306	2.095	1.789
7.5.59	2.275	0.60	0.410	1.675	1.265
15.5.59	1.609	0.70	0.105	0.909	0.804
18.5.59	0.786	0.70	0.055	0.086	0.031
19.5.59	1.462	0.70	0.180	0.762	0.582

TABLE 4: STANDARD CATCHMENT SUNGAI KEMANSAH: VALUES OF K IN EQUATION

$$K = 1 - \frac{f(R)}{R} - \frac{L}{R}$$

Rainfall in Inches and Antecedent Conditions	$\frac{L}{R}$	$R-L$	$\frac{f(R)}{R} = \frac{0.75(R-L)}{R}$	K
1.0 Dry Moist Wet	0.700	0.30	0.225	0.075
	0.600	0.40	0.300	0.100
	0.500	0.50	0.375	0.125
2.0 Dry Moist Wet	0.350	1.30	0.487	0.163
	0.300	1.40	0.525	0.175
	0.250	1.50	0.562	0.188
3.0 Dry Moist Wet	0.233	2.30	0.575	0.192
	0.200	2.40	0.600	0.200
	0.167	2.50	0.625	0.208
4.0 Dry Moist Wet	0.175	3.30	0.619	0.206
	0.150	3.40	0.637	0.213
	0.125	3.50	0.656	0.219
5.0 Dry Moist Wet	0.140	4.30	0.645	0.215
	0.120	4.40	0.660	0.220
	0.100	4.50	0.675	0.225

ACKNOWLEDGMENTS

This paper is published with the kind permission of the Director, Drainage and Irrigation Department, Federation of Malaya.

The author wishes to acknowledge his appreciation of all those whose hard work in the establishment of stations and in the collection and statistical analysis of data made this paper possible. In particular he would like to mention J.H. Mather Esq., Enche Abdullah bin Yahya, the Technicians of the Hydrological Branch, and also Mr. Im Koon Hai, who prepared the figures for this paper.

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compounds release sulphuric acid, which in extreme cases may depress pH values below 2.0. Values of 3.0 to 4.5 are common, either in a single horizon or throughout the profile. As a result of the breakdown of clay minerals in these acid conditions, free aluminium and iron are released in the profile.

Differences in soil reaction are accompanied by variations in base saturation, averages ranging between 40 and 70 per cent. The very acid sulphate soils described above are less saturated, but even in these profiles base saturation is seldom below 20 per cent. Typically, the ratio of adsorbed Mg to Ca in acid sulphate soils is between 2.0 and 3.0. Neutral to alkaline alluvials are completely saturated and may contain Na, free Ca, or both. Although the base exchange capacity of the clay fraction varies considerably, it is mostly well above 20 m.e./100 grams clay; lower values are found in soils developed in smaller floodplains surrounded by acid soils, while values over 60 m.e./100 grams clay are found in alluvial soils derived from basalts or limestones.

Environmental Conditions

The influence of climate upon the evolution of alluvial soils is less marked, since soils of the group are taxonomically intrazonal formations. However, those developed in drier areas are usually more base saturated, have higher pH values, and may even contain alkaline inclusions. Climatic factors are dominant in the agricultural utilization of such soils; their secondary characteristics are often derived from cropping practices. Since most alluvial soils in South-east Asia are cropped, it is difficult to deduce the nature of the original natural vegetation. Well drained virgin soils may carry forest or bamboo, poorly drained phases are often under grass, and highly acid alluvials are colonized by marsh vegetation such as rushes and *Melaleuca leucadendron*. The saline alluvials forming coastal flats are usually under mangrove forest.

Geographical Distribution

The most extensive areas of alluvial soils in continental South-east Asia are found in the Mekong deltaic plain of Cambodia and South Vietnam, the Red River Delta of North Vietnam, the central plain of Thailand, and the Irrawaddy and Sittang valleys of Burma. In insular South-east Asia, the largest tracts of alluvial soils occur on the east coast of Sumatra, the south and west coasts of Borneo, and the north coast of Java. Away from the coasts, especially in regions of stronger relief, the alluvial areas rapidly diminish in size, and may be virtually absent in mountainous regions. In Java and Sumatra, however, lacustrine deposits in old volcanic lakes are of great local importance.

Land Use and Agricultural Potential

These soils are among the most important agricultural soils of the region. They are everywhere extensively cropped, with the exception of very acid sulphate soils, saline mangrove soils and some alluvial soils in interior valleys in poor upland soil areas. Population densities of up to 1,900 persons per square kilometre are supported on alluvial soils in Java. Rice is the chief crop, and more than 80 per cent of irrigated or wet padi in South-east Asia is grown on soils of the group. Yields vary from a few hundred kilograms per hectare on certain acid sulphate soils, to over five tons per hectare on the well managed and better alluvial soils. Practically all the tropical crops are grown on alluvial soils, except for coffee, tea, cinchona and similar upland crops. Coconut, sugar cane and fruit are extensively cultivated on well drained levees, while maize, tobacco, cotton, jute and kenaf are locally significant. Cropping patterns, rotations and crop management are

closely related to hydrological conditions: a single crop of rice is usual, but double cropping of rice, or of rice and an unirrigated crop, is common. Where deep floods of up to 3 metres occur, floating rice is grown, provided that the flooding is gradual.

The productivity of these soils can be greatly increased by appropriate fertilizer treatments and by improving irrigation and drainage, since large areas of the alluvial plains are seasonally submerged or subject to flash floods. With such measures, and appropriate diversification of crops, the agricultural productivity of the alluvial soils of South-east Asia could be doubled or even trebled.

Nomenclature

REGOSOLS

As indicated above, this group of soils has little or no profile differentiation, being derived from sediments other than those deposited in water. It is included together with the alluvial soil group in the entisol order of the 7th approximation.

Morphology

In terms of parent material, three kinds of regosol are important in South-east Asia. The morphological features of each kind are outlined separately for convenience, and not in an attempt to erect subdivisions at a high level.

Firstly there are regosols on aeolian sands of at least 50 centimetres depth. On shifting dune sands, the A and B horizons are normally weak or absent. On recent dunes and beach sands, these soils are usually yellowish-brown to very pale brown in colour, with a considerable amount of weatherable minerals present. By contrast, older profiles are leached of all carbonates, and devoid of weatherable minerals. The subsoil under the A horizon in such profiles is frequently a whitish pure quartz residue which may be several metres deep and may resemble the bleached A₂ horizon of a podzol. Possibly older variants, formed on early Pleistocene or Tertiary marine terraces, are reddish soils composed almost entirely of quartzitic residues coated with ferruginous materials; these have little weatherable minerals, but contain a certain amount of clay. Such weathered regosols form intergrades to soils that are characterized by marked profile development.

Secondly, regosols on slope colluvium are mostly of medium texture, ranging from sandy loams to clay loams. Often a gravelly or stony phase occurs, sometimes to the extent that they might be considered as lithosolic regosols. At the base of slopes in hilly cultivated regions, these soils may be made of materials derived from profiles further upslope, in which case they are not stony, and their colours are related to those of the adjacent profiles from which they are derived.

Thirdly, regosols may also evolve from volcanic materials, chiefly andesite ash. Variations in texture and composition appear between similar soils of different areas and even within individual profiles as a result of successive volcanic eruptions from different foci and of different mineralogical composition. In general, the coarser-textured regosols develop near eruption centres, while finer-grained profiles evolve further away. At the same time, their silica content increases with distance, but calcium, magnesium and iron decrease. Such soils may be very stony, with large boulders at the surface. Those evolved from volcanic ash frequently develop hard pans at various depths.

Environmental Conditions

The characteristic absence of horizons in aeolian sands is largely a result of the coarse nature of the parent material. The regosols developed on colluvium

and on volcanic deposits are generally too youthful to develop horizons. In addition, continual renewals of the parent materials interrupt pedogenic processes. Topographically, sandy regosols form on flat to hilly land, colluvium regosols on steeply sloping land, and those from volcanics in undulating to mountainous areas. The group has an equally ubiquitous climatic range, being found throughout South-east Asia. Its natural vegetation is determined more by climate than by intrinsic soil properties.

Geographical Distribution

Sandy regosols are found mainly along shores in strips of varying width. Inland sand dunes are rare in South-east Asia, but some regosols are found on aeolian sands resting on broad river terraces. Regosols formed on red sands appear to be confined to drier coastal areas where very old terraces have escaped erosion. Those formed from colluvium are found in all the hilly areas of South-east Asia, especially in drier climates. In wetter climates, some profile development occurs, even on youthful parent materials. On cultivated hilly ground as in Ceylon, regosols are found on man-made erosion products. Regosols from volcanic materials are extensively distributed in such regions of active vulcanism as Java, Sumatra and Bali.

Land Use and Agricultural Potential

Sandy regosols have a low agricultural potential and are not generally cultivated. Where the watertable is not too deep they are used for extensive coconut plantations in Indonesia, Ceylon and the Philippines, while in areas with adequate rainfall they may be used for pineapples. Regosols developed on old red sands, especially those containing some clay, permit an extensive type of dry farming with manioc and groundnuts as the chief crops.

Most regosols on slope colluvium are too stony for cultivation. In the wet zone of Ceylon however, such soils are put to the same use as those of the adjacent hillsides, with coconut, rubber or tea planted according to the altitude. The regosols derived from volcanic ash, especially when medium to fine-textured, are terraced and used for irrigated rice at altitudes below 1,000 metres. Above this height, forest is dominant. In central and east Java, high quality tobacco is grown on such soils; elsewhere they support soya beans, groundnuts, sweet potatoes and maize.

Nomenclature

GRUMUSOLS

The term grumusol was proposed in 1951 by Oakes and Thorp (6) to include the dark clay soils of warm regions variously called black cotton soils, regurs, tirs and rendzinas. In South-east Asia, the term regur has been applied to such soils in Indonesia (7) and South Vietnam (8); 'margalitic soils and black earths' in Indonesia (9); 'compact dark savannah soils' in Burma (10); 'terres noires basaltiques' in Cambodia and Vietnam (11); and 'Guadalupe clay' in the Philippines (12). The group falls into the vertisol order of the 7th approximation, the low-lying grumusols forming the aquert suborder, and the better-drained grumusols on undulating ground forming the ustert suborder.

Morphology

The normal horizon sequence in grumusols is A₁-AC-C. The surface horizon is a thick, black to dark brown layer, relatively poor in organic matter; this horizon is darker in low-lying profiles, and often possesses a strong granular structure for

a depth of 5 to 10 centimetres. In some cases, however, there is a tendency to form crusts at the surface. The structure of the surface horizon is blocky, composed of prismatic peds.

As a group the grumusols are heavy soils, with clay contents of 40 to 80 per cent. These clays are mainly montmorillonitic, so the soils are very plastic and sticky when wet, and very hard when dry; as moisture conditions change, they swell and shrink greatly, with heavy fissuring and deep cracking. As a result, gilgai topography may develop at the surface. Intensive churning of the soil produces slickensides, i.e. grooved surfaces, on the peds. With the washing down of surface soil into the fissures, the upper horizons of the soil are subjected to a cyclic mixing process.

Some grumusols have marked accumulations of calcium carbonate in concretions or filaments deep in the profile. Surface concretions are also known. Mottling may occur in some part of the profile owing to low permeability and slow surface drainage. In some dry areas, salt accumulations may be found at depth, produced by saline groundwater.

In rolling country, grumusols vary widely in depth due to erosion, while in basaltic regions they may be very stony.

Chemical and Physico-chemical Characteristics

The average clay content of 40 to 80 per cent is maintained throughout the profile unless stratigraphic discontinuities occur. The pH values in surface horizons range from 6.0 to 7.5, and increase to 7.8 with depth. Grumusols formed from igneous rocks tend to be more acid than usual, with a pH of 7.0 or even lower in the subsoil. Base saturation is generally over 50 per cent, increasing with depth to 100 per cent. Ca and Mg are the dominant adsorbed cations, but in dry areas Na may become significant in the lower horizons. Grumusols normally contain free calcium carbonate in quantities of 1.5 to 8.0 per cent.

Their clay fractions, mainly montmorillonitic, with small quantities of illite and kaolinite, have average base exchange capacities between 50 and 80 m.e./100 grams clay. Organic matter averages 1.0 per cent, ranging between 0.5 and 1.5 per cent in the surface horizons. Higher levels of organic matter are associated with poorly drained profiles that grade into humic gleys. Their carbon:nitrogen ratios range between 10 and 14.

Environmental Conditions

The parent materials of grumusols are usually of basic composition, such as marls, calcareous alluvials, lacustrine deposits, basalts and andesites. These materials contain swelling clays or weather to produce clays of the montmorillonitic group. The climatic environment is strongly seasonal, the dry season lasting from four to seven months. Annual rainfall varies between 800 and 2,500 mm., temperatures between 22° and 28°C. The natural vegetation associated with these conditions has not been studied in detail, but it appears to be a mixed grass-forest savana or an open forest.

Most grumusols occur on flat or slightly undulating ground such as old alluvial plains, lake basins, marine or fluvial terraces, where surface drainage and the lateral inflow of groundwater from adjacent uplands favour the accumulation of bases. In more accidented areas such as dissected plateaus, grumusols are invariably found on basic parent materials, mainly basalts.

Geographical Distribution

These soils are common in South-east Asia, but on the whole they are not as extensive as other groups. The largest areas appear to be located in central and east Java, in Madura and the Lesser Sunda Islands, where they overlie marls, old alluvials and colluvials in limestone areas. Fairly extensive areas of grumusols occur in and around the central plain of Thailand, developed on alluvium and on colluvium from calcareous regions. In Cambodia and South Vietnam, scattered outcrops are associated with basalt plateaus and old alluvium. They have also been reported from Luzon in the Philippines, north Ceylon, and central Burma, but not from Malaya.

Land Use and Agricultural Potential

Adequate water supply is the key to the utilization of grumusols. Where irrigation is practised, grumusols are extensively cropped to rice, often in rotation with sugar cane; the latter is common in central and east Java and the southern Philippines. Where water is in short supply, dry rice, maize and soya beans are grown. Cotton yields satisfactorily on these soils; it was formerly grown in the Demak area of central Java, and today it is planted by smallholders in central Burma, central and north-east Thailand and Vietnam. However, cotton is less commonly associated with grumusols than in Australia or America, owing to unresolved difficulties with pests and diseases. Other suitable crops are tobacco and kapok, the latter being prominent in the Pati area of central Java.

In rolling country, grumusols have much lower agricultural value because of their liability to erosion. Reafforestation is possible on badly eroded profiles, as the regenerated teak forests of Java indicate, but the initial establishment of timber stands is difficult. In places, eroded grumusols are used for rangeland of very low carrying capacity.

As these soils have low levels of phosphorus, they respond favourably to dressings of superphosphate with added nitrogen. Because they are neutral to alkaline in reaction, the use of acid-reacting fertilizers is recommended. The main difficulties encountered in cultivation arise from their physical properties of stickiness when moist and hardness when dry, properties that impose great burdens on peasants using simple implements. When irrigated they may accumulate salts, but such accumulations are returned to the subsoil by the continual mixing process, and rarely interfere with crops.

Nomenclature

ANDOSOLS

The name of this group was first used by the U.S. Natural Resources Section in a reconnaissance soil survey of Japan in 1951 (13), and was later adopted for soil surveys in Indonesia (7, 14). Soils of this group have also been called 'high mountain soils' (15), 'mountain black earths' (16), 'humic mountain soils' (17) and recently, 'black latosols' (18). They fall within the andept suborder of the inceptisols in the 7th approximation.

Morphology

Andosols show a distinct and relatively thick, black to very dark grey-brown surface horizon rich in organic matter, which overlies a brown to dark yellowish-brown subsoil. The clay fraction is dominated by amorphous aluminium and silica oxides which in many soils have been identified as allophane compounds. The

profiles are of medium depth, the parent material being reached at about one metre or less.

The soils are medium to light in texture, with a crumb structure in the surface layers, low bulk density, and a high silt to clay ratio. They are porous and very friable. They have a high water-holding capacity and smear typically when rubbed. In permanently humid conditions, the surface horizons and subsoil materials dehydrate irreversibly when dried; this tendency is less pronounced with andosols developed in alternately wet and dry conditions.

A hard pan, some 20 centimetres thick and from 40 to 100 cm. below the surface, often occurs. The pan is frequently pumaceous, gritty, and of coarser texture than the overlying horizons. It is yellowish, porous, but not easily penetrated by roots. In moist conditions it crushes under moderate pressure, but when dried becomes very hard. The nature of the cementing material has not been investigated, but may be partly silica which, when freed rapidly in weathered volcanic ash, leaches downwards in areas of high rainfall. Normally the hard pan is continuous, following the contours of the surface; in other places it is discontinuous and wavy and does not appear to be related to soil depth. This suggests that the pan is a geological formation on which soil-forming processes are superimposed. Andosols are associated with brown to yellowish-brown soils having features in common with both andosols and latosols. Present data are insufficient to make clear distinctions between the so-called dark andosols, brown andosols and brown latosols.

Chemical and Physico-chemical Characteristics

Andosols are light to medium in texture, with clay contents of between 10 and 40 per cent; silt may range between 30 and 75 per cent. The pH of the surface horizon is about 5.5, increasing slightly with depth to 6.5. Base saturation ranges from 20 to 40 per cent. The clay fraction is composed of amorphous aluminium and silica oxides, meta-halloysite and locally some kaolinite. Base exchange capacity varies from 20 to 30 m.e./100 grams clay. Organic matter in the A₁ horizon is between 5 and 20 per cent. Andosols are generally well supplied with nitrogen and potassium, but phosphorus may be absent. Deficiencies of minor elements, such as Mn, may occur.

Environmental Conditions

So far andosols have been found only on volcanic ashes which, under humid conditions, weather down to fairly stable amorphous oxides of aluminium and silica. These conditions are met at elevations from sea level to 2,500 m., and where annual rainfall is between 1,800 and 7,000 mm. Most andosols, however, occur at heights above 500 m., where relatively cool annual mean temperatures of 14 to 20°C. occur. At lower levels they occur on the undulating topography of volcanic fans, but at higher altitudes they are found on the hilly to mountainous relief typical of the upper parts of volcanoes.

Geographical Distribution

Andosols occur extensively in the volcanic areas of South-east Asia, mainly in Java, Sumatra, Bali and the southern part of Luzon. Some are reported from the volcanic islands off the west coast of Burma.

Land Use and Agricultural Potential

At high altitudes, andosols are occupied by natural montane vegetation, which in places is replaced by plantations of *Pinus merkusii*, *Agathis alba* and

eucalyptus. When cropped, these soils are used mainly for tea up to 1,500 m. and for cinchona between 1,500 and 2,000 m. In east Java, *Arabica* coffee is grown on andosols. Below 1,000 metres, the soils are extensively used for irrigated rice in rotation with dry crops such as groundnuts and sweet potatoes. In many places in Java these soils are important producers of vegetables, fruit and flowers, while in north Sumatra, oil palm and wrapper tobacco are located on such soils.

Nomenclature

(ACID) BROWN FOREST SOILS

These soils have many characteristics in common with the group of similar name found in temperate climates but they may not be exactly equivalent. In Ceylon similar soils have been called 'immature brown loams' (19). This term has been avoided here since it may create confusion with the 'brown loams' of New Zealand, which are developed from volcanic rocks and have clays rich in iron and aluminium. In the 7th approximation, this group is included among the eutrochrepts, dystrochrepts and ustochrepts of the inceptisol order; some soils of the group may overlap into the mollisol order.

Morphology

Brown forest soils have a coloured B or (B) horizon underneath an A₁ or Ap, and do not show dominant signs of wetness. The original stratification and structure of the parent material is lost in the (B) horizon, but both the A and (B) horizons contain considerable amounts of weatherable material in their silt and clay fractions.

These soils do not normally exceed 80 cm. in depth. The A horizon, ranging from a few centimetres to 25 cm. in thickness, is usually weakly developed and passes gradually without clear colour contrast into the (B) horizon. The (B) horizon does not show appreciable illuviation and clay coatings are absent. The clay content of this horizon is equal to or less than that of the A horizon, but is higher than that of the C horizon, indicating a certain amount of clay formation by weathering *in situ*. The B horizon is lighter and brighter coloured than the A horizon, and has strong brown to yellowish-brown colours. There is a distinct colour change between the B and C horizons. The A and B horizons have crumb or weak subangular blocky structures, a friable consistency and low bulk density.

Chemical and Physico-chemical Characteristics

These soils have medium to high levels of base saturation, minimum values being around 30 per cent, increasing to 100 per cent in regions of lower rainfall, where free CaCO₃ may be present at depth, especially in soils evolved from calcareous parent materials. On intermediate parent materials pH values are usually above 5.0 and often above 6.0. The base exchange capacity of the clay fraction usually exceeds 40 m.e./100 grams clay, and may be as high as 100 m.e., indicating the presence of illitic and montmorillonitic clays.

Environmental Conditions

Brown forest soils are young soils and are found only where their parent materials are subject to continuous erosion, or where transported materials have recently accumulated. Such conditions prevail on steep slopes, on talus slopes of colluvium, and on easily eroded calcareous rocks; youthful andesitic ash may also give rise to similar soils, but they have yet to be described. The parent materials are residual or transported materials from moderately basic rocks such as mica schists.

Their climatic range is ill-defined since they appear in both hot lowlands and cool mountains where the annual rainfall varies between 600 and 3,000 mm. These soils appear to be absent from the continuously wet zones of South-east Asia, but this awaits verification. The natural vegetation ranges from open forest with grass undergrowth to tropical rainforest.

Geographical Distribution

The brown forest soils seldom occupy large continuous areas, being found in patches of a few acres on hills and mountains. The total area of these patches is, however, significant.

Land Use and Agricultural Potential

Since they occur in hilly regions, most brown forest soils are under natural savana or forest; some areas are used for shifting hill cultivation. When used for permanent agriculture, the type of crop depends on adjacent usage. In the wet zone of Ceylon these soils coincide with coconut and rubber plantations which extend over other soil types, while in the dry zone they are under grass and forest. In central Java, where brown forest soils are associated with regosols evolved from marls, idle land is dominant, but there is limited subsistence cropping of maize and upland rice; attempts are being made to reforest the area. Although these soils have considerable intrinsic fertility, more intensive utilization seems limited by topography, shallowness and liability to erosion.

Nomenclature

PODZOLS

The term podzol is a classic in soil literature. It has been used in Indonesia by Hardon (20), Dames (21) and by Dudal and Soepraptohardjo (7); in Malaya by Panton (22); and in Sarawak by Dames (23). In South-east Asia these soils are known locally as 'Padang soils' (20) or 'Kerangas soils' (23, 24). The terms 'groundwater podzol' or 'humus podzol' are also common, but South-east Asian podzols are not limited to soils formed under groundwater influence. In the 7th approximation, these soils fall in the spodosol order, mainly in the aquod and humod suborders, with local variants in the orthods.

Morphology

The podzols of South-east Asia are always light in texture. Under natural forest, they develop an organic surface layer of matted mor. Their subsurface horizon is light grey and strongly bleached, grading into a dark brown to reddish illuvial horizon composed of organic matter and iron oxides, or of organic matter alone. The great majority of podzols in this region contain only organic matter in the B horizon; these are the groundwater podzols. Iron-humus podzols, developed in West Borneo beyond groundwater influence, have a bleached horizon 40 cm. thick, a dark brown illuvial horizon of 15 cm. depth, and a reddish-brown accumulation of iron 20 cm. deep which grades diffusely into yellowish-brown sandy parent material. In these soils, the B horizon is only slightly hardened, and there is no sign of poor drainage.

The depth of podzols varies widely, those on level ground having bleached horizons over 100 cm. thick and illuvial horizons extending to 250 cm. below the surface. In sloping terrain, the profiles are shallow, overlying nearly impermeable bedrock, and the B horizon may be reduced to a band a few centimetres thick. The lower parts of the illuvial horizons often show dark bands and streaks which

thin out with depth; the underlying material is greyish or whitish, strongly mottled or completely reduced.

Chemical and Physico-chemical Characteristics

Podzols are very acid, with average pH values of 4.5 or less in their surface horizons; these values may increase slightly with depth. The surface horizons have 1.5 to 4 per cent of organic matter, and the B horizons of humus podzols 10 per cent. Carbon : nitrogen ratios range from 15 to 25 in the surface layers to a maximum of 100 in the B horizon. Seepage from podzolic areas has a typical dark brown colour ('black water') due to finely dispersed organic matter. Generally these soils are sandy or loamy sands, with the sand fraction exceeding 80 per cent. The clay fraction is usually below 10 per cent, except sometimes in the lower part of the B horizon where textures may range from sandy clay loams to clay loams. Base saturation is normally below 15 per cent.

Environmental Conditions

Podzols normally occur on level or slightly undulating terrain in continuously wet regions where the annual rainfall exceeds 2,000 mm. They are most extensive on old coastal terraces covered with sandy materials, but are equally common on sandstones and quartzites, and on acid volcanics such as liparites and dacites. They also occur on steep slopes made of coarse acidic materials where rainfall is high. The humus podzols evolved in these places have poor internal drainage due to the shallowness of their profiles overlying impermeable subsoils. Elsewhere, as on partly dissected raised beaches, humus podzols are generally well drained at the present time, although they probably evolved in conditions of impeded drainage.

The natural vegetation on lowland podzols is the so-called 'Kerangas forest', which in Sarawak and Borneo has such characteristic species as *Dacrydium elatum*, *Casuarina sumatrana*, *Agathis dammara* var. *borneensis*, *Agathis alba* and *Whiteodendron moultonianum*; orchids and mosses are abundant, both on trees and on the ground. Where the 'Kerangas forest' is degraded, it is replaced by 'Padang' vegetation, consisting of scattered groups of stunted trees over patches of ground mosses and resembling a heath forest. The natural vegetation changes with altitude; *Pinus merkusii* forests occur around Lake Toba in north Sumatra. At about 1,500 m. on Gunong Padang in Malaya, podzols with peaty top layers are found under savana.

Geographical Distribution

Extensive areas of podzols occur on the coasts of west and south Kalimantan, Sarawak, Brunei and North Borneo. They occupy significant areas in Bangka and Billiton, while minor outcrops are found along the coasts of south Cambodia, south Thailand, Malaya, east Sumatra and southwest Ceylon. At high altitudes, they have been reported from north Sumatra, Malaya and New Guinea.

Land Use and Agricultural Potential

The data outlined in this section are based mainly on field surveys conducted in Sarawak by Dames (23).

Under present levels of management, the podzols do not have great agricultural potential and are in fact utilized only adjacent to settlements, where vegetables

and subsistence crops are grown with the help of heavy manuring. In Borneo, Chinese farmers use these soils for pig rearing and associated cultivation; in Bangka and Billiton, white pepper is fairly common and yields satisfactorily with good management; in Ceylon coconuts have replaced cinnamon on these soils.

Forestry offers the best returns, especially the 'Kerangas' forests with large *Casuarina sumatrana* and *Agathis alba* trees growing on the very deep or 'giant' podzols; on shallower or on badly drained profiles, the 'Padang' or very poor 'Kerangas' forest, typified by stunted trees and open vegetation with small *Dacrydium elatum* is of little or no commercial value beyond the provision of firewood and poles for local use. The clearing of natural vegetation on podzols should be avoided as regeneration is very slow and secondary stands are of low quality. Forest improvement by scientific silviculture merits investigation.

Nomenclature

NON-CALCIC BROWN SOILS

This great soil group is named after soils with similar characteristics in the south-western United States. In Ceylon, Joachim called them 'non-lateritic gray-brown sandy loams' (19), but Moormann and Panabokke in 1962 (25) assigned to them the present group name, which corresponds in part to the red-brown loams and brown loams distinguished by Stephens in Australia (26). The present term was also used in soil surveys of Indonesia (7) and Vietnam (8). These soils are generally considered to have affinities with red-yellow Mediterranean soils, a group that includes the non-calcic brown soils (sometimes called 'brown Mediterranean soils') and the red-brown earths dealt with in the following section. The non-calcic brown soils belong to the ustalf suborder, alfisol order of the 7th approximation; most are ultustalfs, but a few may be typustalfs.

Morphology

Modal soils of the group have an $A_1 - A_2 - B_t$ horizon sequence under natural vegetation. Most profiles are relatively shallow, the A and B horizons together varying from 30 to 60 cm. in thickness. On sandy parent materials the soil may be deeper, but here the B_t horizon becomes less pronounced.

The brownish to greyish-brown A_1 horizon is distinct, but not very dark or strongly differentiated, while the A_2 horizon is rather thin and somewhat lighter in colour. Hardening of the whole A horizon often occurs in the dry season. The textural B horizon is usually yellowish-brown to reddish-yellow in colour; soils with dark red or dark reddish-brown colours are classified as red-brown earths, and colours indicating dominant wetness place such soils outside the present group. The B_t horizon has a higher clay content than the A_2 , with a subangular blocky structure and moderately developed clay coatings. Its lower parts are compact and may form a hard pan.

Chemical and Physico-chemical Characteristics

A diagnostic feature of the group is the high level of base saturation, which increases with depth to a maximum of 100 per cent in the subsurface or C horizon. The B_t horizon should have a base saturation level of at least 35 per cent, accompanied by pH values above 5.0; these values increase to neutral or even slightly alkaline levels with depth. The dominant clay mineral is kaolinite, but some 2:1 lattice clays are also present. Weatherable minerals are present in the coarser fragments throughout the profile, especially in soils evolved from residual parent

materials. The base exchange capacity of the clays is above 15 m.e./100 grams, with average values between 20 and 40 m.e./100 grams clay.

Environmental Conditions

Non-calcic brown soils are found in regions with a long and marked dry season, an annual rainfall of less than 1,500 mm., and mean annual temperatures of over 20°C. Their parent materials are acid to intermediate rocks containing limited amounts of ferro-magnesian minerals, such as granites, gneisses, quartzites, sandstones and intermediate volcanics; these soils also often form on transported materials derived from such rocks. Relief does not appear to play any role in the formation of these soils, which occur on widely varying topography. Their prevailing natural vegetation is an open forest or shrub cover, but they may occur in savanas.

Geographical Distribution

Environmental conditions of the kind outlined above are limited in South-east Asia, and soils of this group are confined to the dry areas of central Burma, Ceylon, south-east Vietnam, east Java and the Lesser Sunda Islands. In Thailand they occur in the central plain and in parts of the north-east.

Land Use and Agricultural Potential

Although non-calcic brown soils are moderately fertile and respond well to fertilizers, the principal restriction upon their agricultural utilization is lack of water. In addition, local profiles may be shallow, stony or limited by rocky outcrops. With irrigation, the deeper soils found on relatively flat ground provide satisfactory crops of cotton and tobacco. In central Burma and central Thailand, they may be used for irrigated rice. Attempts have been made to introduce cotton on such soils in east Java in recent years. They are already used to support pastures for buffaloes, cattle, sheep and goats, but higher carrying capacities could be attained with controlled grazing, selective pasture management and clearing of the brush. The natural vegetation at present occupying such soils is of little economic value.

Nomenclature

RED-BROWN EARTHS

In Ceylon these soils were called 'non-lateritic red loams' and 'terra rossa' (19), and at a later date 'reddish-brown earths' (25). In central Burma similar soils are included among the red-brown savana soils by the Land Use Bureau (10). Workers in Indonesia (7), Cambodia, Laos and Thailand (27) have applied the term 'red-yellow Mediterranean soils' to the group. The present term is introduced in conformity with the Australian nomenclature (26). In the 7th approximation, these soils fit into the rhodustalf great group, some may overlap into the ultustalfs and typustalfs, all forming part of the ustalf suborder, alfisol order.

Morphology

Modal profiles show an A_1 - A_3 - Bt sequence. The A horizon may be weakly developed, especially in soils derived from limestone; with organic matter, this horizon is somewhat darker and browner than the Bt horizon, and when cultivated has a typical reddish-brown or strong brown colour. The textural B horizon has a markedly higher clay content, with colours varying from dark or dusky red to dark reddish-brown; in profiles with a certain degree of hydromorphism, this horizon may be dark brown. It has a blocky structure, with moderate to strongly developed clay coatings, and dries to a hard or very hard consistency.

The soils do not show dominant signs of wetness. Deep profiles are found on colluvials, intermediate profiles on weathered residues, and shallow profiles on limestone topography.

Chemical and Physico-chemical Characteristics

The red-brown earths have medium to high levels of base saturation which usually increase with depth, the Bt horizon averaging more than 35 per cent. Surface pH values are between 6.0 and 7.0; the subsoil is neutral or slightly alkaline. The subsoil of members of a catenary sequence in depressions may be distinctly alkaline (28).

The clay fraction appears to be mostly kaolin, but illitic clays are present in most profiles (28). Micas and feldspars are always present throughout the profile, and may occur in substantial quantities in some shallow soils. The clay fraction has a base exchange capacity of 20 to 50 m.e./100 grams clay. Carbon:nitrogen ratios vary considerably, but in most of the profiles observed they were below 12.

Environmental Conditions

The formation of red-brown earths seems to be determined primarily by parent material and climate. Their parent materials, whether residual or transported, must have fairly high amounts of ferro-magnesian minerals, and the climates in which they evolve have a marked alternation of wet and dry seasons, with average annual rainfall below 1,500 mm. On basic parent rocks such as certain basalts, and especially on limestones, these soils may occur in regions with a higher rainfall and less pronounced dry season. They occur in regions with fairly wide ranges of temperature, but most are found where the average annual temperature exceeds 20°C.

Red-brown earths occupy moderately well to well drained relief. In south-central Java they are found in typical karst topography. The dominant natural vegetation is an open forest, often with spiny shrubs and anthropic savana.

Geographical Distribution

These soils occupy a major part of the dry zone of Ceylon; elsewhere, as in central Burma, Cambodia, Laos, south-east Vietnam and around the central plain of Thailand, they occur in small scattered outcrops. In Indonesia they are found in central and east Java and in Madura, where they are associated with volcanic rocks and limestones.

Land Use and Agricultural Potential

As with the previous great soil group, utilization of the red-brown earths is limited by the availability of water. The shallower and steeply sloping phases are only used for extensive grazing, and on deeper phases shifting rice cultivation is general. Where rainfall is adequate, the dry farming of vegetables, fruits and a wide variety of crops is practised. With irrigation, these soils produce excellent results, but such facilities are rare, particularly in heavily fissured limestone areas. Results from the experimental station at Maha Illupalama in Ceylon indicate that the impervious character of the soil and its temporary saturation during the rainy season pose greater problems than the lack of water. Further research on dry farming is necessary if the potential of these soils is to be exploited. When irrigation is impossible, improved livestock grazing seems the best use. In Java and Thailand teak plantations have been established on these soils, but in general they offer limited potential for forestry.

LOW HUMIC GLEY SOILS AND GREY HYDROMORPHIC SOILS

Nomenclature

In American publications these terms are used for hydromorphic soils with a wide range of morphological characteristics, but not for alluvial soils or for soils which have the prominent A_1 horizon typical of the so-called humic gleys. In this paper, the group includes those hydromorphic soils which possess a textural B horizon, but which lack a thick or highly humic A horizon. In general these soils have not been recognized as a great soil group in South-east Asia. Hydromorphic soils with soft laterite at various depths were assigned to the groundwater laterites. The 7th approximation places such soils both in the ochraquult great group (ultisol order, aquult suborder) and in the aqualf suborder of the alfisols.

Morphology

These soils are characterized by gleying throughout the profile or gleying immediately below the surface. They have a textural B horizon which frequently shows conspicuous strong mottles. In a well developed undisturbed profile the horizon sequence is A_1 (Ap) - A_2 - Btg. The A_1 or Ap is dominantly grey or greyish-brown and not very thick or dark; the A_2 horizon, which may be absent in cultivated soils, is lighter in colour and leached, developing into an ashy-grey layer in soils of low base saturation. The leached A and illuvial B horizons have wide differences in clay content and are sharply differentiated. The Bt horizon is mottled, its matrix colours ranging from light brownish-grey to light olive-grey. It has a weak to moderate subangular blocky structure; clay coatings, sometimes thin and discontinuous, occur on the soil peds. Some or all of the mottles may become lateritic concretions on drying, forming irregular aggregates or a continuous layer in the lower part of the B horizon or in the material below. Lateritic concretions are not normally found in soils of high base saturation.

Chemical and Physico-chemical Characteristics

When found associated with leached soils, such as red-yellow and grey podzolics, the low humic gleys show low base saturation throughout their profiles; in addition, their clay fractions will have low levels of base exchange, usually below 20 m.e./100 grams. When found with less leached soils, they show a higher base saturation throughout and may be alkaline at depth. The pH values vary from about 4.0 in the leached phases to about neutral in profiles with a higher base saturation.

Environmental Conditions

The low humic gley soils are developed on poorly drained low-lying ground above alluvial or colluvial parent materials; only a few examples of profiles developed on acid-rock residuals have been noted. Climate does not appear to play a leading role in their distribution, but in regions where the annual rainfall exceeds 1,500 to 2,000 mm., base saturation of the Bt horizon is usually under 35 per cent, while higher percentages are found in drier areas. Where the annual rainfall is below 800 or 900 mm. no low humic gleys were observed. Their natural vegetation is wet grassland, sometimes with scattered shrubs and trees.

Geographical Distribution

The soils are prominent on all the older terraces of the main rivers in continental South-east Asia, occupying large areas along the Mekong River in Cambodia, Laos and Vietnam. They are also common in central and north-east

Thailand. In these localities, laterite is usually present at depths of 100 to 200 cm. below the surface. Elsewhere in South-east Asia, these soils form small patches on the lower slopes of hilly ground in association with red-yellow podzolic soils; here too laterite may be present. They also form inclusions amidst non-calcic brown soils and red-brown earths in the drier areas.

Land Use and Agricultural Potential

Most low humic gley soils are continuously cropped to rice that depends solely on rainfall; as the groundwater level drops sharply during the dry season, a single crop is normal each year. Rice yields, in the absence of fertilizers, are seldom higher than 1,500 kg. padi per hectare, but can be raised by as much as 60 per cent when adequate applications of fertilizer are made. Other crops, such as tobacco, sugar cane, vegetables and kenaf are also grown on these soils. Fertilizers and irrigation could greatly increase their potential. Thus simple irrigation from wells, as practised in the surroundings of Saigon, would enable a second crop to be grown. At present they are seldom cultivated during the dry season and patches remote from inhabited areas, along the Mekong terraces for instance, are not used at all.

Nomenclature

RED-YELLOW PODZOLIC SOILS

The term red-yellow podzolic soil, drawn from soils of the south-eastern United States, has been used in Indonesia (7), Vietnam (8) and Ceylon (25). These soils occur in association with the yellow latosols of Malaya (29). In South-east Asia generally, these soils are commonly referred to as 'lateritic soils', usually with a qualifying adjective such as 'red', 'yellow' or 'yellowish-brown' to differentiate individual members (9, 30, 19). The term 'lateritic' does not necessarily indicate the presence of laterite, as it is based on low silica:sesquioxide or low silica:alumina ratios, or simply on a red colour. It should also be noted that not all soils that have been called 'lateritic' belong to the present great soil group. This group is mainly part of the suborder of ochrults (ultisol order) of the 7th approximation. Some variants, occurring in the monsoon regions, appear to fall in the alfisol order, ultustalf great group.

Morphology

In modal soils under natural vegetation, the A horizon is distinctly differentiated into a humiferous A₁ and a somewhat paler-coloured leached A₂. The thickness, colour and organic matter content of the A₁ horizon depend largely on climate: at low altitudes the horizon is usually weakly developed, but at higher altitudes it may be 25 cm. thick and extremely humic, especially on level ground. In some profiles, now included in this great soil group, no A₂ horizon is present; the horizon sequence is A₁ - A₃ - Bt, described as reddish-brown lateritic soil in Ceylon (25). A separate great soil group may have to be drawn up for these soils.

The textural Bt horizon has colours of high chroma varying from red to yellow, with a characteristic blocky structure and clay coatings on the soil peds. It varies greatly in thickness, from a few centimetres in sloping profiles to over a metre, while its clay content often differs sharply from that in the A or C horizons. The ratio of clay content in the A and Bt horizons ranges from 1:1.2 to 1:8.0.

The profiles often contain laterite as concretions or as continuous layers; concretions may occur throughout the profile, but continuous layers, whether hard

or soft, mainly develop in the lower B horizon or in the weathering zone below. Soft laterite usually occurs at depths below 100 or 150 cm., and seems to be associated with profiles in high rainfall areas such as the wet zone of Ceylon, southern Cambodia, west Java, Sumatra and Malaya.

Chemical and Physico-chemical Characteristics

In general, red-yellow podzolic soils have a low level of base saturation or of base exchange capacity in their clay fractions, or both these characteristics together. Base saturation is low in the continuously wet regions, rising in areas where there is a definite dry season. In the wet zone of Ceylon, the Bt horizon has a base saturation of 10 per cent, while in the Vietnamese uplands where the dry season is five months long, the same horizon may have a base saturation level of about 50 per cent, accompanied by a cation exchange capacity of under 15 m.e./100 grams clay. In most profiles, the base exchange capacity of the clay fraction is less than 25 m.e./100 grams clay. The dominant clay mineral is of kaolinitic type, with little or no illite or montmorillonite.

The pH values of these soils are usually under 5.5 in virgin profiles, and those of the subsurface horizons from 4.5 to 5.0. There is no marked change in pH with depth, but lower values tend to be found in wet regions. Carbon:nitrogen ratios are generally over 12, and higher when the organic matter content of the A₁ horizon increases.

Environmental Conditions

Red-yellow podzolic soils form on acid to moderately basic parent materials, mostly on residuals of sedimentary, igneous or metamorphic rocks. They rarely occur in areas with less than 1,500 mm. annual rainfall or in areas with a marked dry season. Average annual temperatures are generally above 10°C. The control exerted by topography is slight, as these soils form on all land from nearly flat to mountainous relief; however, topographic conditions are reflected in the depths of profiles and the thickness of the A₁ horizon. Finally, these soils are found under natural vegetation ranging from lowland tropical forest to short grass savana. In the highlands of Vietnam, Laos and Cambodia, they occur under pine forests.

Geographical Distribution

These soils are dominant in the wetter parts of South-east Asia wherever non-basic parent materials outcrop. In Vietnam they occupy more than half the total area of the country, and are strongly developed over the non-volcanic parts of west Java, Sumatra and Borneo. Current investigations indicate similar patterns of distribution in Malaya.

Land Use and Agricultural Potential

The red-yellow podzolic soils are very poor in nutrients and highly susceptible to erosion because of their low permeability, low aggregate stability, sharp transition between surface horizons and heavier subsoils; even on slight slopes, intense rainfall and runoff may cause great damage. In addition, since crop yields are disappointing without skilled management, vast areas have been cultivated and subsequently abandoned to 'alang-alang' (*Imperata cylindrica*), as in south Sumatra and west Java. In the wetter areas, these soils are extensively used for rubber, as in Ceylon, Indonesia, Malaya and south Thailand. At low altitudes, coconuts and oil palm plantations are found, with tea on higher ground in Ceylon. Locally, some shifting cultivation is practised, leaving poor secondary forest or coarse grass-

land in its wake. Important tracts are forested, especially in areas of rugged relief. Better use of these soils depends entirely on improved agricultural practices involving fertilizer amendments, soil conservation and water storage, as are applied to the flourishing vegetable plots on the high plateaus of Dalat in central Vietnam, and to the pineapple fields of south Sumatra.

Nomenclature

GREY PODZOLIC SOILS

This term is introduced by the authors on the basis of their surveys in countries along the lower Mekong River (8, 27). French studies in Vietnam have called these soils 'terres grises' or grey soils. Pendleton's Korat Series of Thailand (31) is largely equivalent to this group, which has also been referred to as groundwater laterite. The grey podzolic soils are comparable to certain podzolic laterite soils of Australia (26), but no satisfactory place for them is yet available in the 7th approximation. Most would be classified as ochrults (ultisol order), but those of higher base saturation would fall into the ultustalf great group, alfisol order.

Morphology

Grey podzolic soils generally show poor horizon development, the colours under the weak A_1 being rather uniform. The A_1 or A_p horizon has a weak crumb structure, and the A_2 may be structureless. When evolved from sandy parent materials, there is no definite field evidence for a textural B horizon, yet all analytical data show the existence of an eluvial A and illuvial B, the latter having colours of low chroma ranging from reddish-brown to greyish-brown or brown. In profiles evolved from medium-textured parent materials, the Bt horizon is more pronounced, reaching depths of 100 to 200 cm. below the surface, and with weak subangular blocky structures discontinuously coated with thin clay films.

In many profiles, a somewhat compacted layer, not attaining the status of a hard pan, occurs just below the surface. When exposed by erosion, this layer is bare of vegetation. Most profiles contain concretionary or continuously layered laterite, 0.5 to 2 m. thick, at depths of from 1 to 5 metres depending on the level of the past or present watertable. Sometimes two or more superposed layers are found. In areas where the watertable has been lowered following erosion, the laterite is usually hard, but in stable landscapes the laterite horizon, or at least its lower part, is soft and used widely for construction.

Chemical and Physico-chemical Characteristics

These soils lack appreciable quantities of weatherable minerals, and their pH is mostly about 4.5 in the surface layers, increasing only slightly with depth; in drier areas, the values may be higher. Base saturation also varies with climate, more specifically with the length of the dry season, but averages are low. Levels of 10 to 65 per cent were found in soils from different parts of the Mekong basin. Base exchange capacity is consistently low, often falling below 10 m.e./100 grams clay, which consists almost entirely of kaolin. Indeed, some clayey layers offer good prospects for industrial use. Coarser fractions are almost exclusively quartzitic, sometimes white, but more often coated with coloured layers. Typically, the loose bonds between the organic and mineral components of the soil permit rapid erosion of the organic matter and clays from surfaces exposed to rain, leaving a light grey-brown or even whitish surface.

Environmental Conditions

Most grey podzolic soils form on transported materials such as the acid, light- to medium-textured old alluviums forming terraces along rivers in continental South-east Asia. Surface relief is flat to gently rolling, with slow surface drainage; no soils of this group have yet been found on steeper slopes with excessive runoff. Climatically, they occur in the monsoon areas, typical profiles developing where annual rainfall exceeds 1,500 mm. Minor outcrops have been seen in the equatorial belt in Borneo and Sarawak, and large tracts occur in north-east Thailand, where the climate is considerably more arid. In these environments, the grey podzolic soils dominate, with red-yellow podzolic soils and red-yellow latosols forming minor inclusions. They are found under open forest dominated by dipterocarps, and in wetter areas under non-dipterocarp woodland.

Geographical Distribution

These soils are the dominant soils of the Mekong River terraces in north-east Thailand, south-west Laos, Cambodia and Vietnam. They also occur on terraces of the Chao Phaya and Ta Chin rivers in central Thailand, and of the lower Irrawaddy in Burma. Smaller outcrops are found in the wetter regions of central Vietnam, south Thailand, Sarawak, Borneo, Bangka and Billiton.

Land Use and Agricultural Potential

The agricultural potential of the grey podzolic soils is low, and most are uncultivated. Some shifting rice is found, but less than occurs on red-yellow podzolic soils. Subsistence agriculture involving fruit gardens and tapioca is practised around settlements bordering low-lying rice lands or where the watertable is shallow enough to allow well irrigation. In the last few years, weakly hydromorphic phases of these soils have been increasingly used for kenaf in shifting cultivation in north-east Thailand. In Vietnam, medium-textured soils of the group have been successfully planted to rubber; with modern management and fertilizer practices, especially those involving the use of potassium, yields are satisfactory. But further extension of rubber growing can only be possible in areas with at least 1,500 mm. annual rainfall or in areas with a good watertable at medium depth (3-10 m.). Erosion hazards and low levels of fertility make sedentary agriculture by peasant farmers a precarious business.

Nomenclature DARK RED AND REDDISH-BROWN LATOSOLS

These soils were once called lateritic soils, a term which has become too broad and confusing as it has been extended to a wide range of soils and soil concepts in various parts of the world. Accordingly, Kellogg introduced the term latosol in 1949 (32), and the authors now apply it to the soils of South-east Asia previously known as 'red earths' (16), 'rotlehme' (33), 'lateritic soils' (17) and 'terres rouges' (11). The defining adjectives are included in the name of the group, since variations in colour appear to be related to soils of different composition and fertility. This nomenclature, and the subdivision adopted, are tentative; further studies should provide more precise criteria for differentiation.

In the 7th approximation, these soils fall in the udox suborder of oxisols, which are permanently moist. In certain areas in east Java, Cambodia and central Vietnam, some soils of the group may fit the ustox suborder, as they are dry for part of the year.

Morphology

These soils are deeply weathered and leached so that primary minerals are insignificant and their clay fractions dominantly kaolinitic and sesquioxidic. A typical profile is deep and uniform, showing little horizon differentiation. The surface horizon, with a relatively low humus content around 1 per cent, passes gradually downwards into a dark red or reddish-brown clay which extends to depths of at least 3 metres, and may attain a thickness of 10-15 m. The upper part of this horizon is very friable, with granular to subangular blocky structures of high porosity and great stability, the result of the combination of crystalline clays and sesquioxides. In the field, these soils feel like silty clay loams or silty clays, but textural analysis shows that they are clays; this is the result of the dissolution of iron and the destruction of micro-aggregates of crystalline clay and sesquioxides. There is little or no clay migration in the profile, but some discontinuous clay coatings and patches of firmer consistency may develop. Concretionary layers and mottled horizons may be found occasionally in the lower parts of the profile.

Chemical and Physico-chemical Characteristics

The dark red and reddish-brown latosols are acid to slightly acid with pH values ranging from 4.5 to 6.5. Base saturation varies between 20 and 60 per cent. The sorptive capacity of the clay complex is low, normally under 20 m.e./100 g. clay. The silica:sesquioxide ratio of the clay fraction ranges from 1.2 to 2. The 7th approximation adopts a minimum value of 12 per cent of sesquioxides in the clay fraction of such soils. Clay contents vary from 50 to 60 per cent and may be as high as 80 per cent; the silt fraction is low, and sand is often insignificant.

Environmental Conditions

Soils of the group evolve mainly from basic parent materials such as basalts, diabases, diorites, andesites or from granites and gneisses containing substantial amounts of black mica. Topographically they occupy well drained sites on undulating to hilly land between sea level and 1,600 m. These soils occur in the humid tropics where the average annual temperature is above 22°C., the annual rainfall between 1,000 and 3,000 mm., and the dry season usually of less than four months' duration. The soils developed in regions with a definite dry season have higher levels of base saturation and higher pH values.

The natural vegetation is primary rainforest or forest savana, but extensive secondary forest is common in areas subjected to shifting cultivation. In South-east Asia large tracts of these soils have been cleared for permanent agriculture.

Geographical Distribution

Soils of the group occur extensively on the lower volcanic ranges of west Sumatra, Java, Bali, the Moluccas, Philippines, south Vietnam and east Cambodia; they also occur on the basic rocks forming the high plateaus of east and west Burma and west Thailand. Other formations are reported from central Laos, south-east Thailand and central Malaya.

Land Use and Agricultural Potential

Although these soils do not have a high level of intrinsic fertility, they are among the most productive soils of the region due to their excellent physical properties, depth and resistance to erosion. They are extensively terraced for

irrigated rice on volcano slopes in central Java. They support food crops such as peanuts, sweet potatoes, beans and tapioca, the last grown for local consumption as well as for export; fruits such as papaya, citrus, jackfruit, bananas and pineapples; and industrial crops such as rubber, sisal and kapok. The world's most productive rubber plantations, in Cambodia and south Vietnam, are located mainly on these soils, while coffee and, locally, cocoa are produced from them in Java, Burma and Vietnam. In Cambodia, the Philippines and Vietnam, these soils are used for shifting cultivation. Since they are resistant to erosion, the practice does not seem unsuitable, and is certainly preferable to continuous cultivation under poor management, which may cause structural degradation of the surface horizons and accelerate erosion. Secondary regeneration of vegetation in the wake of shifting cultivators seems to restore soil fertility and physical condition when the land is not cropped too frequently. These soils respond well to combined dressings of nitrogen and phosphorus, especially in wet areas. Minor elements are sometimes needed for specific crops.

Nomenclature

RED-YELLOW LATOSOLS

The nomenclature of this group has developed along similar lines to that outlined for the dark red and reddish-brown latosols, and the colour adjective used here reflects different colours as well as variations in other characteristics. These soils appear to fit into the udox subgroup of oxisols, but the present distinction between the dark-red and reddish-brown latosols and the red-yellow latosols has no exact parallel in the 7th approximation.

Morphology

Like the dark red and reddish-brown latosols, these soils are deep, friable, low in primary minerals and have little horizon differentiation. However, they are more acid, less clayey, less strongly structured, and have lower base saturation than their darker relations. In addition, some profiles formed on old alluvial materials may be quite sandy. Their surface layers are distinctly lower in clay than the subsoils, but there is no horizon of clay accumulation (Bt). They often have mottled horizons and concretionary layers at depth. The solum ranges from bright red to yellow, the actual colour being related apparently to the iron content of parent materials, to soil drainage or to climate; with lower iron contents, poorer drainage and higher rainfall, the soils tend to become more yellow.

Chemical and Physico-chemical Characteristics

Red-yellow latosols have pH values averaging 4.5, and base saturation seldom exceeding 30 per cent. However, secondary resaturation may occur in shallow soils and in soils in low rainfall areas. The base exchange capacity is less than 20 m.e./100 g. clay. The silica:sesquioxide ratio is generally below 1.5. Clay content varies between 15 and 60 per cent, and the silt fraction is low. The sand content is considerably higher than that of the dark red and reddish-brown latosols. Water-holding capacity, which is related to texture and structure, is lower than that of the reddish-brown latosols.

