SOIL AND LAND POTENTIAL OF THE SARAWAK - KIRI, SAMARAHAN AND SADONG RIVER BASINS

1 st Division

by
J. P. Andriesse
(Soil Surveyor)

Soil Division
Research Branch

January, 1965.

Dept. of Agriculture
Sarawak

SOIL AND LAND POTENTIAL OF THE SARAWAK-KIRI, SAMARAHAN AND SADONG RIVER BASINS

(1st Division)

(Soil Survey Report Number 59)

by

J.P. Andriesse.
Soil Surveyor.

CONTENTS

SUMMARY

This report is concerned with a survey on soil and land potential in an area of 1,400 sq. miles situated in the middle of the 1st. Division. The report is introduced by a description of the general background and the methods employed in the survey.

The first part gives an account of the general geographical situation describes the climatic, topographic, and geological environment of the soils described in the second part of the report.

The area is densely populated by Sarawak standards and some of the most intensively developed land occurring in Sarawak can be found in this region (mixed zone land along the main roads and Nonok Peninsula). Topographically it forms a cross section of almost all landforms present in Sarawak: coastal plains, riverine basins, peat swamps, dissected peneplains, old terraces and steep mountainous terrain rising to 3,000 feet altitude. Geologically it is also very varied and most parent materials of soils occurring in Sarawak are also found in this region. Its climate is typically that of a Humid Tropical Lowland.

Land tenure and land-use have been briefly described, together with some notes on the population.

The second part of the report outlines the classification system adopted for this survey whereafter the main soil groups are described according to their genesis, main characteristics, classification at a lower level, and their utilization.

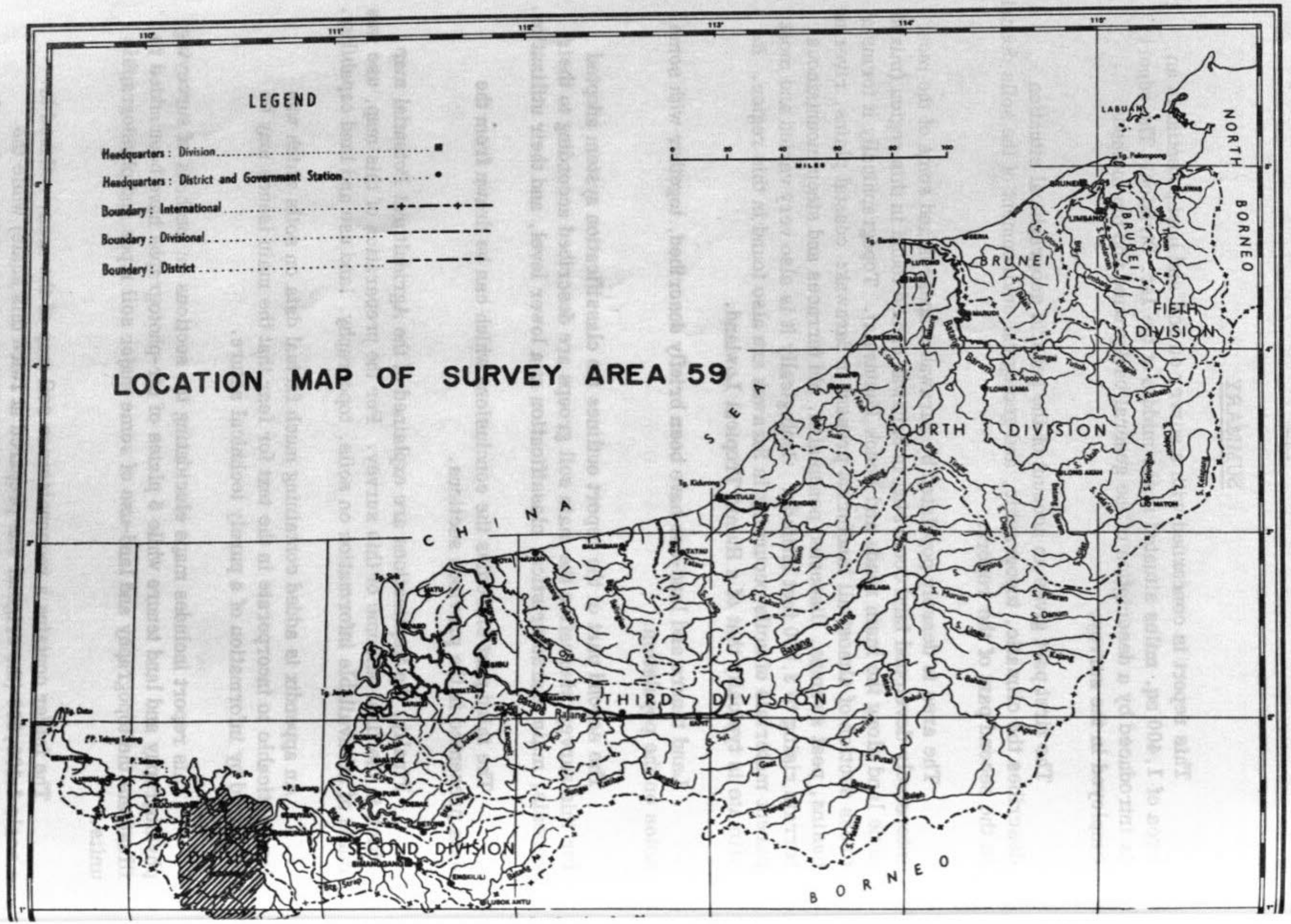
The third part embodies the conclusions which can be drawn from the data presented in the previous sections.

Finally, the implications are explained of the Agricultural Potential map which is the final outcome of this survey. For the preparation of this map, use was made of all available information on soils, topography, land use and land capability.

An appendix is added containing much factual data on soils which was impracticable to incorporate in the text for fear that the main issues may be obscured by information of a purely technical nature.

This report includes maps elucidating the sections on methods of surveying, physiography and land tenure while 5 plates of air-photographs have been added to illustrate the topography and land-use of some major soil types and physiographic units.

The folder contains a reconnaissance soil map of the area, reduced to a scale 1:100,000 (the original was prepared at twice this scale) while the Agricultural Potential Map is of a scale 1:125:000, the original being also of a scale 1:50,000.


LOCATION MAP OF SURVEY AREA 59
LEGEND
Headquarters : Division
Headquarters : District and Government Station
Boundary : International
Boundary : Divisional
Boundary : District
MILES
NORTH BORNEO
BRUNEI
FIFTH DIVISION
FOURTH DIVISION
THIRD DIVISION
SECOND DIVISION
CHINA SEA
BORNEO
LABUAN

INTRODUCTION

1. Object of the report.

This report aims at consolidating knowledge on soil and land resources found in the Sarawak Kiri, Samarahan and Sadong river basins, an area of approximately 1,400 square miles, forming approximately one third of the total land surface of the 1st Division.

The information contained in this report has been collected during several reconnaissance soil surveys, the first of which having been carried out as far back as 1961, while the last part of this survey was carried out in 1964. Several areas had already been surveyed at a more detailed level before the reconnaissance survey of the whole area was completed. This is one of the reasons why the completion of this reconnaissance survey had to be postponed until this year. Although a large portion of the area has never been reported upon, (approx. 450 sq. miles) some parts have been the subject of separate soil survey reports because they were surveyed for specific purposes. The following reports have already been issued on parts of the area and some information contained in these reports has been incorporated in the present one.

Report No.2 - Soil Survey of Area No.2, Serian, Field Report,1st. Division by C.D. Sutton, March, 1960.

Report No.4 - Notes on a detailed Soil Survey of Tarat Agricultural Station, 1st Division by J.P. Andriesse and Benjamin Chen, October, 1962.

Report No.5 - Field Report of Soil Survey Area No.5, Paya Megok, 1st Division by C.D. Sutton, September, 1959.

Report No.6 - Field Report of a Reconnaissance Soil Survey in the Semongok Forest Reserve, 1st Division by T.W.G. Dames, March, 1959.

Report No.7 - Field Report of Soil Survey Area No.7 Balai Ringin (Serian District) 1st Division by J.R.D. Wall and C.D. Sutton, April, 1960.

Report No.13 - Field Report of Soil Survey Area 13: Samarahan Estate by J.R.D. Wall, June, 1960.

Report No.17 - Field Report of Soil Survey Area No.17, Gedong, Middle Sadong, 1st Division by C.D. Sutton, May, 1960.

Part of Report No.27 - Report on a Reconnaissance Soil Survey of the Tebakang - Mongkos Road Area, 1st Division by J.P. Andriesse, September, 1962.

Part of Report No.33 - Report on a Reconnaissance Soil Survey, 1st Part, of the Serian-Simanggang Road, 1st-2nd Divisions by J.P. Andriesse, February, 1961.

Report No.44 - which is now superceded by this report, the former being a progress report of this survey. (Progress Report of a Reconnaissance Soil Survey 1st Division, for 1961 (Proposals for Development of the Serian Area, 1st Division)) by J.P. Andriesse, March, 1962).

Report No.44/1 - Report on a Semi-Detailed Soil Survey of the Serian Dev. area, 1st Division by J.P. Andriesse, April, 1964.

Report No.46 - Paya Paloh Detailed Soil Survey, 1st Division by J.P. Andriesse and Rosli bin Sahari, October, 1962.

Report No.49 and 49/1 - Report on a Detailed Soil Survey of the Semongok Agricultural School Site, 1st Division by J.P. Andriesse and Benjamin Chen, August, 1962.

Report on a Detailed Soil Survey of Semongok Agricultural Station and proposed extensions, 1st Division by I.M. Scott, October, 1964.

Report No.60 - Report on a Semi-Detailed Survey of the Nonok Development Area, 1st Division by J.P. Andriesse, September, 1964.

The consolidation of these reports into the present one and the joining of all these separate soil survey areas into one large survey has the advantage that an overall picture can be obtained of the soil and land resources in the whole region which will facilitate regional planning. A second consideration has been that in many reports the same soils had been given different names and in this report an attempt has been made to eliminate the difficulty of comparing soils by reclassifyi soils into one system.

The soil map is necessarily of a small scale (1:100,000) and some degree of generalization had to be employed in order to classify the soils into a system which is not too complicated and which would not obscure the main soil pattern in the area.

The reader is therefore advised to consult the more detailed reports existing for certain areas if more precise information is required. This is particularly the case with areas reported upon in Reports Nos. 44/1 and 60.

The report does not aim to give a full account of all soils occurring in the area, neither, because of lack of much necessary data, could all soil-forming processes be adequately explained.

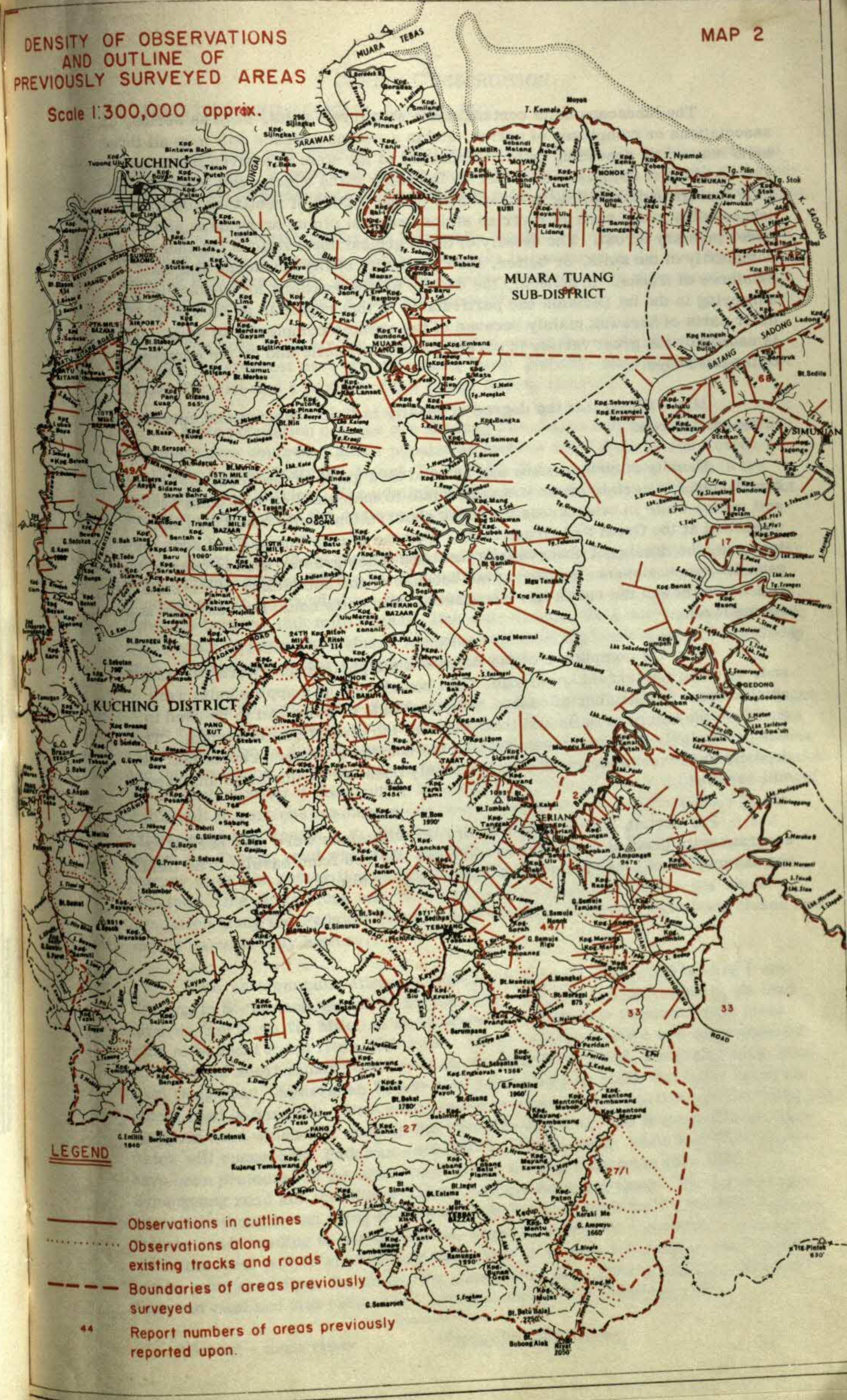
Many problems therefore remain unanswered, especially those on the usefulness of certain soils for agriculture. The lack of agronomic experience in this country is too great to enable the writer to give definite recommendations. However, the aim has been to show the general pattern of soil distribution in this region which does not change and to give recommendations for development in the light of the present knowledge and adapted to the present requirements.

2. <u>Methods of surveying</u>.

For most of the region reconnaissance methods were employed and in certain areas the reconnaissance survey was followed by more detailed investigati

The reconnaissance method employed in Sarawak is briefly as follows:

Prior to fieldwork an air-photo analytical study is carried out by which means landscape units are recognised and delineated on the photographs. The fieldwork consists largely of checking the soil types which occur in these landscap units. For reconnaissance surveys these form the basis of the soil mapping units. The terrain conditions in Sarawak do not permit the surveying of boundaries of every soil type without going into detailed surveying which is both time consuming and costly.



DENSITY OF OBSERVATIONS
AND OUTLINE OF
PREVIOUSLY SURVEYED AREAS
Scale 1:300,000 approx.
MAP 2
KUCHING
MUARA TUANG
SUB-DISTRICT
KUCHING DISTRICT
SERIAN
SIMUNJAN
GEDONG
TEBAKANG
BATANG SADONG
K. SADONG
LEGEND
Observations in cutlines
Observations along existing tracks and roads
Boundaries of areas previously surveyed
44
Report numbers of areas previously reported upon.

The landscape units contain either single soil units, such as series, or associations or complexes of series, and in a reconnaissance soil map all three units may occur depending on the complexity of the soils in a given landscape unit. The checking of soils is done either by following paths which exist frequently in hilly terrain under shifting cultivation or by the cutting of rentisses (cutlines) in inaccessibly areas such as riverine strips, coastal plains or swamps and areas under primary forest. The density of these ground observations depends on the complexity of the soils, or better, the complexity of the landscape and the existence of tracks. In general, the density of observations for reconnaissance surveying in the lst Division and particularly in this region is greater than in other parts of Sarawak mainly because of the greater complexity of soils. This is caused by the great variety in parent material of soils and by the complexity of the landscape.

Map 2 illustrates the degree of density in field observations carried out in the whole area.

Density of observations can be used as a guide to the accuracy of the soil boundaries. In certain areas it was possible to map smaller soil units such as soil series while in other areas with less observations soils could only be classified at the Great Soil Group level. For the Muara Tuang Road area for instance, the density of observations has been much greater than is usually the case for reconnaissance surveying but because of the complexity of the soils this was essential and the result has been that certain soils could be classified at a series level.

After the completion of the fieldwork air photographs were re-examined and, by using the terrain knowledge, final boundaries of mapping units were established. In a number of cases, analytical data of soils had to be used to establish the nature of soils and their place in the classification system. This was particularly the case in establishing the boundary between recent marine deposits and riverine deposits which was only possible by chemical analyses of soil samples.

For certain localities laboratory investigations were also needed to separate soils derived from arkose and those derived from basalt. The field characteristics of these soils are sometimes very similar.

GENERAL DESCRIPTION.

1. LOCATION AND GENERAL GEOGRAPHY

This region is situated in West Sarawak and forms the middle section of the 1st Division. It embraces the whole eastern portion of the Sarawak Kiri river basin, the whole Samarahan river basin and most of the Kayan-Sadong river basin.

The northern boundary is formed by the South China sea and the southern boundary by the Indonesian border. The area is bordered in the west by the Sarawak Kiri river while the eastern boundary is formed by, from north to south, the Sadong river, Batang* Krang and Sungei** Kerait.

The area is by far the most populated one in the whole of Sarawak and contains the greatest part of the Kuching Rural District, almost the whole Upper Sadong District and a portion of the Lower Sadong District.

Main population centres are Kuching Town Area and Serian which are administrative centres. Minor population centres are Tebakang and Tebedu in the Upper Sadong District, Muara Tuang, 17th Mile bazaar, and Nonok in the Kuching Rural District. The administrative centre of the Lower Sadong District, Simunjan, lies just at the eastern border of the area.

Apart from these main towns and villages, which also form the marketing and shopping centres for the rural population a number of bazaars of secondary importance can be found along the Kuching-Serian road, namely 7th mile bazaar, 10th mile bazaar, 15th mile bazaar, 19th mile bazaar, 24th mile bazaar and 32nd mile bazaar. Terbat and Muara Mongkos are shopping centres for the Ulu Kedup area. Numberous minor shopping centres exist.

It can be noticed that some of these bazaars are becoming outdated because of the rapid improvement in communications. With the building of new roads the rural population is able to reach larger shopping centres within a reasonable time and the likelihood is strong that in future an increasing number of people will make use of such centres if the country is opened up. Already some bazaars have found it difficult to continue business since their existence has been threatened by the existence of new roads: e.g. Tebakang bazaar is only a shadow of what it was before the Tebedu road was built, because the rural population continues its journey to Serian rather than doing their shopping in Tebakang. Pankut bazaar situated on the Serin river was once a thriving shopping centre for the whole population along the Padawan road beyond Simpok. All shops have been closed now and its name is only history.

Internal communications are maintained by the main road leading from Kuching to Serian and beyond to Simanggang. From this road minor roads lead towards Bau from 7th Mile, to the Indonesian border (the Padawan road) from 22nd mile and Tebedu from 38th mile. Local communications are maintained by a number of short minor roads such as the Batu Kawa road, Pangkalan Quop road, Batu Gong road, Samarahan Estate road and Penrissen road, the latter being the oldest road in Sarawak. New roads in the process of construction are the Tebakang-Mongkos road which will open up the Upper Kedup area, the Semeru-Kohom road which will connect the Padawan road and the Tebedu road, while two other roads have been projected in the area, namely the Gedong road from 45th mile Simanggang road and the Muara Tuang road via Kampong Quop. The local people, especially those living along the Kuching-Serian road have built a number of small private roads leading to the main road, some of which are motorable. In the rural areas the local people are building new roads at an ever increasing rate. Of these can be mentioned Kpg. Karuh to Penrissen road, Kpg. Subang and Kpg. Krian to Padawan road and 21st mile, Kpg. Lanchan and Ri-i to Tebakang road.

---

*Batang - main river **Sungei - small river.

The road communications are mainly of use in the interior of the area because along the coast and between the main river valleys swamps do not allow the building of roads and communications are mainly maintained by boat. One could say that from approximately 3 miles north of the Kuching - Serian road up to the coast road building is virtually impossible and lack of communications in this area appear to be a major stumbling block for development. Although in certain instances roads could be built over some hummocky terrain leading towards the coast this does not mean that communications in the whole area will be improved because of the impossibility of constructing side roads through deep peats, and people will have to reach such roads by boat which involves long detours. From the soil map it can easily be seen why road communications in this area will be extremely difficult to provide.

Farming is the main activity of the rural population. Most small-holdings with a cash economy are situated along the main roads and the settling of Chinese in the mixed zone land created along these roads has caused a 'ribbon' development giving the impression of a thriving agriculture while in fact behind the screen of pepper garden and vegetable gardens the native population is still largely engaged in a subsistence type of farming growing hill and swamp paddy on a rotation basis (see plate 5) Apart from this ribbon development along the main roads, in the coastal areas, a mixed Malay and Chinese population grow cash crops such as coconut, soya-bean, groundnuts, maize and pineapples.

The bulk of the agricultural produce coming from the area is formed by rubber coming largely from scattered small-holdings. This is followed by pepper produced mainly in the Kuop area, 17th-19th mile area and 32nd mile to Serian area along the road. Copra is produced mainly in the Nonok and Muara Tebas coastal areas. Vegetable gardening forms a substantial income for farmers in the vicinity of Kuching.

The only estate of some magnitude is the Samarahan Estate where rubber is planted. Some large rubber gardens mainly owned by Chinese are located at 16th mile Penrissen road and at 4th and 15th mile Kuching-Serian road. Some older rubber gardens are located in the Kuop area but are largely out of production.

Agricultural stations and research stations are located at Tarat (34th mile Kuching road) and Semongok (13th mile Penrissen road). A padi Research station has recently been opened at Paya Paloh near Muara Tuang.

The only port of significance is Kuching Port which has a quay of 800 feet long and a depth alongside of 17 feet at low water. (Ref. Sarawak Annual Report 1961).

The area has one major airport, that of Kuching Town which serves both external and internal communication.

---

2. CLIMATE

The main meteorological station in the area is that of Kuching Airport, (altitude 120 feet above sea level) stations of secondary importance are at Serian (± 100 feet) and a Departmental Station at Tarat (± 150 feet). Rainfall figures are also available over a number of years from Sg. Serin (25th Mile Kuching-Serian road) and from Tebakang along the Kayan river (both approximately at 100 feet).

Rainfall statistics (tables 1 and 2) from these stations give a good coverage over the middle portion of the area but may not be fully representative for the coastal areas and the interior areas near the Indonesian border. However for our purpose, which is to indicate the climatic environment of soils, they are probably representative enough to indicate the general trend for the whole area.

Temperature statistics (table 3) are given for Kuching and Tarat and the general trend in most of the area is probably the same as at these stations.

The climate in the whole region is typical for a Humid Tropical Lowland. Lowest temperatures do not fall below 67^{o}F. in Kuching while for Serian this is even higher (70^{o}). Highest temperatures recorded in these stations during the year for which the readings were taken are 96^{o}F. for Kuching and 92^{o}F. for Serian. In the coastal areas the cooling effect of sea winds is possibly greater than in the interior and temperature variations are greatest there. It has been noticed that at altitudes of 1,000 feet and higher nights are much cooler than in the lowlands but probably this has little effect on soil genesis as daily temperatures are as high as those near the coast.

Generally speaking there is little variation in temperature in the region over the whole year and tropical temperatures above 80^{o}F. prevail.

The rainfall varies within a small range from place to place due to local topography and distance from the coast. Kuching receives the highest rainfall, on average approximately 160 inches per year while the station of Tebakang situated furthest in the interior receives the lowest amount, 130 inches (annual average). The rainfall recordings for Sg. Serin are over a short period and the average figure of nearly 168 inches is probably on the high side.

According to the rainfall classification by Mohr (ref. 1) the whole area can be placed in Class 1 which is defined as a continuously wet climate without any months in the year in which the rainfall is lower than 4 inches. It means also that the periods of dry weather are too short and not intensive enough to dry out soils appreciably in which case the process of leaching would come to a halt or be reversed into a process of evaporation of capillary groundwater by which salts would move upwards.

The soil forming processes in the whole area are therefore characterised by a continuous leaching process through which soluble parts of rocks and soil are removed from the solum.

Local storms occur frequently and the distribution of rain over the months may vary on account of steep and high mountain ranges which have an effect on the direction of such storms. This may be of importance for agriculture as flowering and fruit setting of crops react to short periods of dry sunny weather or short periods of wet weather. The present statistics are unable to throw any light on such aspects of rainfall.

TABLE 1a.

MONTHLY RAINFALL AT KUCHING - in inches.

Latitude: 01° 33'N
Longitude: 110° 20'E

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1951	23.24	20.36	13.58	9.72	15.88	5.85	6.73	9.56	10.03	11.33	10.66	15.52	152.46
1952	24.56	22.44	10.05	13.40	7.63	7.38	13.82	7.82	10.16	10.63	12.95	18.40	159.24
1953	32.64	21.75	13.11	16.61	11.95	5.74	14.67	4.58	7.04	11.35	13.76	12.93	166.13
1954	15.62	9.99	12.11	16.31	14.65	7.74	9.35	7.97	16.09	12.30	16.01	14.76	152.90
1955	42.41	30.09	10.74	14.21	6.21	5.50	8.48	9.12	14.39	9.09	10.56	23.16	184.13
1956	15.29	8.48	9.02	10.05	11.21	6.68	10.05	7.78	12.67	12.38	17.97	17.40	138.98
1957	18.66	17.68	10.28	11.01	9.72	6.17	9.03	7.86	13.89	17.65	13.82	16.26	151.99
7 Years' Mean	24.63	18.68	11.27	13.04	11.06	6.44	10.30	7.81	12.04	12.10	13.68	16.92	157.98

Reference: Civil Aviation Department, Sarawak.

TABLE 1b.

MONTHLY RAINFALL AT TARAT - in inches

Latitude: 1° 12'N
Longitude: 110° 32'E

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1950	10.73	18.66	19.87	16.54	7.43	8.83	6.50	5.72	11.52	11.80	22.30	16.52	156.42
1951	20.79	8.73	8.43	16.36	12.26	7.03	6.22	4.38	19.71	13.29	12.75	9.79	139.74
1952	19.78	14.09	9.01	18.03	13.53	6.62	7.36	7.53	8.30	8.37	16.07	10.89	139.58
1953	27.39	12.07	10.25	9.66	9.20	5.11	9.15	3.34	7.96	5.62	11.91	8.20	119.86
1954	16.57	17.56	9.91	9.66	5.32	6.10	6.38	8.63	8.46	17.38	14.06	11.65	131.68
1955	27.44	16.28	9.23	10.86	9.11	4.24	3.56	9.34	13.45	3.71	18.99	11.71	137.92
1956	21.58	14.45	14.20	8.85	8.22	6.88	8.82	9.48	10.36	14.84	15.82	14.36	147.86
1957	21.06	16.57	7.59	6.54	10.91	2.98	11.89	8.11	13.21	15.65	8.86	16.50	139.87
8 Years' Mean	20.67	14.80	11.06	12.08	9.50	5.97	7.49	7.07	11.62	11.33	15.09	12.45	139.13

Reference: Civil Aviation Department, Sarawak.

