RESEARCH BRANCH
DEPARTMENT OF AGRICULTURE
SARAWAK

Technical Paper No. 2

A CLASSIFICATION OF SARAWAK SOILS

SOIL SURVEY STAFF

Kuching
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INTRODUCTION

The first systematic study of soils in Sarawak was made by Dames in 1955 while on attachment from F.A.O. to the Sarawak Forest Department. This work was largely confined to soils described in this classification as Podsols and Groundwater Podsols. In 1958 a soil survey organisation was established and for the first year was headed by Dames while on a second assignment attached to the Department of Agriculture. In the period 1958 - 1965 a total of 10,100 square miles were surveyed, largely by reconnaissance methods, this comprising 20.9 per cent of the State. A further 4,480 square miles were covered by terrain classification maps, based on air photograph interpretation. Survey methods have been described in the Soil Survey Division Annual Report (SARAWAK MINISTRY OF NATURAL RESOURCES, 1964, pp.7-13).

A tentative classification of the main Sarawak soils was made by Dames (1962). Until 1964 no systematic attempts were made to improve on his work except for the preparation of the 'field classification' (ANDRIESSE, 1962) which enabled standardisation of soil association mapping units on reconnaissance soil surveys in the State. By 1965, however, sufficient data were available from a large portion of Sarawak to allow a comprehensive classification of the State's soils at a great soil group and family level to be attempted. The classification resulting from that work is described in this paper.

Table 1 : Sarawak Soil Classification - great soil groups and families.

Great soil groups	Families
Skeletal soils	Meluan, Kapit, Sedong, Binatang Kelupu, Gaya.
Brown Forest soils	Kabuloh, Kedadum.
Lateritic soils	Tarat, Antayan.
Red-Yellow Podsolic soils	Matang, Nyalau, Bekenu, Merit, Semilajau, Malang, Sabangang, Lupar.
Grey-White Podsolic soils	Kerait, Saratok, Lubai, Triboh.
Podsols and Groundwater Podsols	Silantek, Bako, Buso, Miri, Jerijeh.
Groundwater Laterite soils	Rapak, Bentang.
Gley soils	Gerawat, Semadoh, Luis, Sebandi, Plan, Bijat, Gong, Embang, Matu, Tatau, Daro.
Saline Gley soils	Nonok, Belat, Pendam, Rajang, Limbang.
Peat soils	Igan, Mukah, Anderson, Mulu.
Recent Alluvial soils	Ramun, Terbat, Sematan, Kayan, Seduau, Kabong.

The Sarawak classification is basically a genetic one. The great soil groups recognised are listed in Table 1. The concepts at this level are, in general, those of Baldwin et al. (1938) as revised by Thorp and Smith (1949). Where the range of soils within a group is altered a change in nomenclature has been made to avoid confusion. The main differences between the present classification and this earlier system are as follows:-

(a) Skeletal soils - are equivalent to Lithosols but include soils which Baldwin et al. would have considered shallow phases of soils in other great soil groups.

(b) Lateritic soils - Reddish-Brown and Yellowish-Brown Lateritic soils are grouped together under this title. Both occur in Sarawak but colour does not appear to correlate with other characteristics.

(c) Grey-White Podsolic soils - are not included in the earlier classification unless they are considered Yellow Podsolic soils but are an important group in Sarawak.

(d) Podsols and Groundwater Podsols - while the concept remains unchanged, these are considered as one group as, in practice, it is difficult to distinguish between them in many localities.

(e) Gley soils - are equivalent to the Low-humic Gley soils of Thorp and Smith (1949) but include some soils classed by them as Half-Bog soils. It is considered that there is little genetic justification for a group of Half-Bog soils and such soils are classed as either Gley or Peat soils, depending on the depth of the organic deposits.

(f) Saline Gley soils - are included in Saline soils by Baldwin et al. but are separated here as those soils formed in a marine environment differ markedly from Saline soils formed in an arid climate.

(g) Peat soils - comprise Bog soils and the majority of Half-Bog soils.

(h) Recent Alluvial soils - comprise Alluvial soils and Regosols as it is considered that the latter do not require separation at this level of classification.

Classification at a family level is largely based on genetic factors, such as the origin and nature of the parent material and the degree of profile development. It is hoped that in time it will be possible to replace the present classification by that of the U.S.D.A. Soil Survey Staff (U.S.D.A., 1960) and, in anticipation of a future change, the limits of many diagnostic horizons and other soil features used in defining the families have been chosen to agree with those of the American classification.

The main practical drawback of the Thorp and Smith classification is the lack of precise definitions. In the present classification, therefore, the concept is interpreted in terms of properties which can be seen and measured in the soil profile or can be established by simple laboratory analysis. Such an interpretation involves, in some cases, the creation of artificial limits. It is felt, however, that this classification has two major advantages. It allows consistent placement of soils at the great soil group and family levels, largely using properties which can be easily recorded in the field. In addition it is much easier to improve the classification when couched in terms of well-defined soil features than when it is limited to generalities.

In Sarawak chemical weathering proceeds to considerable depths and where deep road cutting exposures are available for study it is seen that pedogenetic processes may extend to depths of 10 or 20 feet. In soil mapping and classification, however, such deep soil horizons must be ignored as the soil surveyor's auger is generally four feet in length, although profile pits are dug to greater depths where representative profiles are required for analysis. In the Sarawak classification, therefore, the soil profile is taken to be the surface 48 inches (measured from the base of the 0 horizon if one is present). Only in a few cases does this lead to anomalies. There may be, for example, no profile difference other than a spodic horizon between a Podsol and a Grey-White Podsolic soil and, as the classification stands, a Podsol in which the spodic horizon, however well expressed, in not encountered within 48 inches of the surface must be classified as a Grey-White Podsolic soil. Such difficulties arise, however, wherever soil investigations rely on auger sampling. The inclusion of this limiting depth in the framework of the local classification merely recognises a situation which exists in any soil classification.

Where bisequent profiles are considered - the commonest example being thin clayey alluvial deposits overlying peats - an arbitrary depth of 20 inches is used in classifying the soil. Where the overlying material is greater than 20 inches in thickness, underlying horizons are ignored; where it is less than 20 inches in thickness, the features of the underlying material are used.

The definitions of the majority of descriptive terms and diagnostic horizons used in the great soil group and family definitions follow those of the U.S. Department of Agriculture (U.S.D.A., 1951, 1960). For ease of reference the definitions of the main terms employed are restated in the Appendix. Some general terms for texture have been defined for local use. These definitions are also given in the Appendix and the terms are marked with an asterisk where used in the text.

SKELETAL SOILS

1. GENERAL

Skeletal soils are equivalent to the Lithosols defined by Thorp and Smith (1949, p.119), being a group of soils having an incomplete solum or no clearly expressed morphology, and consisting of a freshly or imperfectly weathered mass of hard rock or rock fragments.

Skeletal soils in Sarawak occur mainly in association with Red-Yellow Podsolic soils, principally over sedimentary and igneous rocks. The soils are predominantly young and commonly have only weak development of A horizons. They are generally stony.

2. LOCAL DEFINITION

Skeletal soils are mineral soils in which:-

An R or C horizon is present within 10 inches of the base of an O horizon.

3. ENVIRONMENT

3.1. Climate. These soils are found under a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. The periodic extremely heavy rainfall is known to lead directly to the formation of Skeletal soils in places through large scale erosion.

3.2. Parent Material. The rocks over which Skeletal soils are found range from limestone to sandstone, shale and all igneous types in Sarawak. They also occur in screes and boulder fans, particularly close to igneous rock outcrops, and in old riverine alluvium. In some areas Skeletal soils are of mixed origin, for example, where bedrock is overlain by a thin veneer of alluvium.

3.3. Topography. Skeletal soils are found predominantly on rugged topography with slopes exceeding 25^{o} but the associated landforms range from lightly dissected lowlands and terraces to ridges, cuestas, karst and igneous massifs. Skeletal soils have also been found on almost flat land having an unusual geomorphic history, such as rock platforms formed by river or sea erosion and subsequently covered by a thin deposit of alluvium.

3.4. Vegetation. The primary vegetation is varied. On soils derived from igneous rocks, and to a lesser extent sedimentary rocks, it consists of Mixed Dipterocarp Forest. On the harder and more arenaceous sedimentary rocks, however, it is principally Heath Forest or, at altitudes exceeding about 3,000 feet, Moss Forest.

4. FAMILY CLASSIFICATION

The limit of 10 inches as the maximum permissible depth for Skeletal soils is chosen to represent the approximate lower limit to which the bulk of root systems normally penetrate soil. The initial separation between families is based on their origin because both the physical and chemical properties of wholly residual soils are different from those of mixed origin or those developed in coarse-textured alluvium.

A separation of the residual soils is then made between those overlying C and those overlying R horizons. The R horizon is defined as solid bedrock, which for the purpose of field identification, is considered material too hard to auger through and which is therefore probably too hard for root penetration. The C horizon is considered weathering rock which can be augered. Two families are established with C horizons based on the total phosphorous content of the fine earth fraction. This basis for separation is tentative and is chosen to divide the relatively fertile Sedong family soils overlying basalt and intermediate rocks, from the poorer soils of Kapit Family.

The soils of mixed origin are divided on their internal soil drainage. Texture is not considered to be sufficiently important in these shallow soils to warrant a further subdivision.

Skeletal soils formed entirely in alluvial material are classed in one family as their texture and drainage characteristics have a limited range.

Table 2 : Skeletal soils - family classification

Origin of parent material	Diagnostic horizons		Family
Residual	R horizon within 10 inches of surface		MELUAN
	C horizon within 10 inches of surface	Less than 500 ppm total phosphorous in fine earth	KAPIT
		More than 500 ppm total phosphorous in fine earth	SEDONG
Mixed	Well to imperfectly drained above IIC or IIR horizon		BINATANG
	Poorly to very poorly drained above IIC or IIR horizon		KELUPU
Alluvial			GAYA

5. NOTES ON THE FAMILIES

5.1. Meluan. Soils of this family are mainly found on steeply sloping uplands underlain by sandstone and also on some karst land. They are brownish, well-drained, clays and loams and are rarely cultivated.

