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Report on a Reconnaissance Soil Survey
of the
BALINGIAN BASIN

3rd. Division

by

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INTRODUCTION

A broad reconnaissance soil survey of parts of the coastal and the floodplain areas of the lower Balingian drainage basin was made by Wall (1961, 1962). Much of the coastal work is difficult to interpret against the published base maps, however, now that it is established that considerable coastal erosion has taken place in this area. In addition, many of the records from the work in the lower Balingian have now been lost. A terrain classification map of part of the interior was prepared in 1965 (SCOTT, 1965). In 1967 the writer attempted reconnaissance in the upper Balingian but found that a long dry period had made river travel off the main stream impossible. After two weeks work the field parties were diverted to work elsewhere in Third Division and the project postponed. This reconnaissance was, however, requested as a 'first priority' need by the Third Division Development Committee in recommending the soil survey programme for 1970 as a result of the rapidly extending road network and the fact that the roadhead from Sibu was approaching this area. In addition, more detailed information regarding many localities along this section of the coast was urgently required in connection with proposed block plantings of coconut. A reconnaissance survey of the whole Balingian Basin was therefore programmed together with a detailed reconnaissance survey of the coastal area. The coastal area was surveyed by Assistants Rosli bin Sahari and Timothy Kinok and has been reported on separately (SCOTT, 1970). The interior was surveyed by the writer and Assistants Ismuni bin Omon and Donald Lawan. The five field parties spent approximately 14 weeks in the area, field work starting in February and being completed in mid-July, 1970.

For the purpose of presenting the information and for convenience in planning field work the actual watershed boundary of the drainage basin was ignored in delimiting the area of work, which has been bounded by arbitrary sheet lines. In the east, small portions of Fourth Division have thus been included while the upper end of the Arip valley has been omitted. In the south the extremely rugged terrain upstream of Sg. Lirai, which is of no interest for agriculture, has been ignored. In the west, where a confused pattern of generally low hills separates the Balingian from the Mukah drainage and the watershed is difficult to define, the map includes small portions of the Mukah drainage basin surveyed by the writer in 1966. Work in that area is as yet unreported. The coast is taken as the boundary in the north and the soils data from the detailed-reconnaissance survey presented separately on a larger scale (SCOTT, 1970) is included in the present map.

It is calculated that the soil map covers approximately 1,010 square miles, including some 48 square miles of detailed reconnaissance work and also including some 230 square miles previously surveyed by Wall at a broad reconnaissance level near the coast or by the writer on the borders of the Mukah basin. The map thus presents approximately 730 square miles of 'new coverage' in this area. The survey area is located in Fig. 1.

GEOLOGY

Geological information for this area is largely based on Wolfenden (1960) and Liechti (1960) although some additional inferences regarding lithology have been made from the character of the soil mantle.

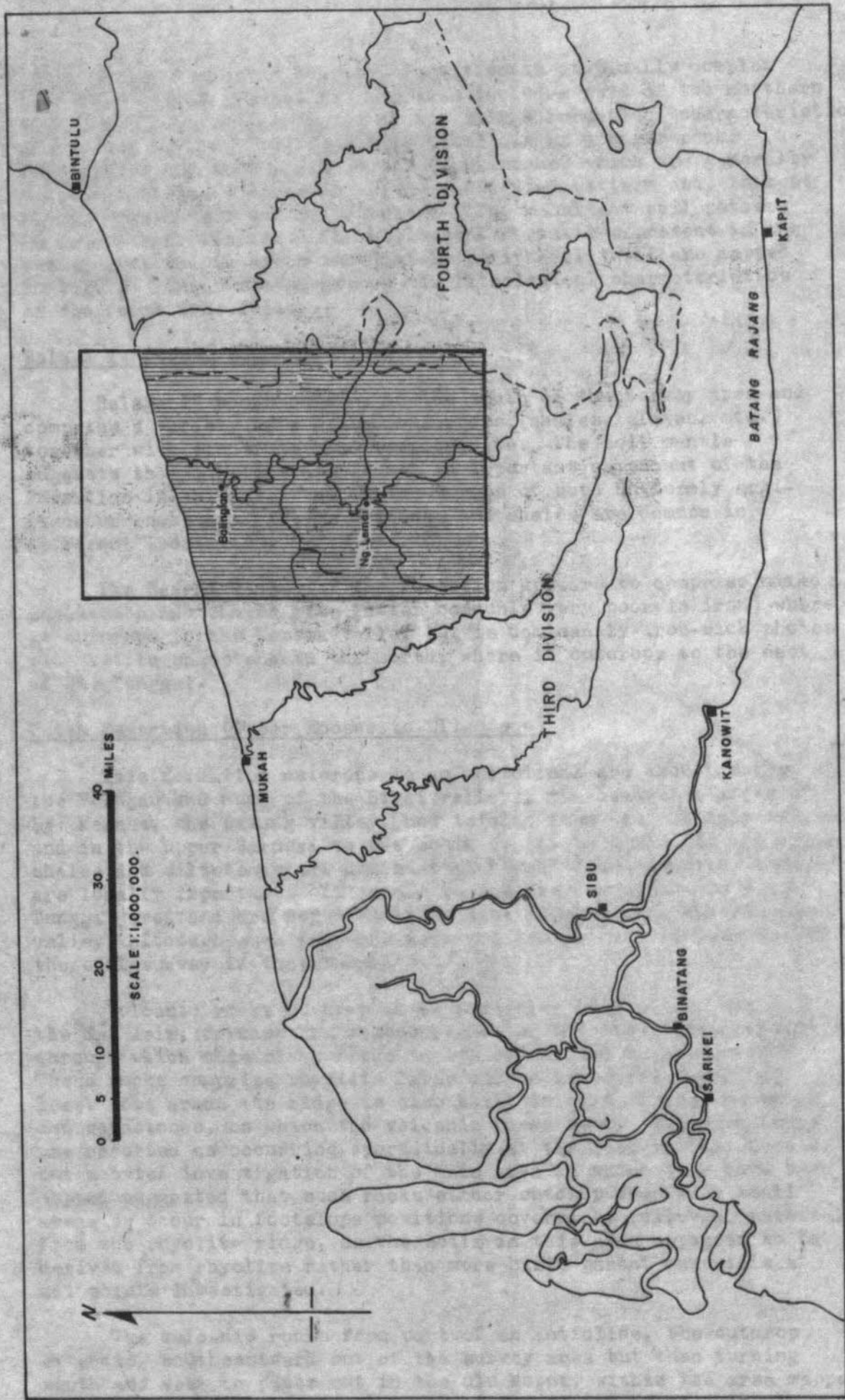


FIG. 1. LOCATION

The pattern of geological formations is atypically complex for coastal Third Division. The area includes part of the northern end of the geosyncline formed by the Belaga Formation, characteristic of central Sarawak, but is mainly underlain by younger rocks (ranging in age from upper Eocene to Pliocene) which are generally not conformable, outcrop in a rather confused pattern and, in most cases, have a very varied lithology. The resultant soil pattern is exceedingly complex. The geological formations present in the survey area and in areas immediately peripheral to it are mapped in Fig. 2. Brief statements on the lithological characteristics of the formations follow.

Belaga IV (Upper Eocene)

Belaga IV rocks outcrop in the south of the survey area and comprise a variety of argillaceous rocks (shales, slates, etc.) together with sandstones and conglomerate. The soil mantle suggests that conglomerate is not an important component of the formation in this area and that outcrops of both uniformly argillaceous rocks and mixed sandstones and shales are common in different localities.

The Bawang Member of the formation appears to comprise mixed sandstones and shales (the latter commonly very poor in iron) where it outcrops in the Kemena valley but is dominantly iron-rich shales with little sandstone in the north, where it outcrops to the east of Bt. Tunggal.

Tatau Formation (Upper Eocene to Oligocene)

This formation outcrops in an anticlinal are encompassing the Pelugau and much of the Lirai valleys, the headwater areas of Sg. Kemena, the Bawang valley, and is also found in the Arip valley and in the upper Sarupai to the south of Bt. Tunggal. In all areas shales and siltstones are dominant although thick sandstone beds are locally important. Limestone lenses are common in the Arip-Tunggal area and are reported to be also important in the Pelugau valley, although such features were not crossed on rentises during the soil survey in that locality.

Volcanic rocks outcrop in an irregular belt to the south of the Sg. Arip, forming the southern wall of the distinctive trench through which this river flows in its middle and upper portions. These rocks comprise rhyolite lavas and welded tuffs but in at least some areas the ridge is also built in part of conglomerates and sandstones, on which the volcanic rocks rest. Andesite lavas are reported as occurring sporadically at the base of the succession but a brief investigation of the main area in which they have been mapped suggested that such rocks either outcrop over very small areas or occur in footslope positions covered by colluvial material from the rhyolite ridge, as the soils in this area appeared to be derived from rhyolite rather than more basic parent materials at all points investigated.

The volcanic rocks form part of an anticline, the outcrop extending southeastward out of the survey area but then turning south and west to peter out in the ulu Muput, within the area mapped. On the basis of the geological map, the soil association in ulu Muput is inferred to be the same as that over these rocks in the Arip area but this has not been checked during the present soil survey.

Buan and Nyalau Formation (Oligocene to Miocene)

The Buan Formation only outcrops in the Arip valley in this area, where it comprises shales similar to adjacent Tatau rocks. Overlying these shales are the rocks of the Nyalau Formation. The latter comprise mixed sandstones and shales and, as the basal members of the formation are thick hard sandstones, there is a distinct boundary with the underlying Buan Formation rocks. The Arip valley is bounded on the north by a steep scarp formed of these sandstones and the remainder of the outcrop in this locality, forming a wedge between the Sg. Arip and Sg. Maong, is also dominated by thick sandstone outcrops forming distinct scarp features. In contrast, Nyalau rocks in the Anap-lower Arip area comprise soft sandstones and shales, giving rise to much lower terrace.

Balingian, Begrih and Liang Formations (Miocene to Pliocene)

The hills extending north between the Mukah and Balingian rivers from the main hill mass of the Belaga Formation comprise outcrops of the Balingian, Begrih and Liang Formations, the oldest rocks outcropping in the north. All three formations comprise mixtures of arenaceous and argillaceous material (both being commonly only semi-consolidated) together with some conglomerate and beds of lignite. While the Begrih Formation is described as being rather more arenaceous than its neighbours to north and south, the variety of lithology in the field was found to be too great for any soil boundaries based on the geological formations to be confidently drawn. (Outwith the survey area to the west a soil complex, in which profiles developed in sandy material are dominant, has been mapped. This closely agrees in areal extent with the mapped outcrop of the Begrih rocks but this dominance of arenaceous material appears to be less pronounced farther east within the present survey boundary.)

/and Soils developed in sands/conglomerates were found to be locally important on the swamp fringes to the south of Sg. Basai and to the north of Sg. Duan, all in areas mapped as outliers of the Liang Formation. Soils developed in similar material near the Sg. Setawa (Kemena), which has been mapped as Bawang formation, may also indicate an outlier of Liang rocks. (See the distribution of Tika Family on the soils map).

Conglomerates and sandstones form a prominent arcuate ridge at Bt. Tunggai, continuing across the Sg. Sarupai to form Bt. Ladang and Bt. Keladan. Conglomerates are also dominant, with subordinate shales, at Bt. Ransi to the south of Bt. Tunggai in the upper Sg. Sarupai (distinct from Bt. Ransi in the upper Sg. Saporai, Tatau, which is quoted as the eastern limit of such outcrops). These rocks have been tentatively referred to the Liang Formation, with the exception of Bt. Ransi, which is included with the Tatau rocks by Wolfenden (1960) and as part of the Bawang member of the Belaga Formation by Liechti (1960).

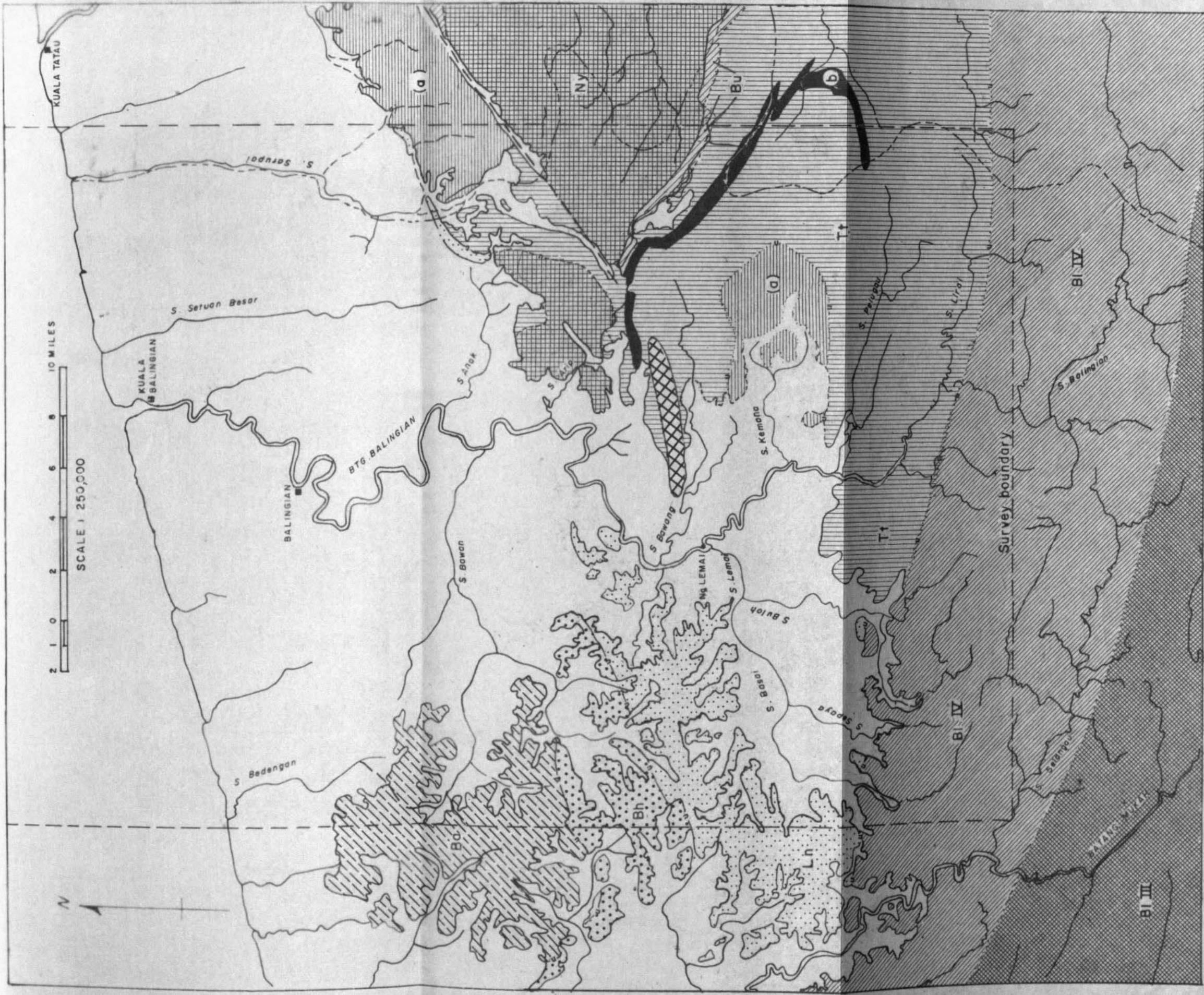
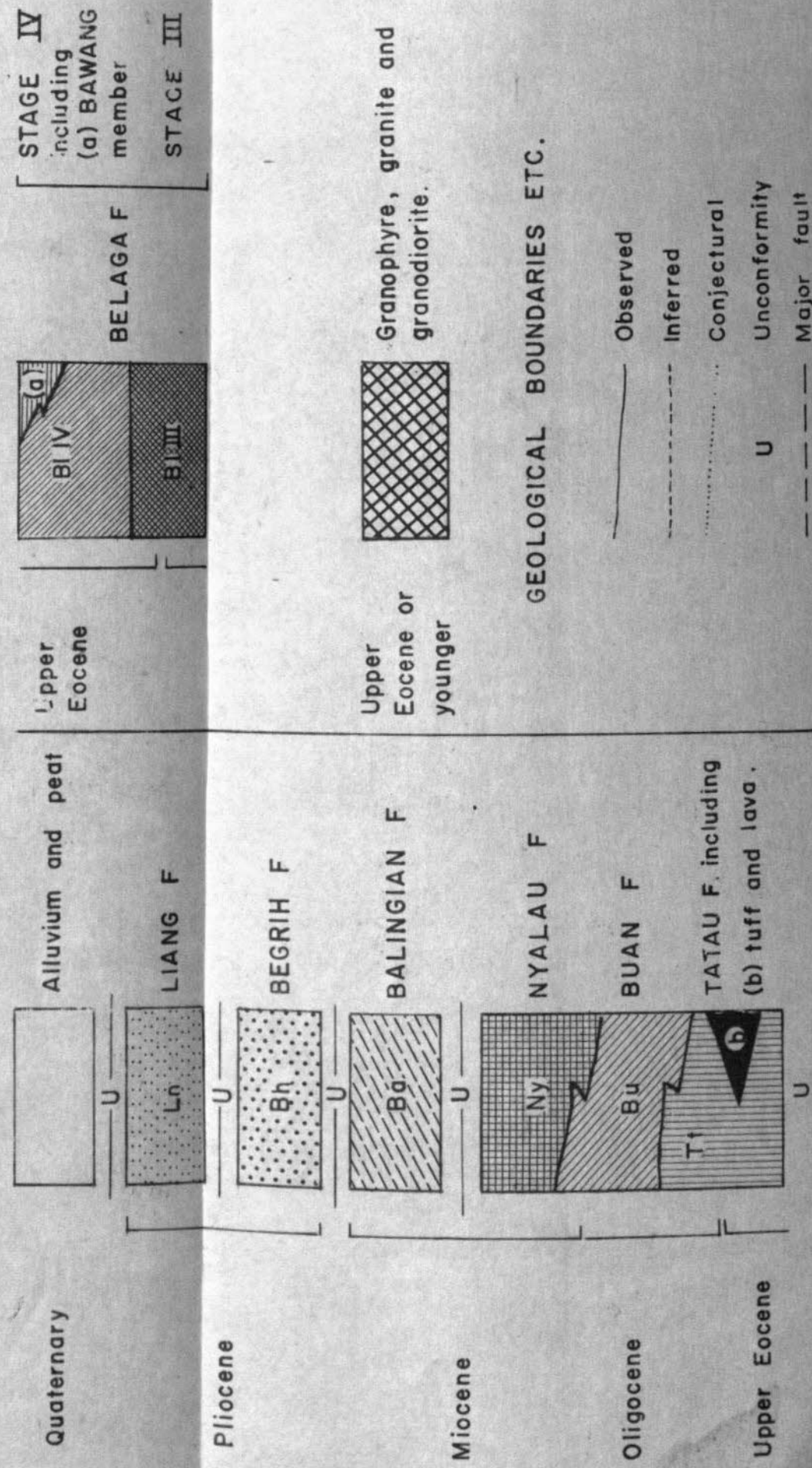


FIG. 2. GEOLOGICAL FORMATIONS.
(from Wolfenden, 1960).



Granodiorite, etc.

Bt. Piring, north of Sg. Bawang, has been mapped as an intrusion (extending some six miles long) of granodiorite, granite and granophyre. Wolfenden (1960) describes it as being surrounded by sedimentary rocks metamorphosed to biotite hornfels. The soil mantle suggests, however, that a large part of the outcrop itself is hornfels and that acid igneous rocks exposed at the surface cover a much smaller area than the geological map suggests. They are dominant at the western end of the outcrop but at other points investigated soils derived from hornfels or mixed hornfels and granodiorite appear to be widespread.