TABLE 2a.
MONTHLY RAINFALL AT TEBAKANG
in inches.

Latitude: 1° 18'N
Longitude: 110° 30'E

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1950	4.66	11.89	20.71	16.62	9.57	12.35	4.74	6.17	11.69	13.31	14.55	9.51	135.77
1951	13.93	11.41	10.95	13.23	8.73	8.01	5.82	6.08	16.11	12.95	11.99	9.70	128.91
1952	14.66	12.42	8.29	14.05	11.95	6.62	13.75	5.19	8.12	11.12	12.99	9.25	128.90
1953	23.79	13.86	12.56	9.02	10.25	6.88	10.71	2.40	8.51	11.70	12.99	13.64	136.31
1954	15.05	9.94	12.64	12.73	4.35	5.22	8.53	9.31	5.64	17.84	15.74	10.97	127.96
1955	20.61	17.44	7.31	11.51	6.07	3.95	8.13	14.66	20.62	19.80	9.05	10.61	139.76
6 Years' Mean	15.45	12.83	12.08	12.86	8.49	7.17	8.61	7.30	11.86	12.79	12.55	10.61	132.60

Reference: Civil Aviation Department, Sarawak.

TABLE 2b.
MONTHLY RAINFALL AT SG. SERIN -
24th Mile Simanggang Road.

Latitude: 1° 16'N
Longitude: 110° 26'E

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1949	18.50	12.46	16.27	19.06	16.49	8.21	5.59	11.74	9.70	16.44	10.66	14.30	159.42
1950	12.60	18.60	14.51	19.13	9.31	18.83	9.55	20.55	9.64	12.02	18.16	19.09	182.05
1951	19.23	13.05	14.96	13.56	13.83	5.83	10.85	7.42	13.62	15.36	11.98	19.99	159.68
1952	32.63	22.63	10.16	15.53	12.59	5.51	12.75	5.50	5.16	13.24	17.75	16.33	169.78
4 Years' Mean	20.74	16.69	13.98	16.82	13.06	9.59	9.68	11.30	9.53	14.27	14.64	17.43	167.71

Reference: Civil Aviation Department, Sarawak.

TABLE 3a.

TEMPERATURE STATISTICS FOR KUCHING.

1952

(Degree Fahrenheit)

	Month	Mean maximum	Mean minimum	Highest maximum	Lowest minimum	Lowest maximum	Highest minimum	Mean Relative humidity	Bright sun-shine daily means (hours)
Kuching	January	85.2	73.3	88.6	70.5	79.6	75.0	77	2.68
	February	86.0	73.1	90.5	71.5	79.2	75.3	76	3.00
	March	88.7	73.1	92.2	70.5	80.6	75.0	69	4.80
	April	89.9	73.0	93.8	70.0	83.0	75.0	70	5.13
	May	90.4	72.9	94.0	70.3	84.2	75.5	71	5.12
	June	93.0	71.9	96.4	67.0	87.8	75.0	61	6.14
	July	89.7	71.3	93.8	68.8	83.0	73.2	67	4.47
	August	90.2	71.6	94.0	69.8	82.4	75.0	63	5.05
	September	89.9	72.5	94.0	70.5	81.3	75.2	67	4.40
	October	89.0	72.7	93.0	70.7	80.7	74.3	67	4.31
	November	87.3	71.5	91.0	70.2	80.2	73.3	75	4.46
	December	85.3	71.5	89.0	68.5	79.4	73.0	76	4.50

Reference: Civil Aviation Department, Sarawak.

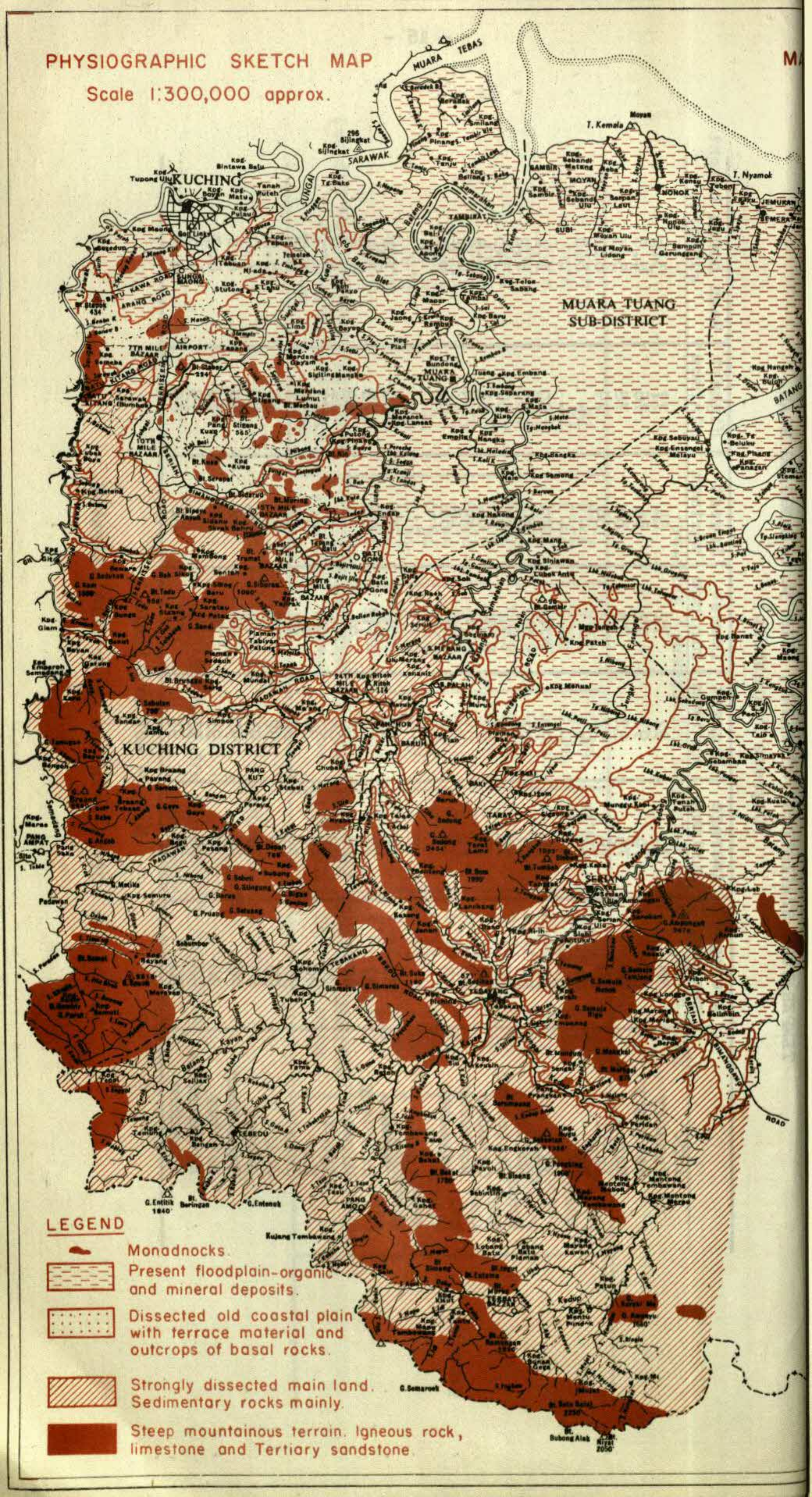
TEMPERATURE STATISTICS FOR TARAT, MILE 34 SIMANGGANG ROAD.

(Degrees Fahrenheit)

	Average maximum	Average minimum	Highest maximum	Lowest minimum	Lowest maximum	Highest minimum	Mean hours bright sunshine
1952							
January	88	74	92	72	84	77	3.6
February	89	74	91	72	86	76	4.8
March	89	75	92	73	84	78	5.3
April	80	76	92	72	84	79	6.2
May	N.A.	-	-	-	-	-	8.0
June	N.A.	-	-	-	-	-	-
July	89	74	92	70	82	80	N.A.
August	89	76	91	74	84	80	6.2
September	90	78	81	74	87	80	5.3
October	89	78	92	76	84	81	4.4
November	89	78	91	75	88	79	4.7
December	88	78	90	76	86	81	4.6
1953							
January	87	78	91	76	82	80	3.2
February	87	77	90	74	80	78	3.3
March	89	78	90	74	82	82	3.9
April	90	79	92	76	88	81	5.9
May	90	69	92	77	86	89	6.3
June	90	79	92	77	88	81	6.0
July	90	79	92	77	88	80	5.9
August	89	78	91	74	84	80	7.0
September	90	78	92	76	88	80	4.8
October	90	78	91	76	88	80	4.2
November	90	78	91	76	88	79	4.5
December	90	78	91	77	88	80	4.8

N.A. - not available.

Reference: Civil Aviation Department, Sarawak.


PHYSIOGRAPHIC SKETCH MAP
Scale 1:300,000 approx.
KUCHING
MUARA TEBAS
SARAWAK
MUARA TUANG SUB-DISTRICT
KUCHING DISTRICT
SERIAN
LEGEND
Monadnocks.
Present floodplain-organic and mineral deposits.
Dissected old coastal plain with terrace material and outcrops of basal rocks.
Strongly dissected main land. Sedimentary rocks mainly.
Steep mountainous terrain. Igneous rock, limestone and Tertiary sandstone.

3. PHYSIOGRAPHY

As shown on map 3 (Physiographic sketch map) four major physiographic units can be distinguished.

a. The present floodplain.

This unit comprises the coastal plain, riverine basins and those parts of riverine valleys where deposits are still accumulating. The coastal plain can be sub-divided into three parts: the Sadong river estuary, the Nonok coastal plain and the Samarahan-Sarawak river delta.

In the funnel-shaped mouth of the Sadong river strong currents exist during changes of tides and a strong tidal bore occurs. Along the borders of the Sadong river clay is deposited in a brackish water environment. Sands are absent in this area possibly because of the long distance from any upstream sources and only clay and silt is able to reach the mouth of this river.

In the Nonok coastal plain, situated between the Sadong and Samarahan rivers, an approximately 4 miles wide belt of clay has been deposited. Remnants of Mangrove and Nipah forest in these deposits indicate that this plain has slowly emerged. In the west of the plain the coast is still growing out into the sea and a large coastal mudflat emerges there during low tide. In the eastern section of this plain a cliff coast indicates that erosion is taking place. Brackish water deposits can be found in the western part and along the great number of creeks intersecting this plain. Only near Sambir the remnants of an old coastal bar, consisting of fine sand can be found. This low sand ridge has possibly been partly eroded by the Samarahan river as this fine sand can still be traced along the mouth of this river while sandy deposits are lacking further upstreams.

The Samarahan and Sarawak river delta consists of a network of many channels in between of which clays are deposited in a brackish environment. If these deposits are sufficiently high above tide levels the local population endeavours to utilize them. Only near Beliong a very small fine sand ridge was found, possibly of the same age as the one at Sambir.

The riverine valleys and basins comprise almost one third of the whole region. In the basins clay levees were built up by the Sadong, Samarahan and Sarawak rivers of which the former two are the most extensive ones. Between the levees of the Samarahan and Sadong rivers extensive swamps with organic deposits can be found. These organic deposits are true raised bogs, the centres of the peat swamp being much higher than the river banks (in Nonok area this can be more than 15 feet). See Plate 4.

The peat swamps are most extensive in the Sadong area and become smaller towards the Sarawak river delta. It is suggested that these peat swamps were able to develop there owing to the existence of a bay with shallow waters in which the Sadong and Samarahan rivers firstly built up levees along their courses thereby creating low lying basins between them. After these had been cut off from the sea by the emerging coastal plain, peats could form in these basins. While the clays along the coast are situated at a higher level than the clays found underneath the centres of the peatswamps it is unlikely that these peat swamps have grown out towards the sea, although originally conditions in these basins may have been brackish. Tilting of the coastal plain towards the basin swamps may have played a role as well.

The riverine valleys penetrate quite far into the main land and even peat deposits can be found quite far upstreams. This is in some instances explainable because of blocking of small river valleys from the main stream by the building up of levees. These deep valleys filled up by peat (sometimes deeper than 20 feet) suggest also that at one time strong dissection took place. Then, through a rise in sea-level, erosion and depositing came to a halt followed by the accumulation of peat in these valleys owing to a rising groundwatertable.

Organic deposits follow in places (especially east of Serian) almost the 20 feet contour while valley peat in the interior can be found as high as 50 feet above sea level.

The present floodplain also penetrates into the main land in areas underlai by flat-bedded limestone. It is suggested that such areas are slowly subsiding owi to dissolving of limestone by acid groundwater. Flooding in such areas is notoriou (19th mile, 21st mile, 24th mile, 27th mile). The boundary between the present floodplain and the second major physiographic unit (the dissected old coastal plain) lies roughly between 20 and 50 feet.

b. <u>The dissected old coastal plain.</u>

The dissected old coastal plain is formed by terrace materials which eithe form terrace remnants or have been eroded and redeposited again in valleys which have formed after dissection took place. Where much of the original material has been eroded residual soils have formed on the exposed rocks which frequently consist of shale, sandstones, phyllite and chert.

It is suggested that this coastal plain was formed in times when the sea level was much higher (possibly an interglacial period) and that much coarse material was laid down as littoral deposits in a shallow sea. In many places these coarse sandy deposits are underlain by very dense clays, (Analyses suggest that they are possibly sea clays; more information is however required).

The non-existence of these coarse old alluvials at elevations higher than 150 feet suggests that the plain originally existed between the present 150 and 20 feet level. Tilting may have obscured this picture. A similar plain was found in the Lundu-Sematan area where the old materials are relatively untouched by erosion. They are of the same nature as found in this area although more homogeneous.

The flat to gently undulating topography can still be noticed in relatively preserved surfaces such as the Pangkalan Kuop-Muara Tuang and Batu Gong-S. Empila areas.

Remnants of the terraces can also be traced in the centre of peat swamps between S. Ensengei and Batang Sadong.

In the old coastal plain numerous monadnocks consisting mainly of igneous rock intrusions can be found. The presence of laterite (Endap area) at a level of approximately 120 feet suggests the presence of groundwater at that level at one stage. Laterite of this kind has never been found by the author on the igneous intrusions in the mainland unless bordering swamps. Possibly these monadnocks formed little islands in a shallow sea, the level of which may have bee at approximately the present 120 feet level.

The old coastal plain borders the old mainland at approximately the 100 to 150 foot level. The boundary is in places quite abrupt (e.g. 19th to 22nd mile) while in other places the boundary is obscure. The nature of the soil is in such places the only reliable indication. Sandy material overlies there residual soil up to a certain level in the valleys (e.g. Samarahan Estate area, areas east of Serian).

c. The strongly dissected old mainland.

Most of this strongly dissected land consists of sedimentary rocks, shales and sandstones. The relative height of the hills is usually between 50 feet near the floodplain and 150 feet farther inland. Hardness of the underlying rock plays a role as well. This is the case for instance with arkose which forms the main rock type in the Padawan road area between Simpok and Perayan, (see plate 3) and along the Kuching-Serian road from 27th mile to 36th mile. In such areas slopes are steeper and valley bottoms frequently deeper than 150 feet.

Above an elevation of 350 feet sedimentary rocks are rare with the exception of Tertiary sandstones. The dissected mainland lies therefore generally between an elevation of 150 feet and 350 feet up to 500 feet maximum.

Little alluvial material has accumulated in this dissected terrain unless main river courses have formed valleys of some magnitude (see Plates 2 and 3). Most of the eroded material is deposited in the present floodplain and local alluvium is but little. Many small intrusions of igneous rocks form prominent higher hills (plate 3) in the otherwise monotonous sequence of valleys and hills, which become higher and steeper the deeper one moves into the interior.

d. The Mountainous areas.

Mountainous terrain is formed by large massifs of igneous rock types (plate 1) /by Cretaceous limestone which forms very steep mountains with almost /and vertical slopes (plate 2), and by Tertiary sediments. Altitudes in this terrain range from 500 feet to over 2,000 feet. Waste through erosion on these steep mountain slopes is considerable, soils are invariably shallow, and bouldery and rocky land is common. Much of the coarse material is deposited in alluvial boulder fans (plate 1) while the finer material is carried away to the present floodplain unless flatlying limestone is found at the foot of these mountains through which alluvial basins could form in which much of the fine eroded material of these mountains was deposited. (e.g. near Bukit Sedong, near Kpg. Sikog and 17th mile) See also plate 2.

DRAINAGE

The whole region is drained by three main rivers, the Sarawak Kiri, the Samarahan and the Sadong. It is surprising to note the width of these rivers especially in their lower stretches in relation to the small catchment areas they have. The total length of each course is at the most 100 miles. Tidal movements combined with the insignificant fall of the rivers in the floodplain have probably played an important role in causing the preservation of large channels in the once submerged plain.

While in the floodplain itself the number of subsidiary streams is very small (probably some of them are old creeks in direct contact with the sea when the present plain emerged), in the old dissected mainland subsidiary rivers and minor streams are numerous. Many of the minor streams only carry water immediately after rain; rivers of secondary importance have sufficient water during the whole year.

The existence of a large almost flat floodplain fronting a deeply dissected old main land in which altitudes may rise from 50 feet to more than 2,000 feet over short distances, has caused a considerable flood problem.

Surplus rain water reaches the joining points of subsidiary streams with main rivers within very short periods after rain and if rain occurs over a wide area the water in the main river rapidly reaches flood level if this rain persists. The low fall in the flood plain coupled with the tidal effect, which can be felt to more than halfway upstream and almost to the point where the rivers reach the old mainland, causes backflooding in interior plains and along the banks of the main river because the river cannot dispose quickly enough of the great amount of water it is receiving from all subsidiary streams.

It is very unlikely that any means can be found to remedy this type of flooding. Rainwater cannot be stored in upper valleys to any significant extent because the valleys are many and in general too small. The cutting of meander bends in the floodplain may have a local effect but would not remedy the back-flooding in interior valleys. It may even get worse since the tidal effect may be able to penetrate farther upstream. (The blowing up of rocks in the Tuang river near Batu Gong serves as an example).

During the less wet season such improvements in the river courses may have an effect because the rivers can then cope with the amount of drainage water.

The only possible way to prevent land from being flooded would therefore be the building of bunds around the land so that flood water can be kept out. While this would prevent drainage of rainwater of the land itself unless it is pumped out, this land could best be used for wet padi.

4. PARENT MATERIALS OF SOILS

Much of the factual data in this section is derived from the Memoirs prepared by the Geological Survey and covering this region (ref. 2 and 3).

Parent materials, soils and topography show an intimate relationship and for this reason a discussion on parent materials is based on the physiographic subdivision used in the previous chapter.

a. Parent materials in the present floodplain

Most parent materials in this area are of quaternary age and consist of recent alluvium. They are mainly clays originally deposited in a brackish environment. Only the present day levees bordering the mainriver courses upstream of the brackish water penetration limit have been built up in a freshwater environment. Remnants of old mangrove and nipah forest exist even in the Paya Megok area (27th mile area) indicating that much of the base layers were deposited in an estuarine or deltaic environment.

Fine sands are only found near the coast at Sambir, the sources of which are unknown. The lack of sand deposits in the floodplain is mainly due to the, in general, flat topography and the lack of sandy parent materials in the catchment area. The flat topography causes the small amount of coarse sediments to settle upstream (frequently in the upper valleys of subsidiary streams). In places where sandy deposits were found underneath peat the source could be traced back to the old terrace materials occurring nearby. Recent alluvial materials in the upper stream valleys not included in the floodplain are mineralogically varied, their nature depending largely on the source rock.

A number of small outcrops of igneous intrusions occur in the floodplain in the Sungei Kuop area. They are mainly of basic igneous stock. Such outcrops also occur near Kpg. Endap while only one outcrop of Greenstone was found in the coastal plain of Nonok.

Organic deposits have developed in many riverine basins and overly the basal alluvial clays.

b. Parent materials in the dissected old coastal plain.

The basal geological formations in this area are varied in nature. In the Kuop area the geological maps indicate that they comprise phyllites, quartzites, massive cherts and feldspathic grit of Permian and/or Carboniferous age. More to the east (between 7th mile and 23rd mile) they are formed by sedimentary rocks of Cretaceous age comprising shales, sandstones and some flat-bedded limestone, while in the eastern section (23rd mile and beyond) the underlying formations are from Triassic age comprising shales, sandstone (feldspathic) and arkose. In certain localities, e.g. the Triboh - Lebor area, outcrops of schist are also common.

Apart from these sediments igneous intrusions of varied nature are common in the Kuop area, and in the area between Kuop and 19th mile. Such intrusions are most common in the Permian and Cretaceous sediments.

In places where the old deposits covering the surface of the old coastal plain have been eroded the basal geological formations form the parent materials of soils. Where the old deposits have been preserved they frequently form deep sandy layers either overlying rock or a basal marine clay. The sources of these coarse-textured materials is obscure. It is possible that most of the material was deposited there by the Sarawak Kiri river which must have been a much greater river in the past (old ox-bows in the Batu Kitang area indicate its size). These materials are most widespread in the Pangkalan Kuop area. Sungei Kuop may have formed a major channel in the Sarawak river delta in former times.

There is also the possibility that the Permian and/or Carbonaceous formations, which are all quartzitic in nature, may have contributed to this material.

The occurrence of pebble beds near Serian and sandy deposits in the swamps downstream of Serian cannot be satisfactorily explained. The occurrence of such coarse material at such distances from the sources would indicate a much steeper gradient of a former Sadong river than one would think possible.

Finally a number of prominent outcrops of basic and igneous intrusions forming monadnocks in the old coastal plain form the source material of some local recent alluvium deposited near these intrusions.

c. The parent materials in the strongly dissected peneplained old mainland.

The parent materials in this unit comprise mainly sedimentary rocks of Cretaceous/and Triassic Age. Especially in the Cretaceous sediments many intrusions of acid and intermediate igneous rocks occur. Many of these intrusions are however too small to be shown at the employed scale of mapping and no further attention is given to them.

Apart from these igneous intrusions the Cretaceous sediments contain limestone beds which give rise to conspicuous mountains dealt with under the next physiographic unit. However, small outcrops of such limestones occur also in the present unit, giving rise to very steep low hills with no soil cover.

The Cretaceous sediments, apart from fossiliferous limestone, contain shales, cherts, sandstones, greywacke and conglomerates. The Triassic sediments contain conglomerates, feldspathic sandstones, sandy shales, and carbonaceous shales. Minor occurrences of limestone have been found in the Triassic sediments.

The Cretaceous sediments are in general of a finer texture than the Triassic ones and fine-textured soils are therefore more common in the areas underlain by Cretaceous sediments than in the areas underlain by the Triassic ones. The latter soils are therefore dominant east of the Sadong Kayang-Robin rivers.

In the Triassic sediments metamorphosed sandstones (arkose) and tuffaceous shales occur in sufficiently wide areas to influence soil formation, and typical soils have formed on these two rock types. Apart from the texture, soils derived from sedimentary rocks of both Cretaceous and Triassic sediments do not show much difference in field characteristics although chemically there is a small difference. (The potassium content in the Triassic sediments derived soils appears to be somewhat higher). The carbonaceous shales in the Triassic sediments give rise to the formation of typical white soils which have not been found on the Cretaceous shales.

DIAGRAMMATIC TABLE SHOWING RELATIONSHIP BETWEEN TOPOGRAPHY, PARENT MATERIAL AND SOILS

GREAT SOIL GROUPS	PHYSIOGRAPHIC UNITS			
	PRESENT FLOOD-PLAIN	DISSECTED OLD COASTAL PLAIN	STRONGLY DISSECTED OLD MAINLAND	MOUNTAINOUS TERRAIN
1. LATERITIC SOILS	SMALL OUTCROPS OF GREENSTONE AND BASALTS FORMING MONADNOCKS	SMALL INTRUSIONS OF BASIC- TO INTERMEDIATE IGNEOUS ROCKS FORMING MONADNOCKS.	SMALL INTRUSIONS OF BASIC- AND INTERMEDIATE ROCK-TYPES. MAINLY INCONSPICUOUS HILLS OR DYKES.	LARGE MASSIFS OF BASIC AND INTERMEDIATE ROCK FORMATIONS
2. RED-YELLOW PODSOLIC SOILS	NONE	ON OUTCROPS OF CRETACEOUS, PERMIAN AND TRIASSIC SEDIMENTS. SHALES AND SANDSTONES MAINLY. SHALLOW SOILS.	CRETACEOUS SHALES, SANDSTONES, CONGLOMERATES. TRIASSIC SANDSTONES, CARBONACEOUS AND TUFFACEOUS SHALES, CONGLOMERATES. ACID IGNEOUS ROCKS AS SMALL INTRUSIONS. ARKOSE	MAINLY ACID IGNEOUS ROCKS, TERTIARY SANDSTONES AND CONGLOMERATES, TERBAT FORMATION (SHALES, CHERTS, AND SANDSTONES)
3. SALINE SOILS	RECENT, DELTAIC AND ESTUARINE CLAY DEPOSITS.	NONE	NONE	NONE
4. LOW HUMIC GLEY SOILS	ON LEACHED, RECENT, DELTAIC AND ESTUARINE DEPOSITS. ON FRESH WATER DEPOSITS. MAINLY CLAYS.	MINOR OCCURRENCES ON OLD MARINE CLAY DEPOSITS		NONE
5. PLANOSOLS	NONE	OLD COARSE TEXTURED AND SILT DEPOSITS. TERRACE MATERIALS.	OLD TERRACE REMNANTS FREQUENTLY BORDERING AREAS UNDERLAIN BY FLATBEDDED LIMESTONE.	NONE
6. HALF BOG SOILS	ORGANIC DEPOSITS	NONE	NONE	NONE
7. BOG SOILS	ORGANIC DEPOSITS	NONE	NONE	NONE
8. MOUNTAIN PEAT SOILS	NONE	NONE	NONE	PARENT MATERIAL: FOREST GROWING ON LIMESTONE.
9. TROPICAL PODSOLS	NONE	OLD, COARSE TEXTURED TERRACE DEPOSITS.	POSSIBLY CARBONACEOUS, SILICEOUS SANDSTONES AND SHALES	COARSE TEXTURED, SILICEOUS, FLATBEDDED TERTIARY SANDSTONES.
10. SKELETAL SOILS		ON OUTCROPS OF IGNEOUS INTRUSIONS (SEE 1)	NONE	ON STEEP SLOPES OF IGNEOUS ROCK MASSIFS, TUFFACEOUS SANDSTONES, AND ON SCARPSLOPES OF TERTIARY SANDSTONES.
11. REGOSOLS	SUBRECENT SAND DEPOSITS (MARINE)	OLD, VERY COARSE, TERRACE AND RIVER-BED DEPOSITS	NONE	NONE
12. RECENT ALLUVIALS	FRESHWATER ALLUVIUM OF MIXED SOURCES IN UPPER STREAM VALLEYS	INCLUSIONS, DERIVED MAINLY FROM IGNEOUS ROCK INTRUSIONS.	INCLUSIONS, DERIVED FROM MIXED SOURCES	NONE

Apart from the Triassic and Cretaceous sediments the Terbat formation of Permian and/or Carboniferous age is of importance in the Upper Kedup river. They comprise mainly shales and chert in this landscape unit.

d. Parent materials in the steep mountainous terrain

The dominant parent rocks in this unit are igneous rocks, mainly basic in nature, limestone of Cretaceous Age, and Tertiary sediments. The majority of the igneous rocks comprises basalts, andesites and related rock types. Most of the basalts have been metamorphosed and not much of the original mineral composition has remained. Acid igneous rocks in this area comprise granites, granodiorite, dacite, rhyolite, and related rocktypes. The majority of the acid igneous rock types give rise to the formation of Red-Yellow Podsolics, while on the basic igneous rocks Lateritic soils have formed.