5.2. Kapit. Soils of the Kapit Family are widespread either singly or in association with podsolic soils throughout upland Sarawak, and in Third Division particularly. The underlying rock is generally shale, sandstone or granite. The soils are brownish, well-drained, stony and heavy textured. They are used for hill padi in many areas.

5.3. Sedong. These soils are generally found in areas underlain by basic and intermediate rocks such as occur in parts of First, Second and Third Divisions. They are normally brownish, well-drained, stony and heavy textured, and are commonly cultivated except where slopes are very steep.

5.4. Binatang. Soils of the Binatang Family occur in First, Third and Fourth Divisions in small valleys where thin alluvium rests on augerable shale, or on hard limestone. The soils are yellowish, well-drained and normally heavy textured.

5.5. Kelupu. This family of soils has only been seen in Third Division where it occurs in small valleys. The soils are poorly drained, heavy textured and rest on gleyed weathering shale.

5.6. Gaya. Gaya Family soils are common in parts of First, Fourth and Fifth Divisions in valley infill material, in alluvial fan deposits or on low to high terraces close to rivers which drain areas containing much sandstone. Characteristically they are poorly sorted fragmental deposits and are rarely cultivated.

BROWN FOREST SOILS

1. GENERAL

Brown Forest soils are rare in Sarawak and occur mainly in association with Red-Yellow Podsolic soils although in some karst areas containing igneous intrusions they are found in complex association with Lateritic soils. (WALL, et al., 1962). As in many other countries Brown Forest soils are developed over calcium-rich rocks (DUDAL and MOORMANN, 1964) and are believed to be similar to soils described by Dames (1955, pp.100-103) and to resemble some in Australia (STEPHENS, 1956, p.30). Characteristically they are weakly developed, brownish, moderately well-drained and heavy-textured soils. Their base exchange capacity is higher than normal for residual soils in Sarawak and is dominated by calcium.

The characteristics of Brown Forest soils are summarised by Baldwin et al (1938, p.1001) as very dark brown friable surface soil grading through lighter coloured soil to parent material; little illuviation; high absorbed calcium; good drainage.

2. LOCAL DEFINITION

Brown Forest soils are mineral soils in which:-

1. There is no C or R horizon present within 10 inches of the base of an O horizon,
2. the C.E.C. of the lower B horizon exceeds 20 m.e. per cent,
3. chromas are 4 or more in the B horizon,
4. there is no gley horizon within 20 inches of the base of any O horizon,
5. there is no argillic horizon.

Brown Forest soils are differentiated from Skeletal soils by the depth to C or R horizons; in places, particularly where hard limestone is beneath the soil, they may form a complex with Skeletal soils. The chemical features and the lack of an argillic horizon separate these from Red-Yellow Podsolic soils and the absence of gleying at shallow depth differentiates them from Gley soils.

3. ENVIRONMENT

3.1. Climate. These soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. Since these soils are found in close association with Red-Yellow Podsolic soils it is considered that climate does not have an overriding influence in their development.

3.2. Parent material. The rocks found beneath Brown Forest soils have in common a high content of calcium and range from limestone and marls to calcareous shales and sandstones, intermixed in places with non-calcareous rocks. In places there is an admixture of alluvial material that has acquired a calcium-rich nature from contact with underlying limestone. The calcareous nature of the parent material is believed to be primarily responsible for the differences between these soils and the associated Red-Yellow Podsolic soils. Where the soil overlies hard limestone the soil is considered to be colluvial and not residual.

3.3. Topography. The landforms found in areas of Brown Forest soils range from rugged karst to gently rolling hills that merge into valley land containing alluvial soils.

3.4. Vegetation. The primary vegetation consists of Mixed Dipterocarp Forest which, on areas of karst in particular, shows specialization.

4. FAMILY CLASSIFICATION

Since the Brown Forest soils have not been studied in detail the family classification is probably incomplete. In particular, it is thought that some soils of this nature may be developed partly in alluvium as well as in colluvial material.

Table 4 : Brown Forest soils - family classification

Texture	Family
Heavy textured (l)*	KABULOH
Light textured (l)*	KEDADUM

5. NOTES ON THE FAMILIES

5.1. Kabuloh. The soils of this family occur in small areas in First and Fourth Divisions overlying mainly argillaceous rocks rich in calcium. Some rest on hard limestone, which in Sarawak is invariably extremely pure, and these are believed to be derived from material (mainly sedimentary in origin) that once overlay the limestone. Their calcareous nature is, in this case, an acquired feature rather than an inherited one. Similarly, other Kabuloh soils are possibly derived in part from originally non-calcareous alluvium. These soils are characterized by light yellowish brown to brownish yellow colours, heavy textures and an abrupt change from the B to C or R horizons. They tend to be dense, moderately well-drained and are commonly calcium-saturated in the deep subsoil.

5.2. Kedadum. Where sandstone lenses are interbedded with limestone, or where calcareous sandstones occur Kedadum Family soils are present. They are brownish in colour, sandy in texture and irregular in depth.

LATERITIC SOILS

1. GENERAL

The only Lateritic soils recorded in Sarawak are similar to those described as Reddish-Brown Lateritic and Yellowish-Brown Lateritic soils in the classification scheme proposed by Thorp and Smith (1949, p.120) and which have been defined in more detail by Nyun and McCaleb (1955).

Lateritic soils are homogeneous, strongly coloured soils in which a podsol or podsolic morphology is absent. They have no albic horizon and they are usually found on parent materials rich in ferro-magnesium minerals and poor in both crystalline and compound silica.

There are recent alluvial soils derived from the same parent materials and these soils have comparable profile characteristics to Lateritic soils but are genetically distinctly different from them. It is necessary to emphasize the residual origin of Lateritic soils in the definition.

Lateritic soils are comparable in content of Group III* elements and in colour to one family of the Red-Yellow Podsolic soils (the Abok Family) which can be regarded as an intergrade to Lateritic soils.

It is considered that the main factor responsible for the formation of Lateritic soils is the nature of the parent material, it being rich in ferro-magnesium minerals; under similar environmental conditions but with siliceous parent materials soils with a podsolic morphology are invariably formed.

Although clay skins are not apparent in the profile and other profile characteristics do not indicate clay leaching, clay content is nevertheless higher in the C than in the A horizon. This may be due to leaching of silica and aggregation (which decreases down the profile) of iron oxides as sand and silt particles. This small increase in clay down the profile cannot therefore be considered an argillic horizon and is not of diagnostic value.

2. LOCAL DEFINITION

Lateritic soils are mineral soils of residual origin in which:-

1. there is no C or R horizon within 10 inches of the base of an O horizon,

2. the content of Group III* element is more than 25% in the A2 and B horizons,

3. colours have chromas 4 or more in the A2 and B horizons,

4. there is no gley horizon within 20 inches of the base of an O horizon,

5. there is no hardened plinthite.

Other characteristics usually present are low levels of total silica, no mottles and a stable structure. The total phosphate content is usually higher than in any other soils found in Sarawak.

3. ENVIRONMENT

3.1. Climate. These soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. Lateritic soils in Sarawak are derived from basic to intermediate igneous rocks such as basalt, pyroxene andesite, dolerite, and gabbro. Metamorphic rocks with closely similar chemical characteristics to this range are included. All parent materials have in common high ferro-magnesium mineral and low silica contents. The parent materials are all hard, usually non-porous and the weathering zone is thin. Spheroidal weathering is a common feature.

3.3. Topography. Lateritic soils are usually found on conspicuous hills or mountains, built of hard rock which has withstood erosion better than the usually softer sedimentary rocks surrounding them. Slopes are generally moderately steep to steep and commonly exceed 25^{o}. The soils occur at altitudes ranging from near sea level to at least 3,000 feet.

3.4. Vegetation. The primary vegetation is Mixed Dipterocarp Forest. It is commonly characterised by a denser occurrence of wild fruit tree species than on other parent materials.

4. FAMILY CLASSIFICATION

The group is represented by one family.

5. NOTES ON THE FAMILY

5.1. Tarat family. Soils of this family have a fine to medium moderately developed crumb to angular blocky structure and are usually friable and well-drained. They are susceptible to drying out.

Colours range from olive yellow to yellowish red. Olive yellow profiles are commonly associated with intermediate parent materials such as quartz diarite, yellowish red profiles with basic rocks such as basalt.

Analyses show that the main clay mineral is kaolinite but a high percentage of the clay fraction is iron oxide which gives the soils a high phosphate-fixing power. 'Reserve' phosphate is therefore higher than in other soils of Sarawak and is thus a useful criterion for separating them from Red-Yellow Podsolic soils.

Shallow and deep phases occur, deep phases occupy gentle upper slopes and also develop in footslope colluvium, while the shallow phases occupy moderately steep to steep hill-sides.

The family occupies large areas of First Division. The family is rare in Second and Third Divisions and has not been found in Fourth and Fifth Divisions.

RED-YELLOW PODSOLIC SOILS

1. GENERAL

The Sarawak definition of Red-Yellow Podsolic soils follows that of Thorp and Smith (1949, p.120) but extends the possible drainage limits and interpretes other diagnostic features in terms of properties normally recorded in the field. The definition of Thorp and Smith (op. cit.) is as follows:-

'Red-Yellow Podsolic soils are a group of well-developed, well-drained acid soils having thin organic (AO) horizons over a light-coloured bleached (A2) horizon over a red, yellowish-red or yellow and more clayey (B2) horizon. Parent materials are all more or less siliceous. Coarse reticulate streaks or mottles of red, yellow, brown and light grey are characteristic of deep horizons of the Red-Yellow Podsolic soils where parent materials are thick.'

2. LOCAL DEFINITION

Red-Yellow Podsolic soils are mineral soils in which:-

1. An R or C horizon, if present, is not within 10 inches of the base of an O horizon,

2. chromas are 5 or more in the B horizon; hues are 2.5Y or redder in the B horizon; values are 5 or less in the B horizon,

3. there is no gley horizon within 20 inches of the base of an O horizon,

4. there is an A2 (possibly albic) horizon over an argillic horizon,

5. if a Bir horizon is present there is no gley horizon within 48 inches of the base of an O horizon.

