TERRAIN TYPES AND THEIR AIR-PHOTO CHARACTERISTICS: NORTHERN RUPUNUNI SAVANNA, GUYANA

by
James O. Windapo

(Submitted in partial fulfilment of the requirements for the degree of Master of Science in Geography, McGill University, Montreal)

ABSTRACT

A detailed study of the terrain types of the Northern Rupununi Savanna, Guyana, has been made with the aid of medium scale air-photographs.

The 'land system' approach developed by C.S.I.R.O. scientists in Australia was applied and amplified to include the universal system for recording vegetation.

In the air-photo interpretation stage, the various landscape patterns were recognized by stereoscopic examination, and changes in drainage texture and neutral density (photo grey tone) were assessed.

During the field work, the landform patterns identified in the interpretation were checked and their physical characteristics were examined under the following headings:- soils - grain-size distribution, compactness, structure, acidity, horizon development; morphology - slope inclination, slope form and drainage; vegetation - physiognomy and density.

By relating the actual field conditions to the air-photo image, it was possible to provide a detailed interpretation of the Northern Rupununi landscape in a manner which permits extrapolation to similar areas.

TERRAIN TYPES AND THEIR AIR-PHOTO CHARACTERISTICS

(WINDAPO)

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science.

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TABLE OF CONTENTS

	Page
List of Figures	v
List of Plates	ix
List of Tables	xii
Acknowledgements	xiv

PART ONE

CHAPTER I:

INTRODUCTION	1
The Study Area	3
Climatic Setting	5
Geologico-Morphological Setting	9
Soils	26
Vegetation	31
Land Use	39

CHAPTER II:

TERRAIN CLASSIFICATION AND APPLICATION OF AERIAL PHOTOGRAPHS	42
The role of Aerial Photographs	48
Interpretation and Classification of Northern Rupununi Terrain	51
Interpreting the Photos	54

PART TWO

	Page
CHAPTER III:	
THE PAKARAIMA SCARP COMPLEX	58
The Scarp faces	58
The Pediment	62
The Alluvial fans	62
Surface drainage characteristics of the Landform Pattern	67
Air-photo characteristics of the Landform Pattern	70
CHAPTER IV:	
THE MARAKANATA LOWLANDS	76
Terraces and Sand dunes of the Northern Margin	78
The Central Lowland	83
The Sand dunes of the Takutu-Ireng Confluence to southwest	86
Air-photo characteristics of the Landform Pattern	86
CHAPTER V:	
THE LATERITE UPLANDS	101
General Consideration	101
The Eastern Upland Block	118
The Central Upland Block	126
The Nappi Lowland	128

	Page
The Western Upland Block	129
The Manari Terrace Belt	134
The MocoMoco Flat	136
The Ikuwali-Sapaika Flat	141
The Laterite Outliers	155
Air-photo characteristics of the Laterite Uplands	156
CHAPTER VI:	
THE KANUKU SCARPLANDS	170
Air-photo characteristics of the Pattern	176
CHAPTER VII:	
THE SAPAIKA-SAWARIWAU LOWLAND	178
Air-photo characteristics of the Pattern	189
CHAPTER VIII:	
THE MAJOR FLOODPLAINS	194
The Ireng Flood-plain	194
The Takutu Flood-plain	199
The Rupununi Flood-plain	201
Air-photo characteristics of the Landform Pattern	202

Page

PART THREE

CHAPTER IX:

THE DEVELOPMENT TREND OF THE LANDSCAPE 205

The Role of Rivers 205

The Trend in Vegetation Changes 207

CHAPTER X:

THE TASKS AHEAD 211

PART FOUR

CHAPTER XI:

CONCLUSIONS 216

APPENDIX:

A Index of Terrain Classification and Description 220

B Definitive features of landform patterns 221

C Legend to Surficial Deposit Maps 227

D Structural Diagram Construction 228

BIBLIOGRAPHY: 236

LIST OF FIGURES

Figure		Page
1.	Index Map.	4
2.	Mean Annual Rainfall for St.Ignatius.	7
3.	The Northern Rupununi Savanna within the Guiana Shield.	10
4.	Geology of the Northern Rupununi.	11
5.	Block diagram showing the graben structure.	13
6.	Drainage and settlement.	22
7.	Oxford System for terrain classification.	45
8.	Australian System for terrain classification.	47
9.	Landform Patterns.	55
10.	Block diagram showing the Pakaraima Scarp Complex.	60
11.	Vegetation Map.	61
12.	Structural diagram showing vegetation association east of Moreiru.	63
13.	Structural diagram showing vegetation association on sand fill near Toka.	68
14.	Neutral value density trace for the Pakaraima Scarp Complex.	72
15.	Block diagram showing the Marakanata Lowlands.	77
16.	Comparison of grain-size distribution for Cajueiro and Massara sands.	80
17.	Structural diagram showing vegetation association near Massara village.	82
18.	Grain-size curves for soil samples from the Marakanata Central Lowland.	85
19.	Grain-size curve for soil sample from the south-west margin of the Marakanata Lowlands.	88

Figure		Page
20.	Structural diagram showing vegetation association north of Massu Lake.	89
21.	Neutral value density trace for the Marakanata Northern Margin.	92
22.	Neutral value density trace for the Marakanata central lowland.	95
23.	Neutral value density trace for the Marakanata southwest margin.	98
24.	Block diagram showing the Laterite Uplands.	102
25.	Map of the Laterite landscape.	103
26.	Slope profiles showing stages of reduction in laterite ridges.	106
27.	Grain-size curves of soil samples from a laterite ridge top to the adjacent flat.	114
28.	Laterite types diagram.	116
29.	Structural diagram showing vegetation association on Yupukari high hill.	125
30.	Grain-size curves for soil samples near Manari Outstation.	138
31.	Block diagram showing the MocoMoco Flat.	139
32.	Surveyed profile across the terrace belt along the MocoMoco river.	140
33.	Structural diagram showing vegetation association near MocoMoco School.	143
34.	Structural diagram showing vegetation association near Squeak's ranch.	144
35.	Structural diagram showing vegetation association on MocoMoco terrace belt.	146
36.	Structural diagram showing vegetation association near Inaja.	148
37.	Slope profile across the Nappi high hills.	151

Figure		Page
38.	Structural diagram showing vegetation association within the depression adjacent to one of the Nappi high hills.	152
39.	Structural diagram showing vegetation association along the western slope of one of the Nappi high hills.	153
40.	Slope profile across Meritizero low hill.	157
41.	Neutral value density trace for the eastern laterite upland block.	161
42.	Neutral value density trace for the central laterite upland block.	164
43.	Neutral value density trace for the western laterite upland block.	168
44.	Block diagram showing the Kanuku scarpland.	171
45.	Grain-size curve for a soil sample from the Kanuku colluvial forest belt.	175
46.	Slope profile across a sand hill half a mile east of Central.	180
47.	Block diagram showing the Sapaika-Sawariwau Lowland.	181
48.	Grain-size curve for soil sample from Central high dune and flat.	184
49.	Structural diagram showing vegetation association on sand flat near Central.	186
50.	Grain-size curve for soil from the eastern dune complex east of Central.	188
51.	Neutral value density trace for the Sapaika-Sawariwau Lowland.	191
52.	Profile showing entrenchment along the Ireng river.	196
53.	Structural diagram showing vegetation association near Ireng, south of Good Hope.	197

Figure		Page
54.	Profile showing entrenchment along the Takutu and the Rupununi rivers.	198
55.	Block diagram showing the Takutu Flood-plain.	200
56.	Stages of evolution of Northern Rupununi streams.	208

LIST OF PLATES

PLATE		Page
1.	Takutu shale on the bed of the Takutu river at low water, behind Lethem Police Station.	17
2.	Air-photo showing ribbed effect of light and dark lines within the laterite terrain.	25
3.	Ground photo showing primary forest island.	36
4.	Ground photo showing gully forest island.	36
5.	Ground photo showing anthropic forest island at Parishara.	38
6.	Ground photo showing anthropic forest island at MocoMoco.	38
7.	Ground photo showing open range grazing.	40 & 41
8.	Air-photo stereo pair showing differences in the tonal values of the same objects.	53
9.	Air-photo showing Pakaraima scarp and adjacent lowland.	64
10.	Ground photo showing Lake Moreiru adjacent to the Pakaraima Scarp.	66
11.	Small terrawards adjacent to alluvial fans near Toka.	66
12.	Air-photo showing western part of the Pakaraima Scarp Complex.	69
13.	Air-photo showing eastern part of the Pakaraima Scarp Complex.	71
14.	Air-photo showing the northern margin of the Marakanata Lowlands.	91
15.	Air-photo showing the Marakanata central lowlands.	94
16.	Air-photo showing the southwestern margin of the Marakanata Lowlands.	97

Plate		Page
17.	Ground photo showing the Roraima cobbles.	107
18.	Air-photo showing linear depressions.	110
19.	Ground photo showing circular depression near Karanambo.	111
20.	Ground photo showing laterite surface maintaining forest island with the eastern upland block.	111
21.	Ground photo showing forest island within the eastern Upland block.	121
22.	Ground photo showing high Nappi Hills.	131
23.	Ground photo showing low hills in MocoMoco Flat.	131
24.	Ground photo showing circular depression between Hiawa and Nappi.	133
25.	Ground photo showing blocky laterites in rows near Manari bridge.	133
26.	Ground photo showing blocky laterites near Johnson's ranch.	135
27.	Ground photo showing forest island on raised laterite bed near Pirara.	135
28.	Ground photo showing dense stand of Curatella on MocoMoco terrace belt.	145
29.	Ground photo showing giant termiteria near Lethem on Pirara road.	145
30.	Ground photo showing giant termiteria near Nappi.	149
31.	Terraward zone at Komako.	149
32.	Ground photo showing vegetation along gullies near Komako.	154

Plate		Page
33.	Ground photo showing Ite palm swamp at Upper Parika.	154
34.	Ground photo showing forest island on laterite outlier near Pirara.	158
35.	Air-photo showing the eastern laterite Upland block.	160
36.	Air-photo showing the central laterite Upland block.	163
37.	Air-photo showing the western laterite Upland block.	167
38.	Air-photo showing cultivation sites within the Kanuku colluvial forest belt.	173
39.	Air-photo showing the Sapaika-Sawariwau Lowland.	179
40.	Ground photo showing dwarf termite mounds on MocoMoco flat.	213
41.	Ground photo showing a dwarf termite mound at close view.	213
42.	Ground photo showing giant termite mounds near Lethem on MocoMoco road.	214
43.	Ground photo showing giant termite mounds near Hiawa.	214

Page

LIST OF TABLES

I.	1967 monthly rainfall totals for selected stations.	8
II.	Precipitation between April and August.	8
III.	Pluviometric index for selected stations.	8
IV.	Profile from wells.	20
V.	Lengths of major streams dissecting the laterite terrain within the savanna belt.	23
VI.	Organic matter content of soil types.	28
VII.	Porosity and moisture characteristics of soils of the Northern Rupununi.	32
VIII.	Terrain types within the Northern Rupununi savanna.	57
IX.	Air-photo characteristics for the Pakaraima Scarp Complex.	74
X.	Sieve analysis, pH and colour characteristics of the Massara and Cajueiro terrace sands.	79
XI.	Sieve analysis, pH and colour characteristics of soil samples from the Marakanata Central Lowland.	84
XII.	Sieve analysis, pH and colour characteristics of soil samples from the Marakanata southwest margin.	87
XIII.	Air-photo characteristics for the Marakanata Lowlands.	99
XIV.	Ridge types showing stages of reduction within the laterite terrain.	105
XV.	Sieve analysis, pH and colour characteristics of three samples, summit, sheetwash zone and adjacent flat soils around MocoMoco.	113
XVI.	Sieve analysis of two samples on low sandy ridge and flat near Manari Outstation.	137
XVII.	Profile site description and the characteristics of its different horizons.	142

		Page
XVIII.	Air-photo characteristics of the laterite Upland Pattern.	165
XIX.	Sieve analysis of soil from Kanuku Colluvium Belt.	174
XX.	Air-photo characteristics of the Kanuku Scarpland Pattern.	177
XXI.	Sieve analysis of samples on high dune and flat near Central.	183
XXII.	Sieve analysis of samples on low dune and flat four miles of Central.	187
XXIII.	Air-photo characteristics of the Sapaika-Sawariwau Lowlands.	192
XXIV.	Air-photo characteristics of the Major Flood-plains.	203

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P A R T O N E

CHAPTER I

INTRODUCTION

The reports of the Geological Surveys of Guyana contain a considerable amount of information on the physiography of the Rupununi Savannas. Another major source of information is the publication 'Soil and Land Use Surveys' by the Regional Research Centre of the British Caribbean at the Imperial College of Tropical Agriculture, Trinidad. Almost all the articles published by these sources however suffer the limitation of scope; most of them treat the study area only in parts, and none provides a base map for the area.

Apart from these sources, the McGill University Savanna Research Project centred at St.Ignatius, Lethem, has made notable contributions to the study of the Rupununi by encouraging research work for theses writing and better understanding of Tropical Geography. Through this project, the Department of Geography has produced a number of theses covering a wide range of interests on the Rupununi Savannas. Of these theses, the 'Geomorphic Evolution of Northern Rupununi, British Guiana', by N.K.P.Sinha is worthy of special mention. This presents the most comprehensive coverage for Northern Rupununi, running through the whole gamut of landscape evolution with notable contributions to every branch of the geography of the area.

The author's work is an addition to the research of the McGill Savanna Research Project in the Rupununis. The basic objective is the identification of the terrain types in the Northern Rupununi Savanna, and the co-relation of their air-photo characteristics with the actual ground conditions. Particular attention was paid to geology, morphology, drainage, soils and vegetation of the study area.

Preliminary preparation included library work which started as early as March 1967. A detailed study was made of all available works on the physiography, climate and geology of the area. The aerial photographs coverage of the area (Huntings 1953 scale) was also carefully examined in order to be adequately prepared for field-work. With the aid of these photographs the author was able to delimit the actual areas which required particular attention.

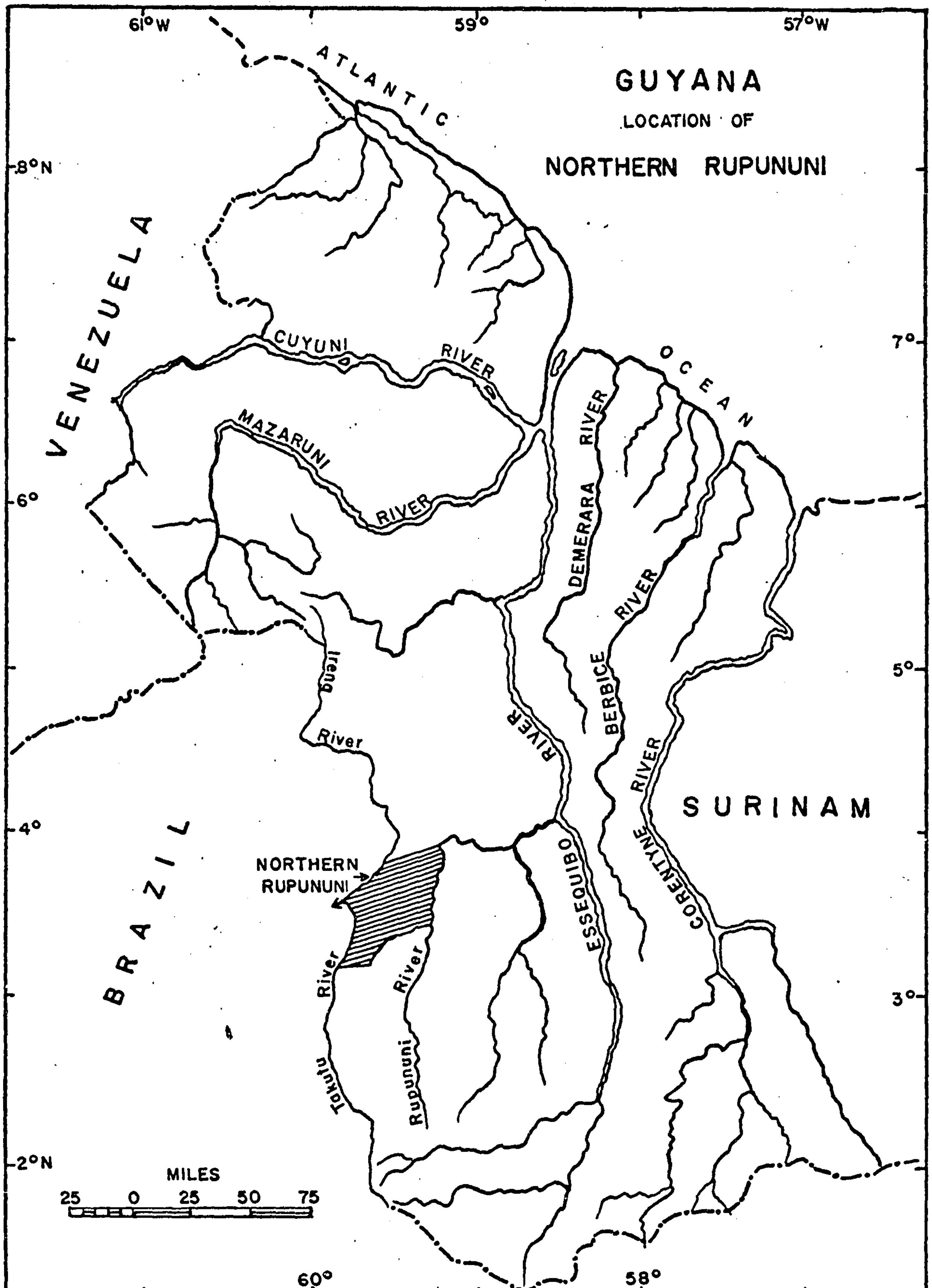
The field-work covered a four month period from July to November 1967. During this time, the author was engaged in studying slopes, soils, drainage and vegetation characteristics. Slope studies were made with abney level, ranging poles and tape. Soil studies included auger work for obtaining samples for grain-size analysis and pH. Some soil profiles were also dug in order to assess gradation of materials and colour in soils. Level traverses were made across river channels and channel depths above water surface were measured by means of poles. Vegetation types were sampled from one physiographic zone to another, and within different soil types. The vegetation characteristics within the sampled zones were examined using the universal system for recording vegetation. With the arrival of the 1962 air-photo coverage, the author began a tentative classification of the land patterns occurring within the area defined as the Northern Rupununi Savanna of Guyana and shown in the index map Fig.1.

The Study Area.

The area of study referred to as the Northern Rupununi Savanna is bounded in the east by the Rupununi River, in the west by the Takutu and Ireng rivers, in the north by the Southern Pakaraimas and in the south by the Kanuku Mountains and the Sawariwau River which separates the 'inselberg landscape' of the South Savannas from the laterite ridges and depressions, terrace deposits, dunes and alluvial fans of the north. The area thus defined falls within the quadrangle bounded on the east by the longitude 59°20'W, on the west by longitude 59°55'W, on the south by latitude 3°9'N, and on the north by latitude 3°55'N.

The area forms a small component of the much larger Rupununi Savannas. It has a maximum width of about 75 miles in the west, tapering to about 15 miles along the Rupununi River in the east. The area of the savanna belt has been variously estimated as 2,000 sq.miles (Loxton et al, 1958), 1,800 sq.miles (Bleakley, 1962) and 1,740 sq.miles (Sinha, 1967). These estimates are approximately correct and without a topographic map, it is not possible to arrive at a more precise figure.

FIG. I



Windapo, 1968.

Climatic Setting.

The Northern Rupununi Savanna area is characterized by a persistently high temperature all year round, and by a marked seasonal distribution of rainfall. It has been described by Aubréville (1961) as a remarkable example of an equatorial semi-arid climate distinguished by the following characteristics:

(i) High rainfall - about 1,500 mm. or 60 inches with a maximum in June.

(ii) Length of rainy season - usually 5 months, from April to August.

(iii) Mean annual temperature - 27.5^{0} to 28^{0}C.

(iv) Range of temperature - very low, 2.3 to 2.8^{0}C.

(v) Annual moisture deficit - high but variable.

(vi) Vapour pressure - 18.8 to 19.4 mm., lower than in the Amazon type.

(vii) Pluviometric index - 5-6-1 (number of months wet, intermediate and dry).

The length of dry season may vary from one to six months.

Precipitation:-

In the Northern Rupununi Savannas, rainfall shows some variations from one area to another according to the location. Areas close to mountain ranges are influenced by convective systems generated locally, and consequently receive more rain than the areas farther away. For example, at Komako station close to the Kanuku mountain, a total of 92.8 inches of rainfall was recorded in 1967 while at Manari farther away to the west, only 68.3 inches was recorded.

The wettest part of the Rupununi savanna lands is the dune and swamp country lying in the embayment of the Kanuku in the southwest. In contrast, the northwestern part, lying in a rain-shadow, is very dry while the western part of the Marakanata lowlands farthest from mountain ranges is the driest.

Generally, rains come in torrential down-pours of short duration in the Northern Rupununi Savannas. This mode of precipitation can lead to intensive erosion.

Over 70 per cent of the annual rainfall is received within five months, from April to August, with June being the wettest month. The marked seasonality in the precipitation of this area is reflected in Fig. 2 which shows the mean annual rainfall for St.Ignatius - a typical station in the study area. Table I shows the 1967 monthly and annual rainfall totals for some selected stations while Table II shows the precipitation between April and May as a percentage of the annual precipitation. A modified pluviometric index was calculated from the monthly precipitation to show the number of months in the wet, intermediate and dry seasons respectively for each station as shown in Table III. From the pluviometric indices, six months were generally within the wet season mark. This seemed to suggest that the generally accepted duration of the wet season - five months from April to August - may be somewhat an underestimate. However, it

ST. IGNATIUS, — RUPUNUNI

MEAN ANNUAL RAINFALL

1930 – 1965

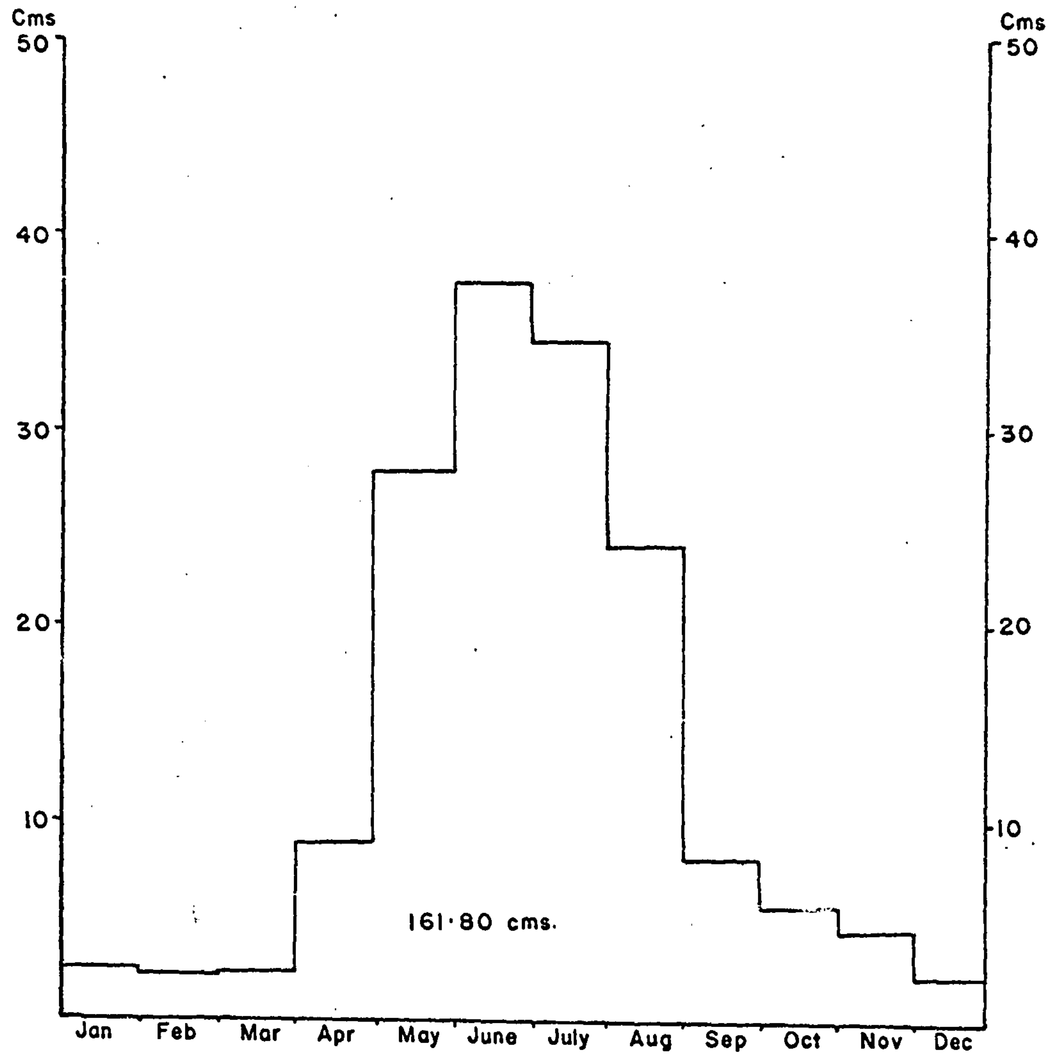


FIG. 2

After D.B. Frost, 1966.

TABLE I

R A I N F A L L

Stations	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Totals
	Monthly Totals												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
St.Ignatius	1.84	0.03	0.04	10.28	17.15	19.23	19.57	5.60	5.22	3.53	4.49	1.42	88.40
Gaskins	3.30	0.50	0.30	9.00	21.40	23.70	12.90	7.90	13.60	0.60	3.10	3.70	100.00
Site 1	1.30	0.10	0.01	9.20	14.70	19.30	16.90	6.70	4.90	1.50	6.40	2.50	83.50
Komako	2.30	0.40	0.00	10.30	20.20	23.60	18.10	6.40	7.50	0.60	1.40	2.00	92.80
MocoMoco	3.80	0.70	0.60	8.70	22.10	23.40	14.00	7.40	13.0	0.40	2.50	3.70	100.30

TABLE II

Stations	Annual Totals (A.)	Totals for April-August (B.)	B/A in %
St.Ignatius	88.40	71.83	81.25
Gaskins	100.00	74.90	74.90
Site 1	83.50	66.70	79.88
Komako	92.80	78.60	84.69
MocoMoco	100.30	75.60	75.37

TABLE III
PLUVIOMETRIC INDICES

Stations	Wet (above 5")	Intermediate (2-5")	Dry (less than 2")	Dry Months
St.Ignatius	6	2	4	Dec. -Mar.
Gaskins	6	3	3	Oct., Feb.-Mar.
Site 1	6	2	4	Oct., Jan.-Mar.
Komako	6	2	4	Oct.-Nov.,Feb-M
MocoMoco	6	3	3	Oct., Feb-Mar.

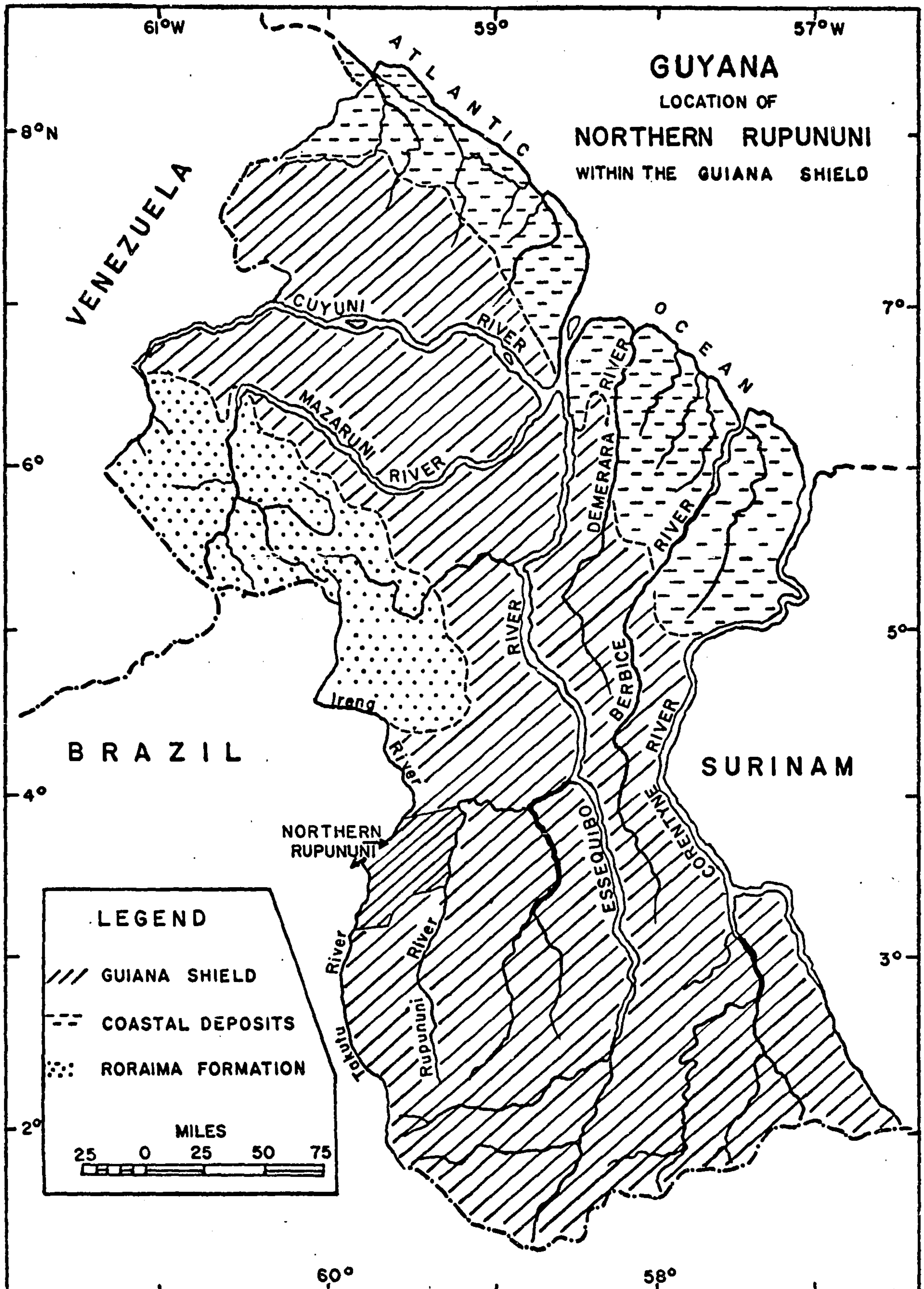
should be pointed out that 1967 was an exceptionally wet year in which monthly precipitation was generally higher than typical, whereas the levels of demarcation used in the analysis were those for typical conditions.

Geologico-morphological Setting.

While the author acknowledges the fact that much has been done to unravel the geologic history as well as give a synoptic picture of the morphology of his study area, he feels the more convinced that more remains to be done to achieve a fuller understanding of the development of the various component parts of the Northern Rupununi Savannas. Inasmuch as it is not the ultimate goal of this particular project to achieve this end, only a summary of deductions from previous works and from the author's observations in the course of his field-work is presented below in aid of a better understanding of the evolutionary history of the landscape.

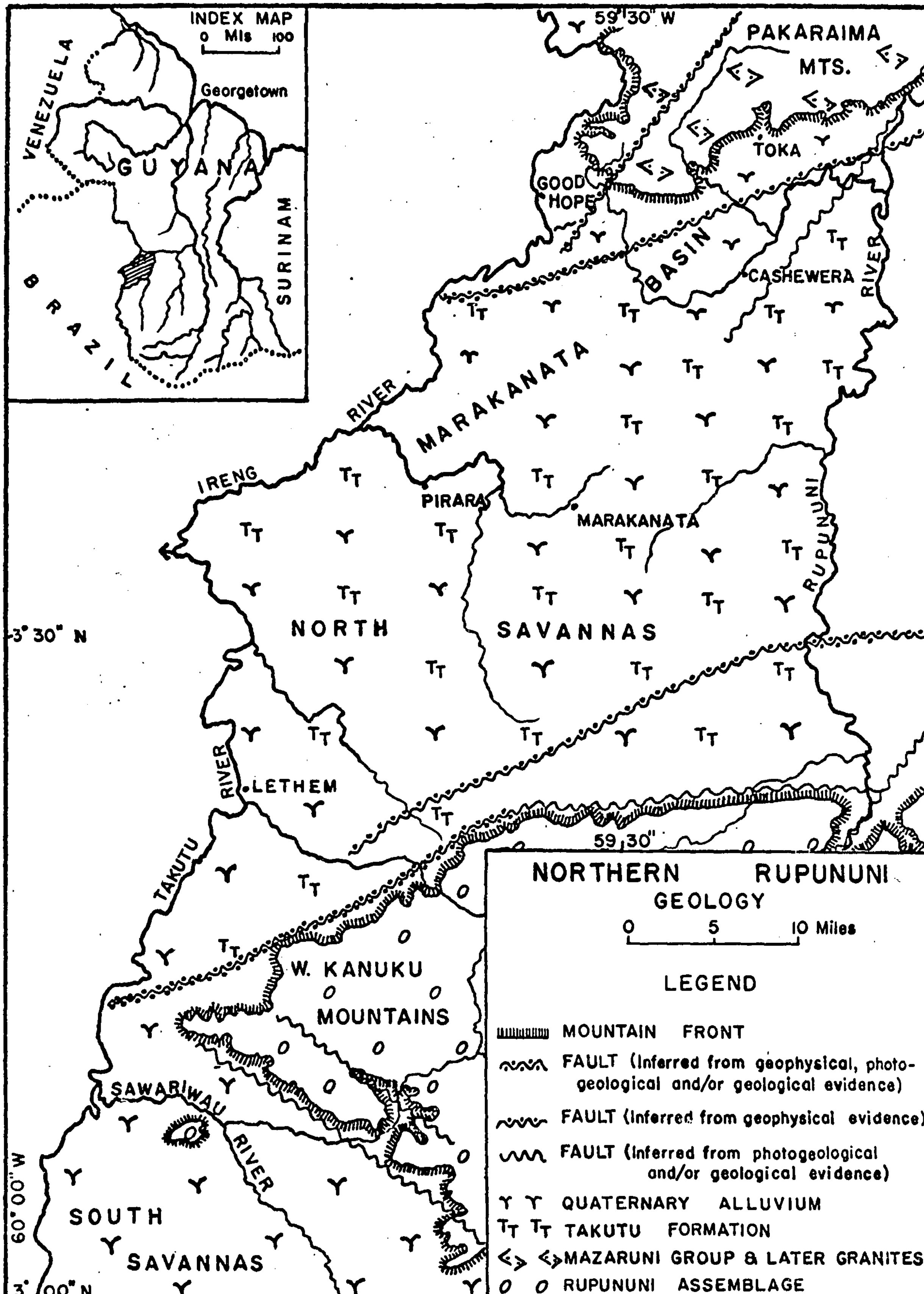
The study area lies in the heart of an ancient geological structure known as the Guiana Shield (Fig.3). In the Proterozoic era, a belt from the Pakaraimas to the Kanukus was uplifted by diastrophic forces. As a result of faulting and subsidence later in the Palaeozoic era, a shallow trough was created into which sediments knows as the Roraima Formation were deposited. Further subsidence of this trough resulted in the formation of a true graben structure, the dimensions of which have been recently confirmed by geological and geophysical mapping (Fig. 4). This graben structure is depicted in a block

FIG. 3



WINDAPO, 1968.

FIG. 4



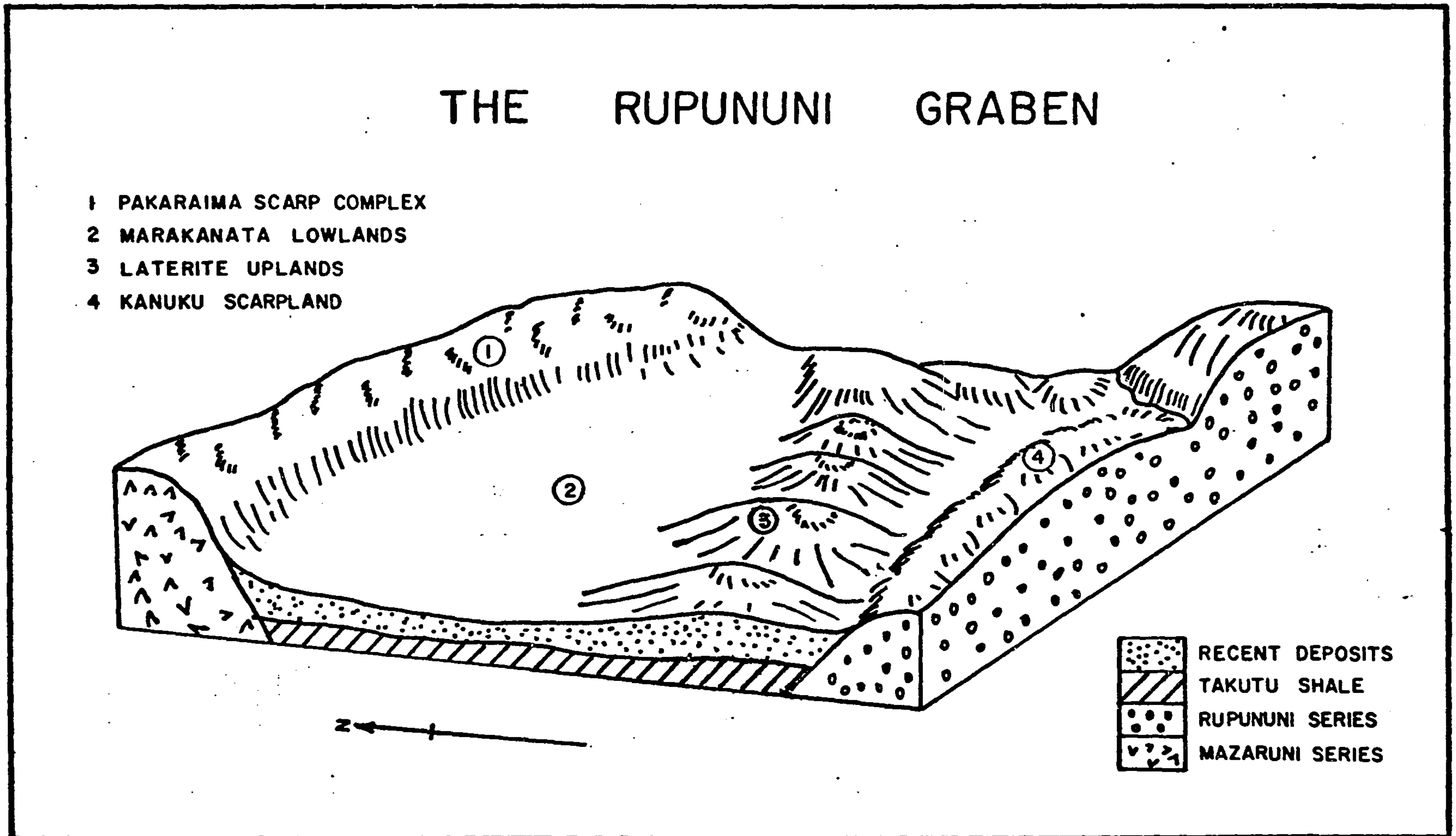
After J.P. Berrange'

diagram as shown in Fig. 5. Within this structure, the Roraima Formation was buried under a thick deposit known as the Takutu Formation deposited in the Cretaceous period. This latter deposit composed of grey, red and purple rocks with intercalations of micaceous shales, flaggy siltstones and soft current-bedded sandstones, was laid down in a shallow inland sea which invaded the graben and which has since disappeared. Today, it is only along the deeply entrenched rivers that both the Takutu and the Roraima Formations are exposed at low water during the dry season.