Environmental Conditions

Most red-yellow latosols are found on residual parent materials which are often acidic in composition. Topographically, they are found on undulating to mountainous land, and from sea level up to 1,000 m. When formed on transported materials, they occupy old coastal or fluvial terraces such as those of north-west

Ceylon and north-east Thailand; such soils appear to have formed under a different climate than that prevailing today, and are considered to be fossil formations. Elsewhere, the red-yellow latosols evolve in a wide range of climates, having been mapped in regions where annual rainfall is as low as 600 mm. or as high as 3,000 mm. and where the dry season is weakly expressed (Borneo) or strongly pronounced (Vietnam, north-east Thailand and north-east Ceylon).

The natural vegetation is a primary rainforest or forest savana; more natural vegetation survives on these soils than on the dark red latosols since comparatively limited areas have been cleared for cropping. But extensive shifting cultivation has produced large tracts covered by secondary vegetation and anthropic savana.

Geographical Distribution

These soils have their greatest extensions in Borneo, north-east Sumatra, Sarawak, Brunei and Mindanao. They also occur in the uplands of south Burma, in Thailand, south Vietnam, Malaya and north-east Ceylon. In south-east Borneo, Bangka and Billiton, they occur in association with groundwater laterite and bauxite formations.

Land Use and Agricultural Potential

The use of these soils varies with topography and local climatic conditions. Extensive plantations of oil palm and rubber are located on them in north-east Sumatra, and white pepper in west Borneo, Bangka and Billiton. Maize, sweet potatoes and tapioca are common crops in subsistence farming, while shifting cultivation is widespread in central Vietnam, central Borneo and Mindanao, leaving in its wake tracts dominated by *Imperata cylindrica*. In Ceylon these soils are not generally cropped. Where rainfall is adequate, they respond well to nitrogen and phosphorus; the latter should be applied in concentrated soluble form.

Nomenclature

ORGANIC SOILS

Organic soils have been variously termed 'bog soils', 'half-bog soils', 'peaty soils', 'marsh soils', or 'soils of swamps'. In South-east Asia they are best known as peat or swamp soils, but since these terms cover a wide variety of soils formed under environments ranging from lagoonal marshes to poorly drained mountain depressions, further subdivision of the group will probably be necessary as further work is done. In the 7th approximation, these soils are histosols.

Morphology

These soils are defined as containing at least 30 per cent of organic matter in a surface layer at least 30 cm. thick. Although thicknesses of 15 m. have been observed in many places on the east coast of Sumatra, the average for South-east Asia lies between 1.5 and 5 metres. This organic surface layer is of mor type, containing large quantities of undecomposed roots, twigs, branches and even tree boles. It overlies a white to grey mineral horizon which is completely reduced or which may have faint yellow mottles.

Chemical and Physico-chemical Characteristics

Because of their limited agricultural potential, no systematic studies have been made of organic soils, and analytical data are comparatively scarce. Most of these soils are known to be very acid, their pH values of around 4.0 in the surface layers increasing only slightly to about 4.5 with depth. The carbon:nitrogen ratio is

always greater than 15. The available nutrient levels in the organic and mineral horizons are very low. The texture of the mineral horizon may range from sand to clay.

Profiles in tidal marshes may accumulate sulphur, and following drainage and oxidation, may become extremely acid, with pH levels well below 3.0. The acidification process is outlined in greater detail in the section dealing with alluvial soils.

Environmental Conditions

Organic soils develop in badly drained localities of sluggish or stagnant water movement, where the watertable is constantly high or even above the ground surface for several months a year. Such conditions are found in coastal marshes, inland swamps and in mountain depressions at various altitudes. These soils occur in close association with podzols formed from sandy parent materials, and with low humic gleys formed from finer-textured materials; in volcanic uplands they are associated with andosols wherever drainage is impeded.

Most of the organic soils of South-east Asia evolve as 'raised bogs' on level to slightly undulating ground only a few metres above sea level or above a floodplain. Rainfall ranges between 1,500 and 2,500 mm. per year, with at most a short dry season; the average annual temperature is 24-26°C. The natural vegetation is 'peat swamp forest', which varies in composition according to local drainage conditions and the peat thickness; in some coastal areas, *Melaleuca leucadendron* dominates. Most organic soils developed in this environment are acid, and are comparable with the high mors of temperate climates; locally, as for example in Java, eutrophic peats have been reported. The raised bog soils are generally 2 to 5 m. deep, and appear to rise rapidly from the surrounding land, there being no appreciable periphery of shallower peat.

Shallower peat soils are found in accreting areas, such as occur on the coast of Sarawak and east Sumatra. In recent floodplains a heterogenous profile composed of alternating layers of mineral and organic horizons may develop.

Geographical Distribution

Organic soils cover large areas in South-east Asia, as for example on the east coast of Sumatra, the west and south coasts of Borneo, the west and east coasts of Malaya, and the coasts of Sarawak, Brunei and North Borneo. Smaller outcrops are found in Ceylon, south Vietnam and in the southern Philippines. It is estimated that they cover about six million hectares in Indonesia, and that they represent 15 per cent of the total area of Sarawak.

Land Use and Agricultural Potential

In Indonesia and Malaya, the natural forests on these soils are exploited for timber. In north-east Sumatra estate and smallholder rubber is established on drained areas; in central Sumatra and south Borneo, rice is grown by repeated transplantations of seedlings to lower areas exposed by receding floods. Locally, pineapples and cachou are found. In general, crop yields are far below those obtained from better-drained soils; thus, in Borneo, yields of only 500-650 kg. of milled rice per hectare are normal.

So far, the organic soils are relatively untouched by agriculture, but with increasing pressure on land resources, particularly in the overpopulated countries of South-east Asia, there is greater interest in reclaiming them for intensive pro-

duction. In tidal areas, reclamation may take the form of canals and ditches which discharge water at low tide. Drainage should not, however, cause irreversible dehydration of the peat, which in extreme cases can shrink to a mere 20 per cent of its original depth, depressing the whole area and making further drainage costly or impossible; such irreversible drying also converts the peat from a spongy mass to hard aggregates which cannot absorb water and which form a poor medium for plants. Such dried aggregates are liable to catch fire. Together, these processes may result in the exposure of the acid mineral subsoil.

When properly reclaimed, however, organic soils provide a good physical medium for crops, especially vegetables. But they are generally deficient in major nutrients and in many minor elements, especially copper and molybdenum. Their successful utilization therefore depends on strict water control and advanced techniques of soil management.

Padi soils

SPECIAL SOIL FORMATIONS

These are soils that develop special characteristics as a result of the artificial flooding associated with wet rice growing. The most important special characteristic is the formation of a surface gley with ferruginous mottling, often concentrated in thin tubes around the rice roots, and set in a grey or greyish-brown soil matrix. During inundation, the surface horizon may become bluish-grey owing to complete reduction. This surface gley, also known as an 'inverted gley', may extend to depths of 50 or 60 cm.; in hydromorphic profiles it grades into the groundwater gley, but in non-hydromorphic soils the original soil colour gradually reappears with increasing depth. In freely drained soils that have been irrigated for a long time, iron and manganese compounds migrate from the upper horizons and accumulate at 20 to 60 cm. below the surface, sometimes forming a hard pan (34, 35). Clay may also migrate downwards in the profile, but does not produce a textural horizon. Many padi soils also develop ploughpans as a result of repeated puddling by cultivators. Other special features are accumulations of the silt carried in irrigation water, and modifications of local relief by terracing.

These special characteristics are produced in greater or lesser degree, depending on local conditions and the duration of cultivation. Although these features are most evident in the surface horizons, the soils maintain their essential characteristics of horizon sequence, fertility status, subsoil physical properties, textures, sorptive capacities and internal drainage, which rapidly reappear when they are used for dry crops. However, the acquired characters of the surface horizons influence rooting depths and fertilizer requirements.

In terms of the 7th approximation, the adjective 'antraquic', meaning a surface gley caused by human action, might be added to the names of the great soil groups whenever the special characteristics outlined above are strongly impressed. At lower levels of classification, detailed subdivisions might be based on the thickness of the surface gley, the presence or absence of a ploughpan or hard pan, the depth of groundwater gley in hydromorphic soils, the depth of irrigation-borne silt, and so on, as proposed in Kanno's systematic classification (36).

Padi soils occur chiefly in the rice-producing alluvials of South-east Asia, and are extensive in low humic gley soils. In upland regions, especially those of Java, the typical surface gley and pan are superimposed on most of the other great soil groups described above but especially on latosols, andosols and regosols derived from volcanic ash. In grumusols, however, the impermeability of the profile prevents downward migration and the widespread fissuring prevents the formation of a hard pan.

Laterite

Laterite, or plinthite in the terminology of the 7th approximation, is defined in this paper as sesquioxide-rich material forming aggregates of varying size and colour or continuous layers with reticulate colour patterns. It embraces hard concretions, pans and soft material which hardens irreversibly on exposure. So defined, laterite may be of fossil or present formation.

Laterite forms extensive horizons in many great soil groups of South-east Asia. Most of the grey podzolic and low humic gley soils occupying old river terraces and penepains in continental South-east Asia contain continuous layers of soft laterite which is commonly used as a building stone. In these soils, hard concretionary forms also occur in association with lowered watertables; these forms may occur close to or at the surface. Similar laterites, mostly of the hard variety, develop in red-yellow podzolic soils, but those found in the subsoils of Ceylon's wet zone are soft, continuous or irregular. Latosols derived from old plateau basalts in south Vietnam and Cambodia, and from sedimentary material in Borneo, Bangka and Billiton, have extensive layers of hard laterite concretions. In soils evolved from young basalts, the laterite concretions and continuous hard pans near the surface are usually confined to the lower, hydromorphic parts of the landscape. In other great soil groups, laterite is less important in extent and in volume; scattered concretions are frequent, however, in alluvial soils and in certain soils of the drier regions such as red-brown earths, non-calcic brown soils and their hydromorphic associations.

Almost all laterite is formed in soil horizons that are seasonally or temporarily saturated by the watertable. In the shallow to medium depths over which the watertable fluctuates, 'active' or soft sheets of continuous laterite may develop, as in the broad river terraces of continental South-east Asia. Similar conditions prevailed on the old basalt plateaus of south Vietnam and Cambodia, where subsequent erosion has left the lateritic formations as remnants on the penepain surfaces. In the dry zone of Ceylon, such 'groundwater laterites' form the summits of tabular hills. In these areas, where the watertable has been lowered steadily during rejuvenation, the laterite is always hard; soft or 'active' laterite formations are typical of areas where the watertable remains stable over long periods.

In soils with profile drainage impeded by bedrock, a clayey subsoil, iron pans, or by a clay-enriched illuvial B horizon, concretionary laterite may develop as a 'suspended' horizon above the less permeable layer. As the impervious layer may be of geological rather than of pedological origin, the suspended laterites may not necessarily conform to the soil horizons or surface contours, and may even truncate the horizons. Such formations are clearly related to climatic conditions, since they often develop over great depths in the soils of wetter regions, but are only found at shallow depths in those of drier regions.

Locally, laterite may develop at or near springs where groundwater containing iron comes into contact with the atmosphere. This occurs on the lower margins of the dome-shaped basalt plateaus and along the sides of incised valleys in south Vietnam and Cambodia; further upslope, no laterite can be found in the deep latosols, indicating that the laterite concretions are limited to the hydromorphic-physiographic border zone. Similar physiographic controls operate in and around depressions found in basalt plateaus where localised runoff or lateral drainage induces laterite formation on the lower slopes and depressions. The adjacent soils contain no laterite, suggesting that saturation never occurs.

Soils in which laterite occurs are not necessarily poor soils, and the laterites themselves, although possibly occupying a large volume of the total profile, are not necessarily made of highly weathered materials; they may include weatherable micas and even calcareous inclusions, depending on the parent materials. In themselves, laterites do not affect the agricultural value of a soil, unless they appear at shallow depth or as continuous hard pans at the surface, when difficulties of root penetration may then present an obstacle to cropping.

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RUBBER SMALLHOLDINGS IN THE FEDERATION OF MALAYA

By J. M. F. GREENWOOD

THE FEDERATION of Malaya is now the world's largest natural rubber producer, contributing 35.4 per cent of world production in 1960. Rubber accounted for 62.5 per cent of the country's exports by value in that year, and of the total production of 706,000 tons, 292,800 tons or 41.5 per cent were produced on smallholdings (1a).

By statistical definition in the Federation, a rubber smallholding is an 'area, contiguous or non-contiguous, aggregating less than 100 acres, planted with rubber or on which the planting of rubber is permitted, and under a single legal ownership' (1a). The majority of smallholdings are in fact less than 10 acres in size. During 1960 smallholdings accounted for more than 25 per cent of the Federation's exports by value, and produced 14.7 per cent of world natural rubber production (1a).

The smallholding sector is thus clearly of major importance in the Federation rubber industry. Surprisingly, it is a sector for which accurate data are scarce. This paper attempts a description of the present situation in the smallholding sector, with special reference to recent developments and trends. However, it must be stated that for lack of data many of the statements made here are based on conjecture and field observation.

SMALLHOLDING ACREAGE

The acreage of smallholding rubber land is not accurately known, but it can be estimated on the basis of data published by the Statistics Department (1a, b) supplemented by data collected by the Smallholders' Advisory Service of the Rubber Research Institute (R.R.I.) of Malaya (2).

In 1952 the Statistics Department estimated, on the basis of Land Office records, that 1,750,766 acres were then alienated for rubber cultivation on 'holdings' of less than 100 acres, and that of this total, 1,616,093 acres were planted to rubber (1b). In view of their source, these figures may well have been subject to considerable error. The area estimated as planted probably included areas that were not in fact planted. More important, the Land Office records were records of alienations of land in lots smaller than 100 acres. No reference is made to ownership, so that some of the area, held by owners of several lots which totalled more than 100 acres, will have been incorrectly classified as smallholding rubber land. The estimate also failed to take account of rubber land originally alienated for the cultivation of other crops and of State land illegally planted to rubber, for both of which no records existed.

From 1946 to 1960 the Statistics Department made no attempt to estimate changes in the smallholder rubber acreage, but published in the Rubber Statistics Handbooks a figure of 1.5 million acres. The estimates made in 1952 are, however, the best available, and for the purposes of this paper the total area planted with rubber on smallholdings in 1952 is taken as 1,616,093 acres. Despite its doubtful origins and accuracy, this figure is useful in calculations which can be checked by data from other sources.

To obtain the present acreage of smallholder rubber, new planting and the rubber land transferred to the smallholder sector by the fragmentation of

estates must be added to the 1952 figure. New planting is undertaken by individual smallholders and, since 1956, by participants in various block planting schemes. All new planters are assisted by the R.R.I. Smallholders' Advisory Service, and the acreages reported by its field staff constitute the most recent available data.

The increase in the smallholding acreage produced by the fragmentation of estates may be calculated from data in the Rubber Statistics Handbooks (Table 1).

TABLE 1: ACREAGE TRANSFERRED FROM ESTATES TO SMALLHOLDINGS, 1953-1961 (1)

YEAR	TOTAL ESTATE ACREAGE	ANNUAL CHANGE	ESTATE NEW PLANTING	TRANSFERRED TO SMALLHOLDINGS
	Acres	Acres	Acres	Acres
1953	2,041,000	—	—	—
1954	2,028,000	— 13,000	7,100	20,000
1955	2,025,000	— 3,000	10,000	13,000
1956	2,017,000	— 8,000	14,700	22,700
1957	2,020,000	+ 3,000	16,100	13,100
1958	1,989,000	— 31,000	13,900	44,900
1959	1,950,000	— 39,000	14,400	53,400
1960	1,942,000	— 8,000	10,000	29,700
1961		10,000*	10,000*	20,000*
TOTAL				216,900

* estimated.

The total acreage of smallholdings in December 1961 can then be estimated as follows:

Planted acreage, 1952	1,616,093 acres
Block new planting, 1956-61	119,750
Individual new planting, 1952-61	83,601
Transferred from estates	216,900
Total:	<u>2,036,344 acres</u>

This total may be exaggerated to the extent that some of the land reportedly under rubber in 1952 was probably not so planted, and to the extent that land fragmented from estates has not entered the rubber smallholding sector. On the other hand, the figure for individual new planting includes only those holdings known to extension workers; rubber has also been planted illegally on land alienated for other purposes and on unalienated land. It is not possible to estimate the acreage affected in these ways, and for the present purpose it will be necessary to accept a figure of a little more than two million acres for the total smallholding rubber area. This is without doubt a more realistic estimate than the total of 1.5 million acres used as a working figure in the past.

THE 1960 AGRICULTURAL CENSUS

The Census of Agriculture taken in April 1960 reported a total smallholding acreage much smaller than two million acres. While examining the Census data, it is necessary to keep three points in mind. Firstly, the relevant published reports

are concerned only with farms of less than 100 acres, but all block plantings and settlement schemes were excluded from the primary enumeration. Census data for this land, which constitutes groups of smallholdings, have not yet been published.* Secondly, the Census specifically excluded farms controlled by residents in urban centres with more than 1,000 households, and by residents in smaller urban centres in which the District Agricultural Census Committees considered that less than 5 per cent of the households were engaged in agriculture (3a). Thus rubber smallholders in 198 urban centres, large and small, were excluded from the Census. Thirdly, the Census took a 5 per cent sample of farms less than 15 acres in size, and a 50 per cent sample of farms with 15 to 100 acres (4).

The Census is thus incomplete; while the omissions may be of little significance for the analysis of padi farms and other short-term crop cultivation, they are of very great importance for the analysis of rubber farms. It is well known that a number of city residents who derive their chief income from commercial activities, also own small areas of rubber land. It is also probable that the majority of the agriculturally employed residents in smaller urban areas are rubber growers. Rubber is an attractive investment to the urban resident, since it is a permanent crop which requires little attention once it is established. Exploitation requires a minimal degree of supervision, and production can easily be adjusted to the market or other factors.

The Census reported a total of 931,104 acres planted with rubber on 175,392 farms; 90,886 of these farms, with 75 per cent or more of their cultivated acreage under rubber, were classed as rubber farms (5a, b). In the light of the omissions noted above, this represents only a part of the rubber smallholding acreage in the Federation. The estimate arrived at above, and other considerations to be mentioned below, suggest that the acreage reported by the Census is in fact approximately half the actual acreage.

NUMBERS OF SMALLHOLDERS

The number of persons owning smallholding rubber land in the Federation is not known, but it can be estimated from the total acreage of rubber smallholdings and the size distribution of smallholdings reported by the Census.

Given that block plantings, individual new planting during 1960 and 1961, and smallholdings fragmented from estates during 1960 and 1961 are not included in the published reports of the Census, an estimate of the acreage omitted and owned by urban residents can be made as follows:—

Total estimated smallholder acreage, 1961 :		2,036,344 acres
Acreage of block planting :	119,750	
Individual new planting, 1960-61 :	34,201	
Transferred from estates 1960-61 :	49,700	203,651
1961 planted acreage,		
less smallholder land omitted from the Census		1,832,693 acres
Acreage of smallholder rubber land reported by the Census :		931,104 acres
	Balance :	901,589 acres

* Data for block plantings and settlement schemes were published, after this paper was written, in *Preliminary Report No. 15* (November, 1962) of the Census.

This balance of 901,589 acres, not included in the Census and not included in block planting, new planting, etc., may comprise land in any of the following categories: (a) land alienated for rubber but not cultivated; (b) land alienated for rubber but used for other crops; (c) lots in holdings of more than 100 acres; or (d) land owned by urban residents and excluded from the Census. The first three categories were taken into account for the estimation of the smallholding area at 1,616,093 acres in 1952. The additions made to this figure to reach the 1961 estimate are, with the exception of the land fragmented from estates, known to be planted with rubber. It may therefore be concluded that the rubber land owned by persons resident in urban centres and excluded from the Census amounts to some 900,000 acres.

The rubber holdings owned by urban residents will be similar to the urban rubber farms reported by the Census, i.e. farms operated by persons resident in gazetted urban areas. From the Census it can be calculated that the weighted mean size of an urban rubber farm is 10.6 acres (6a). It follows that these 900,000 acres of rubber land were owned by some 84,900 urban residents.

New planting by individuals in 1960 and 1961 totalled 34,201 acres. Such planting would be on rubber farms rather than on mixed-crop farms, and the average farm size can be assumed to be the 8.2 acre average size reported by the Census for established rubber farms (6a). The number of persons undertaking new planting was therefore 4,170. It is not possible to ascertain the proportion of formerly landless persons among this number. For present purposes the arbitrary assumption is made that half the number undertaking new planting in 1960 and 1961 were previously landless. Block planting schemes, affecting 119,750 acres, account for a further 19,958 new smallholders, each receiving about 6 acres of rubber land.

The total number of rubber land owners in the smallholder sector can consequently be estimated as follows:

Owners reported by the Census:	175,392
Urban resident owners excluded from the Census:	84,900
Individuals planting new land in 1960 and 1961:	2,085
Participants in block planting schemes:	19,958
	<hr/>
Total	282,335

This is very much fewer than the 392,985 smallholders who, according to official statistics, owned a very much smaller total area of rubber land in 1952 (1b). The source of the disparity lies, without doubt, in the fact that the 1952 figures were reached from land alienation records, each alienated lot being accepted as a holding; the Census shows clearly that 53 per cent of the rubber farms reported comprised more than one parcel, each of which may include one or more lots (6b).

It may be assumed that the total number of smallholdings estimated in 1952 will be comparable to the total number of smallholding parcels reported by the Census. The 90,886 rubber farms recorded in the Census comprise 194,740 parcels. The remaining 84,506 farms reporting some rubber can be assumed to be farms on which the land under rubber is a single parcel. Similarly, it can be assumed that the unreported rubber holdings owned by urban residents are divided into parcels in the same way as the urban rubber farms reported by the Census. The 19,774 urban farms reported comprised 36,916 parcels, or an average

of 1.87 parcels per farm (6b). On this basis the 84,900 holdings not included in the Census would comprise a total of 158,763 parcels.

From the above assumptions and calculations, the number of parcels in the rubber smallholding sector can be estimated as:

Parcels on rubber farms recorded by the Census :	194,720
Parcels on other farms recorded by the Census :	84,506
Parcels on unreported urban farms :	158,763
Parcels newly planted by individuals :	4,170
Parcels newly planted in blocks :	19,958
	Total
	462,117 parcels

This estimate compares well with the 1952 estimate for a smaller total acreage, and it indicates not only the error in assuming that single lots or parcels constitute holdings but also the fact that the size of rubber land parcels in the smallholding sector has changed but little in the last decade.

TOTAL ACREAGE AND NUMBER OF SMALLHOLDINGS ESTIMATED FROM OTHER DATA

Estimates of the total planted acreage and the number of smallholdings have now been made from traditional statistics, with the aid of the mean farm sizes reported by the Census. These estimates depend on the doubtful accuracy of the 1952 estimate of the total acreage. Estimates can however be made from other sources: the production data for the smallholding sector, published by the Department of Statistics, and the rubber yields reported by the Census.

The Census reported a total of 499,137 acres in tapping (5b). Of this area, 487,663 acres were tapped under the control of the owner, and produced in 1960 some 91,210 tons of marketed rubber, or 419 lbs. per acre per year (5c). This figure does not include scrap rubber, and at least 10 per cent must be added to obtain the total production. When this is done, the annual yield per acre becomes 461 lbs.

The total production attributed to smallholdings in 1960 was 292,800 tons. From this figure and from the production of the farms included in the Census, an estimate can be made of the tapped acreage omitted from the published Census reports, if it is assumed that this additional acreage produced at the same rate as the area included in the Census. To obtain the total smallholding acreage, the untapped mature acreage and the immature acreage must then be added.

The Census reported a total of 431,967 acres of untapped mature and immature rubber (5a). Of this area, 404,815 acres were planted after 1945, which can be taken as the immature acreage reported by the Census. The actual immature acreage at the end of 1961 can be estimated, for reasons given later, at 573,983 acres. The immature acreage to be added to the total mature and immature acreage reported by the Census is therefore the difference of 169,168 acres between the estimated total immature acreage and the immature acreage reported by the Census.

The total acreage of smallholdings can then be estimated as follows:

Tapped acreage omitted from the Census

Total smallholders' production, 1960: 655,872,000 lbs.

Production from the 499,137 acres covered by the Census, at 461 lbs./acre :	230,102,157 lbs.
Balance :	425,769,843 lbs.
Acreage omitted, at 461 lbs./acre :	923,579 acres
<i>Total smallholding acreage, 1961</i>	
Area reported by the Census, in tapping :	499,137
Area reported by the Census, not tapped :	431,967
Area omitted by the Census, in tapping :	923,579
Area omitted by the Census, immature :	169,168
	<u>2,023,851 acres</u>

Various yield estimates could be used in this calculation. For instance, if the proportion of scrap to be added to the reported production were raised to the not unlikely figure of 15 per cent, the total acreage would be 1,993,644 acres. On the other hand, if Paardekooper's estimate of the average yield per acre at 450 lbs. is taken, then the total acreage would be 2,058,628 acres (7). Both yield estimates are reasonable, and while the actual acreage of smallholding rubber must remain in doubt, it is nevertheless clear that the estimate of 2,036,344 acres reached earlier is of the correct order and is sufficiently accurate for planning purposes.

The number of smallholders can also be derived from the total acreage estimated from production data. The number of farms on the acreage reported by the Census is 175,392. The owners of newly planted immature rubber land who were not included in the Census were estimated earlier to number 22,043. The number of persons holding the 923,579 acres in tapping and excluded from the Census can be estimated at 87,130, on the assumption that each of these persons possesses 10.6 acres. The total number of smallholders at the end of 1961 is then calculated as follows:

175,392	owners of mature and immature rubber reported by the Census.
19,958	block planting owners not included in the Census.
2,085	individual new planting owners not included in the Census.
87,130	owners of holdings excluded from the Census.
<u>284,565</u>	<u>smallholders</u>

Again, the actual number of smallholders must remain in doubt, but this total is close to the figure of about 282,000 smallholders estimated earlier from traditional statistics and Census data.

In conclusion, it is clear that the total acreage of smallholdings reported by the Census is a little less than half the actual total, and that the total number of smallholders reported by the Census is a little more than half the actual total. The differing proportions are expected, and are explained by the larger size of the holdings of urban residents omitted from the Census.

DISTRIBUTION OF RUBBER SMALLHOLDINGS

The distribution of smallholder rubber land among the States in the Federation is shown in Table 2. When the States are ranked from south to north, as in

Figure 1A, it can be noted that the crop is evenly distributed geographically and is of considerable extent in most States. In Figure 1A both the estimated total smallholding acreage and the acreage reported by the Census are shown. It is evident that the difference between the two is small in some States. The exceptions are Johore, Perak, Selangor, Negri Sembilan, and Malacca. The last four are the most densely populated and developed States, and the difference is not unexpected

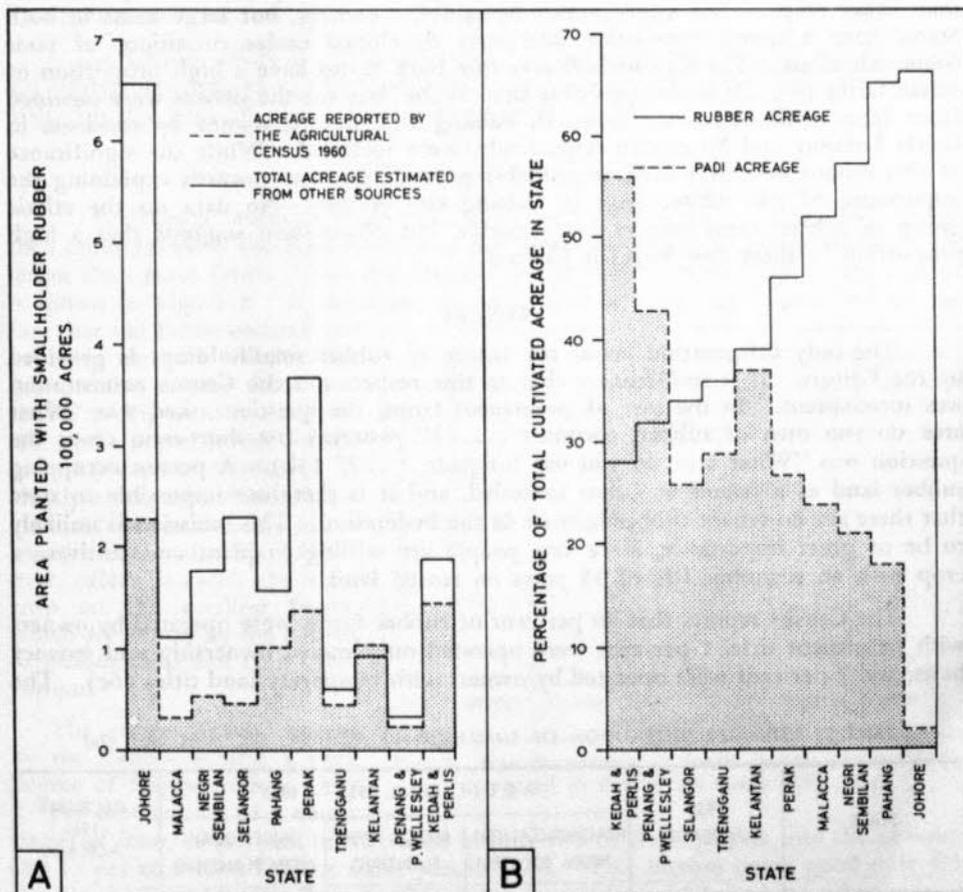


Fig. 1A. Distribution of the rubber smallholding acreage in 1960, according to the Census of Agriculture (5e), and as estimated from other sources.

Fig. 1B. Rubber and padi acreages in 1960, as a percentage of the total cultivated area in each State (14).

here, in the light of the nature of the omissions from the Census. The exception is Johore which, although densely populated along the west coast, is relatively undeveloped over wide areas. It would be expected that the Census omissions should not have affected a large area of rubber land, whereas in fact the difference between the estimated and the Census total is large in Johore. The explanation is probably that rubber land owned by Singapore residents, who were excluded from the Census, is common in this State. In the less developed States, the Census figures approximate closely to the estimates made from other sources.

The relative importance of rubber in each State is illustrated in Figure 1B, which shows the percentage of the total cultivated area planted with rubber and padi in each State. In general, rubber is the major crop, and the proportion of land under rubber varies inversely with the proportion under padi. This is explained by the differing topographical and soil requirements of the two crops. The two largest States, Pahang and Johore, are noticeably dependent upon rubber. In Johore there are large areas with below average soil fertility, more suited to rubber than other crops. The same cannot be said for Pahang, but large areas in both States have a sparse population and were developed under conditions of poor communications. The Census indicates that both States have a high proportion of urban farms (8). It is also probable that, as the data for the Census were obtained from farm operators, some farms in Pahang and Johore, owned by residents in Kuala Lumpur and Singapore respectively, were included. While the significance of this cannot be determined, it probably goes a long way towards explaining the importance of the rubber crop in Pahang and Johore. No data on the ethnic group of rubber farm owners are available, but observation suggests that a high proportion in these two States is Chinese.

TENURE

The only information about the tenure of rubber smallholdings is provided by the Census. It is unfortunate that in this respect too the Census enumeration was inconsistent. In the case of permanent crops, the question asked was "What area do you own of rubber, coconuts,?", whereas for short-term crops the question was "What area do you use for padi," (3b). A person occupying rubber land as a tenant was thus excluded, and it is therefore impossible to state that there are no tenant rubber farmers in the Federation. This omission is unlikely to be of great importance, since few people are willing to plant and cultivate a crop with an economic life of 35 years on rented land.

The Census reports that 80 per cent of rubber farms were operated by owners with permanent title, 1 per cent were operated on a mixed ownership and tenancy basis, and 2 per cent were operated by owners with temporary land titles (6c). The

TABLE 2: ESTIMATED DISTRIBUTION OF SMALLHOLDING ACREAGE, DECEMBER 1961 (2a)

STATE	1952 ACREAGE	ADDITIONS 1952 — 1961			DECEMBER 1961 ACREAGE
		FRAGMENTATION FROM ESTATES	BLOCK NEW PLANTING	INDIVIDUAL NEW PLANTING	
	Acres	Acres	Acres	Acres	Acres
Johore	541,240	61,887	40,226	12,883	656,236
Kedah & Perlis	146,278	23,381	6,721	13,128	189,508
Kelantan	65,108	4,836	13,187	11,113	94,244
Malacca	87,144	12,818	8,754	1,401	110,117
N. Sembilan	128,211	30,300	12,125	6,046	176,682
Pahang	98,453	13,079	23,285	21,485	156,302
Penang & P. Wellesley	29,030	3,101	—	65	32,196
Perak	310,119	29,259	7,696	11,530	358,604
Selangor	163,731	36,287	2,889	412	203,319
Trengganu	46,779	1,952	4,867	5,538	59,136
TOTAL	1,616,093	216,900	119,750	83,601	2,036,344

latter are in general converted to permanent titles in the course of time. The tenure conditions of the remaining 17 per cent of rubber farms were not defined. This suggests that the owners of these farms had no legal title to the land they were using. Such illegal rubber planting is known to be a major problem in Kedah and Perlis, and to a lesser extent in Kelantan, Trengganu and Pahang. The Census reports that 43 per cent of rubber farms in Kedah, 53 per cent of those in Perlis, 34 per cent of those in Kelantan, and 21 per cent of those in Pahang and Trengganu were of unknown or undefined tenure (6d).

The Census makes it clear, however, that the great majority of rubber farms are owner-operated, in contrast to padi farms, of which 52 per cent are tenant-operated and only 37 per cent owner-operated (6c).

SIZE OF SMALLHOLDINGS

The Census indicates that the rubber farms recorded are generally larger than other farms in the Federation, and that those belonging to urban residents are larger than rural farms. The size distribution of the farms covered by the Census is shown in Figure 2. In the light of the omissions from the Census and of the fact that the farms omitted are probably in the larger size groups, the average farm size shown in Figure 2 is certainly too low. Nevertheless rubber growing on smallholdings is clearly a peasant industry, with about 87 per cent of the farms smaller than 10 acres. However, rubber is rarely the main crop on the smallest farms, which are shown by the Census to include padi and fruit cultivation.

The rubber farms covered by the Census exhibit a high degree of fragmentation. Only 47 per cent consist of a single parcel of land, 40 per cent of the farms include two or three parcels, and the remaining 13 per cent have four or more parcels (6b). This picture holds good only for the farms covered by the Census. The farms omitted would have been urban-owned farms, not only larger but also comprising fewer parcels each. The smallholding sector as a whole therefore exhibits a lower degree of farm fragmentation than the Census suggests.

Although such fragmentation must affect economic efficiency in some degree, the adverse effects are less marked in rubber cultivation than in the cultivation of other crops. It is not difficult to operate two or more parcels of rubber land as a single unit. Immature rubber does not require constant and close attention. Hand tools, a minimum of chemicals to control pests and disease, and fertilizers are all that is required. Cultivation is on a tree by tree basis and the size of the parcel is only significant to the extent that shade may affect growth at the margins. Harvesting, although a daily routine, is again on a tree by tree basis, and it is not unusual for the latex collected from a number of parcels to be processed at a central point.

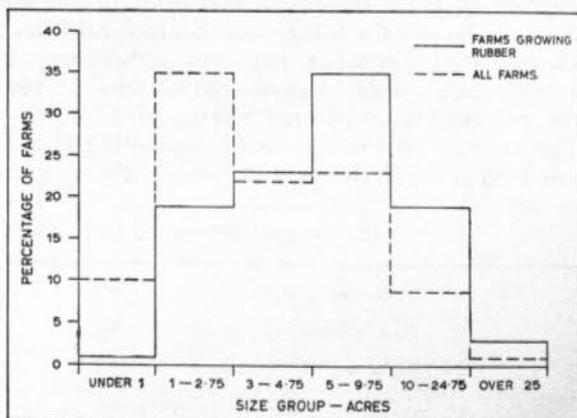


Fig. 2. Size distribution of farms growing rubber (9d), compared to that of all farms (15), 1960.

Fragmentation on a rubber farm is not therefore a serious drawback unless the parcels are far apart or provide in aggregate less than a full day's work for the operator. A full tapping task varies, but 3 acres may be taken as a fair size. Parcels with rubber less than 3 acres in size and presumably providing less than a full day's work, constitute 41 per cent of rubber parcels in the Federation, but 67 per cent of these are on farms combining rubber with other crops (9a). Tapping on the latter need not necessarily provide a full day's work. The layout of the remaining parcels of less than 3 acres is unknown. Some will be sufficiently close to each other to be tapped by the same person. The rest must be considered uneconomic in the strict sense but this situation is mitigated by the prevalence of share-tapping, in which the farmer also taps rubber on neighbouring holdings.

While it is important that new alienations of land should provide farms of economic size, the operation of the small rubber parcels, which constitute 13 per cent of all parcels in rubber farms, is perhaps not as unrewarding as may at first appear.

IMMATURE RUBBER ON SMALLHOLDINGS

The total area of immature rubber on smallholdings in the Federation can be assessed from the reports on new planting compiled by the Federal Land Development Authority, the R.R.I. Smallholders' Advisory Service, and the Rubber Industry (Replanting) Board (2a, 10). All rubber planted or replanted after 1955 will still be immature. Table 3 shows the situation in 1961. The immature proportion of the estimated total planted acreage of 2,036,344 acres is therefore 28.2 per cent. The accuracy of the figures for replanting and new block planting is high, since this land is regularly inspected and in the latter case planting is supervised.

TABLE 3: IMMATURE RUBBER LAND ON SMALLHOLDINGS, 1961

Block new planting, 1956-61	119,750 acres
New planting by individuals, 1956-61	59,100
Replanting by individuals, 1956-61	395,133
Total	573,983 acres

The figure for new planting by individuals was obtained from the reports of extension workers and represents only the acreage of which they were aware. Despite this, the total reached in this way can be considered reasonably accurate.

It is surprising, therefore, that the Census data, given in Table 4 below, show markedly different acreages. The postwar planted area recorded as untapped must be assumed to be immature in large part, though a small fraction may be untapped for other reasons. The immature acreage recorded is thus 404,815 acres, or 43 per cent of the total acreage reported by the Census.

While the total replanted area on smallholdings participating in the Replanting Scheme is recorded accurately by the Rubber Industry (Replanting) Board Fund B, the area occurring on the smallholdings covered by the Census cannot be assessed from these records, because the year of replanting was not ascertained by the Census. Thus no independent check on the Census is possible in this respect. However it is known that by the end of 1959 at least 326,486 acres had been replanted with rubber on smallholdings. The indication is, once again,

that the farms covered by the Census represent no more than half the total in the Federation.

TABLE 4: REPLANTING AND NEW PLANTING ON ALL FARMS REPORTING RUBBER (5a)

	ALL RUBBER LAND	RUBBER LAND PLANTED PREWAR	POSTWAR	
			REPLANTED	NEW PLANTED
TOTAL	Acres 931,104	Acres 460,030	Acres 149,805	Acres 321,295
of which Topped	499,137	432,761	19,209	47,076
of which Untapped	431,967	27,269	130,596	274,219

In contrast, new planting on smallholdings is, according to the Census, approximately four times greater in area than the area estimated from other sources. Even when the bias of the Census is allowed for, it is impossible to reconcile these figures without further field investigation.

The immature area on smallholdings therefore remains in doubt, but observation, supported by production data and records of the distribution of planting material, suggests that the proportion is closer to 28 per cent of the total smallholding area than the 43 per cent suggested by the Census.

The acreage immature at a particular time provides an indicator of management efficiency for permanent crops. If an immature period of seven years is accepted and a minimum economic life of 35 years is assumed, then efficient management requires that one-fifth of the planted area should be immature at any time.

On this basis, smallholder rubber cultivation in Malaya is at present efficient, to the extent that at least 28 per cent of the planted area is immature. The situation would be satisfactory if a similar proportion had been immature in previous years. Unfortunately this was not the case, and it is well known that the greater part of smallholder rubber is overdue for replanting. The Rubber Smallholders Enquiry Committee estimated in 1952 that 937,000 acres of rubber were then over thirty years old and 338,000 acres were between twenty and thirty years old (11). At the present time, therefore, the full 1,275,000 acres should have been replanted, whereas the reports of the Rubber Industry (Replanting) Board show that only 472,455 acres have been replanted (10a). The estimates and data for the smallholding sector that have been given here do not, therefore, offer much evidence of the sector's efficiency, but they do point to a considerable improvement since 1952.

PLANTING MATERIAL

A second indicator of efficiency in an agricultural enterprise is the quality of the planting material used. On this count the smallholding sector is again found wanting, in that the bulk of the rubber currently mature has been grown from unselected material. More recent planting has, however, been mainly of improved material. Those smallholders participating in the Replanting Scheme or undertaking new planting are obliged to use approved high-yielding material. This again has produced a marked improvement in the last decade.

Table 5 is compiled from Census reports, and shows the number of farms reporting the types of planting material used after 1945. Acreage figures for each type of material are unfortunately not available so that, since one farm may report more than one type, it is not possible to determine the relative importance of a particular type. Even though the data are incomplete, they can nevertheless be used to indicate the pattern of use of different planting materials on smallholdings.

TABLE 5: FARMS REPORTING TYPES OF PLANTING MATERIAL USED POSTWAR (5d)

	TOTAL FARMS REPORTING	UNSELECTED SEEDLINGS			CLONAL SEEDLINGS	BUDGRAFTS	MIXED
		TOTAL	OVER 3 YEARS	BUDDABLE			
REPLANTING	40,258	5,726	2,770	2,956	25,510	10,250	1,298
NEW PLANTING	67,246	37,790	18,792	18,998	16,596	7,722	10,800
TOTAL FARMS	107,504	43,516	21,562	21,954	42,106	17,972	12,098

Selected clonal seedlings and budgrafts of selected clones are both high-yielding material, giving similar yields with careful management. Experience and careful selection, in the nursery and in the field, are essential if a uniform high-yielding stand is to be obtained from clonal seedlings. A budgrafted stand requires little selection after planting, since the material is genetically uniform. In consequence, a stand established with a properly selected clone would generally be expected to give the better yield under smallholding conditions.

Clonal seedling material is supplied to smallholders from official nurseries in the form of year-old stumps grown from seed collected in carefully rogued areas of rubber budded with clones known to be good seed parents. The stumps are planted directly in the field by the smallholders. The material is thus simple to use, but it will not produce a yield equal to that of a budgrafted stand unless the selection of clonal seedling material in the nursery was rigorous and unless field selection is carried out to the extent of discarding some 30 per cent of the plants. It can be seen in Table 5 that clonal seedling material is popular with smallholders, but it must be said that they rarely carry out field selection with the necessary rigour. Smallholders tend to plant a denser stand of clonal seedlings than of budgrafts, but they omit the thinning for which the denser stand is designed.

The usual practice in establishing a budgrafted stand is to plant unselected seed in the field and to graft on the high-yielding material when the seedlings are twelve to eighteen months old. This is a skilled operation, but the grafted tree can be expected to produce, without further attention, a higher yield than the clonal seedling tree. The use of budgrafts has been unpopular in the past because of the supposed difficulties of establishment, but it has recently gained considerably in popularity. This change is evident in Table 5, which shows 17,972 farms reporting budgrafted material established between 1945 and 1960, and an additional 21,954 farms reporting seedlings less than three years old, most of which will later be budgrafted. By 1960, therefore, budgrafts closely rivalled clonal seedlings in popularity.

All block new planting in official schemes, with the minor exception of a few small and inaccessible areas, is carried out with budgrafted material. The same

trend is indicated by extension workers for individual new planting; they report the establishment of 30 per cent clonal seedlings during 1961 and 70 per cent ordinary seedlings which will later be budgrafted. It should be added that the extension workers report that all the newly planted seedling rubber of which they are aware is later budgrafted.

The picture then is one of the increasing use of the very highest-yielding material in preference to the apparently easier but slightly lower-yielding clonal seedlings. This trend has gathered strength since 1945, and is the result of a growing awareness of the value of budgrafts, of doubts about the provenance of clonal seedling material, and of a recognition of the selection problems associated with the latter.

TAPPING

Rubber smallholdings in the Federation are peasant farms, and it is to be expected that most of the smaller farms will be worked by family labour. Observation shows this to be the case, and this is confirmed by the Census, which records that of the 116,622 farms covered on which tapping is owner-controlled, 65 per cent are tapped by family labour, 6 per cent by family labour and share-tappers together, 27 per cent by share-tappers, and 2 per cent by wage labour (9b).

Share-tapping, or the *bagi dua* system, is of interest. The Malay term *bagi dua* means division into two parts, but in practice the share retained by the tapper varies between 40 and 60 per cent, the higher proportion being not uncommon. When this system is practised, it is usual for the tapper to undertake processing and, frequently, to sell the sheet rubber as well, passing a cash share to the owner at agreed intervals. The tapper thus has complete control, and while this may be convenient for the owner, its disadvantage lies in the tapper's lack of interest in the property and, perhaps surprisingly, in the quality of the product. The result is often tapping and product of low quality, the tapper preferring to hurry his work rather than to obtain a higher return. The prevalence of share-tapping is one reason why central processing of smallholder latex is not as popular as might be expected. Central processing implies the accurate weighing and grading of the product and a record of the price paid. The tapper often prefers to have control to the point of sale, the owner's share then being less easily verified. Another point of interest is that many share-tappers own rubber land, often in parcels of uneconomic size. This double operation explains the continued existence of farms of less than 3 acres of rubber which are owner-operated by families with no other land.

The use of hired labour varies, as might be expected, with the size of farm. The Census shows that 78 per cent of the farms with less than 3 acres of rubber are family-tapped, while 65 per cent of farms larger than 25 acres are tapped by hired labour alone (9b).

The standard tapping method in Malaya is the half-spiral cut opened every other day. This is satisfactory for the permanent exploitation of most planting material, but not for younger clonal seedlings and clones susceptible to brown bast. Trees susceptible to brown bast cease to yield latex when tapped at normal intensity. Smallholders prefer to tap daily in order to obtain a daily cash return. Eighty per cent of farms on which tapping is owner-controlled are tapped daily, 15 per cent alternate daily, and 5 per cent less frequently (9c).

The daily tapping of old seedling trees is customary, and technically permissible. On younger high-yielding trees daily tapping is too severe. Observation indicates that improved material on smallholdings is tapped every other day rather

than daily. The Census reports state that 20 per cent of farms are tapped alternate daily or less frequently (9c), and it is common knowledge that daily tapping is almost universal on old seedling rubber. This is another indication of better management in the smallholding sector. Further improvement will be required if brown bast is to be avoided in clonal seedling stands.

YIELDS

No accurate data are available on the yields of the different planting materials under smallholding conditions. It is therefore only possible to estimate an overall average yield from the data. This can be calculated as follows:—

Total smallholding production in 1960:	292,800 tons
Total smallholding planted acreage:	2,036,344 acres
<i>Less</i> Immature acreage:	573,923 acres
Allowance of 2 per cent for untapped mature acreage:	29,248 acres
Acreage fragmented from estates during 1961:	20,000 acres
Total tapped acreage in 1961:	1,413,184 acres
Average yield per acre in 1961:	464 lbs.

Data published in the Census reports show that 487,663 acres in owner-controlled tapping produced 1,531,643 pikuls per year, i.e. 419 lbs. per acre per year (5c). This figure does not include scrap rubber, which would increase the yield by 10 to 15 per cent to a total of 460 to 480 lbs. per acre. This indicates the order of the yield on smallholdings, but it is not, unfortunately, a very reliable estimate.

Yield data in the Census were obtained from enquiries about production in March 1960, and the March production was then multiplied by twelve to obtain the annual production. This method is open to error in two ways. Firstly, it has been found in other surveys that yields reported by smallholders for a period of one month, or even less, are rarely accurate. The smallholders keeps no records and sells small quantities of rubber at short intervals. His sheet is usually unsmoked when sold, and contains an unknown proportion of water. The dealer buying the sheet rarely keeps records of his individual clients, and he is very unlikely to have a record of the weight of dry rubber sold to him by a client. It is thus hardly reasonable to suppose that questions put to the smallholder about his production will elicit reliable information. Secondly, the yield of a rubber tree varies from month to month, according to the weather and the number of tapping days. The number of tapping days varies considerably, depending on the weather and the whim of the tapper or the owner. To multiply a monthly production figure by twelve in order to obtain the annual production is hardly an acceptable procedure. Analysis of the monthly smallholder production data between 1950 and 1960, as published by the Department of Statistics, reveals that over the eleven years the March production constituted 8.4 per cent of the average annual production(1). This indicates that the March production should be multiplied by 12.29 to obtain an estimate of the annual production. If the Census figure is corrected in this way, then the average annual yield becomes 429 lbs. per acre, or between 472 and 493 lbs. when allowance is made for scrap rubber.

The best conclusion possible from these calculations is that the overall average annual yield of rubber in the smallholder sector is somewhere between 450 and 490 lbs. per acre. Variations about this average are considerable, and yields of

at least 650 lbs. per acre from fully exploited old seedling rubber have been observed. With the increasing use of high-yielding material, the overall average yield will increase markedly in the coming years.

PROCESSING

A smallholder typically converts his own latex into sheet with the aid of coagulating pans and a hand mangle. The product is usually sold unsmoked and it has been estimated that only 23 per cent of smallholder rubber is smoked by the producer before sale (12). Information on this point is also available from Census data, which show that 86 per cent of smallholder rubber is sold unsmoked, 12 per cent as smoked sheet, and 2 per cent as latex (5c). This estimate is probably the more accurate, but it represents no more than a confirmation of the fact that the bulk of smallholder rubber is sold unsmoked.

All smallholder rubber is smoked at some point, usually at first buyer level. The final product, ribbed smoked sheet, leaves much to be desired as regards quality. In 1956 it was estimated that exported smallholder sheet was 26 per cent RSS Grades I and II, 45 per cent Grade III, 19 per cent Grade IV, with the balance in lower grades (12). Since then there has been some improvement in the quality of smallholder rubber, but this has not affected a significant part of the total production.

RECENT DEVELOPMENTS

It can be seen from the foregoing that the smallholder sector is changing from a stagnant peasant industry, little affected by modern developments, to a progressive industry taking advantage of the best materials and techniques. The rate of change has been slow, but recently it has accelerated greatly, so that improvements during the past decade, especially the last five years, have been marked. These improvements have occurred in both cultivation and processing, stimulated by the Federation Government and by forces within the rubber industry itself.

The Replanting Scheme

The stimulus to replant among the smallholders has been provided largely by the Rubber Industry (Replanting) Board Fund B, which was set up in 1952 under the Rubber Industry (Replanting) Ordinance of that year. Several modifications have been made in the operation and finance of this scheme, and the current one, known as Scheme 3 for the Administration of Fund B, came into operation on 1 January, 1960.

The Replanting Scheme is wholly* financed from the cess of 4½ cents per pound levied on all smallholder rubber exported from the Federation. It provides for the payment of a grant of \$600** per acre to all smallholders undertaking replanting in accordance with the conditions of the Scheme. The grant is payable on the replanting of up to 5 acres, or on the replanting of a third of the holding if the third is more than 5 acres. The same grant is payable for the replanting of old rubber land with such approved crops as padi, coconut, fruit, pineapple, or coffee, and also, under certain conditions, for the new planting of rubber on small areas. The grant is paid over a period of 42 months in five instalments, \$200

* The Federation Government announced, as this paper went to press, that it will contribute to the Replanting Scheme from general revenue.

** From 1 January 1963 replanting grants were increased, and the period over which instalments are paid is to be extended.

when the land is cleared and prepared for planting, \$100 six months after the stand has been established, and \$110, \$105 and \$85 at twelve-month intervals thereafter.

Grant instalments are paid in cash and in kind: planting material and fertilizer are issued to all participants, and those who require them are issued with tree killer, weedkiller, cover crop seed and fencing. The instalments are paid only when inspectors have ascertained that the planting has been properly carried out and maintained.

The success of the Replanting Scheme can be assessed from the number of holdings and the acreage for which complete grants have been paid. The 1960 Report of the Rubber Industry (Replanting) Board Fund B shows that of all holdings replanted from 1952 to 1956 inclusive, the final instalment had been paid by the end of 1960 to 63 per cent. By this date, all the holdings would have received the final instalment if they had been properly maintained. On an acreage basis, final instalments had been paid for 69.4 per cent of the area replanted. This suggests that the larger holdings are making the best use of the Scheme.

The estimate of 69.4 per cent success must be regarded as the maximum, because the payment of the final instalment guarantees only a minimum standard of maintenance over a period of 42 months. Planting that has qualified for the final payment may leave much to be desired from the agricultural viewpoint. A survey was made by the Smallholders' Advisory Service in 1957/8 of a sample of 1,097 farms to which full replanting grants had been paid (13). The survey indicated that growth was short of expectation, probably as a result of high planting densities and poor maintenance. Another survey of replanting in one State in 1961 revealed a similar state of affairs.

The surveys and other more casual observations have prompted suggestions that the period of 42 months over which grant payments are made should be extended, that the specified tree density at the time of planting should be reduced, and that grant payments to budgrafted holdings should be conditional upon the completion of budgrafting on not less than 80 per cent of the trees.

New Planting Schemes

The planting of rubber on new land has also been given financial assistance, in this case from the Federation Government rather than from the rubber industry. Assistance takes the form of grants in kind to different block planting schemes or of loans covering the complete cost of new planting in the settlement projects of the Federal Land Development Authority (F.L.D.A.).