Soils with a gley horizon within 20 inches of an O horizon are considered Gley soils and those with a Bir horizon overlying a gley horizon within 48 inches of an O horizon are considered Groundwater Laterite soils. Lower subsoil chromas than those given above are within the range of the otherwise similar Grey-White Podsolic soils.

3. ENVIRONMENT

3.1. Climate. These soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). Where present at high altitudes they are possibly present under a cooler climate. No data are, however, available for these altitudes. The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class la, no month having less than 100 mm rainfall. There are no contrasts within the group which correlate with climatic differences except an increase in the depth of the O horizon on the higher uplands which possibly correlates with lower night temperatures and slower organic breakdown.

3.2. Parent material. Red-Yellow Podsolic soils are predominantly developed over sedimentary rocks, ranging from coarse-grained sandstones to clay shales. Contrasts within the group commonly correlate with differences in parent material, as is discussed below. These soils have also developed in old alluvial material and to a lesser extent in recent alluvial deposits, almost at present floodplain level, on some acid igneous and siliceous metamorphic rocks.

3.3. Topography. Red-Yellow Podsolic soils are most extensive on gently rolling to strongly dissected hills but also occur on river levees and gentle undulations in river floodplains. On slopes of more than 20 - 25^{o} soil depth is commonly limited and at least on slopes greater than 35^{o} these soils, if they occur at all, are found in complex association with Skeletal soils.

3.4. Vegetation. The primary vegetation is almost entirely Mixed Dipterocarp Forest.

4. FAMILY CLASSIFICATION

In classifying the Red-Yellow Podsolic soils at the family level a primary division is made between those of residual origin and those of alluvial origin, as the latter commonly have higher nutrient levels.

Within the soils of residual origin two distinct but relatively minor families are first separated: those in which an albic horizon is present (developed normally over coarse-grained sandstones) and those which have more than 20 per cent Group III elements in the A2 and B horizons (these being soils mainly developed over igneous rocks).

The other residual soils within the group have no albic horizon and are poor in iron. There is an obvious contrast between the rather homogenous, deep profiles with weakly expressed B horizons over some shales, and shallower heavier profiles with well-expressed B horizons over some sandstones; but no satisfactory criteria appear to be available on which the many observable permutations of profile characteristics between these extremes can be classified at the family level. Classification of these soils is made entirely on the degree of textural contrast between the A2 and B horizons. Three families have been established, approximating to light, medium and heavy textural divisions.

Within the soils of alluvial origin a subdivision is made between those on young deposits and those on old deposits; further distinction is then made between heavy-textured* and light-textured* soils within these subdivisions.

Table 3 : Red-Yellow Podsolic soils - family classification

Origin of Parent material	Other diagnostic features			Family
Residual	Albic Horizon present			MATANG
	No albic horizon	More than 20 per cent Group III elements in A2 and B horizon		ABOK
		Less than 20 per cent Group III* elements in A2 and B horizons	Light-textured (2)*	NYALAU
			Medium textured (2)*	BEKENU
			Heavy-textured (2)*	MERIT
Alluvial	Recent deposits		Light-textured (1)*	SEMILAJAU
			Heavy-textured (1)*	MALANG
	Old deposits		Light-textured (1)*	SABANGANG
			Heavy-textured (1)*	LUPAR

5. NOTES ON THE FAMILIES

Red-Yellow Podsolic soils are the most widely represented group in Sarawak. They are found in all Divisions. It is estimated that, either alone or in association with Skeletal soils, they mantle roughly 75 per cent of the country.

5.1. Matang. The Matang Family is generally found over massive medium to coarse-grained sandstones in small areas of First, Fourth and Fifth Divisions. The albic horizon is commonly thin and close to the surface. The B horizon is generally a yellowish brown to reddish yellow sandy clay loam.

5.2. Abok. Abok Family soils are generally reddish yellow sandy clay loams to sandy clays. They are of local importance in First and Second Divisions, and are derived from acid igneous rocks, schists, tuffaceous sandstone and other iron-rich sedimentary rocks. Abok soils generally have low nutrient levels, the main contrast with other families in this group being the relatively high iron content.

5.3. Nyalau. The Nyalau family is widespread in all Divisions and is developed over medium- to fine-grained sandstones or mixed sandstones and shales. Throughout the profile the soils are commonly brownish yellow sandy loams over yellowish brown to reddish yellow sandy clay loams. The soils is deep and porous. On some weakly consolidated geological formations these soils are rather unstable and liable to gully erosion. Nutrient levels are low.

* Excluding SC in both A2 and B

5.4. Bekenu. The Bekenu Family is present, and possibly widespread, in all Divisions. It mainly comprises soils which, due to the mixed nature of the parent material, have a textural profile transitional between that of soils in the Merit and Nyalau Families. It also includes soils in which the textural contrast between the A2 and B horizons has been accentuated by colluvial processes and is not entirely attributable to vertical clay translocation. Bekenu soils have low nutrient levels.

5.5. Merit. Merit Family soils are generally yellowish brown clay loams to clays over reddish yellow clays and are widespread in all Divisions. They are derived from phyllites and fine-textured sedimentary rocks such as shales and mudstones. The B horizon is moderately well-developed although structure is commonly only weak. Shallow and moderately deep soils are most extensive. Nutrient levels are generally low, although moderately high over some geological formations.

5.6. Semilajau. The Semilajau Family is present on levees of small to medium-sized rivers, particularly where they drain sandstone hills. They are generally yellow or brownish yellow sands to sandy loams with few mottles. These soils are commonly associated with recent Alluvial and Gley soils. Nutrient levels are low.

5.7. Malang. Malang Family soils are generally yellowish brown clays present on river floodplains and are important in all Divisions. They are commonly associated with Groundwater Laterites and Gley soils. Nutrient levels are low to moderate, depending on the source of the parent material.

5.8. Sabangang. Sabangang Family soils are predominantly brownish yellow sands to sandy clay loams. Many profiles are gravelly. They have been recorded on terrace remnants in all Divisions. Unless the alluvial origin can be established by examining deep sections, as exposed in road cuttings, these soils in many instances cannot be distinguished from soils in the Nyalau Family. They are thus possibly more extensive than records indicate. Nutrient levels are low.

5.9. Lupar. Lupar Family soils have been reported on terrace remnants in Second Division. They are generally yellow to brown clays or clay loams with few mottles, commonly having a stoneline (or boulder layer) of river-worn material in the subsoil. As with the Sabangang and Nyalau Families, if no stoneline is present in the profile these soils are difficult to separate from Merit soils.

GREY-WHITE PODSOLIC SOILS

1. GENERAL

Grey-White Podsolic soils are distinguished from the Red-Yellow Podsolic soils on account of a number of characteristics of which the near absence of iron is the most important. Connected with this feature are the generally pale colours of all horizons. Contrast between horizons is therefore weak.

The soils have strong affinities with the 'Bleached Soils' of Indonesia described by Dames (1955 pp.91-94).

The Grey-White Podsolic soils are soils in which podsolic features such as an argillic horizon and the formation of weak to strongly developed albic horizons are conspicuous. They, however, never show development of a spodic horizon.

The group appears to be an intergrade between Red-Yellow Podsolic soils, which also have an argillic horizon, and/or a weak albic horizon, and Podsols which display in Sarawak the same pale colours but have a weak or strongly developed spodic horizon. The available evidence suggests that Grey-White Podsolic soils were formed by some of the environmental conditions under which the Podsols are formed; but other factors, such as texture and slope, prevent the strong leaching and accumulation of humic materials in a definite horizon. Soils which could be classified as immature or weak Podsols are by definition excluded from this group.

At present some soils within the group occur in association with Podsols and are sandy. The environment is favourable for the development of the true Podsols profile in time and, although such soils are very difficult to separate from the Grey-White Podsolic soils, they are best placed in the Podsols on account of genetic factors. In practise they are difficult to separate in some localities and this underlines the weakness of a genetic classification system in which the genetic processes frequently have to be deduced from environmental factors.

The Grey-White Podsolic soils are not included in the scheme proposed by Thorp and Smith (1949).

2. LOCAL DEFINITION

Grey-White Podsolic soils are mineral soils in which:-

1. An R or C horigon, if present, is not within 10 inches of the base of an O horizon,

2. there is an argillic horizon,

3. there is no gley horizon within 20 inches of the base of an O horizon,

4. there is no spodic horizon,

5. chromas are 3 or less in the A2 horizon, 4 or less in the B horizon; hues are more yellow than 2.5Y in the A2 and B horizons; values are 6 or more in the A2 and B horizons.

3. ENVIRONMENT

3.1. Climate. These soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954) is Class la, no month having less than 100 mm rainfall.

3.2. Parent material. The parent materials are almost without exception quartzose and poor in ferro-magnesium minerals. Where consolidated rock forms the parent material it consists mainly of carbonaceous shales, sandy shales, shales rich in vein quartz and some sandstones. Where the parent material is unconsolidated it is invariably colluvium or old alluvium.

3.3. Topography. The Grey-White Podsolic soils have been found mainly on low hilly terrain comprising dissected terraces and strongly dissected erosion surfaces.

3.4. Vegetation. This ranges from Mixed Dipterocarp Forest to Heath Forest, the latter generally being indicative of the more sandy soils in the group.

4. FAMILY CLASSIFICATION

The group is subdivided into four families, the separation of which is based on differences of parent material and texture.

Table 4 : Grey-White Podsolic soils - family classification

Origin of parent material	Texture of B horizon	Family
Residual	fine*	KERAIT
	coarser than fine*	SARATOK
Old alluvial	fine*	LUBAI
	coarser than fine*	TRIBOH

5. NOTES ON THE FAMILIES

5.1. Kerait. The Kerait Family is typically found on Triassic carbonaceous shales in First Division. The soils commonly occur in complex and with Red-Yellow Podsolic soils.

The soil is usually dark grey at the surface becoming increasingly pale with depth. In most profiles the total iron content is too small to show a colour difference between A2 and B horizon although pale yellow mottles may occur in the latter. The B horizon is therefore mainly characterised by an increase in clay content. Structure in the B horizon is usually coarse blocky, and during dry periods large cracks spread from the Al horizon to the deep subsoil allowing surface humic material to leach down. Removal of clay from the A horizon and its accumulation in the B horizon is indicated by thick clay skins lining the cracks.