Alluvium and peat

The large area of Quaternary terrace material mapped by Liechti (1960) from air photo interpretation are in fact deep peat swamps bearing a specialised vegetation cover, as corrected by Wolfenden (1960). Terrace sands do not appear to be very important in this area except as part of the coastal sand complex. Such deposits were, however, locally encountered north of Bt. Piring (where they may be colluvial wash from the adjacent coarse-grained igneous rocks) and in the upper reaches of Sg. Bawan. Here it is possible that they are developed in residual material of the Begrih Formation although a marine alluvial origin of the deposits appears more likely. Isolated records in other areas are largely from footslope sites in localities where sandstones and conglomerates may be present and, unless well-developed, terrace remnants are difficult to distinguish from local colluvium. Wall (1961) reported isolated podzol soils in alluvial sands near Nanga Bawan but there is some doubt regarding records from this locality (see the note concluding the soils section).

There has been an extensive build-up of sandy deposits along the present coast which presumably formed initially as a complex spit extending westwards from near Tj. Kidurong. In most areas the sands rise little above present sea level but on the western edge of the coastal section included in the survey area some fossil strand lines are sufficiently high above the general water table for podzol soils to have developed in them. These become more widespread farthest west outwith the survey area (SCOTT, 1970).

As described by Anderson (1964) there has been a considerable development of peat swamps behind these sandy deposits which is presumed to have followed initial silting of the lagoonal area sheltered from coastal currents by the sand bars and the development of clayey mangrove swamps. In almost all areas the peats are underlain by clays similar to the estuarine clays colonised by mangrove along parts of the present coast. The peats are mainly deeper than 10 feet (and are probably 15-20 feet deep in most areas). Peats underlain by sands are largely confined to a zone behind the coastal sands and only there are extensive areas of shallow peat observed. Basal sand distribution roughly correlates with the distribution of peats shallower than 60 inches although the detailed pattern is rather complex. It appears that the peat accumulation on the old mangrove clays has built up rapidly and extended both seawards, over the lower inland flanks of the coastal sand complex, and in other directions, infilling minor valleys formed by streams draining adjacent hill masses. Peats deeper than 10 feet are commonly found occupying quite narrow valleys on the fringes of the peat swamp proper.

Riverine alluvium, as can be seen from the soil map, does not cover extensive areas, except near the Batang Balingian itself, in the middle Arip and locally in the upper Sarupai and elsewhere. On the banks of most streams, such alluvium grades back very quickly into peat deposits and cannot be separately mapped at the scale used.

RELIEF AND DRAINAGE

Roughly half the area mapped is covered by peat swamps or coastal sand deposits with minimal relief. The remaining hill land has, in contrast, very varied relief which commonly reflects the character of the underlying geological formations.

The Belaga IV rocks and the Tatau rocks south of the Sg. Pelugau area give rise to relief with considerable amplitude except on the swamp margins, these uplands being dominated, especially in the Tatau rocks by prominent strike ridges, trending roughly northwest-southeast. The Bawang rocks in the Kemana area and the Liang, Begrih and Balingian rocks in the west, into which the Belaga and Tatau rocks grade northwards, generally have subdued relief with relatively gentle slopes and no relief features which are obviously structurally controlled.

The Piring-Tunggal-Arip area, underlain by rocks with very varied lithology and resistance to erosion, has a wide range of topography. The granodiorite and hornfels of the Piring area have produced a long steep-sided ridge which rises abruptly out of lowlands developed in adjacent sedimentary rocks and merges eastwards into equally steep-sided hills formed of rhyolites and related rocks. These form the western faulted extremity of the rhyolite outcrops which, farther east where the outcrop is unfaulted, form a continuous high ridge extending for many miles to the southeast and continuing outside the survey area. The resistant sandstones of the Nyalau Formation give rise to a wedge of country with very dissected scarp/dip terrain and the narrow outcrop of easily weathered Tatau and Buan shales which is sandwiched between these sandstones and the rhyolites is responsible for a marked lowland trench through which flows the Sg. Arip. To the north the Nyalau outcrop has a faulted boundary and gives way abruptly to undulating lowlands mainly underlain by Bawang and Tatau sedimentaries. These are bounded on the north by intermittent outcrops of resistant conglomerates which form the prominent ridges of Bt. Keladan, Bt. Ladong and, particularly striking, Bt. Tunggal. Whereas in most other areas a transitional belt of low hills borders the swamps even where the underlying rocks are quite resistant to erosion, the conglomerate ridges of the Tunggal Ladong area abut northwards onto deep peats with no transitional belt.

Most of the area is drained by tributaries of the Batang Balingian although the peat swamps north of Sg. Bawan and Sg. Anak largely drain direct to the coast. The main Balingian tributaries in the west are the Bawan, draining the hills developed on Balingian and Begrih rocks and the Lemai, draining an inland basin bordered largely by Liang and Belaga IV rocks. Both drainage systems flow through many miles of swamp land before entering the main stream and have markedly few secondary tributaries. In the east the Pelugau and Lirai flow mainly in strike-directed courses whereas the Kemena and Bawang streams draining the subdued Bawang and Tatau terrain follow more erratic channels. The Arip, as stated above, flows through a narrow lowland belt bounded by the Nyalau scarp in the north and the rhyolite ridge in the south, and thus drains a very small area in comparison to its length. An unusual feature of the Sarupai is the fact that instead of rising in the swamps as might have been expected it also drains a large area to the south of Bt. Tunggul, the river running north through a narrow gorge between Bt. Tunggul and Bt. Ladong. The dissected land underlain by Nyalau rocks drains eastwards to the Tatau, as does Sg. Maong which follows the fault zone bounding the Nyalau rocks on the northwest.

The upstream portion of the Batang Balingian is small, rapid-strewn and controlled to a considerable degree by strike and fault lines. It widens in the Lirai-Pelugau area and in most of the area covered by the present survey is a large river meandering through swamplands. Most of its tributaries, on the other hand, are very small. While the lower reaches of the majority can be used at all times of year, the hills in which streams such as the Lemai and Bawan rise are virtually inaccessible by boat during the dry season except immediately after heavy rain.

As previously stated, little riverine alluvium is associated with any of the tributary streams in their swamp courses, with the exception of the Arip and, to a lesser degree, the upper reaches of the Sarupai. In both these cases the development of mineral alluvial tracts is probably largely due to the partial blockage of the river valleys, by the convergence of the rhyolite outcrop and the sandstone scarp in the first instance and by the conglomerate ridge in the second. These features have retarded the lowering of the base level in the upstream portions of these valleys and limited the extension of the accumulating peat into these localities. Deep peats are virtually absent from the middle and upper Arip and have developed only to a small extent in the upper Sarupai.

VEGETATION

Primary upland forest remains extensive in hill areas which are too steep for cultivation but generally not elsewhere. The high ridges of the Belaga and Tatau rocks in the extreme south, together with the headwaters of the Pelugau, Kemana and Bawang remain under forest, although much of the extensive forest in the middle Kemana is very poor and verges on heath forest, a reflection of the soils peculiar to that area. The steep-flanked rhyolite ridges and the steepest facets of Bt. Piring are also forested, as is the dissected terrain developed in the Nyalau rocks and the conglomerate ridges to the north of them. Remnants of forest

elsewhere are scattered and inextensive. Where they have been investigated it has generally been found that they indicate poor sandy soils and have been avoided by farmers for that reason. Most uplands on the fringes of the swamps have been cleared for cultivation in the past and the lowlands associated with the major streams in the area, together with the subdued terrain which is general in the west of the survey area, are now under secondary growth of varied age.

The swamps largely bear a cover of broken peat swamp forest, most areas having been extracted for timber in the past. Alan forest is mainly confined to the swamps east of the Batang Balingian. A large tract of Alan forest and some Padang Paya forest is present between the Batang Balingian and Sg. Sarupai. The Alan forest in this area runs to the edge of the swamp at Bt. Tunggal. Peat swamp forest remains dominant very close to the coast. Nipah and mangrove forest are present in the K. Balingian area and locally elsewhere but are not widespread.

SETTLEMENT, AGRICULTURE, and COMMUNICATIONS

Through most of Sarawak settlement tends to be concentrated along the main rivers, but this is less true in the present area. Because there is only a restricted amount of alluvial land close to the main stream and because most of the hill land in the areas downstream of Nanga Lemai are separated from the Batang Balingian by many miles of swamp, settlement has tended to concentrate on the side streams, generally in their upper reaches close to possible farming land. Thus, while much of the interior of the basin has been settled by Iban, only two or three longhouses are passed on the main river between Pelugau and Balingian bazaar. As previously stated, these streams are generally small and cannot be used by large longboats during the dry season. Many longhouses are therefore rather cut off and, possibly in a response to this, a rather large number of small shops and longhouse cooperatives have developed on these minor rivers, compared with many similar areas elsewhere. The main trading centre for the population of the middle Balingian is the bazaar at Nanga Lemai, although permanent floating shops are established at Ng. Kemena and Ng. Bawang also, and people living in ulu Bawan and Anak are within relatively easy reach of Balingian bazaar itself.

The Ibans living in scattered and rather isolated settlements in the uplands of the southern and western parts of the area have cleared much of the land for hill padi and have also established rubber along the majority of the larger streams. There is a concentration of longhouses in the middle and lower Arip. The riverine tracts along this river have been particularly well-developed for rubber and, in poorly-drained tracts, for wet padi. Apart from the lower Bawang and some of the main tanjongs of the Batang Balingian, wet padi is not widespread elsewhere. Although the swamps fringing many hills have been cleared in the past for padi many of these areas have since been abandoned. Considering the depth of peat in many such areas investigated during the soil survey it seems likely that yields were not encouraging. In some areas rubber planted under the R.P.S. 'A' scheme with efficient terracing is seen and scattered pepper farms have also been established but in general the area remains under traditional forms of cultivation

and the trends towards new crops and methods noticeable among Iban farmers in less remote parts of the Division have yet to establish themselves in this area.

Towards the coast the Iban population gives way to Malay/Melanau communities, settled particularly around Balingian bazaar, the lower reaches of the main river, and on the coast itself. While some wet rice is grown their efforts appear to be mainly concentrated on coconut, along the coast, and sago, around Balingian bazaar. Fishing is also important.

Balingian bazaar is the only bazaar of any size in the area and, except for the much smaller settlements at Kuala Balingian and Nanga Lemai, is virtually the only centre of any description larger than the basic kampong or longhouse unit. From Balingian, more or less frequent coastal launches run to Mukah and Bintulu, and one rather more erratic service runs 'monthly' direct to Kuching. While the bazaar provides a focal point for the concentration of sago, timber and, seasonally, illipe nut exported from the hinterland, it is not expanding and much of the justification for its existence will disappear when the roadhead from Sibul reaches the upper Balingian.

Communications within the area are difficult. Apart from the lack of permanently-large tributary streams on which comment has already been made, the present lack of any land link with adjacent river basins other than footpaths in the interior means that at the height of the rainy season, when very rough seas are common for weeks at a time, the many settlements along the coast are cut off from Balingian and Balingian and its hinterland is cut off from Mukah and Bintulu. In these circumstances the extension of the trunk road through the interior part of this area is likely to be a very significant factor in future development and much of the area is likely to alter its mental orientation from the coast towards the bridging point. The projected feeder road into the hill land in the west of the survey area will be equally important and some comments are made on this later in this report.

SOILS

The soils of the area have been mapped in forty-one associations, this rather large number reflecting the variety of soil parent materials present. While the character of the soil mantle within the mapping units has been established by sampling along traverse lines the boundaries of the units are largely inferred from air-photo interpretation. Delimitation of hill land associations from swamp associations is possible from air photographs with considerable accuracy in cleared land but less so where the area is under a forest cover. Boundaries between two upland associations are generally somewhat conjectural, particularly where the associations concerned have many soils in common. All boundaries on the soil map derived from the reconnaissance work in the interior of the basin have therefore been shown as dashed lines. Soil associations near the coast which have been mapped by detailed reconnaissance methods and have greater reliability have been shown as full lines.

The soils are classified in terms of the Classification of Sarawak Soils (SOIL SURVEY STAFF, 1966) with the exception of certain soils for which a new family has been established. This is discussed and defined in Appendix I. With few exceptions the soils of the area are not defined below the family level. The families and great soil groups present in the area are listed in Table 1.

In the following sections the soils of the area are described. They are discussed under the soil association mapping units used in preparing the soil map and these are dealt with in the order in which they appear in the key to that map. Many families are common to a number of mapping units. Full descriptions of the family are not repeated in discussing each association in which the family occurs. They are only described in detail under the association in which they are most important, unless the characteristics of soils in the family are peculiar to particular mapping units. The sections under which the fullest information on each family may be found are listed in Table 2. Selected profile descriptions of some soils are included in Appendix II.

Meluan Association

While Meluan soils are important components of a number of associations, they normally occur in complex with other soils. They have, however, been mapped separately in the Arip area. Meluan soils comprise very young soils developed over sedimentary rocks in which the parent rock is both present within 10 inches of the soil surface and is sufficiently hard to form a serious impediment to root penetration. As argillaceous rocks generally weather fairly deeply these soils are particularly associated with areas in which massive sandstone, resistant to weathering, is dominant, as in this case. The northern boundary to the Arip valley is a very steep scarp formed by thick Nyalau Formation sandstones. While covered by forest, the soil mantle is intermittent, rock outcrops are numerous, drift fragments of sandstone litter the surface and the depth to parent rock is very shallow where a soil mantle has developed at all.

Steep slopes and shallow soils preclude the use of this association for agriculture.

| <u>Great soil group</u> | <u>Family</u> | <u>Series (where separated in this area.)</u> |
|-------------------------|--|---|
| Skeletal | Meluan Kapit | |
| Red-Yellow Podzolic | Abok Nyalau Bekenu Merit Semilajau Malang Sabangang Lupar | Piring. Sebatu. 'Nyaroh'. (?) Gading. |
| Grey-White Podzolic | Kerait Saratok Embang | |
| Podzol | Silantek Bako Buso Miri | Tunggal |
| Gley | Tatau Matu Bijat Sebandi | Tatau. Plan. |
| Saline gley | Pendam Rajang | |
| Peat | Igan Mukah Anderson | |
| Recent alluvial | Seduau Kabong | |
| ('Regosol') | Tika | Tika |

Table 1 : Classification of Families and Great Soil Groups.

following the Classification of Sarawak Soils (SOIL SURVEY STAFF (1966)

Meluan-Bako Association

The Meluan-Bako Association comprises the soils mantling Bt. Tunggal and assumed to mantle Bt. Ladong adjacent to it, although the latter was not inspected. The association comprises soils developed over conglomerates which on the steep hill flanks are mainly shallow Meluan soils with many conglomerate outcrops but on the gentler slopes of the summit zone are dominantly soils of the Bako Family. Bako soils are podzols in which the zone of humus accumulation has developed to a cemented hard pan at depth in the profile. Bako soils in this area are atypical of the majority of these soils in that the bleached sands overlying the humus pan are also hard and very difficult to penetrate with a changkol. As lumps of this material quickly slake in water it is likely that this feature is mainly due to mechanical packing rather than strong cementation, but the feature needs further investigation. A provisional Tunggal Series has been set up to cover Bako soils with this feature. The profile comprises a thin raw litter layer overlying brown loamy sand which grades, at a depth of less than 10 inches, to white or light grey sand. This, unlike normal Bako soils in which the bleached sands are loose, is mainly hard to very hard, becoming uniformly hard at depth. Where it has been possible to penetrate it, an irregular thin dark brown sandy loam is found to underlay these sands. This is also hard in most sections, although the degree of cementation is variable. The humus pan overlies light grey to yellow weathered conglomerate, structural planes and other cracks being infilled by black and brown accumulations of humus and iron and manganese compounds. A detailed profile is described in the Appendix (Profile 1).

Like the Meluan Association, the soils in this mapping unit are not recommended for agriculture, slopes being generally very steep and the soils shallow and very infertile.

Meluan-Silantek Association

It was expected that Bt. Keladan, to the northeast of Bt. Tunggal and Bt. Ladong would have a soil mantle closely similar to that of Bt. Tunggal but on inspection it was found that (in the part of this ridge included in the survey, at any rate) hard conglomerate are here interbedded with rather softer sandstones. Slopes are steep and Meluan soils with conglomerate outcrops are dominant on the hill flanks but the podzols developed on summit flats are generally not cemented and are intermixed with other sandstone-derived soils. The most widespread soils apart from those of the Meluan Family are podzols of the Silantek Family and the mapping unit has therefore been styled a Meluan-Silantek Association. Silantek soils comprise, in this area, greyish brown sandy loams or loamy sands, possibly incorporating some sandstone fragments, overlying a soft humus accumulation zone at a depth of 15-20 inches. This zone is a black to very dark brown sandy loam and is normally less than 6 inches thick. It is easy to auger through and the softness of the humus horizon is the feature which distinguishes these soils from the related soils in

the Bako Family. Below the humus zone is a yellow or yellowish brown sandy loam, commonly retaining some structural features of the sandstone from which it is derived.

At some points, sandstone fragments in the upper part of the profile were found to be numerous and in other areas it was not possible to auger through gravel zones in the subsoil to the humus horizon which was presumed to underlie them. It is therefore possible that soils of the Bako Family also occur. Locally brownish yellow loamy sands to sandy loamy overlying weathered sandstone rubble at depth, which are probably best considered shallow phases of Nyalau Family soils (described in later sections) are also present but these cover very restricted areas.

This mapping unit is not recommended for agriculture. Soils suitable for farming cover too small an area to be worth consideration.

Meluan-Merit Association

This association has been mapped at Bt. Ransi and in the area underlain by Nyalau Formation rocks between Sg. Maong and Sg. Arip.

Bt. Ransi, an isolated hill to the south of Bt. Tunggal, is apparently built of mixed sandstone, shales and conglomerates. On its eastern flanks shallow Merit soils are dominant, in which yellowish brown clay is underlain at depths of 20 inches or less by weathered shale fragments, and Bekenu soils, in which brownish yellow fine sandy clay loams overlie shales or clays with abundant quartz gravel, are also present. The ridge line, however, has many conglomerate outcrops and the western flanks of this hill have a mantle of very shallow Meluan soils underlain by conglomerate or sandstone, the former outcropping at many points.

The steeply dissected terrain between the Sg. Maong and Sg. Arip was only investigated on its southern edge where Merit and Bekenu soils were found to mantle moderately sloping dip-slope areas and, in general, are moderately deep; weathered rock being found in the profile only at depths greater than 3 feet. Such areas alternate with steeply sloping scarps mantled by Meluan soils or bare sandstone exposures. It is likely that Nyalau soils also occur in this mapping unit although they were not recorded on the section inspected.