Folding and tilting of the Takutu Formation towards the close of the Cretaceous in response to cyclic earth movements in the Guiana Shield produced westerly dips of up to 40^{o}. The Takutu beds were later dissected and planed to produce a polycyclic surface of low relief now recognized as a surface of unconformity in the geological sequence of the graben structure. Eroded materials from both the Kanuku and the Pakaraima were deposited on the planed 'Takutu surface' during the Pliocene. These materials hereafter referred to as the 'Pliocene deposits' may correspond to the white sand remnants found towards the Guyana coast and in the Twiwid series of the Southern Savannas. These Pliocene deposits, derived largely from granitic rocks, were very rich in iron and silicate minerals which were the chief ingredients in the formation of laterites.

During the Pleistocene epoch, a series of pluvial phases alternated with dry episodes in the Tropics (Passarge,1904;

FIG. 5



Windapo, 1968.

Emiliani, 1955; Charlesworth, 1957; Flint, 1959: van der Hammen, 1961). Such changes affected the study area, and the associated changes in water-table led to the formation of laterites in stages within the Pliocene deposits of the graben. The first level of laterization hereafter referred to as 'basal laterite' lies unconformably over the Takutu shale from the Kanuku to the Pakaraimas. This level was formed above the water-table which lay on the Takutu shale and later became a limiting factor to infiltration. During subsequent pluvial condition, the water-table lay above the basal laterite and another level of laterite was formed at this level in the following inter-pluvial phase. This level in turn impeded infiltration, creating a new water-table above which another level of laterization developed. In this way, sequential impedence of infiltration raised the water-table and caused new levels of laterization with changes in pluvial and inter-pluvial conditions. The exact number of levels is not known, but at least three are now found as legacies of the Pleistocene laterization.

With the incursion of the Proto-Berbice River from Brazil into the Rupununi laterite terrain in a southwest-northeast direction in late Pleistocene, and the consequent carving out of the Marakanata depression, a reversed process began. The Water-table started to fall as streams and creeks cut into the laterite landscape causing accelerated erosion. The youngest horizon was exposed first and it started to disintegrate into gravels and sands, leaving remnants of massive blocks here and there as laterite cappings on some of the hills especially within the western and central blocks of uplands. These remnants will be referred to as the 'High-Level Laterites'. Where streams and creeks are deeply incised and carved extensive valleys, the second level of laterite formation has been exposed as in the MocoMoco and Komako areas. These exposed beds are hereafter referred to as the 'Low-Level Laterites'. In places, the low-level laterites have created perched water-tables as at Lethem, and are the cause of seasonal waterlogging conditions. Along the channels of the Ireng, Takutu and the Rupununi, where the major rivers have cut very deeply into the Pliocene deposits and the Takutu shale, the third and oldest laterite crust - the basal laterite - has been exposed overlying the Takutu shale. An example of such an exposure occurs on the Ireng three miles from its confluence with the Takutu, while another is found above the bank of the Rupununi at Yupukari.

From the chronology outlined above, it is not surprising that a complex geology exists within the study area. Although this geology is not known in detail, the general sequence has been established in order of increasing age as follows:-

(i) Holocene - terraces, lacustrine and other superficial deposits.

(ii) Pleistocene - laterites.

(iii) Pliocene - laterite parent materials.

(iv) Cretaceous -Takutu Formation i.e. Shales.

(v) Precambrian - Basement Complex:-

(a) Good Hope series - Acid Volcanics.

(b) Kanuku Group of rocks.

The Precambrian rocks are found on the northern and southern fringes of the graben structure. Associated with these rocks are two physiographic zones: The Pakaraima Scarplands to the north and the Kanuku Scarplands to the south (Fig. 5). To the north, the rocks comprise an acid volcanic series of rhyolites which are predominantly porphyritic. This series was later intruded by granites and subsequently cut by dolerite and gabbro dykes striking NNE (Bailey, 1958). The intruded series is now referred to as the Mazaruni Group (Fig. 5).

To the south, the Precambrian Basement Complex is represented by rocks of the Kanuku Group which underlie the Kanuku Mountains and the Savannas to the south. The main rock types are granulites, ultrabasic hornblendite and pyroxenite, and pyroxene granulites (Morris, 1962). These are collectively referred to as the Rupununi Assemblage (Fig. 5).

Rocks of Cretaceous age - the Takutu Formation - underlie the study area from the foot of the Pakaraimas to that of the Kanukus. Red shales are found wherever the formation is exposed, especially along the deeply incised rivers like the Takutu, Ireng and Rupununi. In both Lethem and St. Ignatius, these rocks are frequently exposed along the bed of the Takutu River at low water (Plate 1). Here they are chocolate - coloured and massive. This-bedded red shales have been reported between Lethem and Casa Branca. The beds are said to

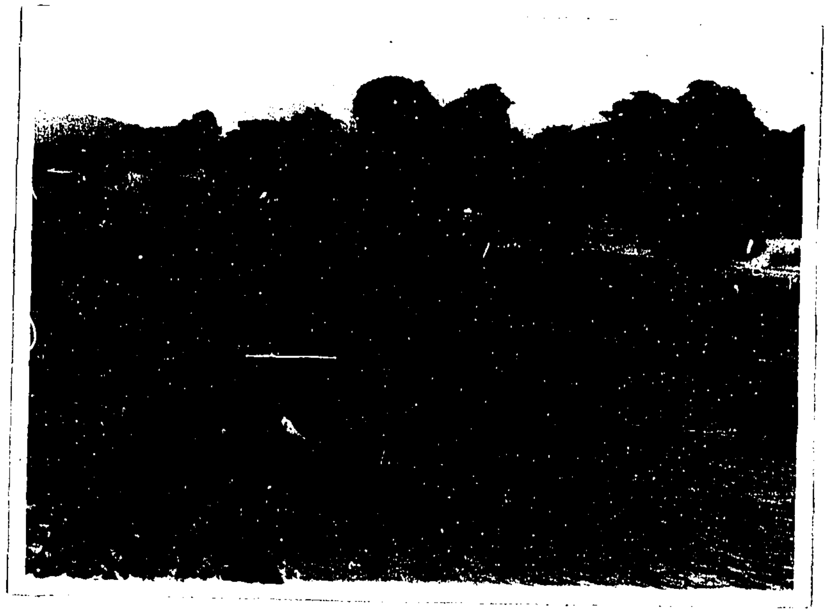


Plate 1: Takutu shale exposures on the bed of the Takutu River at low water, behind Lethem Police Station. (Photo by Windapo).

Plate 1: Takutu shale exposures on the bed of the Takutu River at low water, behind Lethem Police Station. (Photo by Windapo).

be folded with low dips of up to 40^{o}, predominantly in a westerly direction (Bleakley, 1962). Elsewhere, weathered red shales are found east of Marakanata and in the Rupununi and Rewa rivers.

Pliocene deposits laid on the Takutu Formation formed the parent materials for the laterites of the study area. They overlie the Takutu Formation all over the graben structure except where they have been eroded and replaced by Holocene deposits within the Marakanata Lowlands. Within these deposits are the Pleistocene laterites formed as a result of changes in pluvial conditions in the Pleistocene period. And associated with these deposits is a major physiographic unit, referred to as the 'Laterite Uplands' which occupies a zone about 15 miles wide in an approximate east-west belt (Fig. 25).

Holocene deposits are mainly alluvial. They overlie the Takutu Formation only in places where the Pliocene deposits and Pleistocene laterites have been completely eroded within the graben. They originate as fluviatile and lacustrine deposits and consist of two horizons - an upper silty and sandy loam series, and a lower coarse sand series with intercalated red and white clays. The finer silty fraction of white to buff colour within the upper series tends to blow in the dry season at the slightest disturbance by hoofs or wheels as in areas around Good Hope. The major physiographic regions where these deposits predominate are the Marakanata Lowlands, the dune and swamp country between the Sapaika and the

Sawariwau rivers on the southwestern part of the study area, and the major flood plains along the Takutu, Ireng and Rupununi rivers.

South of the Marakanata depression, the silty and sandy loams are associated with laterites and lateritic soils in the upland zone which extends to the borders of the Kanuku Mountains. These loams originate as wash products from both the Kanuku scarplands and the laterite ridges. They are also found along the rivers and creeks, on the flats, and at the bottoms of the many wide valleys and depressions of the upland zone.

Within the coarse sand series, there are laterite bodies usually at depths varying between 10 and 15 feet below the surface. Table IV shows some profiles in which laterites were found. The coarse sands with clays are iron-stained to varying degrees and their colours range from buff to red - a yellowish brown being typical. Where cemented, they form sandstones; and where impregnated with iron oxides, they develop into ironstones. These sandstones and ironstones provide a hard cap preserving outcrops of red shales where the basal laterite has been eroded.

Recent fluviatile sediments occur predominantly as terraces best developed along the Ireng River. They consist of moderately coarse, fairly well-sorted sands with a varying amount of clay. Usually, the first two feet are of a sandy texture, showing little soil development, and the clay content increases with depth. They are usually yellowish brown in

TABLE IV

Profiles from Wells

Location	Depth in feet	Materials encountered*
MocoMoco 1+	0-10	Clay
	10-26	Laterite blocks and gravel
	26-32	Gravels
Parishara	0-8	Sand and Clay
	8-10	Laterite blocks
	10-11	Gravel
	11-18	Soft laterite
Massara 1	0-1	Sand
	1-6	Sand and laterite
St.Ignatius	0-5	Sandy clay
	5-20	Soft laterite
	20-21	Laterite gravel
	21-30	Soft and hard laterite
Lethem	0-12	Sandy clay
	12-32	White clay and laterite gravel
	32-42	Brown laterite rock-soft

* The constituents of the materials dug out from the wells are crudely estimated by the well-digging unit and what is shown in the table is based on a report by G.Henderson as shown in G.S. File No.Let.64/65 in the D.C's office at Lethem.

\+ The numbers in front of names of places refer to the well numbers.

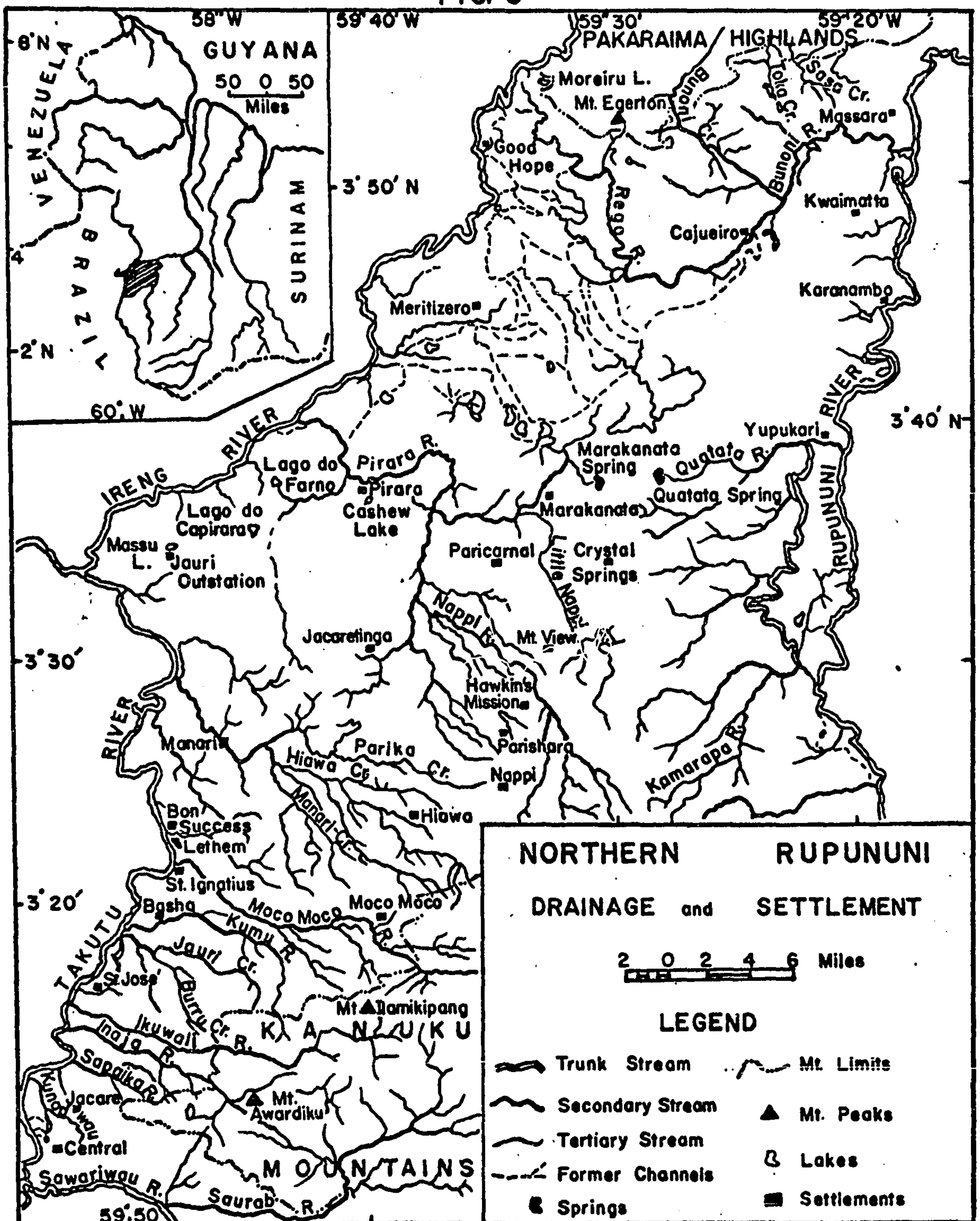
colour.

Lacustrine deposits, such as those in the Marakanata basin, are predominantly sandy clay with a small proportion of silt. They are usually whitish to buff in colour. In areas inundated for most of the year, the sediments remain unweathered and consequently infertile.

The drainage of the different physiographic units has had considerable influence on the superficial deposits and their morphological characteristics observable today. A careful study of Fig. 6 reveals that most of the laterite uplands is drained by rivers flowing northwestwards into the Takutu and Ireng rivers. The largest of these rivers are the MocoMoco, Manari and Nappi from west to east; they all originate in the Western Kanuku Mountains. Table V shows the major streams dissecting the laterite terrain and their lengths within the savanna belt. Characteristic of these rivers are wide flat bottom valleys into which the present channels are deeply incised. Extreme flooding is common in the wet season creating large swamps some of which persist throughout the dry season.

Also dissecting these laterite uplands are innumerable minor drainage ways. In their initial stages, they appear as rills on the higher slopes, sometimes developing into gullies which widen out into flat-bottom valleys on the lower slopes, gradually merging into flood-plains and flats. Runoff in these valleys moves in broad sheets rather than in defined channels. The smooth undulating surfaces often found on the

FIG. 6



After N.K.P. Sinha, 1967

TABLE V

	Streams	Stream Length* within Savanna belt (in miles)
1.	MocoMoco	15.4
2.	Manari	22.6
3.	Nappi	30.2
4.	Hiawa	8.2
5.	Quatata	12.3
6.	Inaja	7.8
7.	Kumu	13.1
8.	Ikuwali	8.3
9.	Sapaika	5.8
10.	Burru	9.9
11.	Parika	8.4
12.	Tabatinga	7.1

* The stream lengths were measured from the 1962 air-photo coverage.

lower slopes and low hill-tops as well as valley sides result from non-erosive sheetwash. In some areas, very wide troughs develop down the slopes of low hills, running more or less parallel and creating a corrugated pattern which appears on aerial photographs as a ribbed effect of light and dark lines (Plate 2).

The Marakanata depression to the north of the laterite uplands is a zone of complex drainage pattern. In places, water movement takes place in broad sinuous channels which often end blindly in flats and shallow depression. Some channels dry out completely in the dry season while others are marked by a string of shallow pools along their courses. The main depression north of Marakanata settlement is characterized by a maze of such channels which form easily in the soft sediments.

North of the Marakanata depression, the drainage pattern is fan-like, reminiscent of the pattern developed under semi-arid or arid conditions. The Velani, Bunoni and Toka creeks branch into innumerable distributaries on entering the savannas from the mountains, spreading their discharge in broad fans. Many other smaller creeks leave the mountains in narrow slash gullies disappearing almost immediately on leaving the mountain front.

Within the Pakaraima scarp itself, an interesting pattern emerges. Here, the dominant east-west trend of the volcanic rocks combined with the NNE -SSW fracturing associated with dyke intrusions, to impose the grid-iron drainage pattern. This pattern results from the fact that the volcanic rocks are

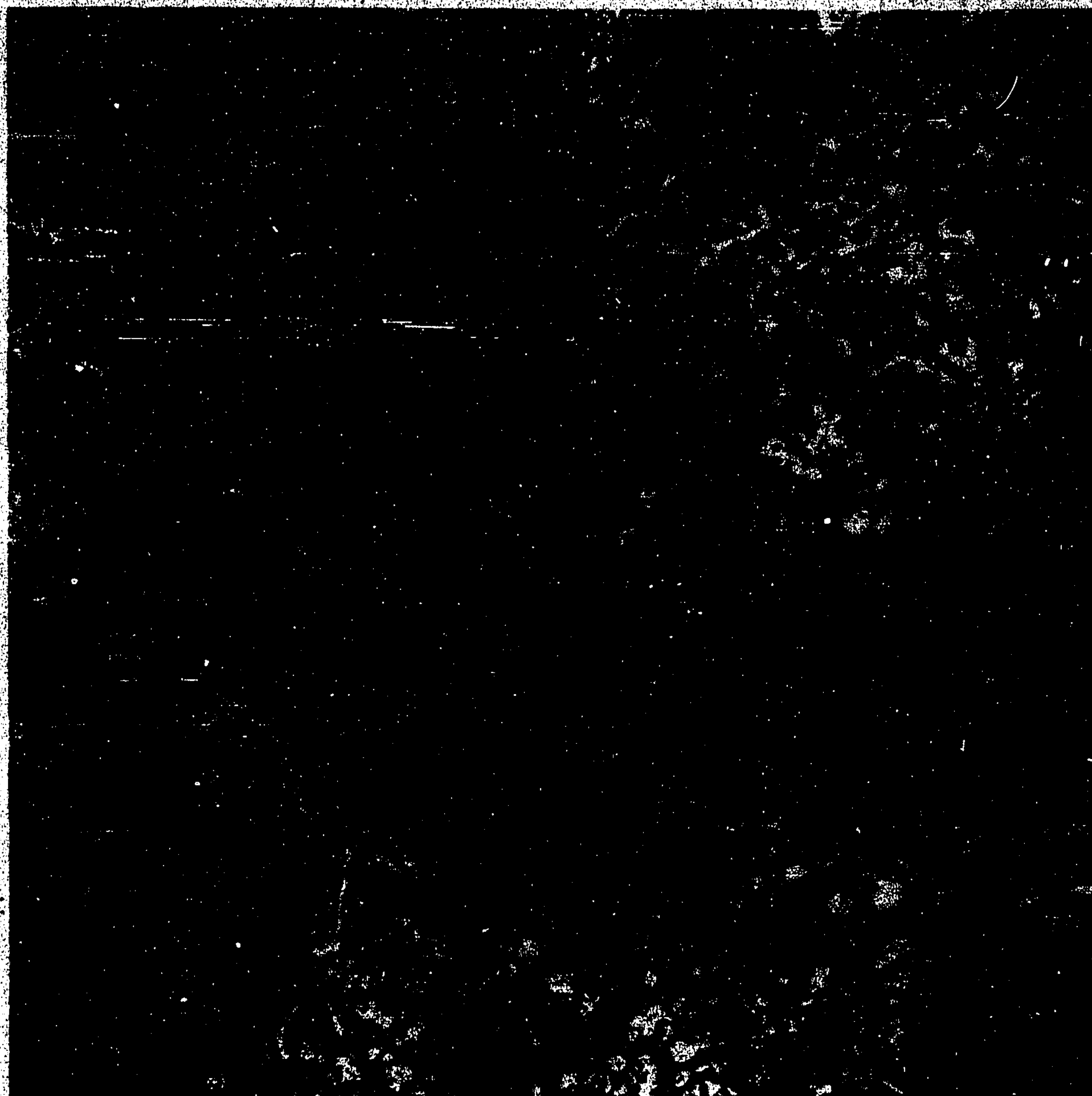
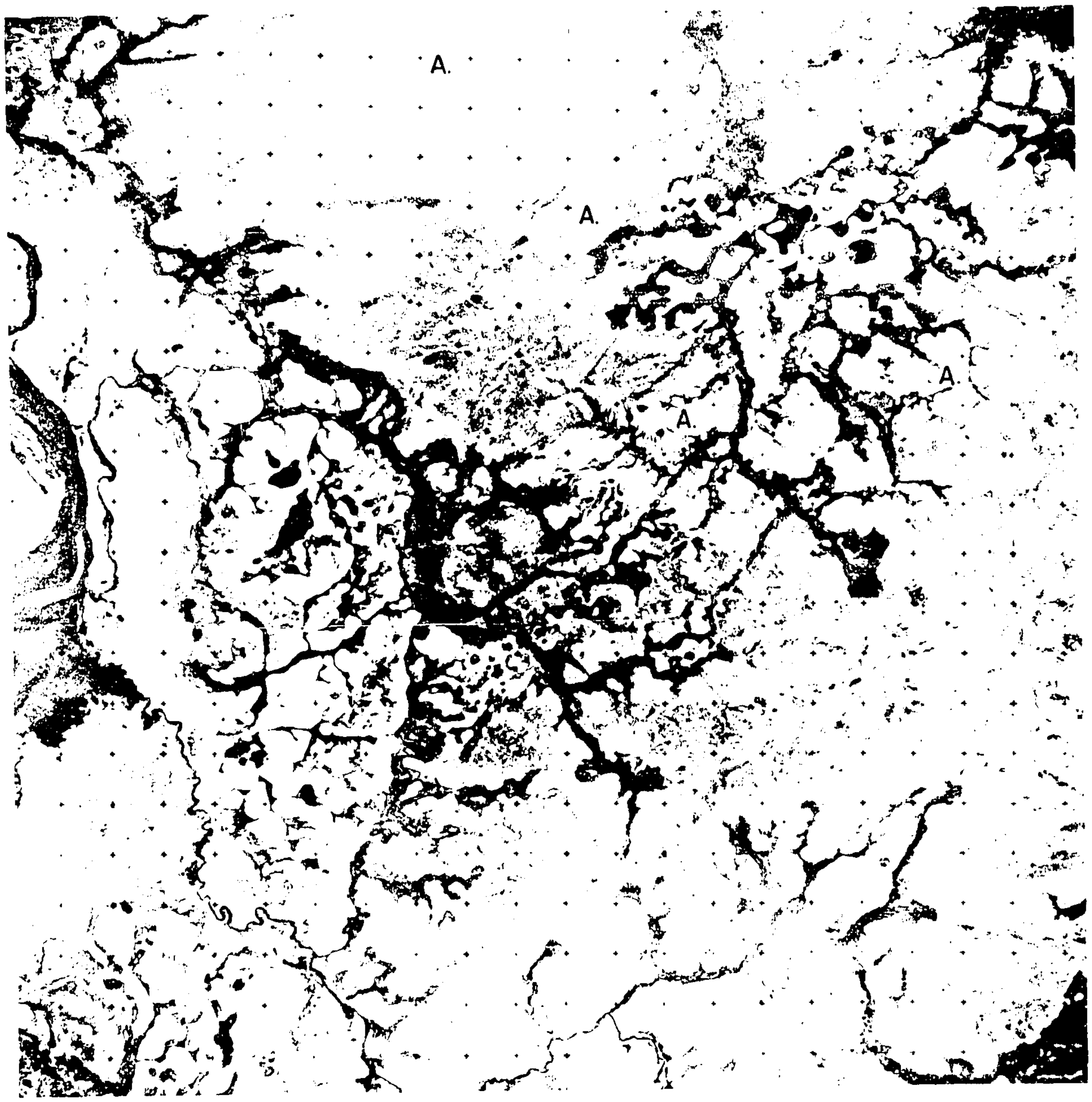


PLATE 2: Air-photo showing ribbed effect of light and dark lines within the laterite terrain. The ribbed effect is prominent in areas marked A on the photo. (Photo by Hunting Aerosurveys Ltd.)


A.
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A

more resistant to weathering than the dolerite intrusions which are marked by stream courses within the scarp while the granites are less resistant than the dykes which then protrude as ridges lower down the mountain foot as at Toka.

Soils.

At the soil group level, variations in soil types are attributed to variations in climate, vegetation, parent materials, age, and topography (Lyon and Bucknam 1943). The effects of these soil-forming factors however change in emphasis from place to place. In the Northern Rupununi for example, all the soil types found within the graben are derived from the thick deposits of sediments lying within the structure. What variations there are now must have been produced mainly by topography, since climatic effects and parent materials are broadly uniform within the shole structure.

In general however, the soils with mature profiles have been referred to as zonal soils all over the graben. But there are soils that reflect local conditions especially of topography, such as swampy or hydromorphic soils, and these are grouped as intrazonal soils. Also present are pockets of young soils that lack definite profiles as in alluvial and colluvial deposits. Such soils are grouped as azonal soils.

The soils are also generally sandy especially in the elluviated A horizon, except the hydromorphic soils with silty A horizon. They are generally infertile too, being low in mineral nutrients and organic matter. Their low mineral nutrient value has been attributed to the severe weathering of the alluvial parent materials, while their low organic content has been attributed to the influence of fire and climate in conjunction. Regular burning destroys much of the organic matter while winds and torrential rains carry away the ashes which otherwise might have enriched the soil. Only in hydromorphic soils could be found a considerable organic content in the top soil. Table VI shows the organic matter content of different soil types within the study area.

Thus soil fertility varies from one site location to another, drainage characteristics being of particular significance. Such site locations based on the United States Department of Agriculture (U.S.D.A., 1951) classification and modified by Eden (1964) include:

(i) Excessively drained,
(ii) Well drained,
(iii) Moderately well drained,
(iv) Imperfectly drained,
(v) Poorly drained, and
(vi) Very poorly drained.

Soil characteristics by site:-

(i) Excessively drained sites:

Soils of such sites are largely regosolic. They have developed on fine to medium lateritic gravel deposits and aeolian materials. The major belt of this soil type is found in the laterite upland blocks with their numerous gravel ridges of varying elevation and slope characteristics, while secondary

TABLE VI

Organic Matter content of Representative Soils, Northern Rupununi

Well drained Savanna latosol		Moderately well drained Savanna latosol		Very poorly drained Swamp humic glei	
Sample depth (Cm)	Organic matter (%)	Sample depth (Cm)	Organic matter (%)	Sample depth (Cm)	Organic matter (%)
0-8	0.8	0-15	0.7	0-13	7.1
8-46	0.5	15-41	0.4	13-25	1.6
46-117	0.2	41-89	0.2	25-58	0.7
117-188	0.2	89-183	0.1	58-102	-

(Analyses from Loxton Rutherford and Spector, 1958 and Stark, Rutherford and Spector, 1959) zones are found in the dune hills of the study area.

In texture these soils range from gravel and sands to loams of high porosity. All profiles within these soil units are structureless with uniform grains, and of a colour range between red and yellow.

(ii) Well drained sites:

Here, soils are mainly latosolic. They have developed on sheetwash alluvium from adjacent gravel ridges as well as on higher sand terrace surfaces. Such sites are characterized by very gentle to gentle slopes which grade downslope into the moderately well drained latosolic sites of higher wet-season ground water.

The soils range from sandy loam to loam in texture amd are generally structureless. Soil colours vary from red in the sheetwash alluvium zones to yellowish brown in the terrace surfaces.

(iii) Moderately well drained sites:

These sites are found in the lower sandy terraces, levees, outwash deposits and sheetwash alluvium within very wide flat-bottomed valleys of the dissected laterite uplands. They occupy gently undulating surfaces as well as very gentle slopes which are intermediate zones between well-drained and imperfectly drained sites. Surface soils are mainly latosolic with loamy sand texture and brown colour hues.

(iv) Imperfectly drained sites:

These sites occupy the many low relief flats characterized by level to gently sloping topography within the laterite terrain; MocoMoco, Nappi and Manari flats being typical site samples. The soils here vary in texture from site to site, but are generally akin to latosolic soils with a distinguishing characteristic mottling and gleying, and occurrence of plinthite in the lower horizons of their profiles. Surface textures vary from sandy loam to sandy clay loam, and the soil colour is predominantly grey.

(v) Poorly drained sites:

These are found on flats and very gently sloping areas of fluvio-lacustrine deposits bordering the laterite uplands to the north and south and on the very low flats and bottom flats of the wide valleys in the laterite terrain. Such sites north of the laterite terrain are found in the Marakanata lowlands, and to the south in the depressions of the Sapaika-Sawariwau lowlands. Within the laterite terrain, these sites are found in the Kumu and Inaja flats of very low relief and in many of the seasonally inundated and semi-waterlogged wide flat-bottomed valleys. Characteristic of the soils of the sites are gleyed profiles with mottlings. The soils are generally more chemically weathered than the imperfectly drained soils as a result of prolonged flooding and waterlogging. The texture varies from silty loam to silty clay loam and the profile is usually layered. Surface soil colours are generally grey.

(vi) Very poorly drained sites:

These sites are found on fluvio-lacustrine and lacustrine sediments in flats of varying dimensions which are generally seasonally inundated and swampy for the greater part of the year. Distinguishing these sites from the poorly drained sites of similar topographic locations is the presence of an organic layer on the surface soil. This organic layer varies in thickness from site to site in accordance with local drainage conditions and thins out towards the margins of its zones of accumulation.

Texturally, the soils vary from silty loam to clay from margins to centres of depressions as in the Marakanata Lowland proper, and the intervening depressions of the dune country between Sapaika and Sawariwau rivers. Such soils are uniformly intensely gleyed with well developed mottling in the lower horizons, and are generally dark grey to black in the A horizons due to the presence of organic matter.

From this analysis of soil characteristics it is not hard to see that the soils of the Rupununi vary in porosity and moisture characteristics. The zonal and intrazonal soils which lack appreciable structure and form the greater percentage of the soils of the study area have low macroposity and moisture retention capacity. On the other hand, the hydromorphic azonal soils have higher porosity and moisture retention characteristics. Table VII compiled by Eden (1964) and modified by the author, shows the porosity and moisture characteristics of soils of the study area. In the table, categories 1-3 are representative of zonal and intrazonal soils while 4 and 5 represent the azonal soils.

Vegetation.

The vegetation of the study area is basically savanna

TABLE VII

POROSITY AND MOISTURE CHARACTERISTICS OF SOILS OF THE NORTHERN RUPUNUNI

	Moisture Content as a function of Porosity	Moisture Content at Field Capacity (%)	Percolated water in 24 hrs (%)	Retained Moisture after 24 hrs (%)	Amount lost by evaporation (%)
1. Structureless Sandy loam	37.8	22.4	2.5	14.5	5.4
2. Structureless Sandy clay loam	39.4	24.3	2.2	10.4	11.7
3. Structureless loam/Silt loam	43.6	28.9	2.0	10.1	16.8
4. Humic silt loam/silty clay loam	65.9	128.5	12.0	65.0	51.5
5. Silt loam with many vesicular pores	61.0	124.5	12.0	72.5	40.0

within the graben structure, bounded by forests of the Kanuku and Pakaraima scarps, and punctuated by galeria forests and forest islands.

The savanna communities are typified by a small number of herbaceous and woody species, especially adapted to cope with drought and burning, in a matrix of grasses, sedges and forbs. They are broadly grouped as:

(a) Open Wooded Savanna, and

(b) Herbaceous Savanna.

Within these broad groupings could be recognized sub-types based on the density of the woody and herbaceous species as related to their substrata of grasses and sedges. These sub-types have been named after Brazilian terminology. Thus within the open wooded savanna are found the following sub-types:

(i) Campo cerrado,

(ii) Campo coberto and

(iii) Campo sujo.

And within the Herbaceous Savanna are:

(i) Campo limpo (grass dominated), and

(ii) Campo limpo (sedge dominated).

The various sub-types have been defined with specific reference to the Rupununi Savannas by Eden (1964) as follows:

(a) Open Wooded Savanna.

(i) Campo cerrado:- A wooded savanna with an herbaceous layer dominated by bunch grasses with an underlying substratum of sedges, and a few forbs. The tree cover is dense but not continuous; individual trees are from five to ten metres apart, and mature specimens normally grow to a height of three to six metres.

(ii) Campo coberto:- A less densely wooded savanna with an herbaceous layer dominated by bunch grasses, with an underlying substratum of sedges and a few forbs. Tree growth may be lower and is more sparsely distributed than in the above: individual trees are more than ten metres apart, and the height of mature specimens is generally two to four metres.

(iii) Campo sujo:- A sparsely wooded savanna with an herbaceous layer generally dominated by bunch grasses, with an underlying substratum of sedges, and a few forbs. Woody growth consists of sparse and stunted low trees and shrubs; they are widely scattered and individuals rarely exceeded one to two metres in height.

(b) Herbaceous Savanna.

(i) Campo limpo (grass dominated):- A treeless savanna with an herbaceous layer dominated by bunch grasses, with an underlying substratum of sedges and a few forbs.

(ii) Campo limpo (sedge dominated):- A treeless savanna with an herbaceous layer dominated by sedges. A few grasses and forbs may occur, but in places almost pure sedge communities are found.

The permanent swamps of the savanna landscape however present different vegetation communities. Some are pure sedge populated while others are inhabited by sedges and Ite-palm communities, depending on the stage of development of such swamps.

The forests too show variations in density. While the forests of the Kanuku scarplands are very dense and tall, those of the Pakaraima scarps are broken with savanna elements. The galeria forests and forest islands on the other hand, vary in thickness from their centres generally becoming thinner as they approach the savanna. The galeria forests fringe the major rivers and many of the large creeks in discontinuous fashion and in favoured localities. The forest islands on the other hand are of two varieties:

(a) the 'primary forest islands', and

(b) the 'regenerated forest islands', which comprise the gully, channel fill and anthropic varieties.

The primary forest islands are associated with unbreached flat tops of laterite plateaus. In these areas, the primary laterite acts as an aquifer embodying sizable reservoirs of underground water. It is postulated that the laterite plateaus were formerly covered by forest under a condition of higher water-table. Progressive dissection of the plateaus and consequent lowering of the water-table resulted in rapid loss of moisture. The soil-moisture equilibrium which supported the forest was thus upset and disappearance of forest from the top of the breadhed laterite plateaus ensued from the periphery. In this way, the former forest cover on the primary laterite surfaces was replaced by savanna vegetation leaving enclaves of forests referred to as 'forest islands' (Plate 3).

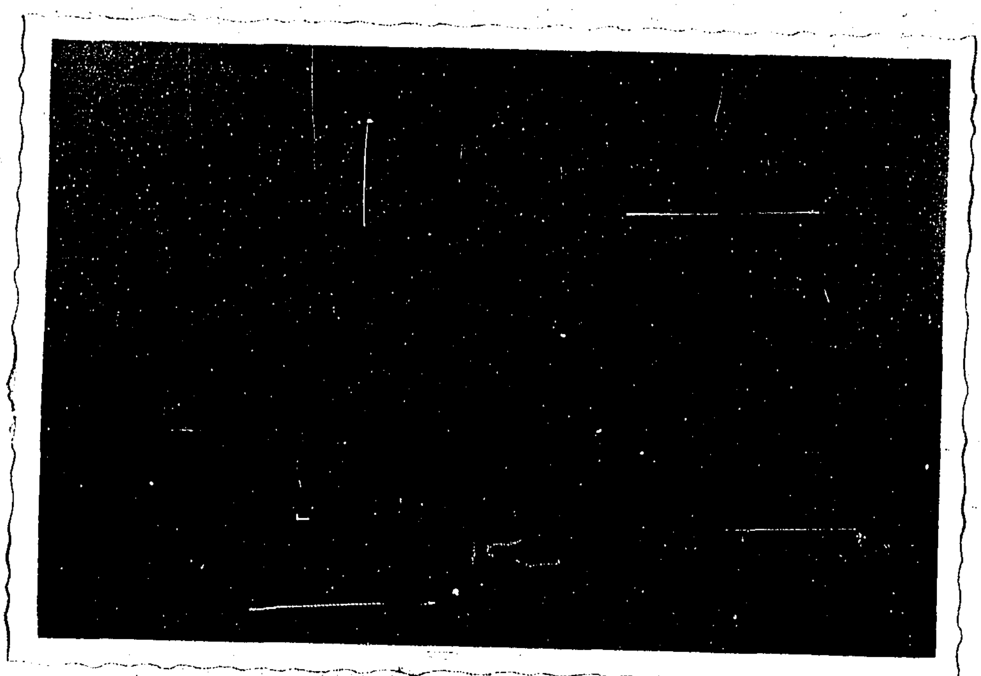


Plate 3: Primary forest island on ridge top. (Photo by Windapo).

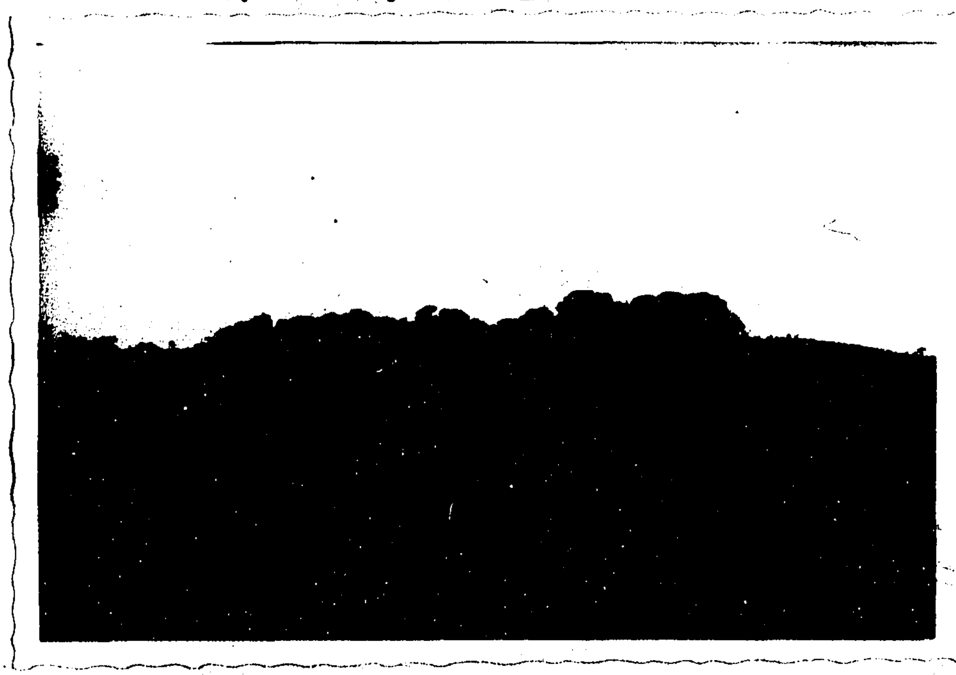


Plate 4: Gully forest island (Photo by Windapo).