Block schemes administered by State Land Development Boards under the Rubber Industry Smallholders New Planting Scheme, 1957, receive a grant of \$400 per acre and, in some cases, further aid from State Government funds. These schemes have undertaken new planting on 63,000 acres, phases of 250 acres or more being developed at a time. The clearing and planting is done by contractors, while the maintenance of the planted rubber is the responsibility of the participants, who live either on the scheme or in existing villages nearby. Each block of land is cleared and planted as a whole, the division into individual holdings, usually of 6 acres each, taking place later.

The major new development now is the responsibility of the Federal Land Development Authority, set up in 1956. The Authority finances and manages large block schemes, typically of 4,000 acres each, providing for the settlers individual

smallholdings of 10½ acres. These holdings comprise 6-8 acres of rubber, 2-4 acres of other crops, and a ½-acre house site in a central residential area. Other facilities, such as schools, clinics, roads, water and electricity are provided by the appropriate Government Authority.

There are now 31 F.L.D.A. projects in operation, undertaking the development of 133,250 acres of new land, of which 81,000 acres are earmarked for rubber. Phases of 1,000 acres are usually cleared and planted at a time in each scheme, and planting is completed in three or four years. Rubber is given priority, since this crop is intended to provide the major part of the settlers' income.

All F.L.D.A. schemes establish high-yielding budgrafted rubber, the clones being selected according to the requirements of the particular site. The planting and the construction of the settlers' houses is carried out by contractors, and each scheme is controlled by an F.L.D.A. manager who organizes and supervises the work of the settlers in the initial years.

The cost of developing new rubber land in this manner is high, but the high quality of the rubber planting has fully justified the investment which the settlers will be required to repay when their rubber is in production. These schemes create high quality smallholder rubber land, and there is no doubt that they will have beneficial effects upon the smallholder sector as a whole. They could have an even greater effect if a variety of farm sizes and farm types were developed. Some F.L.D.A. schemes plant oil palm as the primary crop, but again the holdings are not much larger than the smallest economic size. It may well be that these new smallholdings will provide inadequate employment for the settler families. It would seem logical to take a further step and create a number of larger farms associated with family farms, thus providing greater employment opportunities and a more balanced settlement.

Developments in Processing

The individual smallholder can, with care and simple equipment, produce high quality sheet rubber. Although rubber smoking by the individual smallholder is uneconomic, there are a number of commercial smokehouses, usually operated by rubber dealers, in which the smallholders can have their rubber cured for a small fee. There are, then, no technical reasons why smallholders using traditional methods should not produce Grade I ribbed smoked sheet. The problem so far has been to convince the smallholders of the advantages of producing a better product, since for them the additional return on the daily sale of a few sheets seems very small.

In addition to the normal advisory services, the problem has been tackled by means of different types of central processing, promoted primarily by extension workers but also by the Rural and Industrial Development Authority. Each of the various types of central processing facility has its advantages but none has, as yet, produced both better quality rubber and a quick and higher return to the producer.

Sales of liquid latex by smallholders, via a collecting organization, to commercial enterprises exporting concentrated latex have been partially successful. The improvement in quality is immediate, as is the increase in the producer's returns, but the maximum return can be achieved only if the collection of latex from the smallholders is efficient. In this respect the method has yet to be perfected, since it is extremely difficult to reduce the costs of latex collection when the producers

are scattered and can offer no more than small quantities at a time. World market fluctuations have, however, been an even greater obstacle to the extension of this method.

Attention has therefore been directed towards various methods of centralizing the production of sheet rubber. Such methods can be divided into two types: factories to which the smallholders sell their latex for processing, and centres at which groups of smallholders process their latex themselves. Factories buying latex for processing vary in size from small private enterprises to large cooperative or government-sponsored organizations. The success of all except the smallest is limited by the difficulty of obtaining latex in sufficient quantities to justify mechanized processing and skilled management. The product is of high quality but the processing costs reduce the potential return to the smallholder. In several cases, the operation of such factories has proved uneconomic. The second type, the group processing centre, consists of a simple factory shed equipped with coagulating pans and hand-operated rollers, and a simple smokehouse. The centres are set up either by smallholders or by an individual who charges a small fee for the use of the centre. Smallholders carry their latex to the centre and process it there themselves. The sheet is cured in the smokehouse and then sold, either by the smallholders individually or in bulk. These centres suffer from none of the problems of organization and management associated with the more sophisticated projects. However, the quality of the product depends upon the individual and is consequently variable. The group processing centres are popular, and, given the interest of the smallholder, they offer some solution to the processing problem. Furthermore, they provide a useful forum for technical discussions and the dissemination of educational information.

But it should be emphasised that while group processing centres can promote an immediate improvement in the quality of smallholder rubber, they are not the ultimate solution. Further steps are necessary: firstly the promotion of bulk sales of sheet rubber, and secondly, the introduction of bulk processing methods that overcome the present economic obstacles.

It is clear that there are several possible ways in which the quality of smallholder rubber can be improved. All of them are being tried in Malaya, but none has yet provided the complete solution. An indication of the relative importance of the different methods is given by the data on latex processing in Table 6. These figures do not include the production of central factories operated by the Rural and Industrial Development Authority. One large factory managed by the Authority has been in operation since 1953 and three smaller factories were opened in late 1961. No data are available for them. It is interesting to note that the simplest and smallest type of organization, the group processing centre, accounted for the greatest production and is found throughout the Federation. This is in contrast to the other types of centre, which are found in only a limited number of States.

Research and Extension Work

A key agent in all improvements in the smallholding sector, improvements in both growing and processing, whether assisted or not, is the Smallholders' Advisory Service provided by the Rubber Research Institute of Malaya. The Institute and related organizations are financed by a cess of $\frac{1}{4}$ cents per pound on all rubber exported from Malaya, and they serve the interests of all rubber growers

TABLE 6: MONTHLY PRODUCTION OF CENTRAL ORGANIZATIONS PROCESSING SMALLHOLDERS' LATEX, 1961, PIKULS* DRY RUBBER CONTENT (2a).

STATE	PRODUCTION OF SHEET RUBBER			LATEX FOR CONCENTRATION
	GROUP PROCESSING CENTRES	PROPRIETARY FACTORIES	COOPERATIVE FACTORIES	
	Pikuls d.r.c.	Pikuls d.r.c.	Pikuls d.r.c.	Pikuls d.r.c.
Johore	1,189	2,217	—	1,290
Kedah & Perlis	169	—	—	1,011
Kelantan	323	—	—	—
Malacca	77	—	—	—
N. Sembilan	1,247	—	—	145
Pahang	420	—	—	—
Penang & P. Wellesley	—	—	—	—
Perak	416	716	56	—
Selangor	7,242	744	180	495
Trengganu	234	—	—	—
Total, Pikuls per Month	11,317	3,677	236	2,941
Equivalent Total, Tons per Year	8,083	2,626	168	2,100

* One pikul = 133.1/3 lbs.

in the Federation. To ensure that the fruits of research are made available to the smallholder sector, the Advisory Service maintains a field staff of some 200 trained officers throughout the country and in close touch with the smallholders. Smallholders, like their colleagues in the estate sector, depend for their progress on the results of research. The present picture is that the smallholder sector is progressing rapidly and utilizing the benefits of the research to which it subscribes.

ACKNOWLEDGEMENT

The author is grateful to Mr. S. Selvadurai for making available, before they were published, data collected in the 1960 Agricultural Census.

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SEDENTARY SOILS OF KEDAH AND THEIR SUGGESTED UTILIZATION

By K. T. JOSEPH

THIS PAPER presents a general outline of the sedentary soils of the State of Kedah, Malaya, and suggests suitable crops for the main series and associations. It is based on extensive field surveys covering 2,600 square miles.

THE AREA AND ITS ENVIRONMENT

Kedah is a coastal state in north-west Malaya, bounded by Thailand on the east and north, and by the State of Perak to the south. It covers an area of about 3,660 square miles (2,342,000 acres), stretching from Bandar Bahru (lat. 5°N.) in the south, to Chungloon (lat 6½°N.) in the north (Fig. 1).

The population of the State is approximately 701,000, of which more than fifty per cent is concentrated on the coastal plain in the Districts of Kota Star, Kubang Pasu, Yen and Kuala Muda, where rice-growing is the chief agricultural enterprise. Rubber is grown mainly in south and south-central Kedah, where large plantations are found in the areas bounded by the settlements of Sungei Patani, Gurun, Jeniang and Kuala Ketil on the one hand, and by Sungei Patani, Tawar, Mahang and Kulim on the other. There are no other crops of comparable significance; small areas of tobacco are limited to the free-draining alluvial regions along the Sungei Muda.

The existing road, rail and river communications are adequate for the development of new areas.

Uniformly high temperatures prevail throughout the year, and the rainfall is about 100 inches per annum. The distribution of rainfall, however, shows distinct seasonal variations. From December until February, there is a distinct dry period, and from August to October a wetter period when the average monthly precipitation is at least 10 inches. For other months of the year, the average monthly rainfall is about 6 inches. During the dry season, when the relative humidity is low and evapo-transpirational losses are high, plants may suffer water stresses, especially those on the coarser-textured soils of low water-holding capacity. Plantings in Kedah should therefore be made soon after the dry spell ends, using fertilizers containing potash to accelerate early root development. However, certain crops, such as sugar cane, which require a dry spell during their life cycle, appear to suit the climate regime of Kedah.

GENERAL CHARACTERISTICS OF KEDAH SOILS

As a result of high temperature and adequate moisture conditions, the decomposition rate of the soil's organic matter greatly exceeds that of accumulation; the clearing of natural vegetation invariably results in a rapid loss of organic matter. Thus most soils in Kedah show very low levels of organic matter and nitrogen. They are also acid as a result of intense leaching, particularly of the arenaceous and non-basic igneous rocks. Such strongly weathered and highly leached soils are not only low in plant nutrients, but their base exchange capacities are also low.

The quickest way of building up nitrogen reserves in these soils is to plant legumes, either with rubber and oil palm, or as an element in rotation with annual crops such as sugar cane. However, the latter also needs additional applications of nitrogenous fertilizers, one-half at planting and the rest in one or two dressings at intervals of three months. Soya beans (*Glycine maximus*) and groundnuts (*Arachis hypogea*) will also build up nitrogen reserves.

Most of the sedentary soils of Kedah have a high capacity for fixing phosphates. Ground rock phosphate, which is easily soluble in acid soils, is efficient and economical, and should be applied when crops are planted. Finally, potash and magnesium levels in all soils are very low, especially in coarse-textured profiles. Crops that make high demands on these elements, such as sugar cane and oil palm, require the appropriate fertilizer amendments if their yields are to be maintained.

Textural differences between soils arise largely from their parent materials; soils formed on arenaceous rocks such as quartzites are coarse-textured; fine-grained soils are derived from shales, and some iron-rich shales produce soils which are capable of immobilizing large amounts of soluble phosphates. Typical granite weathers to soils with about 30 per cent of clay and 20 per cent of coarse sand, described texturally as coarse sandy clay loams. Such soils cover about 103,000 acres in Kedah, and are physically very suitable for plants, especially tree crops, since their clay content suffices for holding water and nutrients, while their coarser fractions ensure adequate aeration and drainage.

SOIL SERIES AND ASSOCIATIONS

The basis of the classification of the sedentary soils of Kedah is the *series*, which is defined as a group of soils with similar profile characteristics. Within each soil series further subdivisions may be made; soils with similar profile characteristics but differing only in the texture of the topsoil are known as soil types. In mapping at reconnaissance level, as was carried out for the purposes of this paper, it was not always possible to survey at series level. In such cases the mapping unit used is the *association*, made up of one or more series related to one another by geography, topography, texture, drainage or other natural features. The series and associations mapped are shown in Fig. 2, and their characteristics are outlined below. The marine and fluvial alluviums, covering 670,000 acres in Kedah, are also shown in Fig. 2, but they are not included in the present discussion, which is limited to the sedentary formations.

Gajah Mati Series

This is the most extensive single soil series found in Kedah, covering nearly 360,000 acres, almost wholly confined to the centre and south of the State. It is developed from dominantly shale parent materials, and occupies gently undulating ground with average slopes between 5° and 8°. A typical profile consists of a clay loam topsoil overlying a horizon of loose pisolitic concretions at depths of 15 to 18 inches below the surface. The roots of rubber trees, which are grown extensively on these soils, have no difficulty in penetrating this lateritic horizon. Below this is a pallid zone of kaolinitic clay, usually found some 6 feet or more below the surface. Drainage of the profile is very good. A typical profile is as follows:—

A₁ 0 to 1 inch

Yellowish-brown (10YR 5/4) fine sandy loam. Moderately strong fine subangular structure. Fairly friable consistency.

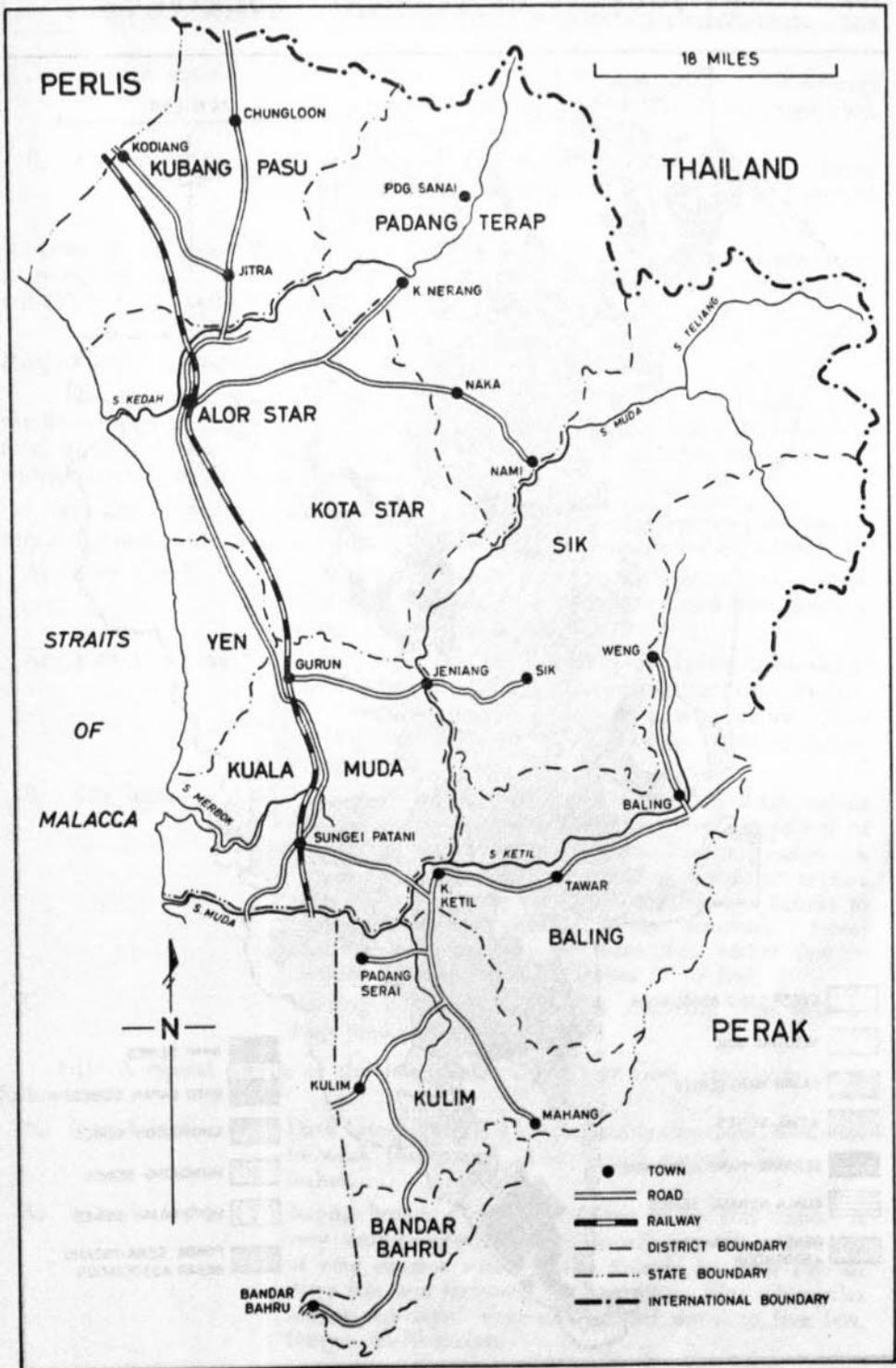


Fig. 1. Kedah.

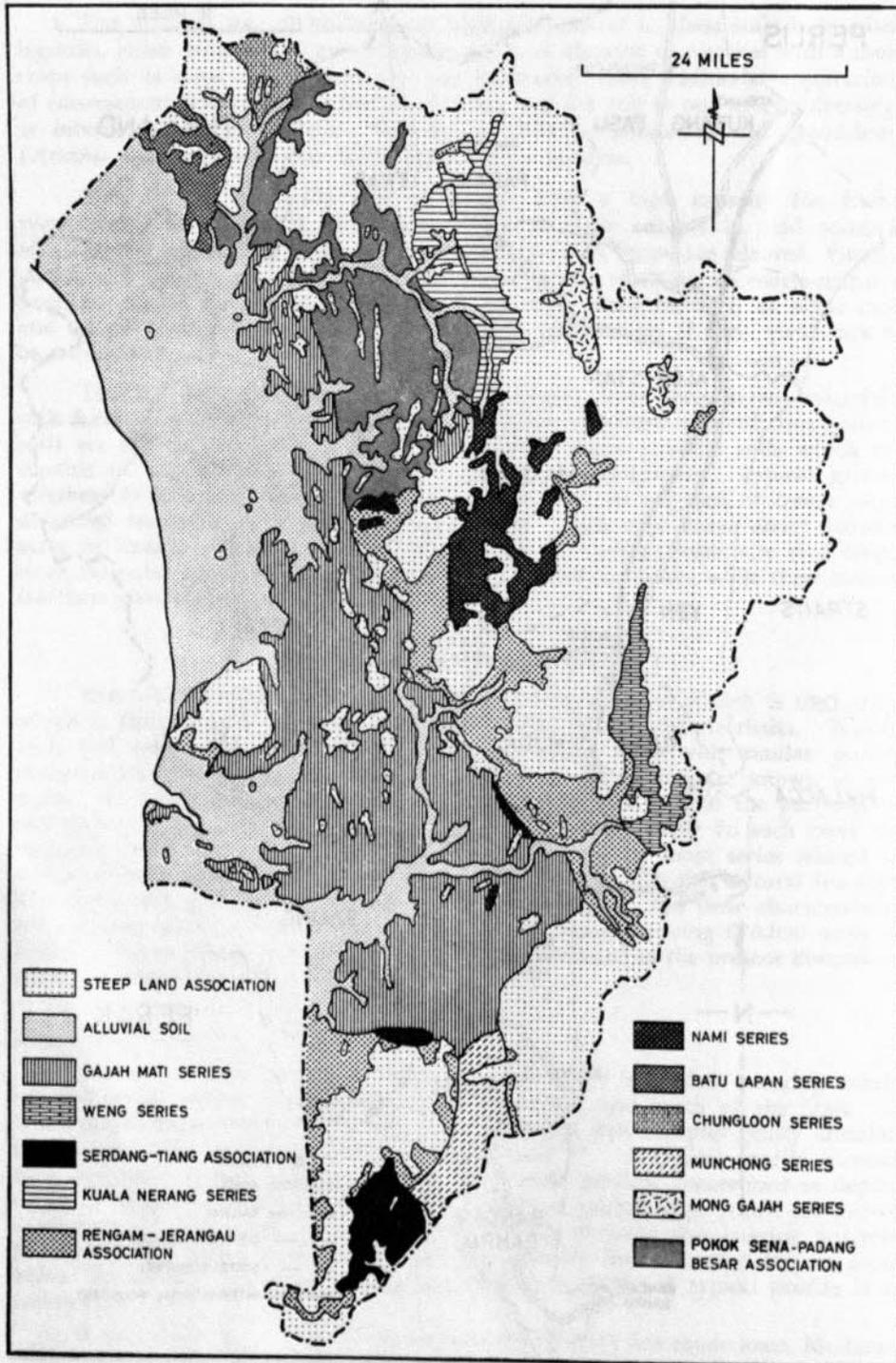


Fig. 2. Kedah : Soil Series and Associations.

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A ₂	1 to 15 inches	Strong brown (7.5YR 5/8) clay loam. Moderately strong medium subangular structure. Firm consistency. Fairly good rooting.
B	15 to 48 inches	Strong brown (7.5YR 5/8) clay loam with dense pisolitic concretions, somewhat elongated, $\frac{1}{4}$ to 1 inch in size.

Variants of the series differ in the colour of the A₂ horizon, which ranges from a strong brown (7.5YR 5/8) to a yellowish brown (10YR 5/8) and yellowish red (5YR 5/0). All variants are, however, texturally similar.

Rengam-Jerangau Association

This association occupies about 103,000 acres, and consists of two series, the Rengam sandy clay loams and the Jerangau fine sandy clay loams, both derived from granitic parent materials. They are well structured and free-draining soils, without lateritic concretions in their profiles.

(i) Soils of the Rengam series are brownish-yellow in colour and are usually very deep, such as that from an undisturbed virgin forest area described below:—

A ₁	0 to 1 inch	Dark brown (10YR 4/3) sandy clay loam. Loose. Moderate medium to fine crumb. Good root development. Range, 1-2 inches.
A ₂	1 to 47 inches	Brownish-yellow (10YR 6/8) sandy clay loam. Moderate medium to fine subangular blocky structure. Friable, with firmness gradually increasing with depth. Root development moderate to good down to 48-60 inches. Range, 36-80 inches.
B	47+ inches	Light red (2.5YR 6/8) coarse sandy clay loam, colour changing very gradually from the brownish-yellow of the horizon above over a wide (6-24 inches) range. A very deep horizon with gradual coarsening of texture with depth. Firm to very firm consistency. Breaks to moderate medium angular blocky structure. Roots confined to upper two or three feet, rather few in number. Range, from 40 inches to 10 feet.
C		Varying depth up to 60 feet, normally seen only in deep road sections or quarries.

(ii) A typical profile of the Jerangau series of fine sandy clay loams is as follows:—

A ₁	0 to 1 inch	Dark brown (10YR 4/3) fine sandy clay loam. Moderate to weak fine crumb. Loose, well rooted. Range, 1-2 inches.
A ₂	1 to 62 inches	Strong brown (7.5YR 5/8) fine sandy clay loam. A very uniform deep horizon showing a slight increase of clay content with depth. Friable for first two or three feet, and increasingly firm below. Fine subangular blocky structure. Very well rooted down to five feet. Range, 40-70 inches.
B	62+ inches	Yellowish-red (5YR 5/6) sandy clay loam. Firm. Very few roots. Continues to unknown depth.

Pokok Sena-Padang Besar Association.

The two soil series that make up this association cover 96,000 acres. They have loose pisolitic concretionary horizons some 2 feet below the surface, and their top horizons have less than 30 per cent of clay.

(i) The Pokok Sena series is found on fairly flat to gently sloping ground averaging between 3° and 5°, and never exceeding 10°. Profile drainage is generally poorer, and the watertable is usually higher in this series than in the Gajah Mati soils. A characteristic profile consists of dark greyish-brown fine sandy loam topsoil overlying yellowish-brown loamy subsoil. Laterite is invariably present in the form of loose, penetrable pisolitic concretions, usually about 12 inches below the surface. A typical profile is as follows:—

A ₁	0 to 1 inch	Greyish-brown (10YR 4/3) fine sandy loam. Fine, weak subangular structure.
A ₂	1 to 12 inches	Yellowish-brown (10YR 5/6) loam. Fine moderately weak subangular structure.
B ₁	12 to 30 inches	Ironstone concretions in matrix of above.
B ₂	30 to 42 inches	Pallid zone of kaolinitic clay with red mottles.
C	42+ inches	Weathered, fairly fine-grained quartzitic sandstone.

(ii) The Padang Besar silty loams have been mapped in south Kedah, where they occur in association with the Pokok Sena series. These soils are derived from siltstone parent materials, and are characterized by the high proportion of silt in their profiles. They occupy fairly flat to gently undulating topography whose slopes are similar to those of the Pokok Sena series. Typical profile characteristics are as follows:—

A ₁	0 to 1 inch	Dark brown (10YR 4/3) silty loam. Weak structure.
A ₂	1 to 6 inches	Yellowish-brown (10YR 5/8) silty loam. Weak, medium subangular structure. Very friable to loose consistency. Rooting restricted to this horizon.
B ₁	6 to 27 inches	Red (5YR 5/8) pisolitic lateritic concretions in matrix of A ₂ material.
B ₂	27 to 44 inches	Pallid zone of kaolinitic clay with red (2.5YR 4/8) mottles.
C	44+ inches	Weathered siltstone.

Kuala Nerang Series

These fine sandy loams are found over about 37,000 acres, forming deep, well drained and light-textured soils in the Kuala Nerang — Padang Sanai — Naka area of north-eastern Kedah. They are derived from conglomeratic parent materials. Typical profile characteristics are as follows:—

A ₁	0 to 2 inches	Dark brown (10YR 4/3) fine sandy loam.
A ₂	2 to 31 inches	Brown (7.5YR 5/4) sandy loam. Moderately weak subangular structure. Good rooting.
A ₃	31 to 38 inches	Yellowish-red (5YR 5/8) fine sandy loam to clay loam.
C	48+ inches	Conglomerate rock fragments.

There is only one major variant of this series, in which the A₂ horizon is a yellowish-brown (10YR 5/6) colour, instead of brown.

Nami Series

The Nami clay loam is a deep, well drained soil, with no lateritic horizon. It covers 27,000 acres. A typical profile consists of:—

- | | |
|--------------------------------|---------------------------------------|
| A ₁ 0 to 2 inches | Dark brown (10YR 4/3) loam. |
| A ₂ 2 to 16 inches | Yellowish-brown (10YR 5/4) loam. |
| A ₃ 16 to 48 inches | Brownish-yellow (10YR 6/6) clay loam. |

Chungloon Series

This series, covering 21,000 acres, consists mainly of the Chungloon clay loam, a soil derived from shale. Two phases of this series are recognized on the basis of differences in the depth of the watertable. In very flat to low-lying sites a higher watertable is accompanied by a massive horizon of laterite, while in more freely drained areas the watertable is lower and the laterite horizon is thinner. The watertable in this series is never less than 30 inches below the surface. Typical profile characteristics are as follows:—

- | | |
|-------------------------------|---|
| A ₁ 0 to 1 inch | Dark brown (7.5YR 4/2) clay loam. Very fine crumb structure. |
| A ₂ 1 to 9 inches | Strong brown (7.5YR 5/6) clay loam. Very fine crumb structure. |
| B ₁ 9 to 24 inches | Yellowish-red (5YR 5/6) clay loam. Extremely friable consistency with small blocky concretions. Moderately weak, medium subangular structure. Fairly densely packed pisolitic laterite concretions. |
| B ₂ 24+ inches | Yellowish-red (5YR 5/9) clay loam matrix to laterite concretions which become more densely packed with depth. Increasingly difficult to root penetration. |

Munchong Series

This silty clay loam occupies 17,000 acres. It is a deep, fairly well structured soil derived from shales with thin bands of interbedded quartzite. Typical profile characteristics are as follows:—

- | | |
|--------------------------------|---|
| A ₁ 0 to 4 inches | Dark yellowish-brown (10YR 4/4) silty loam. Moderately fine crumb. Friable consistency. Range 1-6 inches. |
| A ₂ 4 to 52+ inches | Strong brown (7.5YR 5/6) silty clay loam. Moderate medium subangular blocky structure. Friable to firm consistency, becoming less friable with depth. At least 48 inches deep, continuing to unknown depth. |

Colours in this series range from brownish-yellow (10YR 6/8) through strong brown (7.5YR 5/8) to, more rarely, reddish-yellow (7.5YR 6/8). Textural phases may vary from a fine sandy clay loam to a loamy or silty clay.

Weng Series

This series covers 16,000 acres, and consists largely of clays derived from calcareous shales. In spite of a heavy texture, profiles are well drained and strongly structured, with very friable subsoils. The level of exchangeable calcium of the clay complex is relatively high, and rooting is profuse. This series has been

mapped only in the Sungei Ketil valley north of Baling in central Kedah. Profile characteristics are as follows:—

A ₁ 0 to 1 inch	Yellowish-brown (10YR 5/6) silty clay. Fine crumb structure.
A ₂ 1 to 36 inches	Reddish-yellow (7.5YR 6/8) clay. Very strongly developed fine crumb structure. Fine consistency. Good rooting.
A ₃ 36 to 48 inches	Reddish-yellow (7.5YR 6/8) clay. Medium subangular blocky structure. Firm consistency. Very uniform throughout. Abundant rooting.

Serdang-Tiang Association

Soils of this association have been mapped over 15,000 acres. The two series recognized are evolved from quartzites, those producing the Serdang series being slightly coarser-grained than those forming the parent materials of the Tiang series. Texturally, both series are variable, but most commonly they are fine sandy loams.

(i) A typical profile in the Serdang series has the following features:—

A 0 to 5 inches	Dark yellowish-brown (10YR 4/4) sandy loam. Weak but well developed fine crumb structure.
B 2 to 72+ inches	Strong brown (7.5YR 5/6) sandy loam. Weak medium subangular blocky structure. Well drained, easy to dig and with fair root ramification throughout. A very uniform horizon becoming only slightly heavier in texture with depth. Colour changes to yellowish-red in lower zones.

(ii) The Tiang series shows the following characteristics:—

A ₁ 0 to 2 inches	Dark greyish-brown (10YR 4/2) fine sand. Structureless, loosely packed. Good rooting.
A ₂ 2 to 19 inches	Yellowish-brown (10YR 5/4) fine sand. Structureless. Firmly packed, but loose when dug out. Good rooting.
A ₃ 19 to 48 inches	Yellow (10YR 8/6) silty fine sand. Weak subangular structure. Very loose consistency. Very good drainage throughout. Good rooting to base of horizon. Very susceptible to erosion.

Batu Lapan Series

This series was mapped only in the area between Chungloon, Kodiang and Jitra. It is derived from shaly parent materials, but unlike soils from similar formations it has no pisolitic laterite concretions, although occasional fragments of laterized shale may be present. A typical profile shows the following features:—

A ₁ 0 to 2 inches	Light yellowish-brown (10YR 6/4) silty loam.
A ₂ 2 to 42 inches	Strong brown (7.5YR 5/6) silty loam to clay loam. Moderate granular structure. Firm consistency. Rooting moderately abundant down to 30 inches, decreasing with depth thereafter.
C 42+ inches	Very soft, crumbly shale.

The A₂ horizon may range from yellowish-brown (10YR 5/4) to strong brown (7.5YR 5/6) and yellowish-red (5YR 5/6).

Mong Gajah Series

Soils of this series occupy the smallest area of any so far mapped in Kedah; they cover only 11,000 acres. The most common soil is a clay loam of coarser texture than the Gajah Mati series; pisolitic laterite occurs at about 24 inches from the soil surface.

SUGGESTED CROPS

Nearly 41 per cent of the total area of Kedah State is steep land which, because of erosion hazards, is unsuitable for agricultural use. Controlled afforestation is the best possible utilization system for such land. The main crops suggested for the sedentary soils described above, are :—

Rubber

There is hardly another plantation crop that makes as few specific demands on soil as the rubber tree. Accordingly, physical characteristics such as depth of soil, aeration and moisture-retention capacity appear to be more important than chemical content or nutrient status for this crop, which flourishes on most soils in Malaya. In Kedah, the soils recommended for rubber are the Gajah Mati, Batu Lapan and Mong Gajah series and the Serdang-Tiang association.

Oil Palm

Soils for oil palm cultivation have to be porous and well drained, since the primary root system of the tree is confined mainly to the upper three feet, with only secondary roots penetrating the lower subsoil. Purvis (1) has shown that lignification of oil palm roots occurs at an early stage, so that only the tips of the main roots and the most recently formed branch roots are capable of absorbing water and nutrients. Thus, soils with a stony or gravelly horizon such as the lateritic associations (Gajah Mati, Mong Gajah, Pokok Sena-Padang Besar and Chungloon), and very sandy soils such as the Kuala Nerang and Serdang-Tiang associations are definitely unsuitable. The soils proposed for oil palm cultivation in Kedah are the Rengam-Jerangau, Nami, Munchong and Weng series, totalling some 163,000 acres, mainly in the Districts of Sik, Baling and Kulim. They are among the best sedentary soils found in Kedah and they have a lower phosphate-fixation capacity than the soils proposed for rubber.

Sugar Cane

Sugar cane has been successfully grown on a wide variety of soils ranging from heavy clays to light, coarse-textured sands, including soils with pronounced lateritic horizons. Generally clay loams are preferred, but coarser-textured profiles have the advantage of good drainage. The depth of the soil should be at least 20 inches. In view of the wide tolerance of sugar cane for soils, the area suggested for its cultivation in Kedah has been determined on climatic grounds. Experience indicates that in continually humid areas sugar cane will yield heavy tonnages, but of low sucrose content, as vegetative growth is never retarded sufficiently for the plants to accumulate carbohydrate reserves. The area suggested is in the Padang Terap District, where the main series are the Pokok Sena, Padang Besar and Kuala Nerang soils, totalling 154,000 acres. The Chungloon series might also be suitable for sugar cane, but needs careful management in view of its high phosphate-fixing capacity.

Tables 1 and 2 summarize these suggestions.

TABLE 1: AREA, DISTRICT AND CROPS SUGGESTED FOR SOILS OF KEDAH STATE

SOIL SERIES OR ASSOCIATION	AREA (acres)	PERCENTAGE OF TOTAL AREA	DISTRICT OF MAIN OUTCROP	SUGGESTED CROPS
Gajah Mati	357,000	15	Kuala Muda	Rubber
Rengam-Jerangau	103,000	4	Sik, Baling, Kulim	Oil Palm
Pokok Sena-Padang Besar	96,000	4	Padang Terap	Sugar Cane
Kuala Nerang	37,000	1.5	Padang Terap	Sugar Cane
Nami	27,000	1	Sik	Oil Palm
Chungloan	21,000	1	Kubang Pasu	Sugar Cane
Munchong	17,000	1	Kulim	Oil Palm
Weng	16,000	1	Baling	Oil Palm
Serdang-Tiang	15,000	1	Kata Star	Rubber
Batu Lapan	13,000	1	Kubang Pasu	Rubber
Mong Gajah	11,000	1	Padang Terap	Rubber
Alluvial Soils	670,000	28	Kata Star, Yen	*
Steep Lands	958,000	41	—	Forest

* The alluvial soils are extensively utilized for padi, with some tobacco on freely drained sites.

TABLE 2: AREA AND PERCENTAGE OF SUGGESTED CROPS

SUGGESTED CROPS	AREA (acres)	PERCENTAGE OF TOTAL AREA
Rubber	396,000	16.9
Oil Palm	163,000	7.0
Sugar Cane	154,000	6.6
Forests	958,000	40.9
Total	1,671,000	71.4

ACKNOWLEDGEMENTS

Grateful acknowledgements are due to the Director of Agriculture, Federation of Malaya, for providing facilities for field studies, to Mr. P. Suntharalingam for assistance in Kedah, and to Professor G. Maxwell Davies for his valuable comments on this paper.

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BEACH RIDGES ON THE EAST COAST OF MALAYA

By J. J. NOSSIN

SANDY BEACHES occupy almost the entire length of the east coast of Malaya, running from north Kelantan to south Johore, a distance of more than 400 miles. Sandy deposits trending parallel to the shore often extend for miles inland, interrupted only where the interior hills project onto the coast. The general configuration of eastern Malaya is one of a hilly, and in places mountainous, interior bordered by large alluvial flats. The sandy formations, essentially marine in origin, constitute the seaward flank of these flats, whose landward portions are mostly under freshwater swamp or near-swamp in which tough and homogenous clays are deposited. Occasionally peat layers develop in these clays. Both the marine sands and the swamp clays are usually underlain by tidal flat sediments consisting of alternating layers of sand and clay.

The present paper is based on investigations carried out since 1959 by the Department of Geography, University of Singapore, in north-east Johore, and later also in north-east Pahang (Fig. 1). The objective was to trace the origin of the sandy coastal deposits, and to find criteria to distinguish them from other sediments in the coastal zone. The conclusions presented here are examined in the light of the question of the Holocene stability of the Malay Peninsula.



Fig. 1. Location map.

PREVIOUS WORK

The sandy deposits, known locally as *permatang*, were thought by Scrivenor to be 'raised beaches [which] prove that there has been a recession of the sea and a lowering of sea level of at least 50 feet' (1). This view was based on Daly's assumption of a post-Pleistocene fall in sea level by about 6 metres (2). Van Bemmelen quotes a letter from Scrivenor in which it was suggested that all raised beaches on the east coast of Malaya conform to the 36-foot level, but this seemed 'to be too much to be explained by a recent world-wide lowering of sea level as suggested by Daly in 1920. It tends to prove that in late Quaternary times Malaya was still subjected to a distinct epeirogenic uplift' (3).

A detailed study of the geology of north-east Pahang was carried out by Fitch (4), who devoted a separate paper to recent land emergence in the area (5). He also referred to the coastal sand formations as raised beaches, which, in his view, originated as offshore bars that had migrated landwards when they had grown high enough to be within the reach of breaking waves. In northern Pahang and southern Trengganu, these raised beaches were reported at two distinct levels, 35 and 14 feet above present sea level. Fitch assumed that these levels represented two phases of land uplift, of about 20 and 10 feet respectively, in recent times. He also assumed that an earlier uplift brought the surroundings of Kuantan aerodrome to their present height of 50 feet above sea level. 'It is an area of coastal alluvium which was laid down almost at sea level but is now more than 50 feet above the sea. It therefore appears to indicate an even earlier stage of emergence of the land than the two deduced from the beaches south of Chukai' (5). From the same author's monograph it is clear that he attributed the present 'raised beaches' to isostatic uplift of the land (4).

Roe observed subsidence on the west coast of Malaya and ascribed it to tectonic movements. This, and the east coast beaches, prompted him to suggest that 'a regional tilting of the whole peninsula is taking place with the main range forming the axis about which uplift is occurring in the east and subsidence in the west' (6).

COMPOSITION AND ORIGIN

In view of their morphological appearance as a series of ridges and swales, these so-called raised beaches are referred to in this paper as beach ridges.

They form a series of distinct, though low, parallel sandy ridges of great length, occurring close together and separated by elongated depressions through which the local drainage system is channelled. The height of the ridges is between 10 and 15 feet near the sea, and increases inland. As far as is known the ridges exceed 30 feet above sea level in only a few places: the highest ones, south of

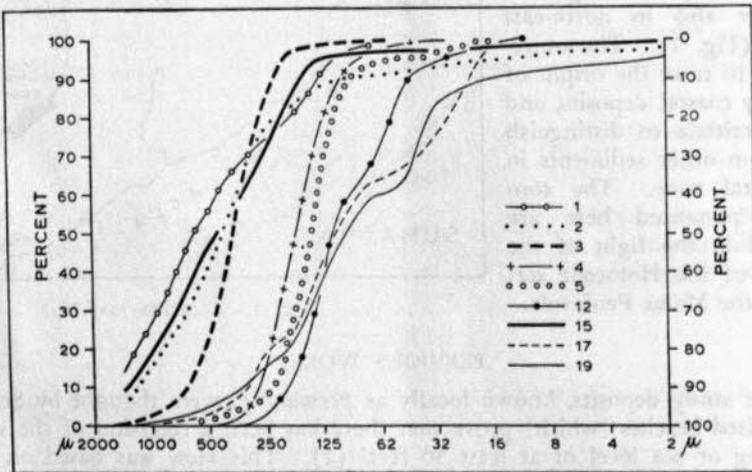


Fig. 2. Grain size frequencies of beach ridge material, north-east Johore.

Chukai, reach 35 feet. The deposits around Kuantan aerodrome referred to by Fitch (4, 5), are more than 50 feet above sea level. These, however, do not show a ridge and swale succession.

The beach ridge deposits are without exception devoid of clay, and in many cases also of silt. The sand ranges from fine to very coarse, but is always well sorted. The results of granulometric analyses of beach ridge material from north Johore are shown in Figure 2, and from north-east Pahang in Figure 3.

The present writer has previously discussed the origin of the north-east Johore beach ridges (7, 8) and it appears that the processes operating there are also active in Pahang. The material forming the ridges is mainly derived from capes where the interior hills abut on the coast. Under-cutting produces steep cliffs where fresh rock is exposed to marine abrasion. The detritus is mechanically broken down into smaller fragments

and finally to sand grade. Current and beach drifting can transport such material over considerable distances. Thus at Kuala Pahang, at the mouth of the Pahang River, the beach consists of layers of fine to medium gravel alternating with sandy layers. The gravel has come from Tanjong Tembeling and Tanjong Pelindong, more than 20 miles away, where granite cliffs are exposed.

The heavy mineral assemblages of the beach ridges closely reflect the mineral composition of the country rock. The ridges in north-east Johore show an association of andalusite with tourmaline, zircon, rutile and staurolite; those in north-east Pahang are characterized by tourmaline, andalusite and amphiboles. The beach ridges contrast sharply with fluvial deposits, which are derived from comminuted regoliths rather than fresh rock outcrops. Only the largest rivers, such as the Pahang, can carry sand as far as their mouths; most other streams supply only clay to the coastal region.

The beach ridges start as spits, bars and tombolos on the leeward side of exposed headlands, and often build up on tidal flats composed of alternating layers of marine sand and estuarine clay. The bars extend under the influence of waves and currents and finally enclose parts of the tidal flats. The latter are then rapidly converted into freshwater swamps in which heavy clays are deposited. As new bars are built up at the seaward margins, the process continues. Considerable progradation of the shore and straightening and shortening of the coast line have taken place in this way through the Holocene.

HOLOCENE STABILITY

Data from the Atlantic coasts (9, 10, 11) cast serious doubts on the validity of Daly's assumption of a post-Pleistocene sea level maximum some 6 metres higher than the present (2). Evidence from the Pacific zone however, strongly supports such a maximum there. Fairbridge suggests several phases (12), while others

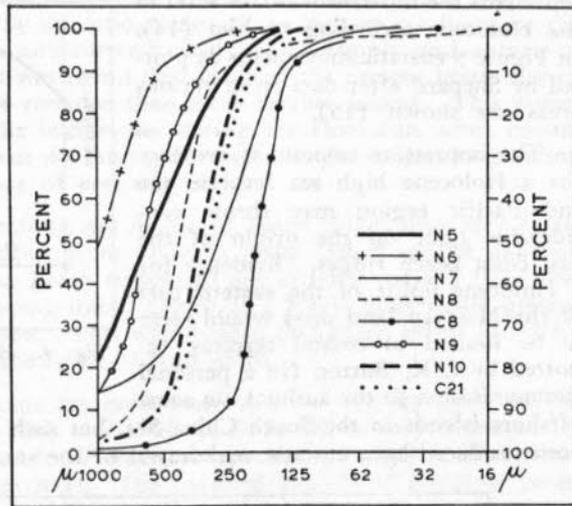


Fig. 3. Grain size frequencies of beach ridge material, north-east Pahang.

differ among themselves regarding the height of this Holocene sea level maximum (13). Umbgrove is inclined to accept 6 metres as a reliable average; Figure 4 represents the movement of sea level in the Holocene according to him (14). In Figure 5 eustatic movements as plotted by Shepard after data from various areas are shown (15).

The impressive amount of evidence for a Holocene high sea level in the Indo-Pacific region may throw considerable light on the origin of the east coast beach ridges. Evidence for a Holocene uplift of the eastern part of the Malayan land mass would seem to be limited to coastal terraces, reported by C. K. Burton (in a personal communication to the author), on some offshore islands in the South China Sea, but such terraces could equally well have been produced by a eustatic withdrawal of the sea.

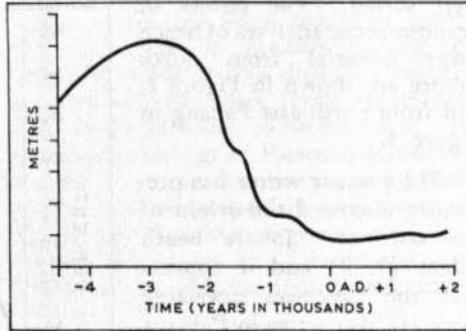


Fig. 4. Holocene sea level movements, after Umbgrove (14).

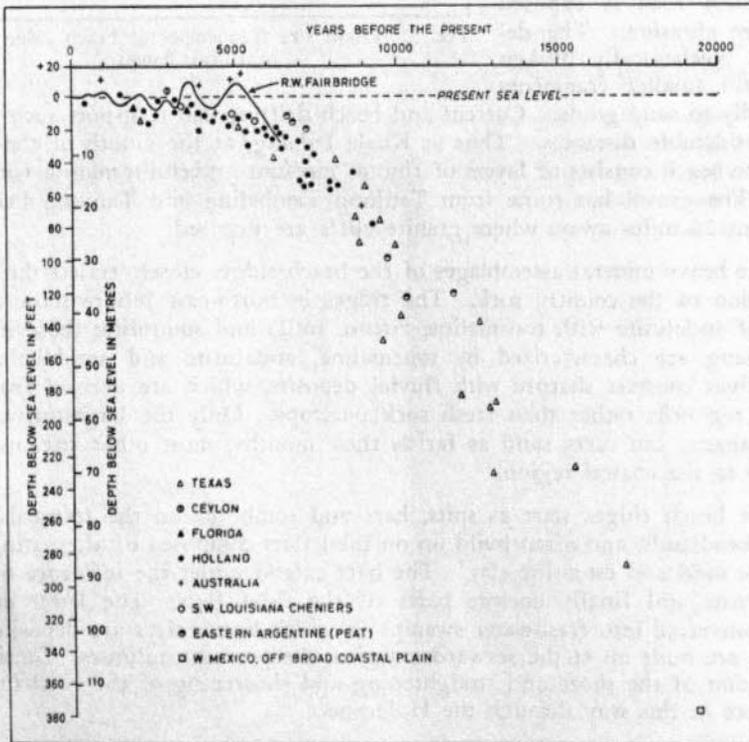


Fig. 5. Late Quaternary sea level movements, after Shepard (15).

Consideration of the height of the beach ridges also suggests that they do not necessarily indicate uplift of the land. Those immediately on the coast are between 10 and 15 feet above mean sea level. Reliable estimates of the 'initial'

height of a beach ridge can only be obtained from ridges whose formation has just been completed. Older ridges, when exposed on the coast to marine erosion, as for instance at Sungei Pahang Tua, may give a false impression. The height of a beach ridge will be influenced by the topography of the inshore sea floor, by the direction and strength of waves and currents, and by the supply and nature of material. In north-east Johore it was found that sands of the present beach and of the coastal beach ridges are more rounded than those further inland. This points to a progressive shallowing of the inshore sea during the Holocene, when coastal outgrowth was taking place, so that the sand grains were longer subject to grinding and rounding under the influence of breaking waves.

The different factors controlling the height of beach ridges may vary somewhat in their importance and effect from place to place, but it can be assumed that the initial height of the older beach ridges did not differ materially from that of the younger ones. The prevailing initial height of a beach ridge under present conditions is between 10 and 15 feet. This would mean that beach ridges of Fitch's 14-foot level need not represent the result of land uplift.

It is likely that the Holocene sea level maximum has left its mark on the east coast. The estuarine plains, such as that of the Endau River in Johore and the smaller example along the Kuantan River, may represent estuaries infilled since the Holocene phase of higher sea level. The outward growth of the coast seems to have been promoted largely by the eustatic withdrawal of the sea from its maximum (7, 8). If we take Umbgrove's value of 6 metres for this eustatic maximum, the older beaches formed at that time would then have stood 10 to 15 feet above sea level. With the withdrawal of the sea to its present level, they are now exposed at heights between 30 to 35 feet. The decrease in height of the beach ridges towards the sea provides confirmation of this view of a gradually falling sea level.

The apparently similar formations at 50 feet or more near Kuantan aerodrome remain to be explained. Granulometric analysis, the results of which are presented in Figure 6, reveals that they differ markedly from the beach ridge sands. They have a considerable clay content, are ill-sorted, and have a high percentage of

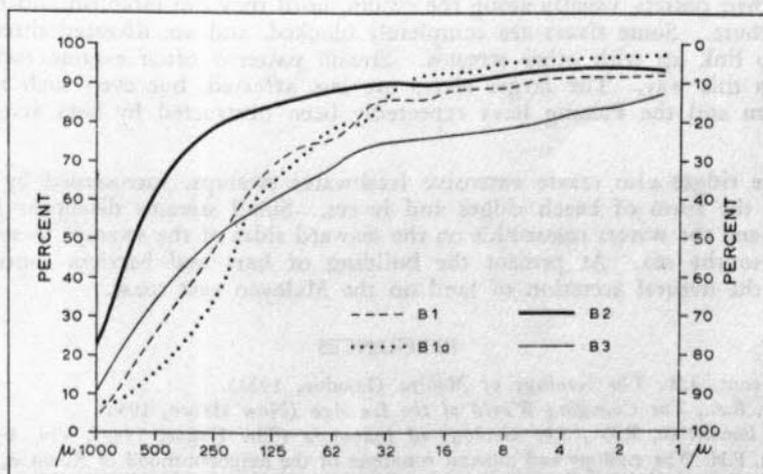


Fig. 6. Grain size frequencies of granite wash from the surroundings of Kuantan aerodrome.

particles over 2,000 microns in diameter; the last consist of quartz grains showing no trace of water rounding and are up to 1 cm. in diameter. These characteristics closely resemble those of granite wash material weathered in situ and transported colluvially. An analysis of granite wash from eastern Pahang is presented in Figure 7. The close resemblance between this and the Kuantan sample indicates that the latter material is derived from granites at Gambang, a little further west.

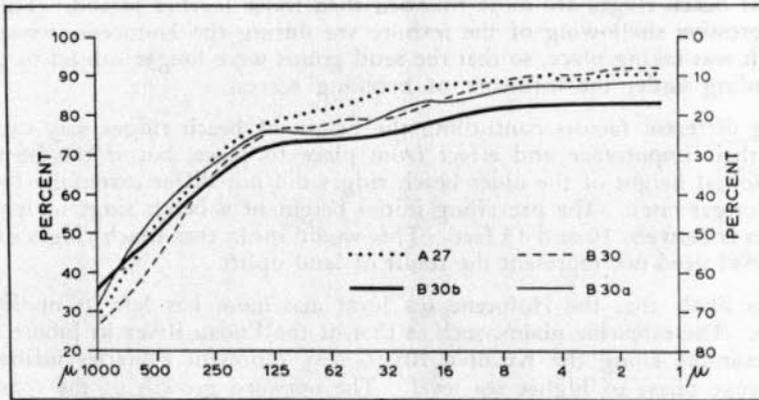


Fig. 7. Grain size frequencies of granite wash deposits around Bukit Ubi and Bukit Besar, near Kuantan.

It would therefore appear that the beach ridges can be accounted for without recourse to an assumed uplift of the land in the late Holocene. This confirms the deductions made from a previous study of the coastal geomorphology of north-east Johore (7). It also implies that there is little evidence for Roe's theory of a tilting of the Malayan land mass.

MORPHOLOGICAL EFFECTS OF THE BEACH RIDGES

The beach ridges tend to hamper the flow of rivers, which are often forced to shift their outlets, usually along the swales, until they can establish and maintain a debouchure. Some rivers are completely blocked, and are diverted through the swales to link up with other streams. Stream patterns often assume rectangular shapes in this way. The larger rivers are less affected, but even such rivers as the Endau and the Pahang have repeatedly been obstructed by bars across their mouths.

The ridges also create extensive freshwater swamps, surrounded by natural dykes in the form of beach ridges and levees. Small streams disappear into the swamps, and the waters reassemble on the seaward sides of the swamps to seek some channel to the sea. At present the building of bars and barriers continues to increase the natural accretion of land on the Malayan east coast.

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THE 1962 SOIL MAP OF MALAYA

by W. P. PANTON

THE NEED for a soil map of Malaya has become increasingly apparent in recent years, especially in view of the major projects envisaged under the First and Second Five Year Plans for the development of new areas and the improvement of existing rural lands. The accompanying soil map of the Federation of Malaya is the first to be published. It is based largely on a limited number of soil surveys, supplemented by information from published geological and topographical maps. It represents only a transitional stage in the cataloguing of the national soil resources, and is therefore not a completely accurate record, but it is hoped that this map will stimulate further pedological work in Malaya.

Studies on the classification of Malayan soils can be traced to the early years of this century. The published works of Akhurst and Haines (1), Barrowcliff (2), Belgrave (3), Dennett (4, 5, 6, 7), Grantham (8, 9, 10), Greenstreet (11), Hamilton (12), and Savage and Wilshaw (13) show how much attention this subject received between the First and Second World Wars. A notable advance was made in 1951, when Owen published a provisional classification of Malayan soils, in which he proposed names for a number of soil types then known to exist in the peninsula (14). In all these studies the importance of parent material was recognized and repeatedly stressed, and frequent reference was made to existing geological maps. However, apart from a map of the Rubber Research Institute's Experiment Station at Sungei Buloh (1), no true soil maps were published, and the only systematic surveys known to have been made of extensive areas were those commissioned by certain large planting companies for their own properties. The unpublished works of Tommerup and Cole were excellent pioneer efforts in this sphere.