The influence of igneous parent rock on soil formation is often more widespread in area than the area of the rock itself. Lateral movement of iron and other elements through seepage and solifluction, especially if the areas are steeply sloping, influence a large area surrounding these igneous intrusions.

The Cretaceous limestones in this unit do not play a role in soil formation because they are almost 100% pure calcium carbonate. Little or no soil develops from this kind of rock.

The Tertiary sandstones comprise coarse sandstones, conglomerates and red and grey mudstones. Most rocks are siliceous in composition and of a coarse texture. Sandy textured soils are therefore common on these rock types. Apart from being the parent material of residual soils formed in situ, the Tertiary Sediments also form the source of many old alluvial deposits which have acted as parent materials in the old dissected coastal plain. The diagrammat table (table 4) illustrates the relationship between topography, parent rock and soi

5. LAND TENURE AND POPULATION (See map 4 and plate 5).

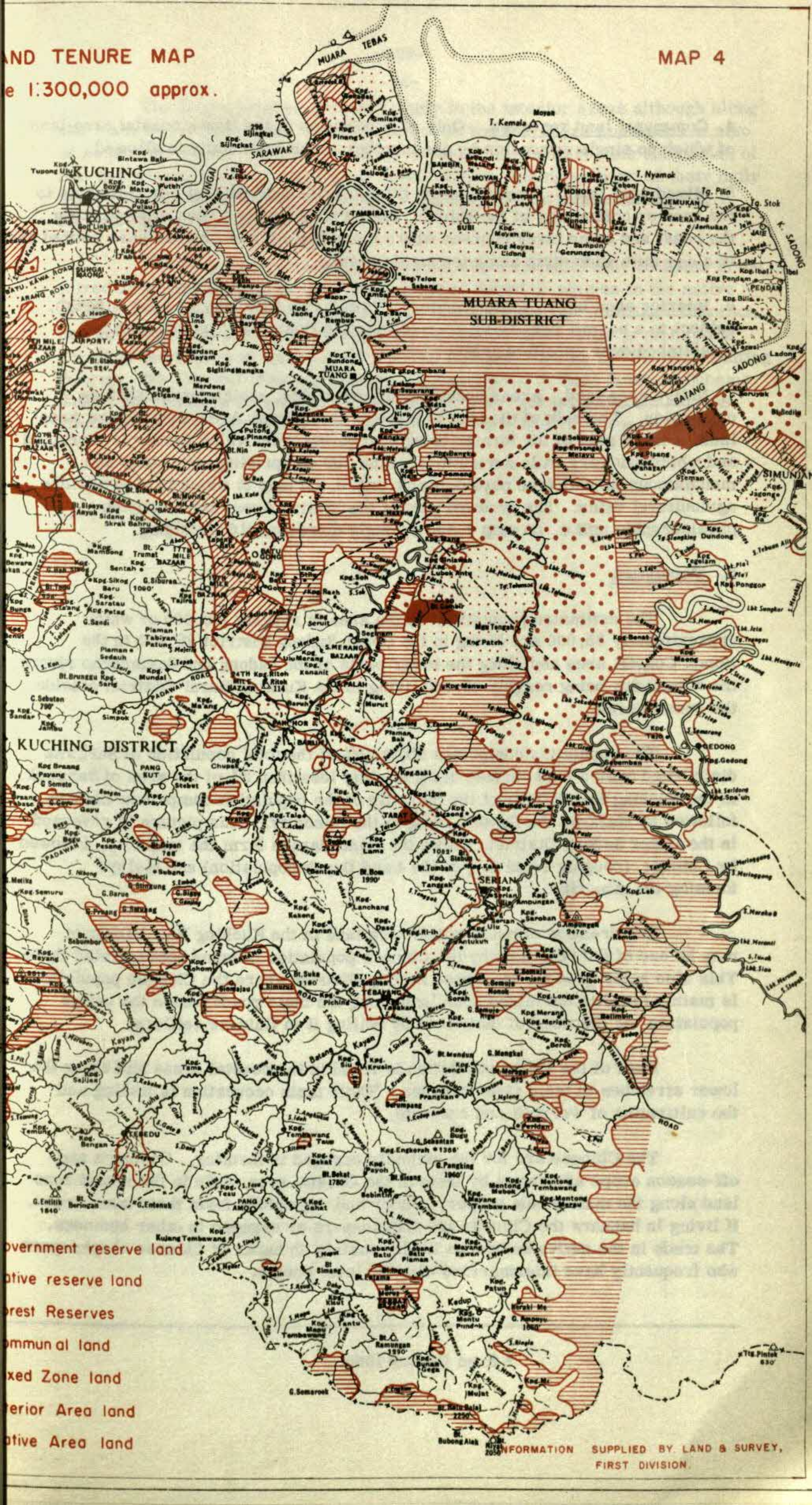
a. Land tenure.

Land in the area has been classified according to tenure systems. The following definitions are partly according to Annual Report 1957 of Lands and Surveys Department.

1. Government Reserve Land. Land owned by Government on which no individuals hold titles nor is it affected by native customary rights these having been relinquished to Government, or the land is still under Primary Forest.

2. Native Reserve Land. Titles may only be held by a member of one of the native races of Sarawak or by a person who has been absorbed into one of the native communities.

3. Forest Reserves. Government-owned land declared 'Forest Reserves' and 'Protected Forest' areas.


AND TENURE MAP
MAP 4
e 1:300,000 approx.
MUARA TEBAS
KUCHING
SARAWAK
MUARA TUANG SUB-DISTRICT
MUARA TUANG
BATANG SADONG
SIMUNJAN
AIRPORT
KUCHING DISTRICT
SERIAN
TEBAKANG
GEDONG
PADAWAN ROAD
TEBEDU
overnment reserve land
ative reserve land
orest Reserves
ommun al land
xed Zone land
terior Area land
ative Area land
INFORMATION SUPPLIED BY LAND & SURVEY, FIRST DIVISION.

4. Communal land reserves. Only of importance in the Nonok coastal area,land of which no single ownership by one member of the community is allowed.

5. Mixed zone land. Land on which titles may be held without restriction as to the race or community of the holder. Mixed zone land has been created along the coast and some river courses where many Malays and Chinese have settled an in a one mile wide strip along the major roads.

6. Interior area land. Mainly primary forest. No title may be held although, subject to a permit first being granted, 'Native Customary' rights may be established over specified areas.

7. Native area land. Areas under customary rights, mainly under shifting cultivation. The bulk of the land is classed as 'Interior Area' and 'Native Area' land, a large part of the former being peat forest from which timber is extracted and which has very little agricultural value, or comprising very steep and mountainous terrain (see physiographic unit d. on map 3) which is also of little agricultural value. The greatest part of the 'Native Area' land occupies physiographic unit c. on map 3 (the strongly dissected old mainland).

b. Population

The estimated population* in the area is roughly 100,000 of which approximately 35,000 are living in the Upper Sadong District 25,000 in the Nonok Coastal area and along the lower parts of the Sadong and Samarahan rivers the remainder being roughly 40,000 living in the Kuching Rural District outside the coastal area.

The population comprises about 15% of the total population of Sarawak distributed over a land surface being slightly less than 3% of the area of Sarawak. In the Kuching Rural District the majority of the population comprises Chinese, followed by Malays, the Dayaks being in the minority. This picture is reversed in the Upper Sadong District, where the Land Dayaks form the majority, followed by Chinese (roughly equal to ½ of the Land Dayak population) and Malays forming the minority.

The creation of much mixed zone land in the Kuching Rural District may be one of the reasons why the Chinese population is found concentrated there This also holds good for the Upper Sadong District where the Chinese population is mainly found in the mixed zone land along the main roads where the native population has disposed of their land by selling it to Chinese settlers.

Most of the Malay population is found in the coastal areas and along the lower stretches of main river courses. Their main occupation is fishing and the cultivation of wet padi and coconuts.

The Chinese are for the majority engaged in farming. Coconuts and off-season crops are grown by them in the Coastal area while in the mixed zone land along the main roads pepper, rubber and vegetables form their main crops. If living in bazaars the Chinese are shopkeepers or engaged in other business. The trade in the native kampongs is also mainly in hands of Chinese shopkeepers who frequently have intermarried with the local people.

---

* from Census 1960.

The Dayak population lives largely in the interior areas although along the main rivers and in the Nonok coastal plain the Sea Dayak population is also of some importance. Their occupation is mainly agriculture, the cultivation of hill and wet padi on a rotation basis (padi/Fallow), taking up most of their daily work. In certain areas the growing of cash crops by natives is becoming increasingly more important.

Until recently permanent cultivation could virtually only be found in the mixed zone land except for old rubber gardens owned by natives in the native areas. More and more native area land previously used for shifting cultivation has now been converted into permanently cultivated land. This is mainly the result of the impact of agricultural subsidy schemes such as the Rubber Planting Scheme, the Coconut Planting Scheme and Assistance to Padi Planters Scheme. Such a development is however patchy in nature and not immediately obvious although the total acreage of land affected by such schemes is considerable.

PART 2.

SOILS

Note: The following high level classification system employed for this area and which is mainly of academic interest, does not necessarily represent a formal classification of Sarawak soils at this level. Such a classification system is still the subject of discussion.

1. OUTLINE OF HIGH LEVEL CLASSIFICATION (SEE TABLE 5)

For the classification at higher levels the framework of the American system as discussed and outlined by Thorp and Smith (ref. 4) has served as a basis. Although it is fully realised that this classification with its heavy bias on genesis has many loopholes it has been found to be the most practical solution to classification problems in Sarawak. Soil mapping in Sarawak - and the present area is no exception - depends heavily on soil genetic relationships which can often only be inferred from studying environmental conditions by using air photographs. A natural classification system depending heavily on factors such as climate, topography, parent material and time, appears therefore the only possible way to bring order in the great variety of soils; the alternative being time-consuming and expensive detailed surveying which appears to be a prerequisite for classifying soils according to the new American system, (7th approximation), (reference 5). Moreover, the latter classification system depends heavily on specific analytical data which is not available.

(i) Orders

The soils in the area are firstly classified according to their zonality. For normal soil mapping little attention has so far been given to a separation of soils at the Order or Suborder level, this being a classification of purely academic value. The present area however is sufficiently large to attempt a grouping of soils at this highest level of classification. The concept of zonality is accepted in Sarawak as proposed by Thorp and Smith (ref. 4). It is however realised that many soils are difficult to place because of their unknown genesis.

Zonal Soils - are in general characterised by well-differentiated horizons and by profiles that differ markedly according to the climatic ecological zone within which they occur. Their physical and, to a certain extent, chemical characteristics are a reflection of the climatic and ecological zone in which they occur.

Following this definition the podzols and podsolic soils other than Red-Yellow Podsolics occurring in the area do not belong to the zonal soils because they are not primarily related to the climatic ecological zone but rather to pedoenvironmental factors such as parent material and drainage.

Intrazonal and Azonal Soils - A separation between these Orders is even more difficult than between zonal and intrazonal soils. In general Intrazonal Soils are soils with well-developed genetic horizons which have formed primarily through the influence of the pedo-environment rather than the climate. For this reason a placing of the tropical podsols in this order is therefore favoured. It is well realised that many intergrades exist between the Intrazonal and Zonal Soils and also between the Intrazonal and Azonal Soils. This is mainly due to the weakness of the system which leans heavily on genesis for which it is impossible to draw sharp lines.

TABLE 5.

ORDERS	SUBORDERS	GREAT SOIL GROUPS
Zonal soils	a. Lateritic soils of forested warm-temperate and tropical regions	1. Reddish Brown and Yellowish Brown Lateritic soils (Lateritic soils)
	b. Light coloured podsolised soils of the timbered regions	2 Red-Yellow Podsolics
Intrazonal soils	c. Halomorphic soils	3. Saline soils
	d. Hydromorphic soils	4. Low Humic Gley soils
		5. Planosols
	e. Organomorphic soils (local suborder)	6. Half Bog Soils
		7. Bog Soils
		8. Mountain Peat Soils (local group)
	f. Tropical Podsols and podsolic soils (local suborder)	9. Tropical Podsols (local group)
Azonal soils		10. Skeletal soils (Lithosols)
		11. Regosols
		12. Recent alluvials

Azonal soils are in general weakly developed soils in which little profile development can be noticed. Also in this Order intergrades do occur and skeletal soils may show certain podsolic or hydromorphic features. Such features are however used to differentiate soils at a lower level but they remain in the Order of the Azonal Soils.

(ii) Suborders

For a subdivision into Suborders soil profile characteristics and genesis are both used. In the area the only existing Suborders in the Order of Zonal Soils are:

a. Lateritic Soils of forested warm-temperate and tropical regions in which a lateritic process is noticeable.

b. Light-coloured Podsolised Soils of the timbered regions in which podsolic features are dominant.

The Intrazonal Soils in the area are represented by the following Suborders:

c. Halomorphic Soils (soils in which saline or alkaline features are the dominant characteristics). In the area only the saline members are found.

d. Hydromorphic Soils (mineral soils characterised by periodic or permanent excessive moisture). In the American system peat soils are placed in this Suborder. Because of the vast difference which exists between these organic soils and mineral soils for the purpose of this report a Suborder called Organomorphic Soils has been added to separate the two. (In the American 7th Approximation a special order for these soils was created namely the Histosols).

e. Organomorphic Soils - soils with more than 35% organic matter. The hydromorphic or arid nature of these soils is used for separation at the level of Great Soil Groups.

f. Tropical Podsols and Podsolic Soils - this Suborder groups together all soils with podsolic features which have formed outside their normal zone, (temperate regions).

The Azonal Soils are not subdivided into Suborders.

(iii) Great Soil Groups

At the level of Great Soil Groups attention is given to field characterist and chemical characteristics of soils and a classification at this level is of a mo agricultural significance than the classification at higher levels. Definitions are according to Thorp and Smith unless specified otherwise.

The Suborder of Lateritic soils of forested warm, temperate and tropical regions is represented in the area by:

1. Reddish Brown Lateritic Soils and Yellowish Brown Lateritic Soils (hereafter named Lateritic soils). Definition: A solum of 36 inches in which latosolic features such as few primary minerals other than quartz, no argillic horizon, more than 15% clay, sesquioxides and kaolin predominant in the clay fraction. Iron oxides in the clay fraction exceeding 10% in the first 12 inches. Low organic matter content (less than 4% in the A1 horizon) crumb structure to weak fine angular blocky. Low base saturation.

The Light-coloured Podsolic Soils of the temperate regions are represented by:

2. Red-Yellow Podsolic Soils. Definition: Well developed, well drained (in the area imperfectly drained soils belonging to hydromorphic intergrades are included) acid soils having thin organic (A_o) horizons over a light coloured bleached (A2) horizon, over a red, yellowish-red or yellow more clayey (B) horizon. Parent materials are more or less siliceous. Coarse reticulate streaks or mottles of red, yellow, brown and light grey are characteristic of deep horizons where parent materials are thick.

The Suborder of Halomorphic Soils is represented in the area only by the Group of Saline Soils.

3. Saline Soils - Definition: Soils in which the chemical characteristics are dominated by the presence of large amounts of soluble sodium salts. (local definition).

The Suborder of Hydromorphic Soils is represented in the area by:

4. Low Humic Gley Soils - Definition: Imperfectly to poorly drained (in the area mainly poorly drained) soils with very thin surface horizons, moderately high in organic matter, over mottled grey and brown gley-like mineral horizons with a low degree of textural differentation. Texture ranges from sand to clay and parent materials vary widely in physical and chemical properties. The soils occur largely under a natural cover of swamp forest and perhaps some marsh plants in some areas. A large proportion of them ranges from medium to very strong acid in reaction. Few are neutral or alkaline.

5. Planosols - In the scheme proposed by Thorp and Smith only a provisional definition was given: Intrazonal Soils having one or more horizons abruptly separated from and sharply contrasting to an adjacent horizon because of cementation, compaction, or high clay content usually but not always with a fluctuating watertable. In many instances the cemented or compacted horizons lie beneath a moderately well developed B horizon. Because of the low incidence of occurrence of Ground-water Laterite and Ground Water Podsols in the area these soils have been classified together with the Planosols.

The Suborder of Organomorphic Soils is represented by the following Great Soil Groups:

6. Half Bog Soils - Definition (Local): Half Bog Soils have thick (6-36 inches) organic A horizons of which the organic matter content is between 35% and 60%, overlying gleyed mineral soil. Watertables are high. Texture of the mineral part of the solum varies from sand to clay.

7. Bog Soils - Definition: (Local) Bog Soils have thick (more than 36 inches) horizons of which the organic matter content exceeds 60% and which overly gleyed mineral soil. Watertable is high. Texture of lower subsoil ranges from sand to clay.

8. Mountain Peat Soils - This Great Soil Group is recognised for the area and is not mentioned in the system prepared by Thorp and Smith. Its particular nature does not permit a placing in the existing scheme and the soils have therefore been placed in this proposed group. Provisional Definition: A group of organic soils with thick (more than 6 inches) organic top horizons having an organic matter content of more than 35%, overlying bare rock. Watertables are low, the soils are acid in reaction.

The tropical podsols and podsolic soils are represented by the following proposed Soil Group:

9. Tropical Humus Podsols - Definition (Local): A group of soils displaying all morphological features of humus podsols as occurring in temperate regions but which are chemically distinctly different (very low iron and base contents, very high silica content and relatively high pH in A_2 horizon.

Finally the Azonal Soils are represented in the area by:-

10. Skeletal Soils or Lithosols. - Definition: A group of soils in which the solum is not thicker than 36 inches and in which the C horizon is found not deeper than 12 inches from the surface. In general soils with little or no profile development.

11. Regosols. - Definition: Loose, unconsolidated material with little or no profile development. Frequently coarse sands and gravels.

12. Recent Alluvials. Recently deposited material ranging from fine sands to clays in which little or no profile development has taken place. In the area a large number of alluvial soils display the features of this soil groups and also some of the features of other soil group . These belong typically to the intergrades but they have all been placed in this group. These intergrades have been separated at a lower level of classification.

Orders and suborders are not shown on the soil map. The Great Soil Groups are for the majority shown in colour while for some symbols have been used.

2. OUTLINE OF LOW LEVEL CLASSIFICATION (See table 6)

For the map-user in Sarawak this level of classification is of most importance because it has greatest agricultural significance. It is needless to say that a classification below the level of Great Soil Groups is of a local character which is shown by the fact that local names have been given to any group of soils separated within a Great Soil Group.

The Great Soil Groups are broken down into groups of soils having in common a number of typical morphological characteristics which are thought to be of agricultural significance. The lack of agronomic data makes it impossible to test the value of such groupings and they are necessarily arbitrary in nature. They are however of great practical value, specifically for soil mapping.

OUTLINE OF LOW LEVEL SOIL CLASSIFICATION

TABLE 6

GREAT SOIL GROUPS	FAMILIES		PARENT MATERIALS	OTHER DIAGNOSTIC FEATURES	SERIES		PARENT MATERIALS
I. LATERITIC SOILS	Ta	TARAT	Basic and ultrabasic igneous rocks.	Crumbly structure throughout, more than 25% iron and alluminium oxides in all horizons, but A.I.	(Ta)	TARAT	Basic and ultrabasic igneous rocks
	An	ANTAYAN	Intermediate to acid igneous rocks.	Blocky structure in subsoil, more than 25% iron and alluminium oxides in all horizons, but A.I.	(An)	ANTAYAN	Intermediate igneous rocks
2. RED - YELLOW PODSOLICS	Ab	ABOK	Rhyolites, tuff. Shales and sandstones. Volcanic tuffs. Metamorphosed sandstone, schists. Acid to intermediate igneous rocks.	Blocky structure in subsoil, not less than 10% iron and alluminium oxides in top horizon, more than 20 % in lower horizons (tentative def.).	(Sn) (Ba)	SERIN BAYUR	Metamorphosed sandstone (arkose). Schists.
	Ny	NYALAU	Medium textured sandstones.	Sandy textured topsoil (in general sandy throughout) no A.2 horizon.			
	Me	MERIT	Fine textured sandstones, shales.	Clayey textured topsoil (in general clayey throughout) no A.2 horizon.			
	Sem	SEMONGOK	Fine textured sandstones, shales.	Grey mottled below A.I horizon - no A.2 horizon.	(Sem)	SEMONGOK	Carbonaceous shales.
	Mt	MATANG	Coarse textured sandstones.	Bleached A.2 horizon present.			
	Sa	SABANGANG	Subrecent coarse textured alluvium.	Gravelly and sandy throughout.			
3. SALINE SOILS	Ra	RAJANG	Clayey deltaic and estuarine deposits	High soluble salt content.			
4. LOW HUMIC GLEY SOILS	Pe	PENDAM	Leached clayey deltaic and estuarine deposits.	Low soluble salt content in topsoil, medium content in subsoil.	(Pe)	PENDAM	As for the Family.
	Bi	BIJAT	Freshwater clay deposits.	Free of soluble salts.	(PM)	PAYA MEGOK	Freshwater, fine textured, deposits overlying limestone.
5. PLANOSOLS (including some ground-water laterites)	Tr	TRIBOH	Resorted old alluvium mainly.	In general bisequent profiles, fine textured compact subsoils.			
6. HALF BOG SOILS	Mu	MUKAH	Freshwater organic deposits.	Not deeper than 36" overlying clays.			
7. BOG SOILS	A	ANDERSON	Deep freshwater organic deposits.	Deeper than 36"	A1 A2 A3	ANDERSON 1 ANDERSON 2 ANDERSON 3	As for the Family
8. MOUNTAIN PEAT SOILS				On mountains or hills.		KEDADUM	(as part of Bau Association)*
9. TROPICAL PODSOLS AND PODSOLIC SOILS	Mi	MIRI	Coarse textured old alluvium.	Humus podsols (humus B present).			
	Bk	BAKO	Coarse textured sandstones				
	Ke	KERAIT	Carbonaceous shales and sandstones.	Podsolic features (no humus B present).			
10. SKELETAL SOILS	Se	SEDONG	Igneous rocks.		(Se) (Bu)	SEDONG BURI	On basic and ultrabasic igneous rock. On acid and intermedidte igneous rock.
11. REGOSOLS	Ka	KAPIT	Sedimentary rocks.				
	Tt	TATAU	Coarse textured marine deposits.	Weak hydromorphic.	(Tt)	TATAU	As for the Family.
	Ga	GAYA	Very coarse textured old alluvium.	Mainly gravels.			
12. RECENT ALLUVIUM	Ma	MALANG	Recent freshwater fine textured deposits.	Weak hydromorphic.			
	Sm	SEMILAJAU	Recent freshwater medium				

These groups of soils are called Families.

The Families are again subdivided into series based on the American concept (ref.6). For certain soils field characteristics are quite similar although the chemical characteristics vary considerably. This is often the case with the Low Humic Gley Soils and Recent Alluvials. In such cases the chemical characteristics are used as a basis for separation. In the present area a great number of series have so far been mapped on a semi-detailed and detailed scale but it is impossible to show all these series separately on the small scale soil map accompanying this report. Only series which are important in area and which have agricultural significance are shown on the soil map and are discussed in detail in this report (see also the Appendix).

The Families are indicated on the map by letters while for the series lettering also has been used, but in brackets. Where groups of soils occur in such a complex manner that it was impossible to show them separately on the map, use has been made of Associations. Associations of Families within one Great Soil Group are shown by a double or triple lettering denoting the Families concerned. In cases where two different Great Soil Groups are involved the Great Soil Groups are shown by hatched colouring while lettering has been used to denote the Families concerned. It is emphasised that our object has been to show the major distribution of soils and that in areas shown as certain soil groups inclusions of other soils do occur. Any attempt to use this soil map for purposes for which a detailed soil separation is necessary is therefore most likely an invitation to failure. In such instances use should be made of the separate, more detailed studies which have been carried out for certain areas (ref. report numbers mentioned at page 6).

3. GENERAL DISCUSSION OF SOILS.

(1) Lateritic Soils

(a) Genesis. Lateritic Soils as found in the area have formed from parent materials which are rich in ferro-magnesium minerals: in most cases basic to intermediate igneous rock types such as basalts, dolerites, andesite and allied rocks. The occurrence of such rock types is widespread in the Kuching and Upper Sadong Districts. Apart from the specific type of parent materials a number of other factors give rise to the formation of these soils: a topography which enhances rapid external drainage and a hot humid tropical climate. The topography is characterised by steep to moderately steep mountainous terrain where rapid drainage of excess rainwater and lateral leaching of bases is ensured.

Climate and topography is similar in many parts in the country but different soils are formed on parent materials dissimilar from basic igneous rocks. It can therefore be assumed that the nature of the parent material is largely responsible for the formation of lateritic soils in the area.

(b) Characteristics. Most Lateritic Soils in the area resemble the Reddish Brown Lateritic Soils as described by M.A. Nyun and S.B. McCaleb (ref.7). The soils are generally shallow to moderately deep. Soils deeper than 5 feet seldom occur on the generally moderately steep slopes but deeper soils are frequently found at the colluvial footslopes. Probably soil formation and erosion are keeping pace with each other resulting in an accumulation of soil material at the lower slopes while constant rejuvenation occurs on the upper slopes where soils tend to grade into skeletal soils.

The soils are yellowish brown or strong brown to reddish brown in colour. The difference is attributed mainly to the degree of hydration if iron compounds and differences in parent material. Frequently the colour difference is accompanied by differences in structure.

The soils are all well structured, being crumbly to fine angular blocky. Soils are generally in a moist condition and friable. Rooting is dependent on vegetation but in general roots are confined to the top 12 inches which is thought to be the result of an impoverishment of the subsoil by a continuous leaching process. Bases are in circulation between topsoil-vegetation-organic matter. If the soils are fertilised the roots tend to go deeper as can be noticed in rubber gardens on these soils.