Plate 3: Primary forest island on ridge top. (Photo by Windapo).

Plate 4: Gully forest island (Photo by Windapo).

Of the regenerated forest islands, the gully type is closest in character to the primary forest islands. The growth of this forest variety took place on spring valley slopes and within deeply incised gullies of the laterite terrain due to seepage moisture, following the dissipation of the primary laterite cover and the disappearance of its forest cover. Slope wasting and cessation of seepage moisture has caused the disappearance of many such forest islands but many are still found within the laterite landscape (Plate 4). Those of channel fills on the other hand are found both within and outside the laterite terrain. This variety is found within old valleys of streams which have been filled and choked out of existence. Such sites support a fairly dense stand of forest vegetation due to their moisture regime. About five miles to Pirara ranch some such forest islands are found dotting the valley site of an ancient river which meandered over a wide plain into the Pirara extensive swamp. Other forest islands of this origin are found about four miles east of Meritizero ranch within the channel fills of the Marakanata depression. Unlike the other two varieties, the anthropic forest islands are to a greater extent uniform in character all over the study area and consequently appear highly artificial. They are found usually on abandoned village sites and around some of the present settlements, and their tree associations are of fruit tree varieties like mango, orange, guava, cashew, breadfruit, soursop, grapefruit, and coconut palms. Notable sites are found around Parishara and within MocoMoco flat (Plates 5 and 6).

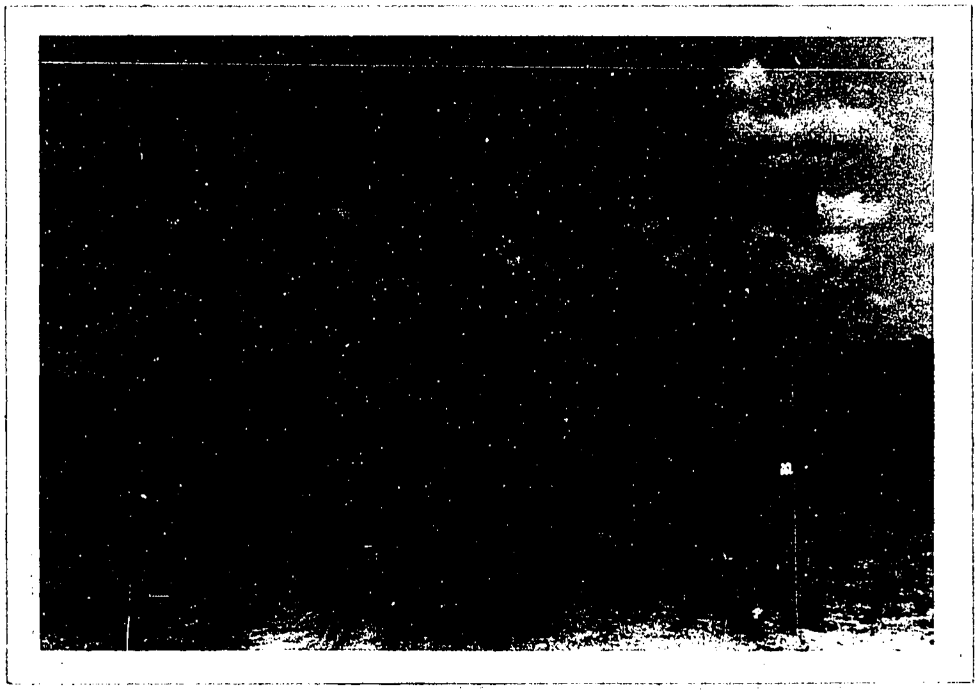


Plate 5: Anthropic forest island at Parishara. (Photo by Windapo).

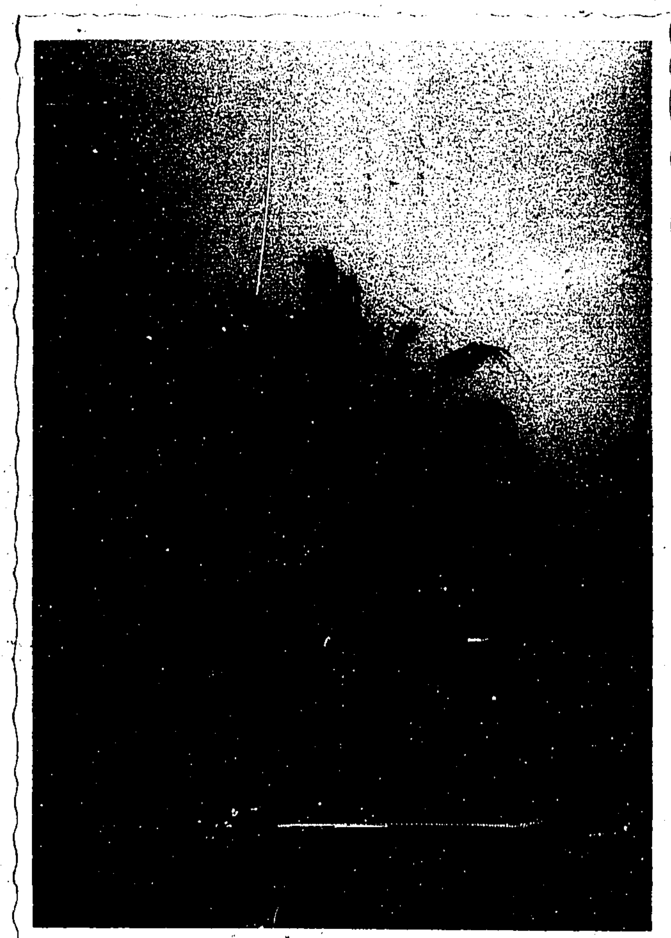


Plate 6: Nucleus of anthropic forest island at MocoMoco (Photo by Windapo).

Plate 5: Anthropic forest island at Parishara. (Photo by Windapo).

Plate 6: Nucleus of anthropic forest island at MocoMoco (Photo by Windapo).

Land Use.

Land use in the area of study is generally poorly developed. The total population is amall and scattered in many small villages (Fig. 6). The general leaning of the inhabitants is towards agriculture. Most of the wide expanse of savanna is however unsuitable for this pursuit and it is only the forest areas that are really exploited. The forest belts along the Kanuku colluvium are particularly utilized for shifting agriculture by both the Amerindians and people who have migrated from the coast to settlein the Rupununi. Major areas of cultivation are centred around Inaja, Kumu, MocoMoco, Hiawa and Nappi (Plate 38), and the major crops include cabbages, oranges, tomato, corn, cassava, plaintain, banana and watermelon. Some arable farming is also practised along the galeria forests and in the forest islands especially for growing tomato as at Pirara.

The savanna landscape is mainly a ranching zone. Here grows a grass-sedge association of low feeding value, except along the flats bordering the major rivers and streams where the grass is of a better quality. The carrying capacity of the land is generally small, 10-15 animals per square mile, and communal grazing is an accepted practice (Plate 7).

Many hands are now employed in the cattle trade. Most settlers of European extraction are dependent on the industry as ranchers, with many Amerindians working as vaqueros and abattoir labourers. The industry has steadily grown to become the mainstay of the Northern Rupununi's economy. The bulk of Guyana's meat comes from the area, and most of the meat is transported to the coast by plane.

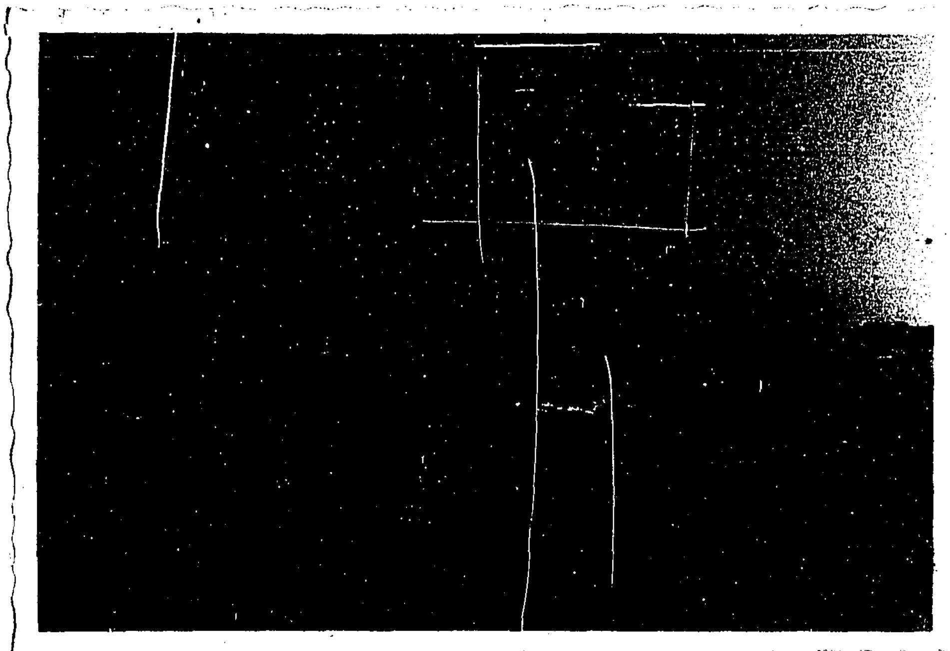


Plate 7: Open range grazing: Marakanata Lowlands.
(a) (Photo by Windapo).

Plate 7: Open range grazing: Marakanata Lowlands.
(a) (Photo by Windapo).

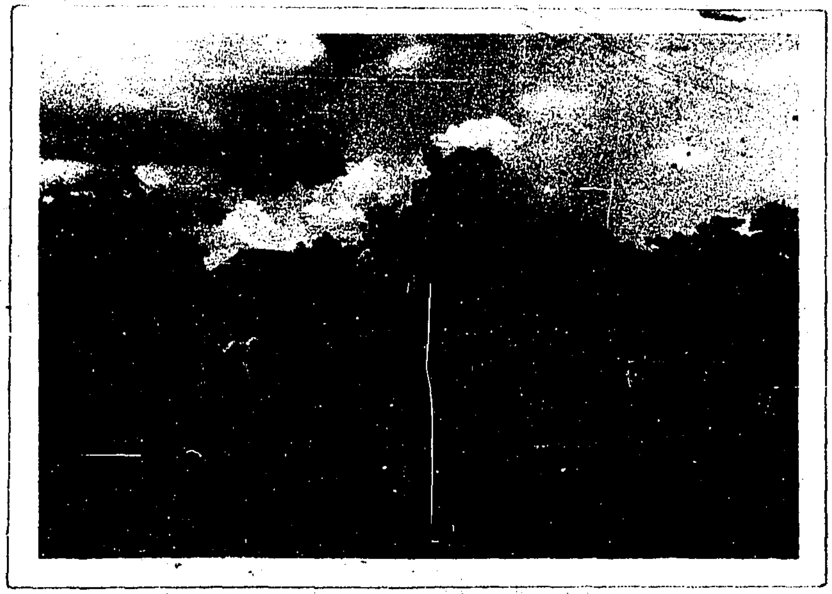


Plate 7: Open range grazing. Parishara village area.
(b) (Photo by Windapo).

Plate 7: (b) Open range grazing. Parishara village area. (Photo by Windapo).

CHAPTER II

TERRAIN CLASSIFICATION AND APPLICATION OF AERIAL PHOTOGRAPHS.

The general approach to terrain classification rests mainly on the identification of terrain types on the basis of attributes which can be recognized and regarded as common to particular areas, and which at the same time differentiate them one from another. Such attributes include geology, morphology, soils, drainage and vegetation which build up distinctive patterns within the landscape. This identification can be done from the air-photo in that it provides a base map which already indicates many of the boundaries in the form of tone and texture differences. Such recognizable units are grouped as major units.

However, features by which a terrain unit is defined and those by which it is recognized are often different. While definitive features must be common to all occurrences of a given unit, recognition features may vary from place to place. For example, a terrain unit may be defined by its water regime as a zone of annual floods, while it may be recognized by cultural and ecological responses to the water regime. Such responses may vary from place to place, depending on the habitats, and justify recognition of sub-divisions within the major units.

In Britain and Australia where terrain studies have been given particular attention and classification systems developed, the definitive characters adopted are those closely related to features of relief.[1] This leaning towards features of relief stems from the argument that:

(a) "a similar climate or succession of climates acting upon similar rocks in areas of similar tectonic history is likely to give rise to terrain with similar attributes";

(b) "the development of the physiographic elements of landscape is regarded to a considerable extent by the properties of terrain"; and

(c) "the spatial variations in properties within the physiographic elements of the landscape reflect the operation of the physiographic processes of erosion, degradation, etc., that have given rise to the physiographic elements" (MEXE, 1965).

Although both the British and the Australian systems agree that definitive characters should be related to relief, defining such physiographic units remains a problem since they must be defined on their inherent properties only, without any genetic inferences, and must be recognized by their visual appearance, not their inferred mode of formation. To solve this problem, the Australian definition adopts slopes, soils and vegetation - features which are readily seen and recognized. The British system likewise defines its major physiographic units in terms of features that can be seen and recognized

1 The classification system developed in Britain is the Oxford System adopted by the Military Engineering Experimental Establishment (MEXE) at Christchurch, Hampshire, England, while the Australian system is that adopted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) of the Commonwealth of Australia.

readily. Thus the terrain units are defined on the basis of:

(a) morphology and size (readily recognizable features);

(b) superficial materials - rocks and soils (also visually recognizable),

(c) water regime (usually visually recognizable); and

(d) direction, kind and degree of lateral variations in (a), (b), and (c) within the units.

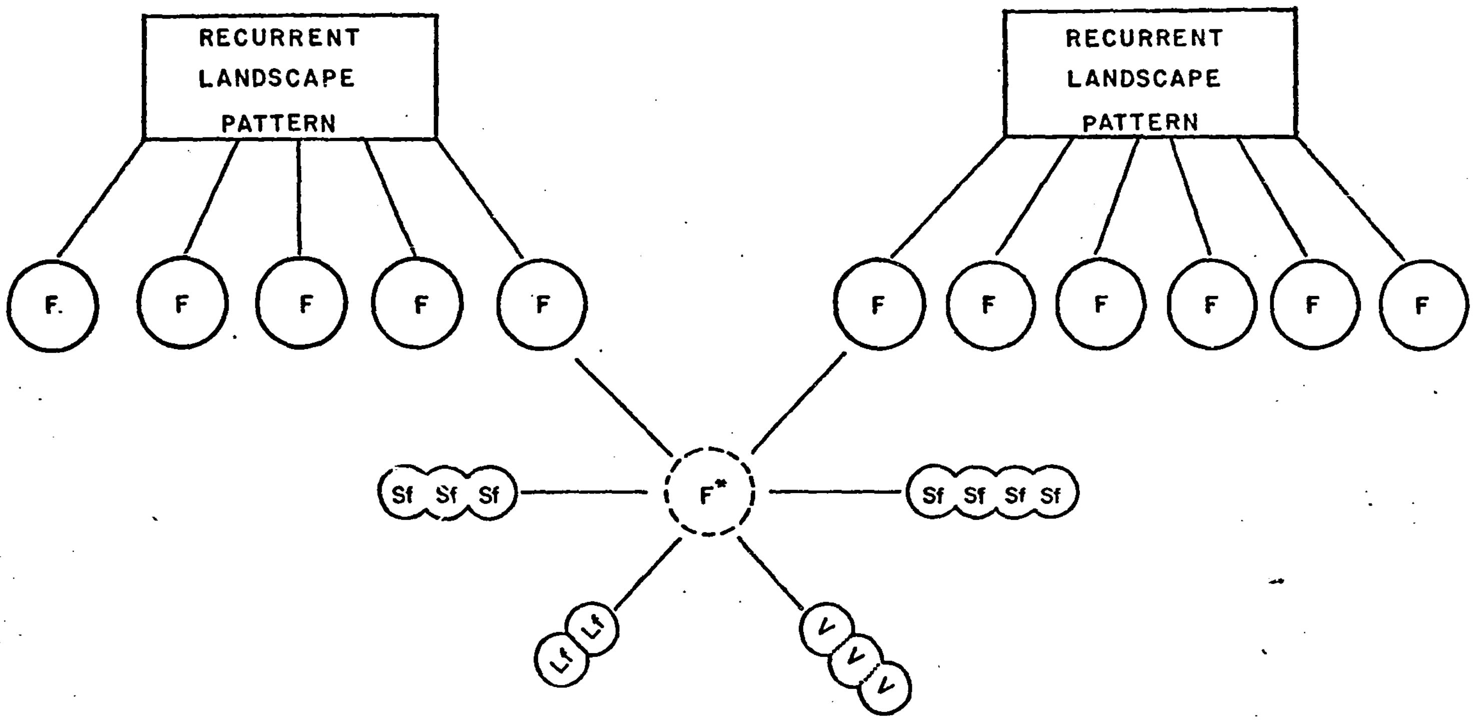
While (a), (b) and (c) are easily determined or observed, (d) allows interpolation and provides a means of distinguishing morphologically similar but genetically different terrain units on the basis of their inherent characters (MEXE, 1965).

Under the Oxford system, the major unit of the terrain is called the Facet, this being the smallest portion of terrain that can be treated as one block mappable at a scale of 1:50,000. For the purpose of convenient reference terminology, groups of facets are treated as Recurrent Landscape Patterns (RLPs). To differentiate parts of a facet, the sub-facet nomenclature is used, and variations in the development processes within the facet are identified as variants or local forms, depending on the extent of such variations. Thus, the overall classification of terrain under the Oxford system can be represented diagrammatically as shown in Fig.7.

Under the Australian land system, the surface is divided into Provinces on the basis of differences in geology. Within each geological province, different terrain associations are recognized and these give the landscape its characteristic

FIG. 7

MEXE'S OVERALL CLASSIFICATION FOR TERRAIN



F — Facet

V — Variants

Lf — Local forms

Sf — Sub-facet

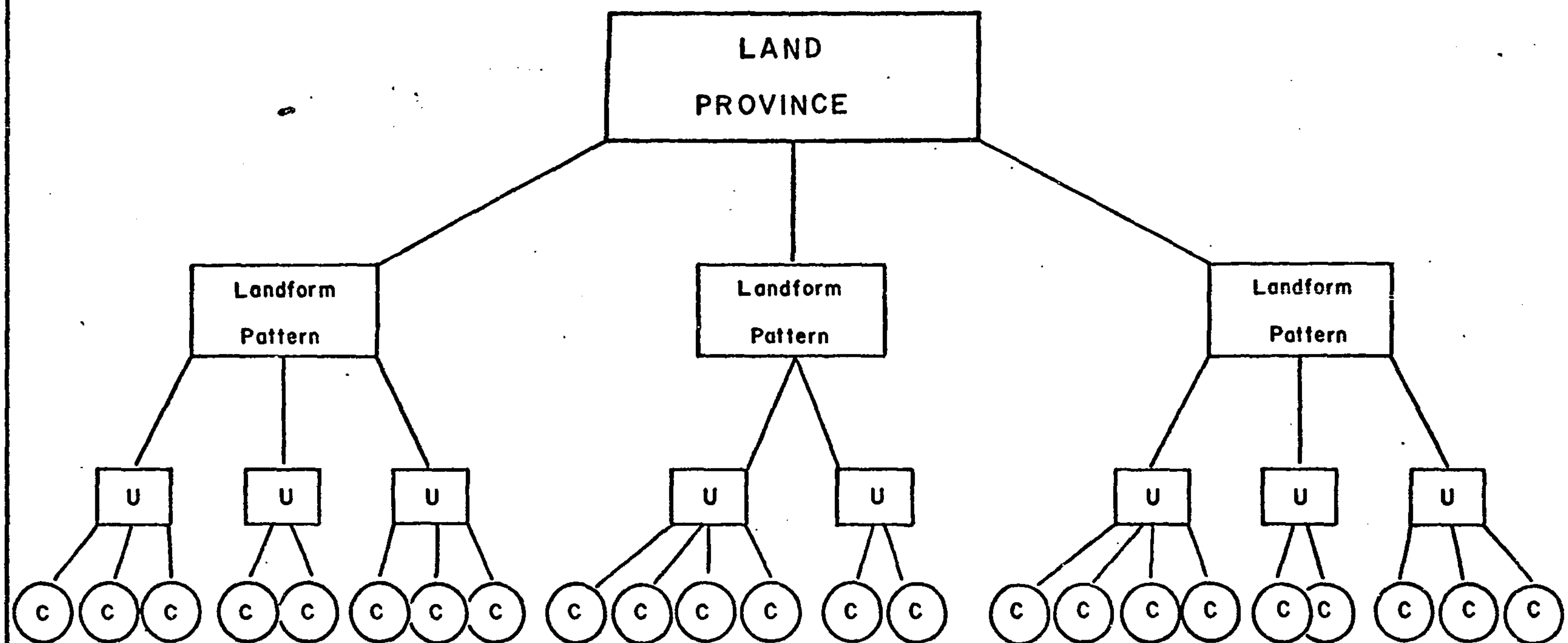
* The Facet is an abstract or generalized terrain unit

Windapo, 1968.

patterns. These patterns are regarded as <u>land systems</u> and can be considered as the largest mapping units. The extent of each pattern is determined by "common factors in the genesis of the landscape such as common geological parent material, geomorphological process, or the stage which the process has reached" (Christian, Stewart and Perry, 1960). Each pattern is described in terms of the units forming it, and such units comprising the pattern are termed <u>landform units.</u> On the basis of slopes, soil and vegetation association, these land units are further sub-divided into <u>landform components.</u> Thus in the Australian classification represented diagrammatically as in Fig. 8, the smallest unit is the landform component. This unit is characterized by a consistent association of soils and vegetation. Next in hierarchy is the landform unit. This is composed of a limited number of landform components which recur in the same sense, forming a distinct but single topographic feature in any landscape. Next to this is the landform pattern which is composed of a limited number of recurring landform units always associated in the same way forming an area of constant geomorphology containing a recurring topography, soil and vegetation association. The largest unit, the land province, is composed of a limited number of recurring landform patterns, always associated in the same sense, forming an area of constant geology at the group level. Moving from one land province to another, there is a change in the entire terrain association. In this way, one land province is distinctly

FIG. 8

AUSTRALIAN OVERALL CLASSIFICATION FOR TERRAIN



U- Landform Units. C- Landform Components.

Windapo, 1968.

different from another.

The Role of Aerial Photographs.

Both the Oxford (MEXE) system and the Australian (CSIRO) Land System rely extensively on the use of aerial photographs. At the planning stage of a classification project, air-photographs are of great assistance because it is often possible to identify many of the land systems or landform patterns within a landscape, and locate the boundary zones. Traverses may then be planned to ensure adequate sampling of all patterns. In this way aerial-photographs greatly reduce the amount of field-work and provide a realistic base map.

For quick reconnaisance study, non-stereoscopic photographs can be used more effectively than prepared maps. They present greater details of relief forms than any topographical maps of comparable scale, and make it possible for investigators to appreciate the continuity of relief and other features in a way that is not possible through field-work alone. In addition, the worker is able to appreciate ecological factors which may provide clues in interpreting soils and moisture conditions, geology and structure. However, they cannot be regarded as accurate maps in spite of the wealth of information they contain. This is because objects are not shown in true position with respect to a horizontal plane as on maps. Apart from possible inaccuracies that may be caused by the altitude of aircraft in the process of photographing, topographic distortion also results from the geometry of the vertical air-photo since it is a radial rather than an isometric projection.

There is considerable advantage in stereoscopic as opposed to monoscopic analysis since the interpreter then has a stereoscopic model of the physiography. Stereo-pairs are particularly useful in studying the microgeomorphology of an area: small features such as ant hills, meander scrolls, undrained depressions, dune forms, intricate ramifications of drainage patterns, and evidences of channel shifting which may not show in relief maps and which may be obscure to field observers, are often shown with striking clarity. In areas of rugged relief however, radial displacement may not permit stereoscopic viewing and vertical exaggeration may be particularly misleading as to the relative relief of the study area. Consequently, the stereoscopic image should be treated as a model which is not true to scale, but which enhances local relief and in this way emphasizes relief differences.

Nevertheless, the use of aerial photographs in terrain classification is in itself a demanding exercise involving mental and technical processes. It is only through careful and correct interpretation of the photographs that information about the ground surface may be gathered. The amount and accuracy of such information however depend, in the first instance, on the purpose of project, the quality of photographs available, and the intrinsic visibility of the objects recorded on the photographs; and secondly, on the ability of the interpreter to collate different pieces of information. The general steps in interpretation have been listed by A.P.A. Vink (1964 a and b) as follows:

(a) detection

(b) recognition and identification

(c) analysis

(d) deduction and

(e) classification.

While detection, recognition and identification depend largely on photo-quality, analysis, deduction and classification require special interpretive ability. Competence to make reliable deductions, for example, depends on the interpreter's reference level or back-ground knowledge, since such deductions are often based on the convergence of evidence from different sources. In this respect and as stated by W.Thornbury (1954), 'a thorough understanding of geomorphic forms with all their implications is the most basic tool in the interpretation of aerial photographs, since features of major interpretive value include distinctive landforms, drainage patterns and texture, outcrop patterns and structural relationships, degree and type of erosion, soils, and types and distribution of vegetation.' Equally important is a knowledge of the basic concepts in the field of geology, geomorphology, hydrology, pedology, climatology and vegetation, particularly in terms of the dynamics of natural processes.

Apart from this general knowledge, it is also essential for an interpreter working on a particular project to have specific or specialized knowledge about that project, as well as acquire local knowledge of the areas shown on the photographs being interpreted. Local and specific knowledge may however be achieved through experience as a result of working in the same area and/or with the same phenomena for many years. It may also be acquired to some extent by studying existing maps and literature of the area being interpreted. But in order to acquire a more reliable local and specific knowledge, it is recommended that field-work should be carried out in conjunction with the photo interpretation.

Interpretation and Classification of Northern Rupununi Terrain.

In classifying the terrain types of Northern Rupununi, the author has employed the Australian Classification which is now being widely accepted, and which is somewhat more referred than the Oxford system. In the Northern Rupununi Savanna three land provinces can be identified which show clear relation to the bedrock geology:-

(a) the Mazaruni Province corresponding with the area underlain by the Mazaruni Group of rocks in the Pakaraima area;

(b) the Takutu Province corresponding with the area underlain by the Takutu shale; and

(c) the Rupununi Province corresponding with the area underlain by the Rupununi Assemblage of rocks in the Kanuku area.

Within each province, there are specific assemblages of landforms which can be delimited on the air-photographs.

For the purpose of this study, the 1962 photo coverage taken by the Hunting Aerosurveys Ltd., was made available to the author. These photographs, of a vertical format, with a forward overlap of 60 per cent and a side overlap of 30 per cent were taken during the dry season of 1962 at a flying height of 30,000 feet with a lens of 6-inch focal length. The nominal scale of the photographs is thus 1:60,000. This is rather small for detailed study of the terrain, since small features such as gullies, cannot be discerned on the photographs, and vegetation communities are difficult to identify. As a result, intensive field-work had to be done to find out the true nature of such features.

Since the aircraft flew at constant altitude, the photo scale varies from the mountain scarps to the adjacent lowlands. However, this variation is not a serious problem, since the main area of study was the lowland and adjacent foothills where the local relief is comparatively limited.

Although all the photographs were taken within the same season, it was noticed that differences not inherent in the terrain were registered. For example, in a stereoscopic pair such as shown in Plate 8, differences in tone of the same feature were observed. These differences probably result from random factors such as cloud shadow and haze intensity and the regularly changing diurnal factors such as the intensity and direction of illumination and the extent and orientation of shadows. In addition, differences in printing produced overall tonal variation from one photo in a particular flight line to another.

One other difficulty experienced in the use of the

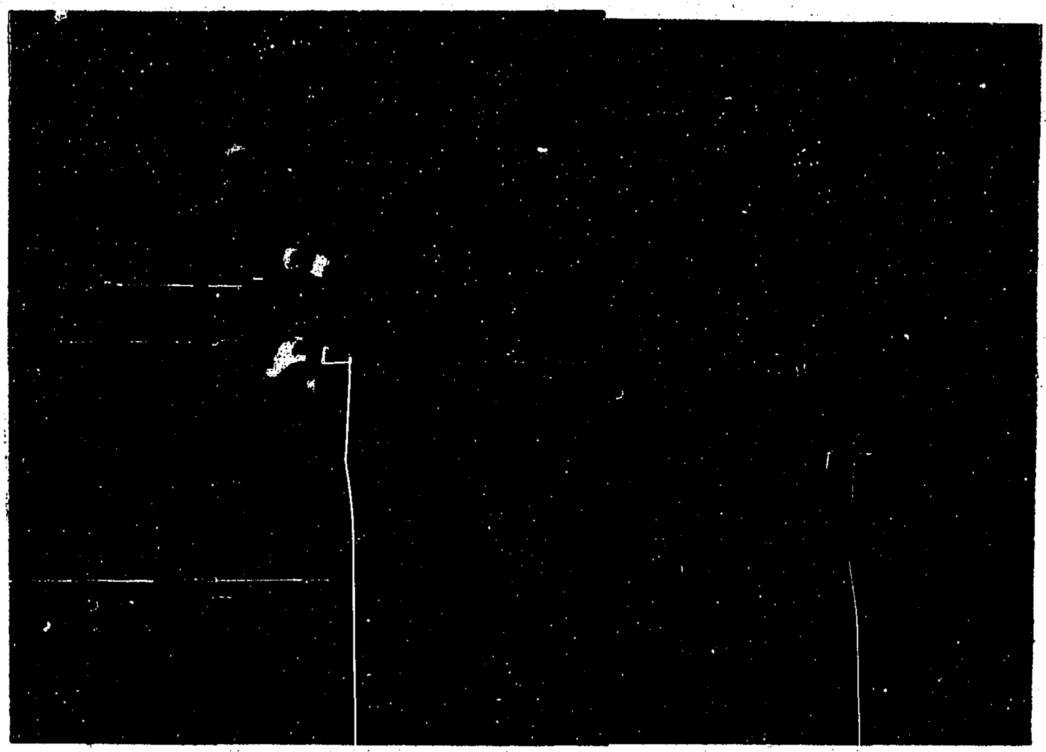


Plate 8: Stereo pair showing differences in the tonal values of the same objects. Note the tone of object A on the stereo pair. (Photo by Hunting Aerosurveys Ltd.)

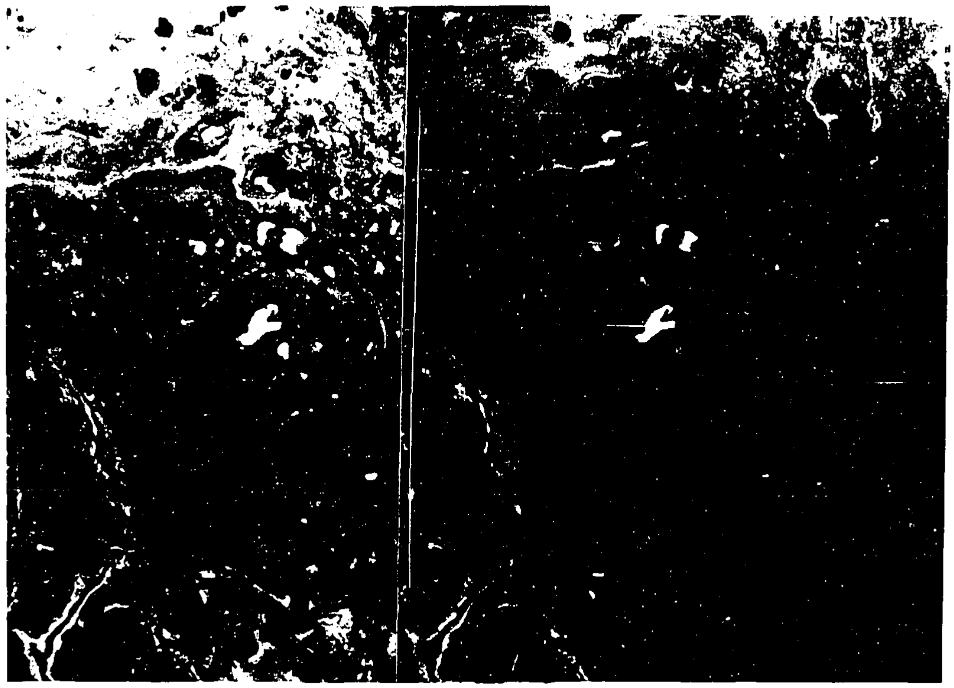


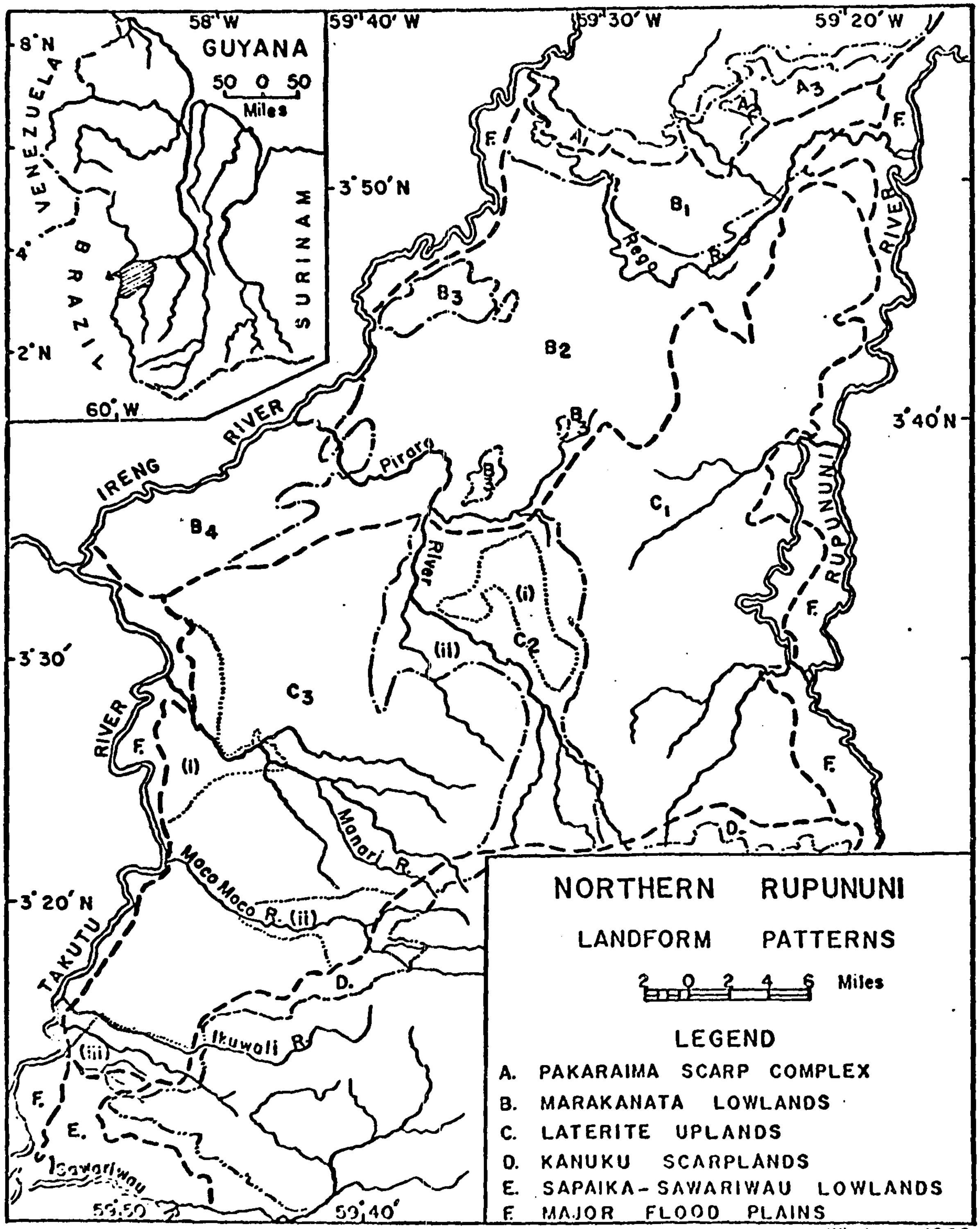
Plate 8: Stereo pair showing differences in the tonal values of the same objects. Note the tone of object A on the stereo pair. (Photo by Hunting Aerosurveys Ltd.)

photographs was connected with incomplete coverage and lack of an adequate mosaic. As a result of the deficiencies more intensive field-work had to be done in the areas not covered in order to be able to correlate them with those covered.

Interpreting the Photos.

In interpreting the Northern Rupununi aerial photographs, the author employed the simple pocket stereoscope with two power magnification. Tonal differences were assessed with the Munsell's Neutral Value Scale. Tonal values along transect lines were then plotted on wave-form graphs for frequency and amplitude assessment along such lines. Measurements of channel length were made with string and translated according to the scale of the photographs. Such measurements were restricted to the savanna streams with distinct courses.

In proceeding with the terrain classification beyond the level of the land province, the author was greatly helped by specific and local knowledge acquired through the study of the existing literature and intensive field-work carried out from July to November in 1967. By taking the photos into the field it was possible to identify and correlate the various patterns on the aerial photographs with their respective terrain units in the field. In this way the author was able to demarcate the landform units and their components. On the basis of surface appearance influenced by the physiography within each land province, the following landform patterns were identified



58° W
8° N
GUYANA
50 0 50
Miles
VENEZUELA
BRAZIL
SURINAM
4°
2° N
60° W
59° 40′ W
59° 30′ W
59° 20′ W
3° 50′ N
3° 40′ N
3° 30′
3° 20′ N
59° 50′
59° 40′
IRENG RIVER
RUPUNUNI RIVER
TAKUTU RIVER
Pirara
River
Rego R.
Manari R.
Moco Moco R.
Ikuwali R.
Sawariwau
NORTHERN RUPUNUNI
LANDFORM PATTERNS
2 0 2 4 6 Miles
LEGEND
A. PAKARAIMA SCARP COMPLEX
B. MARAKANATA LOWLANDS
C. LATERITE UPLANDS
D. KANUKU SCARPLANDS
E. SAPAIKA-SAWARIWAU LOWLANDS
F. MAJOR FLOOD PLAINS
Windapo, 1968

FIG. 9.