The texture is mainly sandy loam to sandy clay loam grading into clays in the B horizon. The soils are generally deep, commonly exceeding 10 feet. In road cuttings, a distinct change from the white soil material to the black weathered carbonaceous shale can be seen. The soils are moderately well drained in the A horizon but drainage is impeded in the lower horizons and water movement is largely confined to the large cracks formed during dry periods. The steep slopes usually enhance rapid run off.

Some soils in this family have distinct reddish mottling in the B horizon but the matrix colour of the whole profile remains white to pale yellow. These soils may be intergrades between Grey-White Podsolic soils and the more strongly coloured Red-Yellow Podsolic soils.

All soils in this family have low nutrient levels. The clays are mainly pure fireclays with few impurities.

5.2. Saratok. Soils of this family usually occur on carbonaecous sandstone, quartzitic sandstone and colluvial material derived from such parent rocks. They are mainly found in First, Second and Third Divisions.

Colours, although pale throughout, are normally somewhat stronger than those of the Kerait Family. Structure is commonly blocky in the B horizon and the consistency is friable in the A horizon but firm in the B. The soils are predominantly quartzose. An albic horizon is usually present but only apparent where the B horizon is pale yellow. Textures vary from sandy loam in the topsoil to sandy clay loam in the B horizon. Usually the silt fraction comprises a high proportion of the fine earth. The clay fraction is essentially kaolinitic but is believed to be partly pure silica. Where the soils are developed in colluvial material, quartz stonelines are normally found at different depths in the profile. Although the texture change from the A2 horizon to the B horizon is normally gradual, in certain bisequent soils it is abrupt. If this change occurs within a depth of 20 inches, and the underlying material is not typical of a Grey-White Podsolic profile, then the soil is classified according to the nature of the underlying material. Bisequent profiles commonly occur in colluvial material especially where outwash material from terraces overlies recent alluvium.

Chemically all soils in this family are poor. The A2 horizon in particular has a low exchange capacity and high pH values.

5.3. Lubai. Little information on Lubai soils is available since old alluvium of a clayey nature is not usually found in Sarawak. They have only been mapped in Lundu District, First Division where they occupy extensive marine terraces.

The carbonaceous shales on which Kerait soils have formed were originally deposited in a brackish water environment and the source material was poor in iron. One cannot therefore expect to find much difference between Lubai and Kerait soils and this presents difficulties in mapping them where they occur in association.

5.4. <u>Triboh</u>. Triboh soils are widespread in First Division and to a lesser extent in Second, Third and Fourth Divisions. They have so far not been found in Fifth Division.

Triboh soils are quartzose in nature and the texture contrast-between layers in the profile may be great. Gravelly layers may alternate with clayey ones. Triboh soils are coarse-textured, chemically poor and are expensive to farm. These soils are only intensively used around Kuching where, through incorporation of much organic material such as dung, vegetable production is economically possible.

PODSOLS AND GROUNDWATER PODSOLS

1. GENERAL

The soils in Sarawak having a podsol morphology, with few exceptions contain a perched watertable within or on the spodic horizon. It is by no means clear, however, if all such soils have formed because of the presence of this watertable, although it is improbable that those found at the existing regional groundwater level can have been formed in any other way. Because there is still some doubt as to their origin, this section is given the heading of Podsols and Groundwater Podsols. For convenience they are all termed Podsols below unless a specific reference is made to the Groundwater Podsols.

All these soils are so highly siliceous and low in sesquioxides that humus is virtually the only constituent leached from the A to the B horizons. They have been described as Humus Podsols by Dames (1962, p.65). Some profiles, however, have iron compounds as the dominant B horizon accumulation. Podsols are described by Baldwin et al (1938, p.997) as consisting of a few inches of leaf mat and acid humus, a very thin dark gray A1 horizon, a whitish gray A2 a few inches thick, a dark or coffee brown B1 horizon and a yellowish brown B2 horizon. They are strongly acid and well drained.

The Groundwater Podsols are described (op. cit, p.1000) as having an organic mat over very thin acid humus, over a whitish-gray leached layer up to 2 or 3 feet thick, over brown or very dark-brown cemented hard pan or ortstein. They are imperfectly to poorly drained.

In Sarawak, soils with a podsol morphology characteristically have a thick O horizon, a thin to thick A1, and thick A2 horizon over a soft to hard Bh horizon. They cannot be classified satisfactorily into either of the two groups defined above.

2. LOCAL DEFINITION

Podsols and Groundwater Podsols are mineral soils in which:-

1. an R or C horizon is not within 10 inches of the base of an O horizon,

2. there is an albic horizon,

3. there is a spodic horizon,

4. groundwater is periodically present in at least the A2 or B horizons.

The presence of a spodic horizon differentiates these soils from all other groups except some Skeletal soils which have this feature within 10 inches of the base of an O horizon. Where gleying occurs close to the surface, which feature would otherwise qualify the soils for Gley soils, the presence of a spodic horizon is taken to be of greater importance, thus all drainage classes may occur in this group.

3. ENVIRONMENT

3.1. Climate. These soils are found under a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class la, no month having less than 100 mm rainfall. Since Podsols occur in close association with Red-Yellow Podsolic and other soils, the importance of climate in their development is considered less than that of parent material.

3.2. Parent material. The parent materials of Podsols are characteristically strongly siliceous and extremely low in weatherable minerals. They range from arenaceous sedimentary rocks of Permian to late Tertiary age, to Pleistocene and Holocene coarse sediments; admixtures of more argillaceous material occur in places.

3.3. Topography. The associated landforms are beaches, terraces, cuesta dip slopes, plateaux and rugged montane areas. The topography is characterized by gentle to moderately steep slopes even in the highland areas.

3.4. Vegetation. The primary vegetation is generally Heath Forest in the lowlands (WOOD and BECKETT, 1961, p.226), but Moss Forest at altitudes exceeding about 4,000 feet. Both tend to be dominated by pole-like trees of a sclerophyllous nature; needle-leaved trees are common.

4. FAMILY CLASSIFICATION

The initial division at family level is based on whether the soils are residual or alluvial in origin. Where the C horizon cannot be examined this difference is in places difficult to establish from morphological evidence alone but taking into account the site properties of a profile there is normally little difficulty in their differentiation. Thus Bako and Silantek soils are derived from thick-bedded, gently dipping sandstone giving ridge-like to plateau and cuesta topography, while the other families occur solely on terraces, alluvial fans and beach deposits.

The next criterion for family separation is whether the spodic horizon is predominantly one of humus, or of iron accumulation. Only the Jerijeh Family has a Bir horizon, which is reddish brown, mottled with paler colours. Soft iron concretions are common in some Jerijeh soils. All the other families have dark-coloured Bh horizons.

The families are then differentiated by the degree of development of the spodic horizon. In the field a strong spodic norizon is taken to be one which cannot be augered through easily. The strong spodic horizons of the Miri and Bako families are thought to be due to periodic drying of the profile which causes cementation of the sand grains. Despite being extremely hard to penetrate by spade or auger, however, broken-off fragments of this horizon are crushable between the fingers and on air-drying disintegrate to single-grain, humus-coated sand. A weak spodic horizon is one which can be augered through without difficulty and is essentially friable. The weak Bh horizon of the Buso Family is thought to be due to permanent waterlogging in the zone of the groundwater table in, for example, beachsand; that of the Silantek Family is suspected to be associated with slightly more clay in the subsoil.

Table 5 : Podsols and Groundwater Podsols - family classification

Origin of parent material	Type of spodic horizon		Family
Residual	Bh	Weak	SILANTEK
		Strong	BAKO
Alluvial		Weak	BUSO
		Strong	MIRI
	Bir	Weak	JERIJEH

5. NOTES ON THE FAMILIES

5.1. Silantek. Soils of this family are derived from arenaceous sedimentary rocks and are found on gentle to moderately steep slopes. Under primary forest they have a thick well-rooted O horizon and a distinct A1 horizon. The A2 horizon is a light-coloured sandy loam to sandy clay loam which overlies a heavier-textured Bh horizon. This consists of pale-coloured sandy clay loam to sandy clay prominently mottled with dark brown humus. The soil beneath is commonly weakly permeable and clayey. The soils are very siliceous, acid and highly leached of bases and soluble mineral nutrients. Structural faces and root channels are favoured sites for humus accumulation.

5.2. Bako. Soils of the Bako Family are found mainly on gentle to moderately steep slopes. Like Silantek soils, they are derived from arenaceous sedimentary rocks. Under primary forest the O horizon is thick and well-rooted and beneath the well-developed A1 horizon is light grey, loose sand. This sand rests abruptly on a dark-brown hard humus pan which overlies rock or more clayey material. The humus pan is always continuous.

5.3. Buso. Buso Family soils mainly occupy flat or gently sloping terraces, bouldery and sandy-textured colluvial fans and some beach deposits. Typically they have moderately thick, well-rooted O horizons and a distinct A1 horizon. The A2 horizon is pale-coloured sand to sandy loam which overlies a soft, continuous or intermittent Bh horizon. The C or IIC horizon beneath is commonly more clayey and may contain gravel and boulders, particularly in the alluvial fans. Those soils developed in beach sand have a permanently high water table, whereas the terrace and colluvial soils dry out periodically.

5.4. Miri. Soils of the Miri Family are found almost entirely on marine terraces. They have a thick, well-rooted O horizon and a distinct A1 horizon which gives way to white, loose, single grain sand, in some locations cemented at the base, that changes abruptly to a hard, dark brown or black humus pan, commonly holding up a perched water table. In some places the pan rests on a relatively unweathered wave-cut rock platform. In other cases the IIC horizon is comprised of impermeable clayey sediments. The original freely permeable nature of the sand is thought to have allowed free movement of humus-containing soil water.

5.5. Jerijeh. Soils of this family are confined to small coastal areas, notably in First Division where basic igneous rocks occur close to the coast. They consist of well-drained sands with a water table periodically rising to about 24 inches. The A2 horizon is irregular in thickness, grey to pale yellow in colour, and changes rapidly to a strong brown B horizon with a concentration of soft iron concretions in its upper part. In the zone of the fluctuating water table the strong brown matrix colour is coarsely mottled yellow and within the permanently waterlogged zone grey colours are dominant.