Later, in the nineteen-fifties, Coulter and others carried out a number of soil surveys of some of the major swamp areas along the west coast of Malaya (15, 16, 17). These surveys were designed primarily to determine the suitability of the soil for padi before planning drainage and irrigation facilities. They sampled soils at regular intervals along specially cut traverse lines, or *rentis*; these samples were mechanically and chemically analysed, and soil maps showing the principal textural groups were produced. During the same period, a number of detailed maps of both sedentary and alluvial soil types were prepared for a few areas of developed land in several regions of the country, using profile characteristics as the basis of the classification. In the mid-fifties, reconnaissance soil surveys of some extensive padi areas were undertaken, and a schematic-reconnaissance soil survey programme for the whole country was also started. In view of the limited staff available, it was decided that the schematic-reconnaissance mapping programme should be carried out on a State basis, commencing with the north-east coast States, and to date soil maps on a scale of 1:500,000 with accompanying reports have been published for the States of Trengganu and Kelantan (18, 19). Field work in Kedah and Perak has been completed, and soil maps and reports for these States will soon be available. In addition, a large number of *ad hoc* surveys have been carried out in various parts of the country, and the information provided by such work, as well as from other sources of a less direct nature, has been used in compiling the present map (20, 21, 22, 23).

Surveys are now in progress in Pahang and Johore, and in a number of large alluvial areas in other parts of the country. Within the next few years the results should allow the preparation of a more detailed soil map. In addition to this official programme, certain private organizations have undertaken soil surveys, mainly of oil palm estates, to help with agronomic studies. Close liaison has been maintained with these organizations, which have mostly adopted the soil classification of the Malayan Department of Agriculture, which in turn is based on Owen's original scheme.

At present, priority is given to reconnaissance surveys of the less developed areas of the country to assess their development potentials and soil patterns. The value of these surveys for the official Rural Development Plan is well appreciated, as shown by the priority allocated to such surveys in recent years.

It may be appropriate to mention some details about soil survey methods in Malaya, a country noted for its thick, luxuriant vegetation and difficult topography, especially that formed by large areas of steep and broken mountains and extensive swamps. These features present considerable difficulties to soil surveyors in undeveloped areas, where, in the absence of tracks, work is often confined to *rentis* lines specially cut to provide access and to locate soil pits and soil boundaries. Aircraft, cross-country vehicles, boats, rafts, bicycles and the human foot are all used frequently, and a not inconsiderable athletic prowess is almost as important as professional ability to the surveyor working in the jungle. Aerial photographs are not as useful as might be expected, owing to the limited variations in the forest cover that might indicate soil differences. On the other hand, local soil surveyors are well served by the one inch to one mile topographic maps of the Malayan Survey Department, which cover the whole country.

The classification of soils in the field is based essentially on the United States Department of Agriculture system, and mapping is carried out at series or at association level, depending on the detail required. The larger groupings shown on the accompanying soil map are based on the Great Soil Groups of Marbut, as revised by Baldwin, Kellogg and Thorp (24), with subdivisions according to parent materials wherever possible. The latosol and laterite groups conform to the definitions given by Kellogg and Davol (25). An outline of the characteristics of the great soil groups that occur in Malaya is given below.

1. LITHOSOLS AND SHALLOW YELLOW LATOSOLS ON STEEP MOUNTAINOUS AND HILLY LAND

This group, which covers some 40 per cent of the total area of Malaya, is one of the least studied of local soil groups, as it is considered to be of very low agricultural potential, due to unfavourable topography rather than to inherent infertility. These soils have not been examined in much detail during reconnaissance surveys, and in practice delineation of their downhill boundaries is all that is necessary. In unsurveyed areas this boundary can be inferred from relief patterns shown on topographic maps or aerial photographs. That shown on the accompanying Soil Map is normally very apparent on the ground, being marked by a pronounced change of slope separating moderately undulating land, with average slopes under 20°, from rising land with slopes exceeding 25°. The break occurs at different altitudes in different parts of the country. It corresponds with the 150-foot contour over a large part of Kedah State, and with the 750-foot contour in the region around Kuala Lipis in north Pahang; in the rest of the country the boundary lies between these two extremes.

These soils are generally thinner and younger phases of the latosolic soils that occupy most of the gentler slopes in adjoining lowlands. At very high altitudes they may consist of thick fibrous root mats and very little else. Their parent material is usually granite, which forms the core of nearly every mountain range in Malaya, but quartzites, conglomerates and shales, which outcrop over large areas of steep land in the eastern half of the country, also produce similar soils.

2. RED AND YELLOW LATOSOLS AND RED AND YELLOW PODZOLIC SOILS
DERIVED FROM ACID IGNEOUS ROCKS

These form a relatively uniform group of medium-textured soils characterized by deep, free-draining profiles. They are usually yellow or reddish-yellow in colour, and are uniform throughout their profiles except in some areas where a textural B horizon can be distinguished close to the surface, indicating a slight development of podzol characteristics. They are mature soils which have undergone considerable leaching under existing high rainfall conditions, and are moderately acid, with pH values ranging between 4.5 and 5.5. They have very low reserves of exchangeable bases, but in spite of this apparent paucity of available plant nutrients they are of good average fertility; in part this is due to their good subsoil structure and considerable soil volume in which the roots of perennial crops can ramify. The gradual release of further nutrients resulting from mineral decay in the lower horizons may explain the anomaly between analytical and yield data.

The parent material of the group is most commonly of granodioritic composition rather than true granite. Differences in grain size, porphyritic structure and the relative proportions of constituent minerals in the parent rock, as well as topographic variations, give rise to a number of series in the group. The most extensive is the Rengam series, originally established by Owen and now recognized in nearly every State in the country.

3. RED AND YELLOW LATOSOLS AND RED AND YELLOW PODZOLIC SOILS
DERIVED FROM VARIOUS SEDIMENTARY ROCKS

These soils show considerable variation in profile character and many series have been established, although much detailed survey work is required to determine their distributional patterns. Large areas remain unsurveyed, even by exploratory methods, especially in Pahang and Johore, and the present grouping is likely to become more complex as further work is undertaken.

All profiles developed over such widely varying parent materials show comparatively uniform development of deep A₂ horizons displaying various yellow and reddish-yellow colours and other latosolic features. But in field diagnoses, an almost infinite number of differences in texture, structure, colour and subsoil drainage may arise from variations of topography and parent material. In gently sloping or low-lying sites, or with iron-rich, heavy-textured parent materials, thin laterite horizons or discrete ferric oxide concretions may develop, emphasising the strong relationship between the latosol and laterite groups. The Serdang series is a typical yellow latosol derived from quartzites (20) and is of widespread occurrence in the west coast States.

4. RED AND YELLOW LATOSOLS AND RED AND YELLOW PODZOLIC SOILS
DERIVED FROM OLDER AND SUB-RECENT ALLUVIUM

In recent years, reconnaissance soil surveys and detailed geological studies in two separate areas of Malaya have indicated the existence of a variable group

of soils developed on dissected terraces and platforms lying at 20 to 230 feet above sea level. These topographic features were formed in unconsolidated shallow-water deposits of Pleistocene age known as Older Alluvium (26, 27). The resulting soils are similar in general appearance to the yellow latosols derived from sedimentary rocks (groups 2 and 3), although some, especially those at lower elevations, are rather looser structured and more freely drained. They are grouped separately on the basis of their lower fertility and, in most cases, marked deficiencies in major and minor elements. Their low nutrient status appears to be a result of (i) the two-fold cycle of weathering to which their parent materials have been subjected, (ii) the lack of profile rejuvenation through erosion, due to the relatively flat topography on which they have evolved, and (iii) their lower content of clay as compared with other latosols. The practical implications of their low nutrient status make further work on these soils a matter of urgency.

5. REDDISH-BROWN LATOSOLS DERIVED FROM BASIC AND INTERMEDIATE IGNEOUS ROCKS

The reddish-brown latosols have a much more restricted distribution than the red and yellow latosols, being confined to areas where dark igneous rocks, largely of andesitic or basaltic composition, occur. They have been found mainly in Pahang State and sizeable acreages have been located in Kelantan and Johore. It is likely that other outcrops of this fertile soils occur in the unsurveyed parts of Pahang. These soils, which are of above-average fertility, possess very deep and uniform profiles with unusually well developed crumb structures. Their marked reddish colour distinguishes them from the less intense chromas of latosols. The two main series forming the group correspond to soils evolved from basaltic and andesitic parent materials, thus simplifying the field classification.

6. LATERITE SOILS

Although soils with indurated concretionary B horizons occur in localized patches throughout the main latosolic groups, those with thick continuous bands of accumulated sesquioxides, known locally as laterite or *batu merah* (Malay for 'red stone'), are largely confined to the three main areas indicated on the Soil Map. These soils have a distinct subsoil zone of limonitic, sometimes bauxitic, pebbles of irregular shape which may be cemented together to form massive blocks. The indurated zone has sharp boundaries, and usually runs roughly parallel to the surface under a uniformly coloured and textured A horizon varying in thickness from six inches to ten feet. The laterite horizon is only exposed following local soil movements of recent occurrence such as sheet erosion and soil creep; occasionally the roots of a falling tree may drag parts of the concretionary layers to the surface leaving a small mound of laterite pebbles after the roots have rotted away. The location and distribution of the horizon is entirely consistent with a contemporary age for its formation, and no pedologist with local experience could fail to appreciate the dynamism of the laterite-forming process in the country at the present day (28).

Under existing climatic and topographic conditions, shales and phyllites appear to be the most common parent materials of laterite soils. The resulting * heavy-textured soils of low permeability often develop a pallid zone of reddish mottles or streaks in a pale grey or white matrix in the subsoil below the laterite horizon, suggesting a possible relationship with the groundwater laterites of Marbut (29).

all p. 102 Gajah Mati Series. K. T. Joseph. (Dominantly shale P.R.)
 Sedimentary
 Beds of Kedah "Drainage of the profile is very good", Rubber extensive
 Owen (1951) p. 36. Malacca series (Dominantly phyllite P.R.)

7. LOW HUMIC GLEY SOILS

The main coastal plains of western Malaya and the lower valleys and flood-plains of the larger east coast rivers contain a variety of grey or brown clays mottled with red and with obvious gleyed horizons developed close to their surfaces. These soils vary widely in fertility. Some are highly acid and present considerable problems in cropping, while others are only moderately acid, possessing abnormally high nutrient reserves by Malayan standards and produce excellent yields of certain crops with adequate drainage. A large number of series have been recognized through detailed mapping of most of the main padi-growing districts; only a limited acreage of the group still remains under natural forest.

8. AZONAL ESTUARINE AND COASTAL SOILS

Large tidal swamps, colonized by dense stands of mangroves (mainly *Avicennia* spp.), occur along the west coast and in smaller areas along the estuaries of east coast streams. The soils in this environment are immature featureless muds or sandy clays with varying amounts of decaying roots and occasional bands of sea shells. Little or no profile differentiation is seen, and in many places the coastal margins of the swamps are advancing seawards rapidly. The high cost of bunding, and subsequent difficulties of draining such areas have limited their agricultural utilization, but they provide valuable timber when well managed by a silvicultural programme of rotational extraction.

9. PODZOLS

Podzols are found on the east coast of Malaya, where they evolve from the coarse sands of low beach ridges which run parallel to the coast and rise to about twenty feet above sea level. The ridges are often separated by lagoonal swamps in which peats or highly sulphurous clays occur. The podzolic soils are very free draining and loose, and have very low reserves of plant nutrients. Their reddish- or yellowish-brown B horizon normally occurs at a depth of four to five feet, and is set within a pale, structureless subsoil; darker-coloured humus horizons are also common. The natural forest cover has in most cases been replaced by a poor open scrub or by low-yielding coconuts.

10. ORGANIC SOILS

Large peat and muck swamps are common in the poorly drained parts of the coastal plains of Malaya, and less extensively in a few inland areas. The muck soils, with 35 to 65 per cent of organic matter, are normally quite shallow, and are usually underlain by clayey mineral horizons at depths of less than twenty-four inches containing varying amounts of sulphur compounds. Malayan peats, or soils with over 65 per cent of organic matter, normally exceed three feet in depth, except for a narrow transitional fringe along the swamp boundaries, and peat depths as great as fifteen or even twenty feet are not uncommon.

In recent years, the muck soils and many of the shallow peats have been extensively cleared and cropped, but with only limited success. Their acidity, the coarse woody texture of the organic matter, and difficult drainage pose problems that are not yet satisfactorily resolved. However, some of the deeper peats, such as those in south-west Johore, have proved suitable for pineapples. Good stands of natural forest often appear in the peat swamps, and their preservation seems to be the best use for such land, at least for the immediate future.

11. DISTURBED LAND

Disturbed soils occupy about 2 per cent of the total area of Malaya, mostly held on mining leases. The white sandy wastes, dotted with mining pools, mark the sites of present or abandoned tin mines which are especially common in western Malaya. They have little or no agricultural potential, but attempts at reforestation are showing considerable promise. These skeletal soils have received very little attention, but they are sufficiently widespread to warrant mapping as a separate group.

ACKNOWLEDGEMENTS

The permission of the Director of Agriculture, Federation of Malaya, to publish this paper and its accompanying map is gratefully acknowledged. The author also wishes to record his thanks to the Director of the Malayan Geological Survey for permission to incorporate into his Soil Map certain geological boundaries as shown on the 1948 Geological Map of Malaya. Finally, it is a pleasure to acknowledge the generous cooperation of Mr. C. K. Burton, of the Geological Survey, in providing information about the Older Alluvium in South Johore.

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CHEMICAL ANALYSIS OF SOUTH MALAYAN PEAT SOIL

By D. B. PARBERY and R. M. VENKATACHALAM

IN MALAYA today pineapples are grown on deep peat soils, a unique medium for pineapple plant growth. The total area under the crop in the Federation in 1960 was in excess of 30,000 acres (1). Coulter has estimated that there are some two million acres of peat in Malaya, mainly in western Johore, Perak and Selangor, with smaller areas in eastern Johore, Kelantan and Trengganu (2). Most of these peats have developed under a forest cover and are consequently termed woody or forest peats. Their development is the result of permanent waterlogging in basin-shaped depressions. The thickness of the peat varies from a few feet to 18 feet or more (3).

Malayan peats have not been chemically analysed in detail. The Director of the Pineapple Research Station of the Malayan Pineapple Industry Board therefore considered the chemical analysis of peat soils to be of primary importance as a background to agronomic studies on the culture of pineapples. This paper presents the initial results of chemical analysis of peat soils at the Pineapple Research Station, situated at Pekan Nanas, Johore.

Peat soil samples were taken at three depths over six fields and a former jungle area. The first three fields (A, B, C) were each divided into two sections, one under continual cropping, referred to as 'old stand' hereafter, and one under experimentation. The six fields are each approximately ten acres in size, and soil samples were taken along diagonal traverses. The soil samples were analysed for: acidity; moisture content; loss on ignition; organic matter and organic carbon; total and nitrate nitrogen; water soluble, easily weatherable, and organic phosphorus; exchangeable hydrogen; exchangeable calcium; exchangeable magnesium; exchangeable potassium; cation exchange capacity; and percentage base saturation. Details of the analyses are given below. Results are expressed on an oven-dry basis, and references to the methods used are given in Table 1.

RESULTS AND DISCUSSION OF CHEMICAL ANALYSES

Soil Reaction

The soil pH values vary from 3.2 to 4.9, with 68 per cent of the samples reading less than 4.1 (Table 1). Malayan peat soil is extremely acid. This is confirmed by the exchangeable hydrogen determinations, which range from 88.0 to 169.9 me./100 grams, indicating that the colloidal complex of the peat soil is saturated with hydrogen ions. In Table 2 it can be seen that, on an average, 89.0 per cent of the exchange complex of the surface soil is occupied by hydrogen ions. This compares with representative figures of 70.8 per cent for a North American woody peat, and 40.1 per cent for a North American humid region mineral soil.

Unpublished research in Hawaii has shown that the Smooth Cayenne pineapple variety grown there achieves optimum growth at a soil pH of 5.0. However, two Malayan canning varieties, the Singapore Spanish and the Sarawak, the latter probably closely related to the Smooth Cayenne variety, grow well on acid Malayan peat soils. The local varieties will achieve satisfactory yields at low soil

TABLE 1: CHEMICAL ANALYSES OF PEAT SOIL FROM THE PINEAPPLE EXPERIMENT STATION, SOUTH-WEST JOHORE STATE, MALAYA

CHEMICAL DETERMINATION	SOIL DEPTH inches	FIELD A*		FIELD B*		FIELD C**		FIELD D**	FIELD E***	FIELD F***	NEWLY ^o CLEARED JUNGLE	AVERAGE
		OLD STAND ^{oo}	EXPERIMENT ^{oo}	OLD STAND	EXPERIMENT	OLD STAND	EXPERIMENT					
SOIL pH (glass electrode, 1:2.5 peat soil; water mixture)	0-6	4.6	4.6	3.6	3.6	4.1	3.9	4.1	3.9	3.8	3.9	4.0
	7-12	4.3	4.3	3.4	3.4	3.7	3.9	3.8	3.7	3.8	3.7	3.8
	13-18	4.2	4.3	3.4	3.3	3.7	4.0	3.8	3.8	3.6	3.8	3.8
MOISTURE per cent (oven dried at 105°C.)	0-6	81.3	77.3	73.5	74.5	64.0	75.4	70.9	79.5	64.9	78.4	74.0
	7-12	84.3	85.8	85.2	84.8	85.5	85.5	85.1	87.5	76.6	83.5	84.2
	13-18	87.9	89.8	87.8	87.8	85.9	89.7	88.6	89.4	84.7	86.8	87.8
ASH per cent (after igniting at 800°C.)	0-6	4.2	5.1	6.9	5.2	8.0	4.4	7.8	9.7	26.5	4.4	8.2
	7-12	1.7	2.3	2.2	2.2	2.0	2.3	3.8	12.1	29.9	3.8	6.2
	13-18	1.7	2.5	1.6	1.6	1.9	1.6	3.3	13.0	30.6	3.0	6.1
LOSS ON IGNITION (100 - ash per cent)	0-6	95.8	94.9	93.1	94.8	92.0	95.6	92.2	90.3	73.5	95.6	91.8
	7-12	98.3	97.7	97.8	97.8	98.0	97.7	96.2	87.9	70.1	96.2	93.8
	13-18	98.3	97.5	98.4	98.4	98.1	98.4	96.7	87.0	69.4	97.0	93.9
ORGANIC CARBON per cent (Walkley and Black, 1934)	0-6	45.1	45.2	44.0	46.3	41.7	43.2	41.4	41.9	33.2	42.8	42.5
	7-12	47.2	47.0	46.9	48.7	45.0	45.2	44.1	41.6	31.2	43.2	44.0
	13-18	48.1	46.7	47.6	49.3	45.5	46.0	45.1	40.2	31.2	44.0	44.4
ORGANIC MATTER per cent (assumed 85 per cent carbon oxidized)	0-6	91.4	91.8	87.2	91.8	85.6	88.7	85.0	86.5	68.2	92.5	86.9
	7-12	95.6	95.3	93.0	96.6	92.3	92.7	90.5	85.3	64.0	93.5	89.9
	13-18	97.5	94.8	94.4	97.8	93.3	94.3	92.5	82.5	64.0	95.2	90.6
TOTAL NITROGEN per cent (Jackson, 1958)	0-6	1.72	1.71	1.81	1.75	1.77	1.54	1.62	1.53	1.28	1.58	1.63
	7-12	1.43	1.41	1.54	1.38	1.32	1.17	1.28	1.11	1.07	1.39	1.31
	13-18	1.39	1.37	1.37	1.31	1.32	1.08	1.22	0.96	0.90	1.41	1.23
NITRATE NITROGEN per cent (Jackson, 1958)	0-6	0.12	0.08	0.04	0.08	0.04	0.05	0.08	0.05	0.05	0.10	0.07
	7-12	0.11	0.07	0.04	0.04	0.02	0.04	0.08	0.03	0.04	0.07	0.05
	13-18	0.08	0.05	0.03	0.05	0.04	0.03	0.04	0.01	0.02	0.06	0.04
CARBON:NITROGEN RATIO C/N. (calculated)	0-6	26.2	26.4	24.3	26.5	23.6	28.1	25.6	27.4	25.9	27.1	26.1
	7-12	33.0	33.3	30.5	35.3	34.1	38.6	34.5	37.5	29.2	31.1	33.7
	13-18	34.6	34.1	34.7	37.6	34.5	42.6	37.0	41.9	34.7	31.2	36.3
EASILY SOLUBLE PHOSPHORUS P ₂ O ₅ ppm. (Bray and Kurtz, 1945)	0-6	27.0	37.0	34.0	35.0	10.0	13.0	32.0	19.0	4.5	21.0	23.3
	7-12	21.0	40.0	32.0	33.0	9.0	11.0	24.0	6.0	3.0	11.0	19.0
	13-18	31.0	32.0	33.0	34.0	7.0	13.0	13.0	0.5	1.5	8.0	15.5

READILY WEATHERABLE PHOSPHORUS P ₂ O ₅ ppm. (Bray and Kurtz, 1945)	0-6	20.0	20.0	27.0	23.0	8.0	7.0	23.0	22.0	1.4	15.0	16.6
	7-12	10.0	13.0	19.0	18.0	5.0	5.0	10.0	6.0	0.5	7.0	9.4
	13-18	9.0	10.0	15.0	16.0	4.0	6.0	8.0	0.7	0.8	6.0	7.6
ORGANIC PHOSPHORUS P ₂ O ₅ ppm. (Legg and Black, 1955)	0-6	443.0	274.0	254.0	270.0	146.0	221.0	123.0	270.0	0.0	381.0	238.2
	7-12	374.0	243.0	246.0	208.0	220.0	188.0	186.0	114.0	0.3	226.0	200.8
	13-18	312.0	209.0	204.0	151.0	179.0	175.0	185.0	67.0	1.3	244.0	173.9
EXCHANGEABLE HYDROGEN me./100 g. (total exch. cap. — total exch. bases)	0-6	101.2	112.3	124.0	124.3	116.1	135.3	111.3	126.4	106.2	146.7	120.4
	7-12	125.4	129.3	155.1	148.9	148.6	153.3	139.8	137.1	111.7	149.2	139.8
	13-18	128.3	138.9	153.6	150.5	153.3	147.2	137.4	132.0	122.0	151.8	141.5
EXCHANGEABLE CALCIUM me./100 g. (Cheng and Bray, 1947)	0-6	10.7	15.9	10.7	9.6	17.8	6.5	20.5	8.0	9.2	7.9	11.7
	7-12	6.6	6.8	6.8	5.2	4.7	2.5	11.8	2.9	8.0	3.9	5.9
	13-18	3.4	4.5	4.8	3.5	4.5	2.0	5.3	1.1	2.2	3.3	3.5
EXCHANGEABLE MAGNESIUM me./100 g. (Cheng and Bray, 1947)	0-6	6.0	3.6	2.3	3.0	0.8	1.5	2.5	2.5	1.1	2.5	2.6
	7-12	2.9	1.9	1.2	1.8	0.7	2.2	2.0	1.6	0.3	1.6	1.6
	13-18	1.7	1.8	1.3	1.3	0.7	2.5	1.4	0.7	0.4	1.7	1.4
EXCHANGEABLE POTASSIUM me./100 g. (Chapman, 1947)	0-6	0.95	0.28	0.35	0.19	0.12	0.09	0.25	0.32	0.18	0.76	0.35
	7-12	0.36	0.36	0.17	0.20	0.10	0.09	0.20	0.15	0.18	0.50	0.23
	13-18	0.32	0.42	0.22	0.22	0.09	0.09	0.17	0.12	0.10	0.50	0.23
TOTAL EXCHANGE CAPACITY me./100 g. (A.O.A.C., 1955)	0-6	118.85	132.08	137.35	137.09	134.82	143.39	134.55	137.22	116.68	157.86	134.99
	7-12	135.26	138.36	163.27	156.10	154.10	158.09	153.80	141.75	120.18	155.20	147.61
	13-18	133.72	145.62	159.92	155.52	158.59	151.79	144.27	133.92	124.70	157.30	146.54
TOTAL EXCHANGEABLE BASES me./100 g. (A.O.A.C., 1955)	0-6	17.65	19.78	13.35	12.79	18.72	8.09	23.25	10.82	10.48	11.16	14.61
	7-12	9.86	9.06	8.17	7.20	5.50	4.79	14.00	4.65	8.48	6.00	7.77
	13-18	5.42	6.72	6.32	5.02	5.29	4.59	6.87	1.92	2.70	5.50	5.04
BASE SATURATION per cent (calculated from total exch. cap. and total exch. bases)	0-6	14.9	15.0	9.7	9.3	13.9	5.6	17.3	7.9	9.0	7.1	11.00
	7-12	7.3	6.6	5.0	4.6	3.6	3.0	9.1	3.3	7.1	3.9	5.4
	13-18	4.1	4.6	4.0	3.2	3.3	3.0	4.8	1.4	2.2	3.5	3.4

Notes: °° FIELDS A,B,C,D,E and F are approximately ten acres in area each. Soil samples were taken along diagonal traverses.

Fields A,B, and C were each divided into two sections, one under continual cropping (old stand) and one under experimentation (experiment). The references in parentheses refer to the experimental procedures used.

° Each entry in the table is an average of six samples.

** Each entry in the table is an average of four samples.

* Each entry in the table is an average of five samples.

*** Each entry in the table is an average of two samples.

pH, provided that adequate nutrition is supplied to the plants in the form of fertilizer or manure.

TABLE 2: SOIL EXCHANGE DATA, EXPRESSED IN ME./100 GRAMS, FOR A NORTH AMERICAN WOODY PEAT (11a), A NORTH AMERICAN HUMID REGION MINERAL SOIL (11b), A SOUTH MALAYAN PEAT* AND A MALAYAN MINERAL SOIL (12a).

	N. AMERICAN LOW-LIME WOODY PEAT	N. AMERICAN HUMID REGION MINERAL SOIL	S. MALAYAN PEAT, SURFACE HORIZON	MALAYAN MINERAL SOIL
Exchangeable Hydrogen	122.30	5.00	120.38	—
Exchangeable Calcium	39.80	5.50	11.68	0.08
Exchangeable Magnesium	9.70	1.70	2.58	0.05
Exchangeable Potassium	0.87	0.27	0.35	0.06
Total Exchange Capacity	172.67	12.46	134.99	—
Percentage Base Saturation	29.17	59.87	10.97	—
pH	4.0	5.7	4.0	5.3

* Average figures from Table 1.

Soil Moisture

Peat soil has a high water-holding capacity. Average moisture content increases with depth, from 74 per cent at the surface to 88 per cent at 18 inches. These average figures for the Station's fields, listed in Table 1, are lowered by the inclusion of field F, in which the soil has a higher mineral content. The moisture content at the surface in field F was 65 per cent, and at 18 inches below the surface it was 85 per cent.

The watertable over most of the sampled area is maintained by drainage channels at from two to three feet below the surface. Even with this good drainage the soil is able to retain large amounts of water. The high water-holding capacity of the peat is attributed to the high exchange capacity of the soil.

Pineapples have been observed growing successfully in areas of relatively low rainfall in Hawaii and Australia, so the Malayan plants on peat soil should rarely suffer from drought.

Ash and Loss on Ignition

The deep peat fields (A, B, C, D) and the newly cleared jungle area have more ash in the surface layer after ignition than at deeper levels. However, the soils of fields E and F, where the peat overlies clay beds, have more ash after ignition in the lower horizons than at the surface. This is due to the presence of the clay beds, and thus of mineral matter in the lower horizons of fields E and F. Over

90 per cent of the samples had a loss on ignition of more than 90 per cent (Table 1), which is indicative of the high organic matter content and low mineral matter content of these soils.

Organic Carbon and Organic Matter

Table 1 shows that organic carbon, and hence organic matter, increase with depth in the deep peat fields (A, B, C, D) as well as in the newly cleared jungle area. However, in fields E and F the situation is reversed, since the underlying clay beds there are lower in organic matter than the peat. The soil from field F may be classified as muck, since two readings show less than 65 per cent organic matter. This soil differs from peat in several ways and represents a transitional stage between Malayan peat and mineral soils.

The organic matter contents of two representative peat soils, one from North America and one from Malaya, are contrasted in Table 3 with the organic matter content of a North American humid region mineral soil. Whereas the organic matter content is only 4 per cent in the surface horizon of the mineral soil, in the two peat soils it is 80 and 87 per cent. This characteristic is the most distinctive feature of peat soil, and is the principal factor responsible for the unusual properties of such soils. Since Malayan peat is formed from tropical forest litter, it is not surprising that the organic matter content is high.

Total Nitrogen, Nitrate Nitrogen and the Carbon: Nitrogen Ratio

The total nitrogen content of the Station peat soil is high; it decreases from 1.63 per cent in the surface horizons to 1.23 per cent at a depth of 18 inches, on the average (Table 1). These levels compare favourably with the nitrogen content of North American peat (Table 3), but are much greater than that of the North American mineral soil.

TABLE 3: SUGGESTED ANALYSES FOR REPRESENTATIVE NORTH AMERICAN PEAT AND MINERAL SURFACE SOILS (11c), AND SOUTH MALAYAN PEAT*, EXPRESSED AS PERCENTAGE DRY MATTER.

	N. AMERICAN PEAT, SURFACE SOIL	N. AMERICAN MINERAL SOIL, SURFACE	S. MALAYAN PEAT, SURFACE SOIL
Organic Matter	80.00	4.00	86.87
Total Nitrogen	2.50	0.15	1.63
Total Phosphoric Acid (P ₂ O ₅)	0.20	0.10	0.03
Carbon: Nitrogen Ratio	19:1	12:1	26:1

* Average figures from Table 1.

Although the percentage of total nitrogen in the nitrate form is relatively low (4.3 per cent in the surface layer, 3.3 per cent at 18 inches), the absolute quantity of nitrate nitrogen present is quite high compared with most tropical mineral soils. Assuming that one acre-furrow-slice of peat weighs 500,000 lbs. (11d), there would be approximately 700 ppm. of nitrate nitrogen in the surface horizon, according to the data in Table 1. Studies on Nigerian mineral soils indicate that 100 ppm. is a not uncommon level during the dry season there (13).

In contrast, Malayan mineral soils have been reported to contain from 15 to 60 ppm. of nitrate nitrogen (14). The high nitrate nitrogen content in the peat soil samples may be due to nitrification after sampling, because the samples were air-dried, and it may not be a true indication of field conditions.

North American peat soils exhibit vigorous nitrification (11), and a similar situation might be expected in tropical peat soils. However the high rainfall of south Malaya, averaging approximately 112 inches per year at the Pineapple Research Station, probably removes the nitrates from the profile as rapidly as they are formed. This might explain why marked responses are obtained from pineapple growing on peat soil when nitrogenous fertilizers are applied, even though the total nitrogen content of the soil reads high by analysis.

The average carbon:nitrogen ratio varies from 26:1 at the surface to 36:1 at 18 inches (Table 1). These figures contrast with 19:1 for the surface soil of a North American peat, and 12:1 for a North American mineral soil (Table 3). Under temperate conditions the ratio generally decreases with depth. The increase with depth exhibited by tropical peat is probably due to the drainage condition of the soil. Water accumulates with depth, increasing the organic carbon content through lack of oxidation and decreasing the nitrogen content through lack of nitrification. The carbon:nitrogen ratio for south Malayan peat could serve as an index of oxidation within the soil profile, and thus also of plant residue decomposition.

Phosphorus

The peat soil phosphorus content was divided, by the use of different extraction techniques, into easily soluble, readily weatherable, and organic components. The first two may be considered available to plants. From Table 1 it will be seen that the available phosphorus in the surface soil varies from 18 to 61 ppm. on the average, decreasing with depth at nearly every site.

If it is assumed that an acre-furrow-slice of dry peat weights 500,000 lbs., the available phosphorus content of deep peat will lie between 9 and 30.5 lbs. per acre, with an average of 22 lbs. If it is assumed that an acre-furrow-slice of mineral soil weights 2,000,000 lbs. (11d), some Malayan mineral soils contain from 6 to 30 lbs. per acre of available phosphorus, which is about the same level as is found in peat soils. But while the peat soils have large reserves of organic phosphorus, Malayan mineral soils are low in organic matter, and hence in organic phosphorus. Phosphorus deficiency in Malayan mineral soils is general; oil palm, rubber and padi all benefit from additions of this element to the soil (15).

Table 3 indicates that Malayan peat soil is low in phosphorus when compared with North American peat and mineral soils. This is confirmed by the data in Table 4. It might be inferred from these figures that pineapple growing on Malayan deep peat would respond to the addition of phosphatic fertilizers. This is not the case: phosphatic fertilizers suppress pineapple growth on peat soil, even at low rates of application (1). The pineapple plant has a low demand for phosphorus (16). The supply of this element in Malayan peat soil is evidently sufficient to sustain satisfactory crops of pineapple. The addition of phosphatic fertilizers to such an acid soil may interfere with the availability of other elements, thereby suppressing growth.

It is of interest to observe the markedly lower phosphorus content of the muck soil taken from field F. As this soil contains a considerable quantity of

mineral matter, the difference may be indicative of the generally low phosphorus levels of Malayan mineral soils. Pineapple grown on such soils might require phosphorus amendments.

The old stand on field A received a dressing of rock phosphate in 1959, which probably accounts for the high levels of phosphorus recorded from this field. It is interesting to note that the applied inorganic phosphorus seems to have been retained in an organic form.

Potassium

An acre-furrow-slice of newly cleared Malayan peat soil contains an average amount of 148 lbs of exchangeable potassium, according to the data in Table 1. Peat soil from the Station fields, with the exception of field A which received a dressing of potash fertilizer in 1959, has on an average 43 lbs. of exchangeable potassium per acre-furrow-slice. According to Bolton (12), the exchangeable potassium content of an acre-furrow-slice of Malayan mineral soil lies between 74 and 24.2 lbs. Assuming that exchangeable potassium reflects the potassium status of tropical soils, Bolton concludes that a level of 0.035 me./100 grams (or 27.3 lbs. per acre-furrow-slice) represents a deficiency, and he states that a better growth response is then obtained if potash fertilizer is applied.

The average content of exchangeable potassium in the Station's surface soils is 0.349 me./100 grams, or 68.1 lbs per acre (Table 1). Although this figure lies above Bolton's deficiency level for Malayan mineral soils, potash fertilizer amendments have produced marked responses in pineapple growth (1).

Tables 2 and 4 confirm that the exchangeable potassium levels in both Malayan peat and mineral soils are very low generally. The North American woody peat is considered to be low in potassium by temperate zone standards, yet it contains far more than the Malayan peats. Without heavy applications of fertilizers, Malayan peat cannot be expected to yield satisfactory crops. Because of the soluble nature of most potash salts, and because of the heavy Malayan rainfall, new techniques of potassium fertilizer application need to be devised for the region.

Calcium and Magnesium

Exchangeable calcium averages 11.7 me./100 grams in the surface horizon, but decreases sharply to 3.5 me./100 grams at 18 inches (Table 1). While this is relatively high by comparison with Malayan mineral soils (12), Tables 2 and 4 reveal that the tropical soils have lower exchangeable calcium contents than the temperate peat and mineral soils of North America. In view of the severe leaching to which the Malayan soils are exposed, this is not unexpected. However, pineapple plants on Malayan peat have shown neither a calcium deficiency nor a growth response to heavy calcium amendments (1).

Table 1 indicates that the exchangeable magnesium content decreases with depth. The average content of Malayan peat soil varies from 2.6 me./100 grams at the surface to 1.4 me./100 grams at 18 inches. While this is higher than the exchangeable magnesium content of average Malayan mineral soils (Table 2), it is considerably lower than that of temperate peat and mineral soil (Table 4). However, experimental magnesium applications at high rates have so far failed to produce measurable responses in pineapple growth (1).

TABLE 4: QUANTITIES OF NUTRIENT ELEMENTS, EXPRESSED IN POUNDS PER ACRE-FURROW-SLICE*, FOR NORTH AMERICAN PEAT (11a) AND MINERAL (11c) SOILS, AND MALAYAN PEAT* AND MINERAL (12) SOILS.

	N. AMERICAN LOW-LIME WOODY PEAT	S. MALAYAN PEAT†	N. AMERICAN HUMID REGION MINERAL SOIL	MALAYAN MINERAL SOIL††
Total Phosphoric Acid (P_2O_5)	1,000	82	2,000	26
Exchangeable Calcium	3,980	1,780	2,200	30
Exchangeable Magnesium	582	48	408	15
Exchangeable Potassium	170	23	210	21

* Assuming that the weight of 1 acre-furrow-slice of mineral soil is 2,000,000 lbs., and of peat soil is 500,000 lbs. (11).

† Surface soil of field C, cleared for about nine years but probably unfertilized.

†† An average from Bolton's data for the no-treatment check plots for three fertilizer trials on rubber (12).

Total Exchange Capacity.

South Malayan peat soil has a high exchange capacity which increases with depth, ranging on the average from 134 me./100 grams at the surface to 147 me./100 grams at 18 inches (Table 1). This is probably due to the increase in organic matter content with depth. The exchange capacity of the muck soil from field F, particularly of the two lower horizons, is considerably less than that of the peat soils.

Table 2 indicates that the exchange capacity of south Malayan peat is less than that of North American peat, but considerably more than that of North American mineral soil. This is due to the very high organic matter content of the Malayan peat soils (Table 3).

Because of this high exchange capacity, peat soil is strongly buffered. In other words, the soil may adsorb large quantities of exchangeable ions onto its colloidal complex, without those ions necessarily becoming available in solution to the plant. This explains why very large applications of lime (up to 14 tons per acre) have had little effect on the pH of the peat in field A (1). It may also play an important, and as yet unstudied, role in the nutrient balance of the peat soil solution, from which pineapple plants draw their nutrition. The high exchange capacity of peat also explains the soil's ability to retain large quantities of water.

Total Exchangeable Bases and Percentage Base Saturation

In Table 1 it can be seen that the exchange complex of south Malayan peat soil is saturated with hydrogen ions, at the expense of bases. Table 2 indicates that the peat is considerably lower in base status than both the North American peat and mineral soils. When it is seen that the surface horizons of south Malayan peat have an average base saturation of 11 per cent, it is clear why the soil is generally infertile and requires large fertilizer applications to produce satisfactory pineapple growth and yields. Since the strongly buffered soil condition and

severe leaching would make it difficult, and uneconomic, to increase the base saturation percentage of the entire soil body by fertilization, it is imperative to find more economic (and efficient) means of spot-fertilizing peat soil.

Pocket and pellet fertilization could provide concentrated patches of fertility exhibiting satisfactory base saturation percentages for optimum plant performance in a generally low fertility soil medium. A trial to test this hypothesis has been started at the Pineapple Research Station, and the results to date are most encouraging (1).

ACKNOWLEDGEMENT

The authors wish to thank Mr. Kannappan, Assistant Analytical Chemist, Malayan Pineapple Industry Board, for help in the analyses.

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THE ORIGIN OF THE LIMESTONE HILLS OF MALAYA

By J. R. PATON

THE LIMESTONE hills of Malaya, with their high vertical cliffs rising abruptly from flat or gently undulating plains, are probably the most remarkable topographic features in the country. For many years their origin has been the subject of comment, speculation and discussion, both printed and verbal. A wide variety of theories has been advanced, ranging from block faulting, nappe thrusting, or jointing, to marine or arid erosion. This paper reviews the theories advanced in the past, examines the explanations offered by geologists of the Geological Survey of Malaya, and attempts to determine the common ground between the theories and to indicate, if possible, the most plausible explanation.

TOPOGRAPHY

From flat or undulating plains, most of the limestone hills of Malaya rise in sheer, vertical or overhanging cliffs of bare rock with only rare patches of soil, reaching up to 2,000 feet in height (Plate 1). In Kedah and parts of Perlis, they rise abruptly from padi fields or swamps. The topography found on other Malayan rocks generally shows a gradual rise from the plains through a series of rounded foothills, without the characteristic sharp break in slope that occurs at the foot of the limestone hills. On the non-calcareous rocks weathering is so intense that bare rock faces occur very rarely. There are some on steep granite slopes, but these are the result of landslides, and are consequently both temporary and restricted in area. Some ridges of quartzite or conglomerate also present cliffs and bare rock surfaces, but only at considerable elevations, where the jungle cover is naturally scrubby and thin.

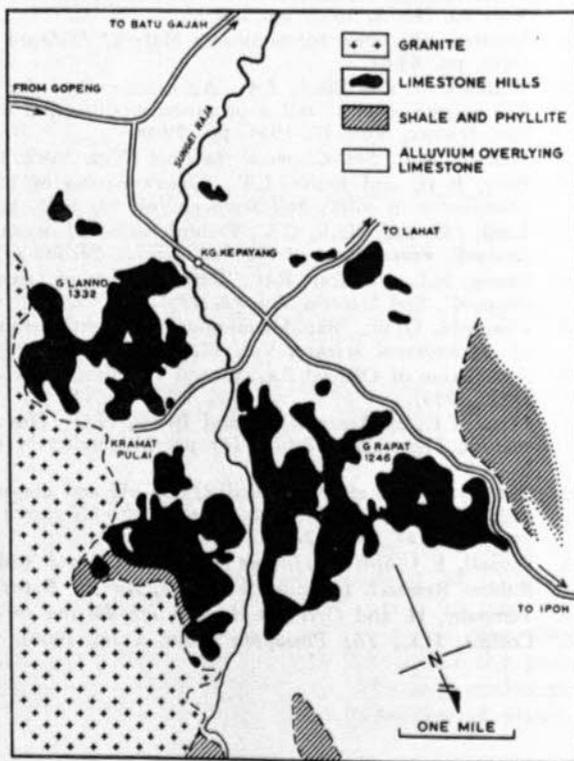


Fig. 1. Geological sketch map of the area south-east of Ipoh shown in Plate 1.

The country rock around the limestone hills varies. In some cases it is shale and limestone, in others shale and quartzite. At Bukit Takun, Gunong Pondok, and the hills north of Lenggong, the country rock is granite. Where it is shale,



Plate 1. Limestone hills, alluvium and (low rounded hills, bottom left) granite, south-east of Ipoh.

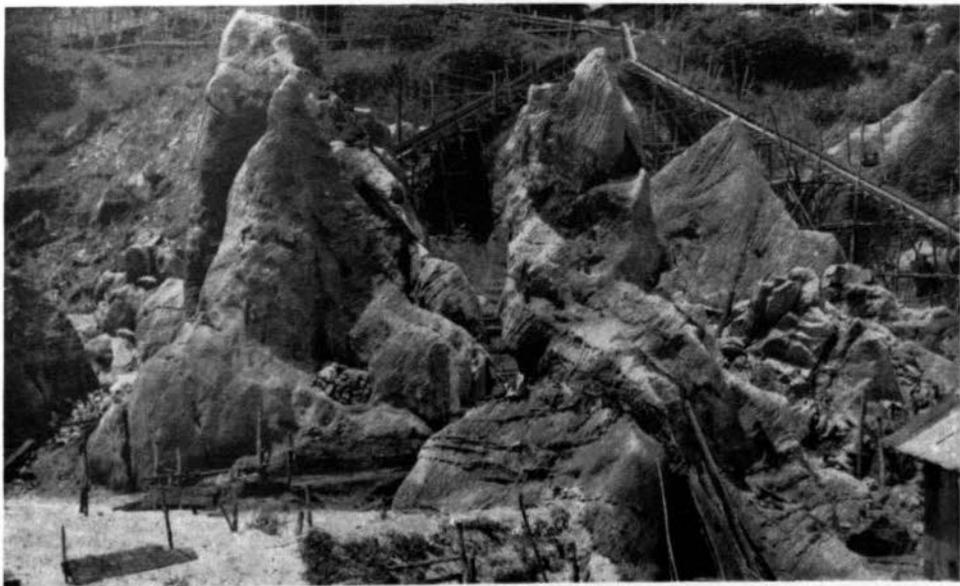


Plate 2. Limestone pinnacles exposed in an alluvial mine, Labat, Kinta.

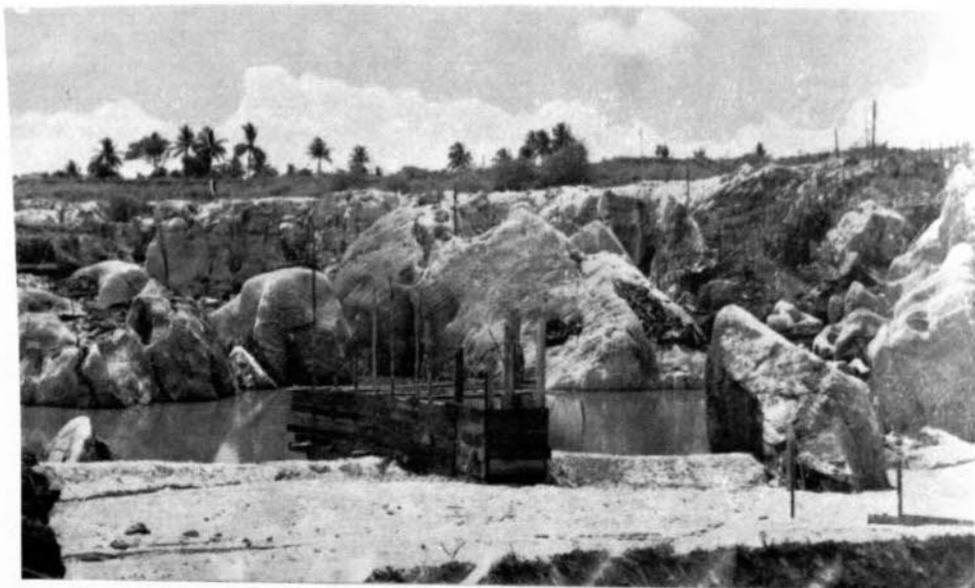


Plate 3. Limestone pinnacles at Lahat, showing the originally continuous horizontal limestone platform.

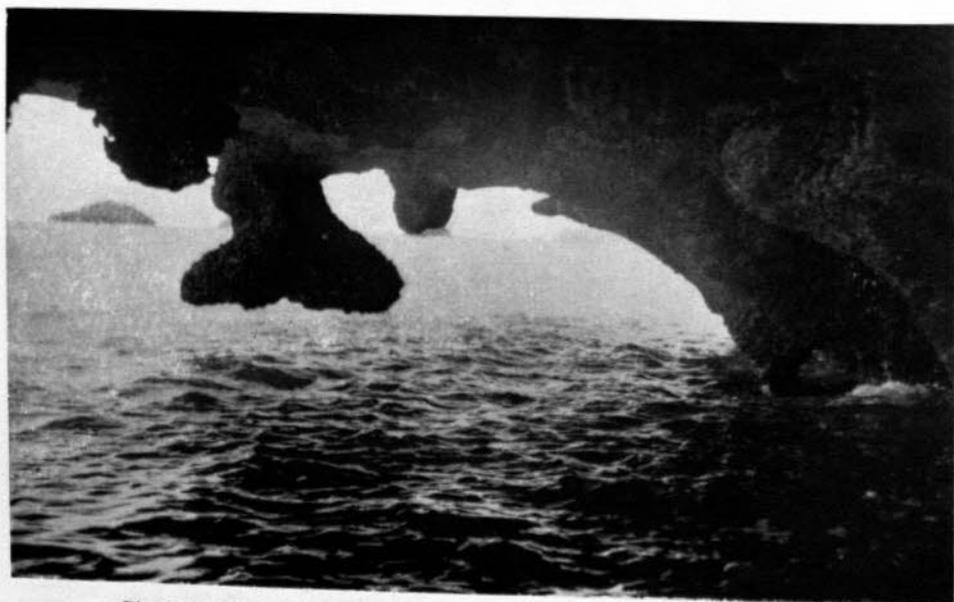


Plate 4. Marine nips in limestone, Pulau Bumbon, Langkawi Islands.

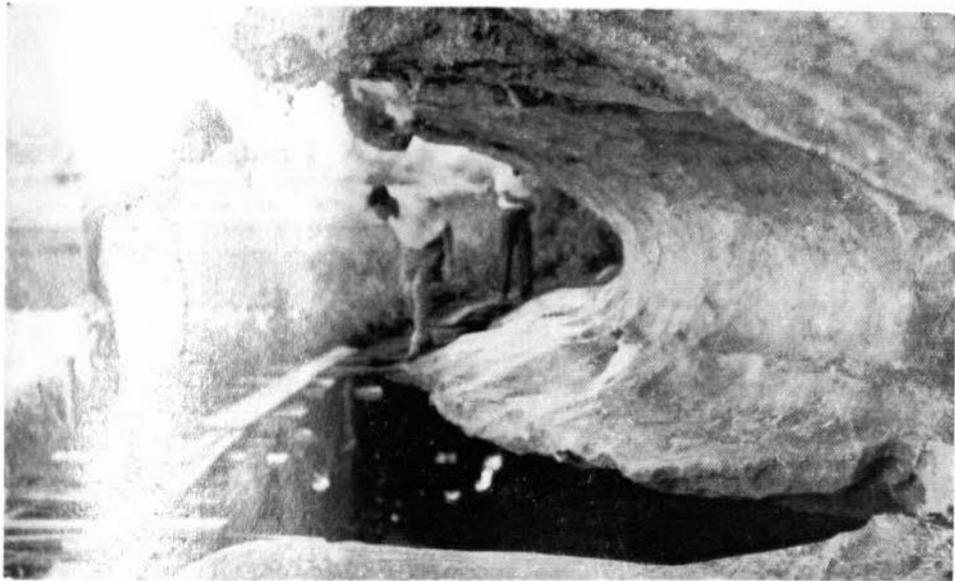


Plate 5. Possible marine nip on the west side of Bukit Koplū, Kedah.

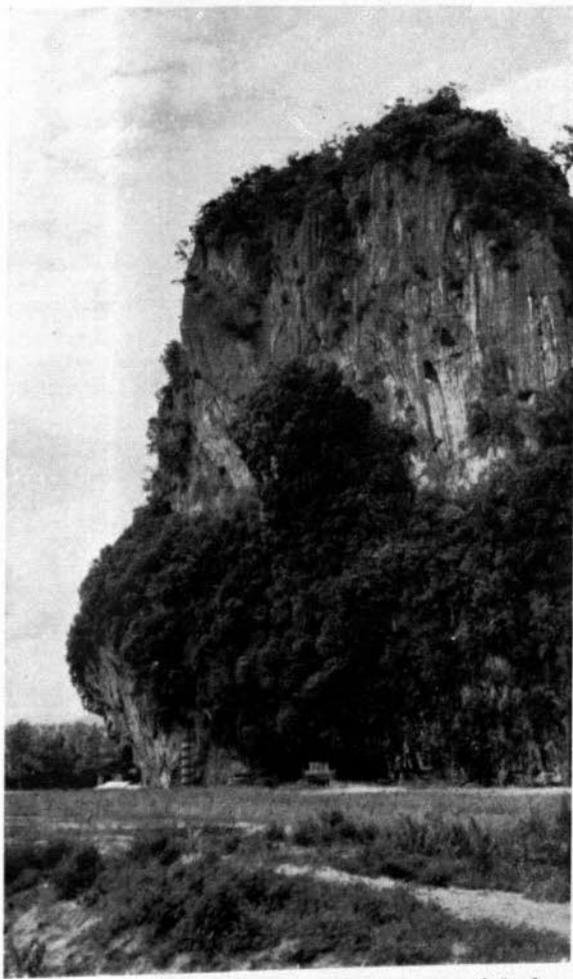


Plate 6. Part of Gunong Rapat, south-east of Ipoh.

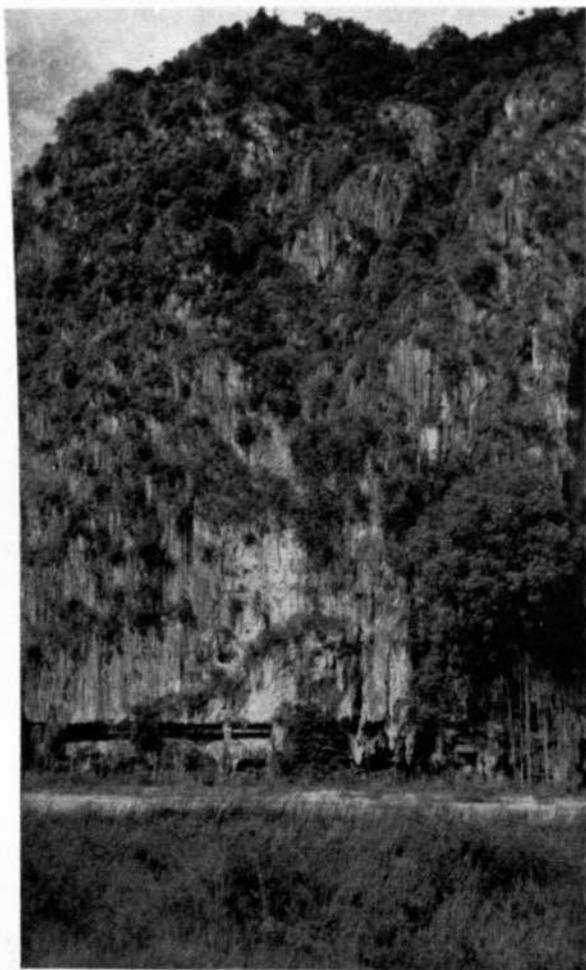


Plate 7. Stream or swamp cut grooves at the base of Gunong Rapat.