DETAILED LEGEND

To Attached Map

A. PAKARAIMA SCARP COMPLEX

A_1 Scarp Faces

A_2 Pediment

A_3 Alluvial Fans

B. MARAKANATA LOWLANDS

B_1 Dunes and Terraces of Northern Margin

B_2 Central Depression

B_3 Laterite Enclaves

B_4 Dunes of Takutu-Ireng Confluence

C. LATERITE UPLANDS

C_1 Eastern Block

C_2 Central Block
- (i) Laterite Islands
- (ii) Nappi Lowlands

C_3 Western Block
- (i) Manari Flats
- (ii) Moco Moco Lowlands
- (iii) Ikuwali – Sapaika Lowlands

D. KANUKU SCARPLANDS

E. SAPAIKA – SAWARIWAU LOWLANDS

F. MAJOR FLOOD PLAINS

Mountain Front

Major Pattern Boundaries

Sub-Pattern Boundaries

Special Unit Boundaries

(Fig.9):

(1) The Pakaraima Scarp Complex,

(2) The Marakanata Lowlands,

(3) The Laterite Uplands,

(4) The Kanuku Scarplands,

(5) The Sapaika-Sawariwau Lowlands,

(6) The Major Floodplains.

These land patterns were differentiated largely on the basis of broad geomorphological characteristics, and they represent blocks within each of which a common lithology and genesis has produced features distinct from other areas. Variations within each landform pattern were examined with respect to soils and vegetation in particular, and the patterns were sub-classified into landform units. Where local variations were found within the landform units, such variations were classified as landform components, while such features which were small scale and highly localized were treated as micro-relief features. The terrain types identified with the aid of aerial photograph interpretation and intensive field-work within the Northern Rupununi Savanna could be tabulated as a hierarchical series shown in Table VIII. An index of classification and description - a summary statement of the reference levels - giving details of what was studied in each terrain type, how it was studied, and how the result of investigation was summed up, is also shown in Appendix A; while Appendix B elaborates on the various land systems and their definitive features.

TABLE VIII

NORTHERN RUPUNUNI TERRAIN TYPES

LAND PROVINCES	LANDFORM PATTERNS	SUB PATTERNS	LANDFORM UNITS	VARIANTS	LANDFORM COMPONENTS	LOCAL FORMS
THE MAZARUNI PROVINCE	THE PAKARAIMA SCARP COMPLEX	THE WESTERN SECTION	SCARP FACES		BARE ROCK SLOPES MANTLED SLOPES DRAINAGE WAYS	SLASH GULLIES * ROCK LEDGES FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
			PEDIMENT SLOPES SCARP FOOT SLOPES		MANTLED SLOPES BACKSWAMPS & LAKES CONES	PROTRUDING BARE ROCKS
				OUTLIERS (a) Metamorphic	MANTLED SURFACES BARE ROCK SLOPES SUMMIT CONVEXITY	ROCK LEDGES
				(b) Granitic	BARE ROCK SLOPES SUMMIT CONVEXITY	
		THE EASTERN SECTION	SCARP FACES		BARE ROCK SLOPES MANTLED SLOPES DRAINAGE WAYS	SLASH GULLIES ROCK LEDGES FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
			PEDIMENT SLOPES ALLUVIAL FANS		MANTLED SLOPES DISTRIBUTARIES SAND FILLS INTERVENING FLATS	PROTRUDING BARE ROCKS POINT BARS TERRAWARDS
				OUTLIERS (a) Metamorphic	MANTLED SLOPES BARE ROCK SLOPES SUMMIT CONVEXITY	ROCK LEDGES
				(b) Granitic	BARE ROCK SLOPES SUMMIT CONVEXITY	ROCK LEDGES
THE TAKUTU PROVINCE	THE MARAKANATA LOWLANDS	THE MARGINS	NORTHERN MARGIN TERRACES		SANDY FLATS DRAINAGE WAYS	
			NORTHERN MARGIN DUNE SURFACES		DUNES MARSH FLATS SWAMPS	TERRAWARDS
			SOUTH-WESTERN MARGIN SAND HILLS		SANDY FLATS SANDY RIDGES SWAMPS & LAKES DRAINAGE WAYS	FLUVIALLY INDUCED SLOPES
			LATERITE ENCLAVES		LATERITE GRAVEL SLOPES MASSIVE LATERITE FLATS	
		LOWLAND PROPER	CENTRAL DEPRESSION		DRAINAGE WAYS CHANNEL FILLS SWAMPS & LAKES SILT-CLAY FLATS DRAINAGE WAYS	FLUVIALLY INDUCED SLOPES TERRAWARDS FLUVIALLY INDUCED SLOPES
	THE LATERITE UPLANDS	THE EASTERN BLOCK	GRAVEL SURFACES	(a) Laterite	SLOPES SUMMITFLATS CIRCULAR DEPRESSIONS ELLIPTICAL DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS FLATS	GULLIES GIANT TERMITERIA FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
				(a) Laterite + Quatz +Flint	SUMMITFLATS, SLOPES SLOPES CIRCULAR DEPRESSIONS ELLIPTICAL DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS	FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
			BLOCKY LATERITE SURFACES	(a) Primary	FLATS, SLOPES SUMMITFLATS	
			MASSIVE LATERITE SURFACES	(b) Recon-solidated	SLOPES SUMMIT LATERITE FLATS VALLEY LATERITE FLATS	
			LOCAL BOTTOMLANDS		COLLUVIAL FLATS ALLUVIAL FLATS MARSH FLATS SWAMPS & LAKES DRAINAGE WAYS	DWARF TERMITERIA TERRAWARDS FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
		THE CENTRAL BLOCK	GRAVEL SURFACES	(a) Laterite	SLOPES SUMMITFLATS ELLIPTICAL DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS FLATS	GULLIES GIANT TERMITERIA FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
				(b) Laterite + Quatz +Flint	SUMMITFLATS, SLOPES SLOPES ELLIPTICAL DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS	FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
			BLOCKY LATERITE SURFACES	(a) Primary	FLATS, SLOPES SUMMITFLATS	
			MASSIVE LATERITE SURFACES	(b) Recon-solidated	SLOPES SUMMIT LATERITE FLATS VALLEY LATERITE FLATS	
			LOCAL BOTTOMLANDS		COLLUVIAL FLATS ALLUVIAL FLATS MARSH FLATS SWAMPS	DWARF TERMITERIA TERRAWARDS
		THE WESTERN BLOCK	GRAVEL SURFACES	(a) Laterite	SLOPES SUMMITFLATS CIRCULAR DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS FLATS	GULLIES GIANT TERMITERIA FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
				(b) Laterite + Quatz +Flint	SUMMITFLATS, SLOPES SLOPES CIRCULAR DEPRESSIONS LINEAR DEPRESSIONS DRAINAGE WAYS	FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
			BLOCKY LATERITE SURFACES	(a) Primary	FLATS, SLOPES SUMMITFLATS	
			MASSIVE LATERITE SURFACES	(b) Recon-solidated	SLOPES SUMMIT LATERITE FLATS VALLEY LATERITE FLATS	
			LOCAL BOTTOMLANDS		COLLUVIAL FLATS ALLUVIAL FLATS MARSH FLATS SWAMPS DRAINAGE WAYS	DWARF TERMITERIA TERRAWARDS FLUVIALLY INDUCED SLOPES AND SIDE GULLIES
	THE SAPAIKA-SAWARIWAU LOWLANDS	THE WESTERN SECTION	WESTERN DUNE COMPLEX		HIGH DUNES SANDY FLATS SILTY DEPRESSIONS MARSH FLATS SWAMPS & LAKES DRAINAGE WAYS	TERRAWARDS FLUVIALLY INDUCED SLOPES
		THE EASTERN SECTION	EASTERN DUNE COMPLEX		LOW DUNES SAND FLATS SILT-CLAY DEPRESSIONS MARSH FLATS SWAMPS & LAKES DRAINAGE WAYS	TERRAWARDS FLUVIALLY INDUCED SLOPES
	THE MAJOR FLOOD-PLAINS	THE WESTERN FLOOD-PLAINS	THE IRENG FLOODPLAINS THE TAKUTU FLOODPLAINS		OX-BOW LAKES SAND FLATS LEVEES BACKSWAMPS	POINT BAR RIDGES
		THE EASTERN FLOOD-PLAINS	THE RUPUNUNI FLOODPLAINS		OVERFLOW SCARS + ABANDONED CHANNELS ENTRENCHED CHANNELS	FLUVIALLY INDUCED SLOPES & SIDE GULLIES SANDS, GRAVELS, LATERITE & TAKUTU SHALE EXPOSURES
THE RUPUNUNI PROVINCE	THE KANUKU SCARP-LANDS	THE SOUTH FACING SECTION	SCARP FACES		BARE ROCK SLOPES MANTLED SLOPES	SLASH GULLIES ROCK LEDGES
			PEDIMENT SLOPES		MANTLED SLOPES	PROTRUDING GRANITE BLOCKS
			SCARP FOOT		BACKSWAMPS COLLUVIAL FLATS DRAINAGE WAYS	TERRAWARDS FLUVIALLY INDUCED SLOPES & SIDE GULLIES
				Outliers	BARE ROCK SLOPES MANTLED SLOPES SUMMIT CONVEXITY	ROCK LEDGES
		THE NORTH FACING SECTION	SCARP FACES		BARE ROCK SLOPES MANTLED SLOPES	SLASH GULLIES ROCK LEDGES
			PEDIMENT SLOPES SCARP FOOT		MANTLED SLOPES COLLUVIAL FLATS DRAINAGE WAYS	PROTRUDING GRANITE BLOCKS FLUVIALLY INDUCED SLOPES & SIDE GULLIES
				Outliers	BARE ROCK SLOPES MANTLED SLOPES SUMMIT CONVEXITY	ROCK LEDGES

* A term used to distinguish the deep vertical sided crevice-like gullies along the scarp faces from the gullies of the laterite terrain.

PART TWO

CHAPTER III

THE PAKARAIMA SCARP COMPLEX

The scarp complex is a landform pattern containing two distinct sub-patterns: one to the west and the other to the east (Table VIII). The western part is characterized by a series of intermediate to basic diorite dykes and sills while the eastern section is distinguished by massive granitic intrusions. The western slopes plunge directly into the adjacent plains with fairly steep scarp-foot slopes and virtually no pediment, but in the eastern section, the pediment is more distinct sloping gently from steep granitic scarp-foot slopes. Both sections are fringed by a number of outliers most of which are composed of metamorphic rocks in the west, and granitic rocks in the east. The major landform units within the western section are scarp faces and pediment slopes while those of the eastern section comprise scarp faces, pediment slopes and alluvial fans. Thus, the major landform units of the scarp complex are generally grouped as:

(a) the scarp faces,

(b) the pediment and

(c) the alluvial fans.

These units have distinct individualities but they are associated both geographically and genetically.

a. The Scarp Faces:

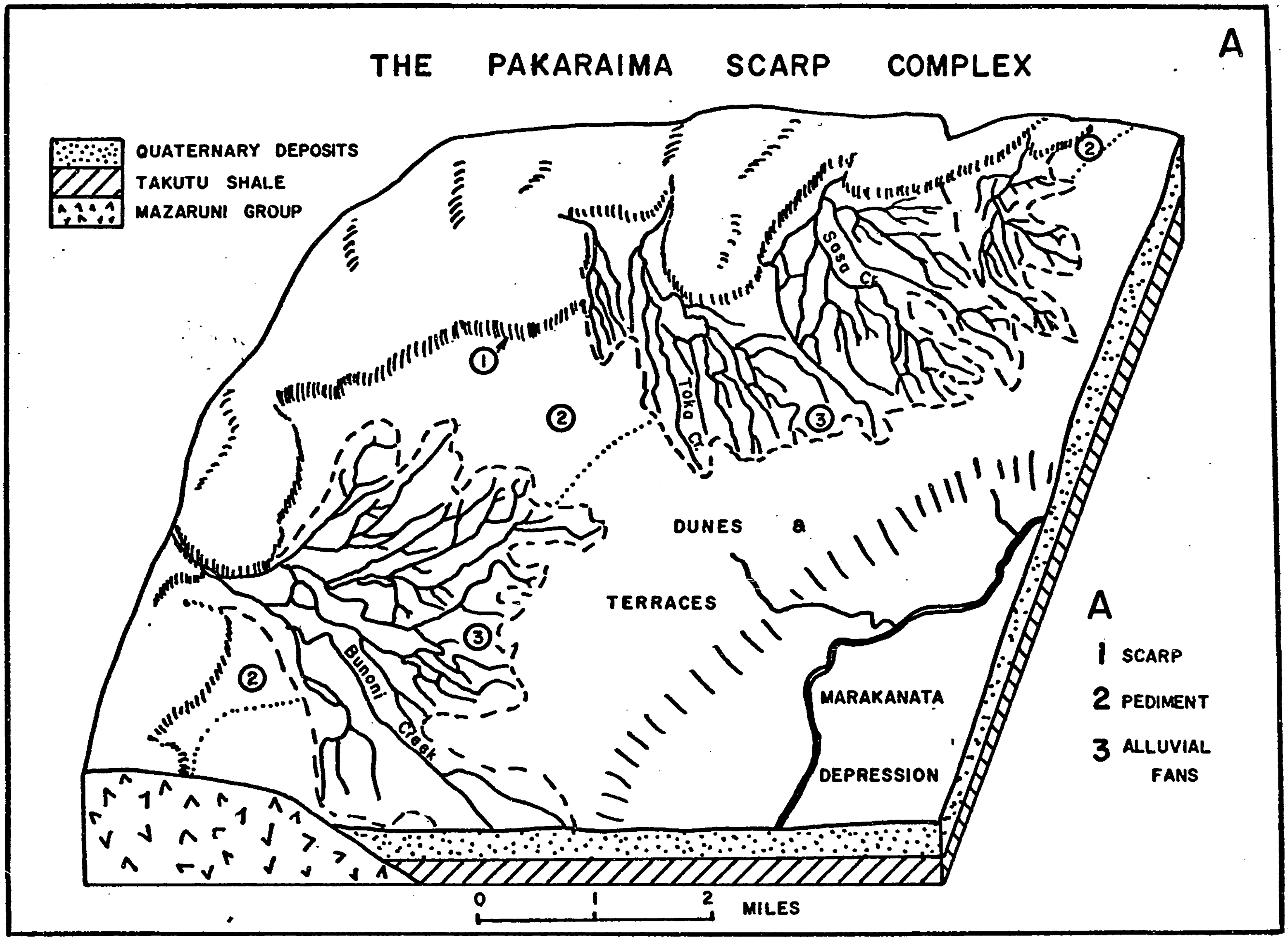
The faces of the fault-line scarp are found in the ranges that border the Marakanata Lowlands to the north. They occur at varying heights of about 400 to 600 feet, and steepness of about 18^{o} to 30^{o}. They are very conspicuous east of Toka, becoming less distinct towards the Ireng River in the west.

The rocks of the fault-line faces are foliated rhyolitic and daotic volcanics of the Iwokrama Formation, with granophyric massifs in association. All the rock types belong to the Mazaruni group (Fig. 10), and strike ENE - WSW to E-W (McConnel et al. 1966).

Soil development on the scarp has been greatly retarded by accelerated erosion. However, stony clay occurs on the lower slopes. At the base of the scarp faces are scree slopes with angular boulders in a matrix of unconsolidated sediments which slump under torrential rains.

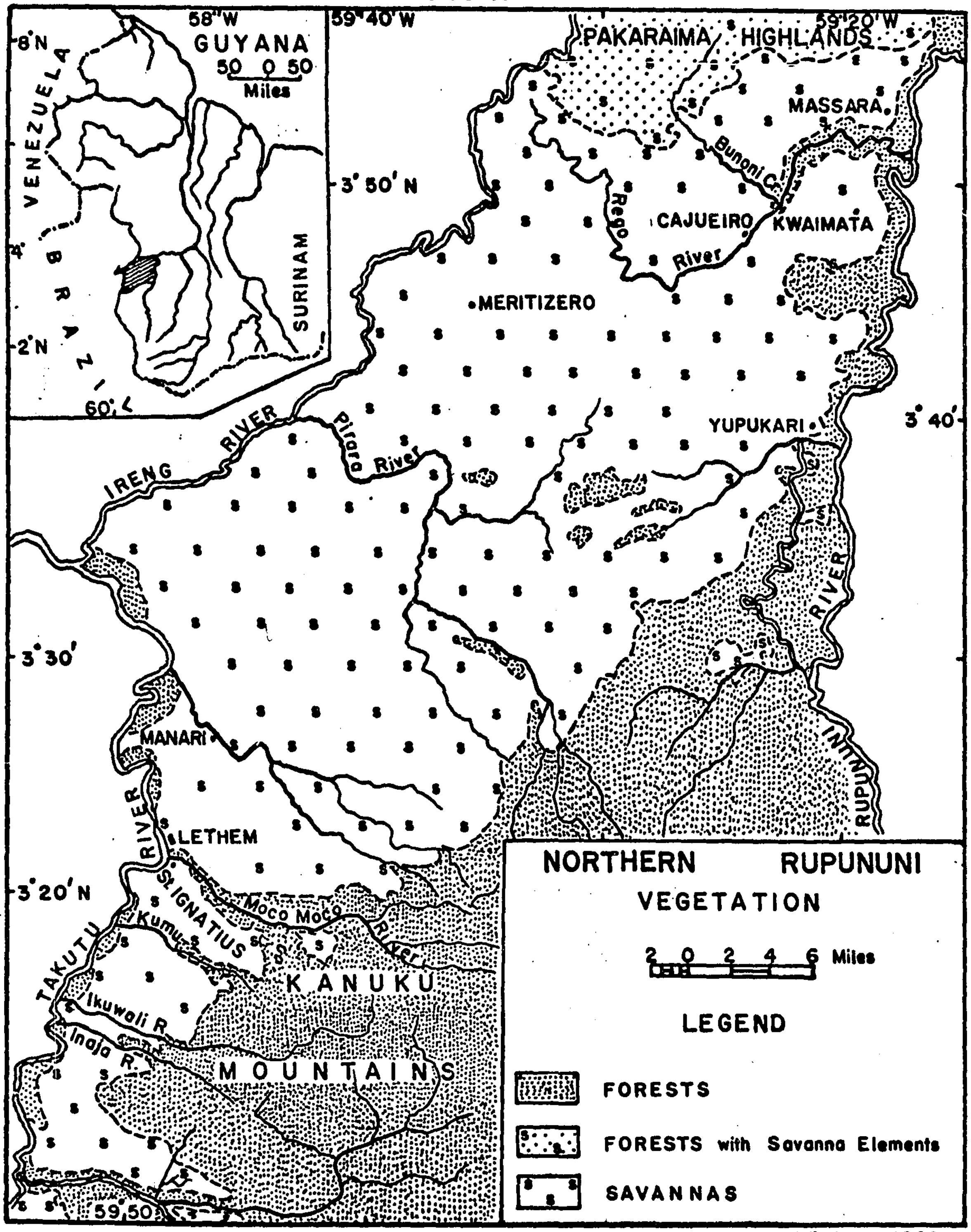
The vegetation on the scarp faces consists of forest with savanna elements, and savanna woodlands of <u>Campo Cerrado</u> type (Fig. 11). The forests are made up of a great mixture of shrubs, lianas, and small trees dominated by Myrtaceae and leguminosae. They lack the strong character of dense rainforests with very tall and hefty trees, and a great tangle of climbers; and Myers (1936) considers them to be deciduous monsoonlike forests. These forests are found irregularly along the slopes (Plate 9). Where they are entirely lacking, the slopes show extensive exposures of small and large boulders and large stones with a very thin covering of soil in parts. In other places where the forest has depleted to form savanna woodlands, the trees are usually stunted, but are mainly forest trees. Discontinuous bands of forests are also found along slash

FIG. 10



Windapo, 1968.

FIG. 11



Windapo, 1968.

gullies of the scarp faces. Such bands are usually thicker in their tree population then the more extensive forests of the slopes. These vegetation types are identifiable by their tonal reflections on the air-photographs of 1962 by Hunting Aerosurveys (Plate 9).

b. The Pediment:

Between the Marakanata depression and the scarp faces is a zone of slightly higher ground. This is the pediment zone on which are strewn the materials removed from the scarps by slope wash. The zone is consequently buried under deposits which grade gently into the Marakanata basin. It stretches in a narrow belt from Moreiru to the point of turning eastwards of the Rupununi River except where breached by alluvial fans.

As a zone of sheetwash deposition, the soils are composed of sandy materials removed from scarp slopes. Examination reveals zones of different textures ranging from loam to fine gravels within the soils which are generally underlain by stones and boulders as revealed along the dry beds of many of the short channels crossing the unit into the Marakanata Lowlands.

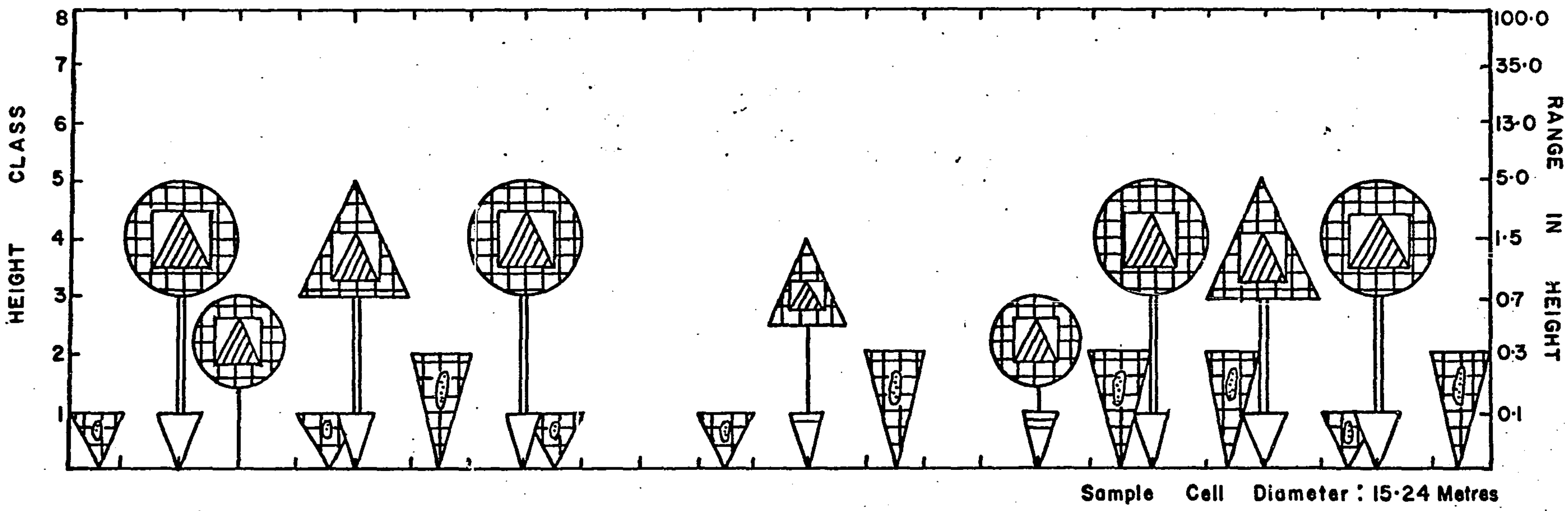
This unit carries a savanna vegetation in open Campo Coberto type dominated by Curatella Americana of heights between three and five metres. The herbaceous layer is dominated by bunch grasses - Trachypogon Plumosus mainly - with a subsidiary layer of sedges. A sampled section east of Moreiru settlement is shown in a structural diagram in Fig. 12.

c. The Alluvial Fans:

The alluvial fans occur where the Bunoni, the Toka

FIG. 12. VEGETATION STRUCTURAL DIAGRAM

East of Moreiru



SITE SITUATION

a. UTILIZATION : Pastured

b. SOIL STRUCTURE : Soft

c. SOIL TEXTURE : Sand / Silt

d. DRAINAGE : Deficient

e. RELIEF : Flat

Windapo, 1968.

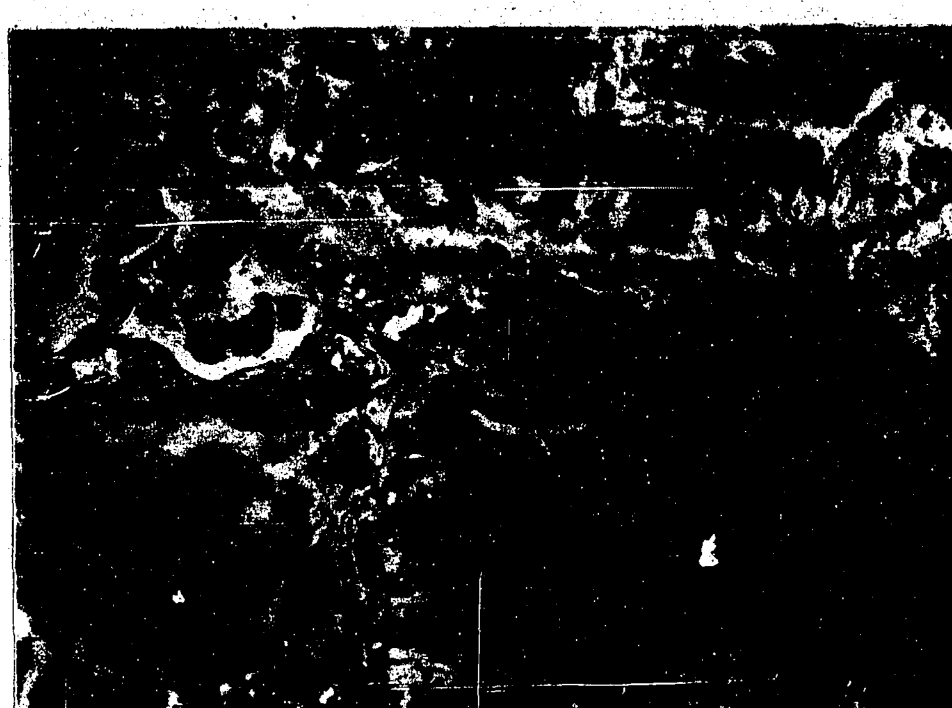


Plate 9: Air-photo showing Pakaraima scarp and adjacent lowlands. Note forest cover broken by open rock surfaces and savanna belts. (Photo by Hunting Aerosurveys Ltd.)

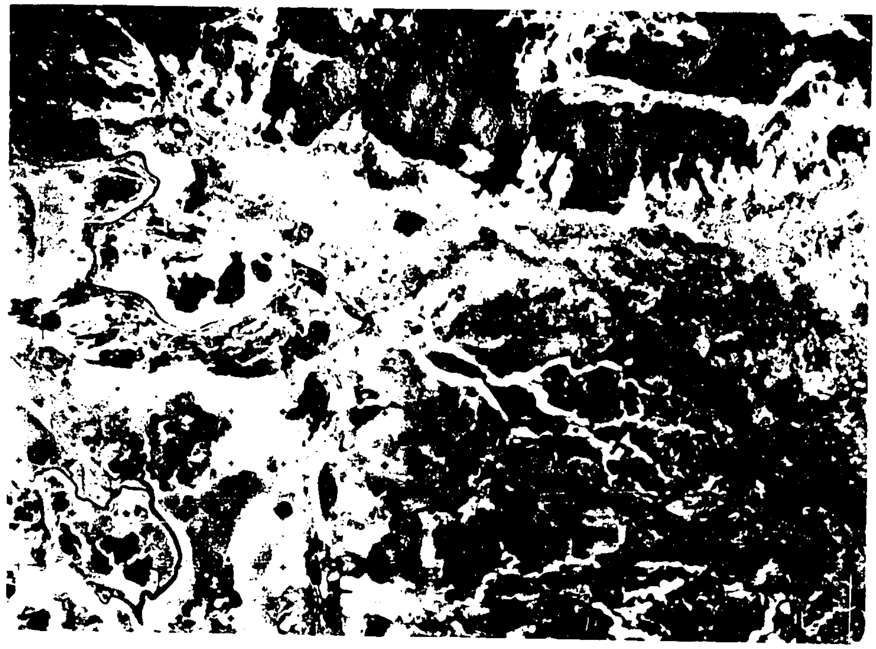


Plate 9: Air-photo showing Pakaraima scarp and adjacent lowlands. Note forest cover broken by open rock surfaces and savanna belts. (Photo by Hunting Aerosurveys Ltd.)

and the Sasa creeks emerge from the Pakaraima highlands unto the lowlands. They occupy a higher position about 10 to 30 feet above the adjoining lowlands to the south. Topographically, they are akin to the Marakanata lowlands, but are distinctly different in that they are not underlain by the Takutu Formation. They develop over quarternary alluvium embayments within the scarp.

The largest of the fans is that of the Bunoni River. It extends for about six miles southwards from the scarp embayment and covers an area of over five square miles (Fig.10). These fans have developed at various positions along the Pakaraima front as a result of the decrease in velocity of the streams emerging from the mountains which are heavily charged with sediment. Successive loads from the highlands debouch on the fan area choking up former distributaries; and choked channels are lined by sandy banks which rise slightly above their immediate surroundings.

The soils of the fans are mainly sandy though textural differences could be observed from place to place from fine loamy sands to medium loamy sands. The depressions and lowlands between the sandy zones are usually of silty materials. The major zones of clay are found along the southern margins of the fans where deposition has been influenced by seasonal inundation of the lakes of the Marakanata lowlands. Such zones of seasonal flooding maintain temporary swamps, many of which are dotted by pockets of terrawards of small dimensions (Plate 11).

The variant elements of the unit are distinctly

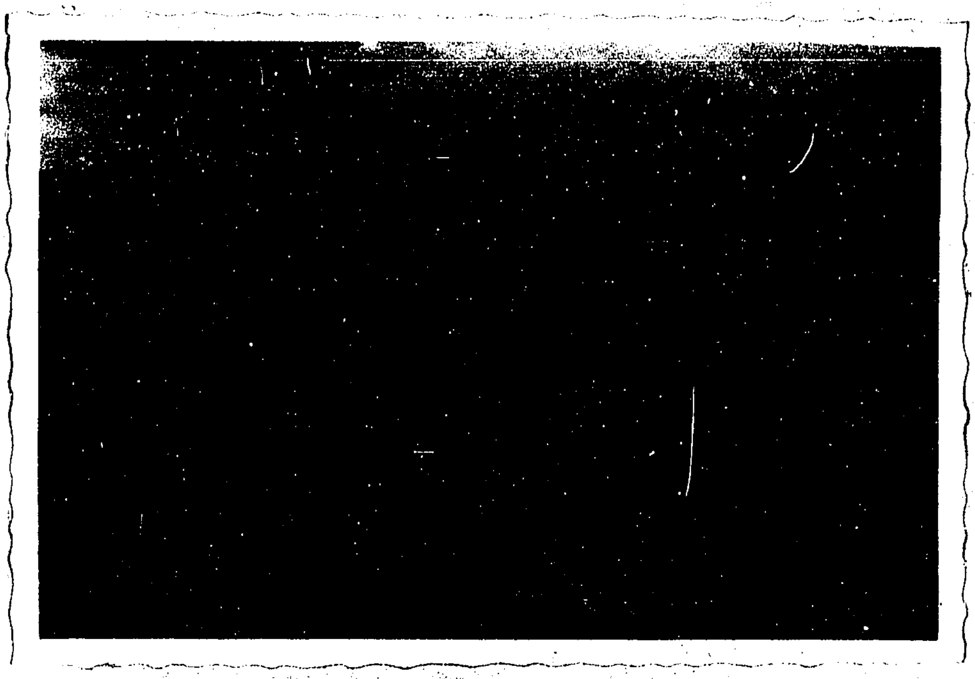


Plate 10: Lake Moreiru adjacent to the Pakaraima Scarp. (Photo by Windapo).

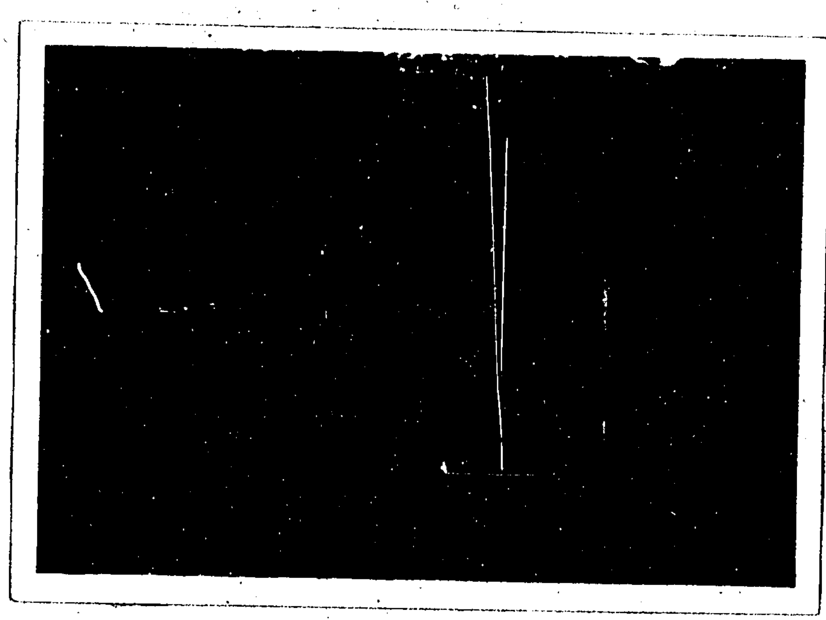


Plate 11: Terrawards adjacent to alluvial fans near Toka. (Photo by Windapo).

Plate 10: Lake Moreiru adjacent to the Pakaraima Scarp. (Photo by Windapo).

Plate 11: Terrawards adjacent to alluvial fans near Toka. (Photo by Windapo).

reflected in the vegetation association of the components. Field evidence shows that the sandy banks and channel fills of slightly higher elevation support a more densely wooded savanna vegetation than the lowlands within the fans. These areas seem to benefit from seepage moisture from the highlands during the dry season when the intervening flats are virtually desiccated. Fig. 13 shows the structural diagram of the vegetation of a typical site on a slightly raised sandy belt south of Toka. The dominant tree species here is the Curatella Americana associated with a few Byrsonima crassifolia. The clay depressions are distinctly different in that they are sedge dominated with bunch grasses in association. The dominant sedge species include Cyperus articulata and elocharis geniculata while the bunch grasses include buchnera elongata and mesosetum loliiforme.

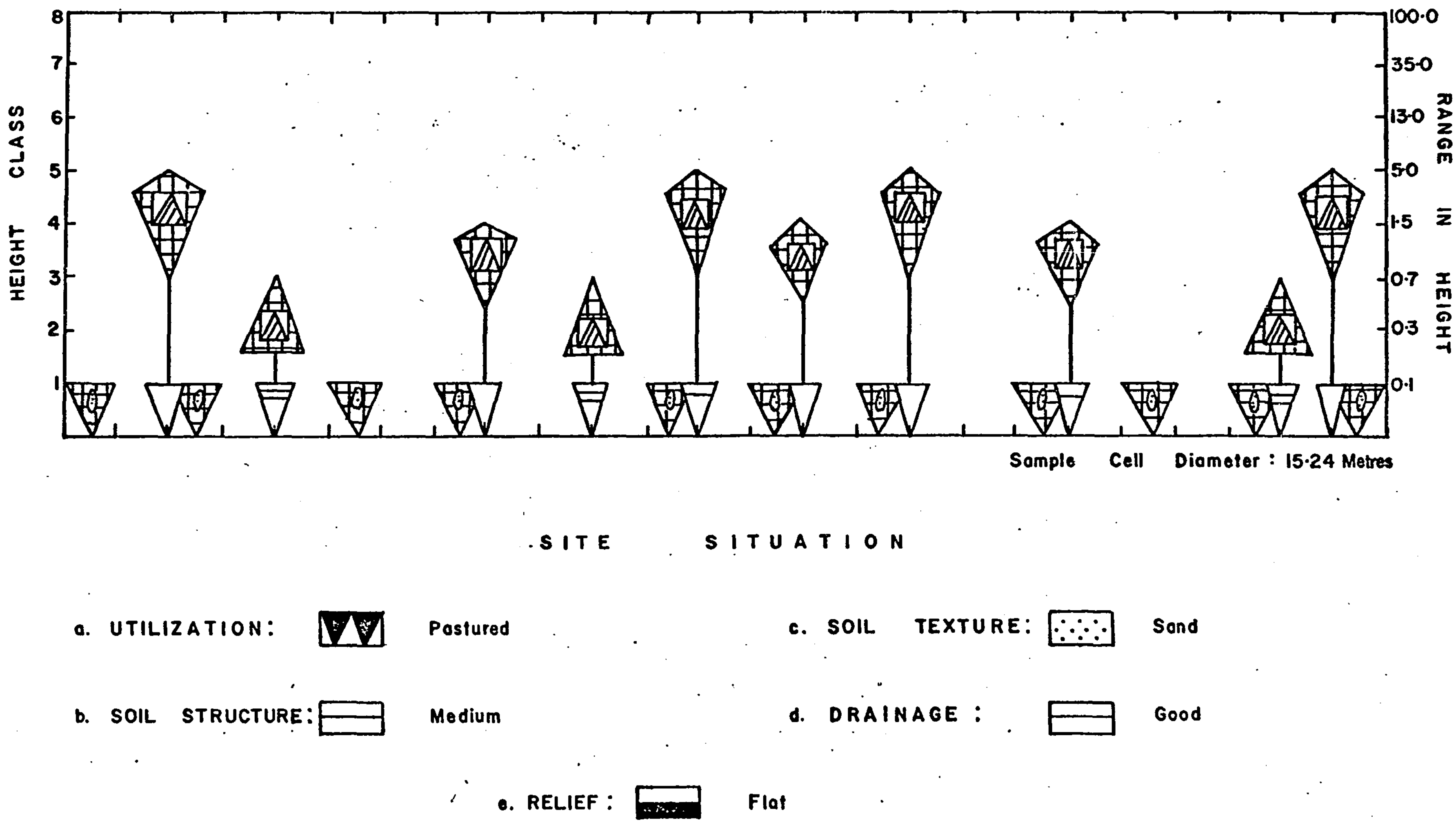
Surface Drainage Characteristics of the Landform Pattern.

The major creeks of the pattern include the Bunoni, the Toka and the Sasa, all of which end up in alluvial fans on leaving the mountain foot, and are noted for their meagre discharge. Apart from these, many small creeks leave the mountain in narrow gullies which disappear often within a few feet of the mountain front, discharging their water in sheets over the adjacent lowland.

All the streams and creeks are seasonal, drying up by mid-November. To a great extent, these streams reflect structural control. A general east-west trend of the folded and metamorphosed rhyolites combines with numerous faults and

FIG. 13. VEGETATION STRUCTURAL DIAGRAM

Near Toka



Windapo, 1968.