GROUNDWATER LATERITE SOILS

1. GENERAL

Groundwater Laterite soils are not defined by Thorp and Smith (1949) and for Sarawak a local concept has had to be adopted to separate these soils from other Groups.

Groundwater Laterite soils occupy small areas and seem to be confined to two distinctly different situations. Firstly, they occur in association with iron-rich soils such as Lateritic soils and some families of the Recent Alluvial soils where intermittent groundwater levels formed iron concretions or cemented iron pans. They also occupy small areas of old erosion surfaces where groundwater is now absent. It is believed that the latter are fossil soils.

All the soils have in common an iron-rich layer which has hardened or may harden on drying out. This material qualifies for plinthite. It has not been possible to distinguish between iron-rich, mottled layers which harden on drying and those which do not. Therefore only the hardened type of plinthite is considered to be diagnostic of Groundwater Laterites.

2. LOCAL DEFINITION

Groundwater Laterite soils are mineral soils in which:-

1. there is hardened plinthite but not within 10 inches of the base of an O horizon,

2. there is no albic horizon,

3. ENVIRONMENT

3.1. <u>Climate</u>. Groundwater Laterite soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. <u>Parent material</u>. These soils have a wide range of parent materials but are most commonly developed on materials rich in ferro-magnesium minerals, such as basic igneous rocks.

3.3. <u>Topography</u>. Where fossil soils occur the associated landforms range from comparatively undissected terraces to strongly dissected erosion surfaces. In the latter Groundwater Laterite soils are commonly confined to the summits of hills but even on such sites they are only patchily present. On the terraces these soils are normally more extensive. Groundwater Laterite soils are also found on footslopes in association with Lateritic soils.

3.4. <u>Vegetation.</u> In all areas mapped the primary vegetation has been removed. The secondary growth is usually stunted and contains Heath Forest species.

. FAMILY CLASSIFICATION

Until more information on these soils is available the only distinction made is between soils of upland localities and those at present floodplain level.

Table 6 : Groundwater Laterite soils - family classification

Site	Family
Upland	RAPAK
Floodplain	BENTANG

5. NOTES ON THE FAMILIES

Normally the families occur in small areas which are only possible to map by detailed surveys. Since little information is available no attempt is made to discuss these families further.

GLEY SOILS

1. GENERAL

Gley soils are comparable to the group of Low-humic Gley soils defined by Thorp and Smith (1949, p.119) and to the Grey Hydromorphic soils defined by Cline (1955, p.84). Both definitions, however, exclude gleyed soils with thin surface peat accumulation. Baldwin et al (1938, p.1000) classed these as Half Bog soils. Where this accumulation is less than 10 inches thick it is considered that such soils are probably best classed with the other gleyed soils. In Sarawak a group of Gley soils has therefore been locally defined.

The majority of Gley soils are easily recognised but in some places they are difficult to distinguish from Saline Gley soils, which may differ only in the salinity of the groundwater as measured by its conductivity. Also, soils on upland sites, where the profile is low in iron and gleying has minimal expression, have many similarities to profiles of Grey-White Podsolic soils. The difficulty of classifying soils in which both mineral and organic layers are found is discussed under Peat soils.

The local definition, given below, is thus not entirely satisfactory for delimiting some soils within the group.

2. LOCAL DEFINITION

Gley soils are mineral soils in which:-

1. an R or C horizon is not within 10 inches of the base of an O horizon,
2. any peaty O horizon is not more than 10 inches in thickness,
3. a gley horizon is present within 20 inches of the base of an O horizon,
4. Groundwater conductivity does not exceed 500 micromhos per cm at 25^{o} C at any time of year,
5. there is no spodic horizon,
6. there is no hardened plinthite.

Groundwater conductivities higher than those stated above qualify for the group of Saline Gley soils. The presence of a peaty O horizon deeper than 10 inches indicates a Bog soil. A spodic horizon is diagnostic for Podzols.

3. ENVIRONMENT

3.1. Climate. Gley soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. No contrasts within the group correlate with climatic differences.

3.2. Parent material. Gley soils are developed largely in marine and riverine clays and to a minor extent in riverine sands. Semadoh and Gerawat Families are developed over shales, and possibly mixed shales and sandstones.

3.3. Topography. These soils are found on flat or gently undulating valley bottoms and old beaches, on low hills and on long gentle dip slopes. Topography is probably the most important environmental factor in the development of these soils. Except where developed in heavy parent material, they are associated entirely with areas of slow external drainage.

3.4. Vegetation. The upland residual soils (Semadoh and Gerawat Families) are found under Mixed Dipterocarp Forest or, where recorded at high altitudes, under Moss Forest. The soils derived from recent riverine material bear a cover of Freshwater Swamp or Riparian Forest in the few areas where they have not been cleared for cultivation. Soils from old riverine material are generally found under Heath Forest and those from marine alluvium under Littoral or Swamp Forest.

4. FAMILY CLASSIFICATION

Classification at a family level is based on the origin of the parent material, the presence or absence of a thin peaty O horizon, and the texture of the subsoil. The classification is given in tabular form below.

Table 7 : Gley soils - family classification

Origin of Parent material	Peaty O horizon less than 10 inches thick	Texture	Family
Residual	present	heavy (1)*	GERAWAT
	absent	heavy (1)*	SEMADOH
Recent riverine	present	light (1)*	LUIS
		heavy (1)*	SEBANDI
	absent	light (1)*	PLAN
		heavy (1)*	BIJAT
Old riverine	absent	light (1)*	GONG
		heavy (1)*	EMBANG
Recent marine	present	light (1)*	MATU
	absent	light (1)*	TATAU
		heavy (1)*	DARO

As can be seen from Table 8, certain combinations of the features used for family classification have not yet been recorded and possibly do not occur.

5, NOTES ON THE FAMILIES

5.1. Gerawat. Gerawat Family soils have only been noted in small areas in Fourth and Fifth Divisions and probably have a very limited distribution. They are found on long gentle slopes where they consist of a shallow, gleyed sandy clay soil overlain by thin, rather mossy peat. Other locations include the ridges of mountains within the Moss Forest zone above 4,000 feet where Peat soils are also found.

Here the soil depth is varied as rock outcrops are common. Gerawat soils are commonly found in association with soils of the Semadoh Family.

5.2. Semadoh. These soils have been recorded in Third, Fourth and Fifth Divisions and are probably present throughout the country although, where they have been seen, they do not cover wide areas and are unlikely to be widespread in any locality. They are grey, mottled, heavy-textured hill soils, the gleyed nature of which is attributed to an impervious subsoil or substratum and/or to gentle gradients and slow surface run-off. These soils are of little agricultural importance.

5.3. Luis. These soils commonly occur as small areas and are usually found with sandy riverine soils of the Plan Family. The most common locations are in headwaters of rivers draining areas with sandy residual soils. The soils are very poorly drained. The mineral soil beneath the surface peat or muck is pale to dark coloured, light-textured and commonly poorly sorted.

5.4. Sebandi. Soils of this family are present in all parts of lowland Sarawak where they occupy a band in riverine floodplains between other Gley soils and Peat soils. The soils consist of pale-coloured, plastic, heavy-textured material overlain by a thin peaty topsoil. The fertility is variable and crops grown range from swamp padi to coconuts, sago and rubber.

5.5. Plan. Plan Family soils are present throughout the country but rarely cover extensive areas. They are commonly recorded in small valleys, particularly where rivers drain uplands mantled by coarse-textured residual soils. They are generally grey in colour, sandy and poorly sorted. These soils are of only local agricultural importance.

5.6. Bijat. Bijat soils are generally light grey mottled clays. They are widespread soils on the bottomlands throughout the country, except where Peat soils are developed. Much of the wet padi in the country is planted on Bijat soils, which are also used for rubber, coconuts, and other crops.

5.7. Gong. Soils of this family are generally light grey sands or coarse sandy loams. They are of local importance in First Division and possibly elsewhere. They occur on low-level terraces or, where associated with underlying limestone, may be at present floodplain level. They are rarely used for agriculture.

5.8. Embang. These soils, like Gong Family soils, have only been mapped in First Division. They are generally grey to light grey clays or sandy clays. They are commonly found at present floodplain level and are used in places for wet land crops.

5.9. Matu. These soils only occur in coastal areas. They occupy wide belts on swamp margins, notably in Third and Fourth Divisions, and long narrow swales between higher coastal beachlines. The subsoil has low chromas, is light-textured, well-sorted and of low fertility. The peaty topsoil has a higher nutrient status than the subsoil although it is acid and poorly decomposed. Coconuts are grown on the soils in some localities, and in Third Division the soils support coarse grasses for grazing.

5.10. Tatau. These soils are common near the Third and Fourth Divisions coasts east of Tanjong Jol. In Second Division they are only important between Kabong and Grigat and in First Division west of Tanjong Po. They are not common along the Fifth Division coast. These grey, poorly-drained sandy soils are commonly used for coconuts and vegetables.

5.11. Daro. Daro soils are reclaimed Saline Gley soils which, through leaching and drainage, have groundwater conductivity levels too low to qualify for grouping in the Saline Gley soils. They are generally grey clays with few mottles. They have been recorded in Third Division near Matu and are probably present elsewhere.

SALINE GLEY SOILS

1. GENERAL

Saline Gley soils are only represented in Sarawak by hydromorphic soils developed in areas subject to incursions by sea-water and thus have medium to high levels of salts in the groundwater. They are included in the Saline soils of Baldwin et al (1938, p.994). In the absence of a standard definition, the limits of this group have been defined locally.

As Saline Gley soils in this classification are considered to be only those which are now saline, soils formed in a marine environment but which occur in areas reclaimed by drainage and have been leached of salts are excluded from the group.

Strongly saline conditions are normally indicated in the field by halophytic vegetation. Weakly saline conditions are less easy to recognise and the soils may have no physical characteristics which obviously contrast with those of non-saline Gley soils. Classification has, therefore, to rely on conductivity measurements of the groundwater, a more detailed study of salinity being normally impracticable under field conditions. It is possible to use conductivity in classifying these soils as, in Sarawak, 'fresh' river water has a conductivity of less than 100 micromhos except in streams draining areas of limestone. A lower limit of 500 micromhos (per cm at 25°C) is therefore used to separate Saline Gley soils from other soils.