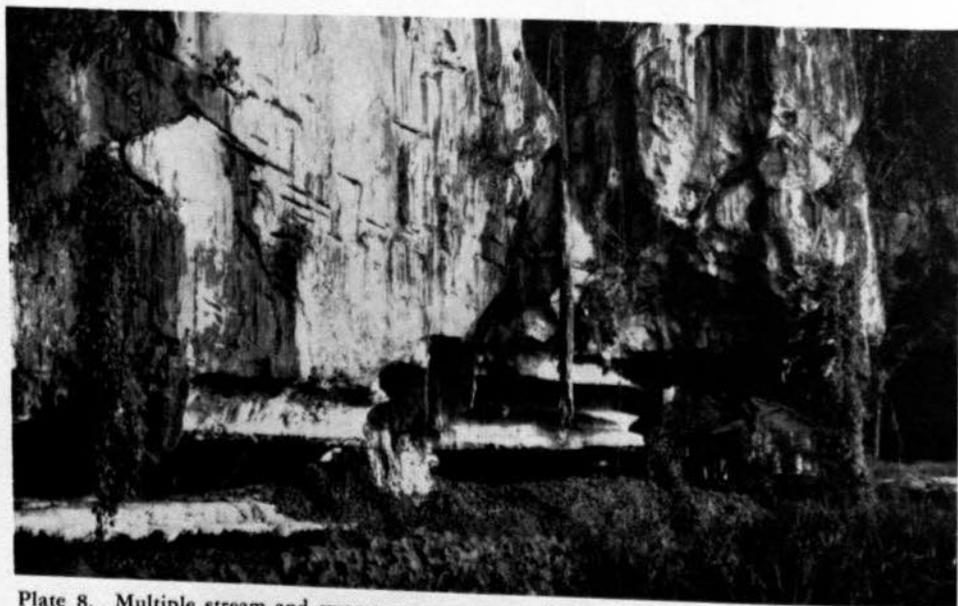


Plate 8. Multiple stream and swamp cut grooves at the base of Gunong Tasek, north of Ipoh.

quartzite or granite, the surrounding topography is undulating and sometimes steep, but none of these rocks give rise to cliffs. In Plate 1, an oblique air photograph of the area immediately south-east of Ipoh, whose geology is shown in Figure 1, there is a sharp topographic contrast between the steep and rocky limestone hills and the adjacent low undulating country to the north-east. Most of the surrounding flat alluvial deposits are underlain by limestone.

The most extreme topographic contrasts occur where limestone occupies a large area around the hills, in the form of a flat bench or platform. Such flat surfaces are generally hidden beneath alluvium or recent marine deposits (hereafter, alluvium is used to include both, since they are in most cases indistinguishable). When the alluvial cover is stripped off during mining operations, as in the Kinta Valley of Perak, it is evident that the original limestone platforms have been reduced to irregular pinnacles by sub-surface solution (Plate 2). However the original level of the platform at any particular place can be deduced from the peaks of the highest pinnacles (Plate 3).

Overhangs may occur at all elevations on the hills, but they are always present at the base. In the basal overhang there are usually some narrow horizontal grooves, whose depth, height, and frequency vary from place to place. The grooves are less common higher up the cliffs, and at more than 70 feet above the surrounding plain they are rare.

The common association of tin ore, in its primary and often in its secondary occurrences, with limestone has led to the exhaustive exploration of the hills. From a distance they appear massive, but closer inspection often reveals that the cliffs are merely facades to empty shells (Plate 1). The hills are honeycombed with deep gullies, amphitheatres, caves and potholes. Many of the hidden valleys have no obvious outlet, and the stream channels are entirely underground. Access to the mines and villages in the spectacular dolines or *wangs* west of Kaki Bukit in Perlis is by means of a path constructed along the underground stream which drains the area. The outflow channel of a *wang* at Gunong Rapat, shown in Plate 1, has not yet been discovered, and the only access to a mine which once operated there was by means of a steep path over a high and narrow limestone wall.

DISTRIBUTION

The best known limestone hills occur in the Kinta Valley and Perlis, but in south-west Kelantan they are found at their most spectacular and prolific development. They are also frequent in Pahang, particularly in the north-west. In Trengganu and Selangor they

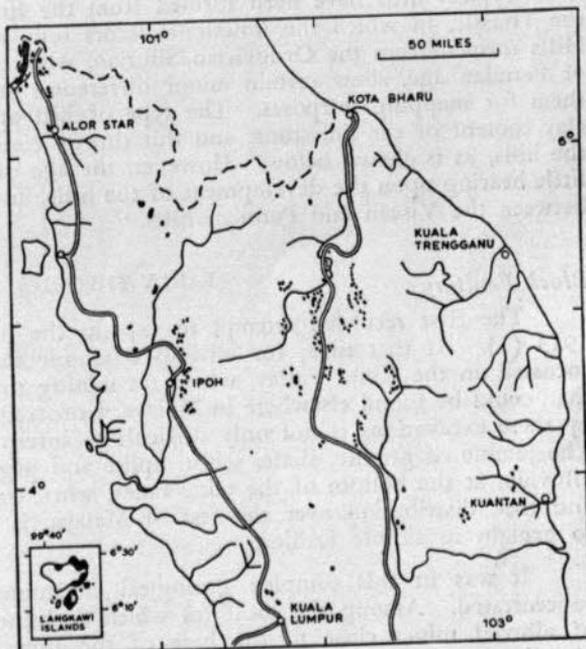


Fig. 2. Distribution of the Malayan limestone hills.

are rare, and south of the latitude of Kuala Lumpur they are unknown. The distribution of the known limestone hills is shown in Figure 2. They occur in well marked linear groups, commonly oriented in a north-south direction.

STRATIGRAPHY

The scarcity of fossils in the limestone has prevented the age-determination of the beds in all but a few cases. Until recently all the limestone in Malaya was thought to belong to the Calcareous Series of Carboniferous-Permian age. Many of the fossils identified confirmed this idea, but anomalies were noted at quite an early stage. The most important of the anomalies arose from the discovery of Lower Carboniferous fossils in the limestone of the Kuantan District, Pahang, and of Permian or possibly Upper Carboniferous fossils at the base of the limestone in Perlis. At first it was believed that one or other of the fossil collections had been incorrectly dated.

Recently the discovery of many new fossils in Pahang, Perlis, and Trengganu has shown that the idea of a single group of calcareous rocks is no longer tenable. A Uralian/Permian age for limestone in Perlis, and a Visean age for that in Kuantan District have been confirmed. More remarkable has been the discovery that some of the limestone in Perlis, Langkawi, Selangor, and possibly in Perak, is of Ordovician/Silurian age. Fossil evidence from the Kuala Lipis area in Pahang has indicated that the range of the limestone there extends to the Upper Triassic.

The Malayan limestones are now considered to belong to four groups, covering five systems. The groups are: Ordovician/Silurian; Lower Carboniferous; Uralian/Permian; and Upper Triassic. They are separated by relatively thick successions of non-calcareous rocks, partly arenaceous in character.

Typical hills have been formed from the limestones of every group except the Triassic, in which the limestone occurs only as thin and impersistent lenses. Hills formed from the Ordovician/Silurian, when compared with those of Visean or Permian age, show certain minor differences sufficient to distinguish between them for mapping purposes. The type of hill appears to be a function of the clay content of the limestone, and this throws considerable light on the origin of the hills, as is shown below. However, the age of the limestone appears to have little bearing upon the development of the hills, and there is no difference in form between the Visean and Permian hills.

Block Faulting

EARLY THEORIES

The first recorded attempt to explain the hills was made by Scrivenor in 1913 (1). At that time, for obvious economic reasons, geological attention was focussed on the Kinta Valley, where tin mining provided more exposures of rock than could be found elsewhere in Malaya. Unfortunately, the information provided by these excavations is not only difficult to interpret but often quite misleading. The jumble of granite, shale, schist, aplite and pegmatite veins, granite wash and alluvium at the bottom of the mine holes, when compared with the regular strike and rock distribution over the rest of Malaya, is still confusing and impossible to explain in simple fashion.

It was in this complex geological environment that the early work was concentrated. Among the localities which Scrivenor investigated were a number of alluvial mines close to the base of the limestone hills south-east of Ipoh. Simplified, they revealed the following situation: against the limestone, within

a few feet of the base of the cliffs, contorted, highly folded and fractured beds of schist, shale, clay and boulders were found beneath a cover of unconsolidated and obviously recent alluvium. These beds, apart from the alluvium, Scrivenor grouped together under the name 'Gondwana Rocks'. He realised that most, if not all, of these non-calcareous sediments were younger than the limestone, since they could be observed resting on the limestone in numerous mine holes elsewhere. Scrivenor called the clay and boulder beds the Gopeng Beds; the controversy over their alleged glacial origin need not concern us here.

Scrivenor came to the conclusion that the Gopeng Beds were older than the granite of the Main Range and younger than the limestone. Thus misinterpreting the age of the non-calcareous beds, he could only account for their presence against the base of the limestone by postulating faults of considerable throw: 'Simple denudation might account for [the hills] if we were to regard the beds overlying the limestone floor at the base of the cliffs as being recent alluvium, and at first, in the absence of evidence to the contrary, this view was adopted. It was soon found, however, that this very simple explanation would not do, because when it became obvious that the Gopeng Beds were older than the granite of the Main Range and when their extent was traced on the east side of the valley, it was realised that the limestone hills owe their origin primarily to faulting, the cliffs being fault faces with the Gopeng Beds faulted down against them' (1).

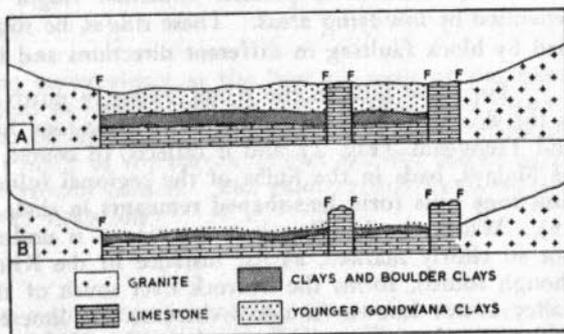


Fig. 3. Scrivenor's diagrammatic sections illustrating the formation of the limestone hills of the Kinta Valley: (A) before erosion, (B) after erosion.

Sub-aerial Erosion

W.R. Jones rejected Scrivenor's explanation of the Gopeng Beds and limestone hills with its important implications for the origin and distribution of tin ore in the Kinta Valley (2). He showed that the distribution of tourmaline-corundum and corundum rocks in the Gopeng Beds is related to recent drainage; that layers of recent lignite occur below these beds; that there are no signs of metamorphism in the clays and boulder beds; and finally he pointed out the unlikelihood of two tin-bearing formations in the Gopeng Beds and recent alluvium.

Jones therefore suggested that the limestone hills are the result of simple, sub-aerial denudation of well jointed limestone. He also showed how improbable was Scrivenor's hypothesis of block faulting which implied simultaneous movements with throws of, in many cases, at least 1,500 feet.

The non-calcareous sediments are now known to belong to two separate groups; the schists, phyllites, and shales are interbedded as layers in the limestone; the boulder and clay beds belong to what is now called the Older Alluvium. Although these beds are as highly folded and fractured as the older formations, the cause is quite different, being the result of slumping into gradually deepening solution hollows in the limestone. These hollows are often 30 to 40 feet below

the tops of the pinnacles (Plate 2) and Jones reported one 130 feet deep near Siputeh.

Folding

Rastall, like other geologists who have visited the Kinta Valley, was impressed by the limestone hills, and published his views on their origin in 1927 (3, 4). He put forward the theory that the present lines of limestone hills in the Kinta Valley represent three parallel anticlinal ridges overfolded from the west and separated by low-lying areas. These ridges, he suggested, were subsequently modified by block faulting in different directions and by denudation.

For some hills in the Kinta Valley, a north-south alignment does exist; this is the dominant trend of most of the limestone hills in Perlis, Kelantan, Pahang, and Trengganu (Fig. 2), and it reflects, of course, the regional trend. Over most of Malaya, beds in the limbs of the regional folds are steep or vertical and some limestone hills form lens-shaped remnants in shale, as is seen in the Merapoh area (5). Where the bedding is less steep or is undulating, the north-south trend is not so clearly marked, as for instance in the Kinta Valley, where the limestone, though folded, forms the bedrock over much of the valley. The structure of the valley is not known in detail, because the limestone can only be observed in a limited number of exposures, so that although some of the hills display the regional trend, there is little evidence for the overfolds suggested by Rastall.

In 1925 Cameron suggested that the hills are the result of the unequal denudation of a strongly jointed limestone lying unconformably on a floor of older and sheared limestone, shale, and schist (6). He was influenced mainly by the contrast between the towering limestone hills and the pinnacled platform around them, and he assumed that the difference must lie in the age of the limestones. Reed modified this hypothesis by suggesting that the hills are the remnants of a nappe of beds overthrust from the east (7). The unconformity postulated by Cameron would then be a thrust plane.

So many sections have now been exposed that there is no longer any doubt that the limestone of the valley floor is continuous with that of the hills. No horizontal breaks or large near-vertical faults have been found, so that there is no evidence to support Scrivenor's major vertical faults, Cameron's unconformity, or Reed's thrust plane.

RECENT THEORIES

None of the theories that have been advanced in recent years have appeared in print, though many have provoked discussion. The views held at different times by geologists in the Geological Survey Department of the Federation of Malaya are summarized below. Through frequent discussion, many of the theories betray similarities, but a number of them are original in conception.

Plastic Flow

One geologist regarded the hills as plastic plugs. The hills with which he was concerned, Batu Kurau and Gunong Pondok in northern Perak, are both isolated. Part of the base of Gunong Pondok is in contact with granite, and alluvium is found at the base of both hills. There is no evidence that the alluvium is underlain by limestone. The geologist was impressed by evidence in the limestone of flow, and he felt that this would be proved if examination of the rock revealed a preferred orientation, indicating the presence of a system of stresses. He believed that the hills originated as plastic calcite plugs, the plasticity having

been induced during a period of orogenic stress at the time of the invasion of the granite. This would in some ways be analogous to the formation of a salt dome, with the process taking place at depth.

Even if the possibility of plastic flow in the limestone were admitted, the theory still fails to account for the form of the hills, except insofar as complete recrystallization of the limestone may have increased its resistance to erosion relative to that of the sediments into which it flowed. On this point there is no evidence.

Aeolian Erosion

In order to account for the undercutting at the base of most of the hills, another geologist suggested erosion by wind-blown sand in an arid environment. He has since abandoned the idea, because the Kinta hills are too highly dissected to be ascribed to such a process. Many of the narrow gullies and the deeper caves could not have been produced by aeolian erosion. The theory also fails to explain why such topography is limited to limestone.

Marine Erosion

Some theories suggest that marine erosion might account for most of the typical limestone hills in the Kinta Valley, Kedah and Perlis. These envisage the limestone platforms and hills as former marine platforms and sea stacks with basal caves and nips. The present writer, after visits to Langkawi and some of the Thai islands further north, where the action of the marine erosion on limestone can be observed, is satisfied that a similar process could have produced the limestone topography of Kinta and Perlis.

Recent work by Walker (8) has confirmed Scrivenor's view that in recent times much of the Kinta Valley was below sea level. Walker has described three types of groove or nip, formed under marine, stream, and swamp conditions, at the base of Gunung Tempurong. It is also certain that much of the Kedah-Perlis plain was below sea level at the same time. The marine fossil *Meretrix casta* has recently been obtained in great numbers from alluvium near the Sungei Muda, where the water-worn shells and coarse sand matrix suggest a beach deposit. Fitch also ascribes to marine erosion certain features of the limestone hills near the coast in Kuantan District, Pahang (9, 10).

Lengthy discussion here on the origin of the grooves or nips at the base of the hills would be misplaced. In brief, it seems possible to distinguish between grooves formed by marine,

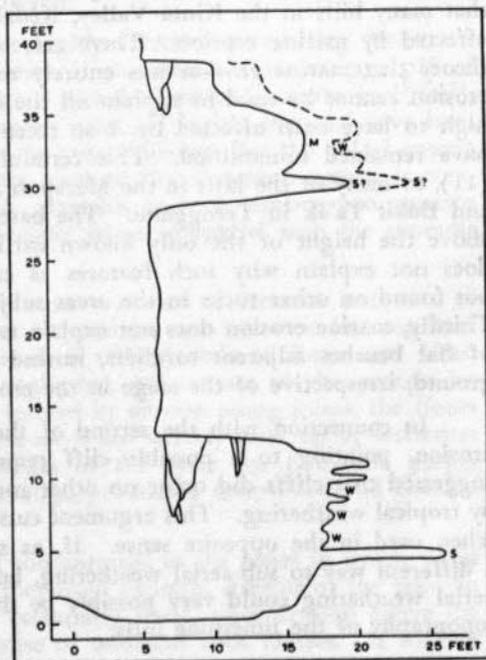


Fig. 4. Section through caves at the base of Gunung Tasek, north of Ipoh.

M: marine notches.

W: freshwater (running) grooves.

S: swamp (stagnant) grooves.

stream, and swamp erosion. The erosive action of streams and swamps has a limited vertical range, so that one would expect grooves of these types to be low, deep, and smooth, with a relatively flat floor and roof. The irregular and frequently rapid lowering of the base level of erosion would probably produce multiple grooves (Fig. 4). Marine notches or grooves would tend to be higher from floor to roof, reflecting wave and tidal ranges; the roof and floor would normally slope inwards with increasing steepness, the notch approaching an arc in section. Scalping of the roof is also held to be a feature of marine notches.

Good examples of marine notches occur around the Langkawi Islands (Plate 4). The only similar notch which the writer has observed at any distance from the coast on the mainland was on the western side of Bukit Koplu near Kodiang (Plate 5). But this could have been formed by swamp erosion, since similar grooves have been observed in Borneo where swamps have been drained for rice cultivation.

Grooves cut by freshwater action can be found on almost all the limestone hills in Malaya (Plates 6, 7 & 8). The grooves are horizontal, and only continuous for short distances. It is usually impossible to correlate the height of the grooves in any single area. There seems little doubt that in each case the groups of grooves are related to local base levels of erosion, and that they were formed independently. Marine notches should be traceable over considerable distances and should occur at one or more consistent levels.

In spite of doubts about the origin of the basal grooves, the process of marine erosion can be used to explain many of the limestone hills. It is known that many hills in the Kinta Valley, Kedah and Perlis, have almost certainly been affected by marine erosion. There are, however, three serious objections to the theory that marine erosion was entirely responsible for the hills. Firstly, marine erosion cannot be used to explain all the hills, because a number of them are too high to have been affected by it so recently that the resulting topography could have remained unmodified. This certainly applies to Bukit Takun in Selangor (11), to many of the hills in the Merapoh area of Pahang (5), and to Bukit Biwah and Bukit Ta'ak in Trengganu. The bases of these hills are more than 250 feet above the height of the only known earlier sea level. Secondly, marine erosion does not explain why such features as caves, cliffs, grooves and platforms are not found on other rocks in the areas subjected to marine erosion in recent times. Thirdly, marine erosion does not explain why limestone shows the distinct contrast of flat benches adjacent to cliffs, instead of simple rounded hills or undulating ground, irrespective of the stage in the erosion cycle (Fig. 5).

In connection with the second of these objections, one advocate for marine erosion, pointing to a possible cliff remnant in granite at Kuala Dipang, has suggested that cliffs did occur on other rocks but they have since been obliterated by tropical weathering. This argument cuts both ways. Indeed it is more plausible when used in the opposite sense. If, as suggested, non-calcareous rocks react in a different way to sub-aerial weathering, but similarly to marine erosion, then sub-aerial weathering could very possibly be the process primarily responsible for the topography of the limestone hills.

Sub-aerial Erosion

Several geologists have suggested that sub-aerial erosion, later modified by marine erosion was the main agent in the formation of the limestone hills. If it can be shown that the action of sub-aerial erosion is not the same on limestone

at it is on other rocks, then this theory has the great merit, which it shares with no other, of accounting for *all* the Malayan limestone hills.

The great distinction is, of course, the high solubility of calcium carbonate compared to the majority of the silicates of which almost all other rocks are composed. In this respect limestone is unique. On silicate rocks, only at the final stage of the erosion cycle does chemical corrosion have an effect equal to mechanical erosion. The latter plays a minor role in the case of limestone. It follows that sub-aerial erosion on rocks of low solubility should have very different effects to those produced on limestone, with its high solubility and greater mechanical strength.

On the surface of silicate rocks there is always a mantle of weathered insoluble rock and soil, which retains intergranular water containing acids. Weathering thus takes place relatively evenly over all exposed surfaces, producing more or less rounded topography. A very different process occurs on limestone. The removal of calcium carbonate in solution from the relatively pure Malayan limestones leaves little alumina or silica to form a soil. Between solid rock and complete erosion there is no well marked stage of rock mantle or soil formation. Vegetation is consequently poor, corrosion by rain water charged with organic acids is slight, and most rain evaporates or runs off quickly. The little calcium carbonate taken into solution is often redeposited almost immediately in the form of tufa or stalactites, because evaporation over bare warm surfaces quickly removes the carbon dioxide in the water. Much of the normally dry and bare limestone surface appears to acquire a patina of residual insoluble material, which is further protection against the solvent action of rainwater.

In contrast, streams and swamps are highly effective in eroding limestone. This may be the result of the higher acidity of the water. The average pH of rainwater at Kuala Lumpur, measured over a period of several months in 1956/7, was found to be 6.6. Samples of stream water with pH higher than 6.6 have been recorded from swift-flowing streams above the coastal plains. But the pH of swamp and stream water in low-lying areas, where most of the limestone occurs, is commonly as low as 3.5. Water continuously available in such streams and swamps must be highly corrosive and erosive, especially when compared with the sporadic action of percolating rainwater.

Because the difference between the erosive power of streams and that of rainwater is so great, downward corrosion is rapid in, and more or less confined to, the stream channels in the early stages of an erosion cycle on limestone. Until base level is reached, lateral erosion is negligible, in contrast to the process on silicate rocks. In underground channels, formed by erosion along joints, the floors are constantly corroded while the walls and roofs are actively built up by stalactites and carbonate deposits. In the latter stages of the cycle the limestone gorges expand laterally with the collapse of overhangs, producing steep-sided and isolated hills.

In this view, erosion in limestone is concentrated in the zones in which water is abundant and continuously available, either from swamps, streams or the sea. In other zones the processes of erosion are essentially static, since erosion above the saturated zone only occurs with the collapse of undercut rock masses. It follows that since two very different rates of erosion are present in limestone, and since the highest rate occurs at the lowest levels, limestone topography must tend to the extreme relief typified by vertical cliffs rising from relatively flat benches (Fig. 5). The mechanical strength of limestone also supports overhanging cliffs which, on other rocks, would collapse.

Seen in this light, the form of the limestone hills in Malaya is not exceptional, and represents the result of the normal cycle of stream erosion on limestone country rock. Of course any erosion process in which solution is a dominant element will produce similar topography, so that marine erosion may well have modified or produced some of the hills in the Kinta Valley, Kedah and Perlis, and it would be difficult to distinguish between a marine platform with shales and mature sub-aerial platforms with hums.

The explanation of the limestone topography is thus not to be linked specifically to a type of erosion, but rather to the lithology of the rock; when the limestone is not pure, the resulting landforms should approach the roundness characteristic of the topography of non-calcareous rocks.

An effective demonstration of this is provided in Perlis, where two types of limestone occur: an argillaceous dark rock of Ordovician/Silurian age, and a younger, relatively pure and light-coloured rock of Permian age. The first produces a residual soil and is wooded, while the Permian lacks a soil cover and supports a thin and scrubby vegetation. The older limestone forms relatively rounded hills with weakly developed cliffs; the younger and purer limestone forms high and isolated hills with vertical or overhanging cliffs.

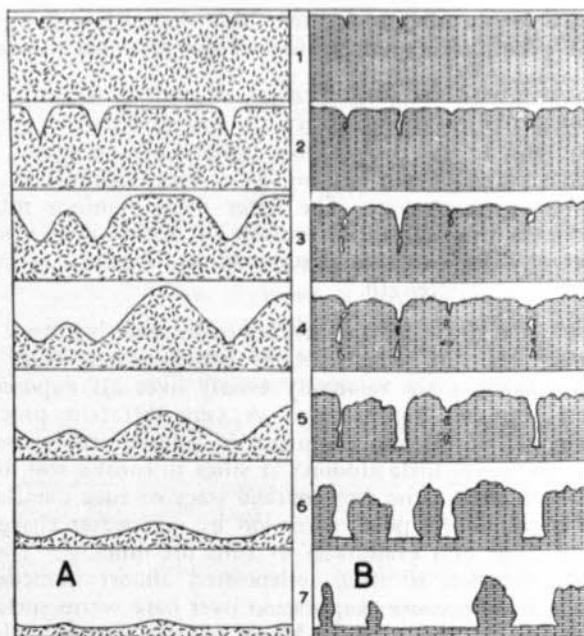


Fig. 5. Seven diagrammatic stages in the cycle of erosion on (A) silicate rocks, (B) limestone.

ACKNOWLEDGEMENTS

The author wishes to acknowledge his appreciation of the comments and constructive criticism made by his colleagues in the Department of Geological Survey.

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THE LITHOLOGY OF THE LIMESTONE HILLS OF MALAYA IS CHARACTERIZED BY THE PRESENCE OF A HIGH PERCENTAGE OF CARBONATE MATERIALS. THE MINERAL COMPOSITION OF THESE ROCKS IS OF THE TYPE DESCRIBED BELOW AND IT IS POSSIBLE TO PRESUME A COMMON ORIGIN FOR ALL THESE FORMATIONS.

The study was carried out on the eastern coast of Malaya, extending from the north to the south, and covering the area of the limestone hills. The results of the study are given in the following table.

1. Limestone series, derived from the limestone hills.
2. Sandstone series, derived from the limestone hills.
3. Shale series, derived from the limestone hills.
4. Gneiss series, derived from the limestone hills.
5. Granite series, derived from the limestone hills.

The percentage of carbon and oil in the limestone hills is given in the following table.

Location	Carbon (%)	Oil (%)
Malacca	12.00	0.50
Port Swettenham	11.00	0.50
Port Klang	10.00	0.50
Port Dickson	9.00	0.50
Port of Spain	8.00	0.50
Port of Borneo	7.00	0.50
Port of Sumatra	6.00	0.50
Port of Java	5.00	0.50
Port of Celebes	4.00	0.50
Port of Moluccas	3.00	0.50
Port of East Indies	2.00	0.50
Port of West Indies	1.00	0.50
Port of South America	0.50	0.50
Port of Africa	0.20	0.50
Port of Europe	0.10	0.50
Port of Asia	0.05	0.50
Port of Australia	0.02	0.50
Port of New Zealand	0.01	0.50
Port of Antarctica	0.00	0.50

Further studies were carried out on the limestone hills of Malaya, and the results are given in the following table.

The limestone hills of Malaya are characterized by the presence of a high percentage of carbon and oil. The results of the study are given in the following table.

SOILS AND THE FERTILIZATION OF RUBBER AND OIL PALM

By E. A. ROSENQUIST

INTRODUCTION

THE PURPOSE of this paper is to demonstrate the effect of soils and fertilizers upon the mineral composition of rubber and oil palm leaves. Foliar analyses of the type described below make it possible to prescribe a fertilizer policy which will provide maximum yields.

The study was carried out on 36 estates, varying in size from 1,000 to 20,000 acres, scattered over the west coast of Malaya. Five soil series, based on Owen's original system of classification (1), were found to be dominant in these estates, namely:—

1. Malacca series, lateritic soils probably derived mainly from phyllites.
2. Batu Anam series, derived from Triassic shales.
3. Seremban series, derived from schist.
4. Serdang series, derived from sandstones and quartzites.
5. Rengam series, derived from granites.

The approximate acreage of rubber and oil palm planted on each series is shown in Table 1.

TABLE 1: ACREAGE OF RUBBER AND OIL PALM, BY SOIL SERIES.

SOIL SERIES	RUBBER	OIL PALM
	acres	acres
Malacca	54,000	2,000
Batu Anam	27,000	2,000
Seremban	19,000	—
Serdang	8,000	2,500
Rengam	32,000	18,000
Miscellaneous soils	14,000	10,000
	154,000	34,500

Rubber stands were divided into units of about 100 acres each, in such a manner that each unit comprised a single clone of one age located on one soil series (Table 2). Shade leaves from mature rubber trees were collected between June and September 1961, one sample taken from 15 trees growing along one diagonal of each unit area, and another sample from 15 trees on the opposite diagonal. Analyses of the leaves from these two samples were carried out separately and the mean values obtained were taken as representing that particular unit. In this way, analytical data from 574 unit areas of mature rubber were obtained. These are shown in Tables 2 and 3, which provide in turn, the number of unit areas, percentages of ash, N, P, K, Mg, Ca and Mn for six clones, one type of clonal seedling and a group of miscellaneous clones on the Malacca, Batu Anam, Seremban

TABLE 2: NUMBER OF RUBBER UNITS, BY CLONES AND SOIL SERIES.

Soil Series \ Clone	Clone									Total
	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscellaneous	Ch.E		
Malacca	11	70	32	13	17	10	38	21	212	
Batu Anam	6	35	16	8	10	9	13	16	113	
Seremban	6	30	20	9	9	8	22	11	115	
Rengam	10	38	20	5	8	4	20	29	134	
Serdang	2	20	10	1	2	3	12	13	63	
Total excluding Serdang	33	173	88	35	44	31	93	77	574	

TABLE 3: FOLIAR ANALYSIS.

PERCENTAGE ASH ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscellaneous	Ch.E	Mean
Malacca	6.52	5.99	5.45	5.30	5.23	4.89	5.41	6.20	5.62
Batu Anam	6.61	6.26	5.23	5.16	4.87	4.90	5.88	6.03	5.62
Seremban	6.15	5.93	5.29	5.24	4.90	4.82	5.21	5.62	5.40
Rengam	6.05	5.36	4.51	4.57	4.70	4.19	4.93	5.37	4.96
Mean	6.33	5.88	5.12	5.07	4.92	4.70	5.36	5.80	

General Mean: 5.40
 S. Error : 0.17
 C. of V. : 3.2

M.S.D. Clones 5% 0.25
 1% 0.34
 0.1% 0.45

M.S.D. Soils 5% 0.17
 1% 0.24
 0.1% 0.32

PERCENTAGE N ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscellaneous	Ch.E	Mean
Malacca	3.95	3.37	3.31	3.53	3.30	3.50	3.46	3.45	3.48
Batu Anam	3.81	3.38	3.41	3.49	3.33	3.42	3.34	3.43	3.45
Seremban	4.01	3.49	3.36	3.58	3.32	3.61	3.53	3.59	3.56
Rengam	3.88	3.57	3.55	3.71	3.38	4.02	3.54	3.50	3.64
Mean	3.91	3.45	3.41	3.58	3.33	3.64	3.47	3.49	

General Mean: 3.53
 S.E. : 0.095
 C. of V. : 2.7

M.S.D. Clones 5% 0.14
 1% 0.19
 0.1% 0.26

M.S.D. Soils 5% 0.10
 1% 0.13
 0.1% 0.18

PERCENTAGE P ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscell- aneous	Ch.E	Mean
Malacca	.224	.256	.229	.283	.203	.229	.220	.246	.238
Batu Anom	.237	.257	.236	.271	.198	.214	.215	.247	.234
Seremban	.245	.254	.224	.271	.201	.216	.211	.238	.232
Rengam	.260	.262	.232	.294	.205	.240	.216	.230	.242
Mean	.246	.257	.230	.280	.202	.225	.215	.240	

General Mean: 0.237 M.S.D. Clones 5% 0.010 M.S.D. Soils 5% 0.007
 S.E. : 0.0068 1% 0.014 1% 0.010
 C. of V. : 2.9 0.1% 0.019 0.1% 0.013

PERCENTAGE K ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscell- aneous	Ch.E	Mean
Malacca	1.48	1.54	1.23	1.46	1.17	1.13	1.25	1.12	1.30
Batu Anom	1.42	1.45	1.20	1.44	1.14	1.18	1.25	1.13	1.28
Seremban	1.53	1.76	1.40	1.55	1.34	1.32	1.34	1.28	1.44
Rengam	1.19	1.38	1.00	1.22	1.20	1.05	1.09	1.10	1.15
Mean	1.40	1.53	1.21	1.42	1.21	1.17	1.23	1.16	

General Mean: 1.29 M.S.D. Clones 5% 0.09 M.S.D. Soils 5% 0.06
 S.E. : 0.059 1% 0.12 1% 0.08
 C. of V. : 4.6 0.1% 0.16 0.1% 0.11

PERCENTAGE Mg ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscell- aneous	Ch.E	Mean
Malacca	.414	.310	.276	.264	.320	.311	.322	.337	.320
Batu Anom	.393	.306	.262	.228	.308	.289	.334	.309	.304
Seremban	.302	.285	.234	.232	.277	.274	.285	.300	.274
Rengam	.338	.284	.258	.238	.282	.275	.298	.316	.286
Mean	.362	.296	.258	.240	.299	.287	.310	.315	

General Mean: 0.296 M.S.D. Clones 5% 0.023 M.S.D. Soils 5% 0.016
 S.E. : 0.015 1% 0.031 1% 0.022
 C. of V. : 5.1 0.1% 0.042 0.1% 0.029

PERCENTAGE Ca ON DRY MATTER.

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscell- aneous	Ch.E	Mean
Malacca	1.19	0.98	1.00	0.75	0.94	0.86	0.97	1.32	1.00
Batu Anam	1.22	1.13	0.91	0.69	0.84	0.78	1.10	1.27	0.99
Seremban	1.10	0.85	0.85	0.73	0.73	0.72	0.86	1.04	0.86
Rengam	1.24	0.88	0.79	0.66	0.76	0.64	0.90	1.07	0.87
Mean	1.19	0.96	0.89	0.71	0.82	0.75	0.96	1.18	

General Mean:	0.93	M.S.D. Clones	5%	0.10	M.S.D. Soils	5%	0.07
S.E.:	0.021		1%	0.13		1%	0.09
C. of V.:	2.2		0.1%	0.18		0.1%	0.13

Mn ppm. ON DRY MATTER

	G.1	PB.86	Tj.1	PB.25	RRI 501	Pil.B 84	Miscell- aneous	Ch.E	Mean
Malacca	167	166	139	130	132	155	159	192	155
Batu Anam	187	181	125	103	119	160	144	164	148
Seremban	136	104	80	106	102	129	98	96	106
Rengam	131	86	91	102	79	106	78	95	96
Mean	155	134	109	110	108	137	120	137	

General Mean:	126	M.S.D. Clones	5%	24	M.S.D. Soils	5%	17
S.E.:	16		1%	32		1%	23
C. of V.:	12.7		0.1%	44		0.1%	31

and Rengam soil series. Results of similar foliar analyses for the Serdang and miscellaneous soils are excluded because the number of samples for certain clones was too small to give accurate means.

The mean nutrient levels found in rubber tree leaves for the 32 clone-soil combinations are entered in Table 4 and are analysed statistically. These means are based on varying numbers of samples; those for the Serdang series are means from 63 samples, and are not directly comparable with other values. For the clone PB.86, grown on Malacca series soils, the mean is based on 70 samples, whereas that for Pil.B 84 grown on Rengam series soils is based on only four samples. For the statistical analysis, the same weight was assigned to each mean.

The results of this foliar analysis show that the Rengam soils differ markedly from the others; the percentages of foliar ash, K, Mg, Ca and Mn are lower, while those of N and P are higher. There are no marked differences between the Malacca and Batu Anam series, but the Seremban series is associated with higher leaf K and lower Mg, Ca and Mn. The data for the Serdang series are less reliable, but suggest that levels of foliar P, Mg and Mn are lower, and those of N and K substantially similar, to those found in the Malacca and Batu Anam series. These differences

are sufficiently great to modify the fertilizer requirements for the different soil series.

TABLE 4: MEAN NUTRIENT LEVELS IN LEAVES OF MATURE RUBBER GROWN ON DIFFERENT SOILS.

SOIL SERIES	AS PERCENTAGE ON DRY MATTER						Mn (ppm)	K+Mg+Ca
	ASH	N	P	K	Mg	Ca		
Malacca	5.62	3.48	0.238	1.30	0.320	1.00	155	2.62
Batu Anom	5.62	3.45	0.234	1.28	0.304	0.99	148	2.57
Seremban	5.40	3.56	0.232	1.44	0.274	0.86	106	2.57
Rengam	4.96	3.64	0.242	1.15	0.286	0.87	96	2.31
Serdang	5.52	3.42	0.228	1.31	0.288	0.97	104	2.57
Min. Significant Difference at 5%	0.17	0.10	0.007	0.06	0.016	0.07	17	0.08
Min. Significant Difference at 1%	0.24	0.13	0.010	0.08	0.022	0.09	23	0.10
Min. Significant Difference at 0.1%	0.32	0.18	0.013	0.11	0.029	0.13	31	0.14

FOLIAR ANALYSES OF OIL PALM

A foliar survey of oil palm was conducted in 1959 and the results are summarized in Table 5.

TABLE 5: MEAN NUTRIENT LEVELS IN FROND 17 LEAVES OF 5-YEAR OLD OIL PALMS.

SOIL SERIES	NUMBER OF SITES	AS PERCENTAGE ON DRY MATTER						AS PPM. ON DRY MATTER			
		ASH	N	P	K	Mg	Ca	Mn	Fe	Cu	Mo*
Malacca	16	8.25	2.36	0.160	1.00	0.24	0.70	300	70	4.2	0.76
Batu Anom	32	9.37	2.34	0.156	1.09	0.26	0.59	287	74	4.1	0.55
Serdang	15	8.23	2.24	0.158	0.92	0.25	0.75	221	71	3.6	0.50
Rengam	80	6.22	2.49	0.166	1.11	0.26	0.72	136	89	4.6	0.42

* The analytical technique used for molybdenum determination has been found to be unreliable and the values are probably too high.

Statistical analysis of the data shown above has not been attempted, but the results support those derived from rubber foliar analysis insofar as the percentages of ash, N, P and Mn are concerned. Oil palms grown on Rengam series soils do not show low K, Mg, and Ca levels in Frond 17 because, as is shown later, fertilizer amendments for several years prior to this survey had been directed towards correcting known deficiencies in these elements. The oil palm data also

TABLE 6.

SOIL SERIES	EXPECTED RESPONSE TO			
	N	P	K	Mg
Malacca	Good	Good	Nil	Nil
Batu Anom	Good	Good	Nil	Nil
Seremban	Fair	Good	Nil	Good
Rengam	Fair	Fair	Good	Good

suggest that levels of Fe, Cu and Mo may vary with the soil series; further work on these, as well as on boron and zinc is in progress. It is suspected that soils derived from finer-grained granites are low in various trace elements.

These two foliar surveys suggest that oil palm and rubber grown in the various soils may be expected to respond to fertilizer amendments as indicated in Table 6.

MICRO-PLOT ANALYSES OF RUBBER

A series of 3⁴ factorial trials on rubber were conducted in 1960/1. Differential treatments were applied to young rubber seedlings, which were pulled up and weighed when about 10 months old; in addition, leaf samples from whorl 2 were

TABLE 7: MICRO-PLOT EXPERIMENTS.

Data relating to 9 month old rubber. Whorl 2 leaf samples

SOIL	MALACCA			BATU ANAM		
	Dia.	Wt.	% N	Dia.	Wt.	% N
Treatment						
N0	17.1	675	3.27	18.8	827	3.44
N1	18.4	786	3.65	20.2	1078	3.67
N2	18.8	844	3.83	19.5	997	3.79
Effect	+ 1.7***	+ 169***	+ 0.56***	+ 0.7	+ 107*	+ 0.35***
MSD 5%	0.8	60	0.13	0.8	85	0.08
% Effect	110	125	117	104	121	110
Treatment			% P			% P
P0	15.4	528	0.146	17.1	725	0.183
P1	19.5	895	0.185	20.1	1028	0.205
P2	19.4	882	0.188	21.3	1151	0.210
Effect	+ 4.0***	+ 354***	+ 0.042***	+ 4.2***	+ 426***	+ 0.027***
MSD 5%	0.8	60	0.005	0.8	85	0.007
% Effect	126	167	129	125	159	115
Treatment			% K			% K
K0	18.6	793	0.923	19.2	956	0.775
K1	18.3	784	1.020	19.8	1000	0.985
K2	17.4	729	1.150	19.5	947	1.232
Effect	- 1.2**	- 64	+ 0.182***	+ 0.3	- 9	+ 0.477***
MSD 5%	0.8	60	0.042	0.8	85	0.018
% Effect	94	92	120	102	99	163
Treatment			% Mg			% Mg
Mg0	17.9	755	0.215	18.9	887	0.171
Mg1	18.0	764	0.231	20.0	1025	0.238
Mg2	18.4	787	0.242	19.6	991	0.265
Effect	+ 0.5	+ 32	+ 0.027***	+ 0.7	+ 104*	+ 0.094***
MSD 5%	0.8	60	0.010	0.8	85	0.011
% Effect	103	104	113	104	112	155

Notes: Dia = Diameter in mm. at 2 inches from collar.

Wt. = Total plant weight in grams at about 10 months.

Leaf Analysis = Leaf samples collected from Whorl 2 at about 9 months, and data expressed as percentage on dry matter.

*: Significant at 5 per cent level.

**: Significant at 1 per cent level.

***: Significant at 0.1 per cent level.

TABLE 7 (Cont.): MICRO-PLOT EXPERIMENTS.

Data relating to 9 month old rubber. Whorl 2 leaf samples

SOIL	SEREMBAN			RENGAM		
	Dia.	Wt.	% N	Dia.	Wt.	% N
Treatment						
N0	24.1	—	3.73	23.5	1144	3.52
N1	25.1	—	3.76	24.6	1350	3.81
N2	24.8	—	3.95	23.9	1489	4.11
Effect	+ 0.7*	—	+ 0.22***	+ 0.4	+ 345***	+ 0.59***
MSD 5%	0.6	—	0.09	1.1	84	0.09
% Effect	103	—	106	102	130	117
Treatment						
	Dia.	Wt.	% P	Dia.	Wt.	% P
P0	23.8	—	0.201	22.1	1160	0.182
P1	24.7	—	0.208	24.6	1417	0.213
P2	25.5	—	0.214	25.2	1405	0.217
Effect	+ 1.7***	—	+ 0.013***	+ 3.1***	+ 245***	+ 0.035***
MSD 5%	0.6	—	0.004	1.1	84	0.006
% Effect	107	—	106	114	121	119
Treatment						
	Dia.	Wt.	% K	Dia.	Wt.	% K
K0	24.2	—	0.873	23.4	1177	0.669
K1	25.2	—	0.985	24.3	1414	0.964
K2	24.6	—	1.029	24.2	1392	1.110
Effect	+ 0.4	—	+ 0.156***	+ 0.8	+ 215***	+ 0.411***
MSD 5%	0.6	—	0.033	1.1	84	0.036
% Effect	102	—	118	103	118	159
Treatment						
	Dia.	Wt.	% Mg	Dia.	Wt.	% Mg
Mg0	24.6	—	0.195	24.2	1279	0.180
Mg1	24.7	—	0.207	23.6	1332	0.232
Mg2	24.8	—	0.220	24.0	1371	0.245
Effect	+ 0.2	—	+ 0.025***	- 0.2	+ 92*	+ 0.065***
MSD 5%	0.6	—	0.012	1.1	84	0.008
% Effect	101	—	113	99	107	136

Notes: Dia. = Diameter in mm. at 2 inches from collar.

Wt. = Total plant weight in grams at about 10 months.

Leaf Analysis = Leaf samples collected from Whorl 2 at about 9 months, and data expressed as percentage on dry matter.

*: Significant at 5 per cent level.

**: Significant at 1 per cent level.

***: Significant at 0.1 per cent level.

analysed. This type of leaf has quite a different composition from that of shade leaves from mature rubber, so the analytical data are not directly comparable. The results are shown in Table 7, which contains data from four micro-plots in relation to four soil series.

As expected, the Malacca series soils responded to N and P but not to K or Mg treatments, while the Batu Anam soils also responded to N and P but not to K. In the latter, an unexpected response to Mg was obtained, but this is due to an unusually low level of Mg in the control plots. As expected, the Seremban soils showed limited responses to N, good response to P, but none to K; the expected response to Mg was not obtained, due to unusually high levels of leaf Mg. Plant weight data were not available for these soils. The Rengam soils gave unexpectedly

large responses to N and P, but the positive responses to K and Mg accord with prior expectations. These results, with the data in Table 3, suggest that the soil series do respond generally to fertilizer amendments, but they are not sufficiently uniform to obtain consistent results.

FERTILIZER EXPERIMENTS ON OIL PALM

Data from directly comparable experiments on the same four soil series are not available for oil palm. In Table 8, however, yield data from two experiments on Rengam and Pamol (an upland series derived from sedimentary rocks) soils are analysed.

TABLE 8: YIELD (in lbs., fresh fruit bunch) PER OIL PALM, 3 YEAR TOTAL.

TREATMENT	RENGAM SERIES		PAMOL SERIES	
	EFFECT	EFFECT AS PERCENTAGE OF MEAN	EFFECT	EFFECT AS PERCENTAGE OF MEAN
N	+ 42*	+ 7.7	+ 42**	+ 11.6
P	+ 28	+ 5.1	+ 80***	+ 22.2
K	+ 182***	+ 33.3	+ 7	+ 1.9
Minimum Significant Difference at 5%	34		29	
Minimum Significant Difference at 1%	45		37	

The Rengam soil has shown very large response to K and a small response to N, whereas the Pamol series responded to N and P, but not to K. It is concluded that for oil palm nutrition, the various soil series have different fertilizer requirements, the Rengam in particular responding to potash.

PERIODIC FOLIAR SURVEYS

The potash needs of oil palm grown on Rengam soils were established soon after the war, and heavy applications of potash were repeatedly given. By 1954, this led to an induced magnesium deficiency which reached serious proportions before it was detected. Corrective applications of Mg were then applied and subsequent foliar surveys gave the following mean levels of Mg for oil palm in the estate involved:

TABLE 9: PERCENTAGE Mg IN LEAVES OF OIL PALM (DRY MATTER)

1953	1955	1956	1957	1958
0.170	0.204	0.220	0.248	0.242

By 1958 leaf Mg had been brought up to the normal level of 0.24 per cent and it was possible to revert from large corrective dressings of magnesium fertilizers to smaller maintenance dressings. In a similar manner, extreme phosphate deficiency developed by 1954 in oil palms grown on Batu Anam soils; corrective dressings of phosphate with added nitrogen raised leaf P from 0.138 to 0.189 per cent by 1958, as compared to a normal value of 0.16 per cent in Frond 17. These two examples have been quoted because it is sometimes held that when a field experiment has indicated a highly significant response to a particular fertilizer element, the level

of dressing indicated as necessary by the experiment should be applied at regular intervals. This is not necessarily true, and in general heavy initial corrective dressings can be replaced by lower maintenance dressings after some time. These examples also indicate the value of carrying out periodic foliar analyses of plantation crops, so that future applications of fertilizers can be made at reduced maintenance levels.

ACKNOWLEDGEMENTS

This paper is published by kind permission of Messrs. Guthrie Agency (Malaya) Ltd., and Chemara Plantation Ltd. The author is also indebted to the staff of the Chemara Research Stations at Seremban and Layang Layang, on whose work this paper is based.

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EMERGENCY RESETTLEMENT IN MALAYA

By KERNIAL SINGH SANDHU

A STATE of emergency, popularly referred to as 'The Emergency', was proclaimed in Malaya on 16 June 1948, following the outbreak of an armed Communist revolt. The revolt aimed at the overthrow of the British system of government in the country and the establishment of a 'People's Democratic Republic'. Almost every aspect of life in Malaya was substantially changed by the Emergency which ended on 31 July 1960 with the defeat of the Communists. One of its most far-reaching effects resulted from the resettlement of a million rural dwellers in more than 600 'new' settlements. The movement has remoulded the population pattern of Malaya. In the following pages an attempt is made to assemble the information relating to the Emergency resettlement and to analyse some of its characteristics and consequences.

THE NEED FOR RESETTLEMENT

In pre-Emergency Malaya all unalienated land was vested in the Malay Rulers and land titles in each State were granted only on the authority of the Ruler in Council. Furthermore, much of the land could be alienated to Malays alone, and could not subsequently be transferred to members of other communities. These restrictions made land acquisition extremely difficult for the other communities, particularly the Chinese immigrants. The result was the development of 'squatting' (1), i.e. the illegal occupation of vacant land. There have been Chinese squatters in Malaya since the arrival of the first Chinese settlers (2). They were few in number, however, until the outbreak of the First World War dislocated trade, halted development on newly opened rubber estates and deprived many workers of employment (3). Many of the unemployed were repatriated by the Malayan Government; others turned to the land — land which they were unable or unwilling to occupy legally.

The position of the squatters was neither stable nor secure, since they lived outside the pale of the law. The Government knew of their existence and recognized the evils of their form of land occupation. The so-called squatter problem was allowed to grow, mainly as the result of administrative 'tidapathy' (from the Malay *tidak apa*, meaning 'never mind'). The Government saw no urgency in the need to deal with the squatters, who were virtually out of sight and who provided a useful source of foodstuffs and labour (4a).

It is not known how many people became squatters during the economic recession induced by the First World War. It is possible that with the temporary improvement in the economic situation between 1918 and 1920 many reverted to their former occupations or found other jobs. If this took place, the drift back to former occupations was short-lived. In the Great Slump of 1930-32 the price of rubber fell sharply, and the price of tin remained at a low level, with the result that unemployment became widespread and a large number of Chinese either left Malaya or moved into the countryside as squatters (5, 6a, 7). Once trade revived again, the number of squatters decreased. The Japanese Occupation in the early nineteen-forties drastically changed this pattern of movement to and from the rural areas. It is estimated that in 1940 there were about 150,000 Chinese squatters in the country; in 1945 there were 400,000 (8a).

The main causes of the sharp increase in squatters appear to have been as follows: (i) natural increase; (ii) illegal immigration during and after the Japanese Occupation; (iii) movement of labourers away from moribund mines and estates; (iv) migration of urban dwellers to the countryside (4a).

Throughout the inter-War period the official immigration policy of the Malayan Government was to improve the sex-ratio among the Chinese, in order to stabilize the population. Accordingly, until 1938, there was no restriction on the immigration of Chinese women. There was a migrational gain of 190,000 Chinese women during the 1934-38 period (6b). The majority of the women were peasant workers who entered the rubber, tin, market-gardening, and building industries. Most of them married, many to squatters, and settled down in Malaya. As a result the Chinese population, including squatters, increased rapidly.

Illegal immigration into Malaya was not a serious problem before 1941, though it was known that some people were entering the country illegally, mostly from China. During the Japanese Occupation and the interim period between the Japanese surrender and the arrival of the British, illegal immigration increased sharply. The Japanese control of immigration was inefficient, and what little control there had been during the Occupation disappeared after their surrender.

At the time of the Japanese attack on Malaya both the rubber and tin industries were working to capacity. By 1943 the Japanese had too few ships to export rubber, and their efforts to distil it into motor fuel were a failure. Rubber became almost unsaleable. The tin dredges were either sunk or out of action for want of spare parts. Many workers became unemployed. At the same time, the price of goods soared. Former sources of food, such as Indonesia, China, Thailand and Australia, were cut off. The unemployed realised that their only hope of survival lay in subsistence cultivation of foodstuffs. Some of them gravitated towards the rice-producing areas, others cultivated food crops on land that had been made available by the Japanese destruction of rubber plantations.

Conditions in the urban centres were even less tolerable. The inefficient Japanese rationing system led to high prices and black markets. Worse still, many families lost their breadwinners when the Japanese conscripted labour for their construction projects. In addition to these economic conditions, there was a political persecution of the Chinese. Large numbers of Chinese, particularly those between the ages of 20 and 35, were killed by the Japanese (9). Many villages were destroyed and thousands of Chinese were moved from one area to another.

The total effect of these adverse conditions was a general exodus from the towns as people tried to avoid both starvation and the Japanese. The Japanese did not object to this exodus, since it relieved pressure on the rationing system. In fact, they encouraged movement into the countryside to grow more food (10, 11), themselves initiating the establishment of three agricultural settlement schemes: Shyonan Bahru at Endau (Johore) for Chinese, Fuji-Go at Bahau (Negri Sembilan) for Eurasians and Catholics, and Bintang Island for Malays and Indians (12).

After the Japanese surrender, as conditions improved, many people returned to their original homes and occupations. But others, having found vegetable cultivation and pig-rearing profitable, remained where they were. They supplied foodstuffs to the urban black markets which continued to flourish during the period of the British Military Administration (13). Estates and tin mines, engaged in the process of rehabilitation, drew on the services of the squatters, many of whom became part-time rubber tappers or tin miners as well as cultivators. Thus

in 1948 there were still more than 300,000 squatters (14a) as a result of this partial 'stabilization': more than twice as many as prewar.

The squatters were engaged in a variety of occupations, ranging from tobacco cultivation in the upper valleys to fishing on the coast (15). Each family was usually employed in a number of activities, including the cultivation of food-stuffs and cash crops, the rearing of livestock and working for wages. But as the machinery of trade was restored in the postwar period, the squatters changed from subsistence to commercial farming. In certain areas, as in Johore, squatters became the chief source of such things as vegetables, eggs and pork, not only for the neighbourhood, but for export as well (16a). In some States, for instance Perak, a squatter could earn as much as M\$1,000 per year on a three-acre farm (17). But the significance of the squatters in postwar Malaya lay not so much in their numbers and growing prosperity as in their potential as a political force and security risk.