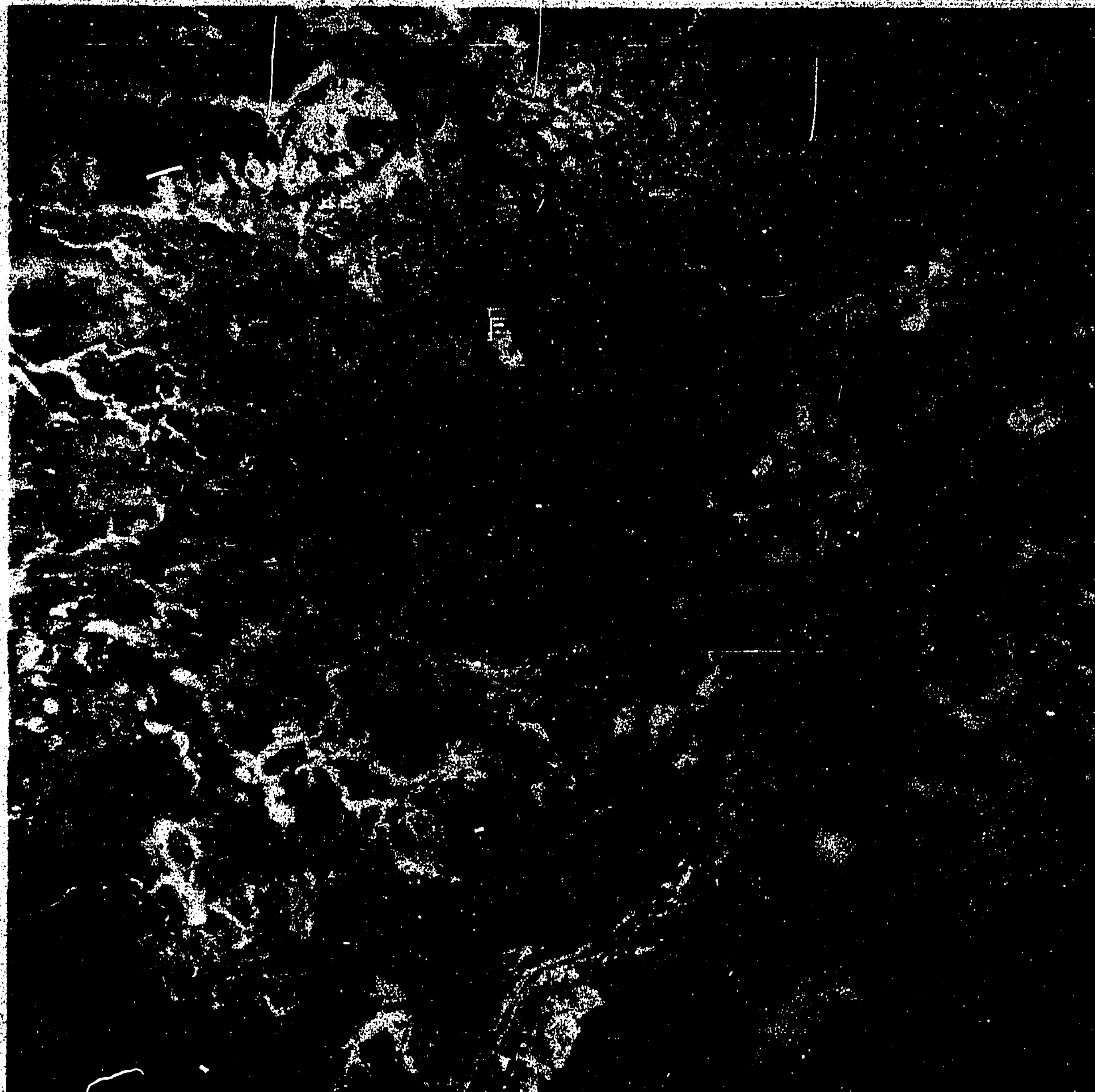
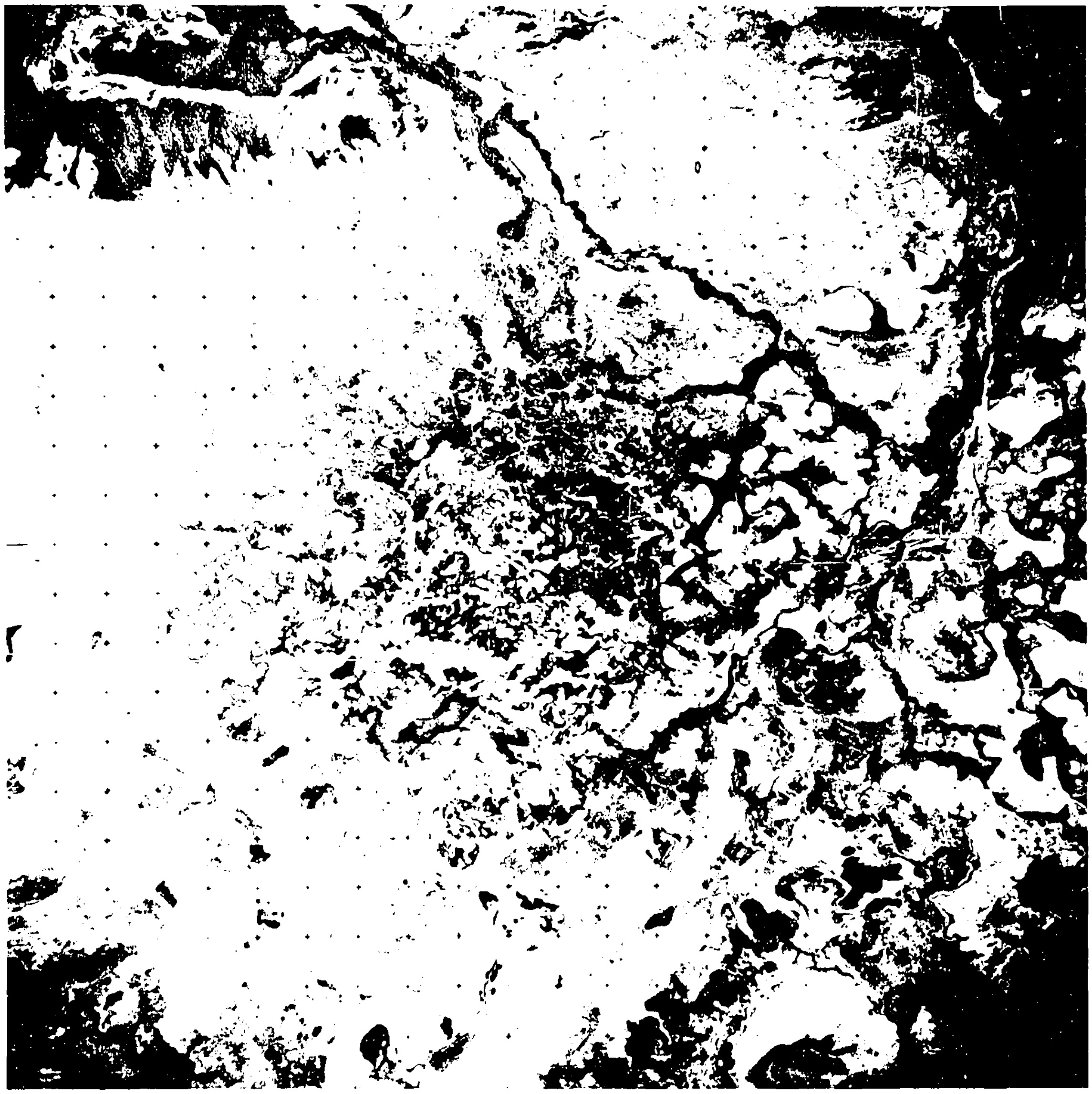


PLATE 12: Western part of the Pakaraima Scarp Complex. (Photo by Hunting Aerosurveys Ltd.)



fractures to produce a rectangular pattern along the mountain scarps.

Conspicuous and dominant modes of drainage in the rainy season are slope wash on the scarps, and sheet wash on the adjacent lowland. During this period, unchannelled water flood the lowlands, creating seasonal swamps up to the mountain foot in some places as at Moreiru.

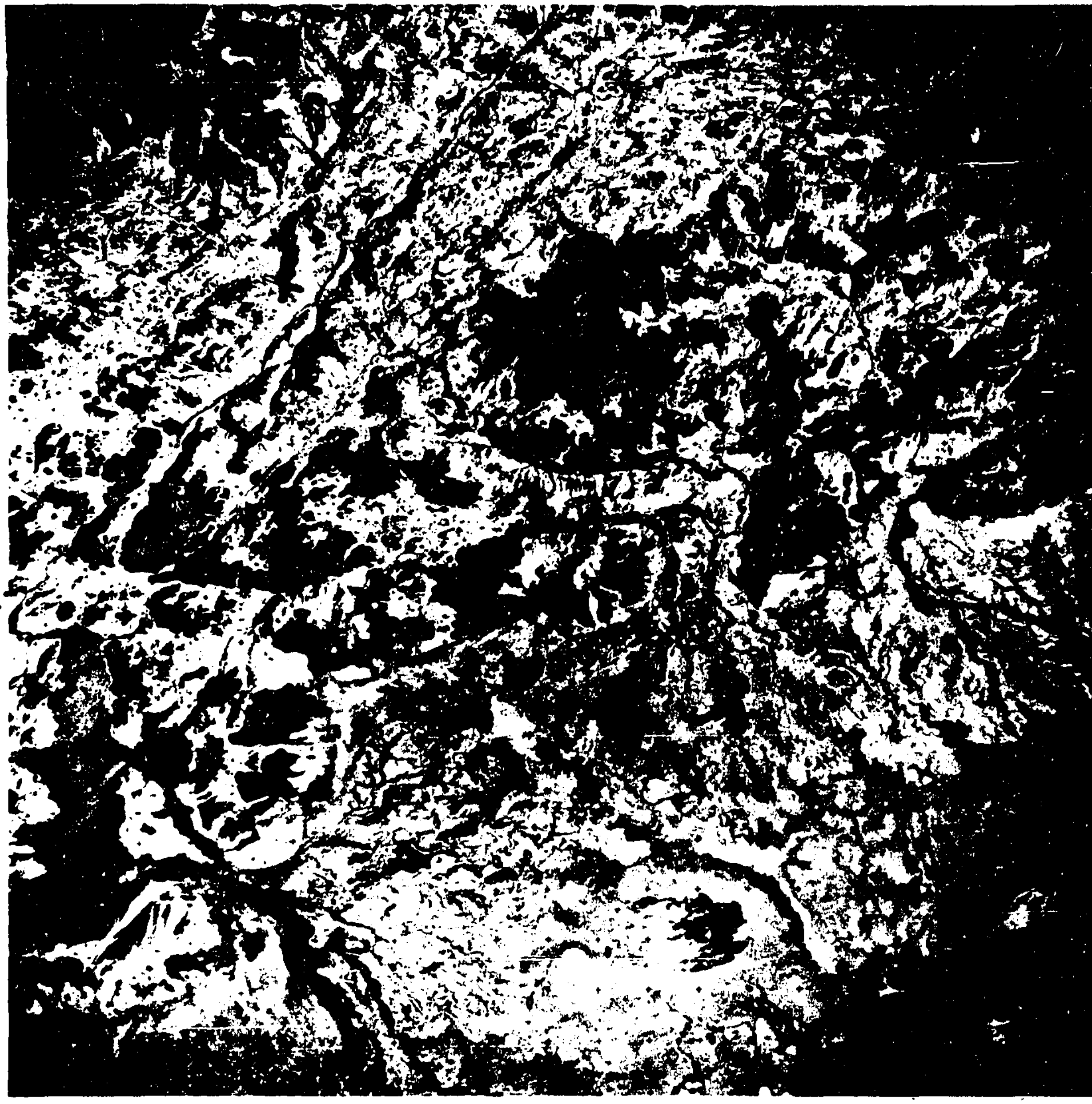
AIR-PHOTO CHARACTERISTICS OF THE LANDFORM PATTERN.

The scarp faces are easily distinguished on air-photographs by their configuration and tone which contrast markedly from those of the alluvial fans and pediments. Within both the scarp faces and the lower areas of pediments and fans, air-photo tones are not uniform, internal variations are appreciable and the tonal boundaries are distinctly sharp for easy demarcation.

All the landform units of the pattern are represented on Plate* 13. A sample transect was made along the line AB on the Plate and the density variations assessed by means of Munsell's neutral value scale which is a standard scale of neutral grays arranged in steps, in sequence between absolute black with 0 per cent reflectance and absolute white with 100 per cent reflectance. The values are plotted in the form of a density trace or amplitude graph as shown in Fig. 14. It can

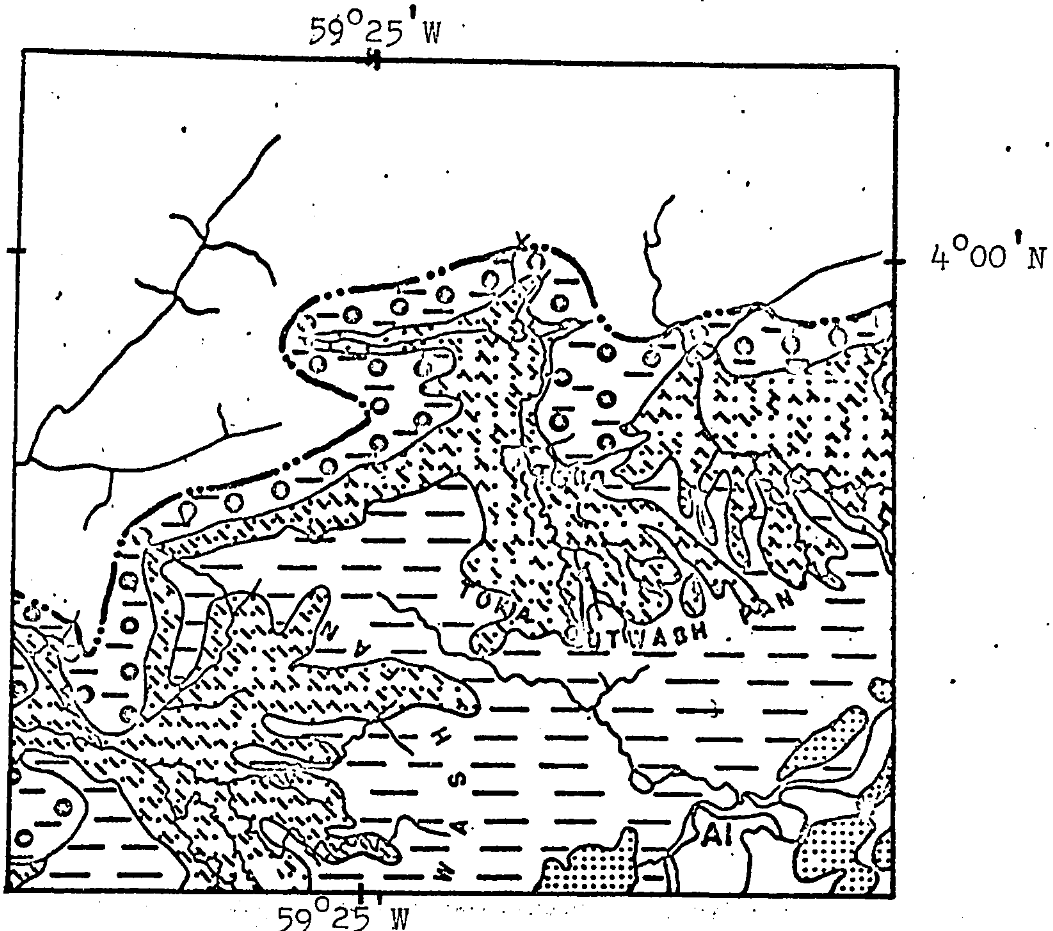
* The photo sheet and overlays showing the land systems are collectively referred to as 'Plate' just like any other photograph used for illustration. The lower overlay shows the landform units and their components while the top one shows the land system boundaries. Attached to the Plate of each land system is a map of its surficial deposits adapted from Sinha (1967), the legend of which is shown in Appendix C.

A.

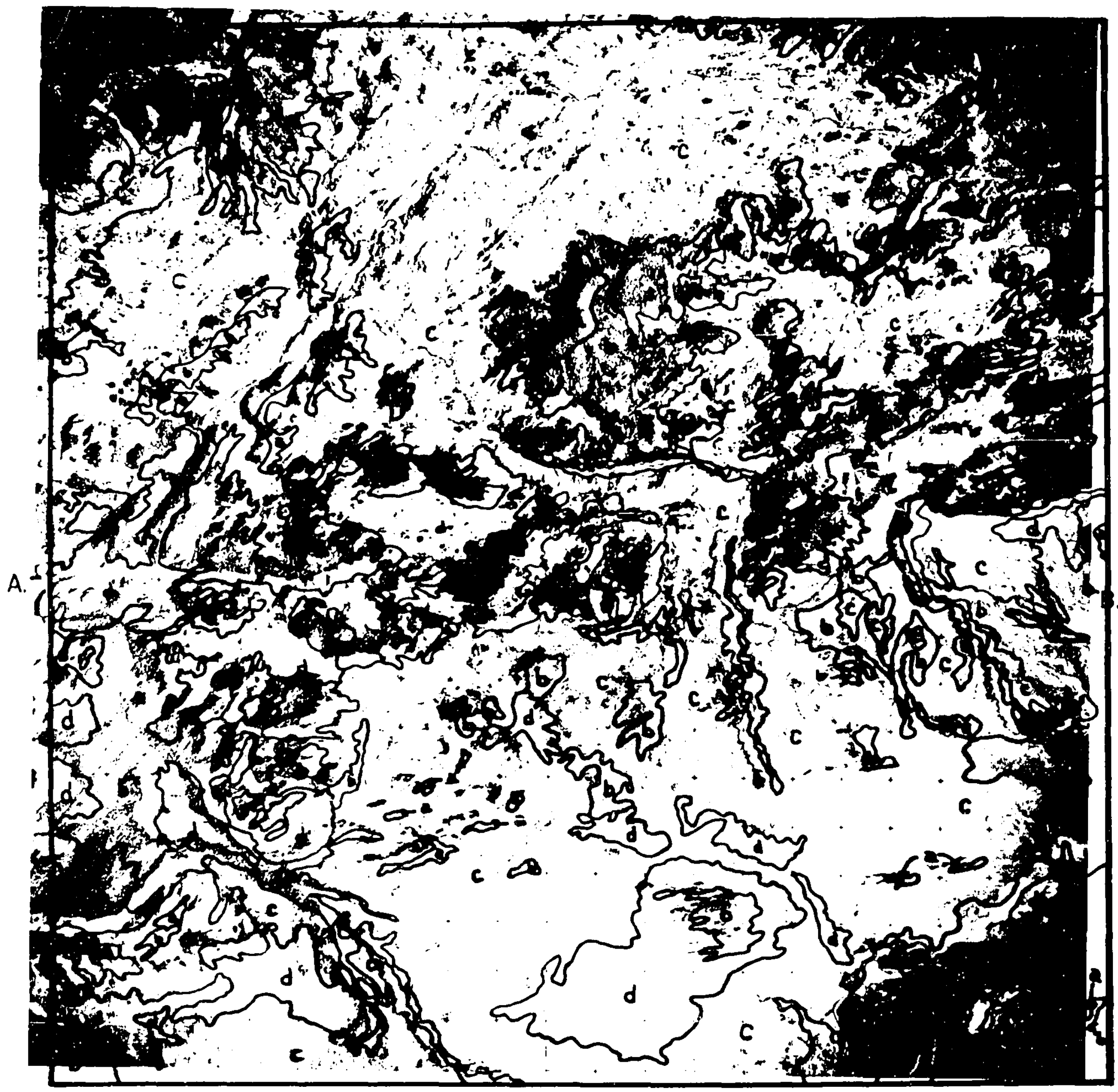


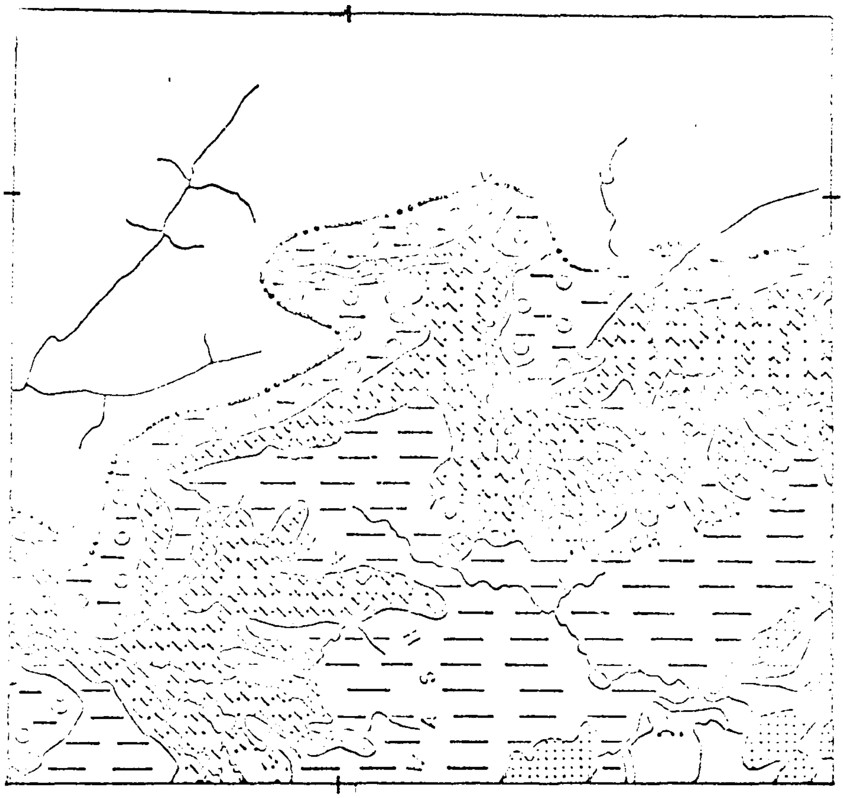
B.

PLATE 13: Eastern part of the Pakaraima Scarp Complex. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha,1967)





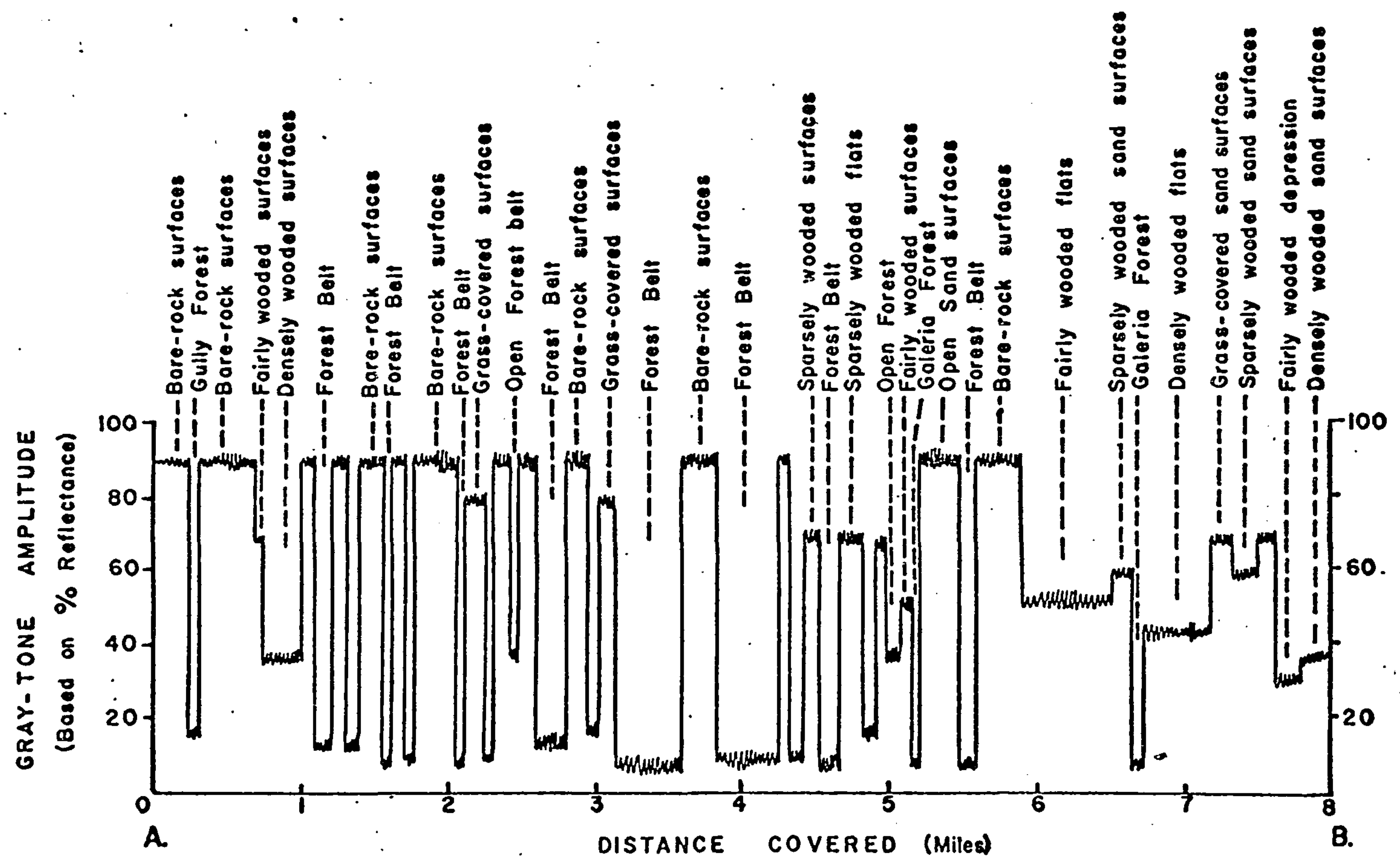


FIG.14 Graphical Comparison of Gray-Tone Values of Terrain Types of the Pakaraima Scarp Complex along Line AB on Plate 13.

Windapo, 1968.

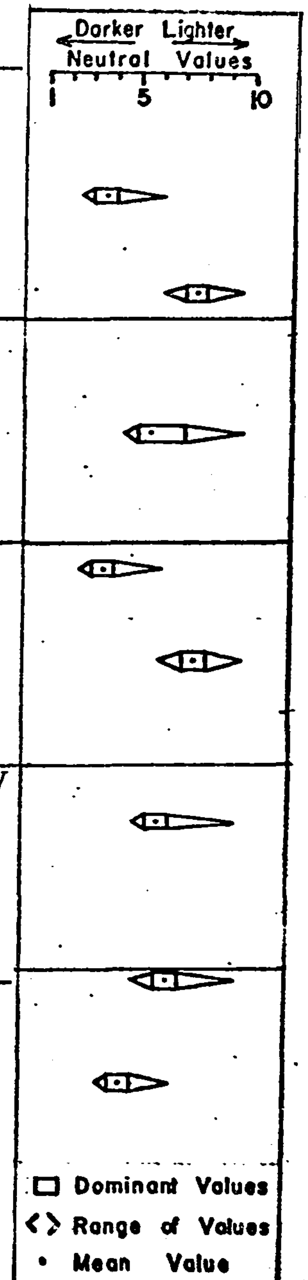
be seen that similar features have similar values and that the boundaries are sharp. Thus differentiation of the various terrain types is possible on the photos once the relationships have been established for a particular area.

For example, on Plate 13, zone 2 of the top overlay represents the scarp faces. Within this zone, the areas marked (a) on the lower overlay are densely wooded areas, while those marked (b) are more open forest belts. Both areas are dark toned, but (a) areas are generally darker with a neutral value dominated by N3, and with a surface reflectance of about 6 per cent; while (b) areas show a range of reflectance between 6 per cent and 15 per cent. The areas marked (c) and (d) on the other hand are light toned non-forested areas. The former areas are savanna belts. Variations in the density of the cover are reflected in the tonal range between N6 and N8.5, because of differences in light absorption potentials of the savanna surfaces. The latter areas are bare rock surfaces with very little absorption capacity. Their very high reflectance of between 78 per cent and 90 per cent give them a very light tone with a value range between N9 and N9.5.

Zone 3 of the same Plate 13 represents the pediment and alluvial fans areas. These areas are generally light toned. The greater proportion of the zone marked (c) is covered by _campo coberto_ type of savanna with low light absorption capacity. The high surface reflectance has caused the area to be light toned with a neutral value range of between N6 and N8.5. The narrow belts marked (b) are generally

TABLE IX: AIR-PHOTO CHARACTERISTICS OF THE PAKARAIMA SCARP COMPLEX

Sub Patterns	Plates & Zones	Landform Units	Approx. % coverage	Drainage	Vegetation	Soils
Western Section	Plate 12 Zone 1	The Scarp Faces	70	Freely drained with grid-iron pattern of drainage due to faulting and differential erosion	Forest with savanna elements	No soil profile; generally shallow pockets of fines.
	Plate 12 Zone 2	The Pediment	30	Well drained zone of deposition crossed by short channels with rocky beds.	Well wooded zone of campo cerrado with a substratum of trachypogon plumosus.	Stony clay matrix surface soil.
Eastern Section	Plate 13 Zone 2	The Scarp Faces	45	Freely drained with grid-iron pattern of drainage due to faulting and differential erosion.	Forest with savanna elements.	No soil profile, generally shallow pockets of fines.
	Plate 13 Zone 3	The Pediment	20	Well drained zone of deposition crossed by short channels with rocky beds.	Fairly well wooded zone of campo coberto with a substratum of grasses dominated by trachypogon plumosus	Stony clay matrix surface soil.
	Plate 13 Zone 3	The Alluvial Fans	35	Generally well drained zone of deposition crossed by narrow distributaries branching from three major trunks in a sub-dendritic pattern	Generally grass dominated with pockets of wooded campo coberto belts on the ridges and galeria forests along trunk streams	Alluvial sandy loam.



darker than (c) areas. They are densely wooded fringes of the major creeks and are consequently more light absorbent, with a neutral value ranging between N3.5 and N5. Still darker than (b) areas are the few belts of galeria forest and campo cerrado type of savanna in the areas of high moisture content. The high moisture has combined with the vegetation cover to effect a high surface absorption and a dark tone with a value range of between N3 and N4. These tonal characteristics are expressed in neutral range diagrams in Table IX which summarizes the air-photo characteristics of the landform pattern.

CHAPTER IV

THE MARAKANATA LOWLANDS

The Marakanata lowlands occupy a depression lying between the Pakaraima scarp in the north and the laterite uplands in the south, and trending southwest-northeast. The depression may occupy the site of a former lake into which flowed the primitive Ireng Uraricuera and the Takutu rivers. This lake was later drained to the northeast through the Proto-Berbice River. Its centre is still swampy for most of the year; its drainage is rather deranged with streams flowing both northeast and southwest to the Rupununi and Ireng rivers respectively. The swampy centre is traversed by the meandering channels of the Rego - a river which now exists as a misfit within the channels of a previously greater river.

This landform pattern exhibits the greatest internal variation in the whole of the study area (Table VIII). On the basis of the complex internal variations, four major landform units have been delineated (Fig. 9), and these include:

(i) the terrace and dunes of the northern margin,

(ii) the central lowland,

(iii) the dunes of the Takutu-Ireng confluence to the southwest, and

(iv) the laterite outliers.

The last unit - laterite outliers - actually belong to the laterite land system but has been mentioned here because of its role as a boundary marker to the central lowland, and because it affects the general air-photo appearance of the Marakanata Lowlands. Its detailed treatment would however

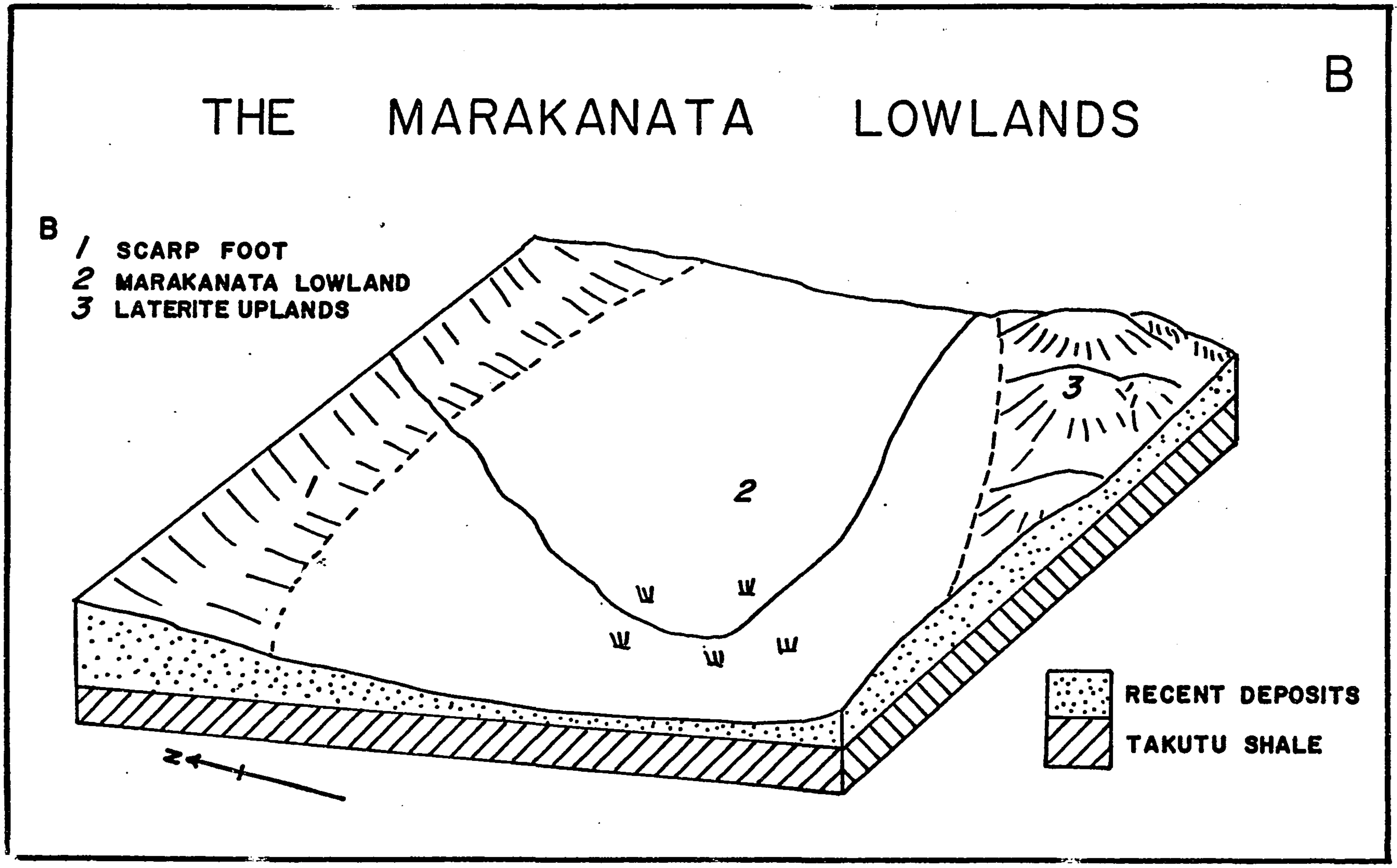


FIG. 15

Windapo, 1968.

be deferred till the laterite landform pattern comes under consideration.

Terraces and Sand dunes of the Northern Margin:

Both the terraces and the sand dune areas have the same surface composition. However, wind action has produced ridges and depressions which characterize the dune areas within the general terraced surfaces. Three levels of terraces could be traced represented at Cashewera, Massara and Jacarinta villages in sequence. Around Massara the terraces are represented by a number of low flat-topped hills that are aligned along the Bunoni River. They may be remnants of former shorelines of an ancient lake that has since disappeared. Massara village stands on one of such low hills. They attain a varying elevation of between 30 and 40 feet above the Bunoni and Rupununi flood-plains. In the wet season they appear as sand swells above the flood waters of the Rupununi.

Westwards, the sand hills attain only heights of between 5 and 15 feet above their surroundings of backswamp and lacustrine clays. Such hills are found around Cajueiro where their heights average about 10 feet above the swamps. An examination of the two types of sand hills reveals differences in their sand texture. Table X shows a comparison of samples from the two belts and Fig. 16 shows their grain-size distribution curves.

On the higher hills of the Massara terrace, the sands are generally loose and structureless. On the flat tops the sands are generally fine becoming coarser on the lower slopes

TABLE X

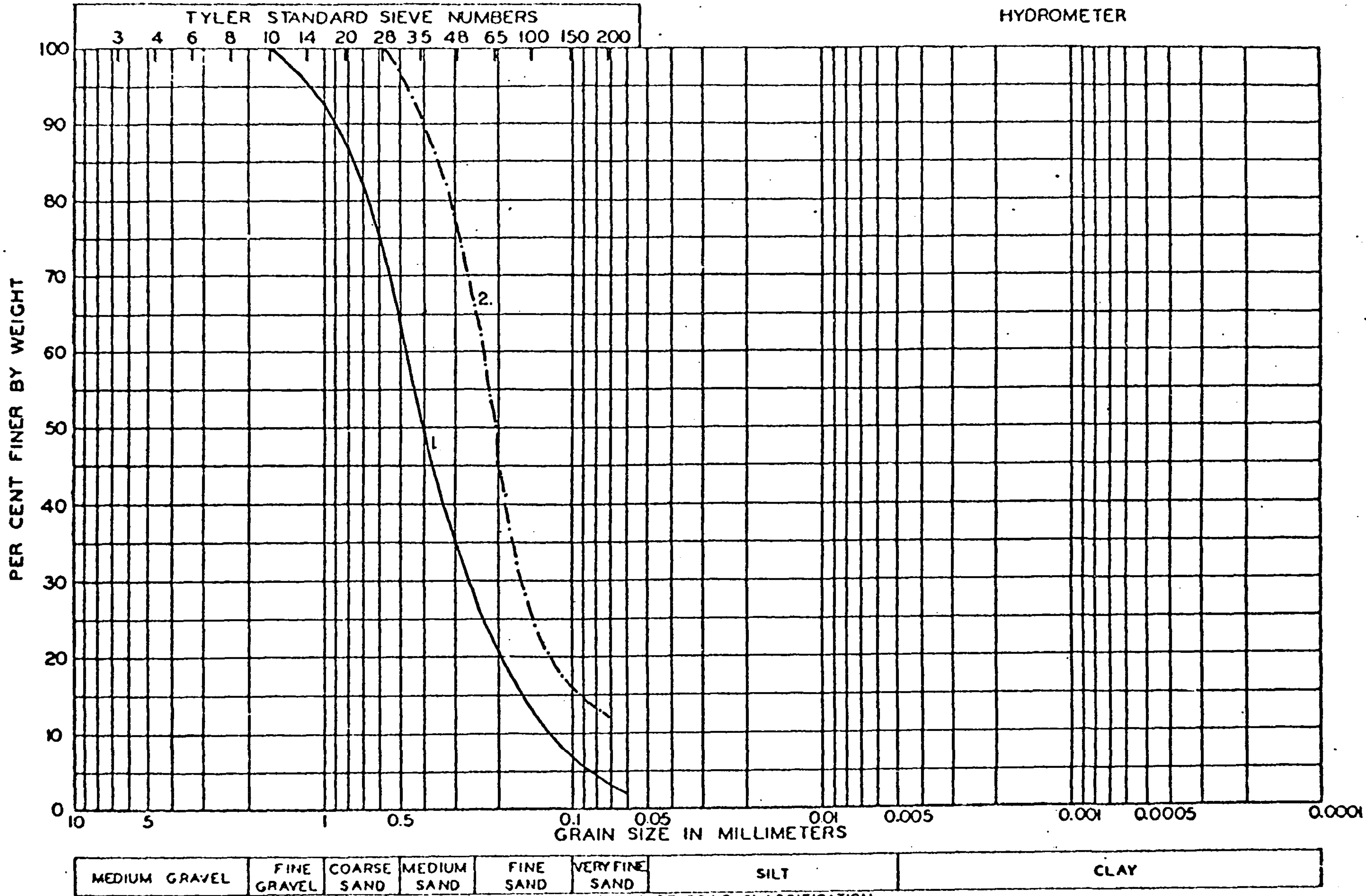
Sieve analysis of Terrace Sands of Massara and Cajueiro.