The Lateritic Soils have an excellent physical condition which is however counteracted by the general lack in bases. The soils are all clays, the majority being iron-alluminium oxides. A considerable amount of analytical data has shown that the available nutrient content is low while the reserve nutrients are also low. Reserve phosphates show moderately high figures but because of the strong phosphate fixation (formation of iron and alluminium phosphates) the phosphate status is probably very unfavourable.

The acidity is high in the topsoils (in general 4.5) while the subsoils have an acidity of 5.5.

(c) Classification The Lateritic Soils occurring in the area have been separated into two families.

Tarat Family - soils with a reddish brown to strong brown colour. Crumbly and friable throughout the profile.

Antayan Family - soils with a strong yellow to olive yellow colour and weak blockly structures.

The Tarat family may represent an older stage in soil formation than the Antayan family. Differences in parent material have however also been noticed, the Antayan family occurring on more andesitic rock types. From the available analytical data it appears that the Antayan family soils are probably better supplied with nutrients than the Tarat family.

One series was mapped within the Tarat family, namely the orthotype, Tarat series. In the Antayan family the ortho-type, Antayan series was mapped separately. Particulars can be found in the Appendix.

(d) Utilization. The Lateritic Soils form an excellent medium for plant growth because of their physical characteristics. The nutrient status is however very low and fertilization of the major nutrients, especially phosphate will be problematic and expensive because of the chemical characteristics of the soils. Because of their basic igneous origin it is thought that the soils are well supplied with trace elements. This however needs further study. The topography of the soils is in general difficult for large-scale development unless use is made of the colluvial footslopes. (See plate 1). Development in the form of scattered small holdings on the less steep slopes appears to be the best way to utilize them. Tree crops with adequate fertilizing are recommended both from a farming point of view as well as for land conservation.

At present most soils are under shifting cultivation. Steeper slopes are still under natural forest or are used for fruit tree reserves by the local populatio An increasing acreage has been planted up with rubber during the last few years. Most gardens are showing a rapid and vigorous growth when managed according to the recommendations of the Rubber Branch of the Department of Agriculture. The soils are physically suitable for cocoa but fertilization may prove to be difficult. Recommendations on this crop must await the result of trials currently planned by the Department. The soils can also be used for oil palm but the topography is generally unsuitable. In Kpg. Kuop it has been shown that this soil can support an excellent stand of citrus. The local population favours the soil for pepper planting, mainly because of the good drainage and the small weeding proble

2. <u>Red-Yellow Podsolic Soils</u>

(a) Genesis. Th e Red-Yellow Podsolic Soils are found on parent materials which are all more or less siliceous in nature. Parent materials comprise rocks of sedimentary origin such as shales and sandstones. The sandstones vary considerably in chemical composition and range from tuffaceous sandstones to the more siliceous ones but very coarse or very siliceous sandstones are excluded.

Shales are of varied texture and comprise silty and sandy shales. Apart fr the sedimentary rocks Red-Yellow Podsolics can also be found on acid igneous roc types such as granodiorites, rhyolites and tonalites. Finally Red-Yellow Podsolics occurs on subrecent coarse-textured alluvium. Although parent material plays an important role in the formation of these soils topography appears to be more important for their formation than is the case with the lateritic soils. On a flat topography podsolic features in soils on the last mentioned parent materials appear to become dominant, definitely so with the more sandy parent materials.

On steeper slopes erosion may rejuvenate the profile before it has matured and full podsolic development is rarely found on such slopes. On colluvial footslopes of mountains built up by coarse-textured siliceous parent material podsolic features are prolific.

Topography is also responsible for the great number of intergrades formed between the Red-Yellow Podsolic Soils, the Low Humic Gley Soils and Podsols.

In general, the flatter the topography the more hydromorphic features are expressed in the profiles and this is specifically so in areas where watertables are high.

These intergrades have been classified at a Family level as it is thought that the significance of the features on which they are separated is mainly an agricultural one.

On steep slopes, Red-Yellow Podsolics grade into Skeletal Soils but this is not necessarily the case. Frequently deep soils can be found on steep slopes or on summits of hills while at lower levels in the valleys shallow soils occur. This frequently happens when fully developed profiles have formed on an erosion surface resulting in deep weathering. After dissection most of the deep weathered material has been eroded and younger but shallower soils have formed at bottom slopes while near the summit of hills remnants of deep weathered soils can be found. Solifluction and colluvial activity appears to interfere also with this picture in many areas.

It has been attempted to map soils on sandstone and shales separately. This is only possible where such formations form continuous thick beds. In many cases sandstones and shales occur interbedded and the parent material on which the soils are formed is a mixture of both shales and sandstones. Solifluction has probably moved much soil material downslope and the parent material found in the profile is frequently different from that of the overlying soil. This can best be noticed in profiles in which stonelines occur, their source being vein quartz in the parent rock some distance away from the profile. Much quartz and fossil iron concretions (haematite and limonite) formed between the beds of sedimentary rocks prior to actual soil formation has been distributed in soils along the slopes of hills.

The topography is characterised by low (in general the altitude does not reach higher than 350 feet with the exception of the soils on Tertiary sediments) moderately to steeply dissected terrain. Slopes vary between 10 and 35^{o}. Steep slopes are dominant in the upper reaches of river courses and tend to level out towards the coast. Nature of parent material plays an important role in the topography. Thus the terrain of Red-Yellow Podsolics derived from arkose is steep and strongly dissected while the topography of shales tends to be rather subdued. (See Plate 3) Red-Yellow Podsolics occurring on acid igneous rocks have invariably very steep slopes.

(b) Characteristics. Type profiles of series in the Group of Red-Yellow Podsolic Soils are given in Appendix together with their relevant analytical data. The depth of soils ranges from 2 feet (shallow phases) to more than 10 feet. The colour of the topsoil is dependent on the amount of organic matter but is generally greyish brown to brownish grey. Gley mottles can frequently be noticed in the topsoil showing that in such locations surplus rain-water collects in this layer thereby causing partial reduction. This may happen on less well-drained sites or if the organic top layer is of a peaty consistency (frequently under primary forest). It can in most cases be observed along paths where the traffic has compacte the top soil.

Below the top horizon colours are pale yellow, yellow to brownish yellow depending on parent material and site. Erosion in many steep areas has removed the top part of the profile and subsoils showing richer colours are exposed.

Subsoils become more reddish tinted with depth unless water-tables or imperfect drainage conditions interfere with this and grey mottles are more dominant than the yellow matrix colours. Carbonaceous shales frequently tend to give very grey-coloured subsoils resembling a gley horizon. The grey colouring is gradually replaced by yellow in the upper horizons often through a grey mottled transition zone. Whether the grey mottling is caused by reduced conditions or by the remaining parts of the carbonaceous parent material needs further study. Observations indicate however that the latter cause may be the most likely one.

The richer the parent material in iron-magnesium minerals the redder are the subsoils. There is a strong correlation between iron content in the soils and the colouring.

Textures range from sandy loams to clays in the topsoil while subsoils are generally more clayey. Texture is dependent on nature of the parent material while texture differentiation in the profile is caused by the podsolic process through which textural B horizons are formed. Thin bedded sedimentary rocks of varied textures which may occur within a depth of 4 feet in the soil profiles tend to obscure this feature.

Structures are difficult to study because most soils are moist throughout the year. Strong blocky structures however can be noticed in the subsoils if the profiles are allowed to dry out. The soils are generally of a firm consistency.

Rooting is generally shallow and confined to the top 6 inches in which most of the available nutrients are stored. All Red-Yellow Podsolics in the area are poor in nutrients. The acidity is high, ranging between 3.5 to 4.5.

Under primary forest the top horizon is frequently well supplied with available nutrients which are rapidly washed out if the forest cover is removed and the humus is oxidised. Topsoils tend to become more poorly structured and under shifting cultivation soils rapidly degenerate.

The most common features in the Red-Yellow Podsolics are: poor structure especially of the subsoil, poor chemical fertility, the in general low iron content if compared with the Lateritic Soils, (Abok family is an exception). Analyses show that the iron oxides tend to accumulate in the B horizon and phosphate fixation is most likely strongest in this horizon.

(c) - Classification - 6 families were mapped:

Abok Family: yellow sandy loams to clay loams overlying reddish coloured subsoils. Structures generally angular blocky upon drying. Textural (if parent material coarse) and structural B horizons present - bleached A2 generally not. Group III elements more than 20% in B horizon, less than 20% in top-horizon.
Parent material: acid volcanic rocks, tuffaceous sandstone and shales, schists, arkose.

Nyalau Family: yellow sandy loams overlying stronger yellow or reddish yellow subsoils. Textural and structural B present. Bleached A2 very thin or not present.
Parent material: sandstones mainly.

Merit Family: yellow clay loams overlying more yellow or reddish coloured subhorizons. Textural B weak developed, structural B present but weak.
Parent material: shale and fine sandstone mainly.

Semongok Family: intergrade to Low Humic Gley. Features as for Merit but grey mottled throughout the profile below Al horizon.
Parent material: carbonaceous shales mainly.

Matang Family: yellow sandy loams overlying more heavy textured and stronger coloured subhorizons.
Parent material: Coarse siliceous sandstones mainly.

Sabangang Family: yellow sandy loams overlying more heavy textured and stronger coloured subhorizons.

Parent material: old to subrecent alluvial deposits probably intermixed with colluvial material from residual soils.

The Family separation within the Red-Yellow Podsolic Group shows some relation with the revised American classification system as proposed by Harris (ref. 8). For completeness sake a comparison between the proposed soil groups by Harris and the families used in Sarawak is hereby given:-

Abok Family - more or less equivalent to Podsolic Latosolic Soils..
Nyalau Family and Merit Family - Latosolic Podsolic Soils.
Semongok Family - Latosolic Podsolic (hydromorphic intergrade).
Sabangan Family - Intergrades to Recent alluvials and Regosols.

In these families only three series were mapped separately.

Serin Series (Abok Family) - occurring widespread in the Ulu Malang area and along the Kuching-Serian road from the 25th mile onwards. Parent material - arkose.

A type profile with analyses can be found in the Appendix.

Semongok Series (Semongok Family) - occurring in the vicinity of the Penrissen Road. Parent material - carbonaceous shales.

A type profile and analyses are given in the Appendix.

Bayur Series (Abok Family) - occurring east of Serian. Parent material - schists. (See Appendix).

(d) Utilization - The Red-Yellow Podsolic Soils are mainly used for hill padi. Most rubber planted in recent years has been put on Red-Yellow Podsolic Soils because of the generally favourable topography. To a lesser extent the soils are used for pepper cultivation mainly by Chinese farmers along the Kuching-Serian road. (See Plate 5). The latter use this soil mainly because of the scarcity of better soils. There is however a strong indication that Red-Yellow Podsolic Soils can be used for pepper with advantage if sufficient attention is given to improvement in drainage. The internal drainage is thought to be rather slow which may cause too wet conditions for the pepper in the wet season.

The Red-Yellow Podsolic Soils are poor in nutrients. Their physical characteristics are moderately good and if sufficient care is given to remedy this factor where necessary the soils can be utilised for a variety of purposes. They need to be well fertilised but probably the problems will be less great than is the case with the Lateritic Soils. This depends also on parent material and in general the redder the soil the less efficiently phosphatic fertilisers will work.

Crops which demand good drainage such as cocoa are better not grown on these soils. Oil palm, providing the topography is favourable, can be grown with success. In the area not much land with a favourable topography for oil palm can be found and therefore the Red-Yellow Podsolics could best be utilised for rubber. The Serin series is the most favourable soil for pepper within this Soil Group.

It can be concluded that the Red-Yellow Podsolics form the greatest expanse of land in the area on which rubber growing could be extended.

3. Saline Soils.

(a) Genesis. This group of soils only occurs in the coastal areas and along the lower stretches of main river courses such as the Lower Sarawak river, the lower Samarahan river and the Lower Sadong river. They are formed on deltaic and estuary deposits of clay texture mainly. They are daily flooded with tidal salt water.

(b) Characteristics. All soils in this group have a high content of soluble salts because of the daily inundation with salt water. Groundwater is high and salty (permanent groundwater level within two feet of the surface). Textures are clayey throughout. The soils are always in a wet condition and structures cannot be studied.

The soils are all under a natural forest cover of Mangrove and Nipah. Under Nipah the salt level is lower than under Mangrove. Many soils in this group have horizons of a mucky consistence caused by the great amount of organic debris originating from the natural vegetation which is buried by constant deposition of fresh mineral material. These organic deposits may give rise to high sulphate levels in soils which may only become noticeable after drying when the iron sulphates are oxidised and sulphuric acid is released. Nutrient levels in the soils are high because of daily additions of mineral salts.

The topography is flat and the soils occur between high and low tide levels. Only in places where the land has sufficiently risen above high tide level can reclamation of these soils become possible.

(c) Classification. Only one Family was recognised in the area, namely the Rajang Family; no subdivisions on a series level have been mapped. A type profile description with available analytical data of the ortho-type in the family, the Rajang series, can be found in the Appendix.

(d) Utilization. At present little use can be made of soils in this Soil Group because of the high expenses involved in any reclamation scheme. They are however potentially good soils once they are reclaimed and brought beyond the influence of salt water infiltration. In certain parts of the world (e.g. Sierra Leone), these soils are reclaimed for wet padi growing with success. Any such undertaking is however dependent on economic values which are liable to change. For the present they are therefore regarded as unsuitable for agriculture.

4. Low Humic Gley Soils.

(a) Genesis. Low Humic Gley Soils are found in the present riverine floodplains which occupy those parts of the coastal area and the river valleys of main river courses which are beyond the influence of daily saltwater flooding. Apart from these areas Low Humic Gley Soils can also be found in small inland valleys which have been blocked off either through levees built up by a main river or through man-made bunds. These areas are however small and, although of local importance, of little significance for the area as a whole.

The Low Humic Gley Soils are formed usually on clayey material in an environment characterised by high groundwatertables and frequent flooding during the wet season. These conditions cause reduction of iron compounds followed by leaching and their subsequent precipitation and accumulation in lower horizons if soils dry out after periods of submerging. In many areas soils are continuously wet and the reduction process is dominant which is made apparent by the generally grey, green and bluish colours in the whole profile.

Continuously wet conditions have also resulted in the formation of organic soils which are dealt with under the Bog and Half Bog Soils. Soils with an organic top horizon of less than 6 inches are however placed in the Low Humic Gley Soils.

Where watertables fall sufficiently during dry seasons iron oxides precipitate as concretions, the maximum expression of this feature being found in the so-called Groundwater lateritics dealt with under the Planosols.

Compared with the overruling influence of groundwater the nature of the parent material is insignificant for the development of these soils. However, the amount of iron present in the parent material sets a limit to the development of mottled redox horizons and the formation of concretions and lateritic pans. Apart from the generally very wet conditions throughout the year resulting in insufficient aeration needed for the formation of oxidised forms of iron compounds, the general low iron content in the parent materials is one of the main reasons that very little concretionary forms of iron could be found in the Low Humic Gley Soils as occurring in the area. Morphologically there is little variation in the Low Humic Gley Soils but their chemical characteristics vary widely depending on the source of sediments, and chemically poor soils can be found next to chemically very rich soils. These chemical differences however have been used for separation at the series level.

(b) Characteristics. The Low Humic Gley Soils have in general dark top soils with colours ranging from greyish brown to grey (depending on organic matter content), overlying a redox horizon which is of varying depth depending on the fluctuation in height of watertables. Colours in the redox horizon depend apart from the intensity of aeration, on the iron content of the parent material. Certain soils from basic igneous rocks are rich in manganese and may contain iron-manganese concretions in this horizon. In general the redox horizon is not thicker than 6 inches to 1 foot. It is characterised by intense grey and orange, brown or red coloured mottles. Frequently the aeration continues along root channels into the gley horizon which is found underneath the redox horizon. The gley horizon is in a permanently reduced state and the upper boundary indicates in general the lowest level of the watertable in the drier season. Colours of the gley horizon vary from light grey to sometimes white; green and bluish colours are frequently found in soils richer in iron. Dark blue colours in these gleyed subsoils may also indicate the presence of organic matter as minute particles, the presence of which is explained by the fact that they indicate the presence of mangrove and nipah forest in former times which could be found much farther upstream than is the case at present. The occurrence of 'cat clay' in such layers support this view. These old mangrove and nipah swamps have gradually been covered by fresh riverine sediments.

Textures may vary from sands to clays but in the survey area clay soils are dominant probably because of the small amount of coarse sandstones found in the catchment areas of most rivers.

(c) Classification. Only two main Families are present in the area, namely:

Pendam Family - Low Humic Gley Soils which have moderate to low contents of soluble salts in the upper horizons, the subsoils may have high contents of soluble salts. The Pendam soils are probably all leached Rajang Family soils which have raised above high tide level.

Bijat Family - Low Humic Gley Soils with no soluble salts in the whole profile or very low contents in the lower horizon. (Low and high salt contents in this context refer to levels which are of agricultural significance and which are related to sensitivity of crops usually grown in these areas). The separation is necessarily arbitrary in mapping because of the impossibility to check such values in all places. Definite levels have been laid down for a separation at a series level for which more detailed analytical data is normally available.

The boundary between the Pendam and Bijat Families is an arbitrary one especially in areas where the Families grade into each other, which is the case along the lower stretches of most main river courses. The present boundary has been taken there where normally no salts in any significant quantity are found in the riverwater at high tides.

A great number of series have been recognised in this soil group and in previous studies for certain parts of the area series could be mapped. The differences are mainly of a chemical nature which however have a great bearing on fertility and agricultural potential.

At this scale of mapping it is not possible to show such detail and the reader is referred to the reports on these areas if more information is required.

On the present soil map only two series are shown, namely:

Paya Megok Series (Bijat Family) - which is characterised by the fact that it is underlain by flat-bedded limestone (see Plate 2) and the Pendam Series, the orthotype of the Family. In the appendix more information is given on the characteristics of these series.

(d) Utilization. If occurring in upper river valleys the soils are mainly used for wet padi cultivation generally on a rotation basis. The use of this soil for such purposes depends largely on the possibility of keeping sufficient water on the land during the growing season. In many cases infrequent heavy rains cause havoc because of high flooding of long duration. In the dry season insufficient care is given to aerate the soils properly. Only in areas where drainage (and thus aeration and oxidation of iron compounds) is adequate, better yields are obtained. Yields are also dependent on natural fertility (and thus on the nature of the source material) but water control appears to be essential for making the most of the available potential. At the lower stretches of river courses wet padi is grown together with coconut for which proper drainage is essential. (See Plate 4). Unfortunately the growing of these two opposites - wet padi requiring inundation and coconut requiring drainage - too close to each other can be seen too often. Neither of the crops benefit from such a conflicting land use. At the lower stretches of river courses rubber is also grown on these soils but also here, drainage is often inadequate to ensure a good crop.

In the Nonok coastal area the Pendam soils are used for off-season crops in the dry season and good results are obtained. The problem here also is one of ensuring proper drainage.

The Low Humic Gley Soils are best utilised by growing wet padi and coconut. In places the growing of fodder crops, off-season crops and possibly rubber could be envisaged.

The potential of these soils has only been touched upon and the utilization of these soils could be greatly expanded. The greatest problem is however the provision of proper drainage which, for the present, appears to be impossible in many areas on economic grounds. The future of rice growing in Sarawak and the expansion of coconut growing is largely dependent on the amelioration of these soils.

5. Planosols.

(a) Genesis. In the way in which a great number of soil types with varying characteristics have been put together in this group the Planosols form a sort of dustbin in our classification. They comprise soils in which the textures vary widely and heavy clays can be found next to sands, soils with hydromorphic features are found next to soils which occur in well drained localities. They have however all one feature in common: they are all siliceous in nature, poor in iron and bases, very pale in colour and are probably all old alluvial deposits.

From the morphology of the terrain (flat to low gently undulating), the location of the soils (all below approximately the 100 ft. level) and the bisequent nature of many profiles (proved by analytical data, see Appendix) the following theory has been developed to explain the occurrence of these soils over such a wide area.

The original material is thought to be littoral in nature and deposited in shallow seawater. In many places, the basal layer appears to be clay, probably marine in nature. The upper layers are of varied textures ranging from silts to sands. After a fall in sea level this coastal basin emerged and eroding agents started to work on the material. Much of the original material (frequently silty) has been eroded, resorted and deposited again filling up old channels. Where the deposits overlie geological formations such as shale, sandstone, phyllite and chert, the material is frequently coarse in nature and higher lying.

These are probably remnants of old terraces. Similar deposits were mapped in the Lundu-Sematan areas where they occur relatively untouched by erosion.

Depending on the texture of the parent material and the locality some soils show podsolic features, while others are hydromorphic in nature. In most cases however, topsoils seem to overlie more dense, more compact and more clayey subsoils. This has formed the main consideration in placing these soils in the group of Planosols.

(b) Characteristics. Most soils have grey to greyish white sandy textured topsoil. In lowlying localities a raw organic matter layer frequently overlies the mineral soil. Below the top horizon more clayey horizons of pale yellow or white with yellow coloured mottles occur. In certain localities e.g. the Kuop area, near Kpg. Nangka and near Kpg. Tabuan deeper sandy deposits occur. At a depth ranging from two to sometimes over four feet compact clay or cemented silt layers occur. In other profiles this layer is formed by well-weathered black coloured carbonaceous phyllite. This compact layer causes perched watertables and hydromorphic conditions in the upper horizons. In more gently undulating topography, hydromorphic conditions are absent and the soils are better aerated. The mottles in the lower horizon are of a stronger yellow or orange colour and soft iron concretions may be present.

In one profile a true iron pan was found which had formed over the dense clay layer, representing a true Groundwater Laterite. The soil at this particular place (path Putong - 17th Mile bazaar) was characterised by unusually rich red colours and the material is thought to be partly derived from igneous intrusions which are common in that area. True Groundwater Laterites also occur in the material deposited in localities where limestone outcrops are prolific (20th mile and in the Chupak area, see plate 2). Here the iron accumulation layer is formed by pea-iron concretions which after erosion of the top layers is found distributed over the surface. This material is also exposed when drains are dug and the material is used for road surfacing.

Why pea iron concretions only form in these localities is still an unanswerable question. Mohr (Ref. 1) indicates that most probably the pH variations in these soils are greater and neutral conditions in the subsoils (the groundwater being rich in calcium carbonates) has caused the leached iron to precipitate in concentric layers around a nucleus of calcium carbonate.

In certain localities humus podsols have formed on the most sandy material one locality is at the 21st mile, the areas however, being small. Although these soils belong to another Soil Group it cannot be avoided that minor inclusions of other soil groups are mapped together with the Planosols.

(c) Classification. Only one Family was mapped, the Triboh Family. No subdivision of this Family has been attempted. Chemically the soils are characterised by a very low base content and almost an absence of iron. The material is mainly silica. Even the clay fraction consists in large measure of silica.

(d) Utilization. Several attempts have been made to utilise these soils. Rubber, for instance, was planted on a large scale beyond Pangkalan Kuop some 40 years ago. The remnants of this small estate (known as Kebun Kongsi) illustrate the poor fertility of the soil. Pepper cultivation on the somewhat better drained soil was attempted between 7th mile and Pangkalan Kuop. Most gardens are abandoned, the bare poles overgrown by shrubs and weeds symbolize the frustrations of many farmers who saw all their efforts wasted in an attempt to utilise these soils.

The only lucrative way of utilizing these soils appears to be the growing of vegetables which is a very intensive form of cultivation. The addition of both night-soil and compost turn the more sandy topsoils into an excellent vegetable garden soil. Vegetable growing is only possible in a limited way and depends on marketing facilities and demand. In conclusion the only possible way to make use of these soils is by intensive farming. Around townships this can be done by vegetable gardening, the growing of a number of fruit trees, raising of poultry and pigs. Such small-holdings can only survive if marketing is ensured, intensive farm methods are employed and above all if the farmer is of the right kind.

Triboh soils, if not too low-lying, form excellent building sites and industries could best be settled on these soils. No large scale agricultural development can be envisaged and the soils could better be left untouched until the potential of better soils has been fully exploited.

6. Half Bog Soils

(a) Genesis. Half Bog Soils are situated in river basins backing the Low Humic Gley Soils usually found along the river courses (see Plate 4). Towards the centres of the river basins the depth of the organic deposits increases and the Half Bog Soils grade into the Bog Soils.

(b) Characteristics. The Soils are continuously wet and the groundwater level is high throughout the year and frequently at the surface. The mucky or peaty top-horizons have a dark brown colour and in the case of muck consist of clay and silt mixed with much raw organic debris. In the case of peat the raw organic material is frequently as high as 90%. Subsoils are mainly gleyed clays but in certain localities such as the Samarahan area, sandy clays and sands occur. The chemical composition of the organic matter is varied but shows in general a low base status and high acidity. Although certain peat samples may show high figures in the analytical data for phosphate, it should be realised that per soil volume phosphate is in low supply.

It is impossible to judge the chemical fertility of peats and mucks from analytical data because the values are expressed in percentage of weight of dry samples. The bulk density of these soils is however so low that any comparison drawn between the chemical values of peat and mineral soil will be misleading unless bulk densities are known. Even then the true meaning of such analyses can only be understood if agronomic data is available.

(c) Classification. Only one family was mapped, namely the Mukah Family which comprises Half Bog Soils with clay subsoils free of soluble salts. Although in some places sandy textured subsoils were encountered their area is too insignificant in size for separate mapping into another Family. Small inclusions of other Families in the Half Bog Soils are therefore included in the area mapped as Mukah Family.

(d) Utilization. At present Half Bog Soils are intensively used in the Nonok Coastal Area where they are reclaimed by an intensive drainage system. This results in mineralization and oxidation of the organic matter and consequently the surface level will drop after which drains need to be deepened. Because of their location and the high groundwater which is fed by the groundwater stored in the raised bogs, proper drainage of these soils is very problematic. The soils in the Nonok area are mainly used for coconut but because of the bad drainage conditions coconut never shows a good stand. In other localities wet padi is grown if the organic topsoil is not too deep. Good results are obtained if water control can be ensured.

As is the case with the Low Humic Gley Soils, drainage appears to be the main obstacle in utilizing the Half Bog Soils and unless this is done properly farming on these soils will never be a sound economic proposition. Possibly the growing of annual crops in the dry season when groundwater is lower is preferable to the growing of perennials. The latter can however be grown successfully once proper drainage has been provided. Possible perennial crops include coffee, citrus, bananas and coconut. Although the fertility after reclamation appears to be initially high, once the organic matter has oxidised the fertility rapidly declines and fertilizers are needed to sustain moderate crop yields.

7. Bog Soils

(a) Genesis. Bog Soils occupy most of the river basins existing between the lower stretches of large rivers (see plate 4). Smaller areas of Bog Soils are found in the Sarawak River delta and in blocked off small inferior river valleys, the latter occur mainly along the Kedup and Kayan Rivers where levees built up by the main river have caused partial blocking of certain side streams.

If sufficiently large in area the peat soils form raised bogs, the lowest points being near the river courses where Bog Soils grades into Half Bogs and Low Humic Gleys, while the highest points are found in the centre of the swamp. Acentric raised bogs can be found in areas where much of the original peat swamp has been eroded by a meandering stream and in such cases the centre of the bog may be near the river. If two centres occur in one large river basin as is the case with the large bog swamp backing the Nonok Coastal Area, a former river course may have separated the two.