Of the few political organizations in pre-war Malaya the Malayan Communist Party (M.C.P.) was the most important. It was proscribed by the British and generally operated underground until the Japanese invasion in 1941. After the British defeat in the Malayan campaign, the M.C.P. became the spearhead of resistance to the Japanese. With the connivance of the British, the M.C.P. retreated into the jungle to organize an anti-Japanese movement, and slowly built up a powerful fighting force, known as the Malayan People's Anti-Japanese Army (M.P.A.J.A.)

An important contributory factor in the growth of the M.P.A.J.A. was the political and organizational activity of the Communists among the people, especially the Chinese squatters. A large popular mass base for the resistance movement was built up, from which the M.P.A.J.A. could draw food, supplies, intelligence and recruits. In this way the M.P.A.J.A. achieved a fourfold increase in numbers, backed by a sympathetic mass base which by the end of 1944 numbered hundreds of thousands (18a).

The impact of the M.C.P. on the squatters was considerable. The M.P.A.J.A. and its achievements fired the imagination of the rural Chinese and gave them a sense of solidarity. The extent to which they identified themselves with the resistance movement and the M.P.A.J.A. was demonstrated at the time of the Japanese surrender. In most inland areas the 'final victory over Japan was not celebrated to extol the efforts of the Allies. Triumphant arches and inscriptions honoured instead the forces of the Malayan People's Anti-Japanese Army' (18b).

As far as the British were concerned, in the postwar years the squatter ceased to be simply an administrative irritation. He became a dangerous political problem. The import of this was not realized, however, until the outbreak of armed revolt.

The avowed objective of the Malayan Communist Party was the establishment of an independent 'People's Democratic Republic' in Malaya. The *sine qua non* for this was the destruction of British control (19). Opinion on the specific strategic plan to be adopted was divided. Two plans were considered, one advocating an immediate armed struggle, the other a policy of labour organization and agitation. The latter was finally adopted (18b). The M.P.A.J.A. was demobilized (20), labour organization and agitation were intensified. The effects of agitation were gradually vitiated by increasingly repressive legislation, with the result that the M.C.P. decided in 1948 to resort to arms. Contact was re-established with former supporters among the rural population, and the M.P.A.J.A., renamed the Malayan Races Liberation Army (M.R.L.A.), was recalled to the jungle, whence

the M.C.P. expected to launch its attack on the British. Thus the focus of Communist activity shifted from the urban centres back to the squatter areas again.

The tactics of the M.C.P. were 'to strike at the vitally important tin and rubber industries, bring production to a standstill and thereby reduce the economic life of the country to chaos'. Attacks were made on estates and mines, directed primarily against the management, in the hope of disrupting the labour force in general (21).

Malaya in 1948 was the 'biggest single repository of British overseas investment' (8b). It was the source of almost all the dollar earnings of the sterling bloc. It was thus for Britain a vital area, now threatened by the Communist uprising (22a, 23). A State of Emergency was declared in June 1948, and a military campaign was mounted, bringing the Government face to face with the squatter problem (24).

The M.C.P. experienced little difficulty in re-establishing its power among the squatters. Those who showed reluctance to cooperate were threatened with violence (15). Willy-nilly, the squatters became once more the main resource of the M.P.A.J.A., with the difference that they were now assisting the M.P.A.J.A. against the British, instead of the Japanese. To the squatters this distinction was perhaps irrelevant, as the only Government they had known was the 'Government' of the M.P.A.J.A., which had 'defeated' the Japanese and was now about to liberate them from their subsequent oppressors.

Large numbers of the squatters were enrolled in the *Min Yuen* (Mass Organization), the fifth column of the M.C.P. (8c). Many were armed and acted as part-time volunteers: rubber tappers, market gardeners or miners by day, snipers by night. Scattered in the jungle and on the fringes of estates, the squatters provided ears, eyes, and a smokescreen for the Communists. Once among them the Communists were easily concealed from the security forces, much of whose efforts were thus nullified. This then was the 'squatter problem'. Its solution was imperative if the Communists were to be defeated.

RESETTLEMENT

Phase I: 'Blind Man's Buff'

The squatters were only one source of assistance to the Communists. The *Min Yuen* had roots deep in every layer of Chinese society (25). It was well known that almost all Chinese businessmen were paying protection money to the Communists. Subscriptions were collected from rubber tappers and miners, who also provided useful aliases. The solution of the squatter problem would therefore only seal one source of sustenance for the Communists. But without proper analysis, the Government accorded to the squatters a role of greater importance in the Communist organization than they merited. Although the solution of the squatter problem became a crusade, the Government had no positive answer. It resorted to repressive legislation, the uprooting of thousands of squatters, the destruction of their crops and homes, their transfer hither and thither, and their confinement in detention camps prior to repatriation (14b, 26).

A total of nineteen operations, involving the transfer of some 40,000 squatters and their dependents, took place between 1949 and 1952, sixteen of them in 1949. Of these, 26,000 people (24,000 Chinese, 2,000 Indians and Indonesians) were deported (14c, 27, 28).

To accommodate these uprooted people prior to deportation or release, prisons were emptied, and former immigration depots, such as Pulau Jerejak (Penang)

and St. John's Island (Singapore), were hastily converted. These centres were soon filled to capacity; detention or concentration camps were constructed in Malacca, Johore and Perak. The Government soon realised, however, that detention and deportation were not the answer to the squatter problem. To carry this policy to its logical conclusion would have meant the removal of almost the entire squatter population, estimated at 300,000 persons in 1948. Resources were not available for such a task. Secondly, as the Chinese ports were closed, following the establishment of a Communist regime in China in 1949, the deportation of Chinese was hardly possible (29). Thirdly, no significant improvement in the security situation had followed the removal of squatters. The majority of the people transferred were women, children, and the aged (30a), the younger men slipping through the cordon. Finally, detention was distasteful, in that it constituted summary justice and group punishment (29). The transferred squatters experienced excessive hardship in the separation of families and the loss of crops and chattels, and their attitude to the Government was expressed at times in open resentment and hostility. A more constructive plan, based on an analysis of the facts of the squatter problem, was needed.

In 1948 a 'Squatter Committee', under the chairmanship of the Chief Secretary, Sir Alex Newbould, was set up to examine the facts of the squatter problem and to make recommendations for its solution. The Committee's report was completed in January 1950. Its principal recommendations were: (i) wherever possible squatters should be settled in areas already occupied by them; (ii) where this was not possible, they should be resettled in a suitable alternative area; (iii) any squatter refusing settlement or resettlement should be deported; (iv) emergency measures to deal with the security problem of certain areas should be supported by administrative measures designed to re-establish permanently the authority of Government; and (v) legal measures should be introduced to provide for the eviction of squatters by summary process (4b, 14d).

These recommendations were accepted by the Federal Government but their implementation was left to the State Governments, since land was a State responsibility. The Federal Government undertook to provide administration, security and health services in areas where the squatters were to be settled. Other costs were to be borne by the State Governments, which were advised to approach individuals and associations connected with welfare work, especially as regards the Chinese, for financial assistance (14e).

Since resettlement was undertaken solely for security purposes, the Federal Government was clearly avoiding its responsibilities; inasmuch as the State Governments lacked the means to finance resettlement, the Federal Government's attitude was unrealistic. However, the Federal Government remained unmoved by protests from the States, which were left with the major task of financing resettlement. Some States had neither the money, the administrative machinery nor the trained men to begin, let alone carry through successfully, the work of resettlement (31, 32).

Meanwhile the Chinese community, to protect its interests, formed the Malayan Chinese Association (M.C.A.) in February 1949. The cause of the squatters soon became the cause of the M.C.A., which offered financial aid for their resettlement as soon as action was taken on the recommendations of the Squatter Committee (33, 34).

The Johore branch of the M.C.A. was the first to provide squatter relief. It approached the Johore Government for land to build its own resettlement camp for detained squatters in that State. The idea was favourably received by the

State Government, which suggested that the venture should be a joint Government/M.C.A. undertaking, with the Government providing the land and administrative machinery, the M.C.A. the funds. The scheme was to be located at Mawai in Kota Tinggi District, and was to cost M\$422,000, with a capacity for 2,000 families each with three acres of agricultural land. This, the first organized resettlement scheme in Malaya, received its first batch of settlers on 27 October 1949 (35, 26, 30b).

Johore's lead was followed by the other States, and twenty squatter settlement (i.e. official alienation to squatters of their illegally occupied land) and resettlement schemes were planned or begun between 1949 and 1950. Implementation by State Governments was slow, however. Furthermore, with the exception of Johore, the M.C.A. had difficulty in raising funds, so that most of the schemes did not pass beyond the planning stage, or at most the teething stage. Ten of these schemes were abandoned; the remainder were later expanded into 'New Villages' under the Briggs Plan (14f). In Johore, too, the Mawai scheme had to be abandoned in 1952, mainly because of poor security (Fig. 1). The year following the adoption of the Squatter Committee's recommendations saw no substantial progress with regard to resettlement (36a). The situation required not only a comprehensive scheme for the whole of the country and funds to finance this, but also a man able to galvanize the Administration into extraordinary action. In May 1950 General Sir Harold Briggs was appointed the first Director of Operations, with sole responsibility for the prosecution of the Emergency and the coordination of the civil administration and the security forces.

Phase II: The Briggs Plan

General Briggs confirmed that there was no quick way of ending the Emergency. It was necessary to break Communist morale and to remove or disrupt Communist sources of supply. This could only be done by accelerating the pace at which squatters and other rural dwellers were brought within administrative control. General Briggs made resettlement the basis of his strategy. In his first directive in May 1950, he called on the people of Malaya to identify themselves with the Government in its battle with the Communists, ordered the redeployment



Fig. 1. Squatter resettlement centres established between 1948 and 1950.

of the police and army, and set in motion an all-out drive for resettlement. The 'Briggs Plan' envisaged a military 'cordon sanitaire' in the jungle fringes, protecting populated areas and communications from the M.R.L.A. and cutting its links with Communist cells in the populated areas. The police were to dominate the settled areas, to dislocate and break up Communist cells therein, to provide security, and to obtain information from the population, which with greater security was now more responsive (37a).

The resettlement programme became the responsibility of the Federal Government. It had a positive aim for the first time and it attempted as far as possible to persuade rather than to force squatters to leave their jungle clearings. Briggs promised the State Governments what they required in the way of men, money, transport, barbed wire, etc., and demanded in return the successful completion of the resettlement programme. This was to begin in Johore and proceed northwards, and to be finished by 1952.

Resettlement of Malaya's rural population under the Briggs Plan involved two processes, *relocation* and *regroupment* (38).

Relocation means the transfer of dispersed rural settlers, whether legitimate or squatters, to prepared fortified sites, frequently some distance from their homes. This entailed the abandonment of holdings, crops, and houses, and consequently a change of occupation in many cases. However, the development of the resettled areas into New Villages was usually envisaged, and wherever possible and necessary new farm land was made available nearby. In addition every New Village — as the relocation centres were popularly termed — was expected to have such amenities as electricity, roads, a school, piped water, community hall, and so on. These were to be financed by funds from the Federal Government and the M.C.A.

Under the heading of relocation can also be included *close-settlement* or the concentration of squatters into an existing village. This was accomplished in two ways. Where squatters were living adjacent to a village, the perimeter fence was simply extended to enclose the squatter houses. Where squatters were some distance away, close-settlement entailed the removal of houses to the village. In this way the squatters retained the use of their holdings and were not forced to change

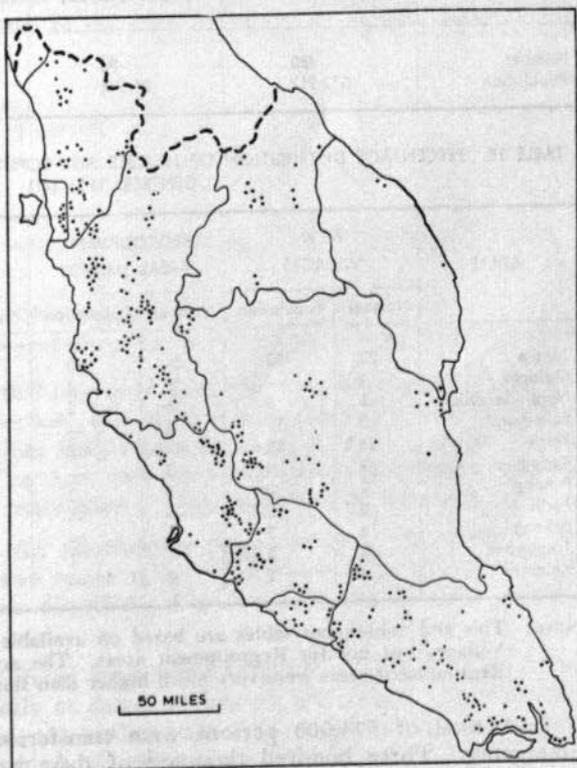


Fig. 2. Distribution of New Villages.

their place of work. Furthermore they were eligible for all the benefits enjoyed by people resettled in the normal way (39).

Regroupment entailed the transfer of dispersed mine and estate labourers, their families and their dwellings, to some fortified point of concentration on the property of the employer or close to it. Families had access to their usual places of work, at least during the hours of daylight. These centres did not qualify for Government or M.C.A. aid in the provision of amenities, nor were they laid out according to a prepared, Government-approved, site plan. Similar to the concentration of mining and estate labour was the regroupment of timber, sawmill, and factory workers, and isolated Malay and *Orang Asli* (aborigine) settlements.

RELOCATION

The work of relocation was carried out with remarkable rapidity; it began in June 1950 and was almost completed by the end of 1952. After this date only a few more New Villages were created, mainly in Kedah and the interior of the country. Altogether 480 New Villages were established during the Emergency (40). Eighty per cent were in western Malaya, nearly half of them in Perak and Johore (Fig. 2, Table 1) (41).

TABLE 1A: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES, 1954 (41)

	NEW VILLAGES	REGROUPMENT AREAS (MIXED)	MALAY REGROUPMENT AREAS	TOTAL
Number	480	94	50	624
Population	572,917	25,344	6,767	605,028

TABLE 1B: PERCENTAGE DISTRIBUTION OF NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES, 1954 (41)

STATE	NEW VILLAGES		REGROUPMENT AREAS (MIXED)		MALAY REGROUPMENT AREAS		TOTAL	
	Number	Population	Number	Population	Number	Population	Number	Population
Johore	20	23	54	80	26	64	25	27
Malacca	3	2	9	4	—	—	4	2
Negri Sembilan	8	5	6	3	4	6	7	5
Selangor	10	17	3	—	—	—	8	16
Perak	26.8	35.6	14	10	20	11	24.8	35
Kedah	9	4	8	—	—	—	8	4
Penang	2	2	3	2	—	—	2	1
Perlis	0.2	0.1	—	—	—	—	0.2	1
Pahang	16	9	1	—	—	—	13	6
Trengganu	1	0.3	1	1	—	—	1	1
Kelantan	4	2	1	—	50	19	7	2

Note: This and subsequent tables are based on available data, which are complete for New Villages but not for Regroupment areas. The actual number and population of the Regroupment areas were very much higher than shown here.

A total of 573,000 persons were transferred to New Villages during the Emergency. Three hundred thousand of these were squatters, the vast majority Chinese. The remaining 273,000 legitimate land occupiers were also largely

Chinese. Of the total population of the New Villages, 86 per cent were Chinese, 9 per cent Malay, 4 per cent Indian, and 1 per cent 'Others' (Table 2). The 'Others'

TABLE 2: RACIAL COMPOSITION OF THE POPULATION OF NEW VILLAGES, 1954 (41)

STATE	TOTAL POPULATION	PERCENTAGES			
		Chinese	Malay	Indian	Others
Johore	130,613	85.9	11	3	0.1
Malacca	9,555	91	7	1	1
Negri Sembilan	30,294	81	15	2	2
Selangor	97,346	93	4	2	1
Perak	206,900	89	4	5	2
Kedah	22,522	65	5	5	25
Penang	10,717	95.9	0.1	4	—
Perlis	682	89	9	2	—
Pahang	50,233	83	13	3	1
Trengganu	1,495	86	13.5	0.5	—
Kelantan	12,560	8	92	—	—
TOTAL	572,917	86	9	4	1

were almost all Siamese, Javanese and *Orang Asli*. Few villages were multi-racial; most of them were wholly Chinese, others were Siamese, Malay, Indian, or *Orang Asli*. Amongst the Chinese, almost all the dialect groups found in Malaya were represented, though the proportion varied from State to State. In Johore, for example, two-thirds of the Chinese in the New Villages were Hokkien and Hakka (Table 3).

TABLE 3: JOHORE: COMPOSITION OF THE CHINESE POPULATION OF THE NEW VILLAGES BY DIALECT, 1956 (42)

TOTAL CHINESE POPULATION	PERCENTAGE							
	Hakka	Cantonese	Hokkien	Teochiu	Kwongsai	Hainanese	Hokchiu	Others
112,200	32.1	9.1	34.8	6.6	3.6	8.8	4.6	0.4

The people who were resettled may be divided into four categories: (i) farmers engaged in food and pig production; (ii) persons engaged in tin mining, rubber growing or other crop production; (iii) wage-labour on tin mines, rubber estates, etc.; and (iv) shopkeepers. The first two were the dominant groups, forming about three-fifths of the total population. They were mainly squatters.

The distance involved in the resettlement process varied. Normally it was as short as possible, generally two to six miles. This enabled people to continue in their former occupations, thus disturbing their lives and the national economy as little as possible.

The transfer procedure differed from place to place. In some areas it was executed without warning, usually at dawn, to prevent the escape of able-bodied men. The area was surrounded, the settlers were told to gather their belongings and get into the transport provided. Compensation for immovable property was calculated on the spot, but paid later. The vacated dwellings and the crops were

then destroyed (8d), but such ruthlessness was exceptional. The general practice was to give prior warning (43). Thus, when the layout plans of the New Village had been completed, notices of removal were served; soon afterwards the move was effected, and the abandoned settlement destroyed.

The people were given a small 'upheaval allowance' and were helped, generally in the form of materials, to put up new dwellings. This aid was a repayable loan (44). Each family was allotted a plot of about one-sixth of an acre for its house and compound. Those who were unable to work their original plots were given about two acres of agricultural land within two miles of the New Village. The villagers were eligible for permanent title to this land.

All settlers were granted a subsistence allowance for two weeks; those who had lost the use of cultivated land elsewhere were given an allowance of about M\$12 per head per month for five to seven months. In the earlier phases of the relocation programme the New Villages were sited astride main roads in order to facilitate access by security forces in case of attack. The fences and guarded entrances obstructed traffic however, so that later New Villages were sited along one side of the road. Sites were chosen on flat land near a stream or river and away from dominating high ground. Theoretically, every site was chosen after an examination of the soil, water supply possibilities, accessibility and potential sources of employment. In practice these preliminaries were omitted; speed was essential and staff was in short supply (36b). Many New Villages were located on sandy *lalang* (*Imperata cylindrica*) colonies, *lopak* (intermittent freshwater swamp), tin tailings, and other inhospitable areas.

The case of Pulai illustrates the hardships endured by some. The Pulai Hakka Chinese had been settled in Ulu Kelantan for more than three centuries. They were mainly vegetable and padi growers. Pulai remained in M.R.L.A. hands until 7 August 1948, when it was captured after a combined British Army/Air Force operation. For their collaboration in this the Pulai Chinese were expelled from Kelantan and sent to detention camps in various parts of Malaya. About four hundred of them were transferred to Batu Rakit Village in Trengganu. The village was sited on uncultivable land, and had to be abandoned. The settlers were then resettled at Pulai Bahru (Gajah Mati) on 31 May 1953. Repeated attempts to grow vegetables, padi, sweet potatoes and tapioca also ended in failure, principally because of poor soils and recurrent flooding (45). Faced with starva-

TABLE 4: KNOWN ABANDONED RESETTLEMENT CENTRES, 1960 (41)

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	2	2,410	2	405	—	—	4	2,815
Kedah	2	1,030	—	—	—	—	2	1,030
Trengganu	1	358	—	—	—	—	1	358
Negeri Sembilan	1	286	—	—	1	380	2	666
Kelantan	—	—	4	1,450	21	3,685	25	5,135
Perak	—	—	2	1,400	—	—	2	1,400
Penang	—	—	2	1,227	—	—	2	1,227
Perlis	—	—	—	—	—	—	—	—
Pahang	—	—	—	—	—	—	—	—
Selangor	—	—	—	—	—	—	—	—
Malacca	—	—	—	—	—	—	—	—
Malaya	6	4,084	10	4,482	22	4,065	38	12,631

tion and without alternative employment, many of the settlers moved a third time, in 1956, to Batu Lima New Village. This was located in a better agricultural area recently vacated by Malay settlers who had been prompted by the improved security situation to return to their own kampongs.

The Pulau Chinese had the distinction of being resettled three times. Most New Villages, in spite of unfavourable sites, remained where they were. Besides Batu Rakit only five other New Villages are known to have been abandoned, generally for security reasons, between 1950 and 1960 (Table 4). The obstacle to re-siting was the cost. This varied with location and size. The average cost of establishing a New Village for 1,000 people was about M\$300,000 (46, 47).

The largest New Village in Malaya is Jinjang (Selangor) which in 1954 had a population of 13,000 on an area of 468 acres (48). The smallest is Labu Besar (Kedah) with a population of 44. The New Villages usually had populations

TABLE 5A: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH LESS THAN 100 PERSONS, 1954 (41).

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	—	—	1	86	—	—	1	86
Malacca	—	—	1	86	n	n	1	86
Negri Sembilan	—	—	n	n	—	—	n	n
Selangor	—	—	n	n	n	n	n	n
Perak	2	110	n	n	2	100	4	210
Kedah	3	179	n	n	n	n	3	179
Penang	—	—	1	n	—	—	1	—
Perlis	—	—	—	—	—	—	—	—
Pahang	7	480	n	n	n	n	7	480
Kelantan	—	—	n	n	1	n	1	n
Trengganu	—	—	—	—	—	—	—	—
Malaya	12	769	3	172	3	100	18	1,041

TABLE 5B: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH 100 TO 499 PERSONS, 1954 (41)

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	18	6,202	33	8,238	11	2,924	62	17,364
Malacca	11	3,920	4	960	n	n	15	4,880
Negri Sembilan	17	5,230	3	736	2	423	22	6,389
Selangor	15	5,164	n	n	n	n	15	5,164
Perak	36	10,641	6	1,620	4	665	46	12,926
Kedah	23	6,704	n	n	n	n	23	6,704
Penang	1	320	1	480	—	—	2	800
Perlis	—	—	—	—	—	—	—	—
Pahang	36	10,068	n	n	n	n	36	10,068
Kelantan	9	3,010	n	n	23	465	32	3,475
Trengganu	3	615	1	194	—	—	4	809
Malaya	169	51,874	48	12,228	40	4,477	257	68,579

n = Information not available

TABLE 5C: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH 500 TO 999 PERSONS, 1954 (41).

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	26	17,192	10	6,491	2	1,320	38	25,003
Malacca	3	1,885	n	n	n	n	3	1,885
Negri Sembilan	13	9,906	n	n	n	n	13	9,906
Selangor	10	7,210	n	n	n	n	10	7,210
Perak	23	16,030	1	938	n	n	24	16,968
Kedah	13	8,159	n	n	n	n	13	8,159
Penang	2	1,124	1	n	—	—	3	1,124
Perlis	1	682	—	—	—	—	1	682
Pahang	19	13,888	n	n	n	n	19	13,888
Kelantan	5	2,930	—	—	1	870	6	3,800
Trengganu	1	880	—	—	—	—	1	880
Malaya	116	79,886	12	7,429	3	2,190	131	89,505

TABLE 5D: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH 1,000 TO 4,999 PERSONS, 1954 (41).

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	48	94,292	4	5,515	—	—	52	99,807
Malacca	3	3,750	n	n	n	n	3	3,750
Negri Sembilan	9	15,158	n	n	n	n	9	15,158
Selangor	20	46,672	n	n	n	n	20	46,672
Perak	60	131,668	1	n	n	n	61	131,668
Kedah	5	7,480	n	n	n	n	5	7,480
Penang	5	9,273	—	—	—	—	5	9,273
Perlis	—	—	—	—	—	—	—	—
Pahang	15	25,797	n	n	n	n	15	25,797
Kelantan	4	6,620	n	n	—	—	4	6,620
Trengganu	—	—	—	—	—	—	—	—
Malaya	169	340,710	5	5,515	—	—	174	346,225

n = Information not available

of between one hundred and one thousand. Over half the villages were of this size; 169 had between one and five thousand inhabitants, 10 had between five and ten thousand and 2 had more than 10,000 inhabitants (Table 5).

The standard New Village possessed such amenities as a police post, dispensary, school, community hall, and a communal kitchen in villages under severe food restriction. A wire fence enclosed the public buildings, settlers' houses, pigsties, and domestic gardens (Fig. 3). The day-to-day administration of a New Village was under the direction of a resident Resettlement Officer, assisted by a committee elected from among the adult settlers. Under the Local Council Ordinance of 1952, the Village Committees in the larger villages were replaced by elected Local Councils.

The term New Village is to some extent a misnomer, for not all of the relocation centres were new. There were three types of New Village: those which

TABLE 5E: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH 5,000 TO 10,000 PERSONS, 1954 (41).

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	2	12,927	—	—	—	—	2	12,927
Malacca	—	—	n	n	n	n	n	n
Negri Sembilan	—	—	n	n	n	n	n	n
Selangor	3	25,300	n	n	n	n	3	25,300
Perak	5	35,178	n	n	n	n	5	35,178
Kedah	—	—	n	n	n	n	n	n
Penang	—	—	—	—	—	—	—	—
Perlis	—	—	—	—	—	—	—	—
Pahang	—	—	n	n	n	n	n	n
Kelantan	—	—	n	n	—	—	n	n
Trengganu	—	—	—	—	—	—	—	—
Malaya	10	73,405	n	n	—	—	10	73,405

TABLE 5F: NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES WITH 10,000 OR MORE PERSONS, 1954 (41).

STATE	NEW VILLAGES		REGROUPMENT AREAS		MALAY REGROUPMENT AREAS		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	—	—	—	—	—	—	—	—
Malacca	—	—	n	n	n	n	n	n
Negri Sembilan	—	—	n	n	n	n	n	n
Selangor	1	13,000	n	n	n	n	1	13,000
Perak	1	13,273	n	n	n	n	1	13,273
Kedah	—	—	n	n	n	n	n	n
Penang	—	—	—	—	—	—	—	—
Perlis	—	—	—	—	—	—	—	—
Pahang	—	—	n	n	n	n	n	n
Kelantan	—	—	n	n	—	—	n	n
Trengganu	—	—	—	—	—	—	—	—
Malaya	2	26,273	n	n	n	n	2	26,273

TABLE 5G: NUMBER OF RESETTLEMENT CENTRES OF UNKNOWN POPULATION, 1954 (41).

STATE	NEW VILLAGES	REGROUPMENT AREAS	MALAY REGROUPMENT AREAS	TOTAL
Johore	—	—	—	—
Malacca	—	4	—	4
Negri Sembilan	—	3	—	3
Selangor	—	3	—	3
Perak	2	6	4	12
Kedah	—	8	—	8
Penang	—	—	—	—
Perlis	—	—	—	—
Pahang	—	1	—	1
Kelantan	—	1	—	1
Trengganu	—	—	—	—
Malaya	2	26	4	32

n = Information not available

TABLE 5H: TOTAL NUMBER AND POPULATION OF EMERGENCY RESETTLEMENT CENTRES, 1954 (41).

STATE	NEW VILLAGES*		REGROUPMENT AREAS‡		MALAY REGROUPMENT AREAS‡		TOTAL	
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Johore	94	130,613	48	20,330	13	4,244	155	155,187
Malacca	17	9,555	9	1,046	n	n	26	10,601
Negri Sembilan	39	30,294	6	736	2	423	47	31,453
Selangor	49†	97,346	3	n	n	n	52	97,346
Perak	129†	206,900	14	2,558	10	765	153	210,223
Kedah	44	22,522	8	n	n	n	52	22,522
Penang	8	10,717	3	480	—	—	11	11,197
Perlis	1	682	—	—	—	—	1	682
Pahang	77†	50,233	1	n	n	n	78	50,233
Kelantan	18	12,560	1	n	25	1,335	44	13,895
Trengganu	4	1,495	1	194	—	—	5	1,689
Malaya	480	572,917	94	25,344	50	6,767	624	605,028

n = Information not available

Notes *Abandoned New Villages, Regroupment Areas and Malay Regroupment Areas are included in the numbers for these centres. Their population, however, is not included in the total as it was absorbed into other existing Emergency resettlement centres.

‡ With the exception of Johore, Penang, Perlis and Trengganu, data on the Regroupment Areas are incomplete. The same applies to the information on the Malay Regroupment Areas, with the exception of Kelantan.

† In the case of Selangor, Pahang and Perak, it is possible that some of the New Villages included are in fact Regroupment Areas. But no information is available to separate the different types.

TABLE 6: DEGREE OF 'NEWNESS' OF THE NEW VILLAGES, 1954 (41).

STATE	TOTAL NUMBER OF NEW VILLAGES	PERCENTAGE IN EACH CATEGORY			
		Type 'A'	Type 'B'	Type 'C'	Unclassified
Johore	94	23	28	12	37
Malacca	17	41	41	18	—
Negri Sembilan	39	62	13	15	10
Selangor	49	26	14	41	19
Perak	129	42	12	18	28
Kedah	44	11	—	—	89
Penang	8	89	11	—	—
Perlis	1	—	100	—	—
Pahang	77	29	34	24	13
Trengganu	4	75	25	—	—
Kelantan	18	9	75	—	16
Malaya	480	32	24	16	28

Notes

Type 'A' — Entirely new

Type 'B' — Built around small existing villages

Type 'C' — New Villages which are suburbs of or appendages to existing towns or large villages but which have a distinct identity of their own.

were entirely new; those which were built around and absorbed small existing villages; and those which were established as appendages to large villages or towns



Plates 1 & 2. Two New Villages established under the Briggs Plan. (By courtesy of the Department of Information, Federation of Malaya).

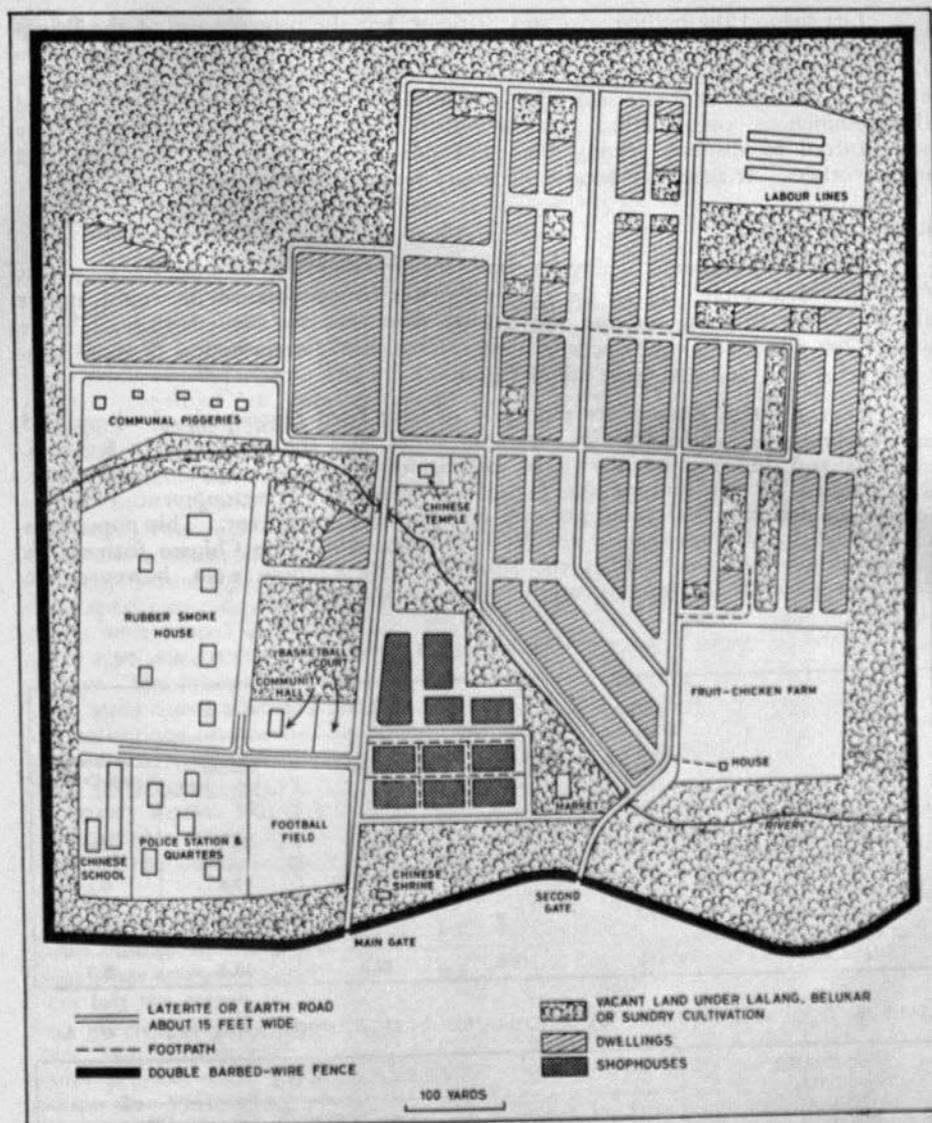


Fig. 3. Plan of a typical New Village.

while maintaining a distinct identity of their own. Nearly a third of the New Villages were of the first type, and a further quarter of the second type (Table 6).

The New Villages were similar in appearance. Many of them were little more than closely packed shanty-towns, with small houses or large *kongsis* (communal dwellings) made of wood, *atap* thatch, lalang or zinc, with bare laterite roads and unfinished drains, all fenced in with barbed wire (Plates 1 and 2).

Life behind the barbed wire was difficult, but the primary aim of the Briggs Plan was achieved. For the first time in the Emergency the initiative passed to the Government. There was a distinct improvement in civilian morale, and the efforts of the security forces met with encouraging success. Resettlement disrupted the Communists' organization and compelled a change in their strategy. They were forced to disperse among the rural population, especially the estate and mine workers. It therefore became necessary to resettle these people too.

REGROUPMENT

Labour Regroupment. Figures for the number of Labour Regroupment Areas are incomplete. From the data on places of employment it would appear almost certain that the number was greater than that for New Villages. There were 5,200 places of employment in 1948, of which 575 were estates of more than 1,000 acres each and 500 were mines (49a).

Some 650,000 persons are estimated to have been regrouped, of whom 71.5 per cent were on estates, 21.5 per cent on mines, and the remainder in factories, sawmills, and timber companies. The majority of the estate workers were Indians, who formed 50 per cent of the population affected by regroupment. Chinese formed 29 per cent, Malays 16 per cent and Javanese 5 per cent. This population structure differed from that of the New Villages, where the Chinese formed the largest group and the Indians the smallest. The Chinese were, however, the dominant group in the mining regroupment areas (Table 7).

TABLE 7A: RACIAL COMPOSITION OF THE REGROUPMENT AREAS, 1952 (41, 49b, 8e)

	ESTIMATED TOTAL POPULATION	PERCENTAGE			
		Chinese	Malays	Indians	Javanese and Others
Estate Regroupment Areas	510,000	29.0	16.0	50.0	5.0
Mining Regroupment Areas	80,000	68.7	17.6	13.6	0.1
Other Regroupment Areas	60,000	71.8	14.0	14.0	0.2
Total	650,000	45.0	32.0	18.0	5.0

TABLE 7B: OCCUPATIONAL GROUPINGS OF POPULATION IN REGROUPMENT AREAS, 1952 (41, 49b, 8e)

ESTIMATED TOTAL POPULATION	PERCENTAGE		
	Estate Workers	Mine Workers	Others
650,000	71.5	21.5	7.0

Estate labour regroupment was of two types: (a) internal; (b) external or extra-estate. In type (a), dispersed labour lines were transferred to a central fortified area within the estate. On the smaller estates all labour lines were concentrated at the factory. In the larger estates, two or more concentrations were not uncommon (Fig. 4). In regroupment of type (b), labourers from medium-sized and small Asian estates were regrouped on a larger estate, usually European-owned (Fig. 5). The number of medium-sized and small estates thus affected

is unknown, but it was large; in Johore alone, 450 such properties were affected, with their labourers transferred to 47 regroupment areas on large estates. Squatters on estates who had previously worked as casual labourers were also resettled in the regroupment area. Squatters from outside were rarely resettled on estates in this way. The cost of regroupment was borne by the estates concerned. With the exception of security supervision, the Government had little connection with these settlements.

There was a sharp contrast in appearance between the internal and external or extra-estate regroupments. The former consisted of neatly arranged labour lines and buildings. The additional accommodation was obtained either by transferring the buildings from the old sites, or by the construction of new buildings according to Government specifications. The settlements were fenced and guarded by special constables, mostly Malays. The external regroupment areas constituted amorphous collections of wooden and *atap* houses, some of which had been transferred, others were temporary shacks. The security arrangements were similar to those of the internal regroupments.

Since the end of the Emergency almost all those people from other estates and holdings have left the estates on which they were regrouped, partly of their own accord and partly under pressure from the host estate. In 1961 there were about 5,400 such people in 50 estate regroupment areas, most of them about to leave. As a result the former regroupment areas are now considerably reduced in population and improved in appearance.

On the mines the effects of regroupment were less noticeable. Most of the mine labour appears to have been relocated

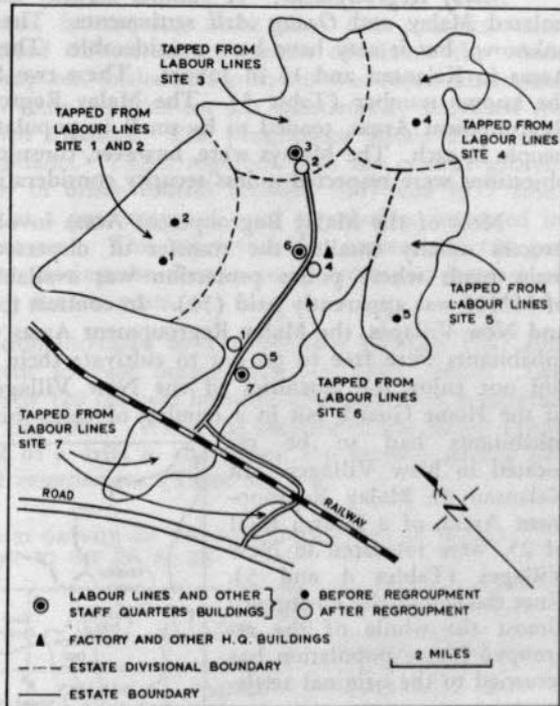


Fig. 4. Fraser Rubber Estate Regroupment Area, Johore: an example of estate internal regroupment.

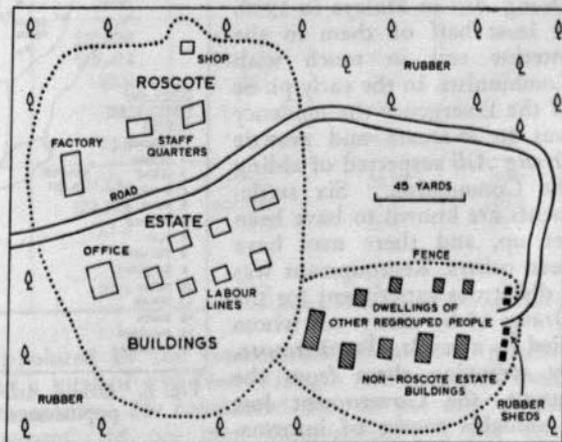


Fig. 5. Roscote Estate Regroupment Area, Johore: an example of estate external regroupment.

in the New Villages, particularly in the case of Chinese mines. Many European mines relocated their labour within the mine area. This often meant little more than fencing the living quarters and providing guards. The regroupment of timber, sawmill and factory workers was similar.

Malay Regroupment. A parallel security measure was the regroupment of isolated Malay and *Orang Asli* settlements. The number of Malays affected is unknown, but it may have been considerable. There were 25 Malay Regroupment Areas in Kelantan and 13 in Johore. These two States contained more than half the known number (Table 5). The Malay Regroupment Areas, like the Labour Regroupment Areas, tended to be small in population, with between 100 and 500 people in each. The Malays were, however, consulted before resettlement and their objections were respected unless security considerations directed otherwise.

Most of the Malay Regroupment Areas involved little or no planning. The process usually entailed the transfer of dispersed kampong dwellers nearer to main roads where police protection was available. An upheaval compensation of M\$100 was apparently paid (50). In contrast to the Labour Regroupment Areas and New Villages, the Malay Regroupment Areas were usually unfenced and their inhabitants were free to go out to cultivate their land. On the other hand they did not enjoy the amenities of the New Villages. Defence was in the hands of the Home Guard, but in a number of cases this proved inadequate so that the inhabitants had to be relocated in New Villages. In Kelantan 21 Malay Regroupment Areas, of a known total of 25, were relocated in New Villages (Tables 4 and 5). Since the end of the Emergency almost the whole of the regrouped Malay population has returned to the original settlements.

Orang Asli Regroupment. There were an estimated 60,000 *Orang Asli* in Malaya in 1950, at least half of them in the interior and in touch with Communists. In the early phase of the Emergency the tendency was to evacuate and resettle *Orang Asli* suspected of aiding the Communists. Six settlements are known to have been set up, and there may have been others. Regroupment was a disastrous experiment for the *Orang Asli*, many of whom died as a result. Furthermore, by removing them from the jungle, the Government lost a valuable source of information about Communist movements. It was therefore decided that regroupment should be avoided as far as possible. In its place a series of 'jungle forts' was

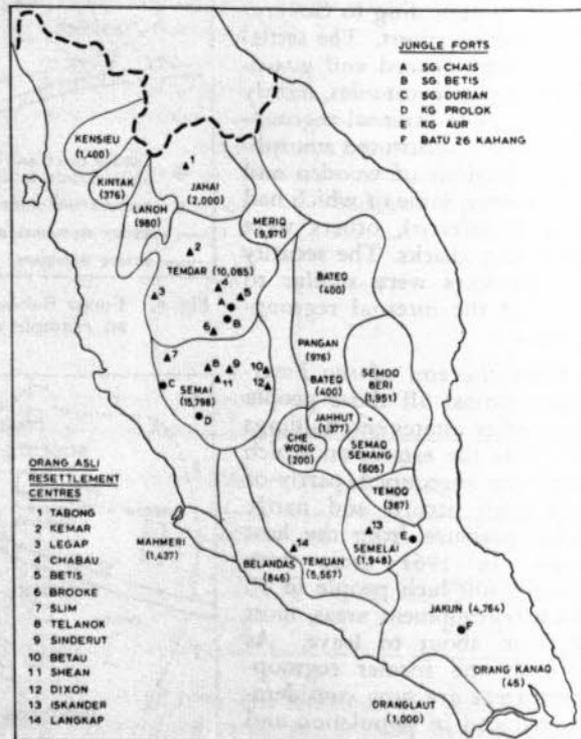


Fig. 6. *Orang Asli* resettlement: tribal territories and populations.

It was therefore decided that regroupment should be avoided as far as possible. In its place a series of 'jungle forts' was

built close to the main *Orang Asli* areas, where protection could be afforded them, trade stimulated, and other amenities provided. Altogether fourteen forts were established (37b, 51) (Fig. 6).

THE CONSEQUENCES OF RESETTLEMENT

The resettlement programme, by creating more than 600 compact 'new' settlements, has permanently altered the settlement pattern of almost the whole country. In Malaya, for census purposes, settlements with 1,000 or more inhabitants are classed as urban, and in this sense resettlement has substantially increased the already high proportion of urban dwellers. The programme added 216 urban centres of more than 1,000 inhabitants. These, together with the normal growth of population, raised the number of urban centres between 1947 and 1957 from 163 to 400. Urban population, as a percentage of total population, increased in this period from 26.5 to 42.5 per cent. This represented an increase of 105 per cent in the total urban population during the decade, compared to an increase of 55 per cent during the preceding sixteen years.

The Chinese urban population increased by 110 per cent between 1947 and 1957, compared to a 62 per cent increase during the 1931-1947 period. The Malay urban population increased by 120 per cent between 1947 and 1957, compared to only 7 per cent between 1931 and 1947. While the increase in the Malay urban population was chiefly the result of a drift to the towns, the increase among the Chinese was largely the result of resettlement (Table 8).

TABLE 8: RACIAL COMPOSITION AND GROWTH OF THE URBAN POPULATION OF MALAYA 1931 TO 1957 (6c, 52, 53)

		1931	1947	1957	PERCENTAGE INCREASE	
					1931-1947	1947-1957
CHINESE	Population	1,284,888	1,884,534	2,332,936	74.0	24.0
	Urban Population	501,600	811,520	1,704,000	62.0	110.0
	Percentage Urban	3.8	43.1	73.0	10.0	70.0
	Percentage of Total Urban Population of Malaya	59.6	62.4	63.9	5.0	3.0
MALAY	Population	570,987	530,638	695,985	-7.0	31.0
	Urban Population	127,040	179,434	286,000	41.0	60.0
	Percentage Urban	25.9	33.8	41.1	31.0	22.0
	Percentage of Total Urban Population of Malaya	17.8	13.8	10.7	-22.0	-22.0
INDIAN	Population	1,863,872	2,427,834	3,126,706	30.3	29.0
	Urban Population	158,750	274,618	604,000	7.0	120.0
	Percentage Urban	8.6	11.3	19.3	33.0	71.0
	Percentage of Total Urban Population of Malaya	19.2	21.1	22.6	11.0	7.0

In 1954, W.C.S. Corry, appointed by the Government to make a general survey of the New Villages, listed a total of 439 New Villages and classified them according to their degree of permanency. He considered that 69 per cent of the Villages were 'supposedly permanent', 18 per cent 'intermediate', 3 per cent 'unclassified' and 10 per cent 'supposedly impermanent and likely to disappear with the Emergency' (Table 9). But in 1962, 47 per cent of these supposedly

impermanent New Villages still existed, and the present indications are that all existing New Villages will remain.

TABLE 9: CLASSIFICATION OF THE NEW VILLAGES ACCORDING TO DEGREE OF PERMANENCY, 1954 (54a).

	TOTAL NUMBER OF NEW VILLAGES	PERCENTAGE IN EACH CATEGORY			
		Type 'P'	Type 'I'	Type 'T'	Unclassified
Johore	94	63	25	11	1
Malacca	17	82	18	—	—
Negri Sembilan	39	43	38	19	—
Selangor	49	80	13	7	—
Perak	129	87	10	3	—
Kedah	44	64	30	3	3
Penang	8	78	—	22	—
Perlis	1	—	100	—	—
Pahang	77	60	13	27	—
Trengganu	4	—	100	—	—
Kelantan	18	8	14	14	—
Malaya	480	69	18	10	3

Notes

Categories of New Villages

Type 'P' — Supposedly permanent

Type 'I' — Intermediate

Type 'T' — Supposedly impermanent or temporary and likely to disappear at the end of the Emergency.

Pilot surveys conducted by the author during 1962 in Perak, Pahang, and Johore indicated that the New Village settlers are generally disinclined to move away. The disinclination to leave the New Village is due to the following reasons: (i) transfer to a new dwelling place is costly; (ii) there is no guarantee that a settler in a rural area will not be moved again; (iii) there is still a lack of security in rural areas; (iv) individuals are unwilling to move to rural isolation, their friends being reluctant to accompany them; (v) the settlers have become accustomed to the amenities and security of the village life, and (vi) village settlers have or will have title to their house lots, and thus a permanent stake in the village. This is particularly true near the towns, where new settlers are buying and settling on vacant village lots. These trends give greater stability to such New Villages and reinforce their growth as urban centres.

The rate of natural increase in the New Villages is estimated to be about 3 per cent per annum. This, together with population growth in the other old and new urban centres, has now raised the proportion of the urban population to more than half the total Malayan population, according to current estimates.

It is estimated that nearly three-fifths of the people relocated in New Villages were originally agriculturists, many of them vegetable and livestock farmers. The movement of these people away from their fields disrupted their livelihood, and when they were unable to obtain cultivable land near the villages, large numbers were compelled to change their occupations. A sample survey in Salak South New Village (Selangor) in 1953 showed that two-thirds of the settlers had abandoned their former agricultural occupations (54b). Similarly in Sri Lallang New Village (Johore), 16 per cent were agriculturists when they entered the village, but all had changed their occupation by 1962 (55). For the New Villages

as a whole the percentage of agriculturists dropped from an estimated 60 per cent in 1950 to 27 per cent in 1952, while the proportion of wage earners in the rubber and tin industries rose from 25 to 55 per cent (Table 10).

TABLE 10: OCCUPATIONAL GROUPINGS OF THE POPULATION OF THE NEW VILLAGES, 1952 (41)

STATE	TOTAL POPULATION	PERCENTAGE IN EACH OCCUPATION GROUP				
		Agriculture	Rubber	Tin	Shopkeeping	Others
Johore	130,613	19	59	—	13	9
Malacca	9,555	35	37	0.4	9.6	—
Negri Sembilan	30,294	29	46	3	8	14
Selangor	97,346	24	47	7	7	15
Perak	206,900	27	46	8	7	12
Kedah	22,522	n	n	n	n	n
Penang	10,717	25	63	—	7	5
Perlis	682	60	20	—	10	10
Pahang	50,233	24	59	1	2	14
Trengganu	1,495	62	35	—	2	1
Kelantan	12,560	n	n	n	n	n
Malaya	572,917	27	52	3	7	11

n = Information not available

This had an immediate effect on the national economy. The acreage under food crops, excluding rice, fell from 95,727 acres in 1948 to 67,465 acres in 1951. Imports of fresh vegetables increased from 7,326 tons in 1948 to 12,680 tons in 1951; exports of fresh vegetables from Malaya to Singapore dropped from 4,608 pikuls (1 pikul = 133.1/3 lbs) in 1945 to 1,277 pikuls in 1950. Pig exports to Singapore also fell from 115,400 head in 1949 to 37,542 in 1951 (36c).

Rubber production also suffered. Food restrictions in the New Villages and Regroupment Areas prevented the workers from taking midday meals to work. This reduced working efficiency and output by 10 to 15 per cent. A 2.00 p.m. curfew further curtailed operations. Regroupment and relocation increased employers' overhead costs, since additional transport and security measures had to be provided. In consequence many of the smaller estates went out of production. Rubber output fell from 697,000 tons in 1948 to 573,000 tons in 1953.

Tin production was less seriously affected, though relocation disrupted the labour supply by restricting labour mobility and removing casual workers. Output fell from 58,000 tons in 1950 to 56,000 tons in 1953. At the same time the population continued to increase rapidly: 500,000 births were recorded in Malaya between 1948 and 1952.

The result was a rise in the cost of living and a decline in national income at a time when the country was spending more than M\$300,000,000 a year on the Emergency. But for the fortuitous trade boom induced by the Korean War, Malaya might have faced bankruptcy.

Not all the economic consequences of resettlement were adverse, however. Concentration of the rural population in New Villages on the main roads offered better access to markets and credit facilities. Amenities which the rural population had not previously enjoyed were now available in all New Villages. Many of the settlers had for the first time a title to the land on which they lived (56). Regroupment of estate labour also reduced rubber thefts. The predatory exploitation of the land by squatter shifting cultivators has been halted. Dispersal from the New

Villages is now to be controlled, and this will assist in the planning of rural development. The relocation of 573,000 rural dwellers into compact settlements has also produced a degree of cultural sophistication among them. About 70 per cent of the adults in New Villages are Federal citizens, eligible to vote, and constitute a group, mainly Chinese, with considerable political power.

Resettlement cost more than M\$100,000,000, not including the M\$4,000,000 spent by the Malayan Chinese Association. But the amenities provided in the New Villages were rarely extended to the Malay Regroupment Areas and Malay villages. This created some resentment among the Malays and has had repercussions with regard to the inclusion of the New Villages in the rural development programme of the Second Five Year Plan. This problem varies from District to District. In some, the New Villages are included in the programme. The future for those that are not included is indeed bleak, as Government maintenance subsidies have ceased and their own resources are meagre.

Finally from the military viewpoint, resettlement made possible the crushing of the Communist rebellion and the defeat of the M.R.L.A. (36d). It is a measure of the military success of the resettlement programme that the same tactics have been adopted in South Vietnam (57).

CONCLUSION

The outstanding development of the Emergency in Malaya was the implementation of the Briggs Plan, as a result of which about one million rural people were corralled into more than 600 'new' settlements, principally New Villages. This was the decisive move in the operations against the Communists.

The resettlement project was an expensive, immense and complicated task. It was accomplished in the face of tremendous odds, not the least of which was a dearth of competent workers. That it was completed at all is a tribute to the efforts of a few able men whose memorial is the 474 New Villages that dot the Malayan landscape. They have permanently altered the settlement pattern of Malaya by substantially increasing the already high proportion of urban dwellers in the total population.

At first essentially a security measure, the resettlement programme developed into a battle for the hearts and minds of the people. Victory in this battle, it was hoped, would help to raise a new generation of Chinese with a stake in the country. Completion of this process would change the New Villages from reservoirs of resentment into bastions of loyal Malayan citizenry. It was a dream, but there was a chance of its coming true. Malaya is now an independent nation. The barbed wire fences of the New Villages have been pulled down. It is more than ten years since resettlement took place. The New Villages are a hive of activity and many of them have become prosperous little towns whose people have no thought of returning to their original settlements. There is a plethora of elections and committees, in which the villagers fully participate.