This system requires improvement and two major criticisms can be made. Firstly, the lower limit of 500 micromhos is only a compromise as (a) it is too high to separate fresh from brackish water and (b) it is too low to have much practical significance for agriculture. On present evidence it appears that salinity only becomes a farming problem in connection with most crops above a level of 1,000 or 1,500 micromhos. Secondly, the conductivity of the soil groundwater varies widely, being influenced by the tide, the degree of fresh-water flooding and rainfall. While one high reading always indicates a saline soil by this definition, one low reading does not necessarily indicate a non-saline soil.

2. LOCAL DEFINITION

Saline Gley soils are mineral soils in which:-

1. An R or C horizon is not within 10 inches of the base of an O horizon,
2. groundwater conductivity exceeds 500 micromhos per cm at 25°C at some time of the year,
3. a gley horizon occurs within 20 inches of the base of an O horizon.

3. ENVIRONMENT

3.1. Climate. Saline Gley soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. Saline Gley soils are developed in alluvial or organic deposits. While such soils are present in coastal sands those developed in alluvial clays are much more widespread.

3.3. Topography. These soils develop on flat terrain situated between low tide and high tide levels. Complex creek patterns and numerous mud lobster mounds commonly give a strongly developed micro-relief.

3.4. Vegetation. While there is no exact correlation between degree of salinity and natural vegetation, mangrove, *Nypa fruticans* and *Oncosperma filamentosa* are useful indicator species which, in the order given, generally reflect decreasing salinity levels.

4. FAMILY CLASSIFICATION

Within the group Saline Gley soils a division is first made between mineral and organic soils. The organic soils are not subdivided further. The mineral soils are subdivided into two texture groups and these are further divided into weakly saline and strongly saline groups. The family classification is given in tabular form below.

Table 8: Saline Gley soils - family classification

Parent material	Texture of mineral soil	Salinity	Family
Mineral	Light - textured (2)*	weakly saline	NONOK
		strongly saline	BELAT
	Heavy - textured (2)*	weakly saline	PENDAM
		strongly saline	RAJANG
Organic			LIMBANG

The mineral soils, when reclaimed and leached of salts, are considered Gley soils (see Tatau and Daro families).

5. NOTES ON THE FAMILIES

5.1. Nonok. Nonok Family soils are grey sandy loams developed on swales formed by old beach deposits and on coastal flats.

5.2. Belat. Belat Family soils are generally grey sandy loams to gravelly sands. They are developed in colluvial wash from nearby marine or riverine terrace deposits and are also found on sandspits below high tide level.

5.3. Pendam. Soils in the Pendam Family are generally greenish grey to dark grey clays, commonly found bordering estuaries although occurring in other coastal situations. Characteristics are varied, as Pendam soils are commonly thoroughly mined by the mud lobster (*Thallassima anomala*). In many areas these soils have been cultivated for wet padi or coconuts and their saline character is only apparent in groundwater analyses.

5.4. Rajang. Rajang Family soils are dark grey to greenish grey clays which, in most areas, have been left in their natural state, have been mined by mud lobsters to give numerous mounds and hummocks and are crossed by a close pattern of tidal creeks. The primary vegetation is mangrove and *Nypa fruticans*.

5.5. Limbang. Limbang soils comprise fine woody debris, largely derived from mangrove and *Nypa fruticans*, or from the debris of Freshwater Swamp Forest tree species.

Saline Gley soils are found throughout the coastal areas of Sarawak although along much of the coast they form only a very narrow and commonly broken belt. They are widespread in the coastal reaches of the Kayan, Sarawak and Sadong Rivers, First Division, in the delta of the Rajang River, Third Division, and around Brunei Bay in Fifth Division.

PEAT SOILS

1. GENERAL

Peat soils are largely equivalent to the Bog soils of Baldwin et al (1938, p.1000) and are widespread throughout lowland Sarawak and in some mountainous areas, covering about 13 per cent of the State. They normally occur in association with Gley soils. Peat soils are permanently waterlogged and consists of raw, generally woody peat exceeding 10 inches in depth and rest on gleyed mineral soil. In places, particularly close to large, meandering rivers, soils occur which consist of deposition sequences of mineral and organic material in lenses or bands. Where the surface organic horizon does not exceed 10 inches and the underlying soil consists of depositional layers of mineral and organic material, the depositional organic layers together must exceed 65 per cent of the profile beneath the O horizon. Where these organic layers comprise less than 65 per cent the soil is classed as a Gley soil, not a Peat soil.

Baldwin et al (op. cit) described Bog soils as brown, dark brown or black peat or muck over brown peaty material, with very poor internal drainage. The local definition of Peat soils follows this concept but specifies a minimum depth of 10 inches, shallower organic soils being grouped in the Gley soils.

2. LOCAL DEFINITION

Peat soils are organic soils in which:-

1. The O horizon consists of peat or muck (more than 35 per cent organic matter) and is more than 10 inches deep,

2. groundwater conductivity does not exceed 500 micromhos per cm at 25°C at any time of year.

3. ENVIRONMENT

3.1. Climate. Peat soils are found in a Tropical Rainy Climate subclass Af (KOPPEN, 1916). Where present at high altitudes, they are possibly present in a cooler climate. No data are, however, available for these areas. The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class la, no month having less than 100 mm rainfall. In the lowlands, climate does not appear to be a major factor in the development of Peat soils, but at altitudes exceeding about 4,000 feet the cooler temperatures, persistent cloudiness and high rainfall are probably the prime reason for the existence of these soils.

3.2. Parent material. Peat soils consist of deep organic accumulations of Freshwater Swamp Forest and Moss Forest debris, although the basal peat of the lowlands is commonly formed of Saltwater Forest remnants (ANDERSON, 1964, p.13). The organic accumulation overlies gleyed mineral material. The organic deposits range in composition from well preserved wood, leaves and grass to comminuted plant remains.

3.3. Topography. Peat soils occur largely in alluvial basins. Where best developed, these topogenic Peat soils have a domed surface, steepest at the margins, the highest point of which is, in some places, 60 feet above river level. Climatogenic Peat soils are and found at altitudes of about 4,000 feet where in some areas they form a more or less continuous mantle over all but the steepest slopes.

3.4. Vegetation. The primary vegetation on Peat soils in Peat Swamp Forest on lowland peat (ANDERSON, 1963, pp.142-144) and Moss Forest at high altitudes.

4. FAMILY CLASSIFICATION

The initial subdivision at family level is based on topography. A secondary subdivision is then made on the depth of the peat, an arbitrary limit of 40 inches being considered of agricultural significance. The shallow peats are then separated on the basis of the texture of the mineral subsoil.

Table 9: Peat soils - family classification

Origin	Other diagnostic features		Family
Topogenic	O horizon 10-40 inches deep	Mineral subsoil light-textured	IGAN
		Mineral subsoil heavy-textured	MUKAH
	O horizon more than 40 inches deep		ANDERSON
Climato-genic	O horizon 10-40 inches deep		MULU

5. NOTES ON THE FAMILIES

5.1. Igan. Soils of this family consist of shallow, acid peats, commonly woody or slightly sandy, overlying sand. They are found mainly in coastal areas particularly in Third and Fourth Divisions. Where successfully drained they are used for vegetables, fruit trees and coconuts.

5.2. Mukah. Mukah Family soils are generally shallow, acid peats, are commonly woody or clayey and overlie plastic clays. They border large inland swamps and form many small separate swamps. They are used in many areas for swamp padi, sago and rubber.

5.3. Anderson. These soils are deep, woody, acid peats occupying most large and many small swamps in the lowlands. Their base, in many places, is lower than mean tide level. Recorded depths commonly exceed 20 feet and may exceed 50 feet (ANDERSON, 1964, p.9). They are used in places for sago and, in the lower Rajang area, for rubber.

5.4. Mulu. These soils have only been examined at Mulu in Fourth Division; they occur under Moss Forest above 4,000 feet where they rarely exceed 30 inches in depth. By comparison with the lowland peats, the soil is more fibrous, spongy and less waterlogged. They are not used for agriculture.

RECENT ALLUVIAL SOILS

1. GENERAL

Baldwin et al (1938, p.1001) described Alluvial soils as stratified soils with little profile development, some accumulated organic matter and a wide range of internal drainage (from poor to good). This concept is followed in Sarawak but the range of drainage conditions is limited to well-drained and imperfectly-drained. Poorly-drained soils are included in the Gley soils.

2. LOCAL DEFINITION

Recent Alluvial soils are mineral soils in which:-

1. an R horizon, or a C horizon, consisting of rock weathered in situ, is not within 10 inches of the base of an O horizon,
2. where the profile consists of bands of coarse and fine earth, there is no band of material with more than 80 per cent coarse earth which is more than 20 inches thick and is within 10 inches of the base of an O horizon,
3. a gley horizon, if present, is not within 20 inches of the base of an O horizon,
4. neither albic nor spodic nor argillic horizons are present.

Where thick bands of coarse earth are present within 10 inches of an O horizon the soil is classed as a Skeletal soil.

3. ENVIRONMENT

3.1. Climate. These soils are found in a Tropical Rainy Climate - subclass Af (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. The parent materials are recent riverine and marine deposits derived from sources varying from igneous and metamorphic rocks to sedimentary rocks. Texture of the parent materials range from gravelly sands to clays. Only where basic igneous or argillaceous rock types are the source, is the clay fraction usually dominant in the alluvium derived from them but there is also a succession along the river courses, from their sources to their lowest points, from coarse textured materials to increasingly more clayey deposits.

The most poorly sorted soils are characteristic of the higher reaches of river courses.

3.3. Topography. These soils are normally found on present levees and riverbanks. They are also found in some small, narrow valleys in interior areas and on alluvial fans. Along the coast the soils are found on recent beaches and sandspits.

3.4. Vegetation. On the riverine families the primary vegetation is mainly Mixed Dipterocarp Forest in which large emergent trees give the impression that it may be of better quality than the more dense forest of the same nature on related upland soils found nearby. Borneo Ironwood (Eusideroxylon sp.) favours the more sandy soils. Wild fruit trees, in particular Illipe Nut (Shorea sp.) are more common than in related Mixed Dipterocarp Forest on the hills.