Bog Soils are formed in a continuously wet and acid environment. The wet environment prevents the total mineralization and oxidation of raw organic material, while the acid environment supposedly prevents the development of sufficient anaerobic bacteria. Subsequent layers of organic debris of forest generations maintain the high groundwater level through absorbing surplus rain-water like a sponge. Subsequent forest generations live mainly on the decomposed remnants of previous forest generations.

(b) Characteristics. Bog Soils are characterised by deep (more than 3 feet) organic deposits of in general a woody character. Layers of a more leafy composition can sometimes be noticed between layers of a woody consistency. The bulk of the material is, however, water. Bog Soils are underlain by sands or clays, the latter being dominant. In the surveyed area very little sand was found unless the bogs border sandy old alluvial deposits. Chemically the composition of peats is varied. The reader is referred to the Half Bog Soils for more details.

(c) Classification. Only one Family was mapped namely the Anderson Family which is characterised by deposits with an organic matter content of more than 60% and having a thickness of more than 3 feet. The deposits are free of soluble salts.

The main series in the Anderson Family is the Anderson Series, the orthotype of the family, and three depth phases have been distinguished, namely:-

Anderson 1 - organic deposits 3 to 6 feet deep
Anderson 2 - organic deposits 6 to 10 feet deep.
Anderson 3 - organic deposits deeper than 10 feet.

From the soil map it appears that the Anderson 3 forms far the greatest area mapped in the group of Bog Soils.

(d) Utilization. Anderson soils have so far only been used for agriculture on a large scale in the Nonok Coastal Area. The results prove that in the long run Bog Soils of this nature cannot be utilized with advantage if water control cannot be kept in hand. The soils can initially be drained by digging ditches but they should be deepened frequently because of subsidence of the surface level. Also, if very woody peat is concerned initial drainage may be followed by a subsidence of the surface level of several feet due to consolidation. The drained raised bogs appear to be fertile in the initial years of reclamation but fertility declines rapidly once the organic matter has oxidised. The organic deposits do not form a good anchorage for perennial crops such as coconut and rubber and the cultivation of these crops should be avoided.

It appears that although the raised bogs can be utilised providing proper drainage can be ensured, ultimately the peats will disappear as a result of oxidation, shrinkage, renewed drainage etc. The life time of these peats if used for agriculture cannot be predicted for certain but on average the surface level drops by 1 to 2 inches per year.

8. Mountain Peat Soils

This is a provisional group in which have been placed peat soils found to occur on limestone mountains and which do not belong to Bog Soils. They are found in local hollows such as occur on steep limestone mountains where organic debris accumulates (see plate 2). In certain localities the mineral content of the soil is high while in others it is totally lacking. This may depend on the occurance of sedimentary rocks or veins of volcanic rock types in the limestone. The soils have not been mapped separately partly because they occur only in small localised areas, partly because they are of little agricultural significance. The character of these soils has not yet been studied sufficiently to explain their formation.

They are mapped together with bare limestone in the Bau Association shown on the soil map.

9. Tropical Podsols

(a) Genesis. This is another group of soils which does not occur in the original scheme by Thorp and Smith. Podsols belong typically to the temperate regions but more and more evidence is accumulating that they occur also typically in the tropics on certain parent materials, namely very sandy siliceous consolidated or unconsolidated material.

In the area Tropical podsols are represented by true Humus Podsols formed on sandy siliceous material, this can be either old alluvium or Tertiary sandstones. In both cases a more or less flat topography is essential for the formation of these soils. It is suggested that these podsols are not primarily a reflection of a special climate neither has vegetation played the major role in their formation. In all cases the parent material is characterised by a very poor base status owing to which normal lowland Dipterocarp forest could not develop. The development of a sort of heath vegetation on these podsols is primarily caused by this poor base status; the acid litter of the heath vegetation may afterwards have played an important role in causing the formation of the podsolic Humus B horizon.

Apart from the humus podsols, also soils with podsolic features such as bleached A2 horizons, and very pale colours (almost pure white kaolin soils) were put in this class because it was impossible to place them in any of the other soil groups on account of other features.

This soil group is therefore heterogeneous in character having the humus podsols with compact humus pans as the one extreme while the other extreme may be formed by a deep white clay soil in which no development of humus pans has taken place. Subdivisions in this group are however made at a family level.

(b) Characteristics.

The Humus podsols are characterised by a dark humic topsoil almost peaty in appearance overlying almost pure white sands to silty sands. This bleached A2 horizon may be several feet deep but if Tertiary sandstone is the parent-material the A2 is very thin and often not deeper than a few inches. The A2 overlies abruptly a dark coloured, compact, firm or friable humus stained B horizon. Underneath the humus B horizon a B/C horizon, densely mottled with yellow, grey and orange colours can be found. This material is grading into the unchanged old alluvium found underneath.

In the case of sandstones the C horizon is often found within a depth of one foot and the soils would on this account qualify for a place in the Skeletal soils. The podsolic features however have in such instance been used as diagnostic for a classification at the Great Soil Group level.

Other soils in this group only display a B horizon with humus staining. This is frequently the case with rather more heavier soils in which the humus cannot freely leach down. Soils on carbonaceous shales and/or sandstones have the following characteristics:-

The topsoil is a grey sandy loam which overlies a heavier textured pale yellow to white coloured A2 horizon which in its turn grades into a pale yellow, blocky structured, frequently brown or orange mottled, clay or sandy clay B horizon. In the extreme case the B horizon is totally white consisting of almost pure fire clays. The B horizon overlies a black coloured C horizon, the boundary being abrupt but irregular. Often a zone of quartz gravel occurs between the B and C and frequently continues into the C horizon. (See appendix.)

(c) Classification. Three families have been distinguished:

a. Miri family - comprising humus podsols and podsolic soils formed on old siliceous alluvium.

b. Bako family - comprising humus podsols and podsolic soils formed on quartzitic coarse sandstones.

c. Kerait family - podsolic soils formed on carbonaceous shales and/or sandstones displaying very pale colours but in which the Humus B horizon is not present.

No series have been mapped.

(d) Utilization. The humus podsols have little agricultural significance. On the soils with weakly developed humus B horizons sometimes rubber has been planted in the past. (e.g. Ridgeway Road, Kuching). The stunted growth of rubber is sufficient proof that this soil is not suitable for this crop.

The Bako soils are mostly under primary vegetation (Heath forest). The Kerait family contains the only soils which can be utilised to a limited extent. Rubber can be grown on these soils although the rate of growth is slow. Fertilization is therefore essential. They probably respond well to magnesium; analyses for these soils show a nil for available magnesium. (Magnesium is usually added to fertilizer mixtures for rubber in Malaya if grown on such soils). The topography of the Kerait family is however rather difficult and hand-made terracing is needed.

It follows that the agricultural potential of this soil-group is low and that limited use can only be made of the Kerait family.

10. Skeletal soils.

(a) Genesis. Skeletal Soils are undeveloped soils in which weathering rock is met at less than 1 foot depth from the surface. Usually a horizon of partially weathered material is found at a depth ranging from 1 to 3 feet which in its turn overlies hard bedrock.

Skeletal Soils are profilic on basic and acid igneous rocks types. These hard rocks usually do not show deep weathering and as they usually form steep high hills or mountains erosion appears to set a limit to soil development (see plate 1).

Skeletal Soils usually occur at slopes steeper than 35 degrees, if the parent material is hard. On soft consolidated material, skeletal soils only occur in the upper catchment areas of river courses. Presumably, at lower levels deep soils were formed during a period of peneplanation. The old peneplain is now strongly dissected showing deep soils near summits of hills while at the base of valleys skeletal soils may be found.

In places where the deep soils have been totally removed (frequently at levels between 20 and 50 feet) skeletal soils do occur also. Topography and type of parent rock therefore play the major role in the development of these soils.

(b) Characteristics. Topsoils of Skeletal Soils are very thin and frequently gravelly in nature (mixed with weathered parent rock). Colours depend on the type of parent material. If basic igneous in nature they are usually dark brown to weak red. If acid igneous rocks form the parent material, yellow colours are dominant. In the case of arkose strong red colours occur. Textures are usually clayey and only if coarse sandstones or granites form the parent material are sandy topsoils formed. Lower horizons (below 1 foot) show a mixture of partially weathered rock material in which clay formation can be observed. This heterogenous horizon may be thick or thin depending on nature of the rocks and steepness of the terrain.

Most Skeletal Soils if occurring on volcanic rocks prove to be more fertile than the fully developed soil types overlying the same parent materials.

Analyses on available nutrients fail to show much difference between the topsoils of undeveloped and developed soils. Probably leaching is already very strong even in the undeveloped soils. It is suggested that the great amount of unweathered material still forming part of the solum is the main source where plants obtain their nutrients. These nutrients may be taken up immediately after they are released.

Chemical characteristics are much dependent on the nature of the parent material and Skeletal Soils on basic igneous rocks are relatively richer in nutrients than those formed on shales and sandstones.

(c) Classification. Two main Families have been mapped:

Sedong Family - Skeletal Soils derived from igneous and metamorphosed rock types.

Kapit Family - Skeletal Soils derived from consolidated sedimentary rocks.

In the Sedong Family two series were mapped separately; the Sedong Series which is derived from basic igneous rocks and the Buri Series which is derived from acid igneous rock types. The subdivision at a series level is based mainly on chemical characteristics and on texture. The Buri Series has not yet been studied in detail. Particulars of the Sedong Series can be found in the Appendix.

In the area mapped as Skeletal Soils much bouldery and rocky land does occur, especially on the steepest slopes. Large areas have been mapped as associations of Skeletal Soils with the more developed related soil types because variations in slopes have in many instances caused a mixture occurrence of both Soil Groups and a separation would need detailed surveying on a much larger scale.

(d) Utilization. The Skeletal Soils are of little value for large scale development. The soils are too shallow and the terrain too difficult. The Sedong Family is however used for shifting cultivation if slopes are not too steep. Clearings on such soils accelerate erosion. Permanent cultivation is only possible on less steep slopes and a permanent soil cover should be established. Possibly perennial crops could be established on the Sedong Series with advantage if attention is given to soil conservation measures and not too steep slopes (less than 35^{0}) are used. Such land can only be found in small localised areas and the majority of the land is therefore unsuitable for large scale development.

11. Regosols.

(a) Genesis. Regosols are undeveloped soils on coarse unconsolidated parent materials. In the survey area they comprise fine sandy marine deposits and coarse gravelly, old (possibly riverine) alluvium.

The marine deposits form a very small area of fine sandy material forming a number of small low ridges in the western part of the Nonok area and near Beliong. The deposits are of a recent nature and time has been insufficiently long to allow much soil development.

The old coarse gravelly riverine deposits occurring near Kuching are very quartzitic in nature. This very hard and chemically quite inert material does not permit soil development and the materials remain virtually unchanged since the time it was deposited.

(b) Characteristics. The marine deposits in the coastal area are light greyish brown, fine sandy soils overlying sandy clays to clays. The depth to the clay horizon varies. On the top of the ridges the sand deposits are deepest while they become increasingly thinner at the bottom of the ridge where they grade into Low Humic Gley Soils.

Hydromorphic features are weakly expressed in places where the clay is found at shallow depth and where perched watertables are allowed to form.

The old riverine deposits are coarse sandy to gravelly in nature. They are deep (more than 4 feet), white to very pale yellow in colour. Most of this material is dry after a couple of days of dry weather. Chemically the marine deposits are richer than the old riverine deposits, the latter being almost neutral in reaction because of the low buffer capacity of the material.

(c) Classification. The sandy recent marine deposits are placed in the Tatau Family of which only the Tatau Series, the orthotype of the family, occurs in the area. The old riverine deposits are placed in the Gaya Family. No sub-division at a series level has been attempted within the latter. Because of the insignificant agricultural value of these soils further details have been omitted from this report.

(d) Utilization. The Tatau Family soils are partly in use for the cultivation of coconut and providing drainage is adequate they are suitable for this crop. Most of the land is however used as kampong sites because these ridges form the highest points in an area which is liable to inundation during the landas season.

The Gaya Family soils are unsuitable for agriculture. Some of them are used for fruit trees and much fertilizer is needed to keep them alive. The Gaya soils are also used as gravel pits.

12. Recent Alluvial Soils.

(a) Genesis. Recent Alluvials comprise all alluvial soils of a medium to fine textured character which show a weak profile development or none at all.

This Group of Soils is normally situated above normal flood-level in rivers and is only inundated for very short periods when rivers are in high flood during the wet season. Their distribution is therefore restricted to the upper stretches of main river courses or to valleys and basins more in the interior where rivers have deposited their heavy load in some quantity. Frequently such areas are located at the foot of igneous rock massifs where they resemble alluvial fans (see plate 1).

The recent nature of these deposits (they are still slowly accumulating) is the reason that very little soil development has taken place. A weak displacement of iron can sometimes be noticed if the material is iron-rich (basic igneous rock derived) while in fine textured deposits weak hydromorphic features can be noticed.

(b) Characteristics. Characteristics vary widely and are much dependent on the source of the material. If sandstones form a large part of the catchment area of a river the recent alluvials are sandy, frequently building up levees along main river courses, or they are found covering small valleys alongside the upper stretches of rivers. The sandy soils are chemically the poorest. Colours in these sandy soils range from yellowish bro to pale yellow. Frequently in the levees, coarse-textured deposits may alternate with more fine-textured deposits which interrupt water movement in the profile. This causes a weak mottling in the fine-textured horizons.

Fine-textured soils such as loams and clays are dominant in the area because the occurrence of coarse sandstones is not widespread. The fine-textu soils have derived either solely from basic igneous rocks or from fine-textured sedimentary rocks such as fine sandstones and shales. Many recent alluvials are also derived from a mixture of these parent materials. The basic igneous rock derived alluviums are of a strong brown to yellowish-red colour. Freque part of this material is eroded Tarat Family soil redeposited again in the flood-plain. Near the foot of the mountains these soils tend to be gravelly. The deposits are deep, and weak hydromorphic features may only be found below a d of 3 feet. Chemically these soils are richer than their residual counterparts. The acidity is low (pH 5 to 6).

The soils of mixed origin are somewhat lighter in colour, yellowish bro to light brown and hydromorphic conditions such as weak grey and red mottling in the lower horizons occur more frequently. Possibly they are located in som what lower lying areas and groundwater is higher. They are also located farthe downriver than the pure basic igneous derived soils. Chemically they are poore than the basic igneous rock derived soils but they are still counted among the so of which the fertility is moderate to high for Sarawak.

The purely sedimentary rock derived soils (shales and related rock type such as arkose, tuffaceous shales and mudstones) resemble the alluvial soils of mixed origin and the only possible way to distinguish between them is to compar the analytical data. Also knowledge of the parent material in the catchment areas of streams may be of help.

(c) Classification. The area of Recent Alluvials is not very great but because of their great value for agriculture, they have received more attention then would otherwise have been the case. A great number of series have been established. It is however very difficult to map them because of the great variation in chemical characteristics.

For the purpose of this map the great variety of soils were placed into two Families:

Malang Family. Recent alluvials of a fine-textured nature. They comprise the loamy and clay soils derived from either basic igneous rocks or are of a mixed origin.

Semilajau Family. recent alluvium of a medium-textured nature. They comprise the soils derived from coarse sandstones mainly.
In the Appendix analytical data is given on four profiles derived respectively from basic igneous rocks (coarse and fine textured), mixed parent material, and sandstone with shale. It should however be emphasised that even within these series the chemical values may vary considerably and the chemical data is only given to illustrate the difference.

(d) Utilization. For the last 50 years the Recent Alluvials have formed one of the most important Soil Groups for the local population as it has provided virtually all the cash income of these people. The soils are used for a variety of crops, rubber being the most important one. Bananas, citrus, coffee, vegetables, sugar-cane and even tobacco are all doing well on these soils, the Malang Family soil being better than the Semilajau. The main problem in utilizing these soils is the frequent floodings which may occur during the wet season. They are therefore unsuitable for crops with low resistance to floods.

The occurrence of these soils is especially important in areas earmarked for large scale development for which new settlement are envisaged. They can provide the villagers with a handsome income from a variety of orchard and garden crops. The utilization of these soils is a smallholders affair and every effort should be made to exploit the potential of these soils where possible.

Only in locations where large areas of these soils occur, e.g. at the foot of igneous rock massifs in the Serian Area, near Kpg. Kuop, near Kpg. Simboh-Sikog and in the Terbat-Bunan area development on a larger scale is possible. The planting of cocoa on the better soils in the Malang family may prove to be a possible new step in utilizing these soils, but firm recommendations must await the result of trials currently planned by the Department. The growing of coffee could be another possibility, while fruit trees and bananas are crops which can be recommended forthwith.

4. THE ASSOCIATIONS.

A number of Great Soil Groups occur in association with other Soil Groups. This is specifically so in areas where skeletal soils occur together with their more developed related soils. For the characteristics and utilization of these associations the reader is therefore referred to the descriptions given for the individual soil groups occurring in the Association. Colours denote the Great Soil Groups concerned.

Within a Great Soil Group two or more Families may occur in association. This is for instance the case where sandstones and shales occur in close succession and Nyalau and Merit soils are formed in association. For the characteristics and the utilization of such associations the reader is referred to t individual family descriptions given under the heading of the Great Soil Group to which they belong. The lettering denotes the families involved.

Only one Soil Association, namely the Bau Association has not been mentio in this report. This Association is for the greatest part bare limestone which for typically very steep hills or mountains and on which hardly any soil has formed, the limestone being of 99% calcium carbonate. However, in certain places remna of old alluvial deposits may occur in hollows (dolines) occurring in these limesto formations. Some limestone formations have dykes of acid and intermediate volcanic rocks running through them from which soil has formed. In other parts sandstone beds may occur mixed with the limestone. Also mountain peat soils as described under section 8 in this chapter, occur in scattered localities (see plate

All these soils together form the Bau Association for which it is impossibl to make any subdivision unless very detailed studies are made. However, the wh Bau Association is unsuitable for agriculture because of its most difficult terrain and it does not play a role if the agricultural development of this region is considered. The only significance of the Bau Association is that it provides an excellent source of fresh water which in many areas could be utilised at relatively little cost.

PART III

CONCLUSIONS

1. Summary of conclusions.

Conclusions already reached in the text of the report are brought together in this section.

a. The present road communications are mainly of use for the interior areas because along the coast and between the main river valleys swamps do not allow the building of roads and communications are mainly maintained by boat. From the soil map it is evident why road communications in the present floodplain will be extremely difficult to provide. This will appear to be a major stumbling block for development in this area.

b. The flood problem, which is a serious limitation to agricultural development in certain areas, cannot be solved by artificial means. It is caused by topographic factors which cannot be altered at economic costs. The cutting of meander bends in main rivers may have a local effect, but would not remedy back-flooding in interior valleys if this is due to the tidal effect in the main rivers. In most areas the only possible way to prevent land from being flooded is the polder system involving building of bunds and installing of pumps sothat flood water can be kept out. Storage of surplus rainwater during the 'landas' season in interior valleys by the constructing of dams is out of question.

In the low lying regions, (the present flood plain), lack of communications and the danger of frequent flooding are the main limitations in utilizing the good land existing there. Both factors will be difficult to overcome, the provision of proper communications being very expensive, while the flood risk is a natural calamity which can only be kept within certain limits in localised areas.

c. The former creation of mixed zone land along the main roads has caused a ribbon development and good soils are utilized next to very bad soils, because of the non-availability of other land to the occupants. Much of this land can only be used if very intensive farming methods are employed and the results obtained on such farmland should not be used as a gauge for the usefulness of these soil types for agriculture. Apart from the great efficiency of the Chinese farmer cultivating such soils, the favourable location alongside the road and near a large market (Kuching) made market gardening possible on an otherwise unfavourable soil.

d. Potentiality of Soils.

The Lateritic soils, (marked in red on the soils map) comprising both Tarat (Ta) and Antayan (An) Families, form an excellent medium for plant growth because of their physical characteristics mainly. The nutrient status is however low and additions of the major nutrients, especially phosphate, will be a necessity to maintain high yields of commercial crops. The soils are suitable for rubber, pepper and citrus.

The topography is in general unfavourable for intensive development, the soils occurring together with skeletal soils on steep slopes of mountains. Unless a sufficient acreage of such soils can be found at the foothills generally surrounding these mountains, the soils can only be utilized by smallholders having their holdings scattered in selected locations. The Lateritic soils are therefore in general unfit for large block development and should be developed by means of individual assistance such as R.P.S. "A" schemes.

2. Red-Yellow Podsolic soils.

Red-Yellow Podsolic soils (shown in orange) form the bulk of the dry-land soils in the area. Their physical characteristics are not so favourable as those of the Lateritic soils, (see 1 in this section) and they are equally poor in plant nutrients. On certain families of this group, phosphate fixation may be much less than in the Lateritic soils. This may be specifically so in the Nyalau, Matang and Sabangan family soils which are in general more sandy than the remaining families.

The topography of the Red-Yellow Podsolics varies and no general conclusion can be drawn. However, the Matang family in the area can be counted as unsuitable for large scale development because of bad topography.

The Serin series in the Abok family could be intensively developed, but most of the topography is difficult for 'block' development and an individual approach in utilizing these soils should be followed for most of the area. For this series small rubber gardens, together with pepper cultivation, seems to be the best way to utilize these otherwise reasonably good soils.

In general the Abok family soils occur on steeper land than the other families and although they are perhaps superior to the other series as far as fertility is concerned 'block' development is not recommended.

The bulk of the Red-Yellow Podsolics (Nyalau, Merit, Semongok, and Sabangan family soils) form the greatest reserve of land suitable for rubber growing. Most of these soils are at present used for shifting cultivation and any future expansion in the growing of rubber will have to be realised by developi[ng] and utilizing these soils.

The prospects for oil palm development on the Red-Yellow podsolics in th[e] area are meagre mainly because the topography is generally too dissected and even the most favourable topography in this area would at present be classified as only marginal for the purpose of oil palm cultivation. Until more is known about the economic limitation of unfavourable topography in an oil palm estate, stated in concrete terms, no recommendations can be given as to the usefulness of these soils for such purposes.

3. Saline soils, (areas shown in dark green), occur widespread in the Sarawak river delta. At present little use can be made of this soil group because of the high salt contents, which are harmful for crops. They are, however, potentially good soils and cultivable once they are reclaimed and brought beyond the influence of saltwater infiltration. Such amelioration is, however, expensive. Small schemes can be envisaged although the danger of flooding and salt infiltrati[on] will be a recurring limitation and influence crop yields if only half measures are taken. The alternative, however, will be very costly amelioration schemes, involving bunding of areas and possibly pumping out of surplus water, measures which are thought to be uneconomic in the present circumstances.

The bulk of these soils is therefore, for the present, regarded as unsuitable for agriculture until reclamation becomes justifiable.

4. Low Humic Gley Soils, (shown in light green), are most important in the present flood plain. The future of wet padi cultivation and coconut planting depends largely on the improvement and utilization of these soils.

If occurring in interior valleys or in the upper stretches of main river valleys, wet padi cultivation in rotation with the growing of annual crops such as groundnuts, soya beans, maize etc. appears to be at present the most efficient utilization. It would perhaps be advantageous to create pastures in some areas to improve crop rotation systems.

An efficient water control is essential if wet padi is to be grown in an economic way. Improvements in the drainage and, if possible, irrigation systems are essential.

In the middle and lower stretches of main river valleys, the Low Humic Gleys could best be used for coconut and wet padi and possibly for bananas and coffee. The cultivation of dry land crops together with wet padi should be avoided. Such a conflicting land use endangers the existence of both crop types and schemes should be designed in such a way that irrigation of one crop does not create drainage problems for the others.

Also here drainage is necessary for a proper utilization of these soils. Because of the difficult location of these soils, (long narrow stretches along meandering rivers and backed by peat swamps), many small drainage and irrigation schemes will be needed to make most of the potential. At present much of this land is misused for wet padi cultivation on a rotation basis and if this land could be developed there would be room for many more farmers and if all the existing land could be cropped yearly there would remain little of the present rice shortage.

As can be seen from the soils map the Low Humic Gley soils occur more extensively along the Samarahan river than along the Sadong river, where the strip of soil along the river is generally very narrow. A concentration of development on these soils occurring downstream of 27th mile up to Muara Tuang, would add a great expanse of cultivable land and the population then could be much increased.

The growing of rubber on the Low Humic Gley soils should be discouraged as there appears to be sufficient soil potential for this crop in the interior and these soils should be reserved for crops which cannot be grown in the interior and which are essential for a diversification in agriculture.

5. Planosols, (shown in grey on the soil map), have very low potential for agriculture. Certain soils in this group could be utilized with efficient and intensive farming methods which cannot be employed for the whole area. Therefore, although certain smallholders can raise a substantial income on these soils because of other favourable conditions such as availability of compost and cattle manure, the nearness of a market for fruit and vegetables for the present the Planosols are regarded as unsuitable for large scale development. If favourably situated these soils should be reserved for industrial land or building sites, thereby avoiding the waste of good agricultural land for such purposes.

6. Half Bog Soils, (shown in blue), occur in the present flood plain and form a transitional belt between the Low Humic Gley Soils and the true Bog or peat soils occupying the extensive river basins.

Present cultivation has in most riverine areas come to a halt on these soils, because they were found too difficult to drain. Only in the Nonok Coastal area serious attempts have been made to reclaim them properly and to utilize them. The Half Bog Soils can only be used if proper drainage can be provided. Draining these soils is in general more difficult than is the case with the Low Humic Gley soils, mainly so because of their position between the swamps and the riverine levees.

If drainage can be provided they are suitable for the same crops as recommended for the Low Humic Gleys. Their potential is at present regarded as marginal because of the serious drainage problem, they could however be included in one scheme with the Low Humic Gley soils if this is topographically possible.

7. Bog Soils, (shown with intermittent horizontal lines on the soil map), occupy extensive areas in the river basins and their usefulness for agriculture is a controversial subject. They have been drained and are used in the Nonok Coastal area and although the results appear to be reasonable at present there are many indications that the utilization of Bog Soils as occurring in the area is only of temporary nature. Because of subsidence, drainage difficulties will ultimately destroy agriculture on these soils unless means are found to pump out ground-water from the basins which will form once the peat has subsided beyond a level at which drainage by gravity becomes impossible. How long its agricultural life will last is a debatable point.

For the present they are regarded as unsuitable for agriculture although they may be profitably cultivated for a number of years.

8. The Podsolic soils and Podsols, (shown in brown), are of little importance because of their small area. Because of their very poor fertility status they are unsuitable for agriculture. If found in suitable locations they can be used for siting industries or buildings.

9. The Skeletal soils, (shown in large dots), are of little agricultural importance because of shallowness of soil and bad topography. For large scale development they should be discarded although small holders may be able to establish good vegetable gardens on them.

In certain areas, specifically where the Sedong family is found, the growing of fruit trees, and in general tree crops, is a possibility. The establishment of gardens on these rocky soils is very difficult and has to remain a small holders affair.