Development is not recommended for this mapping unit. Reasonably deep agricultural soils are confined to fragmented areas and the bulk of the association is too steeply sloping for agriculture to be considered.

| Soil Family or Series | Main association under which soils described | Detailed profile description (App.II) |
|-----------------------|--|---------------------------------------|
| Meluan | Meluan | |
| Kapit | Kapit-Merit | |
| Abok (Piring) | Piring | Profile 6 |
| Abok (Sebatu) | Sebatu | Profiles 2 & 3 |
| Abok ('Nyaroh') | Sebatu | Profile 4 |
| Abok (Gading) | Piring | Profile 5 |
| Nyalau | Merit-Nyalau | Profile 9 |
| Bekenu | Merit-Bekenu | |
| Merit | Merit-Bekenu; Merit-Nyalau | Profiles 7 & 8 |
| Semilajau | Bijat-Mukah | |
| Malang | Bijat-Mukah | |
| Sabangang | Buso-Sabangang | |
| Lupar | Buso-Sabangang; Seduau-Lupar | |
| Kerait | Nyalau-Kerait | |
| Saratok | Nyalau-Kerait | |
| Embang | Buso-Sabangang | |
| Silantek | Meluan-Silantek; Silantek-Kerait | Profile 10 |
| Bako | Bako; Meluan-Bako | |
| Bako (Tunggal) | Meluan-Bako | Profile 1 |
| Buso | Buso; Buso-Anderson; Miri-Anderson | |
| Miri | Buso-Anderson; Miri-Anderson | |
| Tatau | Tatau-Matu | |
| Tatau (Plan) | Plan | |
| Matu | Tatau-Matu | |
| Bijat | Bijat-Mukah | |
| Sebandi | Bijat-Mukah | |
| Pendam | Pendam | |
| Rajang | Pendam | |
| Igan | Igan | |
| Mukah | Mukah | |
| Anderson | Anderson | |
| Seduau | Seduau-Lupar Bijat-Mukah | |
| Kabong | Tatau-Matu | |
| Tika | Tika; Appendix I | |

Table 2 : Key to associations, etc. under which the main descriptions of the soils of the area are given.

Kapit-Merit Association

The soil associations described above, of which Meluan Family is an important member, are associated with conditions in which rocks resistant to weathering give rise to specific landform features and these associations are generally of restricted area. A large tract of country in the east and south of the basin is also, however, characterised by great amplitude of relief and steep slopes although rock strata are generally not sufficiently hard for Meluan soils and rock outcrops to be widespread. The strike-aligned ridges which are typical of the association grade, on the borders of the mapping unit, into less steeply dissected terrain through a transitional zone sufficiently broad that the boundary to the mapping unit must be rather arbitrarily drawn in places.

The rock strata are steeply-dipping and hard sandstone bands commonly forms the spine to the main ridges but such bands are not necessarily thick. The upper slopes and summits are commonly mantled by shale-derived soils. Sandstone outcrops, if present, are generally confined to the heads of gullies. The most widespread soils on those ridges inspected are Kapit Family soils, comparable in depth to Meluan profiles but grading to weathered rock (normally shale) which is soft and is not a complete barrier to root penetration, together with shallow Merit Family soils: brownish yellow to yellowish brown clays in which weathered shale fragments are present within 20 inches of the surface and quickly become dominant with increasing depth. Locally, however, deeper Merit soils are important, particularly on the relatively gentle slopes close to the ridge summits. Bekenu and Nyalau soils also occur, and may be dominant in specific localities. As far as investigations of this unit suggest, Meluan soils are confined to steeply-sloping gully sites where sandstone outcrops.

This association thus has a wide range of soils and is distinguished from other units over sedimentary rocks with comparable terrain by the general absence of Meluan soils. While agriculture is possible in the association, and in some localities it has been partially cleared for hill padi, there is a considerable erosion hazard in clearing these steep slopes, especially where the upper subsoil is sandy, as in Bekenu and Nyalau soils. Expensive conservation measures are therefore necessary and, commonly, the necessity to avoid gullied areas adds to the difficulty of terracing. The soils are not of more than average fertility by Sarawak standards and the difficulty of using them effectively is such that development of these areas is not recommended while more suitable land exists for agriculture in the area.

Sebatu Association

The Sebatu Association and the Piring Association, described below, comprise a variety of soils derived from a wide range of parent materials and are named after series within the association which cover significant areas.

The Sebatu Association covers the soils developed on the rhyolites and associated rocks which outcrop to the south of Sg. Arip. The lavas and tuffs rest on sandstone and shale in places and are locally seen to outcrop on the ridge itself. As, in addition, there seems to be some variety in the constitution of the volcanic material, the soil mantle is not uniform and appears to be commonly derived from mixed parent materials. Shallow Merit and Kapit soils are locally important in the ulu Semabat, where Meluan soils underlain by sandstone and a regosol comprising light grey coarse sand overlying conglomerate, classed in the Tika Family, were also noted. The extent of such soils, developed entirely from sedimentary rocks, is not known but it is believed that they are not widespread. In general the soil mantle is derived, at least in part, from rhyolitic material.

The dominant soil on the main ridge is a brownish yellow, yellowish brown or strong brown clay loam which grades to clay at depth. Colour varies little throughout the subsoil. Structure is at best weakly expressed, although vertical cracks are commonly present and have apparent clay-skin coatings. The profile is 3-5 feet deep on footslope sites, on the gentle slope facets of the ridge shoulders and elsewhere but much shallower on the steeply sloping hill flanks. Two profiles are described in detail in Appendix II. Profile 2 is a deep profile from a footslope site, Profile 3 a shallower soil in a ridge-line position which shows some pedoturbation in the upper subsoil, possibly due to tree fall.

These soils are classed in the Abok Family, on the assumption that their iron content is consistently greater than in similar soils developed over sedimentary rocks. They are distinguished from other Abok soils as Sebatu Series.

Sebatu Series appears to be dominant on the main ridge. On the outliers to the west, at Bt. Tubau and beyond, similar profiles in which the upper subsoil is a sandy clay loam appear to be more common. These are considered to be derived from mixed rhyolites and sandstones and are possibly best placed in the Bekenu Family. They are left unclassified at present.

An outlier of the association occurs between Sg. Arip and Sg. Selian, an Arip tributary. This comprises a tract of moderately rolling hills mantled in part by Bekenu and Nyalau soils. These hills are included in the Sebatu Association as the soils derived from sedimentary rocks are associated with very contrasting soils which are believed to be derived from igneous material, although this is uncertain. The latter have a very deep profile and a uniform yellowish brown colour. They are distinguished from the Sebatu Series described above by the well-developed blocky structure and the prominence of apparent clay skins or pressure coatings in the middle subsoil. At depth the profile grades to variegated yellowish red, yellowish brown and white clay from weathered rock. This rock has not been identified but drift material in a gully near the main profile site comprised rhyolite and carbonaceous shale. The profile is described in detail in Appendix II (Profile 4) and is provisionally separated as Nyaroh Series.

With the exception of the rolling hills described in the last paragraph, which are planted to rubber, the soils of the Sebatu Association are largely uncultivated and are under forest. The forest appears to be of poor quality and it seems likely that Sebatu Series and related soils are chemically poorer than, for example, Merit and Bekenu soils. Heavy fertilizer applications may be necessary on them although no agronomic data are available for these soils. The bulk of the unit is very steeply/sloping and cannot be recommended for development but there appears to be a fairly wide footslope belt to the north of the main ridge (i.e. in the Arip valley) in which slopes are sufficiently moderate for terraced cultivation to be practicable. Further knowledge on the chemical status of these soils is required before recommendations can be made, however, regarding such areas.

Piring Association

The Piring Association comprises those soils mantling the Bt. Piring ridge and derived from granodiorite, granophyre, granite or hornfels, or from mixed granitic and hornfels material. The soil mantle is varied and can be considered in three main series. There are firstly strong brown coarse sandy loams or clay loams overlying coarse sandy clays at depth which are believed to be developed entirely from granitic parent material. These are classed in the Abok Family and probably correlate with Gading Series, which has been mapped in west Sarawak over similar parent materials. Profile 5 in Appendix II is an example of this soil. Secondly, there are strong brown to yellowish brown clay loams grading to clays at depth, characteristically well-structured, rather homogeneous in the subsoil and generally more than 3 feet deep. These soils, which are easily distinguished from the Gading Series by the absence of coarse sand in the profile, have not been linked conclusively with any rock type but are assumed to be developed over hornfels as this is the only rock type present in the locality which is likely to give rise to such heavy-textured soils. These soils are also placed in the Abok Family, and are separated from other Abok soils as Piring Series. Profile 6 in Appendix II gives details of one Piring profile. Thirdly, there are transitional soils which have the yellowish brown colour and deep profile of Piring Series but a significant sand fraction in the upper subsoil or throughout the profile. These are probably of mixed origin and are derived from hornfels and granitic material. They have not been classified. Granitic rocks outcrop in gullies and, locally, as large exposures on steep hill flanks. Hornfels has only been seen in stream gravel material.

There is no apparent pattern in the distribution of these soils. On a section sampled towards the eastern end of the ridge, Piring Series is dominant on lower and middle slopes and Gading Series on the summit. On the path crossing the ridge from Rh. Balong to ulu Tahu, farther west, Piring soils are dominant on the southern flanks, transitional profiles on the north, and no Gading soils were noted. A further section inspected north of Sg. Tekalong, however, had dominantly transitional soils on the southern flanks and Gading soils on the summit. Gading soils also appear to be dominant at the western end of the ridge where it grades out into low rolling terrain. It seems likely that the granitic components

of this ridge are present as numerous outcrops of varied areal extent and that they may be remnants of roof pendants in a mass which, at least in some parts of the ridge, is mainly hornfels. There seems, however, to be a general tendency for good Gading profiles to be confined to the ridge line zone, and its continuation into lower country to the west, which suggests that the granitic outcrop may form a narrow spine to the ridge, flanked by hornfels on both sides. In either event, the soil mantle suggests that the granitic outcrop is of much less areal extent than the geological map indicates.

The Gading soils present on the rolling country at the western extremity of the ridge are used for rubber and pepper but the bulk of this mapping unit comprises very steeply sloping terrain which remains largely under primary forest. Steep slopes limit the possibilities for development of these soils, although they are believed to be inherently fertile by Sarawak standards. On some gentle slope facets in footslope or summit locations they can be recommended for a variety of crops if careful terracing is used but the limited extent of such areas implies that only such smallholder crops as rubber or pepper can be considered.

Piring-Merit Association

Between Bt. Piring and Sg. Bawang on the south and between the ridge and the Sg. Tahu swamps on the north is an intermittent belt of rolling hills underlain by Tatau Formation shales with subordinate sandstones. These lie close to the igneous contact, have been metamorphosed to varying degrees and have in part been altered to hornfels. The soils are heavy-textured and generally deep but range from the brownish yellow over reddish yellow colours typical of Merit Family soils to the uniform yellowish brown to strong brown colours of Piring Series in the Abok Family. The mapping unit is considered to be dominantly a complex of these two soils. Gading Series was not noted and it is likely that the granitic material from which it is derived is confined to the main ridge. Bekenu soils are, however, locally present.

These soils are suitable for such crops as rubber, pepper and oil palm with appropriate fertilizer and conservation measures but possibilities for further development of them are limited as they are at present largely under old rubber.

Merit-Kapit Association

The Kapit-Merit Association which is dominant in the steeply-dissected uplands in the south of the survey area generally grades quickly to moderately deep soils in the rolling country bordering it to the north. In parts of the area, however, a transitional belt is found in which the terrain is moderately rolling but the soil mantle shallow and, as in the adjacent higher hills, Kapit Family soils are common. This has been mapped as a Merit-Kapit Association and generally comprises a complex of Kapit and shallow Merit soils. Bekenu soils are present but are not widespread.

Most of the unit is at present under regrowth of varied age following clearance for hill rice. The shallow soils, broken terrain and probable low fertility of this unit limit its potential but, given adequate fertilizer applications and careful terracing, it can be used for tree crops. There is, however, greater scope for agriculture in the Merit-Bekenu Association, into which this unit grades to the north and west.

Merit Association

The Merit Association is found in two areas: in the lowlands of the upper Arip valley and in a tract of undulating and rolling country stretching south from ulu Sarupai to ulu Maong. Both areas are underlain by shales of the Tatau Formation. The dominant soils are of the Merit Family and in both localities the profile ranges from shallow to moderately deep. A yellowish brown clay loam or clay overlies a yellowish brown clay with many fragments of grey weathered shale at depths of 10 to more than 30 inches. Soils of the Kapit Family, in which the shale fragments are dominant within 10 inches of the surface, are present but are rare. Outcrops of shale are also locally present but do not appear to be widespread. In the ulu Maong area small limestone outcrops were noted at two points and in the Arip valley the association is bounded on the south in the ulu Sabtu area by a series of larger limestone outcrops.

In the Arip valley this mapping unit is associated with very gentle slopes and may be suitable for large-scale planting of, for example, oil palm but the unit is at present covered mainly by poor regrowth and the soils are likely to be exhausted following many cycles of padi cultivation. Heavy fertiliser applications are thus likely to be required. In the Sarupai-Maong area the association occurs on more rolling terrain which would require terracing if cleared for tree crops.

Merit-Bekenu Association

An association in which the dominant soils are of the Merit and Bekenu Families has been mapped in a number of localities where shales with subordinate sandstones are present. Nyalau and Kapit soils are present but not extensive. The association is found overlying Bawang rocks in the northeast, east of the ulu Sarupai; in a broad arc running east and south from Bt. Piring through country underlain by the Tatau Formation; and in the hills drained by the southern tributaries of Sg. Lemai and underlain by Belaga IV rocks. The association continues outside the area to the west and is dominant over a broad belt between Batang Mukah and Batang Oya.

Merit Family soils have varied profile characteristics and most possible permutations are present in this association. A common profile comprises yellowish brown clay loam grading at a depth of 10 - 20 inches to yellowish brown to strong brown clay. Weathered shale fragments are absent from the upper part of the clay horizon but become increasingly common with depth. In areas, however, where the shale is soft and deeply weathered, hard shale fragments may be absent from the profile and the yellowish brown clay subsoil material grades at depths of 3 - 5 feet to a pale-coloured faintly mottled clay in which no rock structure is identifiable. A feature of shale weathering is the mobilisation of iron and manganese compounds which are leached down through the weathering profile and in part redeposited at depth. These deposits tend to be concentrated along main structure planes, channels opened by root penetration and in other situations where downward movement of water is relatively easy. Thin sheets of iron-enriched weathered rock thus tend to develop, which are considerably harder than the surrounding shales. At the soil/weathering rock contact these sheets tend to break up into hard fragments, commonly still containing vestigial rock structure, and concentrate as a gravelly zone of irregular thickness at the base of the soil profile. Any quartz stringers or other particularly resistant material in the underlying rock are similarly expressed in the profile and a 'stoneline' at depth in the subsoil is a common feature. It is sufficiently common that some lateral movement must be inferred in the development of most Merit profiles (slope creep and pedoturbation due to tree fall are the most likely agents) as the concentration of this material is otherwise difficult to explain.

Subsoil colours tend to become redder with depth but in many profiles there is minimal variation in either texture or colour. The subsoil may be yellowish brown clay throughout or yellowish brown clay loam over strong brown clay. Structure is weakly blocky. Apparent clay skins may be present in the lower subsoil but are never well-expressed and, except for the linings of root channels and the larger pores, are probably largely pressure coatings.

The depth of the profile varies, inter alia, with the slope and the resistance to weathering of the underlying shale. Profiles in which fragments of weathered rock (except for iron-enriched material concentrated in stonelines) are present within 20 inches of the surface are considered shallow, profiles with weathered rock between 20 and 48 inches are considered moderately deep. Deep Merit profiles have no recognisable weathered rock, subsoil material retaining rock structure nor the base of a stoneline (if a stoneline is present) within a depth of 48 inches from the surface.

Profile 7 in Appendix II describes a Merit profile in detail. The profile was sampled from the continuation westwards of the Merit-Bekenu Association in the Mukah drainage basin but is of a type equally common in this area. It is moderately deep but with a 'stoneline' of iron-enriched shale fragments in the middle subsoil. The gleying present in the second horizon is a common feature of these soils and may be due to a temporary perched water table above the less permeable clayey horizons which underlie it.

Bekenu Family soils are closely related to Merit soils but are derived, at least in part, from more sandy parent materials. Two types of profile have been included in this family. Firstly, there are profiles in which the texture is sandy loam to sandy clay loam in the upper subsoil and grades to sandy clay at depth. Such soils are developed over sandy shales or thinly bedded shales and sandstones and, as far as can be inferred from the profile character, are developed directly from the underlying material. Secondly, there are profiles in which the upper subsoil is light-textured as described above but the lower subsoil is clay loam or clay, the sand content dropping abruptly at depth. These profiles are considered to be bisequent, the lower subsoil being derived directly from underlying shales, the upper subsoil being partly or wholly drift material from sandier parent material upslope from the profile site. It is doubtful whether this assumption of bisequancy in one case but not in the other can be justified and, as stated above in connection with Merit profiles, there is good reason to consider that the majority of upland soils over sedimentary rocks are not strictly residual in origin. Furthermore, it is illogical within the terms of the classification system presently used to group residual and nonresidual soils in one family. In short, the Bekenu Family is an unsatisfactory classification unit. It does, however, group together those soils which have the general profile morphology of Merit and Nyalau soils but are intermediate in texture between them; this was the point uppermost in mind when the family was introduced.

Bekenu soils generally occur in areas where sandstone beds outcrop but are not sufficiently extensive to give rise to Nyalau soils, or in areas where the underlying rocks are of intermediate texture grade, such as sandy shales. Bekenu soils rarely cover wide areas and most commonly occur in complex association with Merit soils, as in this area.

The topography on which this association is found ranges from gently undulating to moderately rolling. Slopes steeper than 25 degrees are, however, uncommon and the mapping unit as a whole can be considered suitable for cultivation, particularly of tree crops, provided terracing and fertilizers are used. As, however, the terrain is varied, contour mapping (together with semi-detailed soil survey) is recommended for localities considered for development before planning decisions are taken.

Merit-Nyalau Association

The hill land in the west of the survey area (and a minor portion of the ulu Sarupai in the northeast) have been mapped as a Merit-Nyalau Association and comprise, in the main, soils of the Merit, Bekenu and Nyalau Families. These areas are underlain by rocks of the Liang, Begrih and Balingian Formations (Tatau Formation in the Sarupai area). Attempts were made to subdivide this mapping unit but this was found to be impossible on the basis of the reconnaissance-level data available. On the traverses which were sampled, however, the impression was gained that a complex of all three families is rarely found in this unit, that one is dominant in each locality, and that survey at a semi-detailed level would be sufficient to isolate large tracts of both Merit and

Nyalau soils, with Bekenu soils being a minor component in each unit and rarely widespread. Data at present available suggest that Merit, with subordinate Bekenu, soils are dominant in the southern part of the Liang Formation draining to the Sg. Lemai, both Merit and Nyalau soils are important in the northern part of the Liang outcrop drained by ulu Bawan, and that the Balingian rocks are mantled mainly by Merit soils on the border of the survey area but that these are replaced by Nyalau soils on the lower hills fringing the swamps (i.e. in the headwaters of the Bayan, Teres and Bedengan). It appears that in all three formations, while a varied lithology is present, outcrops of one rock type cover a wide area and are directly reflected in the soil mantle. Thin bands of alternating sandstone and shale, which are typical of the Belaga Formation, are less common in the Miocene/Pliocene rocks.

The heavy-textured Merit Family soils have been described under the preceding association. A variant of the normal profile, which may deserve series status, has been noted in this mapping unit in various localities (overlying rocks of all three formations). It is abnormally red in colour and comprises a strong brown to yellowish red clay loam, overlying a yellowish red to red clay. The 'stoneline' material, while largely comprised of iron-enriched shale fragments, includes numerous 'pipes' or root impressions. It was expected that such profiles indicate highly ferruginous shales but analysis of one profile show little difference from the normal Merit profile in this respect and it may be the form of iron rather than the amount which is important. The one profile which has been examined in some detail is located immediately outside the survey area to the northwest (underlain by Balingian Formation rocks). It is included in Appendix II as Profile 8.