1. Massara Terrace Belt.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	10YR
3	-		6/2
2	-		light
1	7		brownish
.5	27		grey
.25	33		
.125	20		
.088	2		

2. Cajueiro Terrace Belt.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	5YR
3	-		7/1
2	-		light
1	-		grey
.5	3		
.25	30		
.125	45		
.088	8		



1. Massara: High Terrace Sands

2. Cajueiro: Low Terrace Sands.

FIG. 16. GRAIN SIZE DISTRIBUTION DIAGRAM; Massara – Cajueiro.

as the intervening depressions are approached. The coarser texture on the lower slopes might have resulted from the winnowing influence of the seasonal flood waters washing the hill sides and carrying the finer materials into the depressions.

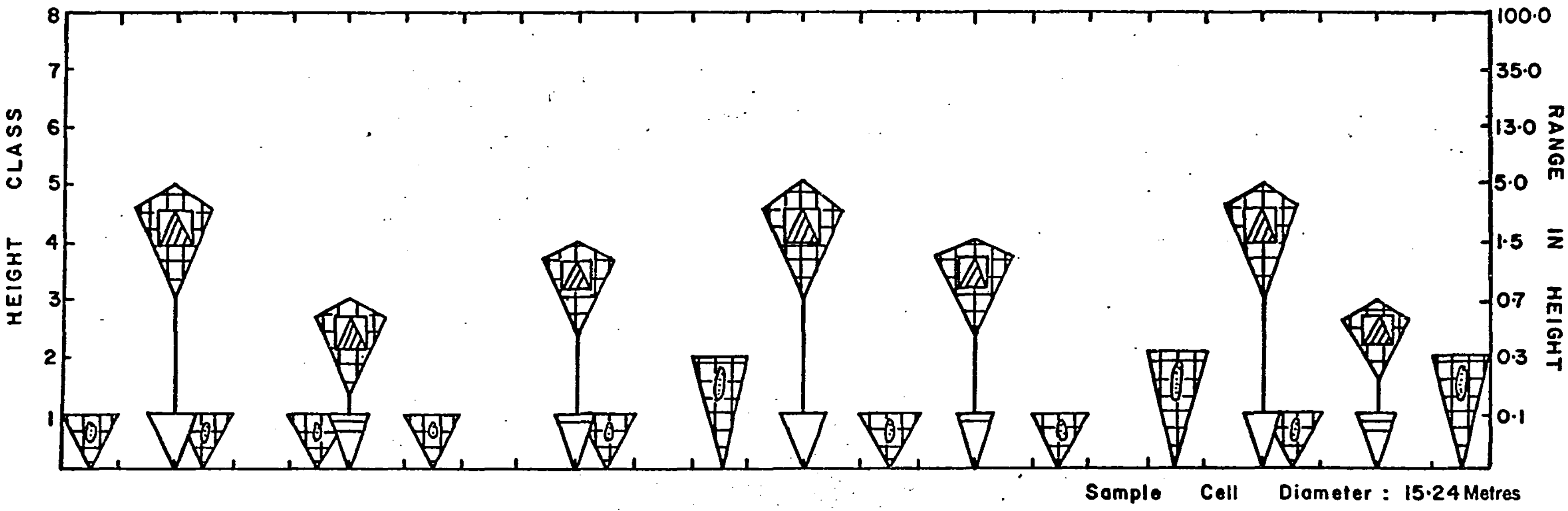
The soils of the lower hills of the Cajueiro terrace are mainly loamy. As in the higher hills, the texture varies from hill top to the lower slopes. While the tops are of fine sandy loam, the lower slopes are of medium sandy loam. Like the sands of the higher hills, the loams are loose and structureless, and the intervening troughs - usually temporarily waterlogged - contain finer materials.

Vegetation on this unit varies from sparsely wooded savanna of campo sujo type to the treeless savanna of campo limpo type. Within the Massara sand hills, the troughs carry a wooded savanna of campo sujo type increasing in density to campo coberto towards the edge of the galeria forests of both the Rupununi and the Bunoni rivers. The dominant tree species in the troughs is plumeria inodora, while curatella americana dominates the hill tops. Fig. 17 is a structural diagram representing the vegetation association in a sampled cell about a mile southwest of Massara village.

Within the lower hills of the Cajueiro type, the savanna community is less densely wooded. The campo sujo here is restricted to the areas of moderate drainage within the troughs while the freely drained sand ridges are practically treeless. The vegetation cover of the ridges belong to the herbaceous campo limpo, grass dominated variety with intrusions of stunted curatella americana and byrsonima verbascifolia shrubs.

FIG. 17. VEGETATION STRUCTURAL DIAGRAM

Near Massara Village



SITE SITUATION

a. UTILIZATION : Pastured

b. SOIL STRUCTURE : Medium

c. SOIL TEXTURE : Sand

d. DRAINAGE : Good

e. RELIEF : Flat.

Windapo, 1968.

The Central Lowland:

The Central lowland occupies a zone of almost imperceptible relief stretching from south of Meritizero to northwest of Marakanata settlement (Fig. 9). The average elevation of this zone is about 340 feet above sea level with very slight increase in elevation towards the margins. The zone is fringed by wooded and bush-covered laterite remnants on the western, southern and southeastern borders. The only features relieving the monotony of the lowlands are a number of sand ridges which mark old stream courses and meander across the lowlands, cutting off basins and ponds.

As a result of its low relief, this zone is covered almost completely by flood waters during the rains. The greater part of the zone is consequently waterlogged for most of the year, and permanent swamps and lake bodies are found scattered all over the area.

The soils of this unit are generally loamy, varying from sandy loam to clay loam (Table XI, Fig. 18). Sandy loam occurs on the ridges while in the depressions where seasonal waterlogging is experienced, silty loam is dominant, and the swamps contain both clay loams and silty clay. The silt and clay zones which experience seasonal inundation are often dotted by terrawards while the lake deposits are predominantly whitish- to buff-coloured silty clays which are usually infertile because of the protecting water bodies over them.

The vegetation of the unit belongs to the herbaceous campo limpo type - sedge dominated in the swamps. A few of the

TABLE XI

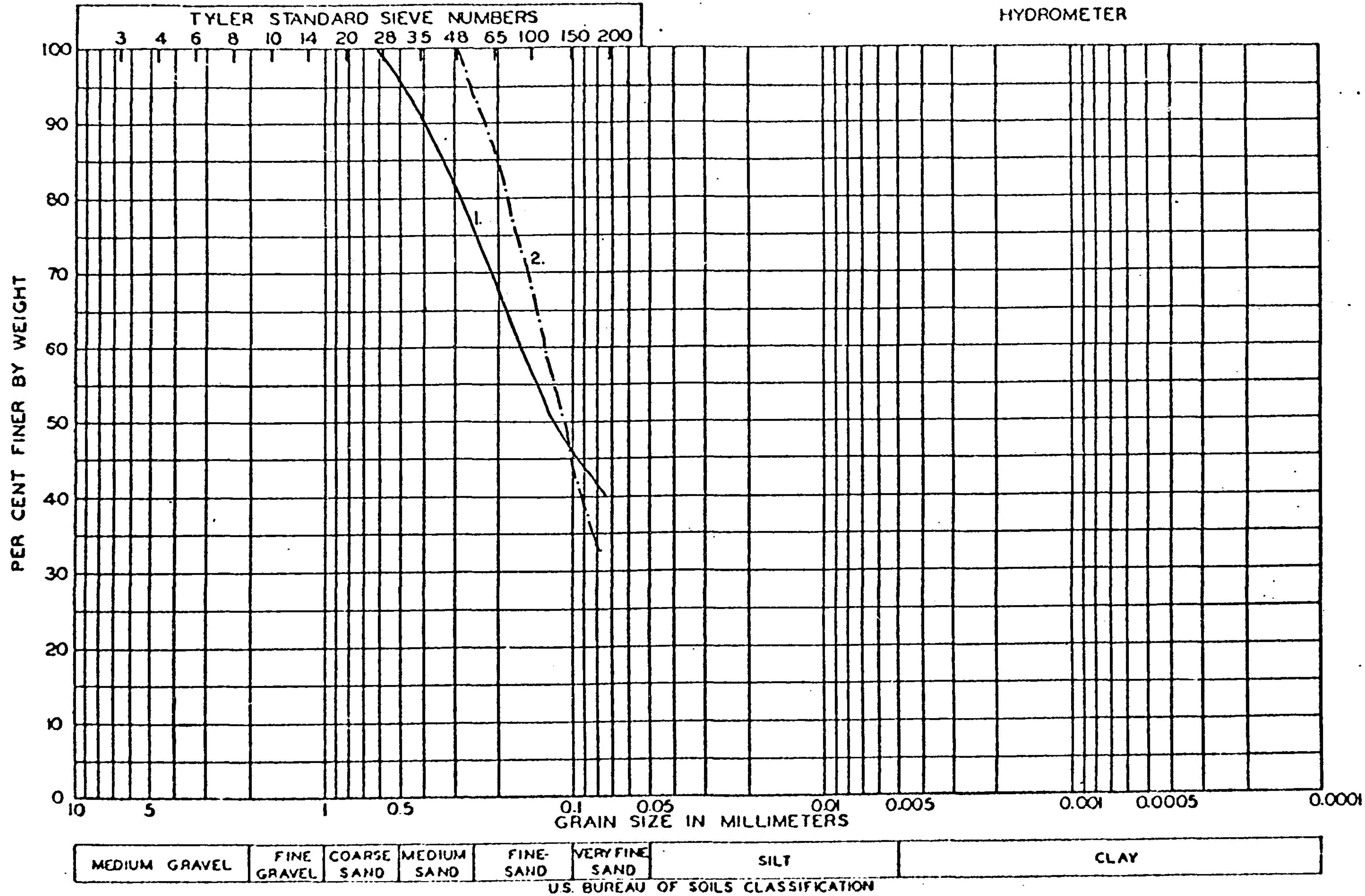
Sieve Analysis of Marakanata Central Lowland Soils.

1. Sand Fill Soils.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.2	10YR
3	-		6/2
2	-		light
1	-		brownish
.5	3		grey
.25	20		
.125	26		
.088	8		

2. Bottomland soils.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	1oYR
3	-		6/1
2	-		grey
1	-		
.5	-		
.25	6		
.125	49		
.088	12		



1. Marakanata Central Lowland: Sandy Loam

2. Marakanata Central Lowland: Silty Loam.

FIG. 18. GRAIN SIZE DISTRIBUTION DIAGRAM: Marakanata Central Lowland

sand ridges support bunch grasses and offer grazing for the ranchers of the area.

The Sand dunes of the Takutu-Ireng Confluence to the southwest.

This unit marks the south-western extent of the Marakanata Lowlands. It extends from west of Pirara settlement in an east-northeast to west-southwest direction to the Takutu flood-plain (Fig. 9). The dunes are generally elongated in a northeast-southwest direction and vary in height from 10 to 20 feet with gentle convex slopes. They are found mainly along the edges of depressions and lakes, particularly the Lago do Capirara, Lago do Farno, Massu Lake and Cashew Lake. The alignment of these dunes and the distribution of the lakes seem to suggest that they mark the flood-plain of a river which has since disappeared or changed course.

The soils of this unit are mainly sandy varying in texture from coarse to medium grained (Table XII, Fig. 19). These sands are well drained but because they are very close to the water-table, they are able to support a savanna vegetation of the campo coberto type with such tree association as the curatella americana, byrsonima crassifolia, baudichia sp. and plumeria inodora. Fig. 20 is a structural diagram representing the vegetation association of a sampled cell north of Massu Lake.

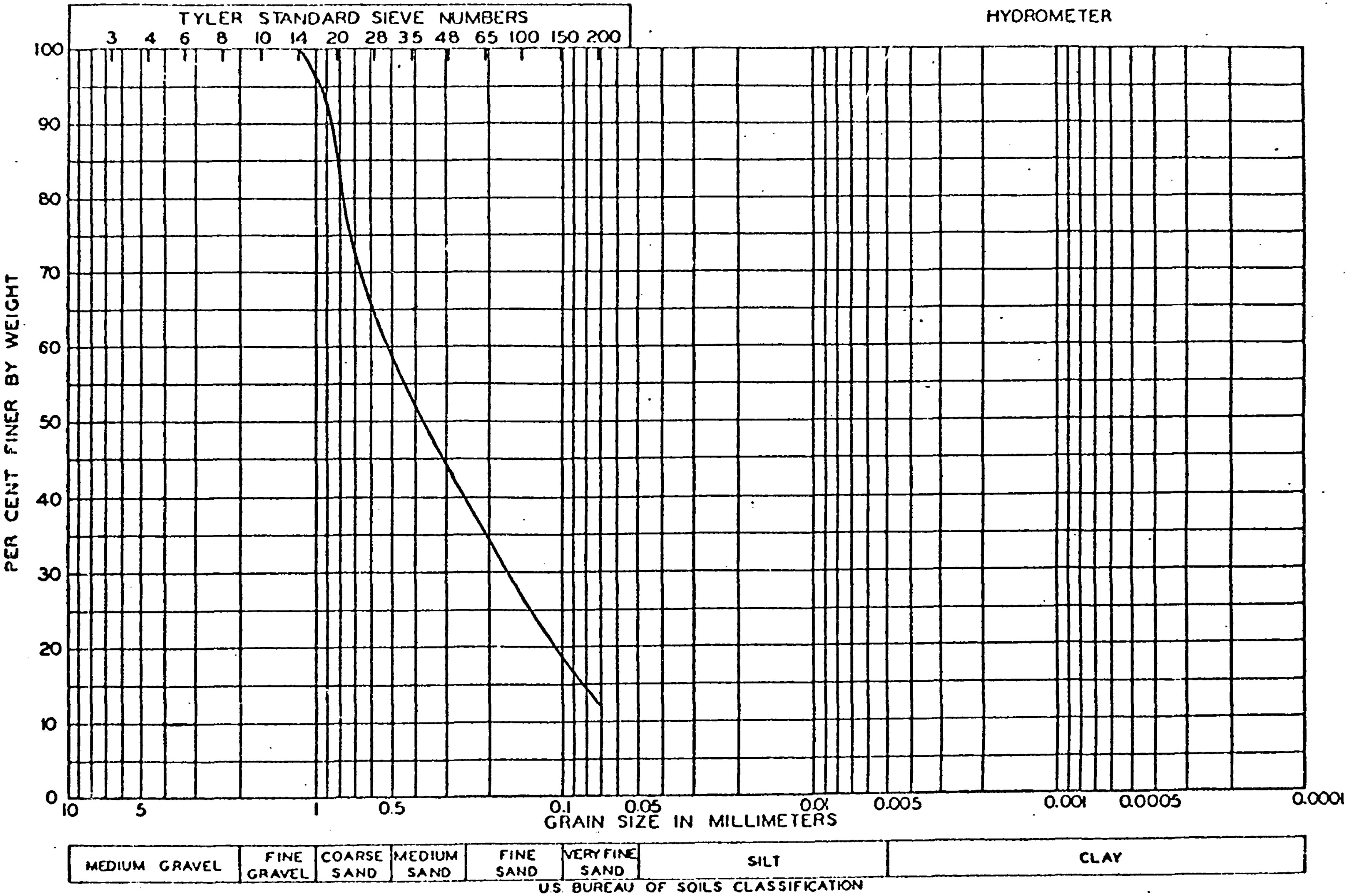
AIR-PHOTO CHARACTERISTICS OF THE LANDFORM PATTERN.

As a result of its complexity, this land system has the most varied air-photo characteristics within the study area. The appearance of the terraces and dunes of the

TABLE XII

Sieve analysis of soil sample from North of Massu Lake in the southwest margin of the Marakanata Lowlands.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.0	10YR
3	-		5/1
2	-		grey
1	4		
.5	38		
.25	18		
.125	18		
.088	8		

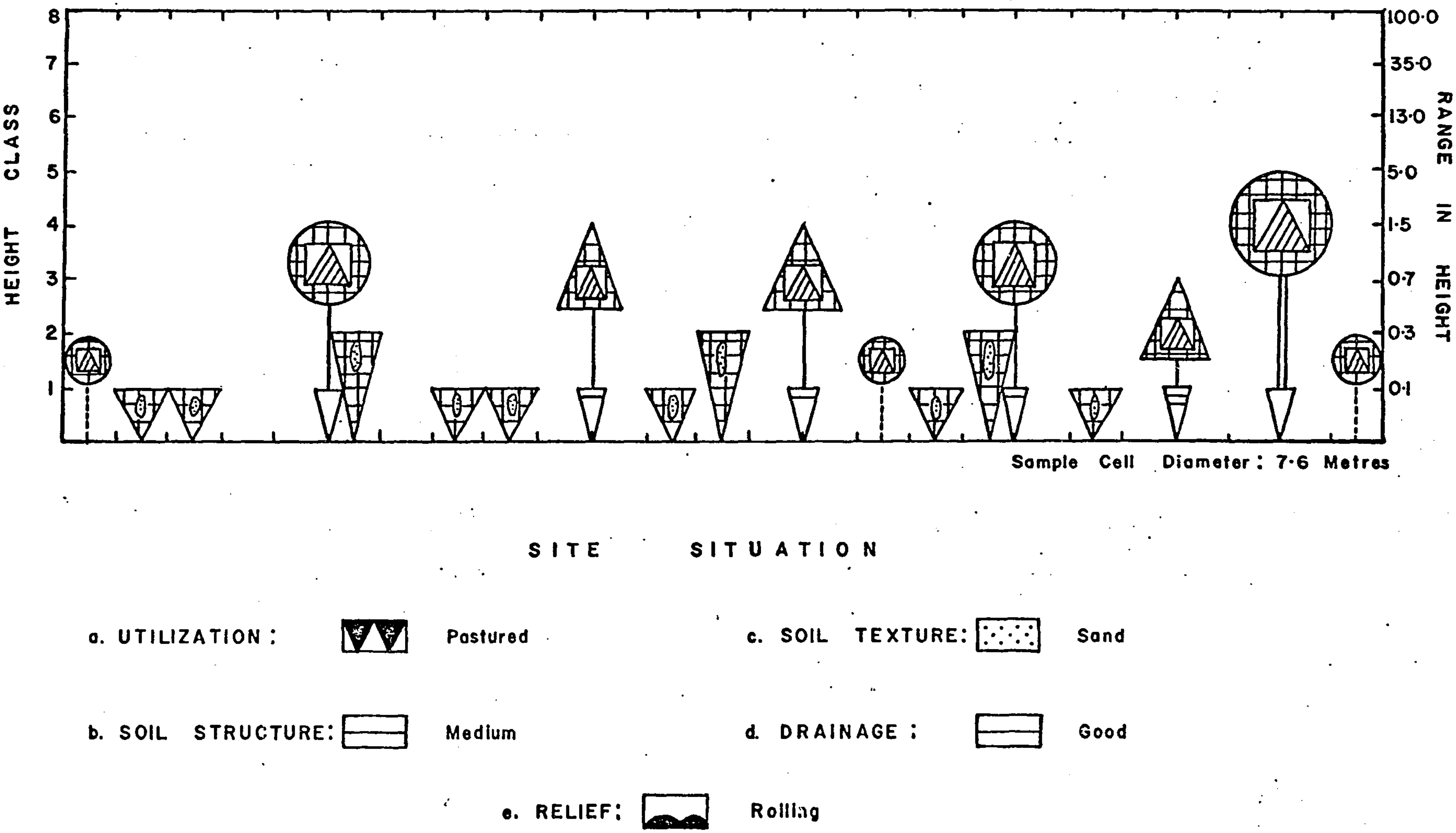


Sandy Loam North of Mossu Lake.

FIG. 19. GRAIN SIZE DISTRIBUTION DIAGRAM: North of Mossu Lake

FIG. 20 VEGETATION STRUCTURAL DIAGRAM

North of Massu Lake



Windapo, 1968

northern margin can be appreciated from Plate 14. Plate 15 covers part of the central lowlands and the laterite enclaves, while Plate 16 shows the dunes of the southwest.

On Plate 14 zone 1 of the top overlay is outside the pattern under consideration and has been treated under the Pakaraima Scarp Complex in Chapter III. Zone 2 is largely the northern margins of the Marakanata Lowlands system. It depicts a zone of sand ridges of varying elevations and alignment with intervening depressions of imperfect internal drainage. The very few areas marked (a) with a neutral value range between N2 and N3, and a low reflectance range between 3 per cent and 6 per cent are generally areas of ponds and swamps covered by phreatophytes as confirmed by field investigation. Areas marked (b) and covering the greater part of the landform unit have a tonal value ranging from N6 to N7 and a surface reflectance ranging between 30 per cent and 43 per cent. These areas mark the bottomlands with a cover of campo sujo savanna. The vegetation cover has been helped by fairly high moisture, to produce the fairly low surface reflectance within the areas. Next in areal coverage are the light toned areas marked (c) with a tonal value ranging between N7 and N9. These are generally drier and more sparsely vegetated. They represent sand ridges with a cover of campo limpo herbaceous savanna, hence their high surface reflectance of about 60 per cent to 80 per cent. Those very light toned areas marked (d) with a tonal range between N9 and N9.5 are generally grass-covered sand fills with a high reflectance of between 80 per cent and 90 per cent. The very high reflectance here has been due to sparsity of

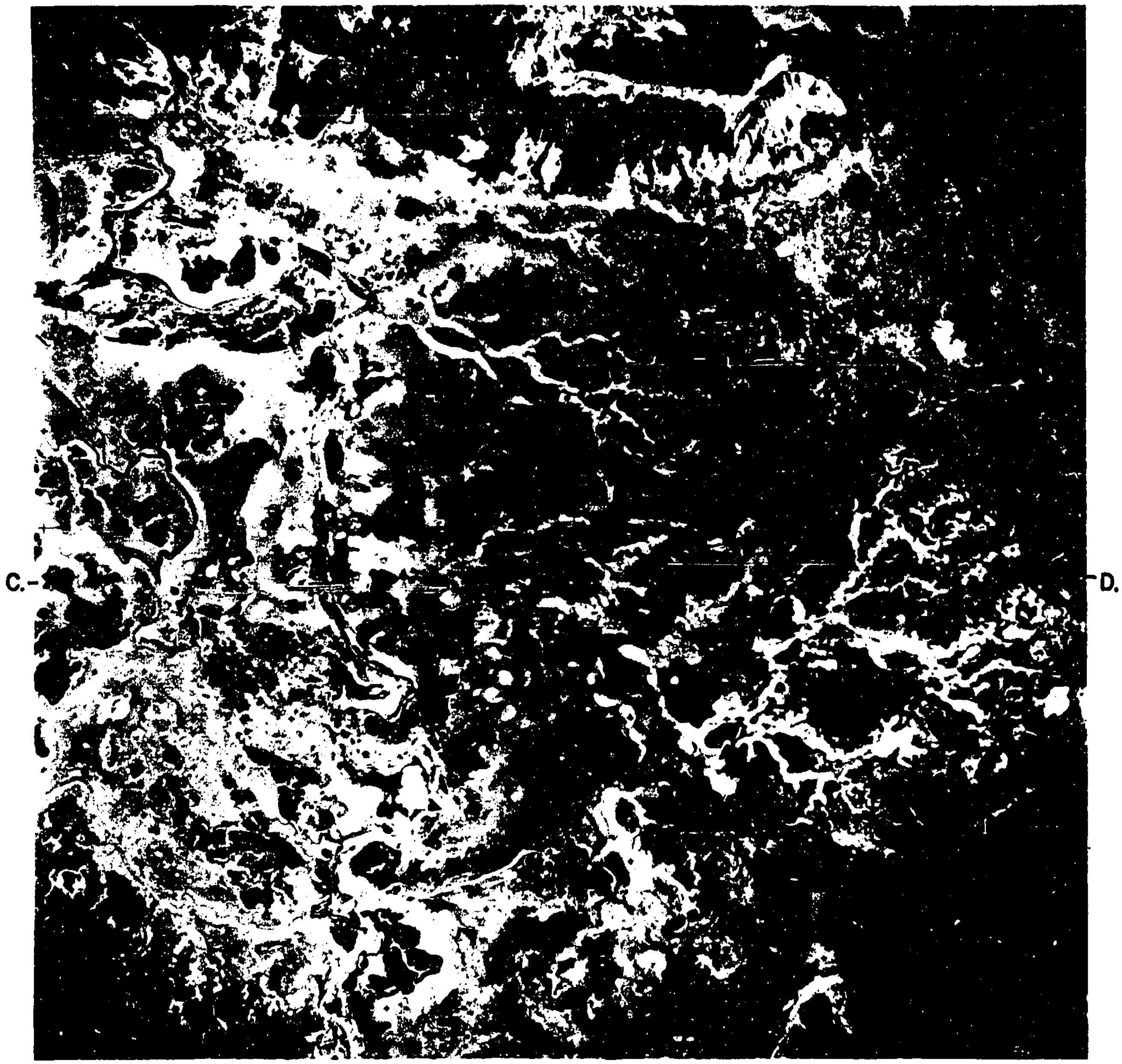
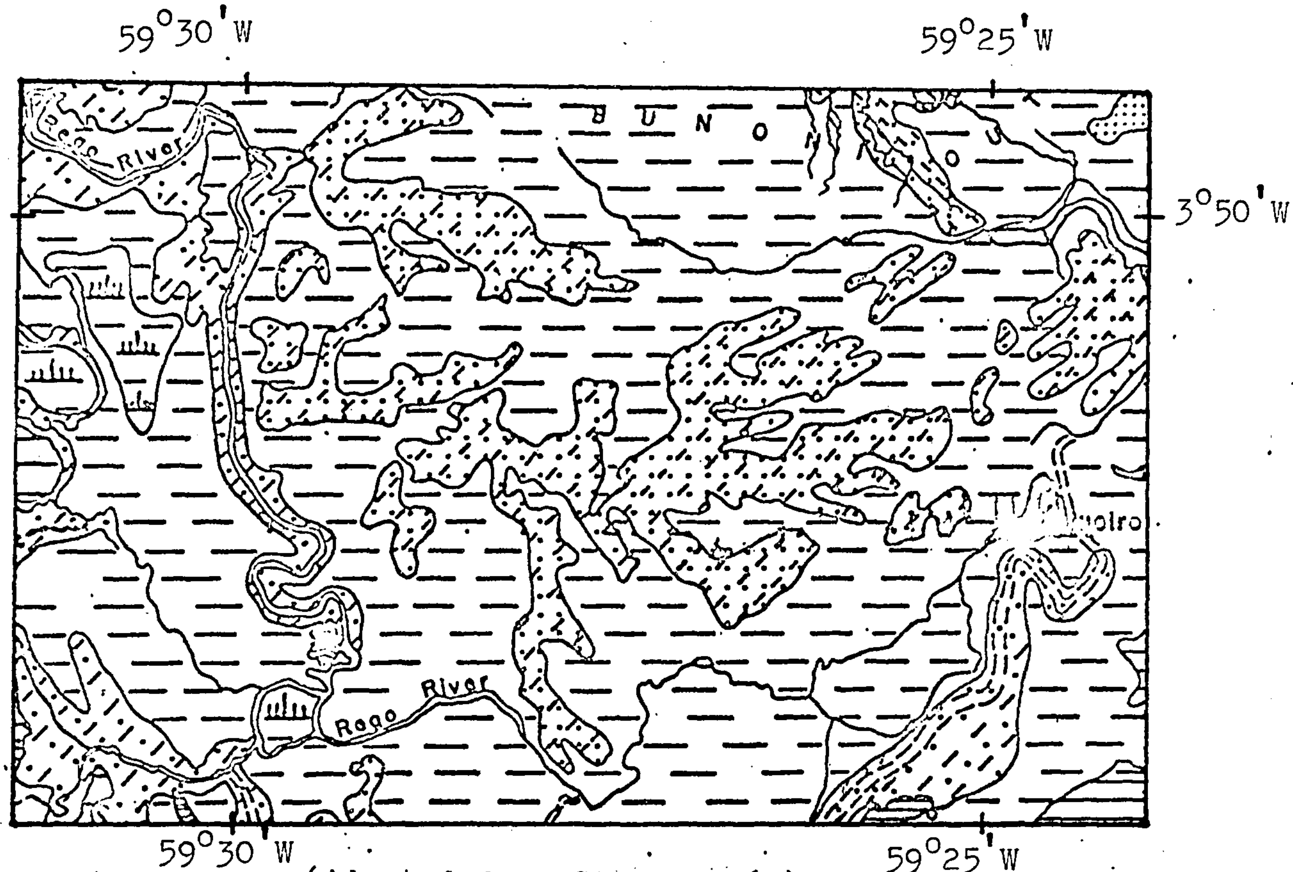


PLATE 14: Northern margin of the Marakanata Lowland. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967)


C.
D.

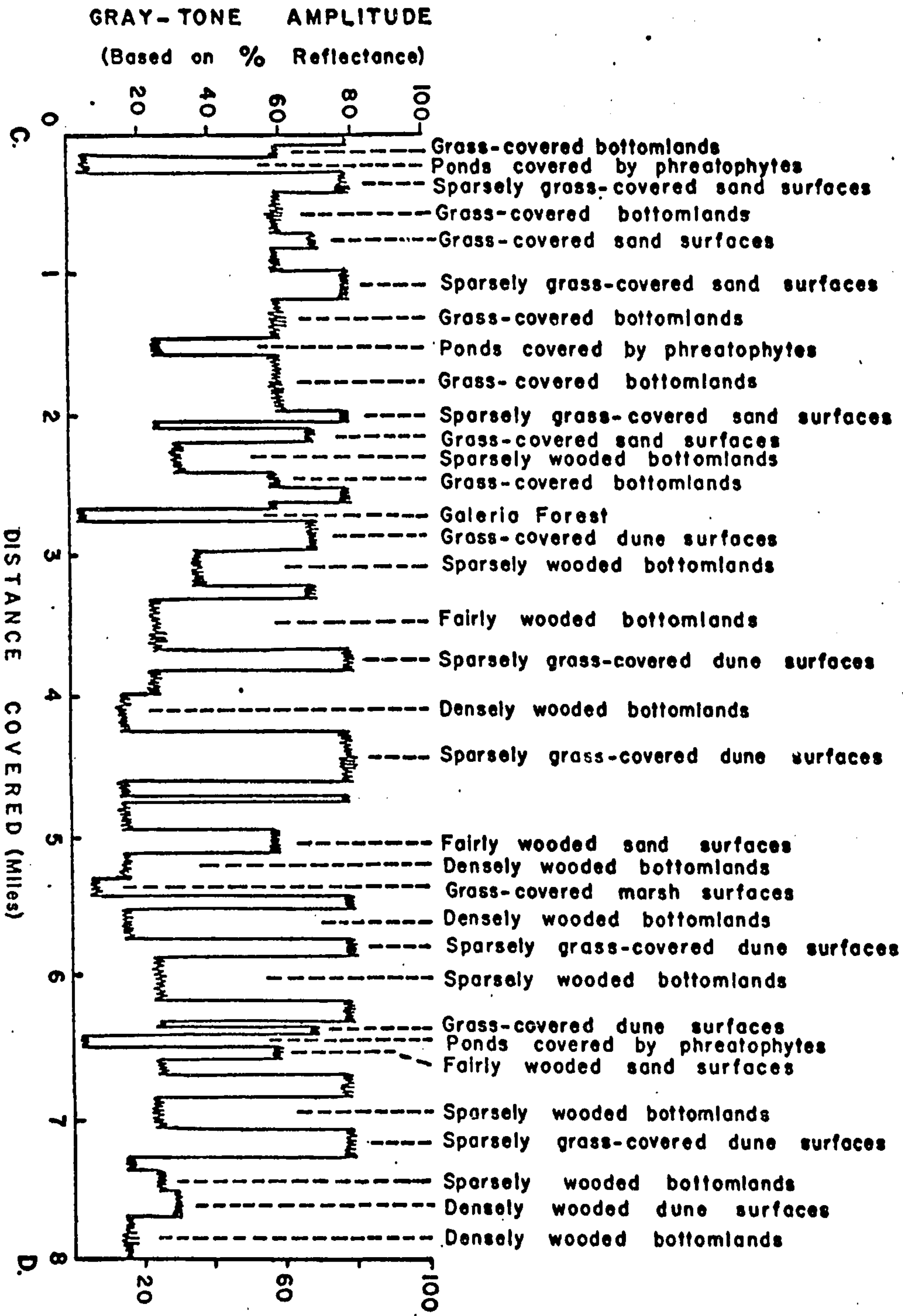


FIG.21. Graphical Comparison of Gray-Tone Values of Terrain Types of the Northern Margin of the Marakanata Lowlands along Line CD. on Plate 14.

Windapo, 1968.

vegetation cover and lack of moisture within the sandy channel fills. Their very high reflectance distinctly mark them out within the landform unit.

In general all the different tonal values are distinct from one another and with generally sharp boundaries as shown in the wave-form amplitude graph in Fig. 21. Their overall prevalence is summarized in neutral value range diagrams in the last column of Table XIII.

Plate 15 shows the central lowland and the laterite enclaves. Zone 1 on the top overlay separates the portion of the dunelands of the southwest from the lowland proper which is covered by Zone 2. Within this central lowland, the largest tonal coverage marked (b) with a neutral value range between N5 and N6.5, and a surface reflectance of about 20 per cent to 36 per cent are areas of herbaceous savanna - sedge dominated campo limpo. These areas are swampy for most of the year. It is this moisture condition rather than the vegetation cover that is responsible for the low surface reflectance all over the areas. The limited but darkest portions of the zone marked (a) with a tonal value range between N2 and N3.5 and a reflectance of between 3 per cent and 9 per cent are permanent swamps grown with sedges and other phreatophytes. The light toned areas marked (c) with a tonal value range between N7 and N8 and a reflectance range between 43 per cent and 59 per cent are mainly belts of sand ridges of channel-fill origin supporting only bunch grasses. The lighter tones of the areas might be attributed to lower moisture content in the soil and higher