14. The Regosols, (shown in small dots), are, for the majority, unsuitable for agriculture and because of their small acreage in the area they play no role in agricultural development.

15. The Recent alluvials, (shown in yellow), form only a minor part of the area, but are nevertheless important for agriculture. Some of these soils, for instance the Malang Family, comprise the best soils to be found in the region and it is not surprising that a settled agricultural system had started on these soils. In the past rubber gardens were mostly established in such areas.

Although much of this valuable land is at present under settled cultivation, the rubber gardens are mostly of inferior quality and replanting should be encouraged. Apart from being admirably suitable for rubber growing, the soils can be used for a wide variety of crops depending on the chemical fertility of soils which varies widely.

If recent alluvials are found together with a sufficiently large acreage of other good soils, such as the Abok family of Red-Yellow Podsolic Soils or the Lateritic soils, such areas could play an important part in small scale development schemes.

In summarizing these points, it is clear:

that more drainage and if possible irrigation schemes are the most essential prerequisites for a proper utilization of potentially good land in the extensive riverine areas and that expansion of wet padi cultivation and coconut planting cannot be realised without such schemes.

that for large rubber planting schemes the Red-Yellow Podsolics with somewhat inferior fertility have to be utilised.

that the development of the best soils found in the area must be largely realised through either small schemes or through individual assistance to smallholders.

2. The Agricultural Potential Map.

This map has been prepared from evidence presented in this report and largely depicts the conclusions reached in the forgoing section.

In addition, data on land alienation up to the present date which has been provided by Lands and Surveys Department, has been incorporated.

The potentiality map must be seen as an interpretation of the soils map for purposes of regional agricultural development seen in the light of the present conditions.

While the soil map can stand on its own for a long time to come, because soils do not change overnight, interpretations are dependent on circumstantial factors such as economic trends, stage in development, present knowledge in the field of agriculture etc. If therefore, the same soil map is re-interpreted in say 25 years time, certain soils now regarded as marginal because of poor nutritional value, may be utilized because of the high price of certain crops or the low price of certain fertilizers.

It is mainly for this reason that a subdivision has been made in land unsuitable for agriculture on account of permanent features, such as rockiness and land unsuitable for agriculture on account of features which are at present thought to be beyond economic improvement.

Lastly, the reconnaissance nature of this map should be kept in view and the map should be used only for a preliminary selection of areas for development or in general for purposes connected with regional development. Thereafter more detailed information should be obtained on a larger scale.

The land classes distinguished on the map are defined below:-

I - Alienated land which potential has not been classified and which can be disregar for further regional planning.

II - Land with no agricultural potential or land which for the present has to be rega as having no potential

Subclass II.A - permanently unsuitable for agriculture because of very steep slope and/or rocky land.

Subclass II.B - land with very low potential for agriculture even when reclaimed (deep peats) and at present regarded as unsuitable for agriculture.

Subclass II.C - land with very low agricultural potential because of poor soil conditions, the amelioration of which is at present regarded as too costly. Recommended use: Industrial sites and the like.

III - Dry land with agricultural potential

Subclass III.a. - High potential for scattered small holdings only. Good soils, but difficult topography.

Subclass III.b. - High potential for small holdings and/or small development schemes, (wide crop choice). In general, areas with good soils and good topography, but of insufficiently large acreage for large development schemes, (1,000 acres and more).

Subclass III.c. - Moderate potential for small holdings and/or small development schemes. In general, areas with moderately good soils but difficult topography so that large schemes cannot be visualised, (main crops rubber and pepper).

Subclass III.d. - High potential for large development schemes and in general for small holdings. Land with moderately good soil conditions and moderately good topography. Main crop will be rubber.

Subclass III.e. - Low potential for large development schemes but with moderate potential for small holdings. Land with poor soils but reasonably good topography.

IV - Lowland with agricultural potential.

Subclass IV.a. - High potential, drainage is essential, but thought to be within the present possibilities. Main crops: wet padi, coconut, annuals, bananas, coffee.

Subclass IV.b. - Low potential, drainage essential but thought to be difficult and expensive. Small holders can at present raise crops on a subsistence level.

V. - Lowland generally regarded as unsuitable for agriculture in the present condition and for which the costs of amelioration is regarded as too high for large scheme development. Land which if reclaimed could be raised to the level of subclass IV A. In localised areas reclamation may be possible at economic costs.

M - Miscellaneous land categories - non classified. Too small in area or too complex in nature for further differentiating.

REFERENCES

1. Mohr, E.C.J. 1944. The soils of equatorial regions (translated by R.L. Pendleton). Ann Arbor

2. Wilford, G.E. 1955. The geology and mineral resources of the Kuching-Lundu area, West Sarawak. Brit. Borneo Geol. Survey memoir 3.

3. Haile, N.S. 1954. The geology and mineral resources of the Strap and Sadong valleys, West Sarawak. Brit. Borneo Geol. Survey Mem. 1

4. Thorp, J. and Smith, C.D. 1949. Higher categories of soil classification: order, suborder and great soil groups. Soil Sc., Vol. 67.

5. U.S. Soil Survey Staff, 1960. Soil Classification (7th Approximation) U.S. Dept. of Agriculture.

6. U.S. Soil Survey Staff, 1951 Soil Survey Manual. U.S. Dept. of Agriculture. Handbook No.18

7. Nyun, M.A. and McCaleb, S.B. 1955. The Reddish-Brown Lateritic Soils of the North Caroline Piedmont region - Soil Science 80 (27-41)

8. Harris S.A. 1963. On the classification of latosols and tropical brown earth of high rainfall areas. Soil Sc., Vol. 96.

9. Bailey, J.M. 1964. Chemical studies on surface soils in Semongok Agricultural Station and proposed extensions. (3rd part, Soil Survey Report 49/1). (Unpublished Government Report, Sarawak).

10. U.S. Salinity Bureau Staff, 1953. Diagnosis and improvement of saline and alkali soils.

Plate 1

Description.

A - Mountainous terrain (5th unit of physiographic map 3).
Parent material: Basic igneous rocks
Soils: An association of Lateritic and Skeletal soils, the Lateritic soils being of the Tarat family, the Skeletal soils being Sedong series soils.
Slopes: Mainly over 25^{o}, frequently over 35^{o}.

B - Strongly dissected, formerly peneplained, old mainland with inclusions of the floodplain along the streams. (4th and 2nd unit respectively of physiographic map 3)
Parent material: in 4th unit mainly arkose, in the area at bottom of plate shales and sandstones. In 2nd unit recent alluvials of basic igneous origin mainly.

C - Alluvial fan at debouching point of stream coming from A.
Soils: Coarse textured alluvial fan soils (Recent Alluvials).

Land Use

a. Cultivated hill padi fields.

b. Secondary vegetation between 1 and approximately 10 years old.

c. Primary forest on rocky land and steepest slopes.

Location: square J/17-18 shown on soil map.

Plate I

TOPOGRAPHY AND LAND USE OF IGNEOUS ROCK MASSIFS

Photo copyright Land & Survey, Sarawak.

Plate 2.

Description.

A - Steep limestone formations (Bau Association on soil map) with almost vertical scarp slopes.

Vegetation: primary forest.

Soils: Mountain peat soils occur in pockets while near places where sandstone beds occur some shallow sandy soils have accumulated in hollows.

Locations marked as 'H' show large dolines in which soils of heterogenous material have frequently accumulated.

B - Steep sloping terrain consisting of limestone cliffs and/or coarse sandst frequently flanking the limestone. Mainly under primary forest.

C - Typical shale landscape, strongl y dissected with slopes varying betwee 15 to 30^{o}. The tops of the hills being almost all of the same elevati above the valley bottoms indicate former peneplanation.

Soils: Merit/Nyalau families (Red-Yellow Podsolics)

Land use: Shifting cultivation, at present mainly secondary forest.

D - Typical arkose landscape with Serin Series soil (Red-Yellow Podsolics) The landscape is similar to C but more dissected and slopes are steeper. In the top part of the plate some primary forest can still be seen, the remainder is under secondary forest.

E - Recent alluvium, riverine valleys with low undulating to almost flat topography. Vegetation is frequently primary with many fruit trees.

F - Present floodplain underlain by limestone.

Soils: Paya Megok series - Bijat family (Low Humic Gleys)
Most of the land is used for wet padi cultivation (white coloured). Darker patches are under secondary forest.

G - Remnants of terraces only a few feet above the level of the present floodplain.

Soils: Triboh family (Planosols) The land is not used and mainly under primary or old secondary forest.

Location: - square J/15-16 shown on soil map.

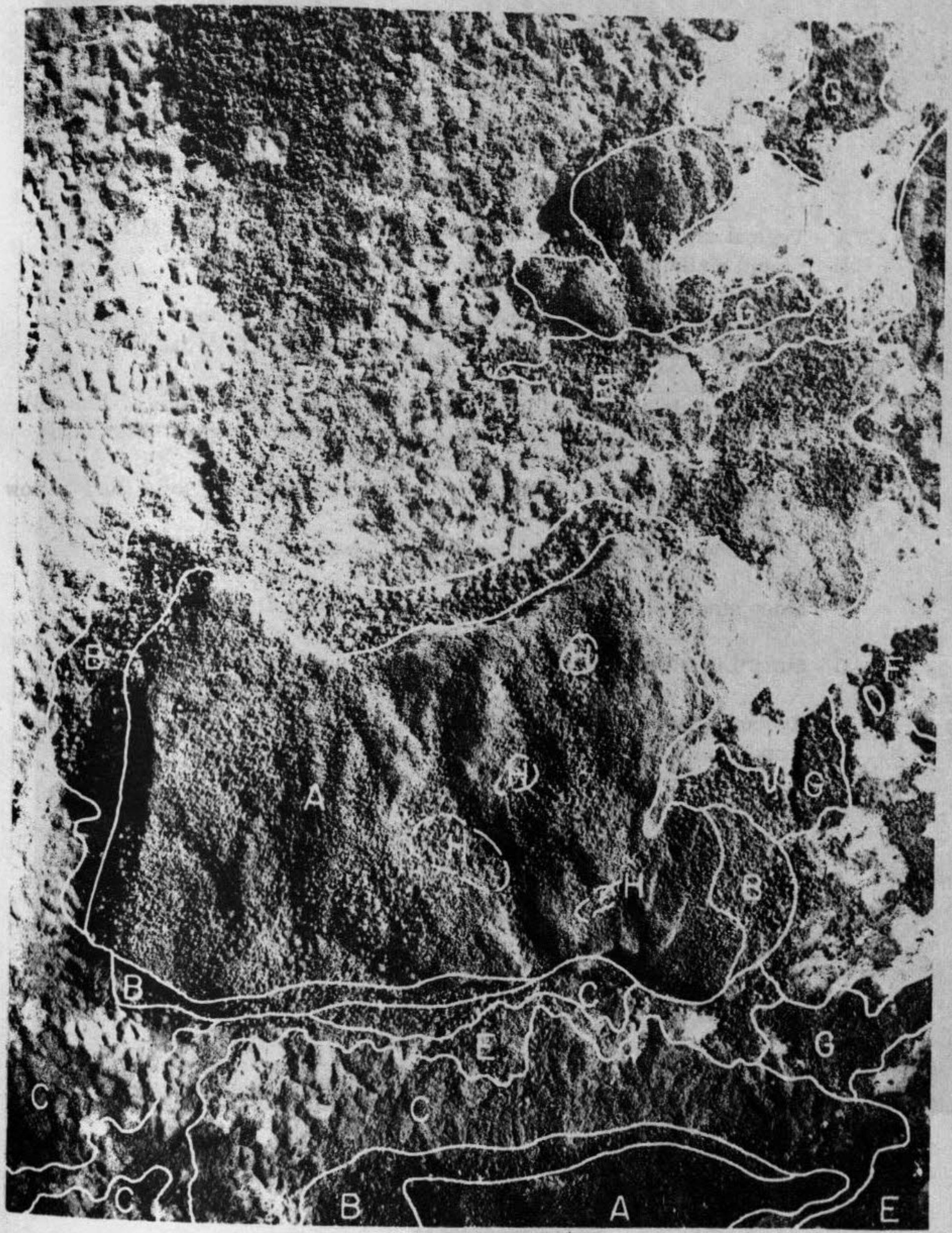


Plate 2

TOPOGAPHY AND LAND USE OF BAU ASSOCIATION, TRIBOH FAMILY, PAYA MEGOK AND SERIN SERIES.

Plate 3.

Description.

A - Typical arkose landscape in the dissected, formerly peneplained old main land. Slopes are steep between 20 to over 35°.
Soils: Serin series (Red-Yellow Podsolics)
Land Use: Shifting cultivation mainly. Secondary forest with patches of present hill padi fields showing up aswhite. (Marked 'G')

B - Typical shale and sandstone topography (in this case mainly shales (B1) and fine sandstones (B2). Hills are lower than in the arkose landscape and slopes are less steep, 15-25°.
Soils: Mainly Merit family soils, some Nyalau family soils (Red-Yellow Podsolics)
Land Use: Shifting cultivation mainly. Secondary vegetation.

C - Steep sloping coarse sandstone country flanking D.

D - Steep Limestone mountains. Primary forest mainly

E - Recent alluvium (Malang series), flat topography.
Land Use: Vegetable gardens, hill padi and settlements.

F - Intrusion of Acid Igneous rock types in the dissected, formerly peneplained, old mainland (4th unit of Physiographic map 3). The intrusions show sometimes up as somewhat higher hills with steeper slopes.

G - Hill padi fields

H - Village

Location: square E/15-16. shown on soil map.

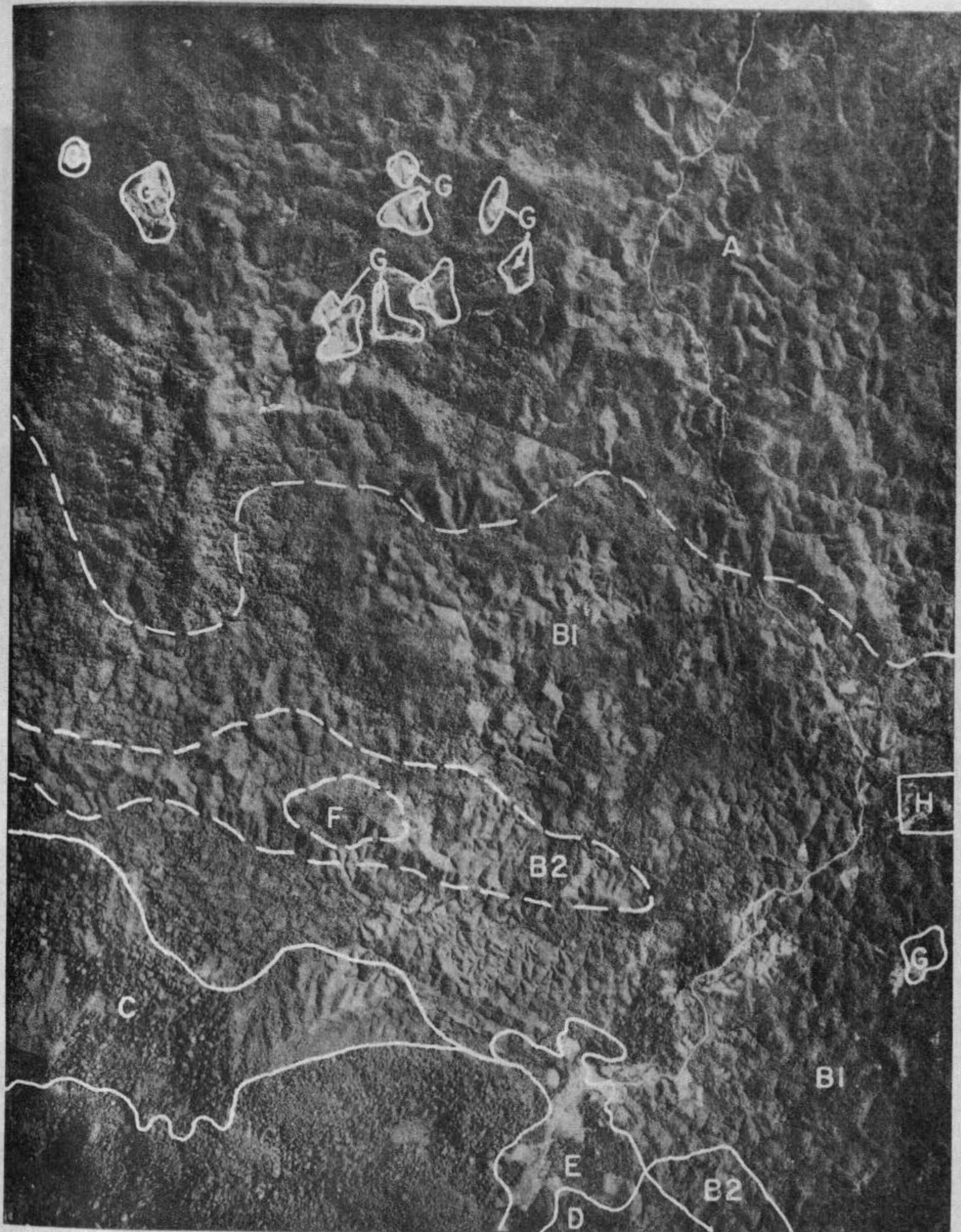


Plate 3

TOPOGRAPHY AND LAND USE OF ARKOSE-SHALE-SANDSTONE LANDSCAPE.

Plate 4.

Description

A - Domeshaped raised Bog backing levees along main rivercourse in the present floodplain (2nd unit physiographic map 3).
Soils: Deep Bog soils (more than 10 feet deep), Anderson Series phase 3.
Land Use: Apart from some minor clearings (G) where timber has been extracted the land is under primary forest.

B - Remnants of old terraces in the middle of a raised Bog. The vegetation is a heath forest (note the higher density of trees and the small size of the crowns compared with the Lowland Peat Forest on A).
Soils: Mixed Bog Soils and Triboh family soils (Planosols) with inclusions of Tropical Podsols (Miri family)
Land Use: Under Primary forest.

C - The area marked as C comprises the clay levee soils with flat topography and the semi-bog soils with organic topsoils ranging from 6" to 36". Both soils are used for cultivating swamp padi mainly. Inclusions of deeper peat soils can be expected (see small areas marked A).
Soils: Mainly Low Humic Gley (Bijat family) adjacent to the river, grading into the Semi-Bog Soils (Mukah family)
Land use: Mainly wet padi cultivation in rotation. Some rubber is planted alongside the river.

D - Areas of Semi-Bog Soils mainly, not used for cultivation.
Vegetation: Riperian forest (Riverine forest grading into peat forest).

E - Conspicuous steep hills protuding out of the present floodplain.
Soils: Serin Series (Red-Yellow Podsolics)
Land Use: Shifting cultivation and rubber.

F - Remnants of terraces. Low, undulating terrain.
Soils: Mainly Triboh (Planosols) and inclusions of Sabangang family (Red-Yellow Podsolics)
Land use: Partly under Primary forest, partly used for rubber.

G - small clearings in Peat Forest.

Location: Square N/15-16 shown on soil map.

Plate 4

TOPOGRAPHY AND LAND USE OF A RIVERINE BASIN

Photo copyright Land & Survey, Sarawak.

Plate 5.

Description.

A - Well developed Mixed Zone land in which pepper gardens and rubber gardens are profilic.
Population lives scatterred in dwellings on the cultivated land.

B - Native Area land, used for shifting cultivation mainly.
B_1: under secondary vegetation mainly, with some scatterred rubber gardens.
B_2: under old secondary and some primary vegetation
B_3: used for rubber mainly.
The population lives concentrated in villages (long-houses) of which one can be seen in the top right corner (V-village)

The land is mainly used for hill padi farming on a rotation basis although new rubber gardens have been established in recent years.

C - Forest Reserves, under primary forest (Lowland Dipterocarp forest)

D - swamp padi land in the Native Area.

R - some rubber gardens.

p - some pepper gardens. In general the pepper gardens show up as many small white patches.

Most of the area is formed by arkose (Serin series, Red-Yellow Podsolic soils) while the topography is that of the dissected, formerly peneplained, old main land (4th unit of physiographic map 3).

Location: Square I/14-15 shown on soil map.

Plate 5

RIBBON DEVELOPMENT IN MIXED ZONE LAND ALONG ROADS.

APPENDIX

Factual data on main soil series.

Note:

Descriptions of main soil groups such as Great Soil Groups and families are generalised and pit descriptions cannot be used to characterise such groups. Descriptions therefore concern series or phases of series characteristing the families in which they are classified. The fertility aspects cannot be discussed without having available field experimental data which is essential for a proper interpretation of the chemical analyses on soils.

It should be realised that much chemical data presented here is from single profiles and of indicative value only. Investigations carried out by the laboratory have proved that for most analytical investigations related to chemical fertility a great number of samples is needed to arrive at statistically reliable average values. (Ref. 9).

1. Lateritic soils

(i) Tarat family

The main series in this family is the Tarat Series.

TARAT SERIES (code number 1303)

RANGE OF CHARACTERISTICS.

1. Parent material: highly weathered basic igneous rocks, mainly basalts which have been partly serpentinised, chloritised and calcitised. Basalts, andesites and pyroxene - andesites.

2. Topography: The topography is varied but generally hilly to mountainous. Slopes range from 10^{o} to over 35^{o}. The steepness of slope influences soil depth while colluviation on foot slopes is a common feature.

The series commonly occurs between an elevation of 250 to 50 feet above sea-level, but can be found to an altitude of 2,000 feet.

3. Occurrence: The series is typically found in West Sarawak on basic igneous rock massifs, but small areas may occur elsewhere on similar parent rocks.

4. Diagnostic horizons: The series is characterised by 4 genetic horizons:

- Al - usually present under forest of grass cover.
- B - always present (undifferentiated)
- C - always present
- D - only found in the shallow phase but occurs often beyond augering depth.

A thin A_o horizon may sometimes have developed under primary forest but is rapidly destroyed once the soil is cultivated.

5. Colour: Colours are usually in the 5YR hue range and vary from reddish yellow (common) to yellowish red (infrequently). In certain localities hues in the 7.5YR range are found (usually strong) brown to reddish yellow. Topsoils, if organic matter is present, are usually strong brown, the subsoils being reddish yellow to yellowish red. Near the weathering parent rock in the C horizon strong red colours occur. Partly weathered parent rock is greenish in colour with black coatings along cleavage planes (probably manganese).

6. Texture: In general topsoils are clay loams while subsoils are clays.

7. Structure and consistency: The soils are fine crumby (when moist) to very fine angular blocky (when dry). When moist the soil is friable and easily workable, when dry the soil is firm to slightly hard. Subsoils when exposed have a granular appearance, but on rewetting the friability is quickly restored (self-mulching).

8. Drainage: The internal drainage is free and not empeded in any horizon. External drainage depends on topography but is generally rapid.

The soils are in general moist throughout the year but during a prolonged dry spell topsoils tend to dry out.

9. **Rooting:** Depends on the vegetation but under a forest cover large roots are generally found down to 3 or 4 feet. Most feeding roots are however concentrated in the top few inches which under any vegetation cover always has a very dense root system. Rooting depths are more related to availability of plant nutrients than to internal drainage.

10. **Phases:** Only depth phases have been classified. The normal phase is 3 to 4 feet deep, while in the shallow phase weathering parent rock is found within the top two feet. The shallow phase is often an eroded normal phase and has been described as such in some reports. Soils deeper than 4 feet are generally covered with soil material derived from upslope areas. Where this is poor subsoil material the phase is called 'buried' while in phases where gravelly basalt material is added to the topsoil it is termed a 'colluvial-influenced phase'. Phase differences occur in complex and no mapping at this level has yet been done.

11. Chemical and mineralogical features.

a. Clay minerals - kaolin dominant
b. Weatherable minerals - none in B and Al horizons. May be present in small amounts in C horizons.
c. Ore content: generally high in all horizons (possibly most of the sand fraction).
d. Silica/sesquioxide ratio's - between 2 and 3 in A horizon but less than 2 in B horizon. C horizon n.d.
e. Sesquioxides ratios (Fe_2O_3/Al_2O_3) - highest in B horizon (in 1 analysed profile 0.47.)
f. Cation Exchange Capacity: in subsoils generally lower than 10, in topsoils between 10 and 20 depending on organic matter content.
g. Base saturation: generally very low in all horizon but highest in Al horizon (seldom more than 20% but commonly below 10 under shifting cultivation).
h. Acidity: Topsoils pH 4 to 5
Subsoils pH 5 to 6 (frequently C horizon pH 6)
i. 'Reserve' cations in ppm: phosphate on average*
350 in topsoils and 200 in subsoils.
calcium: on average 100 in topsoils, 300 in subsoils.
magnesium: on average 1,000 in topsoils and subsoils.
potassium: on average 700 in topsoil, 600 in subsoil.

Characteristic are the high phosphate figures and the low potassium figures for Sarawak soils.

j. Group 3 elements: (Fe/Al oxides) - generally higher than 40% in all horizons, except D. Extractable Al. is highest in topsoils and extractable Fe. almost nil in all horizons.

---

* average figures are based on analyses of 11 profiles.

Typical profile

Soil Group: Reddish Brown Lateritic Soil

Family: Tarat

Series: Tarat

Phase: normal

Location: Simuja Pass, 1st Division.

Latitude: 1° 9' N

Longitude: 110° 36' E

Topography: on mountain

Site: middle slope

Slope: 30°

Parent Material: Highly weathered sheared basalt.

External drainage: rapid

Vegetation: Secondary, mainly bamboo species.

Altitude: 150 ft. above sea-level

Rainfall: 132" per year

Rainfall Class: I (Mohr)

Lab. Nos: 5220/5223

Field Nos: J87/90

Date sampled: 8/1961

½ - 0 inches	Rootmat with vegetative litter (not sampled)
0 - 2 "	Strong brown (7.5YR 5/8) clay loam, dry, crumby and friable. Well rooted (thin roots), some small weathered basalt pieces. Smooth gradual change to
2 - 15 "	Strong brown (7.5YR 5/8) clay, slightly moist, crumbly friable. Some red coloured weathering rock fragments. Some large roots. Gradual change to
15 - 29"	Strong brown (7.5YR 5/8) clay with increasing amounts of weathered rock fragments with 7.5R 3/6 dark red colour and clay texture. Moist. Few roots.
29 - 55+"	Weathered basalt. Mixed green coloured material still showing structure of rock and clayey dark red material.

(In road cutting it can be noticed that the last horizon (C) continues in places for more than 10 feet at which depth often limonite/haematite is coating the weathered rock fragments.)

(ii) Antayan Family

The second family in the Lateritic soils is the Antayan family occurring on intermediate to basic igneous rocks. The main series in this family is the Antayan series which has only been mapped separately in the 15th mile area. The series has the following properties:

ANTAYAN SERIES (code number 1302)

RANGE OF CHARACTERISTICS

1. Topography: Mountainous, with generally steep slopes ranging from 10 - 35^{o} and frequently steeper than that. The series commonly occurs between an elevation of 250 and 50 feet and depending on slopes (less than 35^{o}) it can be found to altitudes of 2,000 feet.