Nyalau Family soils are developed over sandstones or sandstones with subordinate shales. They are light textured throughout the subsoil. The normal profile is a yellow or brownish yellow sandy loam or sandy clay loam grading at depth to a yellow, brownish yellow or reddish yellow sandy clay loam. Apart from drift fragments, recognisable weathered rock is rarely seen within 48 inches of the surface, the profile being normally deep. Sandstones outcropping in central Sarawak appear to be either sufficiently hard to give prominent relief features and very shallow soils of the Meluan Family, or easily weathered and associated with gently rolling terrain and deep Nyalau profiles. Intermediate types which might be expected to give rise to shallow Nyalau soils are not often encountered. Except on lower slope sites, Nyalau soils are generally freely to excessively drained. Structure is at best weakly developed and most profiles appear structureless in moist condition. Profile 9 in Appendix II is a Nyalau profile from this survey area.

A number of other soils are present in this mapping unit, although none cover large areas. Conglomerates are present in all three geological formations underlying the association and pale-coloured gravelly loams and sands derived from them are locally encountered and placed in the Tika and Saratok Families. Saratok soils are morphologically similar to Nyalau soils but are much paler in colour. Tika soils are described in a following section.

These soils are usually encountered in footslope positions in this mapping unit and are probably developed in colluvial wash material. It is likely, however, that in some localities terrace remnants fringe these hills but are too restricted in extent for recognisable landform features to have been preserved. Some of the footslope sandy soils may thus be of old alluvial origin. Weakly developed podzols of the Sibantek Family (also discussed more fully in a later section) are also locally present, particularly in the area underlain by Begrih Formation rocks between Sg. Teres and ulu Bawan. Westward from this area, outwith the survey area, these soils were found to be a major component of the soil mantle. Kerait Family soils, very pale in colour but otherwise similar in morphology to Merit soils, were recorded in many parts of the mapping unit but were nowhere found to cover extensive areas.

Most of this mapping unit has rather subdued relief and comprises gently undulating to moderately rolling hills fragmented by swamp tracts. More steeply rolling terrain is locally present in the north and in the watershed zone between the Lemai and Bawan drainage farther south. Nowhere in this mapping unit, however, is steepness of slope a major limitation to agriculture and the bulk of the mapping unit has been cleared for cultivation in the past. Isolated remnants of primary forest, where investigated, were found to be associated with poor soils, generally of the Silantek Family. The dominant soils of the Merit, Bekenu and Nyalau Families have largely been used for hill padi and are under regrowth. Much of the land has been overworked and the regrowth is of poor quality. Rubber has been planted in some areas and pepper gardens have also been established near some longhouses.

There are good prospects for development in this mapping unit but semi-detailed survey of localities under consideration for agricultural planning would be essential as the soil mantle is varied. Heavy fertilizer applications are likely to be required for most crops and in some localities eradication of lallang may be a problem.

Nyalau-Merit Association

The tract of country stretching southwest from Bt. Tunggai to the lower Arip, which is largely underlain by Nyalau Formation rocks, has been mapped as a Nyalau-Merit Association. In many respects the soil mantle is very similar to that of the Merit-Nyalau Association described above. This area has been distinguished on the soil map because soils of the Nyalau Family are dominant in most parts of it and the numerous other soils which occur rarely cover large areas. Moderately shallow Nyalau profiles are also common, having weathering sandstone within 30 inches of the surface. As previously mentioned, this is unusual for central Sarawak, and is presumed to be a feature related to the Nyalau Formation.

In one locality in ulu Anak, Merit soils were recorded as the dominant Family. This appears to correlate with the outlier of the Tatau Formation shales mapped by Wolfenden (1960) in this area (see Fig. 2) but there is at present insufficient data available to justify bounding these soils off as an isolated portion of the Merit Association which has been mapped farther east over this formation.

Apart from soils of the Nyalau Family and subordinate Merit soils, local occurrences of Saratok, Tika and Silantek soils were recorded on traverses in this mapping unit. Tika and Silantek soils are common to the south of Sg. Arip, but appear to be very restricted in extent to the north.

The western portion of the association comprises gently undulating terrain which has been largely cleared for hill rice and, in some areas, for rubber. Moderately rolling terrain is commoner farther east and here much of the land remains under forest. The agricultural potential of this mapping unit is comparable to that of the Merit-Nyalau Association but as sandy soils are dominant in most localities, the erosion hazard is somewhat greater and steep slopes may be limiting in some areas, particularly parts of the forested tracts in the east of the unit.

Nyalau-Kerait Association

The soils in much of the area drained by Sg. Kemena have a range of characteristic similar to that of the Nyalau - Merit Association but Kerait soils are widespread. In the Nyalau - Merit Association these soils are rarely encountered. The Kemena area soils have therefore been separated as a Nyalau - Kerait Association. The boundary of this unit agrees closely with that of the Bawang Formation rocks mapped by Wolfenden (1960).

This area is gently undulating to moderately rolling and the mapping unit is broken by bottomland tracts associated with the Sg. Kemena and its main tributaries. Nyalau and Bekenu soils are dominant, both being commonly of only shallow depth and underlain by weathered shales and sandstones at 20 - 30 inches. Merit soils are also present in some localities. These yellow to yellowish brown soils are intermixed, however, with paler-coloured soils which are mainly placed in the Kerait Family, although Saratok and Tika soils are also present. Kerait Family soils comprise pale yellow to light grey sandy loams grading to sandy clays of clays at depth and are commonly mottled yellow or reddish yellow in the lower subsoil. Profiles which are silty clay loam over silty clay also occur. The criterion on which the family is separated from Saratok soils is the heavy texture at depth. Kerait soils have clay, sandy clay or silty clay horizons within 48 inches of the surface. Saratok soils have a similar profile form but are coarser in texture throughout the top 4 feet. Normally, sandy loams overlies loams or sandy clay loams in Saratok profiles and there is commonly a stoneline of quartz gravel at the base of the profile. This feature is also found in Kerait soils but, where, present, the stoneline is generally thinner in the latter. Kerait soils are associated with iron-poor shales and mixed shales and sandstones.

Saratok soils are generally developed over iron-poor sandstones or in colluvial deposits on the footslopes of hills which are mantled by light-textured soils, such as those of the Nyalau Family. In this mapping unit Saratok soils do not appear to be widespread. Soils similar to those of Saratok Family in which the subsoil is sand or loamy sand throughout the surface 48 inches are separated as Tika Family, which are described in Appendix I. These soils are present in the western part of the unit but cover very small areas.

The Nyalau-Kerait Association is thus dominantly one of soils with varied texture and natural fertility. Most soils in the unit can, however, be used for agriculture once their fertilizer requirements are established and met. The area covered by the association is of particular interest for development because the terrain is generally not a limiting factor, much of the area remains under forest and the proposed trunk road is projected to skirt it closely on the eastern side. More detailed investigation of this area is therefore warranted.

Kerait Association

The Nyalau-Kerait Association in the Kemena area is associated with undulating and rolling terrain. In many localities this grades to very gently undulating terrain, close to the Sg. Kemena itself and its main tributaries, bearing poor forest. Where investigated these areas proved to be mantled largely by Kerait Family soils, described in the preceding section, although Saratok and Nyalau soils are locally present also. This low terrain has therefore been isolated on the map as a Kerait Association.

The fact that the areas in which these soils are dominant are of low relief and close to main drainage lines or swamp borders suggests that the soils may be developed in old alluvium rather than Eocene sediments. If further investigation proves this to be the case, the soils would be appropriately reclassified as Lubai Family in the system now in use.

Low fertility is the main limiting factor to development of these soils and too few data are available from experimental work for their fertilizer needs to be known. Until more is known about their development of Kerait soils is not recommended. Where, as in the adjacent Nyalau-Kerait Association, they occur in complex association with other better soils they must be included in any planting scheme but where, as in the present association, they are dominant over sizeable areas, such areas are best avoided.

Merit-Kerait Association

An isolated cluster of hills close to the Batang Balingian downstream of Sg. Duan was investigated on one traverse. The dominant soils on the line sampled proved to be of the Merit and Kerait Families and these hills have therefore been isolated as a

Merit-Kerait Association. It appears likely, however, that this is an extension of the Merit-Nyalau Association which is dominant over similar rocks farther west. Further investigation might show that a wider range of soils is present.

The terrain is moderately rolling and is largely used for hill padi at present, with some rubber near the main river. The development potential is similar to that of the Merit-Nyalau Association.

Bako Association

In one locality between Sg. Maong and Sg. Jarupai an extensive belt of gently sloping terrain was noted, mantled by podzols of the Bako Family and bearing poor heath forest. As terrain and vegetation contrast sharply with the adjacent Merit-Nyalau Association on undulating and rolling topography, it has been possible to isolate the unit on the map. Bako soils have been described under the Meluan-Bako Association. In this area, unlike the Tunggal Series of the Bt. Tunggal conglomerates, the normal Bako profile with a loose eluvial horizon is present and the profile is developed over sandstone. The soils comprise a light grey sand or loamy sand, overlying a dark brown sandy loam horizon which may be friable in its upper portions but becomes hard and impossible to penetrate with an auger within a few inches. The hard pan, on the line inspected, was found to be generally within 20-25 inches of the surface. At the foot of the slope, however, the overlying light grey sands are deeper and locally the pan is, if present at all, more than 48 inches below the soil surface. Such deep soils are separated in the Tika Family.

Development of these soils is not recommended.

Nyalau-Silantek Association

A Nyalau-Silantek Association has been mapped on the northern footslopes of Bt. Keladan, on hills between Sg. Arip and Sg. Nibong and in scattered low hills fringing the swamps in the ulu Sg. Sapaya, a tributary of Sg. Basai.

The association comprises soils of the Nyalau, Saratok and Silantek Families, with some Tika Family soils in the Sg. Arip area. In most localities the unit is under poor forest, although some of the Nyalau soils have been cleared for rubber or hill padi in the Sg. Arip area.

Where mapped in the Sg. Arip and Bt. Keladan areas, these soils are developed over sandstones and conglomerates, the latter giving rise to Saratok and Tika soils. In the ulu Sg. Sapaya area the parent material is uncertain. The mapping unit occurs as scattered lowland areas fringing hills which are mainly built of argillaceous material. The sandy soils may be developed in old alluvial material rather than sandstones. If that is the case, they require placement in different families (Sabangang, Triboh and Buso). As the association covers a very small area in all three localities, particular study of these soils is not justified at this level of mapping and they are therefore grouped together.

Where present in the Bt. Keladan area the association covers a very small area and is surrounded by soils which are unsuitable for agriculture. Elsewhere, however, the association is adjacent to tracts of the Nyalau-Merit and Merit-Bekenu Associations which have potential for development. Should planting be considered on these better soils, development can extend into the Nyalau-Silantek Association where Nyalau soils are present. The Saratok, Silantek and Tika soils should be avoided, however.

Silantek Association

Silantek soils rarely occur alone in this survey area. They normally are found in association with Nyalau and Saratok soils, as in the association described above, or with Kerait soils, as in the association described below. In a few localities (the middle Sg. Anak and near Sg. Buloh) these weakly developed podzols were noted as the dominant soil capping low hills and have been separated on the map. In both localities there is some doubt regarding the material in which these soils are developed and it is possible that they mantle alluvial terrace remnants rather than outcrops of sandstone and should properly be placed in the Buso Family.

The association covers a very small area and comprises soils with acute nutrient deficiencies. Development is not recommended.

Silantek-Kerait Association

The Silantek-Kerait Association comprises soils present in the extreme west of the survey area between Sg. Basai and Sg. Danau. In this locality the swamps are bordered by low undulating terrain bearing poor forest and mantled by soils of the Kerait Family. In this unit Kerait soils are light grey to pale brown sandy loams grading at depth to clay or sandy clay, and the profile is mottled yellow throughout. In places the texture is clay loam or sandy clay loam at depth and, while heavier textured horizons are probably present below a depth of 4 feet, such soils are placed in the Saratok Family. This undulating terrain rises back from the swamp margin to a ridge, mantled by heath forest, which is mainly mantled by weakly developed podzols of the Silantek Family. These are, in this locality, light greyish brown sands overlying at a depth of 18 inches dark brown loose fine sandy loams which grade to brownish yellow loam from sandstone with humus staining down the main structural cracks. A detailed profile description of a Silantek profile from somewhat farther north and just outside the survey area is included as Profile 10 in Appendix II.

An outlier of this association has been mapped farther south in ulu Sg. Basai on inference from the vegetation and terrain. It has not been investigated in the field. The terrain suggests that Kerait soils, rather than Silantek, are likely to be dominant in this part of the unit.

All soils in this association are deficient in plant nutrients and the association does not cover a significant area. The mapping unit is best ignored in development planning.

Tika Association

Soils of the Tika Family occur as minor components of a number of associations in the area. They are particularly important in two localities, however, and have been mapped as a consociation between Sg. Pelugau and Sg. Setawak and west of Batang Balingian between Ng. Bawang and Ng. Arip.

Tika Family soils comprise coarse sands to loamy sands with no genetic horizons expressed in the profile. In this area they are normally pale yellow, light grey or white in colour, have a stoneline of quartz gravel at depth in the subsoil and are derived from sandstones and conglomerates. The family is an addition to the system to cater for undeveloped soils of this nature which are otherwise not covered by the classification. The definition of the family and its relationship with other families are discussed in Appendix I.

Tika soils are extremely infertile and bear a poor forest cover. They should not be considered for agriculture where they cover extensive areas, as in this association. Where they occur as minor units in other associations it will probably be necessary to include them in any planting scheme but particularly heavy fertilizer applications are likely to be required.

Merit-Tika Association

To the south of the Tika Association mapped near Batang Balingian the soil mantle is locally a complex of Merit and Tika soils. This area, which is not extensive, has been mapped as a Merit-Tika Association. Without more detailed investigation to assess whether the Merit soils cover a significant acreage the unit is best not considered for development.

Buso Association

Close to the coast in the northwest of the survey area weakly developed podzols are locally present. These become more extensive farther west outwith the survey area (SCOTT, 1970). They are classified in the Buso Family and the unit is mapped as Buso Association. The profile is normally a pale brown to light greysand overlying a dark brown sand, the dark-coloured horizon resting in turn on yellow to pale olive sands. The profile is loose throughout and the dark horizon of humus accumulation shows no signs of cementation. These soils are developed in marine sands which are at a slightly higher elevation than the present beach material and represent a low fossil beach. The difference in elevation is not great, however, and the water table at the time of the survey was rarely more than 2 feet below the soil surface. In depression sites within the mapping unit, Buso soils are replaced by soils of the Tatau and Matu Families, which are described below.

These soils are generally left unfarmed in this area and bear a cover of poor forest. Elsewhere they have been used for agriculture, particularly for coconut and pineapple. They can only be recommended for these crops, however, where heavy fertilizer applications are practicable. It must also be noted that optimum use of adjacent Tatau and Matu soils requires drainage improvement and such improvement is likely to involve complications of droughtiness on nearby Buso soils if the latter are cultivated as well. No recommendations are therefore made for development of this mapping unit.

Buso soils also occur farther inland where they could not be mapped separately from peat soils and a compound unit has been employed. These are described under the Buso-Anderson Association below.

Buso-Sabangang Association

In the middle section of Sg. Bawang, near Rh. Balong and Rh. Mapan, a complex of low hills and terrace flats are found close to the river and are mantled by a variety of soils developed in old alluvial material. The unit has been mapped as a Buso-Sabangang Association although a number of other families were recorded.

At Rh. Balong well-developed Buso soils were noted, comprising light grey fine sand underlain by dark grey fine sand which in turn grades at depth to dark yellowish brown sandy loam. This soil is found on a flat terrace remnant which has been used for the site of the longhouse. It was not noted elsewhere in the mapping unit but may occur. More widespread are pale yellow to yellowish brown sandy loams to sandy clay loams of the Sabangang Family, the texture normally becoming heavier at depth in the profile and scattered subrounded quartz gravel being present at various depths or throughout the soil. These soils occur on undulating terrain in association with heavier soils of the Lupar Family, comprising brown to brownish yellow clay loams, grading to clay at depth and underlain by a stoneline of subrounded quartz gravel. Between Rh. Balong and Rh. Mapan Lupar Family soils are associated on gently undulating terrain with poorly drained soils which, if also derived from old alluvium, are classified in the Embang Family. These comprise light grey sandy clay loams with rusty mottling grading at depth to light grey and yellow mottled clays or sandy clays.

The variability of the soil mantle in this mapping unit is such that none of the soils described above can be considered dominant in the unit without further more detailed investigation. The association covers a very small and fragmented area and has little development potential for this reason. Lupar and Sabangang soils can be used for tree crops and Embang soils can also be utilised with improved drainage and heavy fertilizer applications. Buso soils should be avoided.

Seduau-Lupar Association

During investigation in 1966 of the area upriver of Nanga Pelugau, mature soils of the Lupar Family were noted at many points on spurs close to the river. The profile comprises brownish yellow clay loam or sandy clay loam overlying brownish yellow to reddish yellow sandy clay or clay and a stoneline of subrounded quartz gravel underlies the profile. As the profile is very similar to that of Merit or Bekenu Family soils, and the topography is moderately rolling with no suggestion of terrace remnants, the identification of the parent material of these soils as old alluvium (on which classification as Lupar Family relies) is difficult except where the stoneline is exposed in landslips or river-cuttings. Lupar soils may therefore be more widespread near the main river than is suggested by the map. The mapping unit has been limited to that section where such profiles were observed and includes some Merit and Bekenu soils. In that locality small tracts of present floodplain land mantled by Seduau soils also occur. These cannot be isolated at the mapping scale used and a Seduau-Lupar mapping unit has therefore been employed. Seduau soils comprise brownish yellow to brown clay loams and clays developed in recent alluvial material without horizon differentiation.

Careful terracing is required on the hills mantled by Lupar soils, which commonly have slopes of 15 - 25 degrees. The more suitable agricultural soils of the Seduau Family cover very restricted areas. The unit as a whole is surrounded by land with low potential due to steep slopes. No recommendations are made for development.

Pendam Association

The Pendam Association comprises saline clay soils of marine or estuarine alluvial origin. The association is found immediately upstream of Kuala Balingian, in the lower reaches of Sg. Sarupai and bordering many of the streams flowing directly off the large peat swamp tracts to the sea. Along much of the coast itself an intermittent belt of these soils is present but it is only broad enough to be mapped near Kuala Balingian.

The association comprises mainly soils of the Pendam Family which are poorly-drained bluish grey to dark grey clays and are weakly to moderately saline. They are associated with similar but younger soils of the Rajang Family, which are strongly saline. Salinity levels have not been measured and the salinity status is inferred from the natural vegetation cover. Rajang soils are typically found under mangrove forest on sites close to the sea and subject to frequent tidal incursions of sea water. Pendam soils are less subject to brackish water influence and normally bear a cover of nipah forest. The vegetation in this area suggests that the bulk of the association is appropriately considered to be of the Pendam Family and that Rajang soils cover only restricted areas. More detailed investigation may, however, revise this opinion.

These soils are inherently fertile but, except for wet rice on Pendam soils, require drainage improvement and salt leaching before a wide variety of crops can be recommended. Given the provision of drainage works, the main limitation to cultivation is possible sulphate concentrations. This is a major limiting factor in Rajang soils but is of less importance in soils of the Pendam Family. In view of the lack of factual information on the chemical status of the soils in this association and the limited acreage covered by it, it is not recommended that these soils be developed. If, however, adjacent soils of the Mukah Association are brought into cultivation with improved drainage, planting can extend onto Pendam soils. Elsewhere in the State, Pendam soils have been successfully used for a variety of crops, including rice, coconut and fruit trees.