4. FAMILY CLASSIFICATION

Families are classified initially on colour. This is indicative of total iron content, which in Sarawak is closely related to many other characteristics such as source material, phosphate fixing power and drainage. A second subdivision is based on origin. A further subdivision is then based on texture, two texture classes being used. Where soils consist of depositional layers of contrasting texture, the dominant texture group is estimated by considering the thickness of each layer (to a depth of 48 inches) and the texture group to which it belongs. Where, however, the surface 20 inches is of one texture group, the texture of deeper layers is not considered.

Table 10: Recent Alluvial soils - family classification

Colour	Parent material	Texture	Families
Hues 7.5YR or redder; values 5 or less	Riverine	Light (l)*	RAMUN
		Heavy (l)*	TERBAT
	Marine	Light (l)*	SEMATAN
Hues 10YR or yellower; values 5 or less	Riverine	Light (l)*	KAYAN
		Heavy (l)*	SEDUAU
	Marine	Light (l)*	KABONG

5. NOTES ON THE FAMILIES

5.1. Ramun. This family is widespread in First Division, mainly in the Kuching, Upper Sadong and Lundu Districts and is confined to alluvial fans at the debouching points of small streams draining igneous rock massifs. These soils are usually strong brown gravelly clays to sandy loams, with alternating layers of contrasting texture. They are well to excessively drained soils. They are used for a variety of crops but mainly for perennials. Nutrient levels are higher than normal for Sarawak soils.

5.2. Terbat. These soils occur either in association with Ramun soils in alluvial fans or in small narrow valleys close to basic igneous rock massifs. They are mainly found in First Division, in particular in the Serian and Terbat areas. Textures are usually homogenous throughout the profile and the soils are well drained. Colours are usually strong brown to reddish yellow. Physically they are superior to most soils in Sarawak although nutrient levels are lower than those of the related Ramun Family.

5.3. Sematan. This family occurs on the coast between Tanjong Dato and Tanjong Po in First Division, where rock types rich in ferro-magnesium minerals outcrop. From these outcrops eroded materials are distributed along the coast by long-shore drift. Soils of this family are commonly found in association with the younger Kabong Family soils. Sematan soils are brown to reddish yellow in colour, are well drained but have an intermittent watertable between 24 and 48 inches. They contain an abundance of shell fragments particularly in the lower subsoil where in some localities, calcrete has formed.

5.4. Kayan. These soils are widespread in all Divisions where they occur along the upper reaches of rivers draining areas dominantly of arenaceous rock types. They are usually brownish yellow to yellow sandy soils but thin layers of a loamy texture may occur. The soils are not generally used for agriculture because of their low fertility and susceptibility to erosion and flooding.

5.5. Seduau. This family is found throughout Sarawak but the total area covered by it is believed to be small. It occurs in places in small interior valleys overlying consolidated rocks. These soils are brownish yellow heavy loams. Drainage is usually moderately good but underlying rock may give rise to perched water tables in the wet season. Seduau soils are commonly used for rubber if they occur in areas of significant extent.

5.6. Kabong. Soils of this family have developed in young sand bars, spits, and recent beaches along almost the whole coastline of Sarawak except the stretch between Tanjong Po and Kuala Krian. Kabong soils are quartzose but between Tanjong Dato and Tanjong Po contain muscovite, biotite and sericite. In the latter area they are associated with Sematan soils to which they are related. A common feature of Kabong soils is the relatively high total calcium content derived from shell fragments.

APPENDIX

EXPLANATION OF TERMS USED

For ease of reference the definitions of the main technical terms used in defining e great soil groups and families are given below. In the case of texture some general rms have been defined for local use. These are asterisked in the text above. Some ints which require clarification but are relevant to a number of groups are included re to avoid duplication in the text.

LIMATE

<u>ppen's system</u>. A tropical rainy climate, in this system, is one in which the average nual temperature is at least about 20^{o}C and the annual average rainfall at least 600 mm. bclass Af climates have at least 60 mm rainfall in the least rainy month.

<u>ainfall - Mohr's system.</u> Class la rainfall is defined as a rainfall regime in which all onths of the year have more than 100 mm rain. This Class can be described as 'Con- nuously Wet'.

ARENT MATERIAL

<u>rigin of alluvial parent material</u>. A distinction is made at the family level for many roups between alluvial parent material of recent and past origin. For practical purposes cent alluvium is considered that which is actively accumulating and is within reach of esent river flooding while old alluvium, or alluvium, of past origin, is considered that hich is beyond the reach of present river flooding.

<u>roup III elements</u>. Mainly Fe_20_3 and Al_20_3, obtained by the following method:-

1 gm of fine soil (less than 1 mm) is ignited at 800^{o}C for 30 minutes, it is then gested with concentrated hydrochloric acid (10 mls) for 30 minutes on a sand bath. The ixture is filtered and made up to 50 ml in a graduated flask with distilled water. An iquot (25 mls) is taken for the Group III determination. The aliquot is placed in a 250 ls beaker, methyl red (2-3 drops) is added as indicator. 1+1 ammonia solution is added om a burette until the solution is alkaline. Ferric Chloride (2 drops) followed by bromine ater (1-2 mls) are then added. The mixture is boiled and filtered while hot through a hatman 54 paper. The precipitate is washed several times with hot 2% ammonia chloride. he precipitate is now fused at 800^{o}C, cooled in a dessicator and weighed. The weight of e precipitate over the weight of soil taken x 100 (oven dry basis), gives the Group III figure.

INERAL AND ORGANIC SOIL

ineral soil is considered that which contains less than 35 per cent organic matter. Organic il contains more than 35 per cent organic matter. For classification purposes no distinct- n is made between peat and muck, all being termed peat. Where muck is mentioned, the rd is used in the sense of finely comminuted woody debris, not in the sence of peat with high percentage of mineral matter.

At the great soil group level soils are classified as 'mineral soils' or 'organic soils' on the basis of the horizons below the surface 10 inches.

SOIL DEPTH

For classification purposes the profile is considered only to a depth of 48 inches from the surface or, if an O horizon is present in a mineral soil, from the base of the O horizon. Thus in a definition or in the notes on a family 'no spodic horizon', for example, means no spodic horizon within 48 inches of the surface or the base of the O horizon, if an O horizon is present.

SOIL DIAGNOSTIC HORIZONS

O horizon. Horizon: (1) formed or forming in the upper part of mineral soils and above the mineral part; (2) dominated by fresh or partly decomposed organic material; and (3) containing more than 30 per cent organic matter if the mineral fraction is more than 50 per cent clay, or more than 20 per cent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional organic-matter content. (U.S.D.A., 1960, p.25).

A horizon. Mineral horizon consisting of:- (1) horizon of organic-matter accumulation formed or forming at or adjacent to the surface; (2) horizon that has lost clay, iron or aluminium with resultant concentration of quartz or other resistant minerals of sand or silt size; or (3) horizon dominated by 1 or 2 above but transitional to an underlying B or C horizon. (U.S.D.A., 1960, p.25).

Al horizon. Mineral horizon, formed or forming at or adjacent to the surface, in which the feature emphasized is an accumulation of humified organic matter intimately associated with the mineral fraction. (U.S.D.A., 1960, p.25).

A2 horizon. Mineral horizon in which the feature emphasized is loss of clay, iron or aluminium, with resultant concentration of quartz or other resistant minerals in sand and silt sizes. (U.S.D.A., 1960, p.25).

Albic horizon. A surface or lower horizon having such thin coatings on the sand and silt particles that the hue and chroma of the horizon are determined primarily by the colour of the sand and silt particles. Especially in soils rich in quartz, moist chromas of albic horizons are 3 or less, and dry chromas less than 3. Chromas are lower than those of an underlying argillic horizon, unless the chroma of the argillic horizon is 2 or less. Dry values are higher and moist value usually higher than those of an underlying argillic horizon, and always higher than those of an underlying spodic horizon. An albic horizon usually lies on an argillic horizon, spodic horizon or on a fragipan or an equally impervious horizon or layer. (U.S.D.A., 1960, p.60).

B horizon. Horizon in which the dominant feature or features is one or more of the following:-

(1) an illuvial concentration of silicate clay, iron, aluminium, or humus, alone or in combination;

(2) a residual concentration of sesquioxides or silicate clays, alone or mixed, that has formed by means other than solution and removal of carbonates or more soluble salts;

(3) coatings of sesquioxidis adequate to give conspicuously darker, stronger or redder colours than overlying and underlying horizons in the same sequum but without apparent illuviation to meet requirements of 1 or 2 in the same sequum; condition in sequums lacking conditions defined in 1, 2 and 3 that obliterates original rock structure, that forms silicate clays, liberates oxides, or both, and that forms granular, blocky or prismatic structure if textures are such that volume changes accompany changes in moisture. (U.S.D.A., 1960, p.26).

B2 horizon. That part of the B horizon where the properties on which the "B" is based are without clearly expressed subordinate characteristics indicating that the horizon is transitional to an adjacent overlying A or an adjacent C or R. (U.S.D.A., 1960, p.27).

Argillic horizon.

An argillic horizon forms below an eluvial horizon but may occur at the surface if a soil has been partially truncated. It meets the following requirements:-

1. Where an eluvial A remains, and there is no lithologic discontinuity between the A and the argillic horizon, it contains more clay than the A as follows:-

a. If the A has less than 15 per cent clay in the fine earth (less than 2mm.) fraction, the argillic horizon must contain at least 3 per cent more clay than the A. (13 per cent versus 10 per cent, for example).

b. If the A has more than 15 per cent clay and less than 40 per cent in the fine earth fraction, the ratio of the clay in the argillic horizon to that in the A must be 1.2 or more.

c. If the A has more than 40 per cent clay in the fine earth fraction, the argillic horizon must contain at least 8 per cent more clay than the A. (50 per cent versus 42 per cent, for example).

2. The argillic horizon must be at least one-tenth the thickness of the sum of all overlying horizons, or more than 15 cm (6 inches) thick; and the clay increases required under item 1 must be reached within a vertical distance of 30 cm (12 inches) or less.

3. If peds are present, an argillic horizon must show clay skins on some of both the vertical and horizontal ped surfaces and in the fine pores, or must show oriented clays in 10 per cent or more of the cross section.