2. Occurrence: The series occurs typically in West Sarawak on basic igneous rock massifs but may also elsewhere occur under similar conditions and on similar parent material.

3. Diagnostic horizons:

Al - usually present and well developed
B - usually present, weakly developed (undifferentiated)
C - usually present at depths of 3 to 5 feet
D - generally not found within 5 feet.

A thin A_o horizon has developed under Primary Forest. It is quickly destroyed under shifting cultivation.

4. Colour: Colours are usually all in the 10YR hues. Topsoils are frequently brownish grey to dark brown while subsoils are yellowish brown to brownish yellow. Near the weathered parent rock reddish yellow colours may occur.

5. Texture: Topsoils tend to be more sandy than subsoils and they have a clay loam texture while subsoils are generally clays.

6. Structure and consistency: Topsoils are crumbly to fine subangular blocky while subsoils are generally subangular blocky. Structures in the later are well developed when dry. In moist condition top soils are friable but subsoils tend to become compact and massive. In dry conditions the soils are hard.

7. Drainage: The soils are usually moderately well drained but in locations having gentle slopes, the internal drainage appears to be slow and some weak mottles may be present. External drainage depends on relief but is generally rapid.

8. Rooting: Hair-roots are present to a depth of nearly three foot but roots are mainly confined to the top (Al horizon). Large roots occur in the B horizon when under a tree vegetation. Feeding roots are found concentrated at the surface.

9. Phases: No phase differences have yet been classified, but it is likely that shallow phases on steep slopes do occur. Colluvial influenced phases and buried phases are like-wise probably occurring in complex in mountainous areas.

10. Chemical and mineralogical features

a. Clay minerals: mainly kaolinite, limonite and to a lesser degree goethite are conspiceous.
b. Weatherable minerals: none in Al and B horizons.
c. Ore content: 90% opague in heavy mineral fraction. Light minerals mainly strongly decomposed rock fragments (kaolin?)
d. Silica/sesquioxide ratio's: between 1 and 2 in Al horizon, between 2 and 3 in B and C horizon.
e. Sesquioxides ratio's (Fe/Al): highest in Al horizon lowest in C, showing preferential leaching of aluminum.
f. Cation Exchange Capacity: depending on organic matter but generally more than 20 meq. in Al horizon. In general less than 10 in B and C horizons, rarely more than 15.
g. Base saturation: depending on organic matter content. In Al horizon generally slightly over 10% in B and C horizons less than 10%
h. Acidity: pH 4 - 4.5 in Al horizon, lower horizons (especially C). 5 - 5.5
i. 'Reserve' cations in ppm: phosphate on average* 330 in topsoil, in subsoil 175.
Calcium: on average 400 in topsoil and 275 in subsoil.
Magnesium: on average 800 in topsoil and 600 in subsoil.
Potassium: on average 1,500 in topsoil and 700 in subsoil.
Characteristic are the low potassium figures and the high phosphate figures. In general Antayan series displays the same chemical characteristics as the Tarat series but it shows somewhat lower figures for the chemical composition.
j. Group 3 elements (Iron and Al oxides): highest in subsoils and lowest in topsoils (latter 30 - 40%, former over 40%).
k. Extractable Al and Fe: Al far greater than Fe. In subsoils more than 800 for the former, iron less than 10 ppm. In topsoils near 600 for Al, more than 50 for Fe. This shows leaching of Al. or liberation of Al. in the lower horizons, already confirmed by the sesquioxide ratios.

---

* Average figures in this section are based on analyses of 8 profile.

TYPICAL PROFILE

Soil Group: Reddish-Brown Lateric or Yellow Latosol?

Family: Antayan

Series: Antayan

Phase: normal

Location: $14\frac{1}{2}$ mile Kuching-Simanggang road

Longitude: 110° 22'E

Topography: Low rounded hill

Site: middle slope

Slope: slope at pit less than 5°

Parent material: highly weathered basic igneous rocks (probably colluvial rubble)

External drainage: slow

Vegetation: Secondary forest, mainly bamboo and grasses.

Altitude: estimated less than 250' above sealevel

Rainfall: estimated 160-200 inches a year

Rainfall Class: I (Mohr)

Lab. Nos: 5786/5790

Field Nos: Not recorded

Date sampled: 9.61

0 - 3 inches	Light brownish grey (wet 10YR 5/2, dry 10YR 6/2) loam to clay loam. Dry. Crumbly to fine subangular blocky. Hard to very hard. Abundant fine to medium size roots. Gradual wavy change into
3 - 12 "	Very pale brown (wet 10YR 5/4, dry 10YR 7/4) clay loam to clay. Slightly moist. Few faint mottles, light grey to pale brownish. Massive in profile, subangular blocky when broken up. Firm to very firm . Common fine to medium roots. Small pieces of hard rock. Clear smooth change into
12 - 23"	Yellowish brown (wet 10YR 5/6, dry 10YR 7/4) clay. Moist. Subangular to angular blocky. Clay skins in few small cracks. Massive in profile. Few faint light grey to pale brownish mottles. Firm to very firm. Few medium size roots. Diffuse wavy change into
23 - 33"	Yellowish (wet 10YR 7/6, dry 10YR 8/6) clay. Moist. Massive in profile, angular blocky when broken up. Firm to very firm. Few faint reddish brown to pale yellow mottles. Common fine to very fine roots. Few small medium pieces of soft rock and tiny pieces of soft quartz. Gradual change to
33 - 48"	Yellow (wet 10YR 7/6, dry 10YR 8/6) clay. Moist. Massive in profile, slightly sticky and plastic. Prominant reddish brown mottles. Common small pieces of quartz. Few hair roots and an increasing number of hard, large, rounded and irregular shaped rock fragments.

2. Red-Yellow Podsolic soils

(i) Abok family

Of the Abok family only two series were mapped separately, namely the Serin series and the Bayur series.

Both series have not been sufficiently studied to give the whole range of characteristics. The following profiles are typical for the dominant phases.

SERIN SERIES (code number 2002)

Profile S 2192/95

0 - 4½ inches	Strong brown granular loam, friable, moist. A very thin more sandy layer is found at the surface. Well rooted, earthworms, diffuse irregular change to
4½ - 22 "	Reddish brown crumbly loam to clay loam, friable, well rooted, some quartz pieces, earthworms. Moist. Gradual, irregular change to
22 - 42 "	Weak red, weak subangular blocky sandy clay to gritty clay, firm. Moist. This horizon merges into weathering material, which is soft and earthly containing quartz pieces. Gradual wavy change to
42 - 68 "	Red, gritty to sandy clay, granular porous appearence. Weathering arkose. Few taproots at 62 inches.

Parent Material: Arkose

Vegetation: Old rubber, groundcover-ferns.

Topography: Steep hilly terrain.

Laboratory No.	Depth of sample in inches.	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2192	0 - 3	n.d.	230	130	743	1650	18.8
2193	7 - 20	n.d.	135	30	827	2000	22.8
2194	26 - 28	n.d.	87	130	899	2850	23.3
2195	50 - 68	n.d.	65	140	845	4050	24.1

BAYUR SERIES (code number 2001)

Bayur series, profile S2471

0 - 6 inches	Brown (10YR 5/4) crumbly fine sandy loam. Al horizon. Fine and medium roots, moist, gradual change to
6 - 17 "	Brownish yellow crumbly fine sandy clay loam. Fine and medium roots, few charcoal pieces, moist, gradual change to
17 - 28 "	Brownish yellow, crumbly to weak fine angular blocky, fine sandy clay, few fine roots. Quartz pieces few and fine, moist. Gradual smooth change to
28 - 40 "	Reddish yellow, angular blocky, fine sandy clay with abundant fine quartz pieces. Massive, moist. Gradual smooth change to
40 - 51 "	Reddish yellow fine sandy clay. Massive. Abundant quartz, fragments of red coloured weathered rock. Moist.

Parent material: Schist

Vegetation: Secondary forest, bamboo and scattered trees.

Topography: On top hill (50 - 60 feet high).

Analyses.

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2471	0 - 6	n.d.	65	100	1162	2900	8.82
2472	6 - 17	n.d.	28	130	1240	2400	11.36
2473	17 - 28	n.d.	16	100	1354	2900	12.96
2474	28 - 40	n.d.	9	50	1408	3200	13.86
2475	40 - 51	n.d.	11	100	1503	2900	20.08

(ii) Nyalau family

No separate series were mapped in the Nyalau Family. The family is more or less characterised by the following profile which is a Tebakang series, poor in reserve nutrients and low in Group 3 elements. The Tebakang series is dominant in the Nyalau family occurring in the Upper Sadong District.

Tebakang series, moderately well drained, profile S 1902/06 (code number 3601)

½ - inch rootmat

0 - 4 inches Grayish brown, weak crumbly sandy clay loam, friable, well rooted, abrupt change to

4 - 16 " Yellowish brown massive sandy clay loam, weak friable, weak gray mottling, moderately well rooted, gradual change to -

16 - 28 " Brownish yellow massive sandy clay loam, weak reddish yellow mottling becoming increasingly stronger with depth, no roots; on

28 - 47 " Brownish-yellow massive sandy clay with strong reddish-yellow mottles, no roots, quartz pieces in pockets, gradual change to

47 - ? " Reddish yellow strongly weathered sandstone with strong yellow mottling.

Parent material: Sandstone of Triassic age

Vegetation: near rubber garden, lallang and ferns

Topography: On gentle slope of low hill.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 1902	0 - 3	n.d.	180	200	1102	3750	6.3
1903	9 - 14	n.d.	170	1210	252	2950	3.7
1904	19 - 28	n.d.	110	80	1677	6750	8.7
1905	34 - 42	n.d.	100	90	1611	7750	11.9
1906	47 - 50	n.d.	95	70	1312	5800	11.2

(iii) Merit family

No separate series were mapped in this family. The following particulars are characteristic for the family in the Upper Sadong District where the soils in this family belong to the Bedup series.

Bedup series - Profile 5210/5214 (code number 3107)

1 - 0 inch	rootmat and layer of partly decomposed leaves.
0 - 7 inches	Yellowish brown (10YR 5/6), weak fine angular blocky clay loam, friable, weak organic staining, well rooted, dry gradually merging into
7 - 24 "	Yellow (10YR 7/8) hard and compact clay loam, weak fine red small mottles, some big roots, gradually merging into
24 - 48 "	Brownish-yellow (10YR 6/8) hard and compact clay, common reddish yellow (5YR 7/8) and weak grey mottles. Very small quartz particles (coarse sand size) present.
48 - 52 "	Brownish-yellow (10YR 6/8) massive and hard clay, commonly mottled reddish yellow and grey, with platy, hard iron concretions along structure planes of large peds and iron fillings of old root-channels
Below 52 "	Strongly reddish mottled yellow clay which merges at approximately 15 feet of depth into white grey clay with brown and red mottles.

Parent material: Triassic shales

Vegetation: Secondary forest

Topography; Low hilly terrain, near summit of hill.

No comparative analyses are available.

(iv) Semongok family

The most important series in this family is the ortho-type namely, the Semongok series which has been studied in detail.

General description.

The most commonly encountered profiles of this Series have the following characteristics.

0 - 3 to 8 inches	Dark greyish brown to brown fine sandy loam to clay loam, with possible distinct medium and fine light grey mottles. A medium subangular blocky or medium to fine granular structure may be weakly developed. Well rooted.
- 15 to 24 "	Yellow to reddish yellow (typically brownish yellow) clay loam to clay or fine sandy clay, with distinct to prominent, medium and fine light grey mottles. A medium or coarse subangular blocky structure may be weakly apparent when dry, rarely when moist. Poorly rooted. Possible inclusions are quartz stones, fragments of weathered shale and iron concretions; inclusions are rarely present and never more than few in number.
- 36 to 48 "	Colour as above, but often reddish-yellow rather than brownish-yellow in colour. Clay to fine sandy clay. Structure as above. Inclusions as above but fragments of weathered shale are often many, and in the shallow phase are dominant.
below 36 - 48"	Well-weathered grey or dark grey shale, sometimes with hard bands of iron accumulation along cleavage planes. Alternatively light grey heavily mottled clay or silty clay from weathered shale.

Range of characteristics

1. Parent material: Well-weathered Cretaceous rocks, dominantly shale. The lithology is, however, variable and profiles underlain by sandy shale, mudstone, shale with conglomerate or shale with sandstone have been grouped in this Series provided that the non-argillaceous parent rock is sufficiently limited in areal extent not to alter the character of the A and B horizons to a degree beyond the ranges described below. This particularly applies to texture.

2. Topography: From lower slopes to summits of gently to steeply rolling topography. Of the phase distinctions (described below) imperfectly drained (strongly mottled) profiles commonly occur downslope of and in less well-drained sites than imperfectly drained (weakly mottled) profiles. The shallow phase is typically encountered on the steepest portions of hill flanks (which may exceed 35^{o}). While these tendencies exist, however, there is little consistent correlation between profile characteristics and site within the range covered by the series. Weakly and strongly mottled profiles occupy positions in the relief with little or no regard to slope and the shallow phase is sometimes encountered on quite flat slope facets.

3. Occurrence: the series has been mapped in First and Second Division and is widespread where Cretaceous shales are present.

4. Diagnostic horizons: the series is characterised by the following genetic horizons:

A1 - variable in thickness and may be destroyed by cultivation
A2 - may be only weakly expressed and the transition to the B horizons is often gradual.
B - sometimes only weakly expressed in the field though distinct in the analytical data.
C - often beyond augering depth but shallow phases are common.

5. Colour: Matrix colours in the subsoil range from yellow to reddish-yellow, the most common colours being brownish-yellow and yellowish brown. Matrix colours above the C horizon appear to be invariably of Hue 10YR. The subsoil invariably has many distinct medium and/or fine (rarely coarse) mottles, usually grey or light grey in colour. In the surface soil mottles are usually present but are normal indistinct.

6. Texture: Topsoil texture is variable but surface textures lighter than sandy loam have not been recorded. Subsoil textures range from clay loam to clay above a depth of 24 inches and from fine sandy clay to clay below 24 inches. Where sandstone is intermixed with shale or mudstone in the parent rock fine sandy clays tend to occur; coarse sandy clays have not been recorded.

7. Structure and consistency: Coarse subangular blocky structure develops in the subsoil and, depending on past land use, a medium or coarse granular structure may develop in the surface soil. These features are only weakly expressed. They may not be apparent in the dry soil and are rarely apparent in the moist soil.

8. Drainage: Internal drainage is imperfect in most profiles seen, although much of the mottling is probably unconnected with groundwater drainage conditions. External drainage is moderate to rapid.

9. Rooting depth: The profile is porous in the upper subsoil but may be only slightly porous in the lower subsoil (below 24 inches). Below 6 inches roots and rootlets are generally few in number but they are usually present throughout the 0-48 inch profile, or, in the shallow phase, above the C horizon.

10. Phases: Two phase have so far been set up as mapping units; an imperfectly-drained phase and shallow phase. The imperfectly-drained phase shows a range of variation in the intensity of mottling and on the present soil map it has been possible to separate weakly mottled from strongly mottled profiles within this phase unit. In terms of agriculture it is not known how much significance should be attached to this distinction.

11. Chemical and mineralogical features.

Clay minerals: (from one profile) Kaolin dominant.
Small traces of limonite, goethite and carbonaceous matter.
(by D.T.A.)
Other mineralogical data: (from one profile) Heavy mineral site:-
zircon/tourmaline with secondary (?) anatase and rutile, 10 - 35% opaques; light mineral suite: - 50-80% quartz, bulk of remainder rock fragments; organic SiO_2 - not more than 2%, ore:- 1-11%.
Silica/sesquioxide ratios: No data.
Sesquioxide ratios: No data
Cation exchange capacity: 10-25, usually highest in the topsoil, but often rising again in the B horizon.

Base saturation: low in all horizons, greatest in the A1. Generally below 20 and often below 5 in the A2 and B horizons.

Acidity: Topsoil:- 3.0-4.5, subsoil: 3.5-5.0

'Reserve' Phosphorus in ppm: generally 100-250 in topsoil, 50-150 in subsoil.

'Reserve' cations in ppm:

Calcium - up to 700 in the topsoil (very variable),
50 - 200 in the subsoil

Magnesium - generally 1,000 - 2,000 in topsoil,
1,000 - 4,000 in subsoil

Potassium - generally 1,500 - 3,000 in topsoil,
2,000 - 5,000 in subsoil

Group III elements: 8-33% recorded, about 20% on average, never as high as 40%.

Remarks: The low P figures and high K figures are characteristic of the Series.

TYPICAL PROFILE

Soil Group: - Red-Yellow Podsolic

Family: Semongok

Series: SEMONGOK

Phase: Imperfectly drained, weakly mottled.

Location: Semongok Agricultural Station, near rentis 13, peg 10

Latitude: 1° 23' N

Longitude: 110° 20' E

Site: Summit of 20 ft. high hill on edge of alluvial flat

Slope: 1°

Parent material: Weathered Cretaceous shale.

External drainage: Medium to rapid

Vegetation/land Use: Grassland; Buffalo grazing area.

Altitude: c. 85 ft. above sea level

Rainfall: c. 160 inches (?)

Rainfall Class (Mohr): I

Lab. Nos: S2476 - S2480 and S2486

Field Nos: Al - 6

Date sampled: 17.7.63

0 - 4 inches	Light yellowish-brown (10YR 6/4) loam to clay loam, with many distinct fine and medium light-grey mottles. Rare rusty root channels. Moist. Weak medium subangular blocky structure, breaking easily to medium and fine granular. Slightly firm. Occasional rootlets. Porous. Distinct wavy boundary. (S2480).
4 - 12 "	Brownish-yellow (10YR 6/6) clay, with many faint fine light-grey mottles. Rare rusty root channels. Moist. Course subangular blocky structure, breaking to coarse granular. Firm. Occasional to rare rootlets. Porous. Distinct smooth boundary. (S2469)
12 - 22 "	Brownish-yellow (10YR 6/6) clay, with many faint fine and medium light-grey mottles. Moist. Very weakly coarse subangular blocky structure. Firm. Rare to very rare rootlets. Porous. Diffuse wavy boundary. (S2478).
22 - 30 "	Brownish-yellow (10YR 6/6) clay with abundant distinct fine and medium light-grey mottles and many distinct fine reddish-yellow mottles. Very rare rusty root channels. Moist. Weak medium subangular blocky structure. Firm. Very rare rootlets. Porous. Diffuse wavy boundary. (S2477)
30 - 44 "	Light grey (10YR 7/1) clay. Abundant rusty root channels. Wet. Slightly sticky. Slightly plastic. Very rare rootlets. Rare medium angular quartz gravel. Porous. Diffuse wavy boundary. (S2476).
44 - 55 "	Grey (7.5YR 5/0) clay, with many distinct fine reddish-yellow mottles. Wet. Structureless (weak coarse angular blocky structure when moist). Slightly sticky. Slightly plastic. No rootlets. Slightly porous. (S2486).

(v) Matang family

A typical profile is the ortho type, the Matang series.

MATANG SERIES - (code number 3201)

Profile 5775/5779.

1 - 0 inch	mat of dead leaves
2 - 0 inches	Humus containing abundant fine to medium roots, leaves in varying stages of decomposition.
0 - 4½ "	Pale brown (moist, 10YR 6/3, wet, 10YR 5/3, dry 10YR 6/3). Massive sandy loam with distinct common strong brown mottles towards bottom. Subangular blocky and crumbly when broken up. Moist, friable. Roots common coarse to fine. Clear undulating change to
4½ - 20 "	Pale yellow (moist 2.5Y 7/4, wet and dry 10YR 6/3) Massive clay loam to sandy clay loam with greyish brown (10YR 5/2) mottles common and diffuse; also pale brownish patches coming from horizon above. Few coarse and medium roots. Few spots of charcoal. Diffuse change to
20 - 41 "	Yellow (Wet 2.5Y 7/6, dry 2.5Y 8/4). Massive sandy clay loam with few distinct to prominent white and distinct, abundant, light grey and brownish yellow mottles. Subangular blocky when broken up. Moist to very moist. Firm, slightly sticky. Diffuse change to
41 - 52+"	As above with common white and strong brown mottles in addition. Massive in profile. Subangular to angular blocky when broken up. Moist to very moist. Firm, slightly sticky and slightly plastic.

Parent material: Tertiary sandstone.

Vegetation: Lowland Dipterocarp forest

Topography: Near top of ridge, gentle sloping site at (15^o) otherwise steep slope (30^o)

No comparative analyses available.

(vi) Sabangan family

This family has as yet not been subdivided into series. The following profile is typical for the area mapped at the $14\frac{1}{2}$ mile Kuching-Serian road.

Unclassified Series (Sabangan family)

(code number ?)

0 - 2 inches	Dark greyish brown (10YR 4/2) weak fine angular clay loam, friable, well rooted, abrupt over
2 - 34 "	Very pale brown (10YR 7/4) massive silty clay with weak yellowish brown mottles, few roots, firm, slightly moist, gradual change to
34 - 44 "	Very pale brown (10YR 8/3) massive sandy clay, densely mottled grey and yellowish brown. Few quartz pieces, gravel size, few roots, abrupt over
44 - 50 "	Very pale brown (10YR 8/3) sandy clay with many quartz pieces, gravel size. Also present weathering rock pieces of gravel size from unknown source.

Parent material: probably old alluvium

Topography: Low lying gentle undulating terrain bordering S. Entingan

Vegetation: Old rubber garden.

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 3417	0 - 2	4.0	90	356	83	700	6.74
3418	7 - 12	4.4	45	356	190	750	12.44
3419	19 - 25	4.4	50	158	428	800	14.10
3420	24 - 40	4.3	69	219	463	900	18.80
3421	46 - 50	4.4	50	337	523	850	16.10

3. Saline Soils

The only mapped family in this Great Soil Group is the Rajang family. No series were mapped.

The family as a whole however is characterised by the dominant series in the Rajang family, namely the Rajang series of which particulars follow.

RAJANG SERIES (code number 4109)

The most important feature in the Rajang Series is its saline character which prevents the growing of crops. The natural vegetation is Mangrove in association with Nipah. In less saline places almost pure stands of Nipah are found.

General Characteristics.

The Rajang usually consists of clays deposited in a deltaic environment. The clays are littoral deposits characterised by a high content of soluble salts and a high content of sodium in the exchange complex. The electric conductivity is generally above 4,000 micromho/cm while the Exchangeable sodium is more than 15% of the total exchange capacity. Although the soils are generally clay throughout, a sandy loam phase was found at the mouth of the Samarahan river where the clay deposits are covered with a thin layer of sandy loam texture from Tambirat to as far north as the sea.

Apart from being strongly saline (according to the American definition given by the Salinity Bureau Staff, the soils are classified as saline/alkali soils, ref. 10) the soils are also strongly hydromorphic and display all the characteristics of the Low Humic Gleys to which they are related.

Once the salts of the Rajang Series are leached out the series is similar to the Pendam Series (probably saline phase). The profile consists of a greyish brown sticky and plastic clay (sandy loam for the sandy phase) top horizon of varying depth, depending on undulations of the surface but normally deeper than 24". There is not a normal A horizon in the sense that humus accumulates in it, but deposition of mineral matter takes place continuously thereby covering any amount of organic debris which may fall on the surface. The topsoils which may be two feet thick are therefore mixed with much organic debris, dead leaves and woody material and many roots, dead and alive, while in places whole trees can be found buried under the sediments.

The only difference between topsoil and subsoil (if one can use these terms) is that at a depth of more than two feet the colour is usually more greenish to bluish grey, while in places even a dark grey colour was observed, where the organic matter is more decomposed.

Watertables vary with the tide and location. Near streams they drop considerably during low tide, while at high tides the series is surmerged with salt water. Further away from the river the tidal change is less noticeable and watertables are more stable although most of the time not falling below a level of 2 feet.

Base exchange capacity is moderately high in these samples and is over 20 meq/100 gram of soil. Base saturation is 100%, the adsorption complex being dominated by sodium. Calcium and magnesium in the adsorption complex is high for Sarawak conditions (more than 10 meq.) Magnesium may be twice as high as calcium.

The pH in the Rajang Series shows sometimes a remarkable drop after drying. All pH measurements for the Rajang Series were taken in the wet condition and give values of 7 or over indicating its saline character. After drying the pH did not drop very much but in other areas of Sarawak an acidity of as low as 3.5 has been reported for similar soils. Where this is accompanied by a high sulphate content such a fall in pH can be explained easily as sulphur compounds are most of the time present in the fresh samples of the Series. The sulphur becomes oxidised after drying and the resulting sulphates reduce the pH considerably even in the absence of cations like calcium or sodium.

If the Rajang is reclaimed and salts are leached out its fertility will be much the same as the related Pendam Series. It would be advisable however to lime the Rajang Series if salts are leached out; this will reduce the acidifying effect of the sulphate which may form after draining and will help to revert the sodium clays into calcium clays thereby improving the structure of the soils. The lime requirement of this series should however be worked out prior to reclamation.

Comparative analytical data on one profile from Nonok area is as follows:

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 3268	0 - 9	7.9	317	10,690	3980	6550	9.78
3269	11 - 20	07.9	330	3,465	6344	5300	9.32
3270	21 - 31	7.7	375	4,455	5940	7000	11.32
3271	34 - 45	7.8	285	9,365	6899	7500	11.98

4. Low Humic Gley soils

(i) Pendam family

One important series in this family is the Pendam series which has been mapped in the Nonok coastal area.

PENDAM SERIES (code number 4201)

The general concept of the series is as follows:

Soils recently reclaimed from Mangrove and Nipah forest and converted into agricultural soils through leaching of salts and drainage, or soils which through natural causes have risen above normal high tide level. They are normally situated in river delta's or found at the mouth of main rivers, and occur as far inland as brackish- or saltwater can penetrate during the driest part of the year. Although topsoils and subsoils can contain soluble salts these are easily leached out by rain or freshwater flooding. Groundwater may be salty during parts of the year.

The Pendam soils have developed in a deltaic environment and traces of a former vegetation (Mangrove and Nipah) may still be found in the soils. This is indicated by mucky or peaty layers encountered at depths ranging from 1 to over 4 feet from the surface. The layers are thin and generally not more than 6" thick.

Apart from this morphological variation, chemical features are variable over a wide range because of their proximity to the sea (salt infiltration through flooding and salty ground-water) and human influence (drainage).

The general concept is therefore taken as a guidance for interpreting field and laboratory data and for mapping the series. If one characteristic of the general concept becomes significantly different from the normal soil, phases have been created to allow these soils still to be classified in the Pendam. Some of these characteristics, particularly organic matter and soluble salt contents of topsoil, appear to change quite rapidly when the soils are drained and bunded - after which the soil resembles the modal concept of the series. It is therefore practical to map such differences as phases so that the soil remains in the same series if and when cultivation through draining or bunding takes place.

Textures

Clay and silt fractions are dominant in the Pendam Series but more sandy textures occur in places, especially near the mouth of Batang Samarahan where topsoils can be a sandy clay loam. Normal textures of topsoils range from clay loam to clays. In the subsoil textures range from silty clays to clays.

Structure

Structure in the Pendam Series is usually absent because of the wet condition in which they are normally found. Topsoils however may display a fine angular blocky structure when dry.