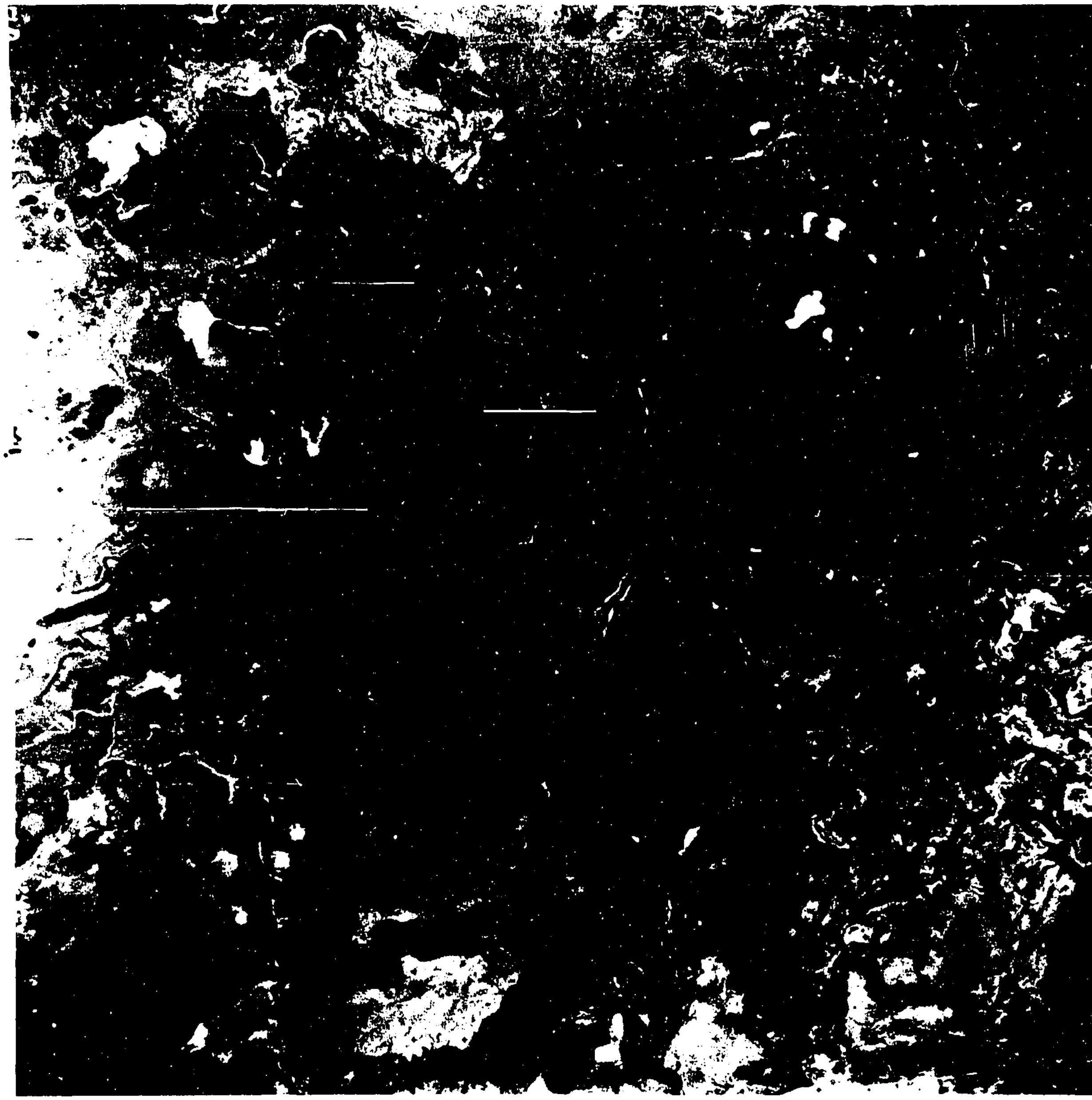
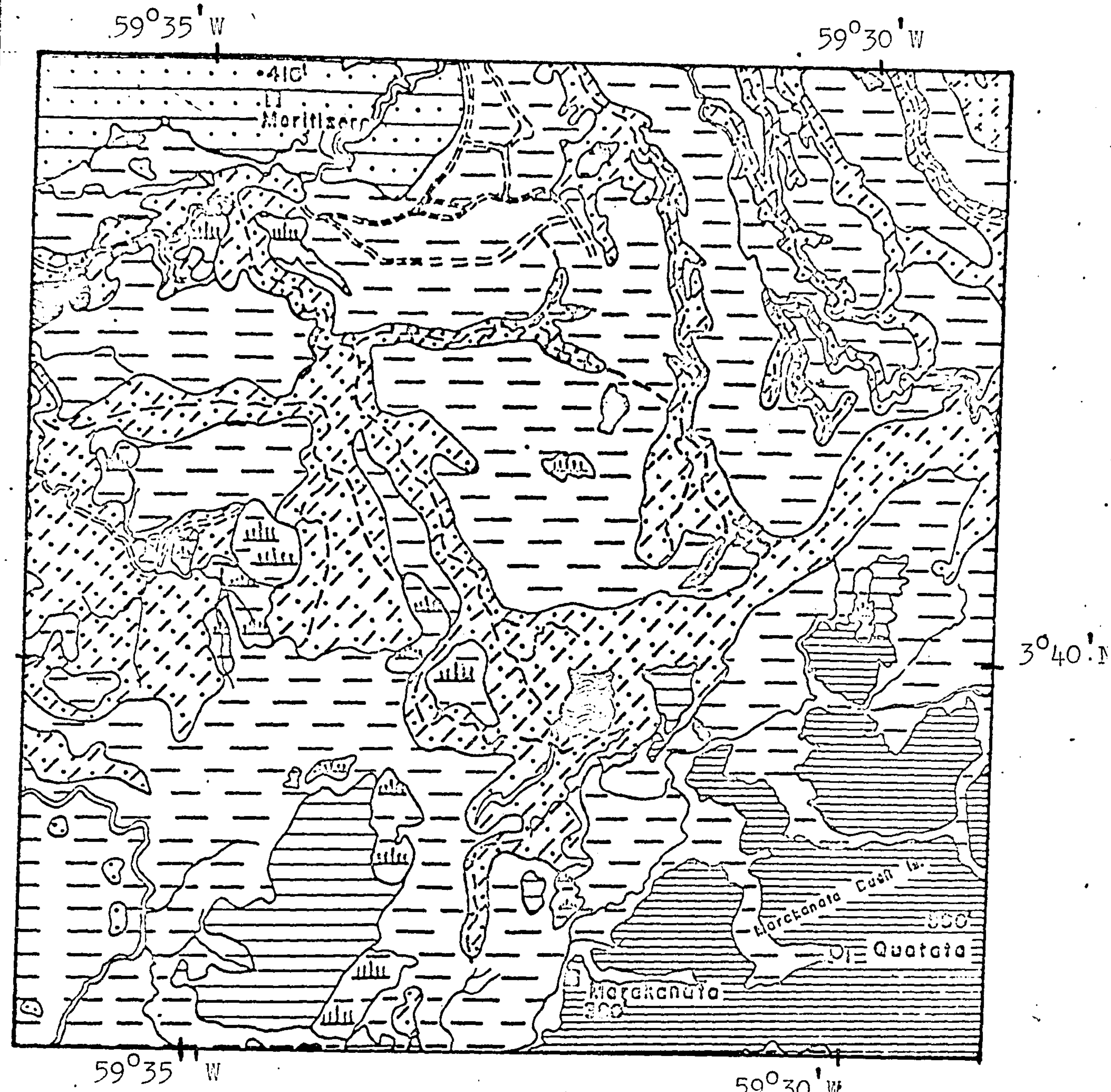
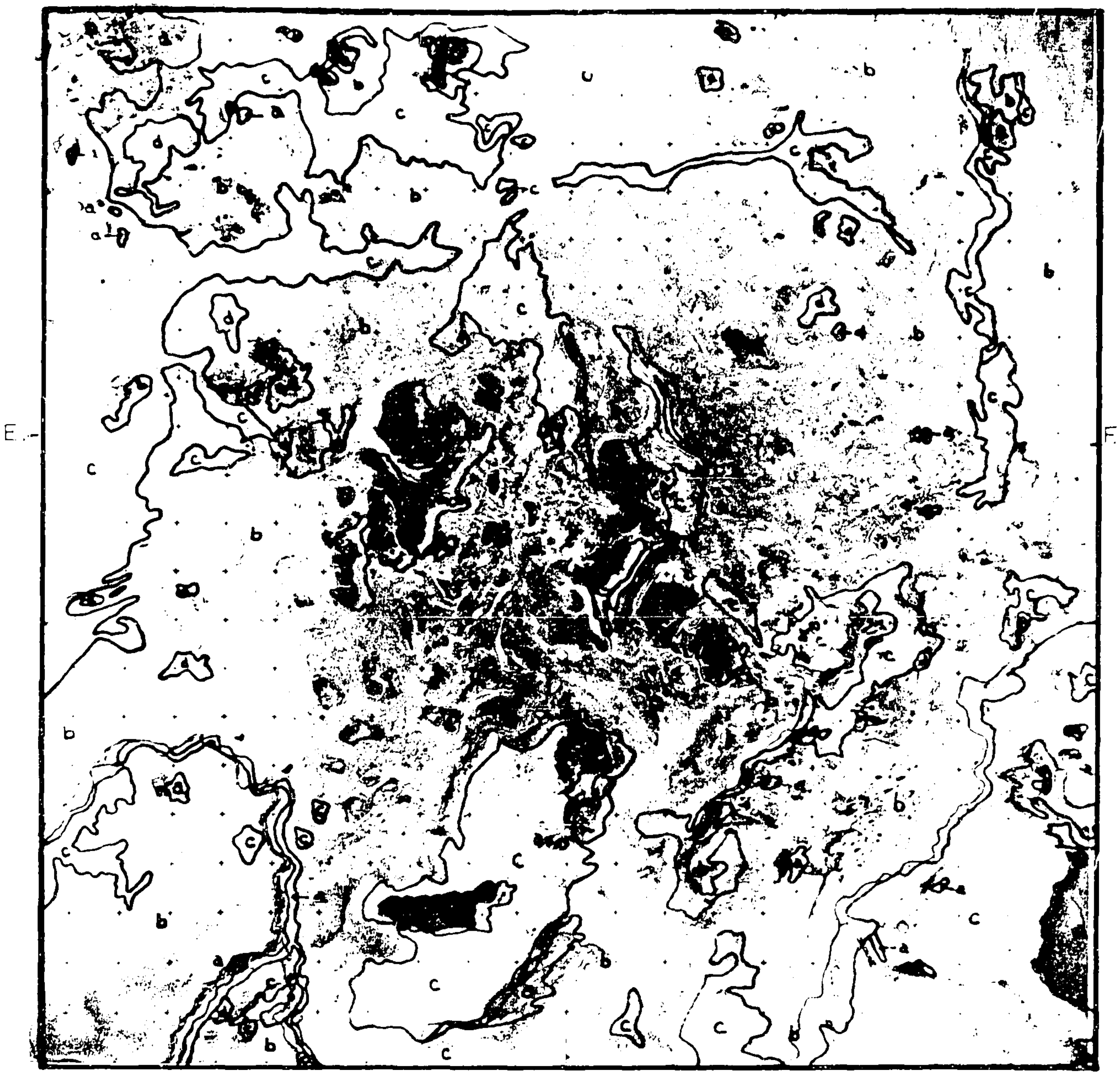


PLATE 15: M[illegible] Central Lowland. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967)


E
F

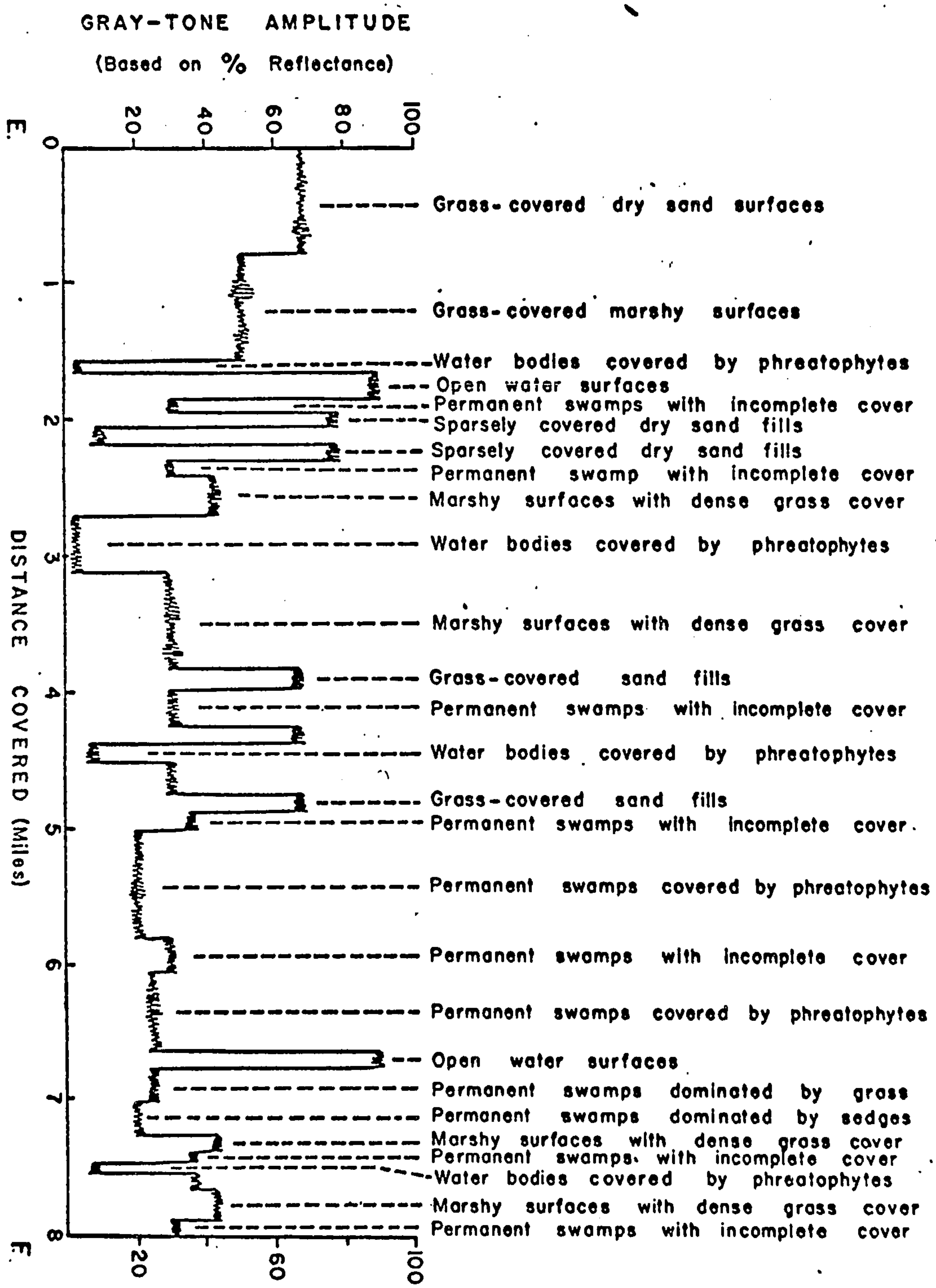


FIG. 22. Graphical Comparison of Gray-Tone Values of Terrain Types of the Marakanata Central Lowlands along Line EF. on Plate 15.

Windapo, 1968.

surface reflectance of both the sandy loam and the grass cover. The very few small pockets of (d) with the lightest tonal value of N9.5 and the highest surface reflectance value of about 90 per cent are open water surfaces in ponds and lakes as proved by field checks.

All the different tones together give a mottled texture to the landform unit. These tones are quite distinct one from another with sharp boundaries as shown in Fig. 22, which is a graphical comparison of tonal fluctuations along a sample transect EF on Plate 15, and their range of characteristics is summarized in neutral value range diagrams in Table XIII.

Zone 4 separates the laterite outliers within which two tonal ranges are recognized. The dark toned areas marked (a) with a value range between N3 and N3.5 correspond with forest islands with a surface reflectance ranging between 6 per cent and 9 per cent. The light toned areas marked (c) with a tonal range between N7 and N8, and a surface reflectance of between 40 per cent and 60 per cent are areas of open herbaceous savanna - grass dominated campo limpo. The very sharp tonal boundaries and value differences could be explained on the fact that the forest zones are more light absorbent than the bunch grasses and open soil surfaces.

On Plate 16, Zone 2 is the only part relevant to the landform under consideration. It marks the southwest limit of the Marakanata Lowlands. Within this zone, the very dark toned areas marked (a) on the lower overlay with a tonal value ranging between N2 and N4 are sedge covered ponds and lakes.

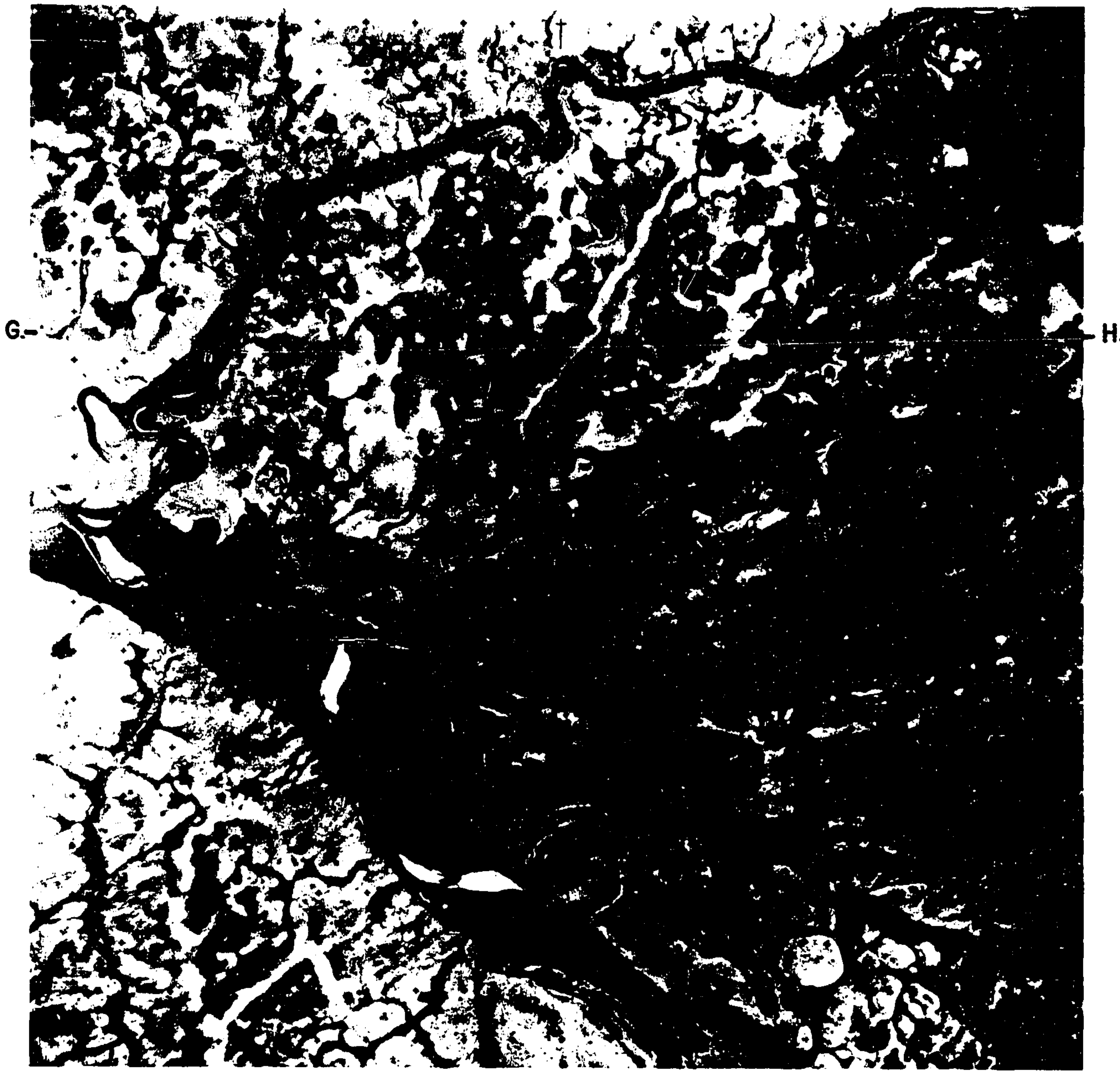
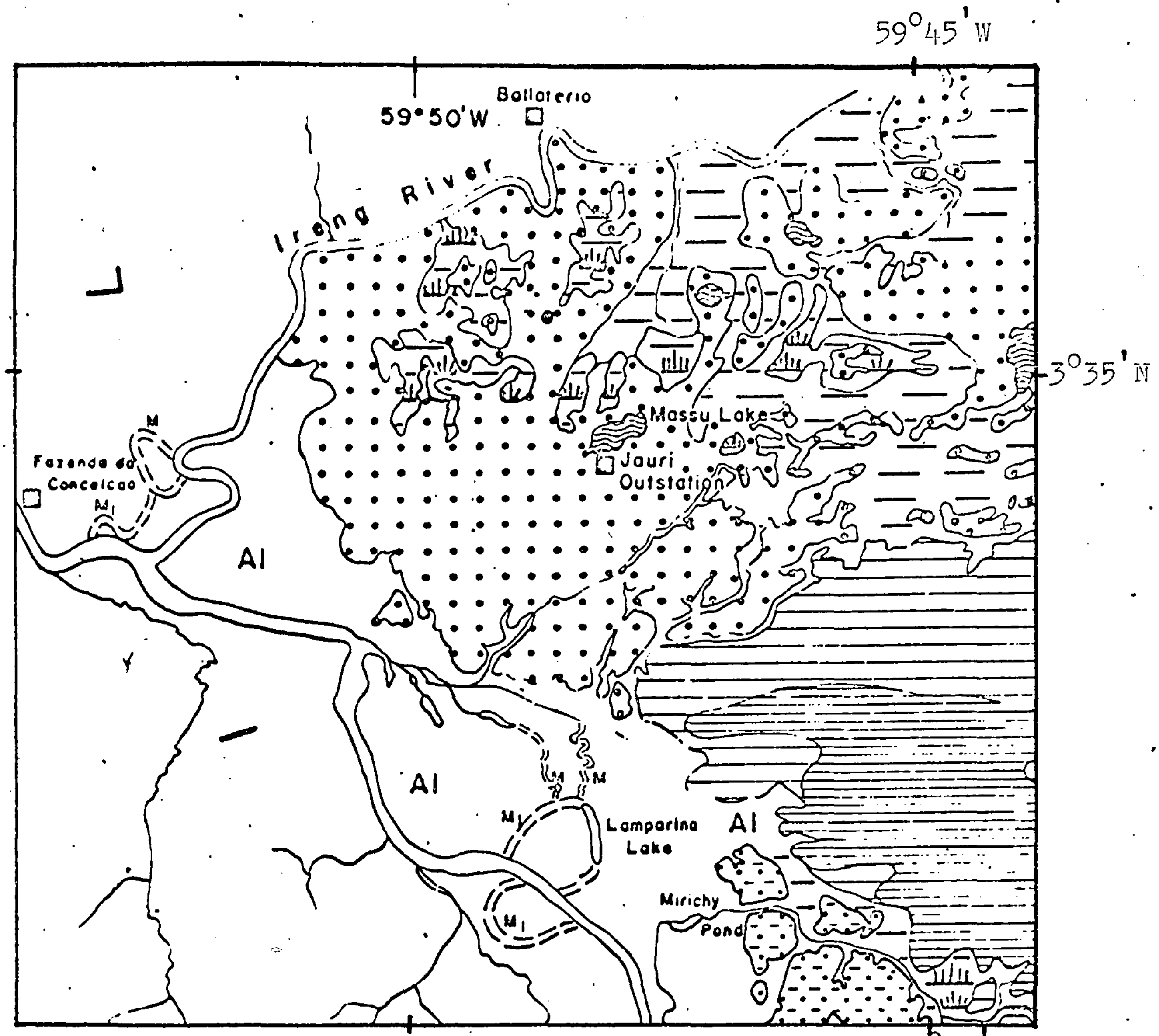


PLATE 16: Southwestern margin of the Marakanata Lowlands.
(Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967.)


G
H

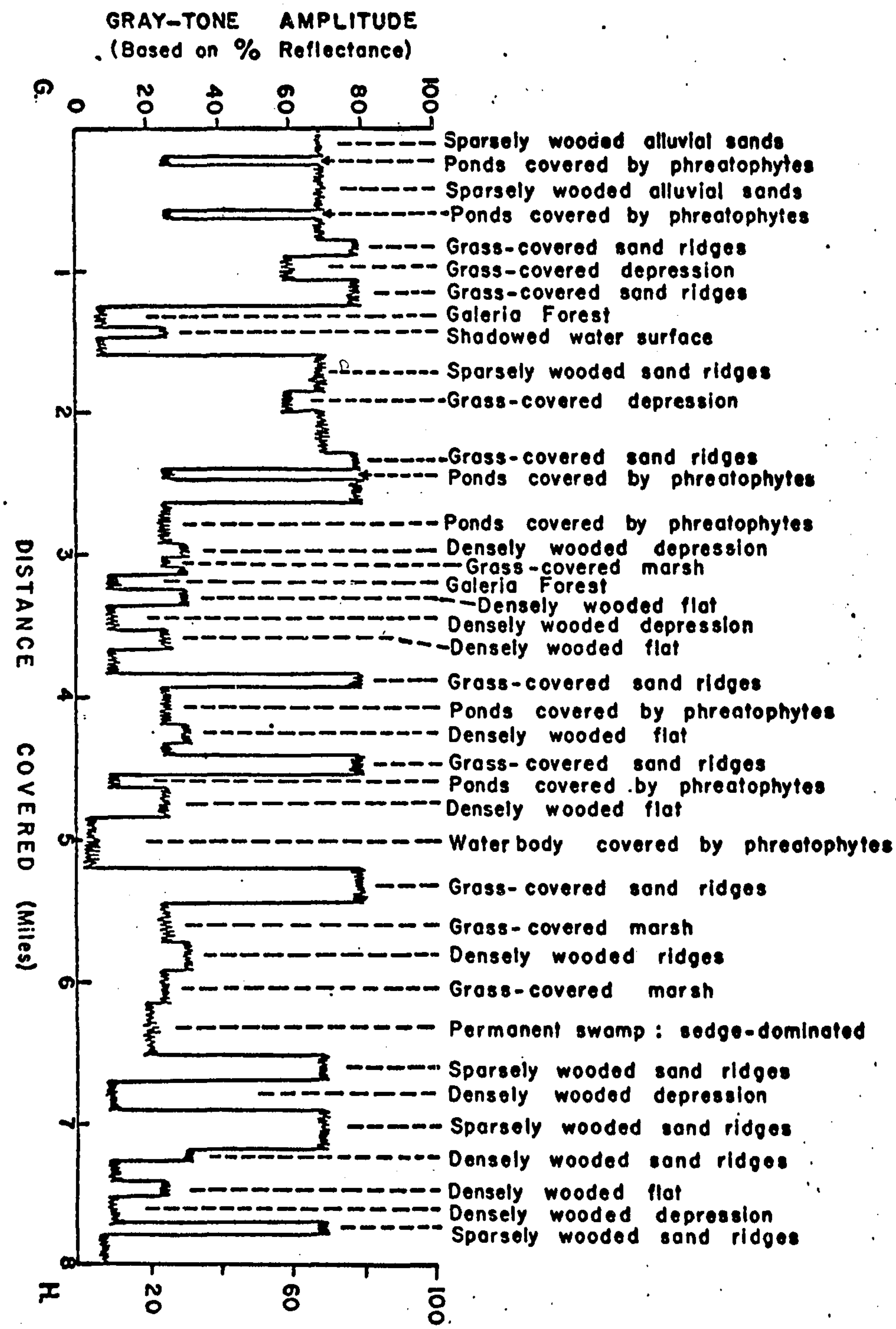
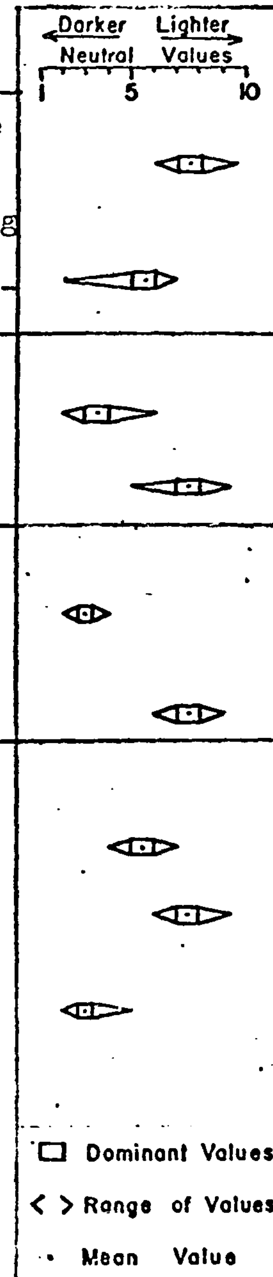


FIG. 23 Graphical Comparison of Gray-Tone Values of Terrain Types of the Southwest Margin of Marakanata Lowlands along Line GH. on Plate 16.

Windapo, 1968.

TABLE XIII: AIR-PHOTO CHARACTERISTICS OF THE MARAKANAM LOWLANDS

Plates & Zones	Landform Units	Approx. & coverage	Drainage	Vegetation	Soils
Plate 14 Zone 2	The Northern Margin	30	Internal drainage varies from well drained on the sand ridges to poor in the depressions surface drainage is characterized by deranged channel patterns	Campo sujo on the ridges depleting to campo limpo in the bottomlands	Generally loose structureless sands on the ridges grading to sandy loam in the bottomlands
Plate 15 Zone 2	The Central Lowland	40	Generally poorly drained with tidal drainage channels with deranged to anastomatic patterns	Campo limpo - sedge dominated except on the channel-fills with bunch grasses.	Clayey loam to silty loam except within the channel-fills with sandy soils.
Plate 15 Zone 4	The Laterite Outliers	5	Generally well drained	Forest islands surrounded by campo sujo savanna.	Laterite gravels and lateritic red and brown loams.
Plate 16 Zone 2	The Southwest Margin	25	Well drained sand ridges and poorly drained bottomlands with deranged surface channel patterns.	Campo coberto on the flats depleting to campo sujo on the sand hills and campo limpo sedge dominated in the swamps.	Generally sandy loam grading to sandy clay in the depressions.



The greater part of the zone marked (b) with a tonal range between N5 and N6 are the depressions and flats which maintain a wooded savanna of campo coberto type. The fairly dark tone of the areas result from the high moisture content of the depressions and the light absorption potentials of the tree covers. Those areas marked (c) with a lighter tone ranging between N7 and N8 are fairly wooded sand ridge tops while the very light toned areas marked (d) with a tonal value ranging between N8 and N9.5 mark open or bare sand ridge tops with a high surface reflectance ranging between 60 per cent and 90 per cent. The various tonal values have combined to give the unit a highly mottled texture within which tonal boundaries could be appreciated from a wave-form graph of tonal fluctuations along a sample transect GH on Plate 16 shown in Fig. 23. The general tonal range characteristics are presented in neutral range diagrams in Table XIII, which gives the overall air-photo characteristics of the Marakanata Lowlands system.

CHAPTER V

THE LATERITE UPLANDS

General Consideration.

This belt is the most extensive but least complicated landform pattern in the whole of the study area. Fig. 24 is a block diagram showing the geology and generalized morphology of the belt in relation to its adjacent areas. The pattern extends in a northeast to southwest alignment between the Marakanata Lowlands in the north and the Kanuku scarps in the south. It is bounded in the east by the Rupununi River, in the west by the Takutu River, and in the southwest by the Sapaika River.

The dissection of this upland belt by the Nappi and the Little Nappi rivers has created two major blocks separated by a zone of fragmented laterite hills here referred to as the Central Upland Block. The two major blocks thus created east and west of this central block are henceforth referred to as the Eastern and Western Upland blocks respectively (Fig. 25).

The main landform units found within the three blocks include laterite gravel ridges, flat wide-bottomed valleys, swamps, alluvial flats, circular depressions, elliptical depressions and blind linear depressions. Minor features include termiteria and terrawards or earth mounds (Table VIII).

From the profile study of the three upland blocks, it is evident that the landscape exhibits varying

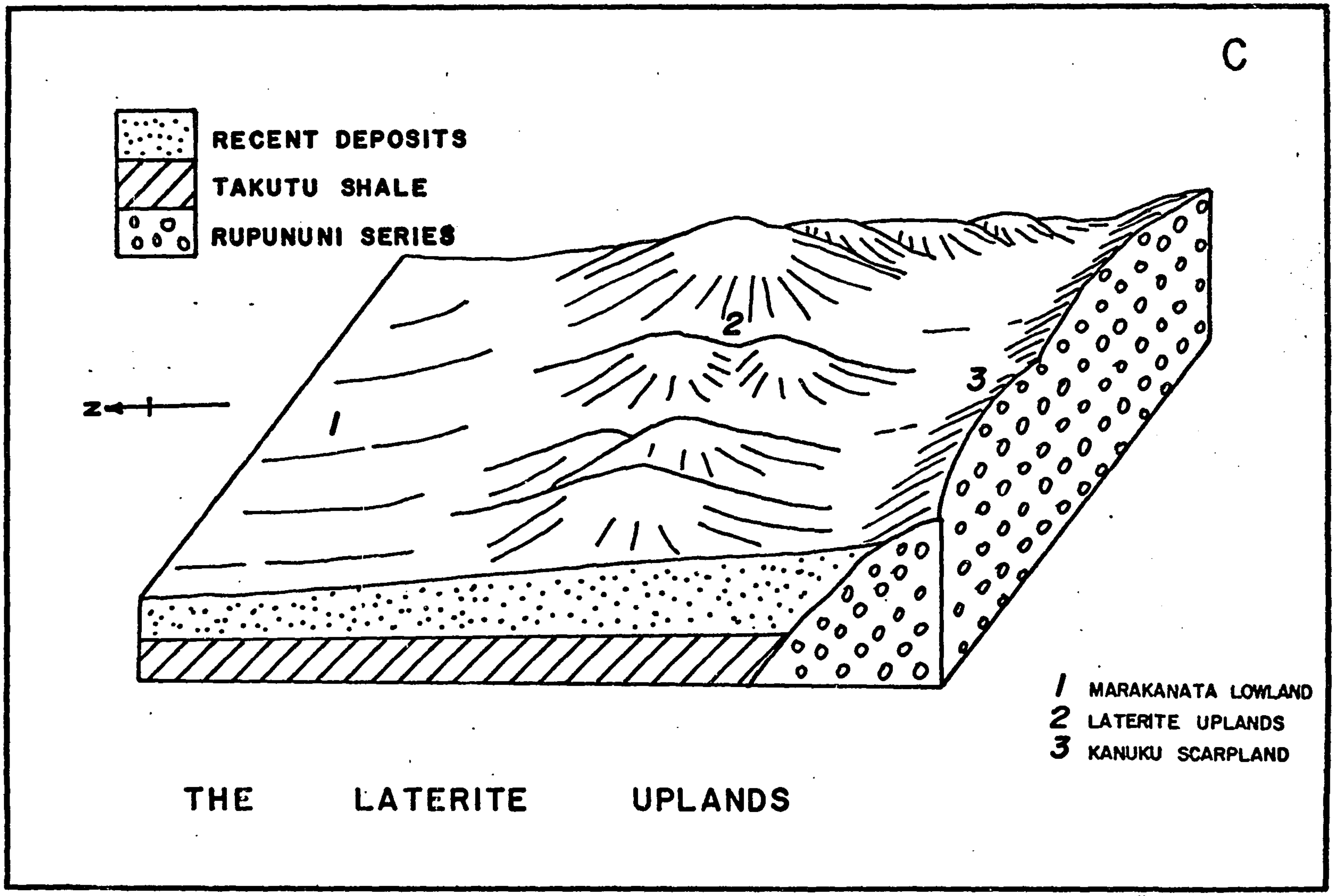
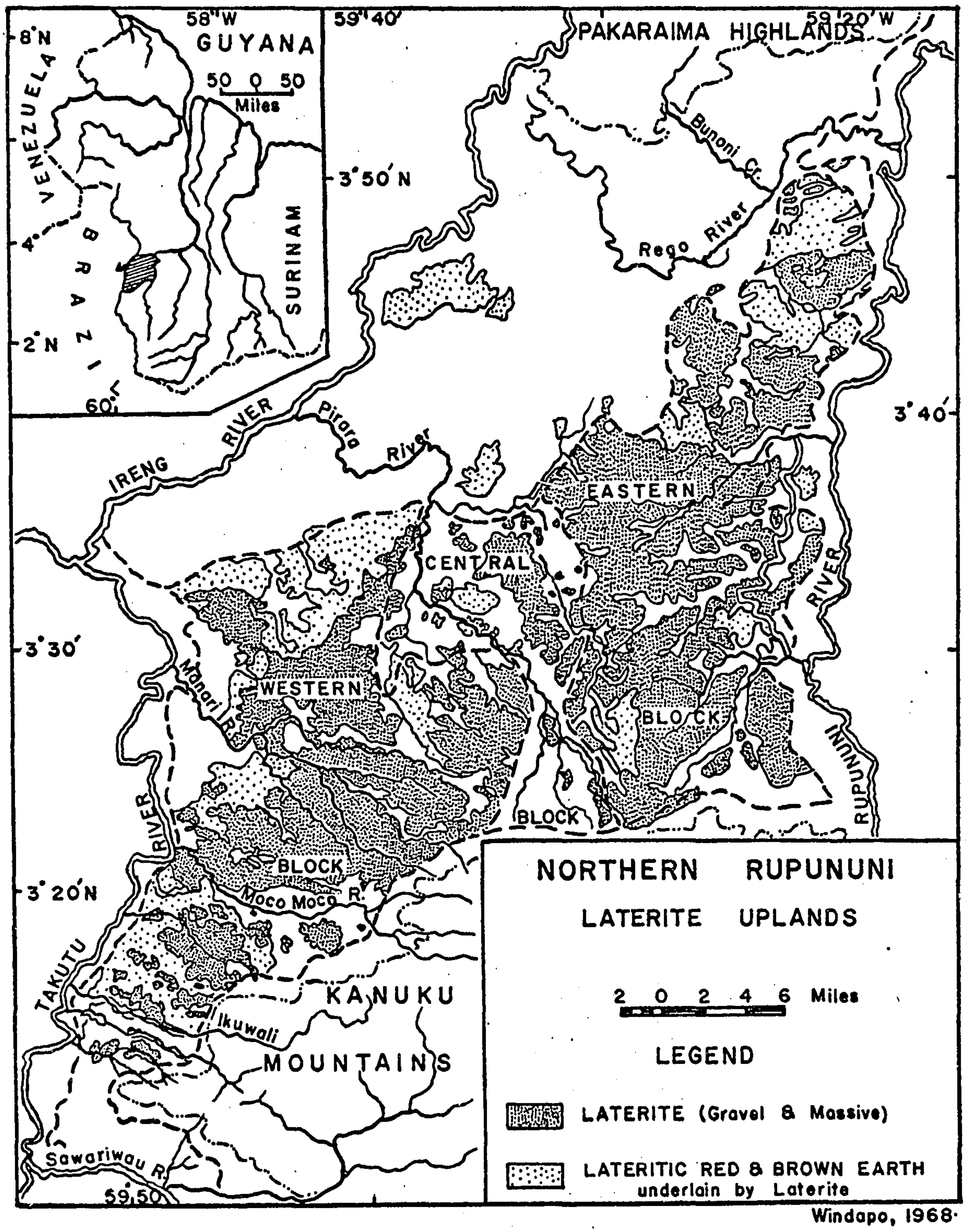


FIG. 24

Windapo, 1968.

FIG. 25



Windapo, 1968·

stages of dissection and reduction and that the landscape is still in the process of developing. Table XIV, based on slope analysis, shows four types of laterite ridge, each representing a different phase in the reduction of the landscape (Fig. 26).

The first group of ridges with a height of between 60 feet and 120 feet, and a general slope of between 15^{0} and 24^{0}, represent the highest ridges within the landscape. The proportion of straight slope segments to convex slope segments here is generally above 70 per cent. These ridges are broad, plateau-like on the summit and are deeply weathered with only fine gravels and coarse sands dominating the summit area. Around Yupukari, Nappi and Quatata, there is a local modification of these general characteristics inasmuch as the hills are covered with white quartz cobbles of the Roraima Formation (Plate 17). These hills are all characterized by convex upper slopes - a product of slope wash, and straight lower slopes - a product of spring line erosion. Close to the sources of springs as at Quatata and adjacent to ponds or hollows, as at Yupukari, the lower slopes assume the characteristics of a scarp slope, with a small concave element. They mark the first stage in the dissection of the original general plateau-like laterite landscape.

The second group of ridges, generally smaller flat-topped ridges, mark a further development in the breaching of the original plateau-like ridges. They are separated by wide flat-bottomed valleys. Such hills are found between Nappi and Yupukari with heights ranging between 40 and 60 feet above

TABLE XIV

RIDGE TYPES SHOWING STAGES OF REDUCTION IN THE LATERITE TERRAIN

Ridge Types	Maximum Slope	Relative Relief in feet	Planar Segment expressed as % of Slope Profile	Sample Location
1. Flat-topped Plateau-like high ridges	$18\text{-}24^{0}$	60-100'	70% and above	Nappi Quatata Yupukari
2. Smaller flat-topped high ridges	$14\text{-}18^{0}$	40-60'	50% and less	Nappi Settlement 2 miles northeast of Nappi Mt.View
3. Medium laterite domes	$9\text{-}14^{0}$	25-40'	30% and less	Parika Hiawa Manari MocoMoco
4. Low laterite domes	$5\text{-}9^{0}$	10-25'	20% and less	MocoMoco North of Manari Bridge Kumu St.Ignatius South of Nappi School

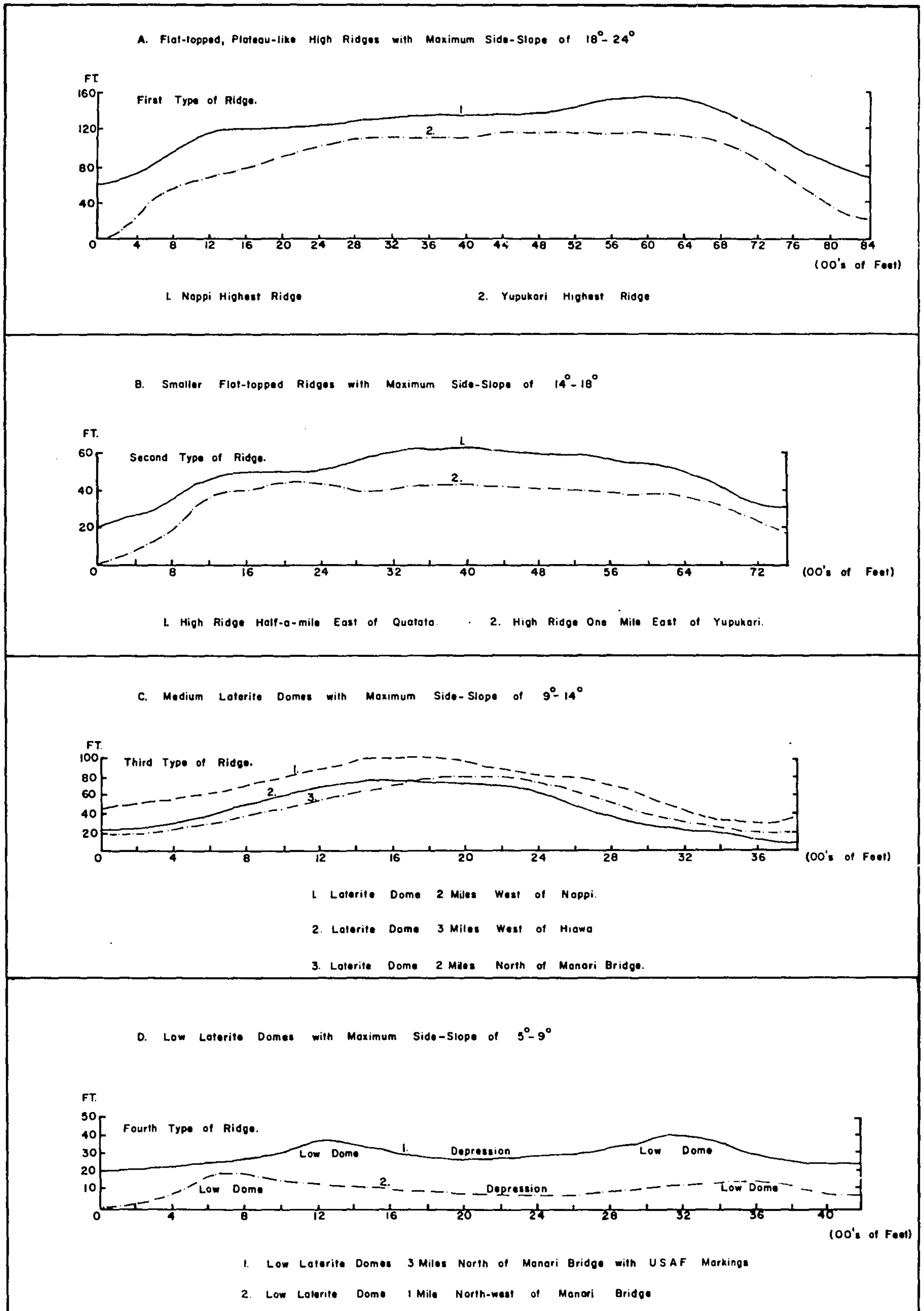


FIG. 26. Stages In The Reduction Of Laterite Ridges

Plate 17: Roraima cobbles on Yupukari high hill. (Photo by Windapo).