The achievements in the New Villages are impressive, and, on the surface, represent a change of attitudes and a new mode of life for the inhabitants. It is too soon to say whether this change is more than superficial.

ACKNOWLEDGEMENTS

This paper is based on fieldwork carried out in 1961-2. I wish to thank those who assisted me in different ways in the field, and my colleagues of the University

of Singapore for their valuable suggestions and advice. Finally, I am grateful to the Department of Labour and Industrial Relations, Johore, and the Chinese Affairs Officers of the State Secretariats for their cooperation.

REFERENCES AND NOTES

Abbreviations

- FLCMCP *Federal Legislative Council Minutes and Council Papers* (Kuala Lumpur).
 FMAR *Federation of Malaya Annual Report* (Kuala Lumpur).
 PFLC *Proceedings of the Federal Legislative Council* (Kuala Lumpur).
 SNVFM *Statistical Information Concerning New Villages in the Federation of Malaya*, mimeo., Ministry of Internal Security (Kuala Lumpur, 1952).
 ST *The Straits Times* (Singapore).

- There appears to be some confusion in the use of the term 'squatter'. For example, both Purcell (22b) and Robinson (8f) use the term squatter to include most of the rural Chinese peasantry regardless of whether they had title or not to the land they cultivated. Government publications are also misleading; they usually begin by defining a squatter as an unlawful occupant of land, but the term is subsequently used to include all Chinese peasants and, at times, even wage-earners (FLCMCP 1950/51, pp. B89-101; FLCMCP 1952/53, pp. B311-22; FMAR 1950, p. 2, and PFLC 1948/49, pp. C533-4). For our purposes the term squatter will, unless otherwise indicated, be defined as an illegal or unauthorized occupant of public or private land.
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- The British Military Administration was the government of postwar Malaya until the inauguration of the Malayan Union in 1946. It was popularly referred to as the 'Black Market Association'.
- FLCMCP 1950/51, (a) p. B102; (b) p. B90; (c) p. B95; (d) pp. B90-1; (e) p. B94; (f) pp. B96-104.
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- Hanharan, G.Z., *The Communist Struggle in Malaya*, mimeo. (New York, 1954), (a) pp. 36-7. At the time of the Japanese surrender the M.P.A.J.A. had eight regiments, each of about one thousand men, almost all Chinese; (b) p. 49.
- Federation of Malaya, *Anatomy of Communist Propaganda* (Kuala Lumpur, 1949), pp. 1-24. The establishment of a People's Democratic Republic had been proclaimed by the M.C.P. as early as 1943.
- The M.P.A.J.A., although disbanded, did not disintegrate. Large amounts of arms were not surrendered and contact was maintained through 'Old Comrades Associations'.
- H.M.S.O., *The Fight Against Communist Terrorism in Malaya* (London, 1951), p. 10.
- Purcell, V., *Malaya: Communist or Free?* (London, 1954), (a) pp. 171-2; (b) pp. 73-83.
- The British Survey* (London, June 1952), pp. 17-8.
- A State of Emergency was first declared in Johore and Perak on 16 June 1948. Communist attacks soon spread to other States, and the State of Emergency was extended to the

- whole of Malaya on 12 July 1948. It was preceded by the enactment of the *Emergency Regulations Ordinance, 1948*, which with subsequent amendments gave wide powers of arrest, detention and deportation to the Executive. Federation of Malaya, *The Emergency Regulations 1951* (Kuala Lumpur, 1951); Federation of Malaya, *Official Year Book 1961* (Kuala Lumpur, 1961), pp. 348-51.
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 30. Patterson, G.S., *Mauai Settlement Area*, mimeo. (Johore Bahru, 1950), (a) p. 6. Among the 326 squatters removed from Batu Caves (Selangor) and Hylam Kang (Johore) in 1949 there were only 10 men between the ages of twenty and forty; (b) p. 1.
 31. Adviser on Chinese Affairs, Negri Sembilan, *Squatter Resettlement in Negri Sembilan*, mimeo. (Seremban, 1950), pp. 1-4.
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 36. *FLCMCP 1952/53*, (a) p. B312; (b) p. B320; (c) p. B317; (d) p. B328.
 37. *FMAR 1950*, (a) p. 2; (b) p. xiii.
 38. The use of the terms relocation and regroupment may not accord with that found elsewhere. Dobby prefers the term resettlement for the process whereby dispersed rural dwellers were transferred to New Villages (16b).
 39. Some writers have preferred the term relocation to close-settlement for this process. See for example, Ooi Jin-bee, 'Mining Landscapes of Kinta', *Malayan Journal of Tropical Geography*, Vol. 4, 1955, p. 52.
 40. These and subsequent statistics have been checked in the field where possible. They do not accord in all instances with those gathered by other writers. For instance in *FMAR 1952*, p. 14 a total of 509 New Villages with a population of 461,822 is recorded. Robinson gives a figure of 500 with a population of 600,000 (8g). The I.B.R.D. *Report on the Economic Development of Malaya* (Singapore, 1955) records that there were 550 New Villages with a population of 570,000. *SNVFM* and Corry (54a) list 446 and 439 New Villages with populations of 458,000 and 532,000 respectively. R. Stead, 'The New Villages in Malaya', *Geographical Magazine*, Vol. 27, 1954/55, p. 642, has a figure of 550 New Villages with a population of 600,000. The Federation of Malaya, *Report of the Land Administration Commission* (Kuala Lumpur, 1958), p. 40, puts the number of New Villages at 600. These totals include the Regroupment Areas. The present writer's total of 480 New Villages excludes the Regroupment Areas.
 41. Unless otherwise indicated the tables in this paper are based on data collected through fieldwork, and that given in *SNVFM* and by Corry (54c).
 42. Based on information on the files of the Chinese Affairs Office, Johore Bahru.
 43. Interview with the Chinese Affairs Officers of Negri Sembilan and Johore, and the Chinese Liaison Officer, Kulai, Johore.
 44. In practice these loans were written off as part of the resettlement costs.
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THE GEOMORPHOLOGY OF SUMATRA

By H. Th. VERSTAPPEN

STRUCTURE

SUMATRA, about 1,650 kilometres in length from north-west to south-east, is the largest island in the Sunda mountain system which stretches from Burma to the southern Moluccas. This mountain system consists of a volcanic inner arc and a non-volcanic outer arc, separated by an interdeep. A geosynclinal hinterdeep lies north and east of the volcanic arc, and there is a deep sea trough on the oceanic side of the non-volcanic arc.

The volcanic arc in the Sumatran section of the Sunda mountain system is represented by the Barisan Range. This geanticline stretches in a NW-SE direction, and lies a short distance from the west coast of Sumatra. The hinterdeep forms the geosyncline of east Sumatra. The islands west of Sumatra (Simalur, Nias, the Mentawai group, Enggano) belong to the partly submerged non-volcanic arc.

Extreme south-eastern Sumatra, the islands of Banka, Belitung and the Riouw-Lingga group, form part of the stable Sunda shelf, which differs markedly from the orogenic and unstable remainder of Sumatra. A small granitic outcrop near Palembang and the results of borings confirm that in south-east Sumatra the Sunda shelf occurs at shallow depth.

Younger Palaeozoic and Mesozoic sedimentary rocks are common in the Barisan Range. They are isoclinally folded, overthrust to the south-west, and intruded by granites and granodiorites as a result of the uplift, folding and rifting which began in the lower Palaeogene. Subsidence during the Oligo-Miocene partly submerged the Barisan Range again; sedimentary rocks of this age now occur west and east of the Range and locally also in the interior, while andesitic vulcanism was important in south Sumatra. Upwarping of the geanticline was repeated in the middle Miocene. Block-faulting, intense acid volcanic activity and granodioritic intrusions accompanied this period of orogenesis. No important subsidence of the Range has occurred since, but a final orogenic episode during the Plio-Pleistocene continued block-faulting and rift formation and initiated the present extensive volcanic landforms. The geosyncline of east Sumatra simultaneously witnessed important sedimentation and subsequent folding. The present outline and relief of Sumatra thus came into being, but important tectonic movements occur to the present day.

Pre-Tertiary outcrops are rare in the islands of the non-volcanic arc west of Sumatra. The islands are composed of mostly non-resistant Tertiary deposits thousands of metres thick. Ultra-basic rocks occur locally. The uplift of the arc began in the Quaternary.

The islands to the south-east of Sumatra form part of the Sunda shelf. They are chiefly composed of Mesozoic (Triassic) sedimentaries, possibly underlain by beds of Palaeozoic age. Granitic intrusions are important. The whole area has been base-leveled and was partially submerged in the early Pleistocene, so that the present island patterns indicate the structural trends of the old land mass.

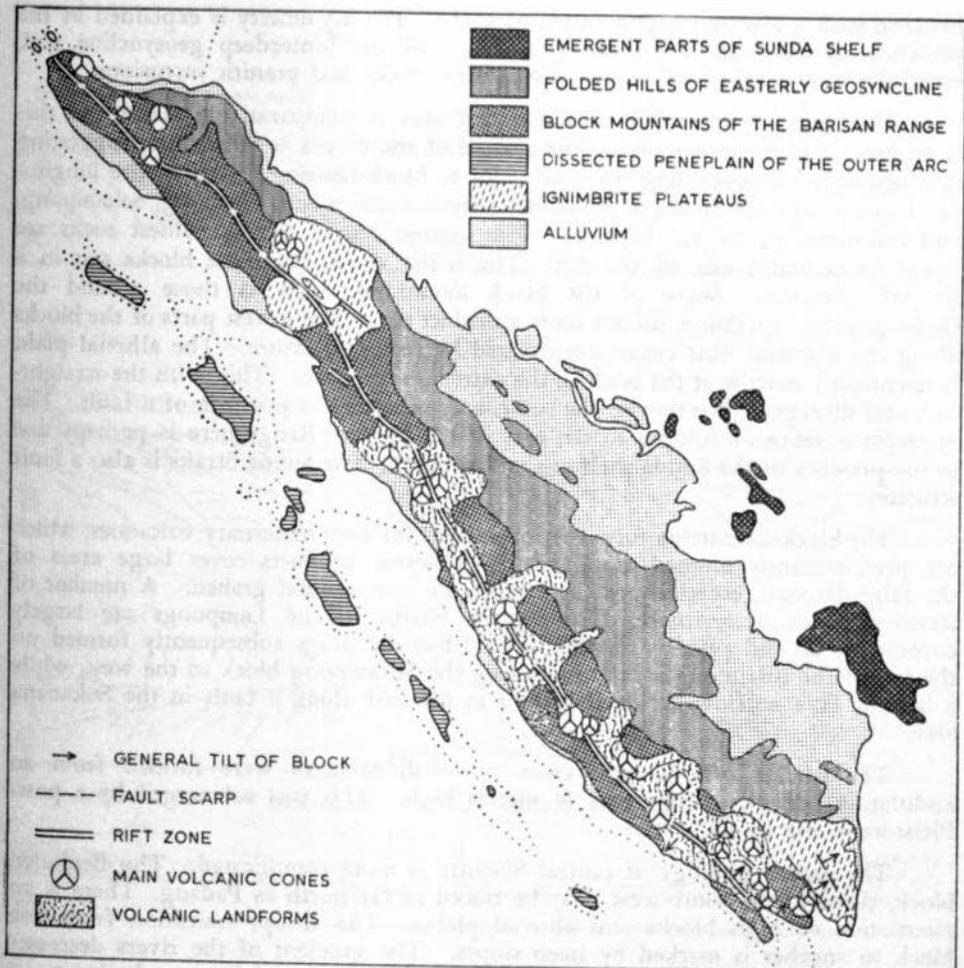


Fig. 1. Geomorphological sketch map of Sumatra.

GEOMORPHOLOGY (Fig. 1)

The process of denudation is rapid in the humid tropics, especially where weak and relatively young sedimentary rocks and volcanic material are involved, as in Sumatra and the adjacent islands. The relief of Sumatra clearly reflects several cycles of erosion in addition to young crustal movements. Since uplift induces increased river erosion and more rapid base-leveling, it is to be expected that the results of older erosion cycles are difficult to trace in the landforms.

Sumatra is two or three times broader in the south than in the north. There are two reasons for this: the presence of the Sunda shelf at shallow depth in the south-eastern part of the island, and the increasing depth north-westwards of the Sumatran geosyncline. The northern parts of this geosyncline are largely submerged, hence the Malacca Straits widens to the north and Sumatra narrows. Another major geomorphological feature of the island is its pronounced asymmetric cross-section. The south-west side is usually steep with only a few small alluvial plains, and the coast tends to be straight and rocky. The north-east side of the island is largely

lowland with a low and highly indented coast. The asymmetry is explained by the presence, to the east of the Barisan Range, of the hinterdeep geosyncline and, especially in southern Sumatra, of pre-Tertiary rocks and granitic intrusions.

The geomorphology of southern Sumatra is comparatively simple as this is an area of block mountains. The surface of the blocks is rather flat, suggesting that prolonged base-leveling occurred prior to block-faulting. West of the longitudinal graben are the blocks of Benkulen (lifted to the west), Lampong, Sekampong, and Sukadana (lifted to the east). The highest blocks and the oldest rocks are found immediately east of the rift. The faults separating these blocks run in a SE-NW direction. Some of the block mountains, such as those around the Gedongsurian depression, do not show a distinct tilt. The lowest parts of the blocks along the east and west coasts are covered by recent alluvium. The alluvial plain is remarkably narrow at the coast in the extreme south-east. This, with the straightness and divergent direction of the coast, may indicate the presence of a fault. The apparent absence of folding to the east of the Barisan Range here is perhaps due to the presence of the Sunda shelf at shallow depth. The Sunda Straits is also a fault structure.

The block mountains form the foundation for the Quaternary volcanoes, which are predominantly aligned along faults. Volcanic products cover large areas of the High Barisan, especially to the east of the longitudinal graben. A number of stratovolcanoes occur there. The eastern blocks in the Lampongs are largely covered by an old plateau of acid tuff. Rhyolitic plugs subsequently formed on the top of the tuff along a fault bordering the Sekampong block to the west, while a basaltic lava outflow occurred further to the east along a fault in the Sukadana area.

The islands off the east coast of south Sumatra were formed from an undulating peneplain some tens of metres high. This was submerged by a post-Pleistocene rise in sea level.

The geomorphology of central Sumatra is more complicated. The Benkulen block, tilted to the south-west, may be traced as far north as Padang. There is an alternation of high blocks and alluvial plains. The abrupt transition from one block to another is marked by steep slopes. The gradient of the rivers decreases suddenly at the foot of the fault scarps, where huge alluvial fans are built up.

The longitudinal graben is well developed in central Sumatra. It can be traced from the Kerintji plain in the south, through the Solok plain and Lake Singkarak to the Padang highlands of Bukittingi and north to the graben of the Sumpur and Angkola rivers (Fig. 2C). High stratovolcanoes also occur in this part of Sumatra and volcanic material covers large areas of the block mountains. East of the longitudinal graben, the block mountains contain several breaches through which volcanic material has passed to form large fluvio-volcanic fans. Such breaches occur between the Garba, Gumai, Tembesi-Rawas, Tadjam and Gumanti-Liki mountains. This distribution of the volcanic products was largely controlled by the topography of the pre-volcanic surface. The same phenomenon, less well developed, can be observed in southern Sumatra. The most important fans are those of Sugiwaras, Muarabeliti, Bangko and S. Sungkai.

A peneplain is found east of the Barisan, cut in the folded Tertiary sediments of the east Sumatran geosyncline, with pre-Tertiary rocks outcropping in the highest parts, chiefly in the Tigapuluh Mountains. The rapid peneplanation of these sediments kept pace with the Plio-Pleistocene folding. Between this surface and the Barisan Range is a somewhat lower zone, the so-called Sub-Barisan depres-

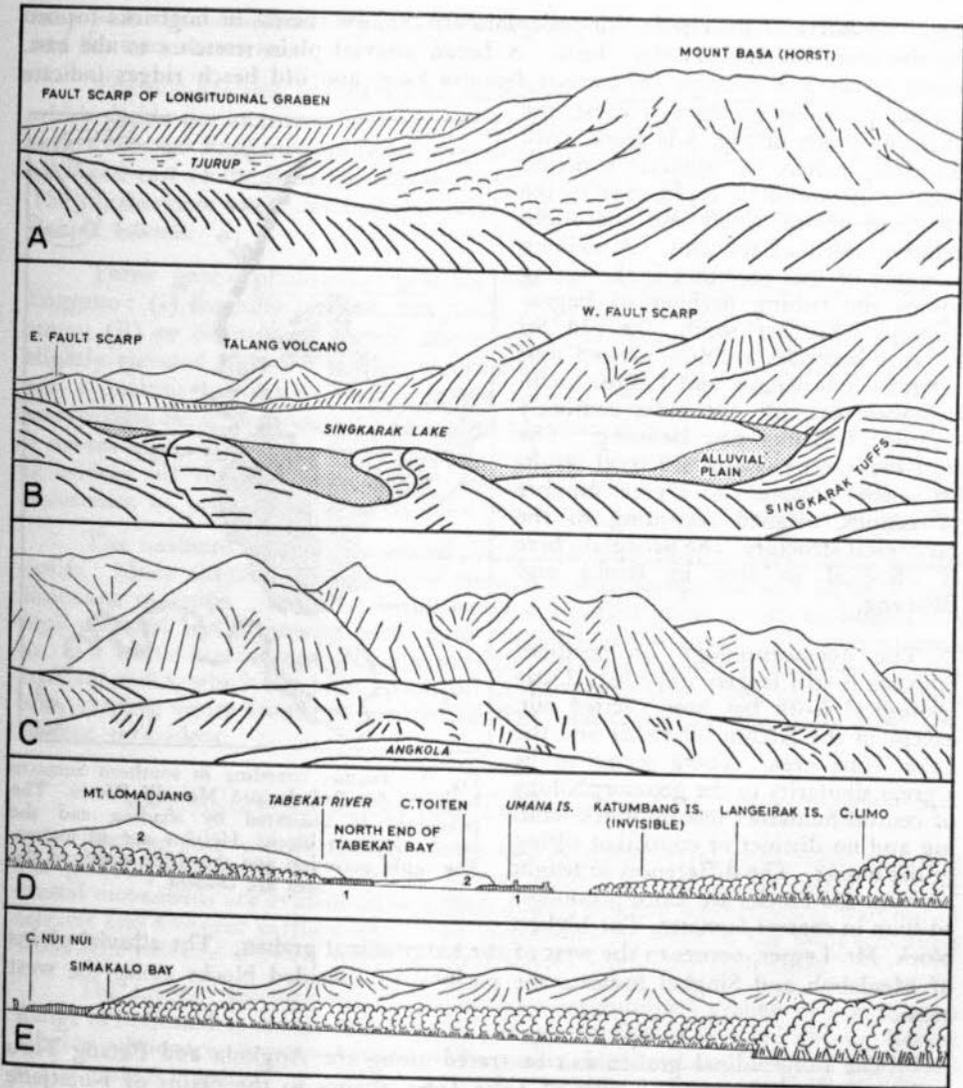


Fig. 2 A. The longitudinal graben near Tjurup in southern Sumatra, looking south-west. Mt. Basa is a horst locally developed in the rift.

B. Lake Singkarak in central Sumatra, looking south-east. The lake is formed in a low-lying part of the longitudinal graben. Volcanic outbursts have formed tuff deposits in the graben and to the east of the eastern fault scarp.

C. Part of the longitudinal graben south of Padangsidempuan (N. Sumatra), looking east. The Angkola River breaks through a minor horst of the complex rift. Some faceted spurs can be distinguished.

D. Tabekat Bay, on the east coast of Siberut (Mentawai Islands), looking north. A row of islands (Umana, Katumbang and Langeirak) indicates the edge of the pseudo-barrier reef, the lagoon being formed by Tabekat Bay.

E. Summit level, indicating an old peneplain, of South Pagai (Mentawai Islands). The mangroves in the foreground indicate a slightly uplifted coastal terrace/coral reef.

sion. Features of interest in this peneplain are the low cuestas or hogbacks formed by the more resistant Tertiary beds. A broad alluvial plain stretches to the east. River levees and swamps are normal features here, and old beach ridges indicate former positions of the east coast; the example given in Fig. 3 is from south Sumatra, where a similar situation occurs. Accretion is rapid, due to the silt load of the rivers and the slight relative uplift of the area. A striking example of this accretion is the silting up of the fishing harbour of Bagan-siapiapi. Further south, the old Sri Vijayan harbours are now located well inland. The Riouw and Lingga archipelagoes resemble the more southerly islands of Banka and Belitung. The post-Pleistocene rise in sea level resulted in the formation of a great number of islands, aligned according to the geological structure. The peneplain here is identical to that in Banka and Belitung.

The geomorphology of northern Sumatra is still largely unknown. Little geological work has been carried out, except in the Atchin oil fields and the Lake Toba area. There seems to be a great similarity to the geomorphology of central Sumatra: intense block-faulting and no distinct or consistent tilting of the blocks. The differences in height between the blocks are more pronounced than in central Sumatra. The highest

block, Mt. Leuser, occurs to the west of the longitudinal graben. The alluvial plains of Meulaboh and Singkel indicate the position of subsided blocks along the west coast.

The longitudinal graben can be traced along the Angkola and Batang Toru valleys to the Renun valley west of Lake Toba, thence to the plains of Kotatjane and Blangkedjeren and to Kotaradja and the Bengalen passage west of Puluw Weh. Other important graben are the Toba depression and the rift of Laut Tawar. Two new geomorphological elements can be distinguished in Atchin. Firstly, there is the development of broader basins in the Barisan Range, such as the basins of Blangkedjeren and Gajodeureut. Secondly, there is a change in the direction of the graben and other structural elements towards a greater east-west orientation. Vulcanism is less important in the northern part of the Barisan Range than in the south. Stratovolcanoes occur mainly to the north of Lake Toba near Laut Tawar and to the east of Kotaradja. An important exception is the Lake Toba area, where a number of catastrophic eruptions of the Katmaian type have resulted in the formation of an extensive ignimbrite plateau. Deep and steep-sided river gorges are characteristic of this flat area. The alluvial plain along the east coast narrows towards the north. Sedimentation was less intense here, or at least it failed to



Fig. 3. Former coastline in southern Sumatra between the Pedada and Mesudji Rivers. The peneplain is indicated by shading and the beach ridge in black. Heights are in metres. The rapid accretion and the slight uplift of the area are evident.

keep pace with subsidence. Thus the Malacca Straits becomes broader to the north and Sumatra narrower.

The non-volcanic islands are connected to Sumatra by three submarine swells which divide the interdeep into separate basins. The southernmost of these swells occurs between Enggano and South Pagai near the island of Mega. The second is to be found east of the Batu Islands, where the island of Pini marks the highest part. The northernmost swell lies between Nias and Simalur, its position marked by the Banjak Islands.

Three geomorphological divisions can be distinguished on the island of Enggano: (i) the hilly interior, composed of folded and poorly resistant Neogene strata; (ii) an elevated coral reef, about 100 metres high; (iii) alluvial plains and slightly elevated reefs. The high elevated reef is absent in the Mentawai Islands, and a summit level is developed in the interior (Fig. 2E). The rocks of this archipelago, being non-resistant, are reduced to narrow crests. Broad terraces, about 5 metres high, occur in the river valleys well into the interior. Recent subsidence is evident off the east coast, where several islands have been submerged. The occurrence of pseudo-barrier reefs also points to the same conclusion (Fig. 2D).

The northern part of the island chain, especially Nias, experienced a greater uplift. Many rivers in this area flow through narrow gorges cut in a series of hard limestone outcrops. There is consequently a stronger relief on these islands. A high elevated reef is present here, as in Enggano to the south. The non-volcanic arc as a whole can be regarded as a strongly dissected peneplain, formed in poorly resistant rocks, which has been upwarped in the Quaternary. The amount of uplift and warping varies from one area to another, and along the east coast some subsidence is evident.

FAULTING PHENOMENA AND RELATED VOLCANIC FEATURES

Faulting and volcanic activity are the two most important phenomena affecting the geomorphology of the Barisan Range; both are still taking place. Recent crustal movements are evident from coastal emergence and submergence, warping of terraces and frequent earthquakes. The further development of the fault structures stimulates volcanic activity, which is concentrated along the fault lines.

The further development of the complex longitudinal graben of the Barisan Range is indicated at certain localities by young scarplets or faceted spurs. Recent relative subsidence of various parts of the graben has produced swampy conditions at the graben bottom.

Terraces occur locally in the longitudinal graben, as around Panti (Sumpur valley), in the Blangkedjeren basin and south-east of Kotaradja in Atchin. It appears that in places river erosion acts more rapidly than the subsidence of the graben. There is possibly some uplift in parts of the graben. The young sediments are thus dissected by the rivers and terraces are formed, reaching a height of 100 metres or more in the Blangkedjeren basin. The lower slopes of these parts of the graben are therefore to be considered as fault-line scarps. They are not the direct result of vertical displacement along the fault, but rather, at least in part, of more recent erosion.

The drainage system is also frequently influenced by young faulting movements. A small valley in the Toba area to the north-west of the Karo highlands originally drained towards the Toba graben; now it drains towards the Renun river in the longitudinal graben slightly further west. This river piracy is the result

of increased retrogressive erosion by the Renun system induced by the further subsidence of this section of the graben. The Solok plain and the Singkarak depression in central Sumatra once had separate outlets to the sea. Subsidence in the graben section between these two areas, and probably of the Singkarak depression itself, has directed the drainage of the Solok plain towards Lake Singkarak.

The complexity of the longitudinal graben is illustrated in the Kerintji section, where young scarps occur at the bottom of the graben, and further south around Tjurup, where Mt. Basa forms a local horst in the rift zone (Fig. 2A). The escarpment bordering the island of Samosir in Lake Toba is a step-fault at its southern end, while to the north, as the distance from the lake shore increases, it occurs as a huge flexure. Extremely young and minute graben structures occur in the tuff and diatome deposits of the northern half of Samosir. Strong post-eruption uplift of the south-eastern part of the Toba trough may be deduced from a warping of the lake terraces (Figs. 4, 5). It has also been observed that the graben is often poorly developed, i.e. narrow and high, where intrusive bodies occur, as for instance west of Kotanopan (Fig. 6). Some of the intrusive bodies apparently acted as a mainstay during the development of the graben structure.

A great diversity of volcanic features occurs along the faults of the Barisan Range. A flat basaltic lava plateau was formed in the Sukadana area of south Sumatra; further west, near Tandjung Karang, there are a number of steep-sided acid boccas. Near Batusangkar in central Sumatra an explosion crater (maar) is associated with a prominent fault. Phreatic eruptions took place in the Suoh depression, which forms part of the longitudinal graben of southern Sumatra. Katmaian eruptions, accompanied by the formation of extensive ignimbrite plateaus, also occurred. The best known example of this is the Batak highland. The vents were the faults bordering the Toba trough, which undoubtedly existed

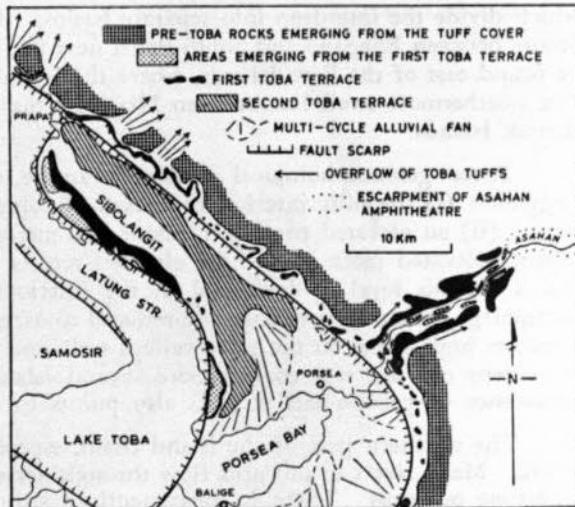


Fig. 4. Geomorphological map of the south-east part of the Toba graben.

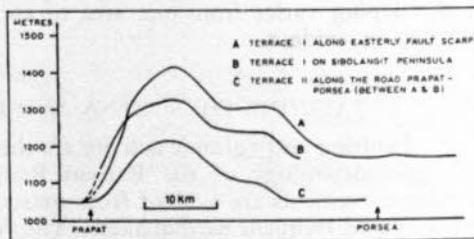


Fig. 5. Warped lake terraces along the eastern shore of Lake Toba between Prapat and Porsea.

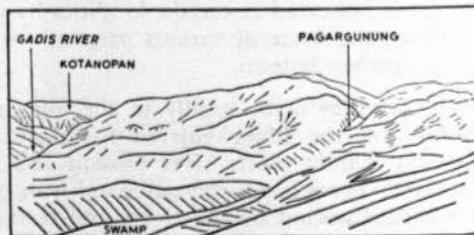


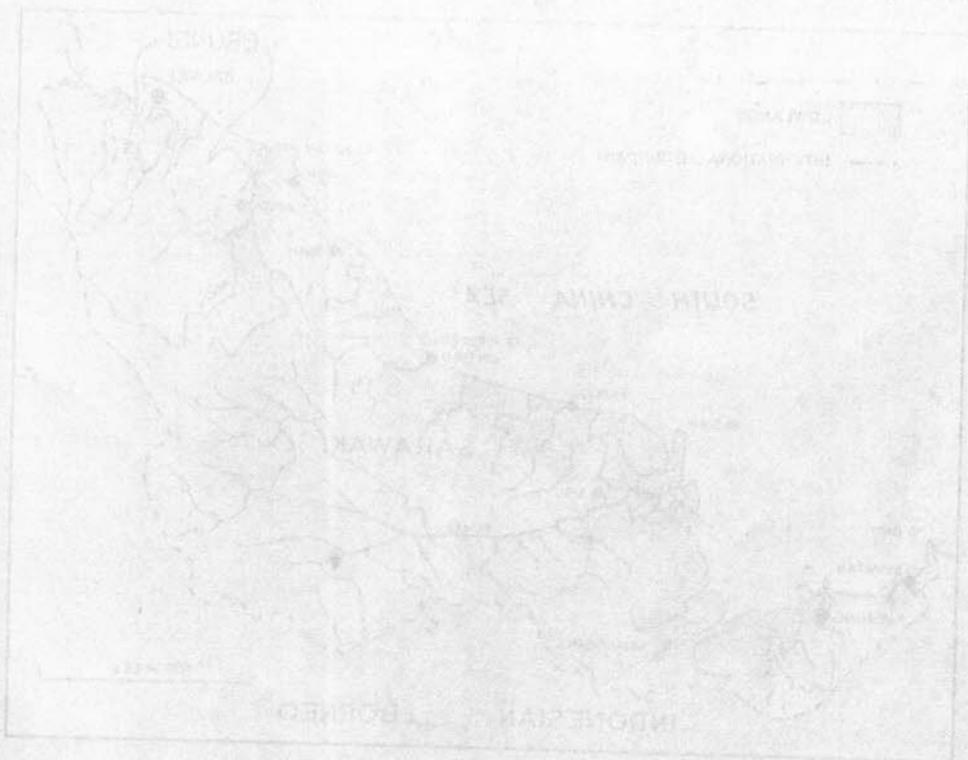
Fig. 6. Graben to the west of Kotanopan. The rift becomes higher and comparatively poorly developed near the granites which occur in the distance to the right of the figure.

prior to the eruptions. Similar ignimbrite plateaus are to be found near Bukittinggi in central Sumatra, in the Singkarak depression (Fig. 2B), and the Pasemah and Ranau sections of the median rift of south Sumatra. An older phenomenon of the same type produced the acid tuff cover of the Lampong district. Younger volcanic activity took place on top of the tuff. The type of vulcanism along the faults was conditioned by the nature and depth of the magma in the chamber below. The Renun section of the longitudinal graben of north Sumatra is an example of a well developed, i.e. broad and low, section of the graben where no vulcanism occurred.

It is evident from the foregoing that the landforms of the Barisan Range are not only young, but are still in the making. The same might be said of the non-volcanic arc, though the evidence there is less striking. The young crustal movements are often perfectly reflected in the geomorphology, and they give rise to a great diversity of landforms.

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TOPOGRAPHY-SOIL RELATIONSHIPS IN LOWLAND SARAWAK

By J. R. D. WALL

TOPOGRAPHIC units in lowland Sarawak are readily distinguished by their relief features, drainage pattern and manner of distribution. Each unit has a distinctive soil pattern comprising a narrow range of soils closely related to one another by mode of origin. In this paper the topographic units, together with their associated soils, are called 'topo-soil' associations. The intention here is to describe the associations that occur in lowland Sarawak and to indicate their use in soil surveying with particular reference to air photograph analysis.

Topography is considered to be the most consistent, and therefore the most important, feature associated with the soil patterns in the lowlands, although vegetation, land use and soil parent material show a close relationship in many places. Vegetation and land-use distributions are less consistently associated with soil than is topography, since they tend to reflect soil fertility rather than soil type. Both soil and topography, on the other hand, are closely related to parent material, but the relationship is of limited value since rock type can rarely be deduced directly from air photographs.

Lowland Sarawak as defined here comprises the swamps and deltas, the beaches and riverine stretches, and the dissected terrace landscape, generally less

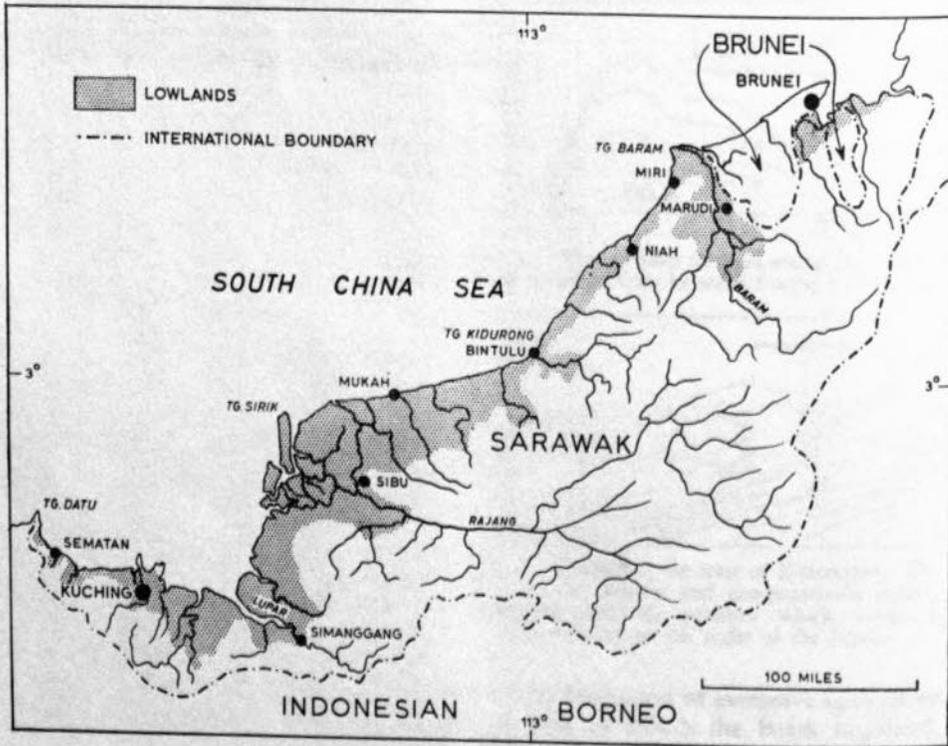


Fig. 1. The lowlands of Sarawak.

than 100 feet above sea level, which flank much of the hilly land (Fig. 1). Such country forms an area of about 10,000 square miles or approximately 20 per cent of the territory.

Beach Association

TOPO-SOIL ASSOCIATIONS

This association forms a narrow belt along the greater part of the coast, varying in width from a few feet to more than a mile. It is distinguished by the presence of numerous old strand-lines, a typical rectilinear drainage pattern and sandy podsolized soils.

The beaches consist predominantly of fine quartz sand and silt, most of which has probably been derived by marine erosion from sandstone beds outcropping in cliffs along parts of the coast. The most recent beach, being as much as four feet above normal high tide level, is generally the highest, and from this height the surface usually slopes down gently inland to peat swamp margins. Old strand-lines, inland and mainly parallel to the present coast, are slightly higher and drier than the swales between, which support a less stunted vegetation than the former. Near river mouths older strand-lines, formerly at the river mouth, are rarely parallel to the coast due to deflection of spits by the combined action of river currents and longshore drift (Fig. 2).

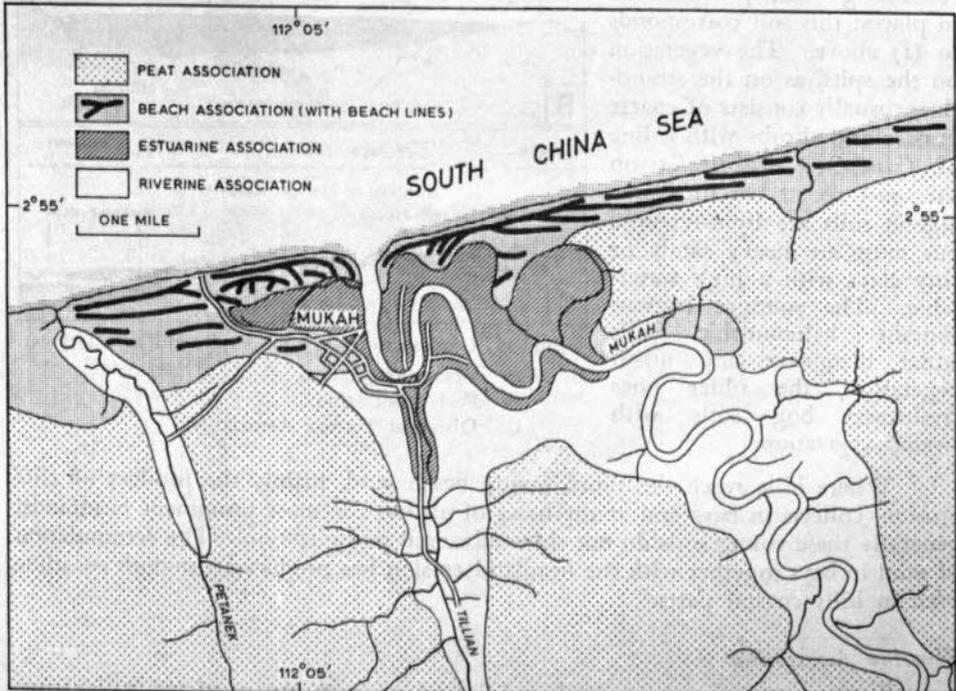


Fig. 2. Topography-soil associations at the coast.

The depth of the watertable decreases inland until, at the edge of the peat swamp, it is at or near ground level. The drainage pattern is rectilinear and individual streams originating from the peat areas tend mainly to flow parallel to and between the old strand-lines. Rainwater penetration in the soil is rapid and

complete, and the soil water moves laterally above the watertable rather than on the surface.

The soils are chiefly deep sands belonging to the regosol-podzol sequence (Fig. 3A). A normal succession from coast to swamp edge is: (i) weakly differentiated sands with a low watertable; (ii) podsolized soils showing the initial stages of humus accumulation above the watertable; (iii) groundwater humus podzols; (iv) semi-bog and bog soils where the watertable is nearer to the surface. Between (i) and (iv) the lower swales between strand-lines in places contain semi-bog or bog soils. Locally, drowned soils of (i) to (iii) can be found in (iv). This succession is commonly interrupted, cut short, or apparently reversed where beach erosion and regression have occurred.

Near river mouths in particular, a mixed Beach and Estuarine Association comprising spits and lagoons often occurs (described later under 'Estuarine Association'). Recently formed spits consist of weakly differentiated sands containing shelly horizons in places; this soil corresponds to (i) above. The vegetation on the spits, as on the strand-lines, usually consists of coarse grasses and shrubs with a line of *Casuarina equisetifolia* on the most recent beach. Some lagoon soils are light-textured but most are heavy sandy or silty clays with a high watertable. The younger lagoons contain halomorphic soils under mangrove and nipah vegetation, the older ones freshwater bog soils with swamp vegetation.

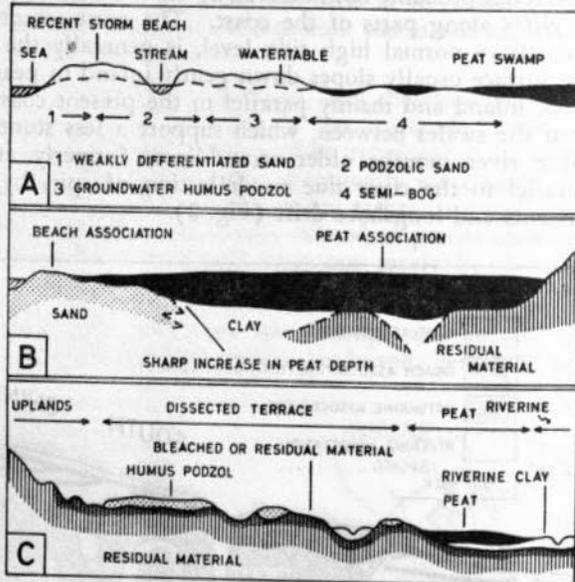


Fig. 3. Cross-sections of topography-soil associations.

- A. Beach Association.
- B. Peat Association.
- C. Dissected Terrace Association.

Where hills reach the shore, young beach sand, mainly the product of cliff erosion, collects in bays and at the bases of all but the most prominent headlands; generally these young soils do not show advanced podsolization. The accumulation of sand in bays together with the headland erosion has produced a smooth coastline even in hilly coastal parts.

Riverine Association

Riverine areas in the coastal and inland swamps are restricted to narrow, slightly winding alluvial stretches of rivers (Fig. 2). The main features are the almost flat topography, the indeterminate drainage pattern and the poorly drained gley soils.

The alluvial areas are generally fully occupied by the river meander belts, and are flanked by peat swamps of the Peat Association which cover much former river alluvium in inter-riverine basins. Distances from outer meander bends to

the peat swamp boundaries range from a few feet to as much as a mile, although the meander belt seldom exceeds two miles in width.

The surface topography of the riverine areas is flat, or gently sloping on the levees. In the wide swampy lowlands levees are low and may be considered as better-drained basin margins. Within the hilly areas the levees are higher and often wider due to the steeper gradients and greater load-carrying capacity of the rivers. Seasonal flooding is common, especially in the downriver areas with low levees, and there is consequently a steady accretion of alluvium.

The drainage pattern of the small tributaries is indeterminate. Gradients are low and streams originating from the peat swamps meander aimlessly across the alluvium before cutting through main river levees. Except in the higher levees of upriver tracts the watertable is always at or near the surface.

A broad division of the soils can be made between those occurring on levees and those associated with the basin alluvium. The levee soils are characteristically variable. At the coast, rivers have generally cut through old beaches with consequent mixing of the sand with riverine clay, and outer meander bends facing the sea tend to be cut into old beaches, thus exposing soils of the Beach Association. In the remaining parts of the swampy lowland where rivers are tidal and the river-borne material is mainly clay, levee soils are sticky poorly drained clays with a high watertable. Soils of levees within the hilly areas are deep, predominantly sandy, and usually show little profile differentiation; in addition they are well drained and the watertable is generally low.

Basin soils behind levees are clayey and badly drained, and since the watertable is always at or near the surface, causing waterlogged anaerobic conditions, there is a strong tendency towards the accumulation of peat or muck as topsoil. The soil type succession from levee to peat swamp edge changes from either a regosol, a podzolic soil, or a low humic gley on the levees to a groundwater gley and finally to a semi-bog soil on the basin alluvium. The soil type strongly reflects the position of the watertable within the profile, which in turn is dependent on the surface topography. Riverine areas are extensively cultivated and there are remnants of primary forest in only a few places.

Peat Association

This association consists of large swamps, in places exceeding 250 square miles, which occupy the basins enclosed by the Riverine and the coastal Beach Associations. It is characterized by an apparent flatness, a coarse radial drainage pattern, and a very narrow range of peat soils.

Peat accumulation, especially in the larger swamps, is faster than the accumulation of riverine alluvium since the surface of some swamp centres may be up to fifty feet above the nearest levee level (1, 2). Between rivers the larger peat swamps are usually lenticular in cross-section (3), although in some areas the smooth subsurface is interrupted by low submerged hills. The peat base near the coast is in places at least three to four feet below mean sea level. The cross-section from the coast through a peat swamp to the hills differs from the river-to-river section described above; on the inland side of the Beach Association a rapid increase in peat depth can be found at the boundary between the coastal sand and the basin clays, although the surface of the peat at this point appears to remain flat (Fig. 3B). The peat commonly exceeds ten feet in depth within fifty feet of the foothills.

The central part of the swamp is drained by outward seepage. Surface channels are few. Around the margins, however, the peat is shallower, and here the underlying material influences drainage. Where peat rests on impervious clay, small streams radiate outwards from the swamp, but where sand underlies the shallow peat, streams are far less common.

The peat usually consists of little-decomposed woody material within a watery matrix of finer organic matter, which may exceed sixty feet in depth. The cultivation of swamp margins allows slow humification of the peat and, with the intermittent deposition of flood material, results in intermixing of peaty matter with alluvium. In such places interstratified peat, muck and alluvium are common. Peat exceeding six feet in depth is rarely used for cultivation.

Swamps also occur in upland tributary valleys behind the high levees of main streams; such swamps are generally small and are caused by impeded drainage. The soils range from deep peats to semi-bog riverine alluvium, and they commonly meet the surrounding steep hill flanks abruptly.

Estuarine Association

Estuaries, deltas and lagoons are the principal landforms of the Estuarine Association, but some abandoned meanders, inner meanders and coastal flats are also included (Fig. 2). The main feature common to all these landforms is frequent saline tidal incursions, which give rise to characteristic halomorphic soils with mangrove and nipah vegetation.

The surface of the ground is at or near high tide level and numerous mounds break the otherwise flat topography. These are made by crabs which burrow into the ground and form mounds from the spoil as much as four feet high and six feet wide at the base. The drainage pattern consists of an intricate network of meandering channels which are best developed in the large deltas.

Despite the great variety of landforms, the soil types are few and mainly reflect micro-relief. Between the mounds are dark-coloured clayey, saline hydro-morphic soils; in such places the watertable is usually high. The soil of newly formed mounds resembles the saline clays described above, but yellowing of the dried surfaces of some older mounds indicates the acid sulphurous conditions of 'catclay'. Soils of other older mounds tend to be podsolized and paler. In places crab activity is so intense that it has resulted in a thorough mixing together of the top foot or so of any soils present.

Dissected Terrace Association

This association is included with the other, more obvious, lowland associations as it contains and is characterized by terraces and other relic lowland features. The association occurs on the hill margins as a discontinuous belt of low dissected hills, usually less than five miles wide, containing terrace remnants intermixed in places with some or all of the other lowland topo-soil associations (Fig. 4). Amplitude of relief is generally less than fifty feet and the drainage pattern is weakly integrated with the underlying rock structure.

The terrace remnants are covered by poor lowland heath forest and they rarely show surface drainage features. Their heights vary considerably, partly due to warping and faulting, but principally because they correspond to several stages in the lowering of the sea level during Quaternary times; most lie between 25 and 100 feet above the local base level (1, 4). The terraces rarely exceed fifteen square miles in area and tend to be elongated parallel to the former coastline.

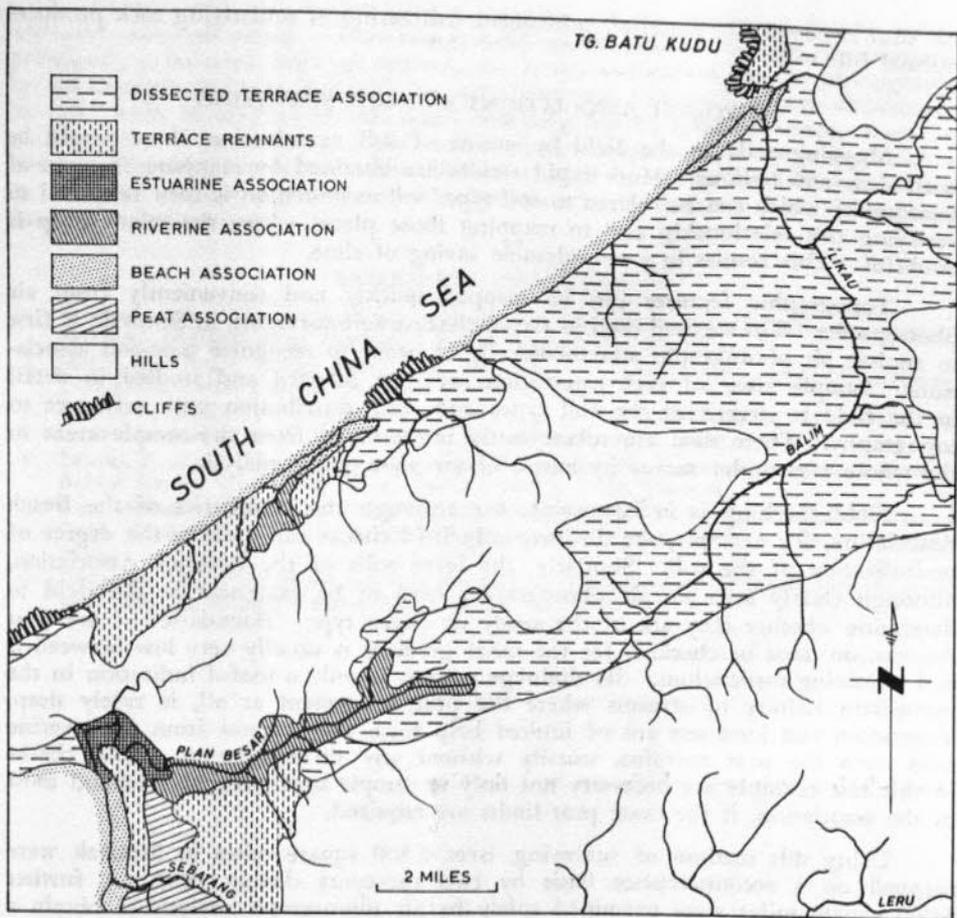


Fig. 4. Topography-soil associations at the hill margins.

Many are less than 300 by 50 feet, and such vestiges commonly form a discontinuous narrow strip on the swamp-facing edge of the hills. In places the coastal terraces merge imperceptibly into riverine terraces, which locally may be traced back into the hills.

Humus podzols are the main soil type of the coastal terraces, and were possibly formed originally as groundwater podzols at sea level before being stranded by subsequent sea level changes. The soil is deep and consists mainly of white quartz sands and silt with a compact humus pan generally below 4 feet. Soil drainage is excessive as far as the pan which supports a perched watertable. Groundwater moves laterally above the pan and terminates at seepage lines on terrace flanks. Riverine terrace deposits are usually less strongly podsolized and consist mainly of pale-coloured, sandy clays to sandy gravel; basal gravel beds are common.

Soils of the dissected land, other than the terraces, vary with the degree of dissection (Fig. 3C). As streams cut back into terraces by gullying at their edges, the covering podzols are gradually eroded until the material beneath is exposed; this usually weathers into a distinctive pale, heavy-textured soil (5). Where erosion

has also removed this material, subsequent weathering of underlying rock produces normal hill soils.

TOPO-SOIL ASSOCIATIONS AND SOIL SURVEYING

Mapping soils in the field by means of soil examination alone would be both slow and tedious. More rapid results are obtained by mapping features of topography which can be related to soil type; soil examination is then restricted to verifying this relationship and to mapping those places where the relationship is doubtful. This results in a considerable saving of time.

Topographic features can be mapped quickly and conveniently from air photographs. The method used in reconnaissance soil surveying in Sarawak, is first to analyse air photographs stereoscopically in order to recognize topo-soil associations. Sample areas of each association are then selected and studied in detail in the field to determine the soil types and their distribution with reference to topography. These data are subsequently interpolated from the sample areas to the whole area under survey by means of air photograph analysis.

Field checking is indispensable, for although the boundaries of the Beach Association, for example, are distinct, only field checks can indicate the degree of podsolization of the soil. Similarly, the levee soils of the Riverine Association, although clearly seen on air photographs, need to be examined in the field to determine whether they are of the sandy or clayey type. Boundaries of the Peat Association must be checked, for the relief gradient is usually very low between it and adjoining associations. Its drainage pattern is only a useful indication in the immediate vicinity of streams where the peat, if present at all, is rarely deep. Vegetation and land use are of limited help since they extend from the riverine soils onto the peat margins, usually without any differentiation. Field checks in this last example are necessary not only in sample areas, but also around most of the association, if the exact peat limits are required.

Using this method of surveying, over 2,500 square miles in Sarawak were mapped on a reconnaissance basis by two surveyors during 1961. A further 5,000 square miles were examined solely by air photograph analysis to obtain a broad indication of potential land development.

The usefulness of topo-soil associations in soil surveying is emphasised by their importance in the first classification of the soils of Sarawak (6). The soil associations in this classification are based on the inter-relationship of soils, topography and parent material.

CONCLUSIONS

Due to the consistently close relationship between topographic units and soil type distribution, it is possible to recognize 'topo-soil' associations.

The soils within an association are narrow in range and are related to each other by mode of origin; with few exceptions they can be placed in the same order of soils. A narrow range of halomorphic soils occurs in the Estuarine Association, and peat and muck are the only soils in the Peat Association. The Beach Association soils are more variable but generally belong to the regosol-podzol sequence, and those of the Riverine Association are mainly types of gleys, with a few exceptions on the higher levees. The Dissected Terrace Association is really a mixture of associations, particularly where dissection is advanced, and consequently many different soils occur.