Organic matter content.

Typical of the Pendam Series is the high amount of organic material found in the whole profile. Loss on ignition shows an appreciable amount of old, partly decomposed and fresh organic material in all layers. Loss on ignition varies from 5 to 10% in all subsoils while in places soil layers can be found with an organic matter content of as much as 60% (muck and peaty layer of organic debris.) Where possible such soils in the Pendam series have been mapped as the 'muck and peaty layered phase' of the series, because this phase may behave differently upon drainage and subside after the organic material has oxidised.

Loss on ignition in topsoils of the whole series is usually more than 10% and is normally within a range of 10 to 20%. However where the series grades into more mucky soils the organic matter content measured as loss on ignition may be as much as 60% and over. Soils in the series with loss on ignition of more than 35% in the topsoil (0-6") have therefore been placed in the 'organic phase.'* Where possible this phase has been mapped separately. It is very likely that with continued cultivation the organic matter in the topsoil may fall to a level of 10-20% because of oxidation and mineralization of the organic matter.

Drainage

a. internal

The soils are slowly permeable (high clay content) and only where the sand fraction is appreciable higher than the silt and clay fractions is the permeability rapid.

b. external

Most soils in the Series are located close to peat areas situated at a higher level. Water draining off the peat tends to keep the water table high in the adjacent clay soils. Watertables are in general very high (at 6" or at the surface in the wet season while in the drier season the watertable may drop to 18" depending on the presence of drains.) Near the drains the watertable may drop to 3 feet, although a daily fluctuation can be expected because the watertable is affected to a certain extent by the tidal movements of the water in the rivers.

All soils in the Pendam Series are therefore poorly to very poorly drained.

Gley features

Gley features are present throughout the profile. Strong brown and orange mottles commonly start in the topsoil or immediately below it. They give way to more yellow coloured mottles while the matrix colour of the soils changes from brown or greyish brown to grey. The gley horizon is normally met at a depth of 2 to 2½ feet and is coloured greenish grey or bluish grey while if much dispersed organic matter is present the gley layer is coloured dark grey. Yellow and rust-coloured mottles may persist to a considerable depth indicating that air is penetrating through root channels or that oxygen is formed by roots of certain plant species. Near drains the permanently gleyed zone is generally deeper than in the remainder of the area and may be found at a depth of 3 to 4 feet.

---

* In practice soils with loss on ignition approaching 35% are also placed in the organic phase.

Salinity

Because of the location and through human interference (digging of drains) brackish water sometimes floods certain areas or the groundwater becomes slightly salty. This increase in salinity is essentially a seasonal feature in the Pendam Series and the salts are leached out by rainfall especially in the wet season. The salts in the Pendam Series are mostly soluble and the percentage of sodium in the adsorption complex should not be more than 15%. Electric conductivity may vary and depends on the time of the year location and the depth in the profile. On the content of soluble salts the Series is subdivided into phases, namely:

(a) Pendam Series, saline phase
(b) Pendam Series, leached phase.

It should be understood that mapping of these two phases is extremely difficult because during the wet season the saline phase may revert into the leached phase while in the dry season the opposite may take place. While our studies on these soils were carried out during the transition period of wet to drier weather the boundary between these two phases shown on the map can never be accurate. The occurrence of crab mounds in the saline phase is often a useful indication to salty conditions.

The saline phase is characterised by an electric conductivity of 1,000 - 4,000 micromoho/cm in the surface horizons (0-12") while in the subsoil the E.C. is more than 4,000. E.C. of the ground-water is generally much higher than 4,000.

The leached phase has surface horizons depleted of soluble salts and the E.C. should not be more than 500. Subsoils in the dry season are permitted to have an E.C. between 1,000 - 4,000, but this is only the case if the groundwater is affected by salt infiltration through drains. The E.C. of groundwater in the leached phase is usually between 500 and 4,000.

Because the former vegetation was Mangrove and Nipah forest the Pendam Series may have high levels of sulphates, especially in the 'muck and peat layered' phase. The coarse textured organic matter in these layers (peat and muck layers) have been tested for sulphate but in all instances the sulphate content did not rise above danger level. Nevertheless Pendam subsoils in other areas of Sarawak have been found to contain high contents of sulphate and probably it is only the layers in which the organic are high and where sulphate becomes toxic after the soils are dried out. It is therefore possible that the electric conductivity values in the Pendam Series, both saline and leached phases, are partly recording the occurrence of sulphates and that high readings do not necessarily refer to sodium salts or chlorides.

Acidity

In the saline phase of the Series the pH ranges from 5 to 7 in both topsoils and subsoils. The pH in the topsoil (0-6") is frequently less than the pH in the subsoil. The pH in the leached phase is generally lower, especially in the topsoil where it varies between 4 and 5. Sometimes the pH of the topsoil may be slightly over 5. The pH in the subsoil is normally between 4 and 5 but depending on the salinity of the groundwater a pH of 6 was frequently recorded. pH may be influenced by the occurrence of 'catclay' which would cause it to be lower.

PAYA MEGOK SERIES (code number 4314)

Profile S 2133/36

0 - 5 inches — Very dark brown, subangular blocky, loam, weak grey mottles (surface gleying, many earthworms, abundant fine to medium size roots, clear smooth change to

5 - 16 " — Grey brown, weak subangular blocky, clay loam with distinct gray and rusty coloured mottles, in cracks soil material from above has accumulated, along rootchannels gray and rust coloured coatings, diffuse wavy change to

16 - 32 " — Grey to light gray, massive, silty clay with distinct gray mottles, sticky and plastic, rich in decayed peaty wood remnants. Watertable at 30". Gradual wavy change to

32 - 52 " — Light greenish gray silty clay with olive green and rust coloured coatings along rootchannels. Wet, very sticky and plastic. Rich in peaty material.

Parent materil: Recent alluvium of mixed origin

Vegetation: One year old secondary growth

Topography: Flat riverine valley.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2133	0 - 3	n.d.	687	3000	3474	3450	16.2
2134	7 - 17	n.d.	524	1850	3720	6100	17.0
2135	19 - 28	n.d.	444	1180	1929	3800	14.2
2136	36 - 52+	n.d.	197	700	1486	3850	10.4

<u>SAMARAHAN SERIES</u> (code number 3406)

Profile S 2068/70

0 - 2 inches	Dark grey (10YR 4/1) massive, silty clay, slightly plastic, much organic matter (raw), very well rooted, red coatings along old rice roots. Clear over
2 - 18 "	Light grey (5Y 7/1) silty clay, slightly wet, plastic, sticky. Bright orange coatings along root channels. Many old and new roots.
18 - 36 "	Greyish green (5GY 6/1) silty clay, (gley horizon), few orange coloured coatings along root channels (18 - 24"). Sticky and plastic. Many roots. Some large old roots. Water table 37"

Parent material: Recent alluvium and colluvium derived from shales mainly.

Vegetation: Padi stubbles and weeds

Topography: In middle of flat, small riverine valley

<u>Analyses</u>

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2068	0 - 2	n.d.	545	1170	3025	7500	14.0
2069	7 - 12	n.d.	295	240	2995	5700	17.3
2070	26 - 32	n.d.	335	730	3360	3000	17.6

5. Planosols

No generalised description of the Triboh family is given, the series in this family being too beterogenous. The bisequent nature of most soils in this family is illustrated by the following profiles with their analytical data. (See dotted lines)

Profile S 4007/12, near Merang, 24th mile Kuching-Serian road.

0 - 4 inches Dark greyish brown (10YR 4/2) sandy loam with few fine quartz gravel, friable. Many fine roots. Moist. Gradual change to

4 - 11 " Light yellowish brown (10YR 6/4) loamy sand, structureless, with medium distinct grey mottles. Few roots. Gradual change to

11 - 17 " Light yellowish brown (10YR 6/4) fine sandy loam to loamy sand with many fine, distinct yellow and grey mottles, structureless, friable, moist. Indistinct boundary to

17 - 33 " Pink (5YR 8/4) silty clay with many distinct medium brown mottles. Much quartz gravel. Moist. Firm. Indistinct boundary to

33 - 43 " Light grey (7.5YR 8/N) fine sandy clay loam with abundant distinct brown, grey and greenish grey mottles. Firm. Moist. Few fine quartz gravel. Irregular but clear boundary to

43 - 50 " Light grey (7.5YR 8/N) clay with abundant large, distinct yellow, brown and grey mottles. Few root channels with iron accumulations. Slightly sticky, wet. Watertable at 46".

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 4007	0 - 4	4.8	63	130	207	950	2.86
4008	4 - 11	4.7	40	136	178	950	4.16
4009	11 - 17	4.9	23	108	454	1150	3.32
4010	17 - 33	5.0	23	238	2061	1900	11.92
4011	33 - 43	5.2	48	268	4012	3200	18.46
4012	43 - 50	5.2	83	1058	10,161	4250	22.22

Profile S 3422/62, S. Entingan area near Kpg. Nangka.

0 - 1 inch — Partly decomposed leave litter and rootmat, dark brown.

1 - 8 inches — Light brownish grey (10YR 6/2) fine sandy loam with slightly lighter coloured mottles, structureless, friable, moderately well rooted, much charcoal, moist. Clear and wavy boundary to

9 - 15 " — White (10YR 8/2) with very pale brown mottles loamy fine sand, structureless, friable, very few roots, moist, gradual change to

15 - 34 " — Light grey (10YR 7/1) sandy clay, densely mottled with yellow, and few strong brown mottles in more sandy lenses. Clay material is plastic but non-sticky, no roots, gradual change to

34 - 45 " — White (10YR 8/1) clay, intensely mottled with fine reddish yellow occurring around fine rootchannels. Massive.

Analyses.

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 3422	0 - 1	3.7	224	198	392	850	1.28
3423	1 - 8	3.7	55	158	107	800	1.74
3424	9 - 15	4.5	35	198	190	800	2.32
3425	15 - 34	4.3	45	99	772	1900	5.36
3426	34 - 45	4.3	142	119	2305	6450	14.10

Profile S 3972/76 - near Batu Gong - terrace outwash on recent alluvium

0 - 7 inches — Dark grey (10YR 4/1) loamy sand with many faint, fine light grey mottles, structureless, friable, many rootlets, very porous, irregular boundary to

7 - 19 " — Light grey (10YR 7/1) very fine sandy, very weak fine angular blocky, slightly friable, very porous, irregular boundary to

19 - 31 " — Light grey (10YR 7/1) very fine sandy clay with few distinct medium reddish yellow mottles, friable, moist, gradual change to

31 - 43 " — Reddish Yellow (7.5YR 6/8) clay with profuse coarse light grey and rusty mottles, moist, massive, indistinctly over

43 - 55 " — Reddish yellow (7.5YR 6/8) clay with profuse, coarse light grey and rusty mottles, wet. Very sticky and plastic.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 3972	0 - 7	4.0	80	277	0	700	0.44
3973	7 - 19	4.4	35	198	0	700	0.52
3974	19 - 31	4.8	42	198	95	1050	1.00
3975	31 - 43	4.8	62	297	808	5250	19.24
3976	43 - 55	4.4	55	198	1485	5700	16.64

6. Half Bog Soils

The only family mapped in this Soil Group is the Mukah family. The ortho-type of the family, the Mukah Series characterises the soils generally found in this family.

MUKAH SERIES (code number 4202)

General Characteristics

The Mukah Series has a 6 to 36" thick organic top layer which can be either peat or muck. In all cases the high loss on ignition of this layer is due mainly to peat (loss on ignition more than 60%) This organic layer rests on a greenish grey to light grey, compact, sticky and plastic clay (probably an old littoral marine clay deposit).

The watertable in the Series is always high and can be encountered at less than 1 foot deep during the dry season; in the wet season the watertables are at the surface. When drained and cultivated watertables near drains are somewhat lower in the dry season but in many areas the drains do not lower the watertable significantly during the wet season.

Where cultivated the organic top layer has subsided and ponded drainage conditions occur during the wet season. The cultivated and drained peat layer looses its fibrous texture and becomes granular (like ground coffee). In this condition the peat is a favourable root medium for many annual crops. The fine textured organic matter becomes more compact with time and tends to consolidate. The top layer forms a compact turflayer on which light buildings can be erected and footpaths constructed.

In areas fringing river meanders the Mukah series is commonly found covered with a clay top soil of varying depth. Generally the clay deposit is not deeper than 1 foot. This clay top has been deposited by the river when in flood at which times the river is able to flow freely over the meander bends. The total area of the Mukah series with these clay tops is however small; they have only been mapped along the Samarahan river, as the 'clay top phase' of the Mukah Series.

Acidity

The pH of the organic topsoil is invariably low (between 3 and 4). The pH of the mineral clay soil found below the organic layer is slightly above 4. Maximum pH recorded was 4.5.

Base Exchange Capacity

Exchange capacity of the organic top layer is high and ranges from 30 to 50 meq/100 gr. of soil.

Base saturation

Base saturation in the organic topsoil is low and is generally below 5%. The clay subsoil is generally better supplied with exchangeable ions but base saturation is this material must still be regarded as low in most cases (between 10 and 25%). Near the larger streams base saturation is higher and can be more than 50% but here the influence of recent saltwater infiltration cannot be ruled out (frequently magnesium or sodium shows a peak in the exchange complex at these places.)

Exchange Bases

Exchange calcium plus magnesium is low (around 1 meq.) in the organic topsoils, while in the clay subsoils a wide range can be noticed from low to moderately high values (2 to more than 7).

Exchangeable sodium is low in all organic topsoils while in the clay subsoil the same trend can be noticed as reported for the Exch. Ca and Mg. contents.

Sample S. 3022 shows an unusually high amount of Exch. Na, the reason is probably recent salt water flooding in this locality.

Total Nitrogen in the topsoil is extremely high for Sarawak conditions but it is unlikely that this is all available to the plant, much of the material being fixed as lignoproteins.

Total phosphorus content in the topsoil is moderately high (between 600 and 850) much of which is available to plants, it being mainly organic phosphate.

It can be concluded that the Mukah Series as far as fertility is concerned can be rated as a soil of moderate fertility for Sarawak conditions. The soils are generally better supplied with nutrients than most mineral soils occurring in Sarawak. However, drainage problems make agriculture on the Mukah Series a risky undertaking. Sound land use planning will be needed to make the most of its potential.

The following data indicates the chemical characteristics:

MUKAH SERIES.

Lab. No.	Depth	pH Wet	pH Dry	P ppm Total	P ppm Av	in Meq/100 gr. soil. Ca	Mg	K	Na	C.E.C.	N% Total	Loss in ignition
S.3022	0-11	3.0	3.0	529	25	0.99	0.14	0.26	2.12	34.27	1.82	88.35
S.3023	20-30		4.3	138	4	5.81	6.12	0.28	0.75	22.31	0.27	15.25
S.3009	0-10	3.4	3.3	678	30	1.15	0.54	0.47	1.55	53.08	2.03	93.33
S.3010A)	10-37	3.5	3.3	254	11	0.91	0.38	0.20	0.46	53.79	1.03	87.23
S.3010B)			3.8		8	2.06	2.55	0.11	0.45	47.35		75.04
S.3011	37-48	4.4	4.5	134	11	3.76	7.0	0.23	0.53	53.08	0.18	9.38
S.3005	0-12		3.2	629	25	1.28	1.22	0.44	0.34	50.35	1.44	65.56
S.3006	17-23		4.0	105	4	0.37	3.15	0.17	0.71	10.60	0.10	6.27
S.3007	27-40		4.4	190	3	0.91	4.71	0.25	1.50	22.05	0.08	4.12
S.3008	40-50		4.3	160	8	1.91	6.47	0.35	1.90	11.41	0.11	5.20

7. Bog Soils

All bog soils are classed in the Anderson family in which at present only one series has been distinguished namely the Anderson series.

The following analyses are representative for the series.

ANDERSON SERIES - code number 5001.

Lab. No.	Depth	pH Dry	P ppm Total	P ppm Av	in Meq/100 gr. soil Ca	Mg	K	Na	C.E.C.	N% Total	Loss on ignition
S.3105	0-2	3.3	535	16	2.86	0.40	0.8	Trace	38.63	1.22	95.91
S.3106	2-7	3.4	328	9	1.45	0.37	0.11	0.17	31.74	1.82	97.54
S.3107	7-16	3.6	165	6	0.60	1.83	0.05	0.22	35.92	1.47	97.56
S.3108	16-42	3.9	123	2	0.36	0.58	0.06	0.35	46.71	1.33	94.71

8. Mountain peat soils.

No analyses available.

9. Tropical podsols

Of the Miri and Bako families no comparative analyses are available from the area.

The Kerait family is characterised by the following profile:

Kerait series, profile S.2287/2291 - code number 3102

½ - 1 inches	litter and leaves, partly decomposed
0 - 5 "	Very dark grayish brown crumbly, sandy loam, well rooted, moist; gradual change to
4 - 12 "	Grayish brown crumbly sandy loam, with faint white mottling, infiltration of clay particles. Moist, Gradual change to
12 - 32 "	White angular blocky, sandy clay, with orange yellow mottles, moist, infiltration of clay along root channels, few small quartz pieces, gradual smooth change into
32 - 45 "	White silty clay with strong orange and yellow mottles. (50% white, 50% mottles).
45 - 50+"	White silty clay with pale grayish mottles. Compact.

Parent material: Carbonaceous sandy shales of Triassic age.

Vegetation: Weeds, such as ferns, cyperacea, melastomea.

Topography: Low gently undulating.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2287	1 - 4	n.d.	150	2625*	90	1000	1.4
2288	5 - 11	n.d.	55	30	150	700	1.5
2289	13 - 30	n.d.	50	60	982	2450	5.1
2290	34 - 44	n.d.	55	60	1989	5300	13.2
2291	45 - 49	n.d.	55	120	2097	4000	12.7

*high Ca and K probably from ash.

10. Skeletal soils

(i) Sedong family

In this family the Sedong series is by far the most important soil type.

SEDONG SERIES (code number 1301)

Analyses

RANGE OF CHARACTERISTICS

1. Parent material; Highly weathered basic igneous rocks presumed to be mainly basalts which have in certain areas been serpentinesed, chloritised and calcitised. In general rocks classified as basalts, andesites and pyroxene andesites. Probably dolerite is also involved.

2. Topography: The topography is mountainous and slopes are generally steep, ranging from 25^{o} to 55^{o}. Erosion and colluviation are common features on such slopes and the topography is generally of a broken nature. The series generally occurs in areas higher than 250 feet above sealevel and the soils have been met up to a height of 2,400 feet.

3. Occurrence: The series is commonly found in West Sarawak on massifs of basic igneous rock-types.

4. Diagnostic horizons:

Al - always present and often the main horizon is the profile
B - (undifferentiated), sometimes weakly developed. In many cases not present
C - always present
D - often encountered within a depth of 4 feet.

Under primary forest a thin A_o may be present.

5. Colour: Usually hues of 7.5YR and 10YR. Topsoils range from strong brown to dark yellowish brown. If a weakly developed B horizon is present usually reddish yellow colours occur. The C horizon displays a variety of colours. The weathered parent material being usually yellowish green with white specks while the soil material is of a dark red colour in the 5R range.

6. Texture: Clays in general. Often with gravel size partly decomposed and fresh rock pieces throughout the profile.

7. Structure and consistency: Structures in topsoils are usually crumbly to fine angular blocky. Structures of subsoils are in general angular blocky. In a moist condition the soils are friable, when dry the soils are hard.

8. Drainage: Internal drainage is moderately good. External drainage is very rapid. The soils are generally moist throughout the year but during prolonged dry spells the soils dry out quickly when not under a well closed vegetation cover.

9. Rooting: The profiles show generally a deep rooting system, which is most developed in the top few inches. Feeding roots occur concentrated in the Al horizon.

10. Phases: Only depth phases have been classified. Depth phase relate in general to erosion and colluviation and therefore the depth to the C horizon may vary. Although the normal phase of the series is shallow (weathered rock material found within 2 feet) deeper phases occur in places where colluvial rubber has accumulated. The deep phases show a deep (3 feet) strong brown Al horizon with many weathered and fresh rock pieces. They may occur at the foot of a steep slope .

'Colluvial influenced phases' occur in places where the topsoils have been covered with fresh rock material. Phases have so far not yet been mapped separately because of the complex manner in which they occur.

11. Chemical and mineralogical features:

a. Clay minerals - n.a.
b. Weatherable minerals - n.a.
c. Ore content - n.a.
d. Silica/sesquioxides ratio's - n.a.
e. Sesquioxide ratio's - n.a.
f. C.E.C.: Topsoils in general slightly over 20 meq. depending on organic matter.
Subsoils - n.a.
g. Base saturation: Depending on organic matter but topsoils frequently 25%, subsoils invariably lower than 20%.
Ca and Mg between 1 and 2 meq. in the topsoils (Mg sometimes 3x as much as Ca.) Potassium 0.5 to 1 meq. can be expected in topsoils.
Subsoils are invariably much less.
h. Acidity: Topsoils pH 5 - 6
Subsoils always slightly lower.
i. 'Reserve' cations in ppm: phosphate on average 275 in topsoils (frequently far more and sometimes more than 900). Subsoils slightly over 200 ppm.
Calcium: topsoils frequently above 3,500. On average slightly over 3,000. Subsoils 1,600 on average.
Magnesium: Topsoils on average more than 5,000
Subsoils on average 3,400
C. horizon over 9,000
Potassium: 1,300 on average both in top and subsoils.
Characteristic are the high Ca. and Mg. figures for this series and the for Sarawak soils low figures for potassium.
j. Group III elements: n.a.

TYPICAL PROFILE.

Soil Group: Skeletal soil, intergrade to Reddish Brown Lateritic Soils

Family: Sedong

Series: Sedong

Phase: normal

Location: Bukit Suka near Tebedu road (lst Division)

Latitude: 1° 7' N

Longitude: 110° 28' E

Topography: On mountain

Site: middle slope, broken terrain

Slope: varying between 20 and 25°.

Parent material: Weathered basic igneous rocks

External drainage: rapid

Vegetation: padi stubble and lallang

Altitude: approximately 350 ft.

Rainfall: approximately 130 per year

Rainfall Class: 1 (Mohr)

Lab. Nos: S 2049/51

Field Nos: J360/362

Date sampled: 14. 5. 1963.

0 - 6 inches   Dark yellowish brown clay, slightly moist, crumbly, friable. Much organic matter. Many small rock pieces and charcoal. Gradual smooth change to

6 - 24 "   between 10YR 5/4 yellowish brown and 7.5YR 5/6 strong brown gravelly clay. Slightly moist, very firm and compact, coarse angular blocky. Many partly decomposed and fresh angular shaped rock fragments.

24 - +   hard weathered basalt mixed with some soil.

Analyses

Profile S3400/3403 from Kpg. Kuop area.

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 3400	0 - 3	5.1	364	1445	4990	1050	23.14
3401	5 - 13	5.2	174	416	7389	1400	34.76
3402	15 - 22	5.7	152	594	7140	1600	35.68
3403	25 - 31	5.7	155	2356	7686	1200	29.84

(ii) Kapit family

Because of its insignificance for the area no further details are given.

11. Regosols

The area of Regosols is very small and no detailed information is therefore given.

12. Recent alluvials

(i) Malang family.

Chemical characteristics in this family depend on the source of the deposits. Particulars on three different series in this family give a good cross-section on the soils in this family.

a. TERBAT SERIES (code number 4316)

0 - 4 inches Dark brown (7.5YR 3/2) crumbly, clay loam, friable, well rooted, smooth change to

4 - 48 " homogeneous horizon of strong brown (7.5YR 5/6) friable, weak angular blocky clay, moderately well rooted. Moist.

Parent material: Recent riverine alluvium of basic igneous origin

Vegetation: Young rubber garden with undergrowth of weeds and ferns

Topography: Slightly undulating alluvial land along river.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2094	0 - 2	n.d.	687	590	2630	1250	30.6
2095	15 - 18	n.d.	345	100	2085	700	38.7
2096	26 - 42	n.d.	270	50	1635	1600	42.8

b. RAMUN SERIES (code number 4402)

Ramun Series, Profile S 2181/83

0 - 4 inches Dark brown (10YR 4/3) nutty loam, moist, loose abundant undecomposed rock pieces. Earthworms, abrupt, irregular change to

4 - 14 " Strong brown (7.5YR 5/6) granular gravelly clay. Very loose, abundant hard rock pieces of gravel size. Few fine roots. Diffuse broken boundary to

14 - 36 " Dark brown (7.5YR 4/4) gravelly clay. Abundant hard partly weathered gravels. Moist.

Parent material: Recent alluvial/colluvial gravel size material from basic igneous rock sources

Topography: Undulating alluvial fan.

Vegetation: Secondary forest, much bamboo.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2181	0 - 3	4.8	763	4750	5062	1350	28
2181	6 - 12	5.2	435	700	7475	1250	38.9
2183	20 - 36+	4.2	505	840	6385	900	39.2

c. MALANG SERIES (code number 4305)

Malang Series, profile S 2148/50

0 - 3 inches Pale brown subangular blocky loam, loose, abundant fine to medium roots. Earthworm activity, moist, clear smooth boundary to

3 - 16 " Very pale brown (10YR 7/4) weak angular blocky loam to clay loam, slightly firm, few fine roots, charcoal, some infiltrated material from top layer through cracks. Gradual irregular change to

16 - 44 " 50%, weak red and 50%, strong brown subangular blocky clay loam, with very weak light gray mottling. Few fine roots, slightly sticky and plastic.

Parent material: Recent riverine alluvium of mixed origin

Vegetation: Old rubber garden (40 years)

Topography: Incipient levee.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2148	0 - 3	n.d.	262	830	1444	1750	11.8
2149	4 - 8	n.d.	207	250	2312	1550	3.7
2150	22 - 44+	n.d.	78	200	1162	2450	20.7

(ii) Semilajau family

No separate series were mapped in this family. A profile of the Kayan series characterises the general features of the family.

KAYAN SERIES (code number 4319)

Profile S 2063/2067

0 - 6 inches	Very dark brown (10YR 2/2) weak crumbly, weak friable to loose, slightly wet, well rooted, overlying.
6 - 14 "	Dark yellowish brown (10YR 4/4) structureless sand, spots of dark coloured material (worm casts), few roots, overlying.
19 - 38 "	Dark yellowish brown structureless, loamy sand, loose, few roots, gradual change to
39 - 48 "	Structureless, coarse loamy sand, loose.

Parent material: Recent riverine alluvium of mixed origin

Vegetation: Mainly bamboo

Topography: Slightly undulating levee approx. 5 feet from river bank.

Analyses

Laboratory No.	Depth of sample in inches	pH H20	P Total	Ca Total	Mg Total	K Total	% Group III (sesquioxides)
S 2063	0 - 3	n.d.	395	1250	1851	1400	4.8
2064	9 - 14	n.d.	95	270	791	2300	4.0
2065	16 - 19	n.d.	197	610	1480	3100	7.0
2066	22 - 29	n.d.	127	380	1234	1500	4.2
2067	41 - 48	n.d.	132	360	773	1850	4.3

Printed by Department of Agriculture, Sarawak.