Mukah Association

The Mukah Association is mainly a consociation of Mukah Family soils. These comprise peats which are more than 10 inches but less than 40 inches in thickness and are underlain by clay or silty clay mineral horizons. They form a transitional belt between the estuarine clays of the Pendam Association (or, locally, the riverine clays of the Bijat-Sebandi Association) and the deeper peats of the Anderson Association. Where the association has been mapped near the coast it also commonly occurs in bands roughly orientated with the present beach and representing clayey depression sites between fossil beach line material which have later been infilled by shallow peat deposits. The association has only been mapped in coastal areas, where detailed reconnaissance data is available. Elsewhere, these soils have been combined with other alluvial and organic soils for mapping purposes. Even in the area covered by this more detailed survey work the soil pattern is too complex for Mukah soils to be accurately isolated from related soils and the association therefore includes minor occurrences of deeper peats of the Anderson 1 Family and shallow peats similar to those of the Mukah Family which are underlain by marine sands. These are classed in the Igan Family.

Mukah Family soils, in their present state, are suitable only for a limited range of crops such as wet rice and sago. Drainage improvement and permanent lowering of the water table is necessary before a wider range of crops can be recommended. In coastal situations in this area there is little prospect of drainage improvement except as part of a large drainage scheme. Development of these soils depends on the practicability of such a scheme.

Pendam-Mukah Association

The transition from Pendam soils near the river bank to Mukah soils farther from the river, which is found near Kuala Balingian, continues upstream beyond the area covered by the detailed reconnaissance survey. The complexity of the soil pattern is such, however, that the associations cannot be reliably separated on the map from the broader reconnaissance data available.

Pendam soils have therefore been combined with soils of the Bijat-Mukah Association in this section of the river and a Pendam-Mukah Association mapping unit employed. The boundary of the unit is taken as the limit of nipah palm observed on air photographs. Where nipah is present it can be inferred that the clayey mineral alluvial soils are of the Pendam Family rather than the nonsaline Bijat Family.

The soils in this mapping unit are discussed under the Pendam and Mukah Associations above and the Bijat-Mukah Association below.

Bijat-Mukah Association

The mineral soils and the shallow peat soils found close to the banks of the Batang Balingian, in the middle Arip valley and locally on the banks of other moderately large streams have been mapped together as a Bijat-Mukah Association as the transition back from the river bank from one soil to another is commonly rapid and the soil family which is dominant in the association changes from place to place. The full sequence of soils is listed below. In practice the complete sequence is not usually present.

The river bank itself is commonly mantled by soils of the Semilajau Family, these comprising brownish yellow or yellow loamy sands or sandy loams with somewhat heavier textures at depth in the profiles and, commonly, rather redder colours. These soils are particularly associated with levee sites, occupy a very narrow band back from the river bank and are generally absent from the association in the lower reaches of the river. Where a well-developed levee is present, they may be replaced by or grade back into soils of the Malang Family, which have equivalent characteristics to those of Semilajau except for texture, Malang profiles being clay loam grading at depth to clay.

Where no levee is present, or is only very weakly expressed as in most streambank situations in this survey area, Semilajau and Malang soils are replaced by soils of the Sedau Family which comprise brown, brownish yellow or reddish yellow clay loams or clays without genetic horizon differentiation.

Semilajau, Malang and Sedau soils are at least moderately well-drained, and only extend far back from the river where a well-developed levee is present and gives rise to a broad band of soils above the general level of the floodplain, or where artificial drainage has been provided as in many tanjongs cleared for rubber or other crops. Most soils in river floodplains, however, are imperfectly to very poorly drained and are classed in the Bijat, Sebandi and Mukah Families.

Bijat Family soils comprise light grey clays which are commonly strongly mottled yellow, reddish brown, etc. Transitional profiles between Malang and Bijat soils, in which the gley colours and strong mottling are confined to the lower half of the profile, are common. Bijat soils are flooded periodically and normally have the groundwater level high in the profile except for a brief

period during the driest part of the year. They are not permanently waterlogged, however, or flooded for sufficiently long periods for surface peat to form. In depression sites or as transitional soils between those of the Bijat and those of the Mukah Families such soils are, however, found and these are classed in the Sebandi Family. Sebandi profiles generally comprise completely gleyed clay, light grey or grey in colour and without strong mottling, on top of which a thin surface peat layer has developed but is not more than 10 inches in thickness. These soils generally grade laterally into soils in which the surface peat is deeper than 10 inches and the latter are separated in the Mukah Family, described in a preceding section.

The well-drained soils of the Semilajau, Malang, and Seduau Families are suitable for a variety of crops, including rubber, oil palm, fruit trees and dry season vegetables. They experience some annual flooding, are actively accreting (although probably only significantly so in Seduau Family soils) and thus have a somewhat higher nutrient status than equivalent residual soils from the same sedimentary parent materials. The potential of these soils is limited by the flooding hazard during the wet season, which restricts the range of perennial crops possible unless protection against it can be provided, the generally restricted acreage which these soils cover and, most important, the fact that they are generally confined to the banks of major rivers which are also the situations in which the settlement of the area is concentrated and these soils are, as a result, fairly fully used for tree crops (especially rubber) at the present time. Unless sufficient interest can be generated for people to cut down their old rubber trees, there is little scope for development on these soils in most localities.

Bijat and Sebandi soils are suitable for wet padi with flooding control and, with the same proviso, can also be used for dry season vegetables with banking. Mukah soils require drainage improvement before they can be recommended for development, as has been discussed under the Mukah Association. The possibilities for improved drainage and flooding control are greater in localities near the Batang Balingian, however, than they are close to the coast. The river meanders widely and it appears practicable for some of the major tanjongs to be banded off from the basin peat swamps which adjoin the shallow peats near the river and improve each tanjong as an independent unit. As can be seen from the map, however, such possibilities are mainly confined to the Pelugau-Lemai section of the main river and areas near Balingian bazaar. In the middle section of the Batang Balingian the association as a whole occupies a very narrow strip back from the river, quickly grading into deep peats of the Anderson Family. Possibilities for improvement also exist in the middle Arip, the upper Sarupai and the upper Buloh floodplain areas but all three areas mentioned are used for wet padi at present and any scheme considered for them would concern improvement rather than the opening up of new land.

Tatau-Matu Association

The Tatau-Matu Association is confined to areas close to the present coast and comprises soils developed in beach sands with no deep surface peat accumulations. The main soils in the association are those of the Tatau and Matu Families. The former comprises poorly-drained sands, pale yellow to light grey in colour, commonly mottled, with the water table normally within 20 inches of the surface. The latter comprises very poorly-drained sands, completely gleyed, in which surface peat is present but is less than 10 inches in thickness. Tatau and Matu soils commonly occur in complex association, Matu occupying depression sites and Tatau undulations with slightly better drainage conditions.

On the beach itself Tatau soils commonly grade into well-drained brownish yellow sands of the Kabong Family (locally these are pale yellow or light grey in colour) but these occupy only a narrow strip back from the beach. Minor occurrences of weakly-developed podzols of the Buso Family are also present but where these are extensively found they have been separately mapped as a Buso Association. In association with Matu soils in some depressions very poorly drained sands with more than 10 inches of surface peat are also recorded and are placed in the Mukah Family, but these also are of minor extent. Near Sg. Bedengan sandy soils with the physical characteristics of Tatau Family were noted under mixed nipah and swamp forest. The presence of nipah suggests that these soils are slightly saline and they may, on that characteristic, be more appropriately classed in the Nonok Family. They do not occur in other areas and no salinity measurements have been made. They are provisionally classed as Tatau soils, therefore.

The soils of this association are commonly used for coconut in this area and can be recommended for this crop if drainage is improved to some extent and fertilizer requirements met. They may also be used for certain vegetable crops but are too sandy for a wide range of crops to be recommended.

Plan Association

The valley tracts bordering the hills in the west and southwest of the survey area are generally infilled by peats and, unless cleared for wet padi, bear a cover of peat swamp forest. One valley in the southwest of the area, however, has a poor grass cover and was briefly investigated. The soils present in the section examined comprise largely grey to dark grey medium sands, faintly mottled yellow. These are poorly drained and are at present floodplain level. They are therefore placed in the Plan Series of the Tatau Family. It is, however, difficult to understand why dominantly sandy alluvium should be deposited in this situation as the surrounding hills, while including Nyalau and Bekenu soils in the mantle, are dominantly clayey soils of the Merit Family. It is thus possible that this unit represents a 'drowned' terrace remnant and these soils, in the present classification, should be considered in the Gong Series. Minor soils with depositional layers of loam and sand were also noted and are unclassified.

The soils in the association are agriculturally poor and the mapping unit is of very restricted area. No development is recommended. The unit is of some academic interest, however, and, together with other possible terrace remnants in the locality, should be further investigated when occasion arises.

Igan Association

Igan Family soils are equivalent in characteristics to Mukah soils with the exception that the moderately deep surface peat layer is underlain by sand rather than clay. The Igan Association is dominantly one of Igan Family soils. It has been mapped in coastal areas and generally occupies a transitional position between soils of the Tatau-Matu Association and the deeper peats of the Anderson Family. Minor areas in which the surface peat layers are deeper than 40 inches are present and these are placed in the Anderson 1 Family. They are generally underlain by sands. The pattern of the basal sand and clay is very complex in detail, however, and minor occurrences of Mukah Family soils have also had to be included in this mapping unit.

Igan soils cannot be recommended for agriculture in their present state but provided drainage can be improved their potential is similar to that of the soils in the Tatau-Matu Association.

Anderson Association

All peat soils in which the peat deposits are more than 40 inches in thickness are classed in the Anderson Family. The character of the underlying mineral horizons is ignored for classification purposes. Three depth phases are distinguished, as follows:

- Anderson 1 - peats 40 to 80 inches deep
- Anderson 2 - peats 80 to 120 inches deep
- Anderson 3 - peats deeper than 120 inches.

The Anderson Association comprises Anderson Family soils with few inclusions of other soils. The latter are likely to be confined to the borders of the mapping unit and comprise outliers of adjacent associations included through faulty interpolation of the boundary on the basis of the survey data. The family is mapped in its three depth phases defined above.

It can be seen from the soil map that the Anderson Family covers an extremely large part of the survey area and that the bulk of the swamp tracts comprise peats which are deeper than 10 feet. Back from the main river the gradation from mineral alluvium through shallow peats to deep peats is very rapid and it is only on the seaward margins of the swamp that significant tracts of Anderson 1 and Anderson 2 soils are consistently present. This appears to be an effect of the 'backslope' of the coastal bar behind which the swamps have developed. Study of the distribution of marine sand underlying the peats (mapped in the report on the detailed reconnaissance of the coastal areas (SCOTT, 1970);

shows that the inland limit of sand deposits in this area rarely extends far beyond the shallow peats of the Igan and Mukah Families, and that basal clay becomes dominant where the overlying peats are 40 - 60 inches thick. The development of large peat swamps of this kind has been described in detail by Anderson (1964).

It can also be seen from the soil map that the deep peats have infilled many of the old river valleys draining into the swamp area and that, particularly in the west and southwest, it is generally the case that the transition at the hill foot from shallow to deep peats is so narrow that only Anderson 3 soils can be mapped at the scale used.

These soils are used to some extent for sago and the peat swamp forest and other forest types which mantle them are extracted for timber. Without a major drainage scheme timber extraction appears the best use for these soils and a drainage scheme for peat swamps of this type does not appear practicable. Considerable quantities of water shed directly off the surrounding hills into the swamp, only part flowing in established drainage courses. There is a considerable flooding risk from the Batang Balingian which flows through the swamp to the sea and this risk would increase as drainage improvement lowered the level of the peat surface. The only possibilities for improving these soils with a view to agriculture appear to be where the peats are reasonably shallow (Anderson 1 soils) and in locations where they, together with better soils (of the Mukah Family, mainly), can be isolated from the main body of the swamp by bunding. Such areas are confined to some of the larger tanjongs of the Batang Balingian and possibly some coastal localities between two major streams.

Bijat-Anderson Association

A Bijat-Anderson Association has been mapped in areas where mineral alluvial soils and peat soils of at least moderate depth are known to occur but where, either the range of soils present and their relative importance is uncertain, or the transition from mineral soil to deep peat occurs over too narrow a belt for the unit to be further subdivided on the mapping scale used. The former situation is present in many of the peat-infilled valleys bordering the main peat swamps. Traverses crossing some of these floodplain tracts encountered only Anderson 3 soils. In other comparable tracts, however, Bijat, Sebandi, Mukah and Anderson 1 soils are all present, and Seduau soils may also occur on stream banks. The Bijat-Anderson mapping unit has been employed for such areas to indicate that peats deeper than Anderson 1 are, if present, of minor extent in these valleys. The second situation mentioned is found in the middle sections of Sg. Basai (Lemai) and its tributaries and near some other streams. Mineral soils of the Bijat and possibly Seduau Families exist along the river banks but grade quickly to shallow and moderately deep peat soils back from the river. Where the association has been mapped in these localities Anderson 1 and 2 soils are dominant within the unit but Anderson 3 soils do not occur.

Only the areas where this mapping unit is found in valley tracts on the fringes of the swamp are of interest for development. As the soil mantle is varied, semi-detailed survey would be required in each case before recommendations could be made.

Nyalau-Anderson Association

In a few localities (near Nanga Lemai, in ulu Sg. Bawan and in the extreme northwest of the survey area) low hills mantled by Nyalau soils are intermixed with swamp tracts mantled by peat soils and the vegetation cover or air photo quality is such that the hill areas cannot be isolated. A Nyalau-Anderson Association has therefore been mapped and has been subdivided into Nyalau-Anderson 1, Nyalau-Anderson 2 and Nyalau-Anderson units to indicate the depth of peat which records suggest occur in the bottom-land areas. In the case of the Nyalau-Anderson unit, no data on this are available and Anderson soils of all depths may occur.

The potential of the soils in this mapping unit have been discussed under the Merit-Nyalau and Anderson Associations.

Buso-Anderson Association

Between Sg. Bakau and Sg. Bayan a complex of swamp tracts and low undulating terrain with podzol soils was encountered and mapped as a Buso-Anderson Association. It is probable that the podzols in this mapping unit are developed in old marine sands. Both weakly and strongly developed podzols occur. Greyish brown to dark greyish brown loose sands overlying very dark brown hard sandy humus pans are present and have been placed in the Miri Family. The pan layer is generally at 20-25 inches depth. Greyish brown to dark greyish brown sands which become somewhat darker in colour with depth but do not develop a humus pan are also present, however, and have been placed in the Buso Family.

The swamp tracts intermixed with the sandy undulations are generally mantled by shallow peats of the Mukah and Anderson 1 Families. Towards the borders of the mapping unit, however, deeper peats may occur.

No development is recommended for this mapping unit.

Miri-Anderson Association

Bordering the northwestern flank of Bukit Piring is a belt of very gently undulating country bearing mixed swamp forest and heath forest and mantled by well-developed podzols of the Miri Family. In this unit the Miri profile is typically a light grey to brown coarse sand overlying at a depth of 15-20 inches a hard black coarse sandy humus pan. Locally this is replaced by deeper weakly-developed podzols of the Buso Family, comprising light grey to greyish brown coarse sand with intermittent dark brown patches

at depth in the profile. The coarse grade of the sand in these soils suggests that they do not represent remnants of old marine terraces like the soils described in the preceding association but are developed in colluvial material derived from the igneous rocks of Bukit Piring.

To the north the podzols give way abruptly to Anderson 3 soils. The boundary cannot be delimited accurately on the air photographs for this locality and the mapping unit has therefore been called a Miri-Anderson Association as some deep peat soils are likely to be included in it.

No development is recommended for these soils.

Soils near Sg. Bawan

Wall (1961) mapped the lower section of the Sg. Bawan drainage area and, where records from this survey are available, field work was not repeated on the present survey. Traverses in this locality were sited to fill gaps in the records. The 1961 map shows a broad belt of Anderson 1 and 2 soils, and relatively restricted areas of Anderson 3 soils far from the Batang Balingian; the bulk of the peat soils in this locality are underlain by sands. Although not indicated on the map, the field records also show minor occurrences of podzols to the north of Sg. Bawan in its lower section. Field work in 1970 showed no agreement with the earlier work and recorded generally much deeper peats, all underlain by clays. This is surprising, particularly as there is fairly close agreement between the two surveys farther towards the coast. There is obviously a need for further work in this area and it is hoped that the Sg. Bawan locality can be reinvestigated in 1971. To avoid delaying production of the soil map, however, the earlier survey has, for the present, been ignored and boundaries extrapolated entirely from the 1970 traverse records.

Until further information is available it should be noted that the soils data for the Sg. Bawan area is of doubtful reliability.

SOIL AND LAND SUITABILITY

A soil suitability classification for Malaysia was recently finalised and circulated (WONG, 1970). For various reasons, this system is not appropriate for assessing the potential for agricultural development in the survey area. The reasons need not be discussed here. This system does, however, give a framework within which the mapping units employed in this area can be compared with soil associations elsewhere from the viewpoint of agricultural potential. For the sake of completeness, the mapping units have been rated in the Malaysian system in Table 3.

| <u>Soil Association</u> | <u>Rating</u> |
|-------------------------|----------------|
| Meluan | Vc |
| Meluan-Bako | Vc |
| Meluan-Silantek | Vc |
| Meluan-Merit | IIIg and Vc |
| Kapit-Merit | Vc |
| Sebatu | IIg and Vg |
| Piring | IIg and Vg |
| Abok-Merit | IIg and IIIg |
| Merit-Kapit | IIg and IIIg |
| Merit | IIc |
| Merit-Bekenu | IIg and IIIg |
| Merit-Nyalau | IIg |
| Nyalau-Merit | IIg and IIIg |
| Nyalau-Kerait | IIg and IIIg |
| Kerait | Ig and IIg |
| Merit-Kerait | IIg and IIIg |
| Bako | IIc |
| Nyalau-Silantek | IIg and IIn |
| Silantek | In |
| Silantek-Kerait | IIg and IIIg |
| Tika | IIn to IIIg |
| Merit-Tika | IIIg |
| Buso | IIId and IIn |
| Buso-Sabangang | IIg and IIId |
| Seduau-Lupar | In and IIIg |
| Pendam | IIIId and Va |
| Mukah | IIIo |
| Pendam-Mukah | IIIId and IIIo |
| Bijat-Mukah | IIIId and IIIo |
| Tatau-Matu | IIId and IIIId |
| Plan | IIId |
| Igan | IIIId |
| Anderson | IIIo |
| Bijat-Anderson | IIIId and IIIo |
| Nyalau-Anderson | IIg and IIIo |
| Buso-Anderson | IIc and IIIo |
| Miri-Anderson | IIc and IIIo |

Table 3 : Mapping units rated by the Malaysian soil suitability classification. For definition of classes see Wong (1970).