The topo-soil associations have a practical use, in particular during reconnaissance soil surveying. The topographic characteristics of the associations, principally relief and drainage pattern, are easily recognized on air photographs by stereoscopic analysis, and once the associated soil pattern has been determined by field work in selected sample areas, mapping can be effected mainly from air photographs. The result is rapid and accurate reconnaissance surveying with a considerable reduction in time and cost compared to surveying by field work alone. In a tropical country such as Sarawak, where communications are poor, this method has obvious advantages.

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A PRELIMINARY VEGETATION MAP OF MALAYA WITH DESCRIPTIONS OF THE VEGETATION TYPES

By J. WYATT-SMITH

NO SYSTEMATIC survey of vegetation types in Malaya is yet available (1). Even broad classifications of vegetation types are comparatively rare, though it was pointed out as early as 1940 that the general division of Malayan forests into mangrove swamp, beach, freshwater swamp, lowland dipterocarp and mountain types, then in common use, was quite inadequate for efficient forest management (2).

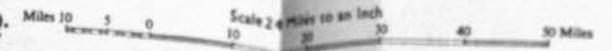
This state of affairs prevailed in the years before the Second World War, when the exploitation of all but mangrove forests was slight by recent standards in Forest Reserve — the permanent forest estate. Such logging as did occur was largely confined to State Land forest and was concerned with a limited number of species: mainly those of the dipterocarp family producing naturally durable heavy hardwood (3), and those of the *Shorea* family yielding Red Meranti, a light hardwood grade of timber. Accessible areas in Forest Reserve, known to have rich seedling regeneration of these valuable species, were pre-treated under a shelter-wood system of management by the Forest Department, and those areas known from systematic enumeration or field observations to possess economically valuable stands were selected for Forest Reserves. Thus economic forest types were already recognized by loggers and the government, and other reserves in hills and mountains were selected more as erosion controls than as reserves for future exploitation. The state of knowledge at that time is shown by Symington's ecological classification, which divided the lowland dipterocarp forest into Malayan and Burmese types (the latter found in northwest Malaya), on the grounds that 'so varied are the communities that comprise our lowland dipterocarp forest that fundamental subdivisions have not been detected' (4). He also divided the hill dipterocarp forest into inland and coastal types and further recognized 'heath' forest, beach forest and three secondary types, namely: *Schima*-bamboo forests, coastal *padang* formations, and *Adinandra* forests.

The war in the Far East and the Emergency in Malaya delayed further progress in differentiating forest types. However, after the Second World War the demand for timber became so great that Malayan forests, including the reserves, were increasingly exploited to higher altitudes, through improved extraction methods, and to a much smaller degree of selectivity, both in species and tree form or defect, than before. These pressures and the necessity to ensure a continuity undertaken to determine the extent of trees of saw log size and seedling regeneration. Accordingly, the work of the Forest Department has since been guided by a decision made in 1950 that the new crop should be derived from natural regeneration under a uniform system of management. To this end, sampling has been undertaken to determine the extent of trees of saw log size and seedling regeneration of economic species prior to logging, and studies of stocking adequacy, distribution and development of the new crop, and of the extent of weed competition have been carried out a few years after logging. At the same time, attention has been directed beyond those areas previously thought to be of economic significance, largely as a result of broadening selectivity. Such studies quickly showed that definite forest types exist within the lowland dipterocarp forests and that the distributional patterns of at least some types appear, not unexpectedly, to be closely associated



VEGETATION MAP OF MALAYA

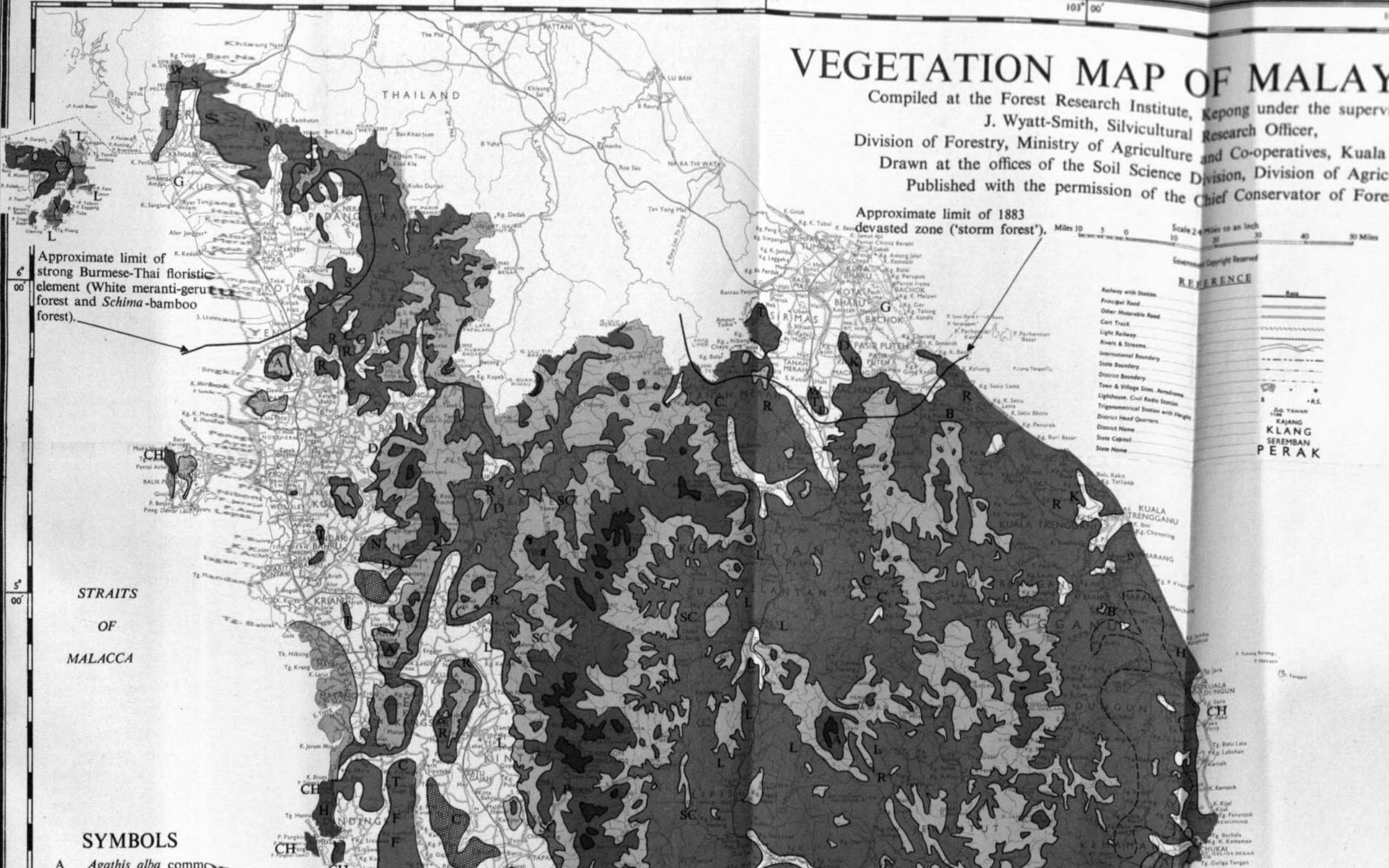
Compiled at the Forest Research Institute, Kepong under the supervision of
 J. Wyatt-Smith, Silvicultural Research Officer,
 Division of Forestry, Ministry of Agriculture and Co-operatives, Kuala Lumpur.
 Drawn at the offices of the Soil Science Division, Division of Agriculture,
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REFERENCE

- Railway with Station
- Principal Road
- Other Motorable Road
- Cart Track
- Light Railway
- Rivers & Streams
- International Boundary
- State Boundary
- District Boundary
- Town & Village Sites, Aerodrome
- Lighthouse, Civil Radio Station
- Trigonometrical Station with Height
- District Head Quarters
- District Name
- State Capital
- State Name



Approximate limit of strong Burmese-Thai floristic element (White meranti-geru forest and *Schima*-bamboo forest).

Approximate limit of 1883 devastated zone ('storm forest').

STRAITS OF MALACCA

SYMBOLS

A *Agathis alba* common

AG. YAHAN
 KAIANG
 KLANG
 SEREMBAN
 PERAK

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VEGETATION MAP OF MALAYA, 1962

Compiled at the Forest Research Institute, Kepong under the supervision of

J. Wyatt-Smith, Silvicultural Research Officer,

Division of Forestry, Ministry of Agriculture and Co-operatives, Kuala Lumpur.

Drawn at the offices of the Soil Science Division, Division of Agriculture.

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Approximate limit of 1883 devastated zone ('storm forest').

Scale 2.4 Miles to an Inch
Miles 10 5 0 10 20 30 40 50 Miles

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REFERENCE

Railway with Station	-----
Principal Road	=====
Other Motorable Road	-----
Cart Track	-----
Light Railway	-----
Rivers & Streams	~~~~~
International Boundary	-----
State Boundary	-----
District Boundary	-----
Town & Village Sites, Airports	•••••
Lighthouse, Civil Radio Station	•••••
Trigonometrical Station with Height	•••••
District Head Quarters	•••••
District Name	•••••
State Capital	•••••
State Name	•••••

Approximate limit of strong Burmese-Thai floristic element (White meranti-gerutu forest and *Schima*-bamboo forest).

Approximate limit of strong bornean floristic element.

SYMBOLS

- A *Agathis alba* common.
- B Balau forest.
- C Chengal forest.
- CH Coastal hill forest.
- D Damar laut merah forest.
- F Freshwater alluvial swamp forest.
- G Gelam forest.
- H 'Heath' forest.
- I Kekatang-merbau forest.
- K Keruing forest.
- L Limestone vegetation.
- N Nemesu forest.
- P *Shorea platyclados* common.
- R Red meranti-keruing forest.
- S *Schima*-bamboo forest.
- SC Shifting cultivation.
- T Kempas-kedondong and poor quality forest.
- W White meranti-gerutu forest.

LEGEND

- Land above 5,000 ft. a.s.l.; Montane ericaceous forest and upper limits of montane oak forest.
- Land between 3,000 ft. and 5,000 ft. a.s.l.; Upper dipterocarp forest and montane oak forest.
- Land between 1,000 ft. and 3,000 ft. a.s.l.; Hill dipterocarp forest and upper dipterocarp forest.
- Land below 1,000 ft. a.s.l.; Forest land unspecified other than by letter symbols.
- Land below 1,000 ft. a.s.l.; Kempas-kedondong forest (see also symbol T).
- Land below 1,000 ft. a.s.l.; Limestone vegetation (see also symbol L).
- Land below 1,000 ft. a.s.l.; Marine alluvial (mangrove) forest, not directly on seaface along east coast.
- Land below 1,000 ft. a.s.l.; Freshwater alluvial swamp forest (see also symbol F) and peat swamp forest.
- Cultivation, urban and mining land, etc.
- Limit of area containing Kapur forest.
- Narrow strip of Beach (strand) forest not indicated; common along east coast, rare west coast.

NOTE

This vegetation map has been compiled from all existing useful records at the Forest Research Institute, Kepong. Within the limitations of the scale, it represents a first attempt at a vegetation map of Malaya which includes some considerably depending upon the steepness of the slopes and the total height and relative position of the main mountain masses; accordingly these types have been broadly delineated on the basis of the three contour lines of 1,000 ft., 3,000 ft. and 5,000 ft. a.s.l. which have been obtained from maps published by the Survey Department, Federation of Malaya. The narrow strip of Beach (strand) forest, which is common along the east coast, and the characteristic riparian fringes are not indicated; nor has it been possible to show that the mangrove forest along the east coast is not exposed to the sea face, but lies within the mouths of tidal rivers. The extent of the 'developed' land (cultivation, urban and mining land etc.) shown white on the map is based upon the Forest Resources Map of Malaya, 1954; very considerable extension has occurred during recent years.

with soils (5), although it would be premature to express definite relationships. It has also become evident that the uniform silvicultural system of management, largely evolved around the Red Meranti-Keruing type of forest, was not entirely satisfactory when applied to those types in which these quick-growing species (*Shorea* and *Dipterocarpus*) are poorly represented or totally absent.

VEGETATION MAPS

The first vegetation map of Malaya of any significance was that compiled in 1958 by van Steenis, who used information supplied to him by the Malayan Forest Department at the beginning of the Second World War. This distinguished the following broad categories: rain forest, comprising all dryland natural forest from sea level to mountain tops; dipterocarpaceous rain forest, the major variant of the previous category; *Agathis* rain forest, another variant of rain forest, which was said to occur in Malaya but not in sufficient areas to be indicated on the small scale of the map (1:5,000,000); freshwater swamp and peat-swamp forest; mangrove forest; secondary forest and grassland.

The second map (scale 1:4,500,000, approx.) was that produced by Ooi Jin-bee in 1960 (6), in which six main vegetation types are shown: montane forest above 4,000 feet, sub-montane forest ranging between 2,500 and 4,000 feet; lowland rain forest found below 2,500 feet; freshwater swamp forest; beach forest; and mangrove forest. This map provided little further information than that shown in the 1:760,300 Forest Resources Map of Malaya published by the Malayan Survey Department on behalf of the Malayan Forest Department in 1954, which indicated the extent of mangrove forest, swamp forest, lowland rain forest under 1,000 feet in altitude, and hill/mountain forest above this height.

The map which accompanies this paper as Figure 1 was compiled from data available at the Forest Research Institute, Kepong, Malaya. The basis upon which vegetation types were selected is economic rather than strictly ecological. Proper ecological studies based on a systematic reconnaissance from aerial photographs and ground checks have only just begun, and even the first phase of this work will not be completed for another two or three years. The map follows closely those forest types in the commercially valuable inland forests mentioned by the author in 1961 (5), and indicates the extent of mangrove forest, which was omitted from the earlier paper. It also indicates the commercially unimportant vegetation types of the country.

It is not possible to show on such a small-scale map the altitudinal limits of all the hill and mountain types of vegetation. On the steep slopes of isolated hills, especially coastal hills, the change from one vegetation type to another is often rapid or occupies a narrow zone. In addition, these altitudinal limits vary considerably on isolated hills and ridges as compared with the Main Range and large massifs. As the only contours shown on the map are those for 1,000, 3,000 and 5,000 feet above sea level, the general upper limits of lowland dipterocarp forests and the lower limits of montane ericaceous forests are correctly indicated, but the upper dipterocarp forest is not separately shown: its lower portions are included with hill dipterocarp, and its upper portion with montane oak forests.

Because of the small scale of the map it is also impossible to indicate the following: the narrow strips of beach forest; the vegetation of quartz dykes, narrow quartzite ridges and other sclerophytic habitats; the interesting and distinct riparian communities; regenerated forest, in which economic species are encouraged by poison-girdling or felling of undesirable competitors; and the numerous types of

secondary vegetation, seral and sub-seral communities that exist in all the main forest types. However, notes on some of these vegetation types are provided, those marked in the text with an asterisk (*) representing the types too small to be shown on the map.

FLORISTIC ZONATIONS

The Malayan flora, amongst the richest if not the richest in the world, and vegetation are of very great interest in view of the geographical location of the peninsula — the most southerly land mass of continental Asia, lying immediately south of seasonally dry climates. The country is a meeting place of several regional floras. The flora and vegetation of the extreme north-west is similar to that of Thailand, and Thai and Burmese species extend as far south as central Malaya. In the south, the flora is typically Sundanese, with an Australian element which is also found along the coasts and in the mountain range of central Malaya. The west coast flora is similar to that of Sumatra, and in the south-east there is a strong Bornean element which extends as far north as the border between Kelantan and Trengganu.

The approximate limits of some floristic and vegetational zonations due to non-edaphic factors are indicated on the map. These are as follows:

(a) *Limit of Burmese-Thai floristic element in the lowlands (White Meranti-Gerutu forest)*

The extreme north-west of Malaya, comprising Perlis, the islands of Langkawi, and that part of mainland Kedah north of Kedah Peak, Bukit Perak and Padang Sanai (but excluding the Bukit Perangin and Bukit Koh Mai hill masses), has a climate with a distinct dry season from December to February; the average monthly rainfall in January and February is less than two inches, and the total annual precipitation between 80 and 90 inches. This seasonality is reflected in the vegetation, which is predominantly Burmese and Thai in species, although the structure of the natural forest is only slightly different from that of other lowland communities. In addition, much of the region has long been subjected to shifting cultivation, so that the precise boundary between the north-western Burmese-Thai forest type and southern lowland dipterocarp forest is difficult to determine. It also seems likely that secondary species of the Burmese-Thai type have extended southwards as a result of long-continued shifting cultivation, which has emphasised the annual seasonal drought through more rapid runoff and accelerated evaporation. There is also a natural overlap between forest types, since many of the species of the Burmese-Thai forest that occupy flat lowlands in north-west Malaya are found at slightly higher altitudes on hill slopes and low ridges further south (north-east Kedah, upper Perak and the Kledang Saiong range, north Kelantan).

(b) *Limit of Bornean floristic element*

The exact limits of the Bornean species are not known, and the line on the map only indicates the area of strongest influence. Many species of typical Bornean affinities occur throughout south Johore and along the east coast to north Trengganu, while yet others are found isolated in the low-lying, semi-swamp localities of the lower valley of the Perak River in western Malaya.

(c) *Limit of 'Storm Forest'*

In 1883, the year when Krakatau exploded, there was a violent hurricane which devastated forests in parts of Kelantan and Trengganu. Destruction was increased by the fires that followed the hurricane (7). The forest is distinctly patchy, there being many areas of apparently immature forest with trees of much

smaller sizes. Species normally found in the main storey are poorly represented, the number of *Shorea* spp. being relatively few. However, the vigorous and aggressive species *S. leprosula* and *S. parvifolia*, the two most common species in young regenerated forests today (8), are frequent to locally abundant in the upper storey. The forest is often of a two-storey structure — in contrast to the three storeys of natural lowland forest — and has a total height of about 100 feet and a relative abundance of lianes and woody climbers. Many of the large stems have a distinct bend or curve between 30 and 50 feet above the ground, possibly the result of former tangles of climbers. Only a few species appear to reach logging size and, although species of *Dipterocarpus* (mainly *D. costulatus* and *D. kunstleri*) are common in the patches of immature forest, large specimens of these species (6 to 8 feet girth and over at breast height) are relatively rare in the 'older' *Shorea* forest. The ecological significance of these patches is not known. Experience in forest plantations does not indicate such a large difference in the rate of growth between *Dipterocarpus* species and the light hardwood *Shorea* species of approximately the same age, as is found in these storm forests. It is possible that a soil factor is involved, since it has been learnt recently that areas of poor soil occur in the Chabang Tongkat Forest Reserve, where patches of apparently immature (stunted) forest containing many *Dipterocarpus* stems are particularly striking. On the other hand, storms occurring in different years and of varying intensities, perhaps coinciding with bumper seed years of different species, might be an explanation.

Similar wind damage to lowland forest occurred in Malacca in 1917, resulting in the evolution of a related *Shorea*-dominated forest such as that occupying the Merlimau Forest Reserve.

VEGETATION TYPES

It is not intended to give detailed descriptions of the various vegetation types, nor to repeat in full the information already published on the forest types of Malaya (1, 5). The following notes, with a few additions which are starred with an asterisk (*), are a guide to the types shown on the preliminary map. For ease of reference the types are arranged alphabetically in three groups, namely:—

- I. Lowland (dryland) vegetation
- II. Hill and mountain vegetation
- III. Swamp and low-lying vegetation

I. LOWLAND (DRYLAND) VEGETATION

A. Primary Forest

The primary lowland forests are usually dense, though comparative freedom of movement on the ground is possible. They are composed of many thousands of species of trees (often up to one hundred different species with a girth of more than one foot are found to the acre), as well as shrubs, herbs and woody climbers. The upper or emergent storey is usually about 100 to 150 feet high, though trees nearly 200 feet in height are often present. This storey is often discontinuous. An average of one to two trees per acre may have a girth of ten feet or more. This upper or emergent storey is usually characterized by a high occurrence, about fifty per cent, of the family Dipterocarpaceae, though in some forests they are rare or almost absent. The main storey or second tree layer, which occupies a region of about 70 to 100 feet from the ground, forms a continuous canopy except immediately below the large emergent storey trees. This storey consists of young trees of the normal upper storey species together with, predominantly, members of the families Burseraceae, Guttiferae, Myristicaceae, Myrtaceae (*Eugenia* spp.) and

Sapotaceae. The understorey or third tree layer consists of saplings of the upper two storeys together with members of such families as Annonaceae, Euphorbiaceae, Flacourtiaceae and Rubiaceae. The density of the shrub layer varies from very thick and dense to open. It contains young saplings of larger trees, shrub species of Annonaceae, Euphorbiaceae and Rubiaceae and palms. The herb layer consists mainly of young seedlings of the other layers and lianes, with some aroids and ferns near streams and in moist valleys. Epiphytes are usually very poorly represented. There is usually a comparatively poor layer of litter, though fallen leaves often cover the forest floor.

Many of the trees are buttressed; some have stilt roots; others have fluted stems. The bark ranges from smooth, scaly to fissured, and the form of the stems is excellent, with typically a long clear bole and little taper.

It has usually been considered impossible to subdivide these lowland dipterocarp forests into recognized associations or consociations. On the other hand it has become increasingly evident during recent years that certain broad and rough divisions into definite types can be made on the basis of the larger economic trees.

Balau Forests. These forests are mainly found in north Johore, east Negri Sembilan, west Pahang and north Trengganu. They are characterized by a high percentage of the Balau or heavy hardwood group of *Shorea*, of which *S. atrinervosa*, *S. exelliptica* and *S. maxuelliiana* are the most common. *Dipterocarpus* spp. and species of the Red Meranti group of *Shorea* are also frequently present.

Beach Forests. These form a very narrow strip of woodland, rarely more than twenty to forty yards wide and frequently less, along the sandy or gravelly beaches of the coast, above the level of all but the highest tides. They occur along much of the length of the east coast, albeit often in a disturbed form. But they are comparatively rare along the more muddy shores of the west coast, where mangrove forests predominate and where most of the sandy and gravelly beaches which do exist have been developed or greatly disturbed by man.

Along the accreting sandy beaches *Casuarina equisetifolia* is the predominant species often with *Calophyllum inophyllum*, *Cycas rumphii*, *Desmodium umbellatum*, *Eugenia grandis*, *Pandanus tectorius*, *Planchonella obovata*, *Scaevola sericea* and *Terminalia catappa*. There is usually in addition a narrow herbaceous formation of *Ipomaea pes-caprae*, *Ischaemum muticum*, *Spinifex littoreus* and *Vigna marina* between the woody belt and the high tide mark.

Along the receding and the gravelly beaches, notably on the west coast, the herbaceous formation is missing and the Casuarina fringe replaced by a narrow belt of trees of characteristic species, of which *Barringtonia asiatica*, *Calophyllum inophyllum*, *Cerbera manghas*, *Desmodium umbellatum*, *Hibiscus tiliaceus* (at the mouths of streams and at points of freshwater seepage), *Pongamia pinnata*, *Scaevola sericea* (a bushy shrub), and *Terminalia catappa* are common.

This type has been destroyed in many places along the east coast and secondary growth allowed to return. Owing to the demand for firewood and poles, the regrowth is very scrubby and scrambling shrubs and woody climbers predominate; the shrub *Rhodomyrtus tomentosa* is particularly common.

Chengal Forest. *Balanocarpus heimii* or chengal characterizes this forest and is Malaya's best known heavy hardwood, occurring in many parts of the country. However it is absent from northwest Malaya and Malacca and poorly represented in much of central Malaya and Johore. The species is found in most types of lowland and hill dipterocarp forest, but it is especially common in the Bukit Goh

and Lepar Forest Reserves of east Pahang and in most reserves of west Pahang. It is also found in some parts of the eastern foothills in Negri Sembilan, some foothill reserves of Selangor and north-east Malaya, and in some foothill and lowland reserves in Perak, apparently preferring a rich soil.

Damar Laut Merab Forest. This forest is characterized by the presence of *Shorea kunstleri* (damar laut merah), which is particularly common in many of the forests in the foothills of south Kedah, north Perak, east Kelantan, Trengganu and north of the Pahang River in east Pahang.

'Heath' Forest. Along the east coast a clear pattern is frequently revealed of strips of high forest interspaced with strips of shorter vegetation, the strips running in general parallel to the present coastline. This high forest is growing on old sandy beach ridges (known as permatang or padang) with a podzolic profile and a B horizon about two feet or more below the surface. The soils become temporarily waterlogged after heavy rain and in particular during the north-east monsoon. There is often a thick layer of litter with a mass of feeding roots on the surface just beneath.

The forests differ from true lowland dipterocarp forest, being simpler in composition and structure (although still strictly three-layered), and lower in height. The main storey is about 50 to 70 feet high and often fairly open with a rather discontinuous upper layer of scattered tall trees reaching a height of 80 to 100 feet. There is a fairly dense small tree (less than 6 inches girth breast height) layer up to about 35 feet. The average clear bole height of the commercial trees is about 40 feet.

This type of forest was formerly, it is believed, fairly extensive along Malaya's east coast and of local occurrence along the west coast, but it has largely been destroyed. A small area, however, still remains in the northern part of Tanjong Hantu Forest Reserve in the Dindings on the west coast, and two accessible areas are known to remain along the east coast — Jambu Bongkok Forest Reserve north of Dungun in Trengganu and Menachali Forest Reserve in the Rompin District of Pahang. All three areas, however, have been subjected to disturbance.

This forest type degrades very easily as a result of timber exploitation, unless exploitation is of a very light nature. When the forest is clear felled the secondary regrowth on cessation of cultivation is that of very open scrub, especially if the land is cultivated for more than one season. This scrub is frequently subject to the ravages of fire, resulting in the development of either an open grassland of tufted grasses or parkland with a few scattered trees or shrubs. Of these trees or shrubs, *Anacardium occidentale*, *Fagraea fragrans*, *Melaleuca leucadendron*, *Melastoma malabathricum*, *Morinda citrifolia*, *Ploiarium alternifolium*, *Rhodomyrtus tomentosa* and *Vitex pubescens* are the commonest, though often only *Fagraea fragrans*, *Ploiarium alternifolium* and *Melaleuca leucadendron* predominate.

Kapur Forests. These forests, characterized by the presence of *Dryobalanops aromatica* (kapur), are found in eastern Malaya, usually never more than about fifteen to twenty miles inland (except in Johore), on low hills and undulating land with a yellow-orange, well drained, sandy clay loam soil. In addition there are two small pockets north of Kuala Lumpur, one in Bukit Lagong Forest Reserve and the other in Kanching Forest Reserve.

The forest structure is typically three-layered, but the individuals forming the emergent or upper storey are generally taller than is usual in lowland dipterocarp forests. *Dryobalanops aromatica* is a gregarious species, and often over small areas

forms a pure crop of tall 'emergent' trees with coalescing crowns. Representation in the smaller (seedlings and saplings) and middle-sized classes is very much better than with *Shorea* and *Dipterocarpus* species and most other emergent layer species of lowland dipterocarp forest. It is usually found mixed with other dipterocarps, both *Shorea* spp. and *Dipterocarpus* spp. and, but for its presence and predominance, the forest would be classified as either Red Meranti-Keruing type or Balau type.

Kempas-Kedondong Forests. These forests, often of poor timber value, with the tallest trees few in number and rarely exceeding 100 feet in height, occur mainly in the rather low-lying and flatter land between the Red Meranti-Keruing or Balau forests and the swamp forests. They are found principally in central and south Perak, Selangor and Johore, where the forests appear to be associated with heavy, white clays of poor status and old beach ridges. These forests are characterized by the comparative abundance of *Koompassia malaccensis* (kempas), *Canarium* and *Santira* spp. (kedondong), *Dialium patens*, *D. platysepalum* (keranji), *Dillenia eximia* and *D. reticulata* (simpoh), *Ixonanthes reticulata*, *Madhuca* spp. and *Palaquium* (nyatoh), and by the relative scarcity or complete absence of dipterocarps. Locally, *Palaquium gutta* is a common species.

Keruing Forests. On some of the less well drained land in north Johore, central, east and south Pahang, east and west Negri Sembilan, the Kinta and Batang Padang Districts of Perak and the northern part of Trengganu, extensive areas of forest are found characterized by *Dipterocarpus* spp. (keruing), which are often associated with *Dryobalanops oblongifolia*, *Hopea mengarawan* and *Shorea lepidota*. Other common species are *Koompassia malaccensis* and *Palaquium* spp. Much of the area is slightly waterlogged at certain times of the year. The height of the upper tree layer is less than that in Red Meranti-Keruing forest, and this layer is frequently very discontinuous, with the large trees resembling true emergents.

Lowland Dipterocarp Forest. The term 'Lowland Dipterocarp Forest' generally includes all the well drained primary forests (cf. swamp forests) of the plains, undulating land and foothills up to an elevation of about 1,000 feet, with the exception of the narrow strip of beach forest. Symington also excluded 'Heath' Forest. They comprise the bulk of the commercially important forests.

Merbau-Kekatang Forest. This type is found in the foothills of the Main Range, principally in north Malaya, and is usually very deficient in dipterocarps and other economic tree species. It is characterized by *Intsia palembanica* (merbau) and *Cynometra inaequifolia* (kekatang). *Sindora* species are also frequently present.

Nemesu Forest. *Shorea pauciflora* (nemesu) occurs throughout the Peninsula except Perlis, but it is particularly common in undulating country and the foothills of north Malaya, where it frequently characterizes the forest.

Red Meranti-Keruing Forests. These forests are mainly found in south Perak, Selangor, Negri Sembilan, Malacca, north and central Pahang, south Kelantan and central Trengganu. They are characterized by a high percentage, in the upper storey, of species of the Red Meranti group of *Shorea*, of which *S. acuminata*, *S. leprosula*, *S. macroptera*, *S. ovalis*, *S. parvifolia* are the most common species, and of *Dipterocarpus*, of which *D. baudii*, *D. cornutus*, *D. grandiflorus*, *D. kerrii*, *D. sublamellatus* and *D. verrucosus* predominate. The species are often gregarious as several or as individual species. Several of the species may be completely absent in some tracts of forest. The shrub and sapling layer is usually rather open, with the palms *Eugeissona triste* (mainly west of the Main Range), *Licuala* spp. (mainly east of the Main Range) and the shrub or woody scrambler *Agrostistachys* spp. often being locally common. The ground flora is poorly represented and consists

mainly of seedlings of the large trees. These are the main commercially important forests of Malaya.

White Meranti-Gerutu Forest. These forests include those which Symington (4) referred to as having a predominantly Burmese flora, and are found where there is a distinct annual dry season of about two months. They are characterized by (a) the absence of the Red Meranti and Damar Hitam groups, (b) the paucity of the Balau group, and (c) the relative abundance of the White Meranti group (Anthoshorea) of the genus *Shorea*. Other common and characteristic dipterocarps are *Parashorea lucida* (gerutu-gerutu), *Anisoptera oblonga*, *Dipterocarpus dyeri*, *Hopea helferi*, *H. latifolia* and *Vatica cinerea* and of non-dipterocarp species *Dillenia obovata*, *Parkia javanica* and *Pentace curtisii*. These forests occur on the flat lowlands of the extreme north-west of Malaya (Perlis and north-west Kedah) and at a slightly higher elevation on hill slopes and low ridges farther south in north-east Kedah, upper Perak and north Kelantan. The forests are less dense and the canopy less tall than those further south, and scramblers and woody climbers are more frequent.

B. Secondary Forest*

The lowlands of Malaya have been subject to much destruction by storms (wind and lightning) and floods, by aborigines practising primitive shifting cultivation for several centuries and by the rapid development of modern Malaya during the past century. Other than on old mining land, pioneer species are normally the same in all areas, but the extent and the length of time to which any particular species may exert any influence undoubtedly depends upon the length of former cultivation, if any, and the care with which the land was treated during cultivation. Furthermore, the pattern of recolonization depends upon the proximity of the land to the source of seed in high forest and in existing secondary areas, and also upon the occurrence of roads, railway lines and large tracts of developed land, which are the invasion lines and introduction centres of many exotic pioneer species. A high percentage of these pioneer species are from the New World.

Trema spp. are the most prominent early pioneer species on gently undulating land deforested and cultivated for one or at the most two years before being abandoned. They are generally followed by species of *Macaranga*, *Mallotus*, *Ficus* and *Glochidion*. If the land is cultivated for several years before being abandoned, and the soil fertility is thoroughly exhausted, a *Melastoma-Eupatorium-Gleichenia* scrub develops; this community readily burns and continual fires soon convert such areas into almost pure *Imperata* grassland. In south Malaya on degraded land a woody community dominated by *Adinandra dumosa* often develops and, once established, it appears to be maintained by periodic ground fires. On foothill slopes banana-ginger thickets and in the valleys of the Main Range, bamboo groves commonly arise after shifting cultivation by aborigines.

In north-west Malaya much of the area formerly covered by White Meranti-Gerutu forests has long been subject to shifting cultivation and the original vegetation has given way to a type characterized by the trees *Schima noronhae* and *Shorea talura* and the bamboos *Gigantochloa latifolia* and *G. ligulata*. The forests are still subject to occasional fire and intermittent selective cutting, and secondary vegetation occurs as a patchwork mosaic in all stages of development from open land, through low scrub, bamboo scrub, bamboo clumps interspersed and overtopped by a discontinuous canopy of scattered trees ranging from 60 to 100 feet tall, to closed forest.

II. HILL AND MOUNTAIN VEGETATION

Hill Dipterocarp Forests. These occur on the inland ranges between the approximate altitudinal limits of 1,000 and 2,500 feet. Aspect and site however are important factors, and the forests have a tendency to be found at lower limits (down to 500 ft) on exposed ridges and at higher limits in the more sheltered valleys. This is very noticeable on isolated mountains and on coastal ranges where the forests are depressed to very low elevations and occur almost at sea level. There is no sharp difference in vegetation at the 1,000 ft. contour, and the main difference between lowland dipterocarp and hill dipterocarp forest is a shift in the floristic composition of the dominants in the upper and main tree storeys. Many of the common lowland forest species are still found in the hill forests, but less frequently, while many species occur which are absent in lowlands. The most common large tree species of this type of forest is *Shorea curtisii* which tends to be gregarious and shows a distinct preference for ridge tops. The balau group (heavy hardwoods) of the genus *Shorea*, in particular *S. laevis*, and several species of *Dipterocarpus* are also commonly represented.

As with lowland dipterocarp forest, it has not been customary to recognize distinct associations, though several association segregates have long been distinguished. Forest differences have also been recognized between the vegetation on the ridges, the hill sides and the valley bottoms. The large trees in hill forest are usually slightly smaller and less tall than the tallest in lowland forest, except for the big trees on the ridge tops which are in general a little taller. The density of trees over four feet girth on ridge tops is greater than in lowland forest, and there are correspondingly fewer trees in the understorey and in the lower part of the main storey. The ground flora is also usually extremely poor, owing partly to the common occurrence of the palm *Eugeissona triste*. The vegetation of hill slopes, particularly steep slopes, is often poorly stocked in woody species and the understorey is usually very rich in stemmed and stemless palms and rattans. In valley bottoms large woody species are also often comparatively poor and the forest is characterized by the richness in the ground flora and shrub layer. *Alocasia* spp., *Colocasia* spp., *Donax grandis* and many ground ferns are common. Litter on the forest floor is frequently, by tropical standards, quite thick.

No attempt has been made to differentiate hill forest types on the map, apart from indicating the presence of Coastal Hill forests and the location of areas known to be rich in *Agathis alba*. These hill types will merit very much greater ecological attention in the future than they have received in the past, since the productive forest estate will be increasingly dependent upon them as a result of accelerating agricultural development in the lowlands.

Agathis alba. This species is very common, almost gregarious, on certain ridges. The reasons for its local but wide distribution are not known, but it is often found on ridges on a comparatively shallow soil over quartzite.

Coastal Hill Forests. In coastal areas, hill forest with a slight change of subsidiary species occurs at very low elevations, sometimes almost at sea level. The most characteristic species is *Shorea glauca* which is often gregarious on the seaward slopes.

Limestone Vegetation. The limestone rocks with their abrupt cliffs are a striking feature of the Malay Peninsula. They are most common in the north-west of Malaya, but they also occur in Perak near Ipoh and north to Lenggong, in Pahang, central inland Trengganu, Kelantan near the railway from the Pahang boundary

northwards to Sungei Pergau, and in Selangor near Kuala Lumpur which is their most southerly locality.

Depending upon the habitat, the vegetation of limestone hills varies greatly in structure from communities of short plants on exposed vertical faces and rocky exposures to those of from a few feet to about 60 feet tall containing shrubs and small trees. Larger trees up to 100 feet tall, however, are often found growing in the pockets of accumulated deep rich soil and around the foot of the hills. In the sheltered gullies, despite the rocky habitat, there is often a microclimate with a high humidity and a lush ground cover is present.

The vegetation has both calcicoles and rock-loving elements and is comprised of lowland species. The number of tree species is not great. *Taxotrophis ilicifolia* and *Zizyphus* spp. are often very common in the shrub layer, and clumps of *Pandanus* spp. are also often a feature. The most characteristic plants however of the limestone vegetation are the small herbs and rockface species, many of which belong to the family Gesneraceae.

In the deep pockets of limestone soil in gullies, at the foot of cliffs and in the often large depressions (sink holes, or 'wangs' as they are termed in Perlis) surrounded by limestone cliffs, high forest occurs, though most of it has been destroyed by cultivation.

Little destruction of the vegetation on the rocky outcrops has taken place other than by total elimination through quarrying and by occasional fire, which may sweep through after a particularly dry spell.

Montane Ericaceous Forests. These forests occur in the cloud belt above the montane oak forest. They may, however, be found on exposed ridges and summits at altitudes lower than 5,000 feet. They differ from the montane oak forest in specific composition, typically a reduction to a single tree layer, in structure by a general dwarfing of the forest to about 30 feet tall (only a few feet tall in extreme cases, as on sharp narrow ridges), a frequent gnarled form of the trees, and normally with a greatly increased development of liverworts, mosses and filmy ferns, both on the trunks of the trees and on the ground. *Sphagnum* spp. are common. These forests are also often characterized by an accumulation of acid humus and peat around the roots of the trees, in which epiphytes, mosses, filmy ferns and herbs abound, the forest giving the appearance of an aggregation of mound communities.

Oaks, so common in the montane oak forest, are not absent, but are limited to a few species. The forest is characterized by the prevalence of ericaceous species. Epiphytic orchids are common and rhododendrons frequent.

Upper Dipterocarp Forests. This type of forest is found on the higher hills between the approximate altitudinal limits of 2,500 and 4,000 feet, but, as in the case of hill dipterocarp forest, it may be depressed in a narrower and much lower belt on coastal ranges or on isolated mountains. The species are very different from those found in the hill dipterocarp forest. The forest structure is much the same, namely three-layered, though the upper layer is less tall (80 to 100 feet) and with a more even upper canopy level, and the trees rarely exceed five feet in girth and are not so frequently buttressed. The second and upper tree layers are frequently less distinct as separate entities. The family Dipterocarpaceae, which is such a characteristic feature of the lowland dipterocarp and hill dipterocarp forests, is represented by only a few species, but these species are distinctly those of a high elevation. The forest is often characterized by the presence of *Shorea platyclados*. The shrub layer is frequently characterized by the presence of rattans and dwarf

palms; the ground flora by species of *Argostemma* and *Sonerila*, *Selaginella atroviridis* and the fern *Thelypteris chlamydophora*; and there is generally a fair amount of leaf litter.

Vegetation of quartz dykes, quartzite ridges and other sterile habitats with severe drainage or lacking available moisture. Scattered in small pockets throughout Malaya from coast to mountain top are non-calcareous habitats, such as quartz dykes and quartzite outcrops, where mineral soil is inadequate, soil moisture is often extremely low, despite a high rainfall, and a dry mor humus or peat over a shallow sandy soil is generally formed.

The structure of the vegetation varies considerably, depending upon the nature of the habitat. On exposed rocks the vegetation takes the form of small cliff-loving plants; on very shallow quartzite soils open scrub 3 to 15 feet tall is found; on slightly deeper soils a 20-foot pole-like crop, frequently with *Calophyllum* and *Eugenia* species predominating, often occurs; where pockets of slightly deeper soil exist, trees 40 to 50 feet tall are found; on still deeper soils, and particularly at high elevations, forest 70 to 80 feet tall occurs, or even forest over 100 feet where *Agathis alba* is present. In the latter instances, however, the vegetation represents only a slightly adverse aspect of the optimal forest type, and one in which the tropical conifers are particularly conspicuous.

On such sites specialized scrub to low forest communities are found. Species present include most of the conifers (*Agathis*, *Dacrydium*, *Podocarpus*), the shrubs or small trees *Baeckia frutescens*, *Leptospermum flavescens*, *Leucopogon malayanum*, *Medinilla*, *Rhodamnia cinerea*, *Rhododendron*, *Tristania*, *Weinmannia blumei*, the sedges *Cladium* and *Gabnia*, the herbs *Didymocarpus* spp. and *Sonerila* spp., pitcher plants, the ferns *Dipteris conjugata* and *Oleandra pistillaris* and the lichen *Usnea barbata*.

Most of the above species, including amongst others the most interesting fern *Matonia pectinata*, are found at higher elevations on similar exposed sites and on those of very shallow quartzite-derived soils.

At high elevations, where there is deeper but still excessively well drained soil on the ridges, forest conditions prevail, but the tropical conifers and other tree species of typical Australian genera tend to predominate over those species occurring normally in forest growing under better habitat conditions at such elevations.

On many of Malaya's mountain summits, but in particular on the Gunong Tahan and eastern massifs of sedimentary rock formation, there occur scrub communities, often only one or two feet tall, which cover extensive flat to flattish areas of very shallow soil. The floristic composition is most interesting in that the individuals are dwarfed representatives of species typically of shrub or tree form.

Another interesting community dominated by *Livistona*, the ecological status of which is unknown, but which is thought to be associated with a drying effect by strong winds coupled with poor shallow soils over sedimentary rocks, is found on the tops of many of the south Trengganu hills — even on low hills near the coast — and between elevations of 3,500 and 4,500 feet on part of the Gunong Tahan massif.

III. SWAMP AND LOW-LYING VEGETATION

Freshwater Alluvial Swamp or Lopak Forests. The soil surface of the land covered by these forests is semi-permanently to temporarily submerged in mineral-rich, non-acid fresh water, and the water level consequently fluctuates, with periodic dry-

ing of the soil. Though a few inches of peat or muck soil may occur, they should not be confused with peat swamp forests, which grow on deep peaty layers entered only by rainwater and which have a restricted and specialized flora (some of these species occur in the shallow and comparatively narrow swampy depressions under 'Heath' Forest, which have very acid water, along the east coast). These forests are found throughout Malaya under a wide environmental and inundation range; accordingly, their floristic composition and structure vary enormously, from those with a few large scattered trees 80 to 100 feet tall over open scrub, or dense 30 to 60 feet tall pole forests, to 100 feet tall peat swamp-like forests. Stilt roots, knee roots and plank-like sinuous buttresses are found in some species, but are not a feature of these forests. Single species often predominate over large areas, such as sedges, screw pines, rattans and palms in the Rompin District on the east coast, the Sungei Tinggi area of Selangor, and the Tasek Bera area of south-west Pahang.

As a result of felling, cultivation, burning or alteration of the natural drainage, many seral and sub-seral communities evolve on land that once bore swamp forest. The most important is *Gelam Forest* (*Melaleuca leucadendron* often associated with *Ploiarium alternifolium*, both occurring as scattered trees in the swamp forest found between old beach ridges or, more characteristically, on the seasonally-wet swamps of coastal flats behind the sandy beaches and mangroves of Kedah, Malacca, Negri Sembilan, Kelantan and Trengganu). *Gelam* regenerates freely by coppice and suckers and is fire-resistant; so that in areas where regular fires occur, either deliberately or spread from adjacent cultivated areas in the dry season, an almost pure stand of *Melaleuca* develops, in which the climbing fern *Stenochlaena palustris* and *Scleria* spp. are characteristic. *Gelam* is a valuable source of firewood and charcoal.

Marine Alluvial (Mangrove) Swamp Forests. These forests are confined to muddy shores, lagoons and the estuaries of tidal rivers. They cover an overall area of about 350,000 acres in Malaya, almost all of which is along the sheltered west coast, mainly in the States of Perak (128,000 acres), Selangor (96,000 acres) and Johore (90,000 acres). Along the east coast, they are found within the mouths of tidal streams. The vegetation is simple in structure, 20 to 80 feet in height, depending on the community, with a comparatively even and unbroken top canopy and a very poorly developed or completely absent under-storey or shrub layer which is poor in species. The principal tree species are found nowhere outside these habitats and are frequently characterized by special root formations such as stilt roots (*Rhizophora* spp.) and pneumatophores (*Avicennia*, *Bruguiera*, *Sonneratia* and *Xylocarpus* spp.) and by the phenomenon of vivipary (*Bruguiera*, *Ceriops*, *Kandelia* and *Rhizophora*).

The composition of this simple forest depends on the soil within the textural range of sands, fine silts and heavy clays; the duration and frequency of inundation; the salt content of the water; the strength of the tides; and the exposure or degree of shelter of the site. Each ecological niche is dominated by a few species, giving rise to a zonation of different communities that is repeated throughout the mangroves and which readily shows up in aerial photographs. *Avicennia alba* and *A. lanata* are pioneer species on stiff clay and on the less sheltered parts of the river mouths along the east coast; *Avicennia alba* and *A. officinalis* are the pioneer species on the exposed accreting portions of the west coast; *Avicennia alba* and *Sonneratia alba* are the pioneer species on soft muds in sheltered areas; *Ceriops decandra* plays a similar role in the soft muds that are deposited in the sheltered parts of east coast estuaries. *Avicennia intermedia* and *Bruguiera cylindrica* together, or the latter species on its own, form an almost pure community on stiff clays. The main mangrove forests, behind the coastal and tidal belts colonized by *Avicennia* and

Sonneratia, which are inundated daily, are made up of almost pure stands of *Rhizophora apiculata* with a little *Bruguiera parviflora*. Along the banks of creeks *Rhizophora mucronata* is found and on the drier and landward margins of true mangroves there are *Bruguiera eriopetala*, *B. gymnorrhiza*, *B. bainesii*, *Heritiera littoralis*, *Intsia retusa*, *Xylocarpus gangeticus*, the stemmed palm *Oncosperma filamentosa* which often forms groves, and the fern *Acrostichum speciosum*. *Hibiscus tiliaceus*, *Sonneratia caseolaris* and *Xylocarpus granatum* are found on the banks of tidal rivers.

Peat Swamp Forests. These forests are of a very special type, found on peats ranging from a few feet to about twenty feet in thickness immediately behind the coast, principally of central and southern Malaya. These peats evolve in permanently waterlogged and anaerobic habitats, where the only incoming water, from rain, is deficient in minerals. This water is almost black in colour when viewed *in situ*, but is clear and tea-coloured when held up against the light; it is always very acid. The peat consists of a crust of a soft to more solid and often woody nature over semi-liquid peat.

These forests have a three-layered tree structure. This comprises a broken upper or emergent layer, often reaching a height of 100 to 120 feet and frequently represented by scattered truly emergent trees; a fairly level main layer, which is often in practice the upper tree layer, reaching a height of about 90 to 100 feet and frequently very open and discontinuous; and a fairly continuous understorey of considerable depth, usually ranging from 30 to 60 feet above the ground or peat surface. Where there is standing water there is frequently a dense thicket of stemless palms; otherwise the 'shrub' layer is in general rather sparse. Ground flora is comparatively poor. There are generally few species in this vegetation type, and they are not normally found outside the peat swamp environment.

As with other types of forest, the local distribution of individual species varies for reasons that are yet unknown. After clearing and cultivation, an almost pure stand of *Macaranga maingayi* develops as an early sub-seral stage in the secondary succession.

*Riparian Fringes**. Numerous types occur as narrow strips along the banks of estuaries, rivers and streams throughout the country; their width varies greatly, depending on the terrain. Their composition, and hence their structure, vary enormously, and depend on tidal influence, the rate of water flow, the elevation, the width of the river, the nature and aspect of the terrain, and the enrichment of the site by water or silt. Several types have been described by Corner (9) and Symington (4). At the mouths of rivers, where saline influence is strongest, are mangroves which have already been described; further upstream, where the water is brackish, *Nipa fruticans* usually lines the banks, especially those of larger and wider rivers. Still further upstream, where the water is tidal but no longer brackish, are found the 'rassau (*Pandanus helicopus*) rivers' of Corner. Beyond tidal influence occur the 'gallery forests' of which those in Kelantan, Pahang and Trengganu with *Dipterocarpus oblongifolius* (the 'neram rivers' of Corner) are the most picturesque; many of these large trees with huge spreading crowns were destroyed during the severe floods of 1926 in Pahang. In north Malaya, *Hopea odorata* plays a similar role to that of *Dipterocarpus oblongifolius*, while in abandoned or seasonally occupied river beds of the east coast, in which 'Heath' Forest grows, several species characteristic of peat swamp forest are found. In the deeper swamps various stemless palms, principally *Licuala* and *Zalacca*, form a dense community.

In the foothills where the rivers become narrower, more rocky, and faster-flowing, the characteristic component of the riparian fringes is *Saraca* species, especially *S. thaipingensis*, forming the 'Saraca streams' of Corner. Some bamboos (*Dendrocalamus pendulus*, *Schizostachyum gracile*, *Gigantochloa scortechinii*) are common in the larger valleys of the Main Range; although probably common in natural forest in such areas, they have certainly become more firmly established as a result of human interference with the environment, mainly in clearing and shifting agriculture.

REFERENCES AND NOTES

1. A more detailed account of the vegetation types of Malaya, from which most of the contents of this paper have been taken, forms Chapter 7, 'An introduction to forest types', of Part III of the 'Manual of Malayan silviculture for inland forests', *Malayan Forest Record* No. 23 (in press).
2. Garfitt, J.E., 'Malayan forest types', *Malayan Forester*, Vol. X, 1940, pp. 136-40.
3. Hardwood is a term used to denote the timber of all trees belonging to the botanical group of Angiosperms. In Malaya, hardwoods are subdivided into three groups: heavy, medium, and light, according to the average weight and natural durability of the timber. The principal species making up heavy hardwoods in Malaya are the balau group (of the genus *Shorea*); chengal (*Balanocarpus heimii*); and merbau (*Intsia palembanica*).
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SOIL MAP OF MALAYA, 1962

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Scale 24 Miles to an Inch
 Miles 10 5 0 10 20 30 40 50 Miles

REFERENCE

Symbol	Description
	Railway with Station
	Principal Road
	Other Motorable Road
	Cart Track
	Light Railway
	River & Stream
	International Boundary
	State Boundary
	District Boundary
	Town & Village Sites, Airside
	Lighthouse, Civil Radio Station
	Trigonometrical Station with Height
	District Head Quarters
	District Name
	State Capital
	State Name

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PERAK

SELANGOR

KUALA

TRERGGANU

IPAH

PERAK

LEGEND

- Lithosols and shallow latosols on steep mountainous and hilly land considered unsuitable for extensive agricultural development.
- Red and Yellow latosols and red and yellow podzolic soils on gently to strongly sloping land, mostly of average fertility, derived from acid igneous rocks.
- Red and yellow latosols and red and yellow podzolic soils on gently to strongly sloping land of variable fertility derived from a variety of sedimentary rocks.
- Red and yellow latosols and red and yellow podzolic soils on flat, gently sloping and strongly sloping land, mostly of below average to average fertility developed over raised terraces and platforms of older alluvium and sub-recent alluvium.
- Reddish brown latosols on gently to strongly sloping land, mostly of above average fertility, derived from basic and intermediate igneous rocks.
- Laterite soils on gently to strongly sloping land, mostly of average to below average fertility.
- Low humic gley soils, being moderately and poorly drained soils developed over coastal plains and in the valleys and flood plains of the larger rivers, of very variable fertility.
- Poorly drained estuarine and coastal soils (azonal) mostly tidal, of limited suitability for agricultural development.
- Freely drained coarse textured grey brown podzols of below average fertility, developed over recently accumulated coast deposits with associated swamps.
- Organic soils, principally peats, with some mucks, developed over mineral alluvial soils in poorly drained situations, of limited suitability for agricultural development.
- Disturbed land, chiefly tin tailings, of limited suitability for agriculture.

NOTE

This soil map has been assembled from all existing useful soil survey records in the possession of the Department of Agriculture, supplemented by inferences based on geological data in the records of the Geological Survey Department, and topographical information drawn from contoured maps published by the Survey Department. It represents a first attempt at a practical soil map of Malaya, and the standard of accuracy varies considerably from place to place, due to the variable accuracy of the records used in its compilation. Broad scale systematic soil surveys have been conducted to date only in the northern States of Trengganu, Kelantan, Kedah, and Perak, and the boundaries in these areas are consequently more detailed and accurate than those shown for the remainder of the country. Large areas in central and south Malaya still remain unsurveyed and geological, topographical, and other sources of value in interpreting the soil pattern, including records from ad hoc soil surveys and inspections, are considered insufficient to enable sound deductions to be drawn regarding the soil types in most of these areas. Some inferences have been made however, and the boundaries of the steep land soils, and some of the granite-derived soils together with the probable boundaries of the peat soils, and of the main alluvial soil boundary with the sedentary soil groups, have been extrapolated even where the areas are pedologically unexplored. Acknowledgement is made to the Director, Geological Survey, for permission to incorporate certain geological boundaries from the 1948 Geological Map of Malaya.

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