4. If a profile shows a lithologic discontinuity between the A and the argillic horizon, or if only a plow layer overlies the argillic horizon, the argillic horizon need show only clay skins in some fine pores and, if peds exist, on some vertical and horizontal ped surfaces, or the clay skins must constitute approximately 10 per cent of the cross section.

5. The argillic horizon does not necessarily have more clay than the C horizon, but it should have more fine clay than the C. (U.S.D.A., 1960, pp.44-45).

Spodic horizon.

A spodic horizon is one which shows the following properties:-

1. Amorphous coatings of humus and allophane or of humus, allophane, and free sesquioxides on particles of sand or silt; or rounded to subangular pellets of humus or of humus and sesquioxides between 20 and 50 microns in diameter; or both.

2. More than 0.29 per cent organic carbon or 1 per cent free sesquioxides in some part.

3. No clay skins; under crossed polarizers coatings in thin sections show slight or no birefringence and no extinction on rotation, which indicates substances forming the coatings are not both crystalline and oriented.

4. No structure, or structure other than blocklike, or blocklike structure only if the grade of structure is weak.

5. Carbon-nitrogen ratios of more than 14, if profile is virgin.

6. SiO_2/R_2O_3 ratio in clay fraction less than that in clay fraction of overlying A2 or albic horizon and less than that in clay fraction of parent material. (U.S.D.A., 1960, p.49).

Plinthite. Plinthite is defined by the U.S. Department of Agriculture (U.S.D.A., 1960) as the sesquioxide rich, humus poor, highly weathered mixture of clay with quartz and other diluents, which commonly occurs as red mottles, usually in platy, polygonal, or reticulate patterns; plinthite changes irreversibly to hardpans or irregular aggregates on repeated wetting and drying, or it is the hardened relicts of the soft red mottles. The lower boundaries of plinthite are often diffuse or gradual, but they may be abrupt at a lithologic discontinuity.

Plinthite may occur as a constituent of a number of horizons, including ochric and umbric epipedons, argillic horizons, oxic horizons, and C horizons. It is a form of the material which has been called laterite, renamed to obtain a better combining form for the new nomenclature. It normally forms in horizons below the surface, though it is commonly exposed at the surface, and may, under some conditions, form at the surface. In Sarawak the term 'plinthite' is used only for the hardened form of this material.

C horizon. A mineral horizon or layer, excluding bedrock, that is either like or unlike the material from which the solum is presumed to have formed, relatively little affected by pedogenic processes, and lacking properties diagnostic of A or B but including materials modified by:- (1) weathering outside the zone of major biological activity; (2) reversible cementation, development of brittleness, development of high bulk density, and other properties characteristic of fragipans;

(3) gleying; (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by such accumulations as calcium or magnesium carbonate or more soluble salts; or (6) cementation by alkali-soluble siliceous material or by iron and silica. (U.S.D.A., 1960, p.28).

R horizon. Underlying consolidated bedrock, such as granite, sandstone, or limestone. If presumed to be like the parent rock from which the adjacent overlying layer or horizon was formed, the symbol R is used alone. If presumed to be unlike the overlying material, the R is preceded by a Roman numeral denoting lithological discontinuity. (U.S.D.A., 1960, p.28).

SOIL TEXTURE

Six broad texture classes are recognised, as follows:-

Fragmental soils: Stones, cobbles, gravel, and coarse sand.

Sandy soils: Sands other than coarse sand, and loamy sands.

Light loamy soils: Light sandy loams (less than 15 per cent clay other than light very fine sandy loam; and light loams (less than 15 per cent clay).

Light silty soils: Silt; light silt loam (less than 15 per cent clay); and light very fine sandy loam (less than 15 per cent clay).

Heavy loamy soils: Heavy sandy loams loams, and silt loams (all with more than 15 per cent clay); sandy clay loam; clay loam and silty clay loam.

Fine-textured soils: Clay, silty clay, and sandy clay. (U.S.D.A., 1960, p.100).

In many great soil groups a distinction is made at the family level between light-textured and heavy-textured soils. Where this single division is made between the classes the descriptive term in the text is followed by the symbol (1)*. Where this symbol is used the following definitions are meant:-

Light-textured (1)* soils. Sandy, light loamy and light silty soils. (Fragmental soils are not included).

Heavy-textured (1)* soils. Heavy loamy and fine textured soils.

Where there is a textural increase down the profile and a textural B horizon is present, classification is made on the texture of the B horizon.

Within the group of Red-Yellow Podsolic soils a division into three texture groups is made in the case of residual soils. Where three texture groups are employed the descriptive term in the text is followed by the symbol (2)* and the following definitions are meant:-

Light-textured (2)* soils. Soils in which the B horizon is sand, light loam, light silt or heavy loam. If heavy loam, the B horizon is heavy sandy loam, heavy loam or sandy clay loam. Silty clay loam and clay loam are excluded.

Medium-textured (2)* soils. Soils in which the B horizon is silty clay loam, clay loam or fine textured but is not clay unless the A2 horizon is sandy clay loam or lighter-textured than sandy clay loam.

Heavy-textured (2)* soils. Soils in which the A2 horizon is clay loam or fine textured and the B horizon is fine textured.

Very firm. Soil material crushes under strong pressure; barely crushable between thumb and forefinger.

Extremely firm. Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and must be broken apart bit by bit.

Salinity. Three salinity levels are recognised, defined in terms of groundwater conductivity (expressed in mmhos per cm at 25^{o}C) -

non-saline	-	under 500 mmhos
weakly saline	-	500 - 4,000 mmhos
strongly saline	-	over 4,000 mmhos .

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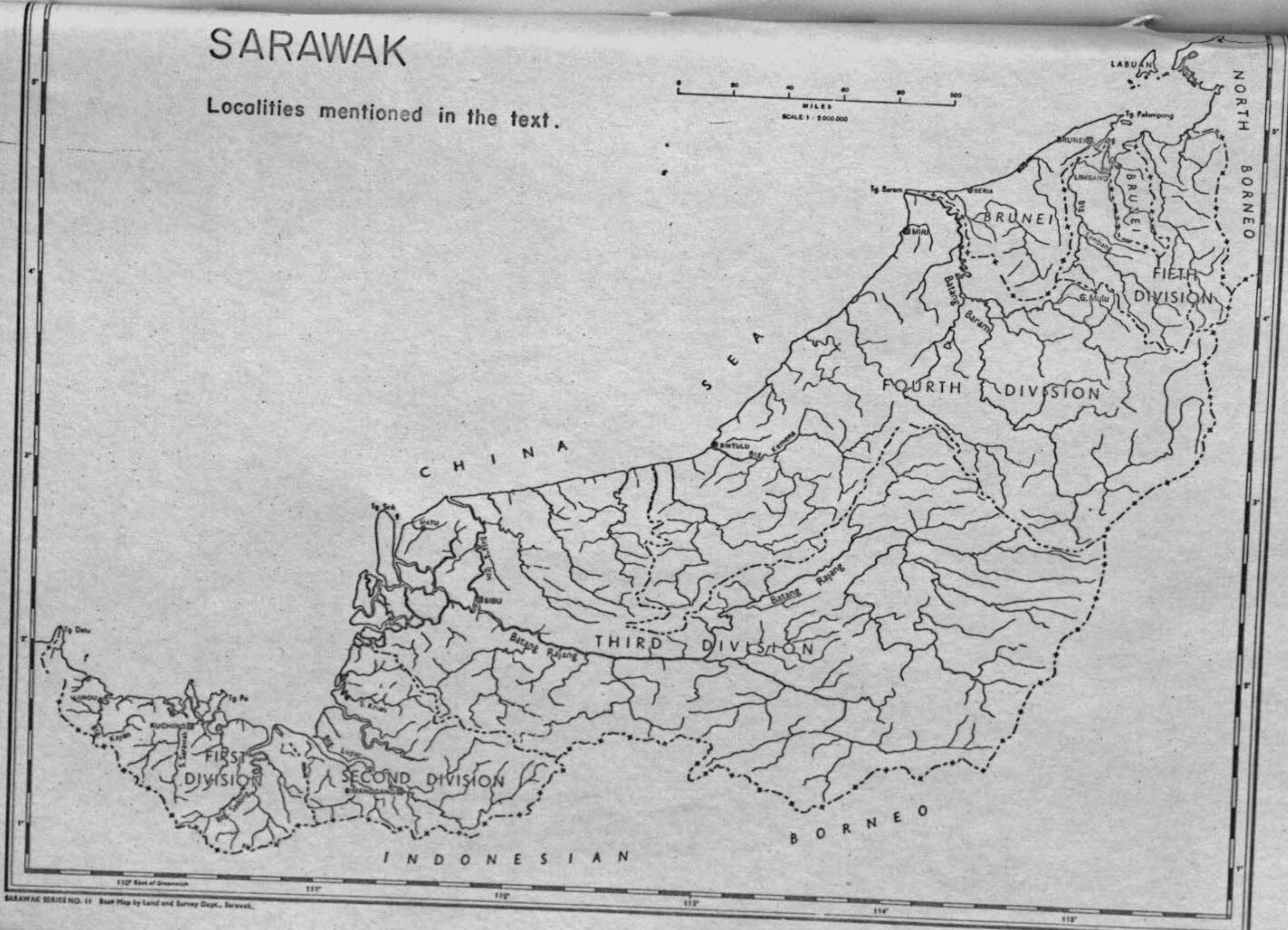
SARAWAK
Localities mentioned in the text.
MILES
SCALE 1 : 2,000,000
0
20
40
60
80
100
NORTH BORNEO
LABUAN
Tg Palompong
BRUNEI
LIMBANG
BRUNEI
SERIA
Tg Baram
MIRI
Batang Baram
FIFTH DIVISION
G. Mulu
FOURTH DIVISION
SEA
CHINA
BINTULU
Tg Sirik
SIBU
Batang Rajang
THIRD DIVISION
Batang Rajang
Tg Datu
LUNDU
Tg Po
KUCHING
FIRST DIVISION
SECOND DIVISION
SIMANGGANG
BORNEO
INDONESIAN
110° East of Greenwich
111°
112°
113°
114°
115°
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