Scale 1:200,000

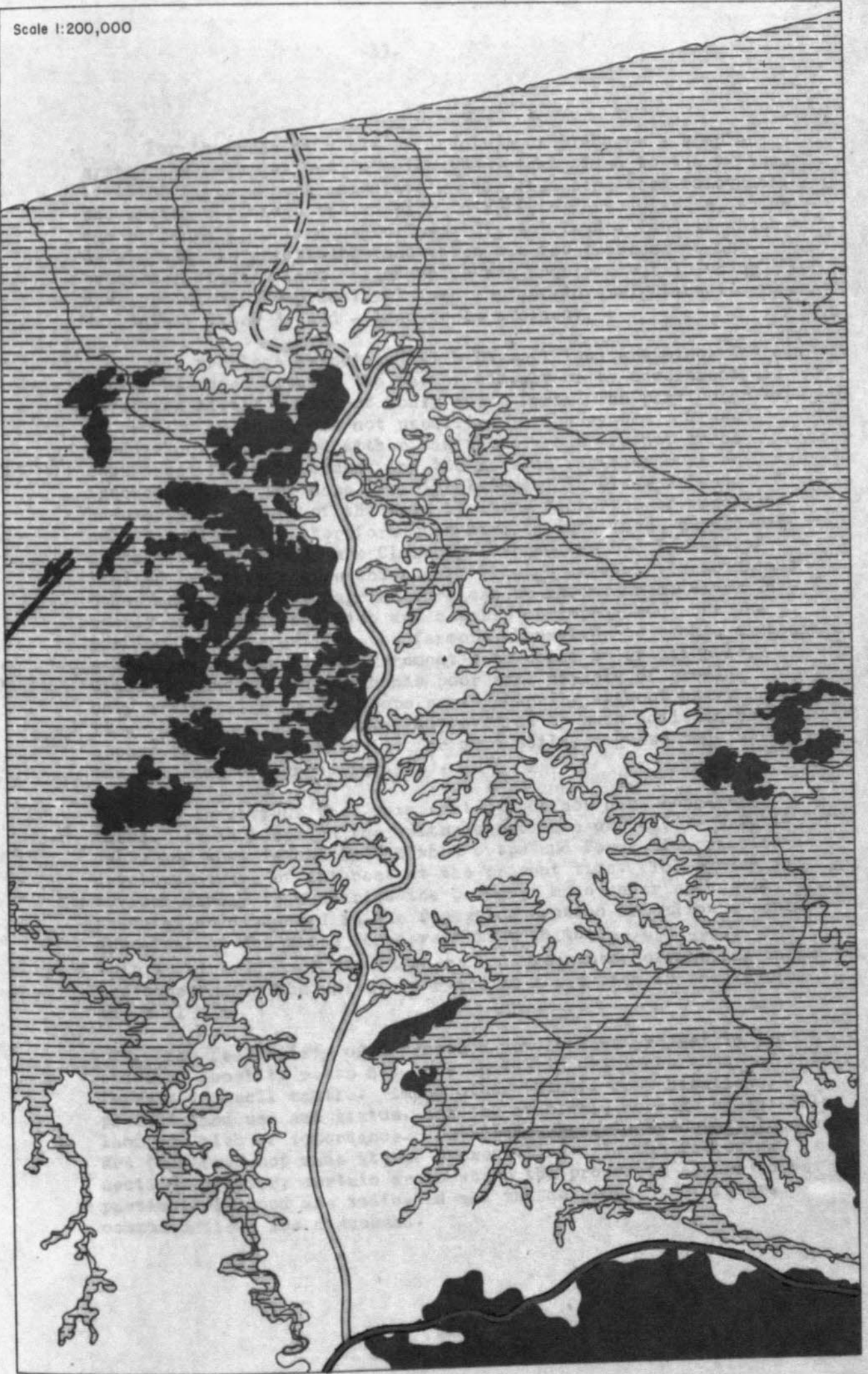


Fig. 3

(For key, see Fig. 4)

For the present needs of development planners a simpler system has been devised in which the weight given to the various limiting factors have immediate rather than long-term relevance. The system organises the mapping units into three Classes, which can be roughly defined as follows: Class 1 land - land in which development is practicable and which has few problems to be overcome; Class 2 land - land which has problems but in which development may be practicable and further investigation is warranted; Class 3 land - land to be avoided.

The problems associated with Class 1 land are minor and can easily be coped with by the farmer himself or by Government aid involving little outlay of money and effort. The particular type of problem is therefore not specified in the system. Class 3 land is not subdivided either, as these areas are not to be considered for development and the reasons why they must be ignored are, in any case, fairly obvious. In Class 2 land, however, the nature of the main limiting factor is of importance and this Class has therefore been divided into three subclasses on that basis. These are Class 2g - where the use is mainly limited by steep slopes which will require careful terracing and other measures before agriculture can be recommended; Class 2d - poorly drained areas which are capable of improvement but the problem is too great for the farmers themselves to tackle although a drainage scheme with Government help would be practicable; Class 2n land - land which has poor soil capable of growing only a limited range of crops satisfactorily without heavy fertilizer additions but in which improvement by such addition would appear to be economic (this is, for most soils, a guess made without the guidance of agronomic data).

It is obvious that this system does not have long-term value. It is based on the writer's estimate of what is practicable and what is not and on what crops and forms of agricultural development are of interest at the present time. The system is devised merely to summarise the comments made under each soil association discussed in the foregoing section and allow a rapid appraisal of the scope for development in the survey area. This is otherwise difficult where a large number of mapping units are concerned. The units are rated in the system in the key to the Soil Map.

The feasibility of a proposed development project in any specific locality rests not only on the inherent character of the terrain and soil mantle. Among other things, communications, present land use and status, and the available acreage of suitable land are also of importance. Detailed suggestions for development are therefore not made at the present time. In the following section, however, certain areas where the prospects appear to be particularly good are indicated and the development of future communications are discussed.

Scale 1:200,000

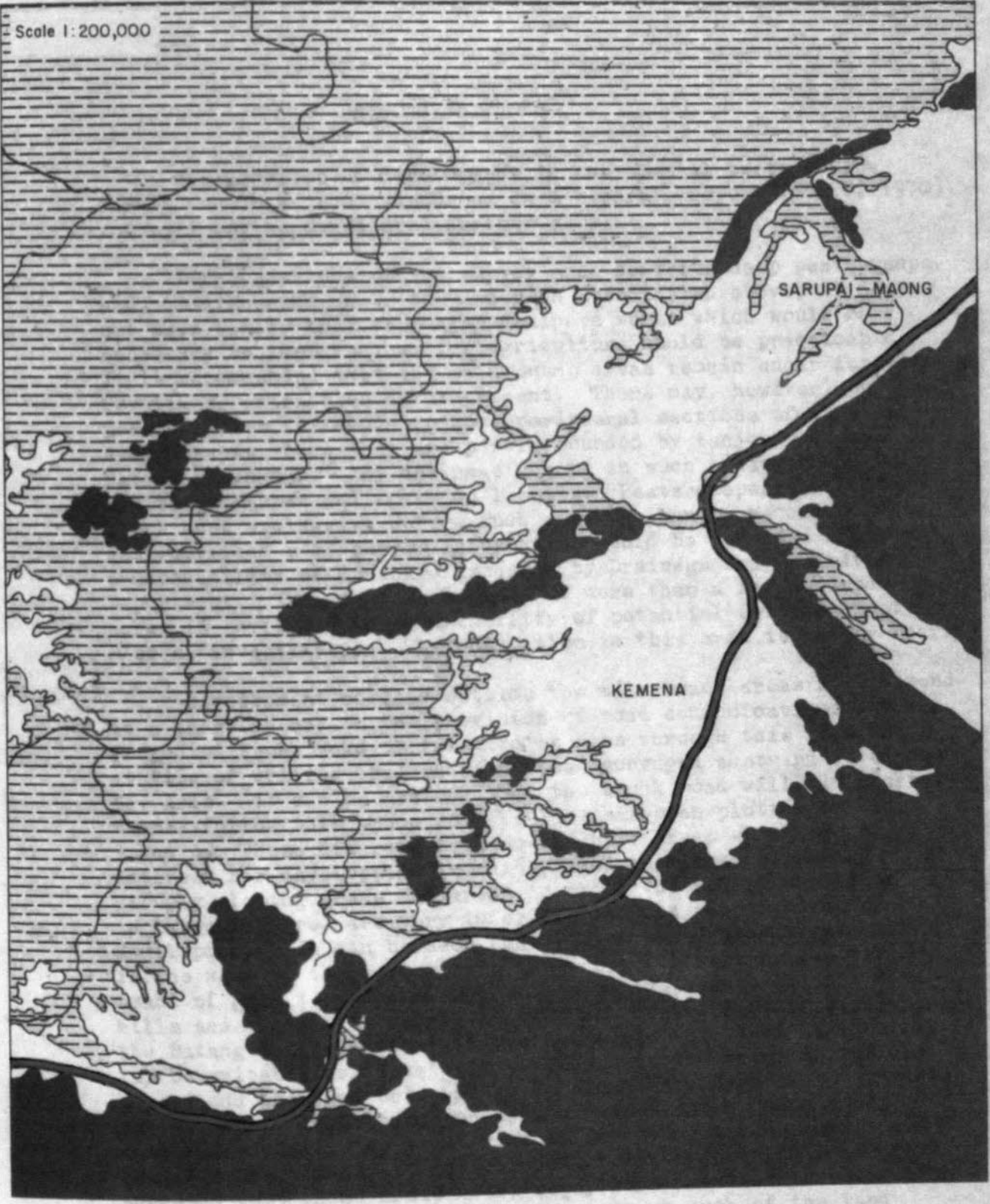




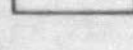


Fig. 4

-  proposed line of trunk road.
-  suggested line of feeder road.
-  steep land or poor soil.
-  alluvium and peat.
-  main upland areas where development is practicable.

RECOMMENDATIONS

The problems of development in the coastal parts of the survey area have been discussed in a separate report (SCOTT, 1970) and will not be considered further here.

Large sections of the survey area comprise deep peat swamps and, as discussed under the Anderson Association above, it does not seem likely that the major drainage works which would be necessary to improve them for agriculture would be practicable. It is recommended that the main swamp areas remain under forest for timber extraction as at present. There may, however, be possibilities for draining some peripheral sections of the main swamp tracts where they are partly bounded by tanjongs of the Batang Balingian. Any drainage scheme in such areas should be limited to Mukah and Anderson 1 soils. Peats deeper than Anderson 1 are best excluded. Before such a scheme can be recommended semi-detailed soil survey information would be required and the practicability of drainage assessed by Drainage and Irrigation Department. If a proposed scheme of more than a few hundred acres is envisaged the availability of potential settlers must also be investigated. The population in this area is rather sparse.

Development of land outside the main swamp areas will depend to a large degree on the provision of road communications. The projected trunk road is intended to pass through this area and at time of writing the trace has been surveyed eastward to beyond Sg. Arip. It can be assumed that the trunk road will, in general terms, follow this trace and the line has been plotted on Figs. 3 and 4. These diagrams isolate the hill areas which are of interest for development in white, land in black comprising steeply sloping areas and areas in which the soils, wholly or in large measure, are very infertile and not recommended for development. It can be seen that the proposed trunk road will, in the west of the survey area (Fig. 3), follow a rather narrow tract of good terrain and soils between the swamps and the main hills and that it is mainly in the east of the area (Fig. 4) beyond the Batang Balingian that it crosses large tracts of land which may be suitable for development. These tracts comprise the ulu Kemena and the land between Sg. Maong and ulu Sarupai. Both areas are extremely isolated at present and development cannot be anticipated until the trunk road is an accomplished fact. Once good communications are established, however, present soils data suggests that these areas would repay more detailed investigation. The ulu Kemena is of particular interest as much of the land remains under forest and presumably would not be found subject to land disputes should a scheme be projected. Most of the Maong/Sarupai area is under customary rights, judging by the distribution of secondary vegetation. In both areas the terrain is varied and some tracts must be isolated from any scheme because the expense of terracing them is likely to be high. Contoured mapping of these areas would be required prior to semi-detailed soil survey to assess the potential of specific localities more closely.

A third area of interest is that in the upper Krip valley where uniformly low relief is widespread, the soils are generally suitable for agriculture (although probably requiring heavy fertilizer applications) and there are possibilities of incorporating the footslope areas of the Piring Association. Most areas in this locality have been cultivated and it includes some swamp tracts of wet padi land. The attitude of the rights-owners to development would require investigation prior to further survey work in this area. A feeder road running southeast from the trunk road to the head of the Krip valley must also be anticipated if development is considered.

A feeder road has already been provisionally programmed to link the hills between the Mukah and Balingian swamps with the proposed trunk road although ground survey for this road has not yet started. The present soil survey only includes part of this hill complex but it must obviously be considered as one unit for planning purposes. Fig. 3 shows the extent of hill land in this area and also isolates tracts of poor soil (largely complexes of Nyalau and Silantek soils under poor forest) which were mapped during 1966 and are as yet unreported. It can be seen that the best agricultural land lies generally towards the east of the hill complex and the feeder road should be aligned with this in mind. A suggested alignment is approximately shown in Fig. 3. This avoids the areas of worst soil and links up with ulu Bedengan in the north. A road along the coast from Mukah to Balingian has been talked of at various times. Should this be programmed and built a link with the interior road network via the Sg. Bedengan will be useful. It may be practicable to continue the feeder road to the coast itself and a possible route is shown in dashed lines on Fig. 3. This involves crossing at least one mile of deep peats before shallow peat and coastal alluvium are reached and would require investigation by Public Works Department. Even if it is found that the peats in this section are sufficiently shallow for road construction to be practicable, it is doubtful whether extension of this feeder road to the coast would be justified unless improved communications along the coast itself were planned at the same time.

As stated above under the Merit-Nyalau Association, the soil mantle in the hill land through which the feeder road is projected is very varied, although most widespread soils are suitable for agriculture and slopes are generally not sufficiently steep for this to be a limiting factor. The hill tracts are fragmented by extensions of the swamps and there are few large areas in consolidated blocks for which development can be suggested. It is recommended that planning for this hill complex be deferred until the feeder road has been built, and more detailed soil survey then programmed. In this instance, further soils information is unlikely to have a bearing on the road line. It can only be varied within narrow limits if the many swamp-filled valley tracts on either side of the suggested line are to be avoided.

Only areas in which large-scale agricultural development appears feasible have been discussed in this section. Numerous smaller areas exist where development can also be considered and reference may be made to the distribution of soil mapping units rated as Class 1 (and some Class 2 land) on the soil map. Most such areas are already in use for agriculture and improvement schemes will depend partly on the needs and wishes of the farmers in specific localities.

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APPENDIX I

A. note on Tika Family

A number of soils are noted which are coarse-textured throughout the subsoil and which have no diagnostic horizons, or none which are more than very weakly expressed. Such soils occur over two types of parent materials over recent alluvial (generally marine) sands and over highly siliceous sedimentary rocks and terrace deposits. Soils over recent alluvial sands are placed in the Great Soil Group of Recent Alluvial Soils in the system currently used (SOIL SURVEY STAFF, 1966). But this system has no place for the other soils mentioned. By most definitions these are Regosols, but such a group has not been included in the system. Tika Family has been established to cover such profiles.

Four distinct soils have been recorded which qualify for placement in the Tika Family. (Other soils no doubt occur also.) These are as follows:

(a) brownish yellow to yellow Nyalau profiles which have loamy sand textures to a depth of at least 48 inches and do not have sufficient clay increase with depth to qualify for an argillic horizon. Such profiles have been noted in the Kolupu area, Binatang District, and elsewhere but they are not generally widespread. Where found, they have been grouped in the Nyalau Family. The lack of sufficient clay increase to qualify for an argillic horizon disqualifies them from placement in this family, however, as an argillic horizon is diagnostic for Nyalau Family soils.

(b) coarse-textured profiles which have been placed in the Saratok Family, being light grey in colour, but which lack sufficient clay increase for an argillic horizon. Like Nyalau soils, Saratok soils must have an argillic horizon by definition. 'Saratok' profiles which do not, in fact, qualify for the family as defined are quite common in colluvial positions.

(c) very deep Podzols, normally of the Miri Family and occurring on marine terrace remnants, which do not have a spodic horizon within 48 inches of the surface. By definition such soils cannot be placed in the Podzol group as it is only the 48-inch profile which is considered for classification in the system. They cannot be considered Recent Alluvial Soils as they are developed in old alluvial material.

(d) pale-coloured coarse sands and loamy sands derived from sandstone or conglomerate and underlain at depths greater than 10 inches by quartz gravel or hard parent rock. These soils are too deep to be considered Skeletal soils and lack the diagnostic argillic horizon of the Saratok Family.

In each case mentioned, the 'regosols' described above are closely related to soils in the Groups of Red-Yellow Podzolic, Grey-White Podzolic or Podzol soils in the present system, but lack sufficient expression of genetic horizons for placement in those groups. It is not considered necessary to create a number of new families, however, to emphasise the differences between these soils and their relationships to other families. An approach similar to that of the U.S.D.A. system (SOIL SURVEY STAFF, 1960, 1967)

is adopted: that, given a lack of genetic horizons and highly siliceous parent material, in very coarse-textured soils the texture itself is the feature of paramount importance. A wide range in colour, and size, mode of origin, etc. is acceptable at the family level and need only be considered, if at all, at the series level. One family - Tika - has therefore been introduced. This cannot be placed in any of the present Great Soil Groups. In a subsequent revision of the system, a Group of Regosols may be added to cover these soils.

Since the system at present in use was compiled, it has been agreed to move towards a pan-Malaysian soil classification using the U.S.D.A. system as a basis for correlation. Few of the diagnostic limits used in the Sarawak system agree exactly with those of the American system. With future correlation in mind, the definition of Tika Family uses the U.S.D.A. limits where these are appropriate. The family is comparable to the typic and lithic subgroups of the Great Group of Quartzipsamments.

Definition of Tika Family

Tika Family comprises soils which:

- 1) have no R or C horizon within 10 inches of the mineral soil surface
- 2) have textures below the A1 horizon of loamy fine sand or coarser to a depth of 48 inches or to an R or C horizon, whichever is shallower.
- 3) have a sand fraction which is more than 95 per cent quartz or other normally insoluble minerals that do not weather to liberate iron or aluminium
- 4) have no spodic horizon within 48 inches of the mineral soil surface
- 5) have insufficient clay increase with depth (to 48 inches) to qualify for an argillic horizon
- 6) are not permanently saturated with water and
- 7) are not found on present river floodplains or present marine beaches.

Within the family three series have so far been recognised but have not been precisely defined. These series are:-

Tika Series: light grey to white coarse sands to loamy coarse sands developed over sandstones and conglomerates and commonly grading to a coarse quartz gravel stoneline or to parent rock within 48 inches of the mineral soil surface. Most Tika soils in the Balingian basin and 'Saratok' soils without argillic horizons can be considered in this series.

Genting Series: light olive brown to brownish yellow loamy sands developed over sandstones, normally gravel-free in the surface 48 inches. Tika and Genting Series are distinguished on the basis of colour.

Kilong Series: established in West Sarawak but also present in Bintulu area and elsewhere on the Fourth Division coast; light grey to white sand to 48 inches but underlain, or assumed to be underlain, by a well-developed spodic horizon; developed in old marine terrace material. Kilong Series is distinguished from Tika and Genting Series on the alluvial nature of the parent material.

APPENDIX II

Selected profile descriptions

Ten profiles are described in this appendix, the profiles being located either within this survey area or in comparable areas immediately to the west of it. While some of the profiles are included because they are representative of important families in the survey area - Profile 7 (Merit Family), Profile 9 (Nyalau Family) and Profile 10 (Silantek Family) - others are included for different reasons. Profiles 2 - 6 (Abok Family) concern soils which have not previously been mapped in central Sarawak and are described to facilitate comparison with similar soils in the Abok Family recorded in west Sarawak. Profile 1 (Bako Family) and Profile 8 (Merit Family) illustrate soils encountered in this area having features which are not typical of the families concerned.

Analytical data are included for these profiles where they are available. Data for those profiles sampled in 1970 are incomplete.

Profile 1

Great Soil Group: Podzol. Parent material: Conglomerate, ascribed to Liang Formation (Upper Pliocene).
Family: Bako
Series: Tungal
Location: Bukit Tungal, Balingian Subdistrict. (Traverse BB120, peg 6)
Site: Summit of high ridge. Slope 30° falling steeply away to 40° on nearby hill flank.
Vegetation/land use: Poor primary forest, probably Heath Forest.
Altitude: Approx. 450 ft. a.s.l.
Field Nos: B312-B316
Lab. Nos: S7778-S7782
Date sampled: 21.6.70.

- 0 - 2 inches Dusky red (2.5YR 3/2) litter in a loamy matrix, the litter raw but finely comminuted. Abundant rootlets. Distinct wavy boundary. (S7778)
- 3 - 7 inches Brown (7.5YR 4.5/2) loamy coarse sand. Moist. Structureless. Slightly loose. Some dark brown staining down main root channels. Many roots. Diffuse wavy boundary. (S7779)
- 7 - 18/19 inches White (7.5YR 8/0) loamy coarse sand. Moist. Structureless. Consistence variable from very firm to very hard at different points in horizon, becoming generally very hard at depth. Rare rootlets. Few pores. Diffuse wavy boundary. (S7780)
- 18/19-22/25 " Brown and dark brown (7.5YR 4/2 and 3/2) banded coarse sand, the thin bands approximately conformable with the horizontal boundaries and black coatings to the few cracks. Moist. Friable to very hard, the consistency unrelated to colour. Rare roots following friable zones. The horizon angles through the profile, 2-4 inches thick. Indistinct irregular boundary. (S7781)
- 22/25 - 26 " Weathered conglomerate, dominantly yellow but in fresher patches grey to light grey. Black (Manganese?) and strong brown (Iron?) coatings to the main structural cracks and some dark brown to black (humus?) infilling of cracks. Very hard. (S7782).

Profile 2

Great Soil Group: Red-
Yellow Podzolic

Parent material: Rhyolite lava
or tuff.

Family: Abok

Vegetation/land use: Poor
primary forest

Series: Sebatu

Altitude:

Location: Ulu Sebatu, Arip,
Balingian Subdistrict.
(Traverse BBL50, peg 100)

Field Nos: B329-B332

Site: Long footslope to
main ridge. Slope 10°.

Lab. Nos: S7789/7792

Date sampled: 27.6.70.

- | | | |
|------------|--------|--|
| 0 - 2 | inches | Dark yellowish brown (10YR 4/4) sandy clay loam. Moist. Weak medium granular structure. Loose to friable. Abundant roots and rootlets. Indistinct irregular boundary. (S7789) |
| 2 - 17 | inches | Strong brown to brownish yellow (7.5YR 5/6 - 10YR 6/8) sandy clay loam. Moist. Massive except for scattered vertical cracks. Few clay skins. Friable. Many roots and rootlets. Few pores. An intermittent thin band of iron-enriched hard rock fragments at the base of the horizon. Indistinct wavy boundary. (S7790) |
| 17 - 27/33 | inches | Sandy clay texture and common clay skins. Slightly firm. Otherwise as above. Indistinct irregular boundary. (S7791) |
| 27/33 - 55 | inches | Strong brown (7.5YR 5/8) clay. Moist. Massive, but vertical cracks as above. No clay skins seen. Few roots. Few pores. Through the horizon run inclined bands of hard weathered rock fragments and soft patches of reddish brown (2.5YR 4/4) weathered rock. (S7792). |

| Lab. Nos. | | S7789 | S7790 | S7791 | S7792 |
|-----------------------|---------------|-------|-------|----------|----------|
| Horizon limits (ins.) | | 0-2 | 2-7 | 17-27/33 | 27/33-55 |
| very coarse sand | % | 0.67 | 0.09 | - | 0.58 |
| coarse sand | | 1.23 | 0.14 | 0.15 | 1.22 |
| medium sand | | 1.92 | 0.28 | 0.22 | 1.13 |
| fine sand | | 8.13 | 5.05 | 4.55 | 4.63 |
| very fine sand | | 46.31 | 45.68 | 41.21 | 35.17 |
| sand | | 58.26 | 51.24 | 46.13 | 42.73 |
| silt | | 20.16 | 19.17 | 18.30 | 22.48 |
| clay | | 20.75 | 32.57 | 32.29 | 36.33 |
| pH (H ₂ O) | | 4.1 | 4.5 | 5.1 | 5.0 |
| pH (Kcl) | | 3.2 | 3.5 | 3.6 | 3.6 |
| C | % | 3.82 | 0.31 | 0.17 | 0.18 |
| N | | 0.219 | 0.050 | 0.032 | 0.050 |
| C/N | | 17 | 6 | 5 | |
| C.E.C. | me/ 100 gm | 14.35 | 12.27 | 8.14 | 7.98 |
| Exch. Ca | | 0.73 | 0.40 | 0.29 | 0.26 |
| Exch. Mg | | 0.53 | 0.04 | 0.06 | 0.05 |
| Exch. K | | 0.38 | 0.08 | 0.07 | 0.08 |
| Exch. Na | | 0.09 | 0.03 | 0.05 | 0.05 |
| B.S. | % | 12 | 4 | 6 | |
| Total P | | 146 | 107 | 66 | 120 |
| Av. P | ppm | 14 | 2 | 1 | 2 |

Table 4 : Analytical data for Profile 2.

Profile 3

Great Soil Group: Red-
Yellow Podzolic

Parent material: Rhyolite lava
or tuff.

Family: Abok

Vegetation/land use: Poor
primary forest.

Series: Sebatu

Altitude:

Location: Between Semabat
and Sebatu headwaters,
Arip, Balingian Subdis-
trict.

Field Nos: B318-B323

Lab. Nos: S7783-S7788

Site: Main ridge line,
less than 1° slope; ridge
flanks of more than 40°
slope within 20 feet on
two sides.

Date sampled: 26.6.70.

- | | |
|--------------------|--|
| 0 - 3 inches | Dark reddish brown (5YR 3/2) loam. Moist. Mainly structureless; few fine crumbs. Loose. Abundant roots and rootlets. Indistinct wavy boundary. (S7783) |
| 3 - 10 inches | Yellowish brown (10YR 5/4) silt loam. Moist. Weak medium subangular blocky structure. Friable. Abundant roots and rootlets. Diffuse irregular boundary. (S7784) |
| 10 - 21 inches | Reddish yellow (7.5YR 6/8) clay loam. Moist. Weak medium and coarse subangular blocky structure. Friable. Many small weathered angular rock fragments and scattered stones and boulders of rhyolite lava. Many roots and rootlets. Indistinct wavy boundary. (S7785) |
| 21 - 35 inches | Strong brown to yellowish red (7.5YR - 5YR 5/6) clay. Moist. Medium to coarse angular blocky structure. Slightly firm. Few roots and rootlets. Diffuse wavy boundary. (S7786) |
| 35 - 40/48 inches | Yellowish red (5YR 5/6) clay. Moist. Weak coarse angular blocky structure. Slightly firm. Scattered coarse quartz grains. Few rootlets. Distinct irregular inclined boundary. (S7787) |
| 40/48 - 48+ inches | Inclined band of weathered rhyolite as cobble-size patches, crushable with difficulty, in a matrix of yellowish red clay as in overlying horizon. (S7788) |

There is a discontinuity in the profile at 21 inches, the material above this level being disturbed, it is assumed, by tree fall.

Profile 4

Great Soil Group: Red-
Yellow Podzolic

Parent material: Unknown,
possibly rhyolite lava or tuff,
with carbonaceous shale.

Family: Abok

Vegetation/land use: High
regrowth and scattered trees,
after hill rice.

Series: 'Nyaroh' (provi-
sionally separated from
Sebatu Series)

Altitude:

Location: Near S. Seliah,
Arip, Balingian Subdistrict.

Field Nos: B353-B359

Site: Upper slope of
moderately rolling terrain.
Slope 4°.

Lab. Nos: S7800-S7806

Date sampled: 13.7.70.

- 0 - 3 inches Olive brown (2.5YR 4/4) clay. Moist.
Medium to fine weak granular structure.
Friable. Abundant roots and rootlets.
Indistinct wavy boundary. (S7800)
- 3 - 11 inches Yellowish brown (10YR 5/6) clay. Moist.
Weak medium angular blocky structure.
Friable to slightly firm. Few apparent
clay skins. Few rootlets. Few pores.
Diffuse wavy boundary. (S7801)
- 11 - 26 inches As above but clay skins prominent and
structure coarse angular blocky breaking
to medium and fine angular blocky. Indis-
tinct wavy boundary.
(11-17: S7802 ; 17-26: S7803)
- 26 - 49 inches Yellowish brown (10YR 5/6) clay with few
medium faint yellowish red mottles becoming
many with depth, and rare fine distinct
white mottles. Moist. Coarse angular
blocky structure breaking to fine to
medium angular blocky. Firm. Few rootlets.
Few pores. Indistinct wavy boundary.
(26-36: S7804 ; 36-49: S7805)
- 49 - 62 inches Variegated yellowish red (5YR 5/6) and
yellowish brown (10YR 5/6) clay with white
mottles as above. Moist. Coarse angular
blocky structure breaking to fine angular
blocky. Firm. Rare rootlets. Rare pores.
(S7806).

| Lab. Nos. | S7800 | S7801 | S7802 | S7803 | S7804 | S7805 | S7806 |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Horizon limits (ins.) | 0-3 | 3-11 | 11-17 | 17-26 | 26-36 | 36-49 | 49-62 |
| very coarse sand | 0.18 | 0.04 | - | - | - | - | - |
| coarse sand | 0.82 | 0.26 | 0.22 | 0.14 | 0.22 | 0.17 | 0.21 |
| medium sand | 3.18 | 1.60 | 1.17 | 0.91 | 0.92 | 0.71 | 0.73 |
| fine sand | 7.48 | 6.39 | 5.12 | 4.62 | 3.94 | 3.55 | 3.36 |
| very fine sand | 12.69 | 12.47 | 14.04 | 11.88 | 10.28 | 7.14 | 6.06 |
| sand | 24.35 | 20.76 | 20.55 | 17.55 | 15.36 | 11.57 | 10.36 |
| silt | 28.33 | 23.24 | 24.70 | 21.64 | 20.03 | 23.70 | 25.04 |
| clay | 52.13 | 56.08 | 59.23 | 65.18 | 65.24 | 65.74 | 62.77 |
| pH (H ₂ O) | 4.4 | 4.7 | 4.9 | 5.1 | 5.2 | 5.3 | 5.5 |
| pH (Kcl) | 3.4 | 3.6 | 3.7 | 3.8 | 3.8 | 3.9 | 3.8 |
| C | 4.7 | 0.95 | 0.64 | 0.52 | 0.47 | 0.37 | 0.30 |
| N | 0.296 | 0.094 | 0.075 | 0.060 | 0.047 | 0.039 | 0.036 |
| C/N | 16 | 10 | 9 | 9 | | | |
| C.E.C. | 17.45 | 7.40 | n.d. | 5.54 | 5.35 | 5.18 | 6.00 |
| Exch. Ca | 0.79 | 0.34 | 0.43 | 0.28 | 0.43 | 0.27 | 0.34 |
| Exch. Mg | 0.35 | 0.07 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 |
| Exch. K | 0.25 | 0.07 | 0.06 | 0.06 | 0.06 | 0.04 | 0.04 |
| Exch. Na | 0.23 | 0.03 | 0.18 | 0.03 | 0.03 | 0.03 | 0.04 |
| B.S. | 9 | 6 | | 7 | 10 | | |
| Total P | 171 | 158 | 118 | 349 | 129 | 157 | 133 |
| Av. P | 7 | 2 | 1 | 2 | 1 | 2 | 1 |

Table 5 : Analytical data for Profile 4.

Profile 5Great Soil Group: Red-Yellow PodzolicParent material: Granodiorite.Family: AbokVegetation/land use: Old rubber.Series: ? GadingAltitude:Location: Near Rh. Layang, west of Bt. Piring, Balingian Subdistrict.Field Nos: B285-B290Lab. Nos: S7762-S7767Site: Upper slope of moderately rolling terrain; slope 5°.Date sampled: 28.2.70.

| | | |
|-------------|----------------|--|
| /sandy clay | 0 - 1½ inches | Brown to dark brown (7.5YR 4/4)/loam. Moist. Weakly cloddy. Friable. Abundant rootlets. Diffuse wavy boundary. (S7762) |
| | 1½ - 5 inches | Strong brown (7.5YR 5/6) coarse sandy clay loam. Moist. Weak coarse subangular blocky structure. Friable. Many rootlets. Diffuse wavy boundary. (S7763) |
| | 5 - 14 inches | Strong brown to yellowish brown (7.5YR - 10YR 5/8) coarse sandy clay loam. Moist. Weak coarse subangular blocky structure. Friable. Few rootlets. Diffuse wavy boundary. (S7764) |
| | 14 - 22 inches | As above. (S7765) |
| | 22 - 32 inches | Strong brown (7.5YR 5/6) coarse sandy clay. Moist. No structure seen. Friable. Rare rootlets. Scattered fragments of well-weathered granodiorite. Diffuse wavy boundary. (S7766) |
| | 32 - 40 inches | As above but no roots seen and abundant fragments of weathered rock. (S7767) |

| Lab. Nos. | | S7762 | S7763 | S7764 | S7765 | S7766 | S7767 |
|-----------------------|--------------|-------|-------|-------|-------|-------|-------|
| Horizon limits (ins.) | | 0-1½ | 1½-5 | 5-14 | 14-22 | 22-32 | 32-48 |
| very coarse sand | % | 5.80 | 1.64 | 1.87 | 2.18 | 7.74 | 10.82 |
| coarse sand | | 13.19 | 12.15 | 11.66 | 11.23 | 13.66 | 14.69 |
| medium sand | | 16.86 | 17.56 | 17.51 | 16.14 | 11.74 | 9.66 |
| fine sand | | 21.24 | 19.74 | 20.24 | 17.56 | 10.63 | 9.89 |
| very fine sand | | 12.57 | 15.83 | 16.00 | 14.35 | 7.71 | 8.60 |
| sand | | 69.66 | 66.92 | 67.28 | 61.46 | 51.48 | 53.66 |
| silt | | 8.21 | 3.86 | 4.93 | 8.90 | 7.23 | 10.66 |
| clay | | 23.59 | 26.81 | 27.11 | 33.56 | 35.86 | 33.17 |
| pH (H ₂ O) | | 5.0 | 4.9 | 5.0 | 5.2 | 5.7 | 5.6 |
| pH (Kcl) | | 3.4 | 3.9 | 4.0 | 4.1 | 4.5 | 4.8 |
| C | % | 3.28 | 1.33 | 0.85 | 0.64 | 0.40 | 0.29 |
| N | | 0.277 | 0.124 | 0.075 | 0.055 | 0.043 | 0.031 |
| C/N | | 12 | 11 | 11 | 12 | | |
| C.E.C. | me/ 100gm | 9.03 | 3.04 | 2.09 | 1.57 | 1.37 | 1.47 |
| Exch. Ca | | 0.58 | 0.32 | 0.42 | 0.32 | 0.29 | 0.32 |
| Exch. Mg | | 0.22 | 0.06 | 0.03 | 0.02 | tr | 0.05 |
| Exch. K | | 0.23 | 0.08 | 0.05 | 0.06 | 0.04 | 0.05 |
| Exch. Na | | 0.27 | 0.10 | 0.07 | 0.05 | 0.07 | 0.08 |
| B.S. | % | 14 | 18 | 27 | | | |
| Total P | ppm | 278 | 360 | 395 | 198 | 378 | 335 |
| Av. P | | 10 | 3 | 1 | 1 | <1 | 2 |

Table 6 : Analytical data for Profile 5.

| Lab. Nos. | | S7768 | S7769 | S7770 | S7771 | S7772 | S7773 |
|-----------------------|--------------|-------|-------|-------|-------|-------|-------|
| Horizon limits (ins.) | | 0-4 | 4-15 | 15-26 | 26-35 | 38-49 | 49-60 |
| very coarse sand | % | 1.34 | 0.03 | 0.06 | 0.18 | 0.64 | 0.96 |
| coarse sand | | 1.76 | 0.38 | 0.30 | 0.42 | 1.07 | 1.83 |
| medium sand | | 2.35 | 1.04 | 0.96 | 1.01 | 1.29 | 2.72 |
| fine sand | | 5.48 | 3.54 | 4.02 | 3.67 | 6.35 | 5.33 |
| very fine sand | | 11.48 | 10.64 | 9.00 | 10.68 | 4.91 | 14.09 |
| sand | | 22.41 | 15.63 | 14.34 | 15.96 | 14.26 | 24.93 |
| silt | | 30.90 | 25.81 | 22.06 | 21.57 | 59.82 | 29.68 |
| clay | | 46.92 | 61.87 | 60.96 | 62.21 | 20.88 | 47.22 |
| pH (H ₂ O) | - | 4.6 | 4.8 | 5.0 | 5.2 | 5.1 | 5.1 |
| pH (Kcl) | | 3.4 | 3.7 | 3.6 | 3.7 | 3.7 | 3.6 |
| C | % | 5.10 | 0.85 | 0.30 | 0.27 | 0.23 | 0.15 |
| N | | 0.362 | 0.073 | 0.026 | 0.032 | 0.019 | 0.023 |
| C/N | | 14 | 12 | 12 | 8 | | |
| C.E.C. | me/ 100gm | 18.33 | 6.93 | 6.04 | 6.35 | 5.57 | 6.21 |
| Exch. Ca | | 0.46 | 0.21 | 0.30 | 0.41 | 0.20 | 0.27 |
| Exch. Mg | | 0.28 | 0.07 | 0.09 | 0.14 | 0.13 | 0.11 |
| Exch. K | | 0.23 | 0.07 | 0.04 | 0.04 | 0.04 | 0.05 |
| Exch. Na | | 0.17 | 0.10 | 0.05 | 0.09 | 0.08 | 0.08 |
| B.S. | % | 6 | 6 | 8 | 11 | | |
| Total P | ppm | 153 | 441 | 38 | 118 | 48 | 49 |
| Av. P | | 6 | 4 | 2 | 1 | 1 | 2 |

Table 7 : Analytical data for Profile 6.

Profile 7

Great Soil Group: Red-Yellow
Podzolic.

Parent material: Shale (Tertiary;
Belaga IV Formation)

Family: Merit

Vegetation/land use: Regrowth after
hill rice, one year old.

Series:

Altitude: c. 100 ft. a.s.l.

Location: Ulu Sg. Sebatu,
Mukah Subdistrict.

Field Nos: S888-S894

Site: Summit of moderately
rolling terrain; slope 3°.

Lab. Nos: S4857-S4863

Date sampled: 31.8.66.

- | | |
|----------------|---|
| 0 - 1 inch | Brown to dark brown (10YR 4/3) clay. Moist. Structureless. Friable. Abundant rootlets. Indistinct wavy boundary. (S4857) |
| 1 - 6 inches | Yellowish brown (10YR 5/5) clay loam, with many very coarse pronounced light brownish grey gley mottles. Moist. Structureless. Friable. Many rootlets. Indistinct wavy boundary. (S4858) |
| 6 - 11 inches | Brownish yellow to strong brown (10YR 6/6 - 7.5YR 5/6) clay. Moist. Very weak coarse sub-angular blocky structure. Few apparent clayskins. Firm. Few rootlets. Rare fine quartz fragments. Diffuse wavy boundary. (S4859) |
| 11 - 16 inches | Strong brown (7.5YR 5/7) clay. Moist. Coarse angular blocky structure, breaking to medium. Many apparent clayskins. Firm. Many small fragments of iron-enriched weathered shale and some iron-stained quartz. Few rootlets. Indistinct wavy boundary. (S4860) |
| 16 - 23 inches | Structure weak and rootlets rare; otherwise as above. Diffuse wavy boundary. (S4861) |
| 23 - 30 inches | Strong brown (7.5YR 5/7) clay, interbedded with greyish brown (10YR 5/2) to light yellowish brown (10YR 6/4) weathered clay shale, flecked with red and yellowish brown. The clay and shale bands are inclined across the profile face, the former having weak medium angular blocky structure. (S4862) |
| 30 - 38 inches | As above. (S4863). |

| Lab. Nos. | | S4857 | S4858 | S4859 | S4860 | S4861 | S4862 | S4863 |
|--------------------------------------|--------------|-------|-------|-------|-------|-------|-------|-------|
| Horizon limits (ins.) | | 0-1 | 1-6 | 6-11 | 11-16 | 16-23 | 23-30 | 30-38 |
| very coarse sand | % | 0.06 | 0.18 | 0.17 | 2.51 | 7.00 | 0.47 | n.d. |
| coarse sand | | 0.06 | 0.53 | 0.67 | 3.21 | 7.84 | 1.63 | n.d. |
| medium sand | | 0.59 | 0.83 | 0.56 | 1.77 | 3.82 | 3.05 | n.d. |
| fine sand | | 0.89 | 1.18 | 0.83 | 1.07 | 1.70 | 1.47 | n.d. |
| very fine sand | | 16.23 | 18.76 | 13.26 | 12.36 | 7.63 | 7.61 | n.d. |
| total sand | | 17.83 | 21.48 | 15.49 | 16.82 | 54.27 | 14.23 | n.d. |
| silt | | 40.69 | 45.55 | 39.63 | 34.51 | 28.62 | 44.55 | n.d. |
| clay | | 41.65 | 33.31 | 44.73 | 44.92 | 43.60 | 41.11 | n.d. |
| pH (H ₂ O) | - | | | | | | | |
| C | % | 4.29 | 2.01 | 0.73 | 0.41 | 0.45 | 0.41 | 0.43 |
| N | | 0.309 | 0.140 | 0.066 | 0.063 | 0.057 | 0.086 | 0.077 |
| C/N | - | 14 | 14 | 11 | 7 | | | |
| C.E.C. | me/ 100gm | 21.16 | 15.38 | 12.38 | 11.52 | 10.58 | 12.41 | 11.95 |
| Exch. Ca | | 0.32 | 0.20 | 0.26 | 0.06 | 0.11 | 0.14 | 0.20 |
| Exch. Mg | | 0.78 | 0.14 | 0.19 | 0.25 | 0.14 | 0.19 | 0.06 |
| Exch. K | | 0.29 | 0.21 | 0.10 | 0.07 | 0.09 | 0.09 | 0.10 |
| Exch. Na | | 0.14 | 0.11 | 0.12 | 0.11 | 0.13 | 0.09 | 0.10 |
| B.S. | % | 7 | 4 | 5 | 4 | 4 | 4 | 4 |
| Extr. Ca | ppm | <100 | 103 | <100 | 206 | 103 | 103 | 206 |
| Extr. Mg | | 1374 | 1300 | 1480 | 1605 | 2528 | 3031 | 1852 |
| Extr. K | | 3664 | 3212 | 3304 | 2676 | 4511 | 6838 | 6762 |
| Extr. P | | 200 | 142 | 115 | 115 | 103 | 124 | 103 |
| Extr. Fe | | 85 | 105 | 39 | 14 | 3 | 3 | <1 |
| Extr. Mn | | - | - | - | - | - | - | - |
| Extr. Al | | 929 | 684 | 671 | 814 | 603 | 963 | 734 |
| Total SiO ₂ | % | 66.43 | 71.36 | 69.08 | 62.59 | 51.77 | 58.99 | 57.39 |
| Total Fe ₂ O ₃ | | 3.18 | 3.61 | 4.41 | 7.53 | 13.56 | 4.49 | 4.42 |
| Total Al ₂ O ₃ | | 11.76 | 12.92 | 14.89 | 29.29 | 19.12 | 23.60 | 22.49 |

Table 8 : Analytical data for Profile 7.

Profile 8

Great Soil Group: Red-Yellow Podzolic.

Parent material: Shale (Miocene: Balingian Formation)

Family: Merit

Vegetation/land use: Regrowth (approx. 4 years old) after hill rice.

Series:

Altitude:

Location: Penipah-Bedengan area, Mukah Subdistrict; (Traverse OM8, peg 47)

Field Nos: S972-S979

Lab. Nos: S5165-S5172

Site: Summit of low knoll rising slightly above surrounding gently undulating terrain; slope 1°.

Date sampled: 12.10.66.

- 0 - 5 inches Brown to dark brown (10YR 4/2) clay loam. Moist. Weak fine angular blocky structure. Friable. Many rootlets. Some clods of material from underlying horizon. Diffuse wavy boundary. (S5165)
- 5 - 15 inches Strong brown (7.5YR 5/6) clay loam. Moist. Weak coarse angular blocky structure, breaking to fine. Slightly friable. Few rootlets. Some humus staining down main root channels. Diffuse wavy boundary. (S5166)
- 15 - 23 inches Strong brown to yellowish red (7.5YR 5/6-5YR 5/8) clay loam. Moist. Coarse angular blocky structure, breaking to fine. Some apparent clayskins. Slightly friable. Few rootlets. Some humus staining on larger cracks. Diffuse wavy boundary. (S5167)
- 23 - 31 inches Strong brown to yellowish red (5YR 5.5/8) clay, reddish yellow (7.5YR 6/6) on some ped faces. Moist. Weak coarse angular and subangular blocky structure. Clayskins and humus staining as above. Slightly friable. Few rootlets. Rare iron-enriched weathered shale fragments. Indistinct wavy boundary. (S5168)
- 31 - 36 inches Yellowish red (5YR 5/8) clay with abundant irregular or platy iron-enriched rock fragments and many root impressions ('iron pipes'). Indistinct wavy boundary. (S5169)
- 36 - 42 inches Red (2.5YR 4/8) and yellow (10YR 7/6) finely mottled clay. Moist. Structureless. Slightly friable. Few rootlets. Diffuse wavy boundary. (S5170)
- 42 - 54 inches As above with many fine distinct white mottles and many medium distinct weak red mottles. Indistinct wavy boundary. (S5171)
- 54 - 60 inches Weathered shale, dominantly light grey, partly variegated pinkish grey and yellowish brown with strong brown staining in the few root channels and some hard bands of iron-enriched shale breaking to platy fragments. (S5172)

| Lab. Nos. | | S5165 | S5166 | S5167 | S5168 | S5169 | S5170 | S5171 |
|-------------------------------------|--------------|-------|-------|-------|-------|-------|-------|-------|
| Horizon limits | | 0-5 | 5-15 | 15-23 | 23-31 | 31-36 | 36-42 | 42-54 |
| very coarse sand | % | 0.12 | 0.20 | 0.11 | 0.39 | 5.01 | 0.32 | 0.67 |
| coarse sand | | 0.66 | 0.43 | 0.29 | 0.49 | 4.01 | 0.42 | 1.66 |
| medium sand | | 1.82 | 1.68 | 1.34 | 1.35 | 2.33 | 0.95 | 1.83 |
| fine sand | | 15.78 | 9.53 | 8.88 | 8.16 | 8.75 | 4.64 | 0.73 |
| very fine sand | | 23.42 | 27.86 | 28.06 | 24.35 | 19.65 | 24.14 | 28.23 |
| sand | | 41.80 | 39.70 | 38.68 | 34.74 | 36.75 | 30.47 | 33.12 |
| silt | | 31.33 | 25.27 | 23.15 | 18.81 | 19.63 | 25.38 | 27.00 |
| clay | 27.20 | 36.24 | 39.84 | 44.80 | 42.12 | 46.14 | 42.28 | |
| pH(H ₂ O) | | 4.5 | 4.5 | 4.8 | 5.0 | 5.0 | 5.0 | 5.0 |
| C | % | | | | | | | |
| N | | | | | | | | |
| C/N | | | | | | | | |
| C.E.C. | me/ 100gm | 10.42 | 10.24 | 10.48 | 13.34 | 12.66 | 16.49 | 18.99 |
| Exch. Ca | | 1.30 | 0.26 | 0.19 | 0.06 | 0.06 | <0.06 | 0.06 |
| " Mg | | 0.78 | 0.32 | 0.14 | 0.14 | 0.20 | 0.27 | 0.33 |
| " K | | 1.41 | 0.47 | 0.27 | 0.40 | 0.40 | 0.54 | 0.62 |
| " Na | | 1.50 | 0.91 | 1.20 | 1.08 | 0.87 | 1.42 | 0.88 |
| B.S. | % | 48 | 19 | 17 | 13 | 12 | | |
| Extr. Ca | ppm | 318 | 105 | 105 | 212 | 321 | 214 | 215 |
| " Mg | | 315 | 376 | 948 | 1271 | nd | 1287 | 581 |
| " K | | 477 | 370 | 852 | 1152 | nd | 1733 | 1738 |
| " P | | 48 | 48 | 67 | 70 | 46 | 68 | 49 |
| " Fe | | 127 | 281 | 14 | 7 | 7 | 5 | 7 |
| " Mn | | - | - | - | - | - | - | - |
| " Al | | 504 | 739 | 718 | 856 | 803 | 1343 | 1629 |
| Total SiO ₂ | % | | | | | | | |
| " Fe ₂ O ₃ | | | | | | | | |
| " Al ₂ O ₃ | | | | | | | | |
| P retention | % | 69.24 | 63.02 | 60.87 | 55.22 | 41.42 | 40.18 | 35.90 |
| Av. P water dispersible clay | | 5.33 | 8.78 | 0.30 | 0.13 | 0.15 | 0.15 | 0.15 |
| Free Fe ₂ O ₃ | | nd | nd | 4.05 | 4.97 | 6.24 | 5.04 | 5.75 |

Table 9 : Analytical data for Profile 8.

Profile 9

Great Soil Group: Red-
Yellow Podzolic

Parent material: Sandstone
(Miocene: Nyalau Formation)

Family: Nyalau

Vegetation/land use: Primary
forest.

Series:

Altitude:

Location: ulu Bunyoh, Arip,
Balingian Subdistrict.

Field Nos: B342-B348

Site: Upper slope of high
ridge; slope c.15°.

Lab. Nos: S7793-S7799

Date sampled: 12.7.70.

- | | |
|-------------------|--|
| 0 - 2 inches | Dark yellowish brown (10YR 4/4) sandy clay loam. Moist. Structureless to very weak subangular blocky. Loose. Abundant roots and rootlets. Indistinct wavy boundary. (S7793) |
| 2 - 6/12 inches | Brownish yellow (10YR 6/6) sandy loam to sandy clay loam, with prominent dark brown and reddish brown patches, largely as infilling of root channels. Moist. Structure as above. Loose. Many roots and rootlets. Diffuse irregular boundary. (S7794) |
| 6/12 - 19 inches | Brownish yellow (10YR 6/6) sandy loam. Moist. Massive except for large vertical cracks. Friable. Few large pores. Many rootlets. Diffuse wavy boundary. (S7795) |
| 19 - 30 inches | Brownish yellow (10YR 6/6) sandy clay loam. Moist. Structure as above. Few apparent clayskins. Friable. Scattered patches of pale brown and yellowish brown weathered rock. Few large pores. Few rootlets. Diffuse wavy boundary. (S7796) |
| 30 - 44 inches | As above but clayskins prominent. Diffuse wavy boundary. (S7797) |
| 44 - 50/55 inches | Brownish yellow (10YR 6/6), light grey (10YR 7/2) and yellowish brown (10YR 5/8) sandy clay loam. Moist. No structure seen. Firm and slightly plastic. No roots seen. Few large pores. Indistinct irregular boundary. (S7798) |
| 50/55 - 75 inches | As above but scattered hard iron-enriched fragments of weathered sandstone in thin bands inclined across profile face, following rock structure lines. (S7799) |

| Lab. Nos. | S7793 | S7794 | S7795 | S7796 | S7797 | S7798 | S7799 |
|-----------------------|--------------|-------------|--------------|-------|-------|---------------|---------------|
| Depth limits (ins.) | 0-2 | 2 - 6/12 | 6/12 - 19 | 19-30 | 30-44 | 44 - 50/55 | 50/55 - 75 |
| very coarse sand | 1.36 | - | - | - | - | 0.11 | - |
| coarse sand | 2.69 | 0.11 | 0.07 | 0.09 | 0.10 | 0.28 | 0.08 |
| medium sand | 11.61 | 11.60 | 12.24 | 11.83 | 10.42 | 9.61 | 10.04 |
| fine sand | 31.70 | 39.00 | 35.16 | 34.92 | 33.90 | 32.35 | 33.52 |
| very fine sand | 12.95 | 16.30 | 15.18 | 15.93 | 16.00 | 15.90 | 14.84 |
| sand | 60.31 | 67.06 | 62.65 | 62.77 | 60.42 | 58.25 | 58.48 |
| silt | 11.91 | 13.32 | 34.02 | 11.79 | 12.60 | 14.99 | 16.44 |
| clay | 26.59 | 20.04 | 3.65 | 26.27 | 26.91 | 27.26 | 27.72 |
| pH (H ₂ O) | 3.5 | 4.3 | 4.8 | 4.9 | 4.9 | 4.8 | 5.0 |
| pH (Kcl) | 2.2 | 3.6 | 3.9 | 3.7 | 3.6 | 3.6 | 3.6 |
| C | 8.87 | 0.83 | 0.56 | 0.09 | 0.12 | 0.09 | 0.07 |
| N | 0.427 | 0.068 | 0.059 | 0.025 | 0.025 | 0.024 | 0.037 |
| C/N | 21 | 12 | 9 | 4 | | | |
| C.E.C. | n.d. | 8.01 | 4.37 | 5.02 | 5.73 | 6.21 | 5.10 |
| Exch. Ca | me/ 100gm | 0.34 | 0.39 | 0.32 | 0.26 | 0.29 | 0.28 |
| Exch. Mg | | 0.59 | 0.09 | <0.01 | 0.02 | <0.01 | <0.01 |
| Exch. K | | 0.52 | 0.10 | 0.06 | 0.06 | 0.06 | 0.07 |
| Exch. Na | | 0.17 | 0.08 | 0.08 | 0.07 | 0.07 | 0.05 |
| B.S. | % | | 8 | 11 | 8 | | |
| Total P | | 157 | 189 | 321 | 64 | 158 | 51 |
| Av. P | ppm | 12 | 4 | 3 | 2 | 2 | 2 |

Table 10 : Analytical data for Profile 9.

Profile 10

Great Soil Group: Podzol. Parent material: Sandstone
(Miocene; Balingian Formation).

Family: Silantek

Vegetation/land use: Heath forest

Series:

Altitude:

Location: Kenyana-Bakau
watershed; Mukah Subdistrict. Field Nos: S946-S957
(Traverse OM5, peg 40)

Lab. Nos: S5146-S5157

Site: Middle slope of moderately undulating terrain; slope 2°.

Date sampled: 1.10.66.

- 0 - 1/2 inch Very dusky red (2.5YR 2/2) raw humus and brown (7.5YR 5/2) fine sandy loam. Moist. Weak coarse granular structure. Very friable. Abundant rootlets. Indistinct smooth boundary. (S5146)
- 1/2 - 3/5 inches Brown (10YR 5/3) and pale brown (10YR 6/3) fine sandy loam, the colours diffusely variable. Moist. Structureless. Friable. Many rootlets. Diffuse wavy boundary. (S5147)
- 3/5 - 7/9 " Very pale brown (10YR 7/3) fine sandy loam, diffusely washed brown (10YR 6/3) and with brown staining down root channels. Moist. Structureless. Very friable. Few rootlets. Diffuse irregular boundary. (S5148)
- 7/9 - 12/16 " Light grey (2.5Y 7/2) fine sandy loam, with few large very pale brown patches and pale brown and brown staining down root channels. Moist. Structureless. Very friable. Few rootlets. Diffuse irregular boundary. (S5149)
- 12/16 - 18 " White to light grey (5Y 7.5/1) loamy fine sand, with many coarse to fine distinct pale yellow and very pale brown mottles, some associated with root channels. Moist. Structureless. Very friable. Rare rootlets. Indistinct wavy boundary. (S5150)
- 18 - 20 " White to light grey (5Y 7.5/1) and light grey (2.5Y 7/2) fine sandy loam, with pale yellow staining along old root channels. Moist. Structureless. Very friable. No roots seen. Indistinct wavy boundary. (S5151)
- 20 - 22/24 " Dark brown (7.5YR 3/2) fine sandy loam with light yellowish brown (10YR 6/4) patches, reddish brown stains down root channels and thin dark reddish brown layers in the body of the horizon. Moist. Structureless. Firm. No roots seen. Indistinct highly irregular boundary, dipping where it crosses an old root channel. (S5152)

- 22/24 - 22/27 inches Pale yellow (2.5Y 8/4) fine sandy loam with yellowish red (5YR 5/8) and strong brown (7.5YR 5/6) staining down main cracks and root lines. Moist. Breaks weakly along vestigial rock structure planes. No roots seen. Indistinct irregular and interrupted boundary. The underlying material tongues up through this horizon. (S5153)
- 22/27 - 27/33 inches Yellow (10YR 7/6) fine sandy loam, mottled strong brown and yellowish red, with yellowish red and pale brown staining down structural lines and old root channels; this material grading laterally to yellowish red (5YR 5/8) fine sandy loam. Moist. Rock structure as above. Very friable; very firm where yellowish red. No roots seen. Indistinct irregular boundary. (S5154)
- 27/33 - 35/42 inches Pale yellow (2.5Y 7/4) fine sandy loam with many medium and fine distinct yellowish red and yellow mottles becoming fewer with depth. Brown staining along old root lines. Moist. Structureless. Very firm. Very rare rootlets. Diffuse wavy boundary. (27/33-34: S5155; 34-35/42: S5156)
- 35/42 - 48 inches Mottles few. No roots seen. Otherwise as above. (S5157).

| Lab. Nos. | S5147 | S5149 | S5150 | S5152 | S5153 | S5155 | S5157 |
|-----------------------|--------------|---------------|---------------|-----------------|----------------|---------------|---------------|
| Horizon limits (ins.) | ½-3/5 | 7/9- 12/16 | 12/16 - 18 | 19/20- 22/24 | 22/24 22/27 | 27/33 - 34 | 35/42 - 48 |
| Very coarse sand | 0.04 | 0.04 | 0.06 | 0.04 | 0.04 | 0.02 | 0.04 |
| Coarse sand | 0.24 | 0.39 | 0.39 | 0.35 | 0.24 | 0.29 | 0.19 |
| Medium sand | 8.72 | 10.58 | 13.62 | 8.89 | 8.25 | 8.00 | 6.62 |
| Fine sand | 32.36 | 31.01 | 42.80 | 25.84 | 28.22 | 26.44 | 28.58 |
| Very fine sand | 24.72 | 28.03 | 19.01 | 21.38 | 20.38 | 23.52 | 21.40 |
| Sand | 66.08 | 70.04 | 75.88 | 56.50 | 57.13 | 59.27 | 56.83 |
| Silt | 26.16 | 27.37 | 21.40 | 22.94 | 24.75 | 24.73 | 23.82 |
| Clay | 5.81 | 2.48 | 2.19 | 8.94 | 11.66 | 14.33 | 17.93 |
| pH(H ₂ O) | - | | | | | | |
| C | | 0.81 | 0.17 | 0.10 | 2.19 | 0.77 | 0.30 |
| N | | | | | | | 0.11 |
| C/N | | | | | | | |
| C.E.C. | | | | | | | |
| Exch. Ca | me/ 100gm | | | | | | |
| Exch. Mg | | | | | | | |
| Exch. K | | | | | | | |
| Exch. Na | | | | | | | |
| B.S. | % | | | | | | |
| Extr. Ca | | 100 | 198 | 99 | 42 | 41 | 242 |
| Extr. Mg | | 84 | 142 | 299 | 226 | 184 | 193 |
| Extr. K | | 607 | 905 | 151 | 528 | 878 | 1171 |
| Extr. P | ppm | 25 | 14 | 8 | 24 | 26 | 25 |
| Extr. Fe | | 51 | 10 | 5 | 16 | 28 | 36 |
| Extr. Mn | | - | - | - | - | - | - |
| Extr. Al | | 66 | 39 | 7 | 813 | 620 | 280 |
| | | | | | | | 136 |

Table 11 : Analytical data for Profile 10 (selected horizons only).