Plate 17: Roraima cobbles on Yupukari high hill. (Photo by Windapo).

the flat-bottomed valleys. As a result of a general surface reduction which accompanied dissection, there is corresponding decrease in their slope angles which vary between 14^{o} and 18^{o}. The proportion of straight slope to convex slope has, within these ridges, been reduced to less than 50 per cent. The concavity of the lower slopes is however greater than in the first group of ridges.

Further retreat of slopes together with further reduction in height result in the disappearance of the flat top. The slopes become generally convex and the ridges stand out as domes of medium height with slopes ranging between 9^{o} and 14^{o} as shown in Fig. 26. The proportion of straight slope to convex slope is generally less than 30 per cent, and the lower concave element assumes a greater proportion than in the preceeding stages.

As erosion progresses the laterite domes of medium height are further reduced to low domes with maximum slopes between 5^{o} and 9^{o}. The proportion of straight slope to convex slope is here reduced to less than 20 per cent. On approaching the flats the slopes change from convex to concave with negligible straight slope segment. The concavity extends for some distance beyond the foot of the hills, below the alluvial fills of adjoining flat-bottomed valleys. Examples of such hills are found near Manari Bridge, Nappi School, and Squeak's flat in the MocoMoco colluvial belt.

Within the laterite upland blocks, the flat-bottomed valleys form the major breaks in the landscape. In most places, they are flanked by steep laterite slopes and are filled by alluvial and colluvial sandy loam grading to silty loam in the lowest parts. Examples of such valleys are found around such rivers as the Nappi, Manari, MocoMoco, Parika, Hiawa, Kumu and Inaja. The origin of these valleys could be attributed to headward erosion resulting from spring sapping helped by slope wash. Consequent widening results in coalescing of many such valleys to form the wide flat-bottomed valleys bordering many of the creeks of this terrain type.

Besides the broad valleys, gently sloping linear depressions also characterize the laterite landscape (Plate 18). These linear depressions are usually formed along seepage lines where solution by sub-surface water has undermined and caused the foundering of the seepage lines. They are usually streamless and of varying lengths depending on the height and slope characteristics of the hills in which they occur. The general pattern is such that they appear as tributaries to the main valleys as at Komako north-east of MocoMoco.

Also found within the laterite landscape are circular and elliptical depressions. These are more conspicuous but less numerous than the linear depressions, and are found especially within the eastern upland block (Plate 19). These depressions must have been caused in the same way as the blind linear depressions - as the result of chemical processes associated with ground water movement.

Apart from the many features found within the upland blocks, four special sub-units found within the

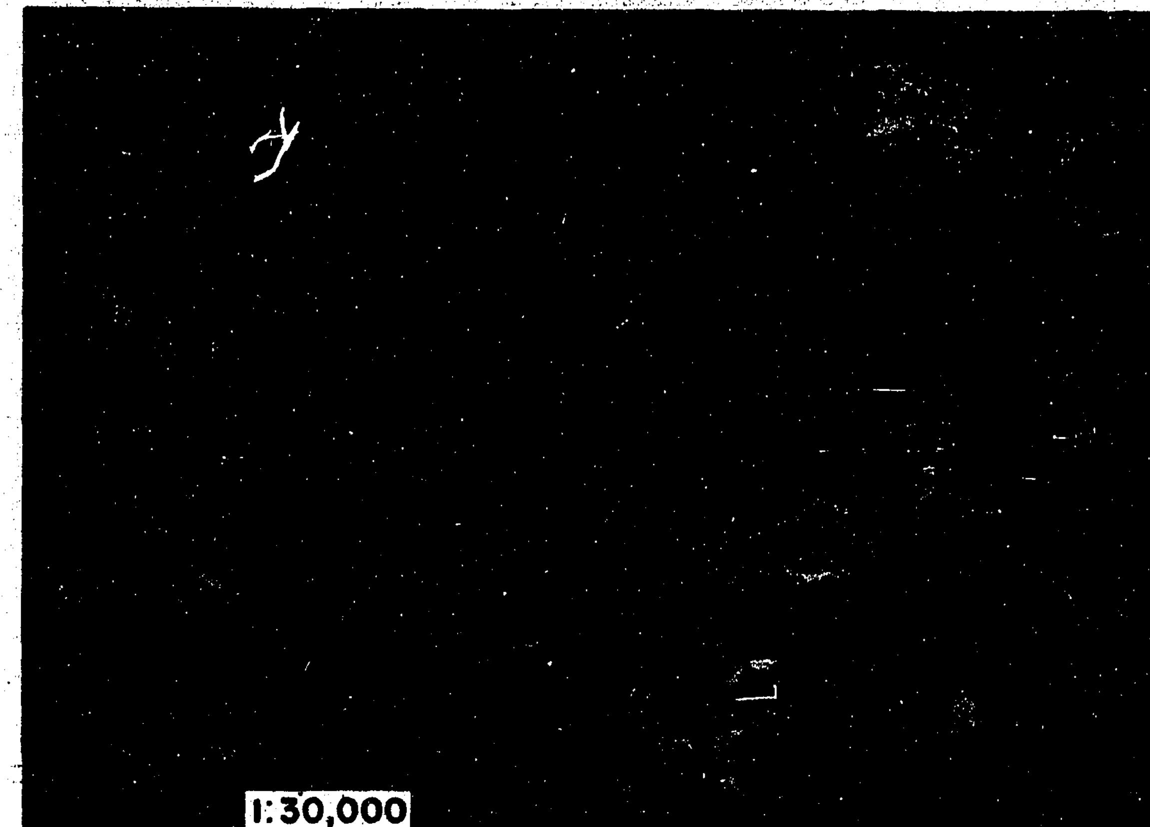


PLATE 18 : A maturely dissected laterite terrain east of Marakanata. A-Valleys of spring sapping origin. B-Blind linear depressions. Note the vegetation on the lower slopes of laterite ridges due to seepage moisture. (Photo by Hunting Aerosurveys Ltd.)
(Adapted from Sinha, 1967).

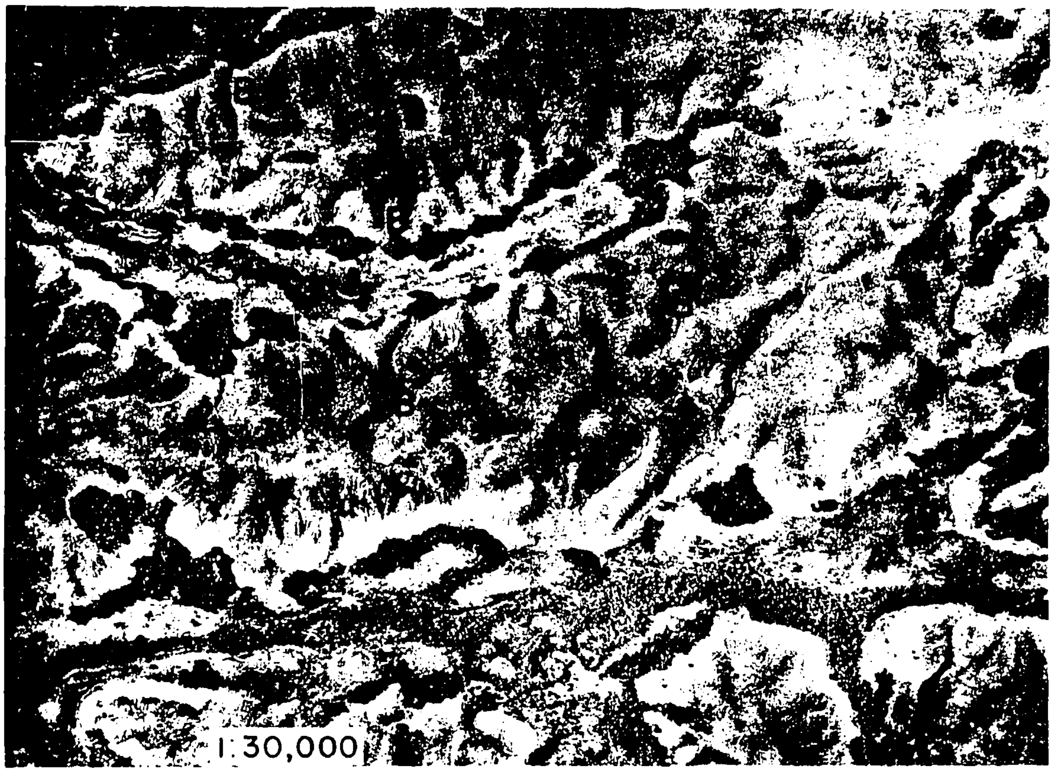


PLATE 18 : A maturely dissected laterite terrain east of Marakanata. A-Valleys of spring sapping origin. B-Blind linear depressions. Note the vegetation on the lower slopes of laterite ridges due to seepage moisture. (Photo by Hunting Aerosurveys Ltd.)

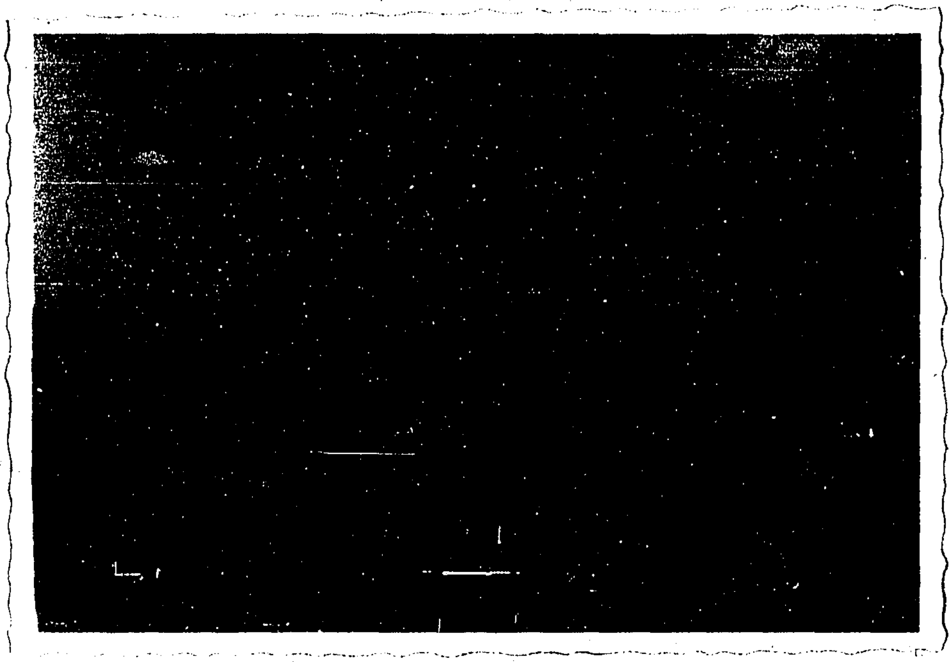


Plate 19: Circular depression near Karanambo (Photo by Windapo).

Plate 20: Forest island on laterite surface. (Photo by Windapo).

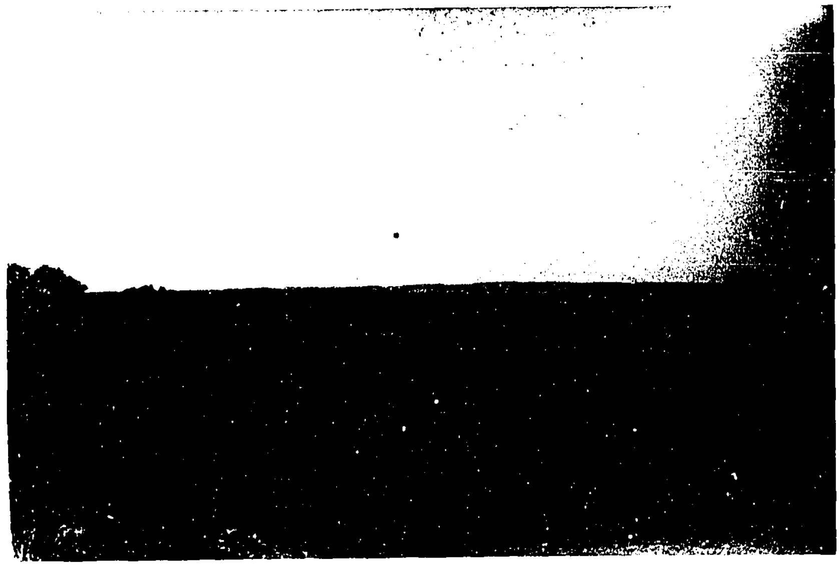


Plate 19: Circular depression near Karanambo (Photo by Windapo).

Plate 20: Forest island on laterite surface. (Photo by Windapo).

central and western upland blocks may be mentioned at this stage. One of these - the Nappi Lowlands - is associated with the central upland block, while the three others - the Manari Terrace Belt, the MocoMoco Colluvial Flat and the Ikuwali-Sapaika Lowlands - belong to the western upland block.

Generally, there is a close relationship of soils and landform patterns. The variations in the soil texture are a result of progressive communition of grains from upland to bottom flats and depressions. On the upland hills, the soil texture is generally gravelly. The highest hills of the zone are strewn with fine gravels and coarse sands, while the medium elevation hills are dominated by coarse gravels and cobbles; and there are exposures of massive laterite. The low hills, on the other hand, are covered by fine gravels in the Nappi area, and by coarse gravels in the MocoMoco area. At the foot of the hills is a zone of sheetwash which is composed of fine gravels and coarse sands. This zone grades into fine sands and silts in the adjacent bottomlands, and clays in the waterlogged depressions. Fig. 27 gives the grain-size distribution curves of some soil samples taken from a hill top, a sheetwash zone, and an adjacent colluvial flat in MocoMoco area, while Table XV shows the sieve analysis and pH contents.

The soil types are derived from the breakdown of the primary laterites of the belt. Both pisolitic and vesicular primary laterites are present (Fig. 28). The former is formed within coarse sandy materials and is

TABLE XV

Sieve Analysis of Three Soil Samples in MocoMoco Area.

1. MocoMoco Hill Summit

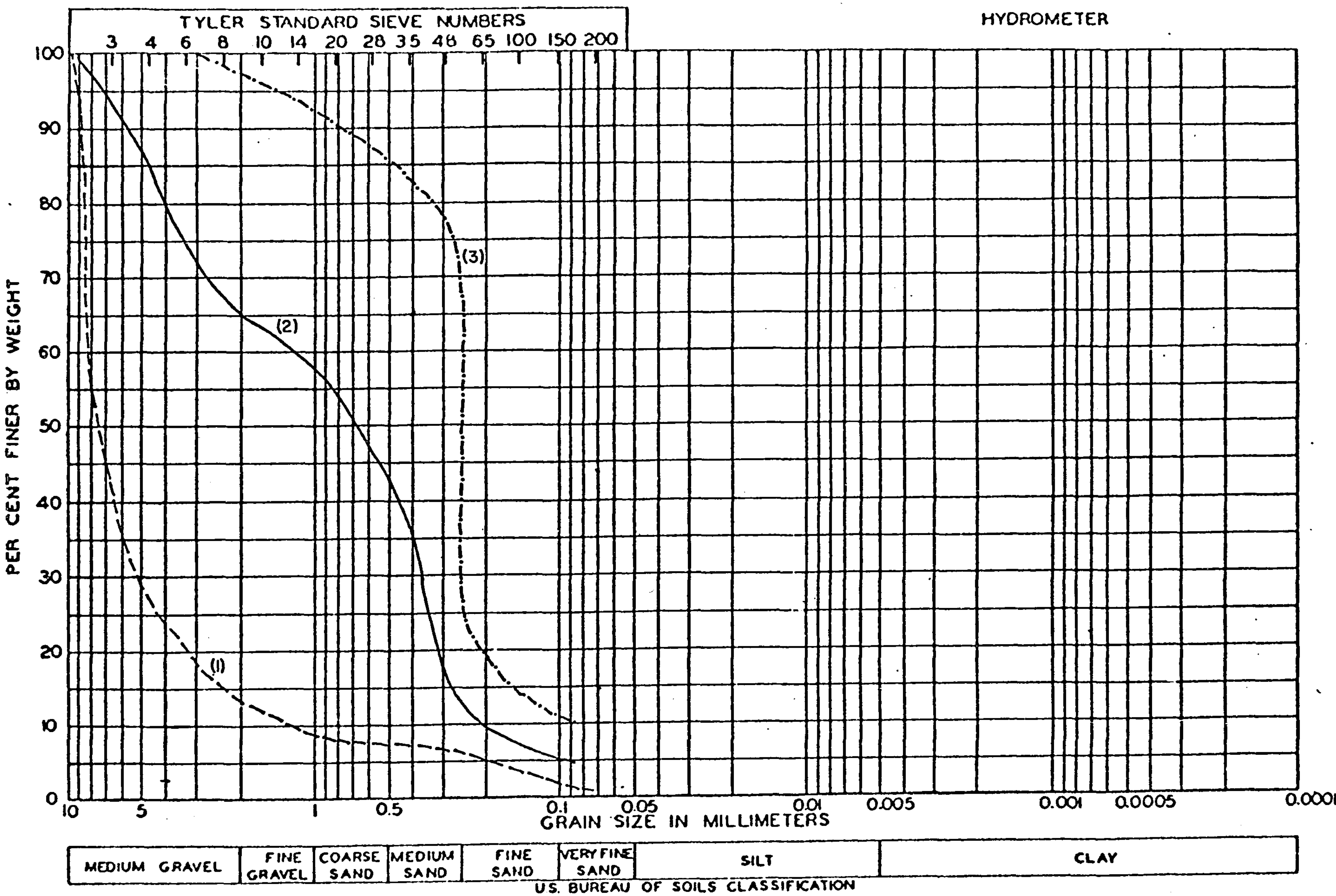
Sieve No.	% of sample above sieve	pH	Colour
5	71	5.6	2.5Y
3	11		5/2
2	4		Grayish
1	5		brown
.5	1		
.25	1		
.125	4		
.088	1		

2. MocoMoco Eastern Lateritic Sheetwash Zone

Sieve No.	% of sample above sieve	pH	Colour
5	12	5.8	10YR
3	16		5/2
2	7		Grayish
1	7		
.5	15		
.25	31		
.125	5		
.088	3		

3. MocoMoco North Flat adjacent to the Hill

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.8	2.5Y
3	-		5/2
2	2		Grayish
1	5		brown
.5	7		
.25	63		
.125	11		
.088	2		



(1): Moco Moco-Hill Summit (2): Moco Moco - Eastern Lateritic Outwash (3): Moco Moco-North Flat

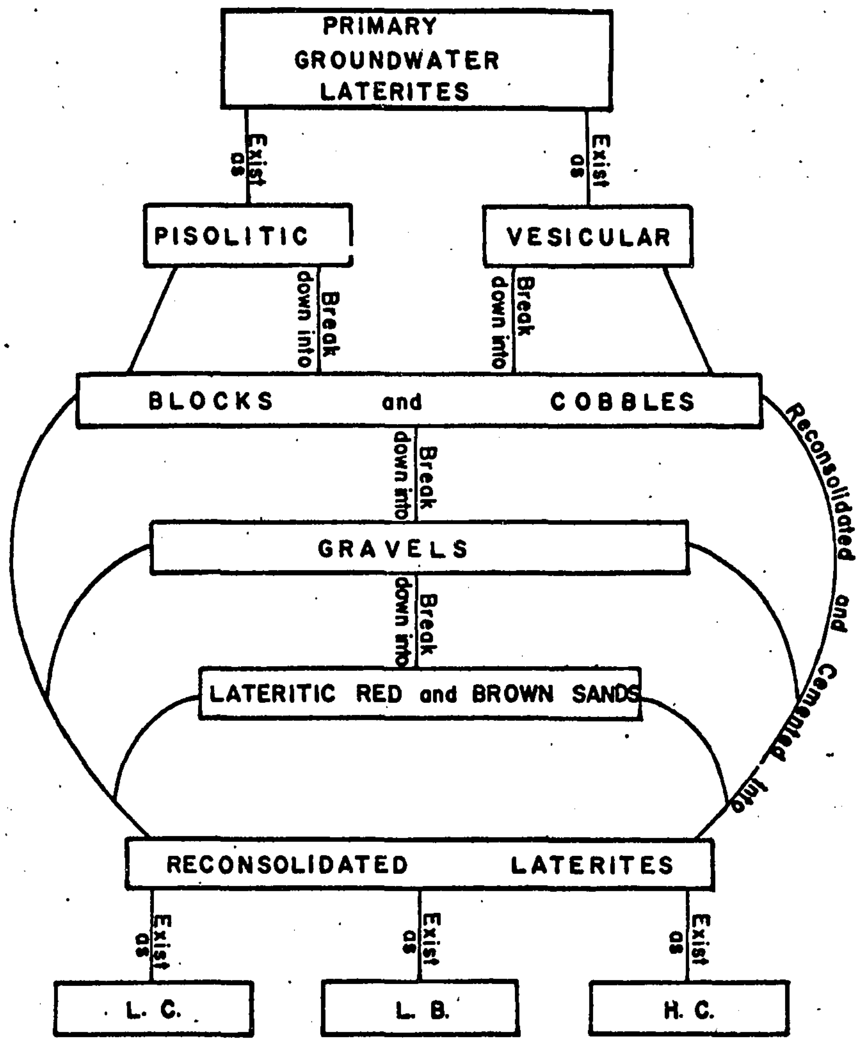
FIG. 27. GRAIN SIZE DISTRIBUTION DIAGRAM: Moco Moco

consequently coarse in texture. When it breaks down, it disintegrates into separate nodules, usually of the size of a pea - a feature which has earned it the name - 'pisolitic laterite'.

The vesicular primary laterite, on the other hand, is formed within fine textured materials like silt and clay. It is common for cracks to develop within such fine-textured materials as a result of dessication. Cracks and large capillaries are responsible for the concentration of precipitates mostly iron oxides and silicates as the result of evaporation. The precipitates often have a vein-like form corresponding to the capillary or dessication crack, and it is this feature which has led to the name - 'vesicular laterite'.

Both types may be exposed in horizontal beds or vertical columns, depending on the topographic position of the surface of exposure. When exposure takes place on flats, the massive laterite is met in extensive horizontal beds of various dimensions. But when exposure takes place along the walls of gullies, for example, the exposed laterite is restricted in surface extent and appears as vertical columns down the walls of the gullies.

Both primary laterite types break down into blocks, cobbles, ironstone gravels, and red and brown sands. Reconsolidation and cementation of these laterites have been observed in many parts of the landscape, especially within the central and western upland blocks as at Hiawa, Manari Bridge, MocoMoco, Lethem and Mt. View. Three types of



L.C. – LATERITE CONGLOMERATES L.B.– LATERITE BRECCIA

H.C.– HOMOGENEOUS CONCRETIONARY MASS.

FIG. 28· FORMS OF LATERITE

Windapo, 1968.

reconsolidated laterites have been identified.

(i) Laterite Conglomerate:-

This contains rounded water-borne cobbles and pebbles of quartz and flint in a matrix of cemented laterite gravels. This type is found in the valley of the MocoMoco River, along the banks of the Takutu River near Lethem, along the cutting on the side of a low hill about a mile to the south of Lethem on the St. Ignatius-Lethem road, and along the banks of the Tabatinga creek in Lethem.

(ii) Laterite Breccia:-

This contains more angular fragments of quartz and flint than in the conglomerates. It is found along the covelinear slopes at the junction of the Parika and Manari creeks, and along the gully bottoms at Hiawa and Komako. Reconsolidated blocks of this type are also found along the MocoMoco valley near St. Ignatius, along the Tabatinga creek near Hawkin's Mission in Lethem, and in the gullies along the lacerated hills about a mile north of Mt. View.

(iii) Homogeneous Concretionary Laterite:-

This contains ironstone cobbles and gravels of various shapes and sizes, but is completely devoid of foreign non-lateritic bodies. They are found mainly adjacent to valley flats in the zones of accumulation of slope wash, and along foot slopes adjacent to creeks or seasonally inundated wide flat-bottomed valleys. Such concretionary masses are found abundantly in the central block and around Nappi and Parishara along foot slopes and gullies. They are also found in St. Ignatius and Kumu-Inaja area as isolated blocks adjacent to alluvial flats.

The Eastern Upland Block.

This block is bounded on the north by the Marakanata depression, on the south by the Kanuku scarps, on the east by the Rupununi River, and on the west by the Nappi Lowlands (Fig. 25). It is fairly maturely dissected, producing laterite hills and ridges in various stages of degradation. It is here that the highest laterite ridges of the Savanna lands are found. Around Quatata and Yupukari, they attain heights of about 500 feet above sea level or 150 feet above the Rupununi flood-plains (Sinha, 1967).

The northern prong of this upland block is severely dissected by springs and ravines advancing headwards from the Rupununi River in the east and the Marakanata Lowlands in the west, creating steep-sided laterite ridges with slopes of up to 20°. Between Yupukari and Quatata, such ridges attain considerable elevation, but northwards they are at lower altitudes with gentler slopes - about 5-10°, while near Karanambo they appear as low platforms finally merging with the terrace sands near Kwaimatta.

The landform units of this upland block comprise gravel surfaces, blocky laterite surfaces, massive laterite surfaces and local bottomlands (Table VIII). Most ubiquitous of all the units are the gravel surfaces. Laterite gravels are found most frequently but mixtures of laterite, quartzose and flint gravels also occur. They are found on summit flats, hill slopes and bottom flats where the sheetwash products debouch on the lowlands adjacent to the ridges.

Less ubiquitous but more conspicuous are the circular, elliptical and linear depressions which are more common within this eastern block than in any other block of the laterite uplands. These features are particularly prominent between Yupukari and Karanambo.

The blocky laterite surfaces are of two types - surfaces of primary laterite and surfaces of reconsolidated laterite. The primary laterite blocks are derived from the breakdown of primary laterite crusts by weathering. Some blocks embedded within the finer materials of the flats could possibly have rolled down the slopes under gravity to their places of rest but the most likely process is surface creep. Others are found along the slopes perhaps trapped on their downward journey by some obstructions along the slopes or through loss of gradient. They are also found on summit flats, especially on hills of medium height east of Karanambo. In this topographic position, they probably result from the 'in situ' breakdown of the last exposed laterite horizon.

The reconsolidated types are found mainly on the foot slopes of the laterite ridges and along gully sides. They are also noticeable along the edges of depressions and swamps. They exist in the form of laterite conglomerate and laterite breccia as the result of laterite cementation of quartzose and flint cobbles and gravels. They are conspicuously absent from the flats presumably because of the excess moisture which prevents reconsolidation and cementation. On the other hand, cementation is also prevented where there is insufficient moisture, and the laterite bodies break down progressively into cobbles, coarse gravels, fine gravels and sands, hence the absence of blocky laterite on summit flats.

Apart from the blocky laterite surfaces, massive laterite surfaces also form an important landform unit within the eastern uplands. They are found mainly on summit and valley flats. On summit flats, they exist in many places under dense stands of forests which are locally referred to as 'forest islands' within an open savanna landscape. These laterite surfaces are particularly significant on the hills of medium elevation fringing the Marakanata depression and near Marakanata settlement itself. They give rise to many forest islands which are observable on air-photographs and which are easily located in the field (Plates 20 & 21).

These summit surfaces of massive laterite are probably remnants of once extensive caps that maintained forest vegetation. With changes in moisture condition following rejuvenation and incision of streams, the laterite caps began

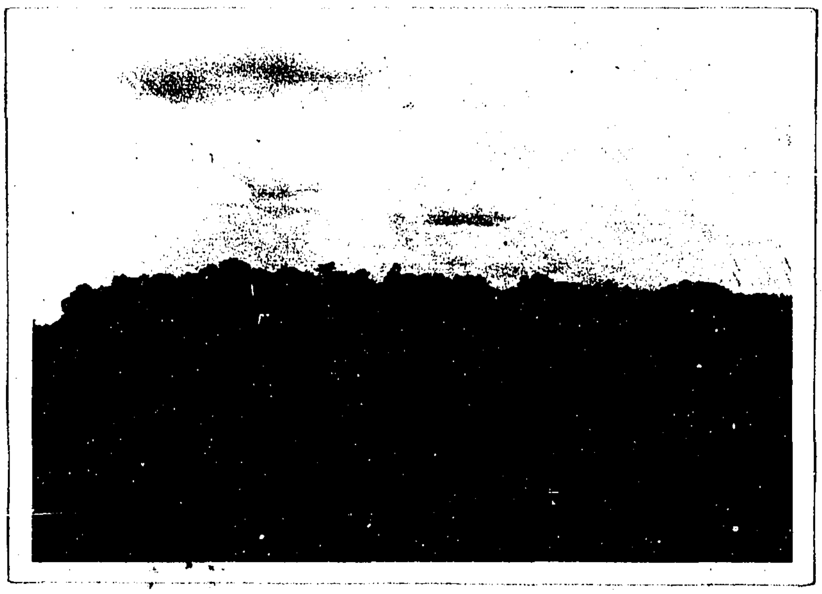


Plate 21: Forest island east of Yupukari.
(Photo by Windapo).

Plate 21: Forest island east of Yupukari.
(Photo by Windapo).

to break down. As they disintegrated, they became less effective in preventing the percolation of surface water and the forests on them started to retreat from the edges. Evidence of this breakdown and consequent depletion of forests can be found around the existing remnants today.

On the valley flats, the exposed massive laterites differ strikingly from those of the summit flats. They do not support forest and are more compact and stronger. Their surfaces are often washed clean of overlying materials and consequently, no surface retention of water except in local depressions where shallow veneers of soil accumulate. When partially covered by colluvial or alluvial materials, they carry clump grasses with wide open spaces between the stands.

Breaking the monotony of the laterite surfaces are the local bottomlands. These are found in the form of colluvial flats, alluvial flats, marsh flats and swamps. Within the highly dissected ridges between Quatata and Yupukari colluvial flats of varying dimensions are very common. These flats receive the fines brought down by slope wash and rill erosion from the numerous gullies of the area. Around Yupukari, such gullies are exceedingly long, usually more than 600 feet in length. The materials deposited on the flats are often reworked and sorted by flood water which covers the flats in the wet season. This results in the sorting of the materials with the fine materials being carried away from the foot slopes towards the centre. Some of these flats are dotted with grey-coloured dwarf termiteria which contrast markedly with the brown giant termiteria found on the slopes of the medium sized hills and on the summits of the low hills of the upland block.

Around many of the creeks and streams like the Quatata are found fairly wide belts of alluvial flats ome of which support dense stands of galeria forests very close to the stream channels. Some of these streams are seasonally flooded, and in fairly depressed areas which have become the zones of deposition for very fine materials, a silty to clayey horizon soon developes and a marsh zone grown with sedges is created. Some of the depressions which receive materials from the surrounding hills may have been partially infilled, creating marsh flats as at Karanambo. Such flats remain waterlogged for most of the year only drying up towards the end of the dry season. Many of these flats are dotted in places by earth mounds referred to as terrawards.

Some depressions maintain a considerable amount of surface water throughout the year and may be regarded as permanent swamps. Other swamps are found along the wide creek valleys in the zone of high ridges. During the rains, these valleys are flooded, but at the height of the dry season, the sluggishly moving water bodies break up creating pockets of swamps along the valleys. Such swamps are particularly noteworthy around Yupukari.

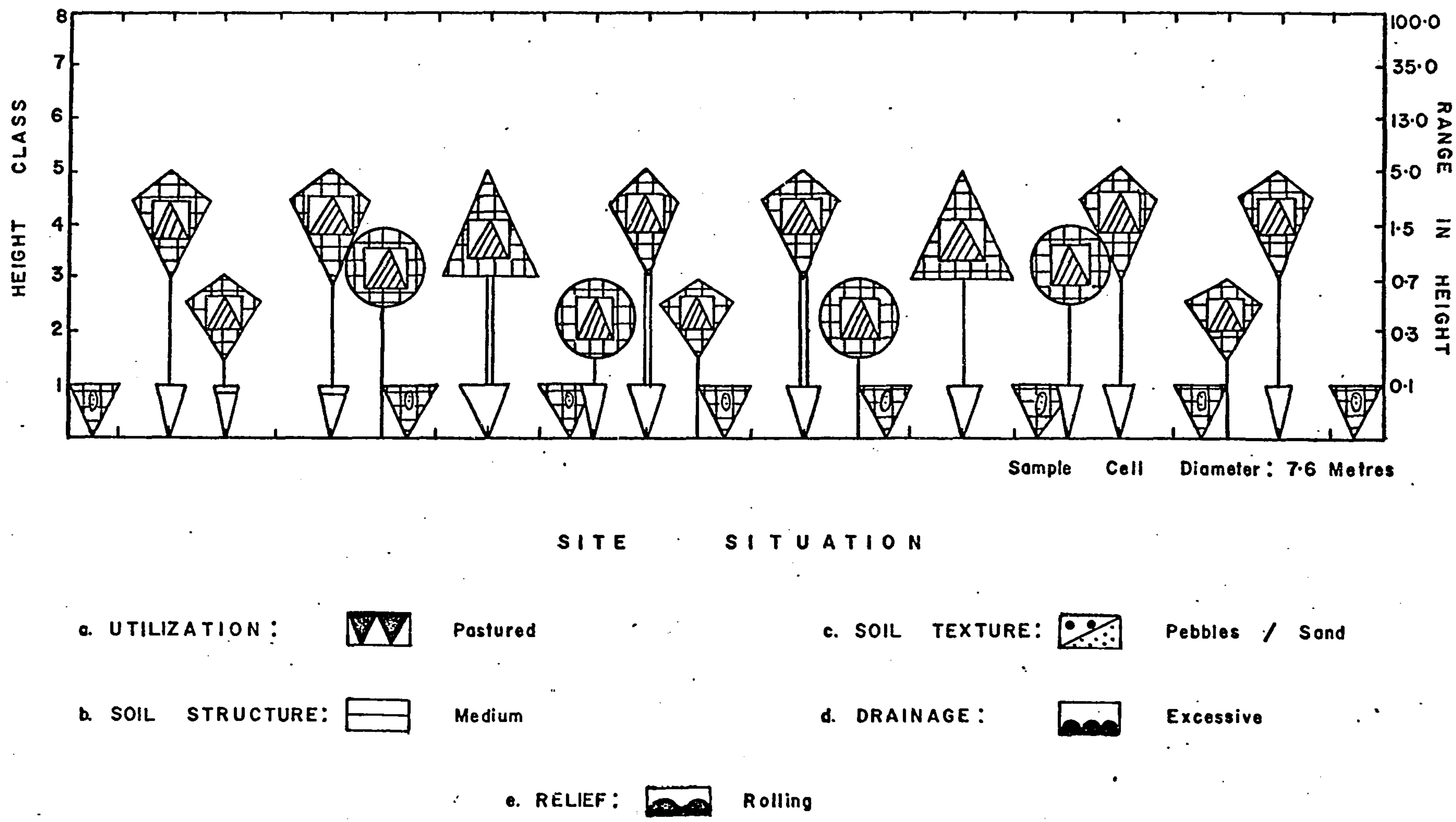
As already mentioned, all the soils of the upland blocks are closely related. The only differences are in texture and these variations result from differences in topographic position. Thus on the high hills of the eastern upland block, the top soils contain fine gravels and coarse sands on the summits, and fine to coarse gravels on the slopes. On the medium hills, the top soil is predominantly gravelly both on the summit and on the slopes, with large exposures of massive laterite; while the low hills are strewn with fine gravels and coarse sands from the summit to the sheetwash slopes, with occasional intrusions of blocky laterites. All over the eastern upland block, the soil texture on the flats varies from sandy loam at the foot of the hills to silt and clay in the depressions. Both the colluvial and alluvial flats are largely sandy loam belts while the marsh flats are predominantly silty and the swamps contain pockets of humic clay.

The vegetation of the eastern upland, however, varies considerably from that of the other sub-patterns. The high hills are covered by densely wooded savanna - campo cerrado - with a great variety of different forest species. Most of the trees are of medium height - about three metres (Fig. 29). Around Yupukari, the curatella americana are virtually absent from the high hills, they are found mainly in the zones of sheetwash, and intervening valleys, colluvial flats, and alluvial flats. The vegetation on the flats is essentially a campo coberto type with the density of the woody species decreasing from the sheetwash belts towards the centres of the flats where the campo limpo with an herbaceous layer of clump grasses takes over.

The marsh flats, on the other hand, are mainly areas of campo limpo dominated by sedges and clump grasses. In some areas between Quatata and Yupukari, sedges dominate the

FIG. 29. VEGETATION STRUCTURAL DIAGRAM

Yupukari Hill Slope



Windapo, 1968.

herbaceous layer of the flats almost to the same extent as in the swamps. Some swamps are fringed by Ite palms (Mauritia Minor), some are pure sedge swamps as around Karanambo, while others are dominated by palms and could be adequately described as palm swamps.

The Central Upland Block.

The Central Upland block belongs to the higher sector of the laterite uplands. It presents an undulating topography attaining a height of about 410 feet near Mt. View in the southwest, and gradually losing height northwards until it finally merges with the Pirara flat at an approximate elevation of 340 feet. The block is elongated in a north-northwest to south-southeast direction as a result of dissection and trimming by the Nappi and Little Nappi streams. Spring sapping along both streams to east and west was responsible for the extreme dissection of the block by east-west valleys, creating laterite enclaves within the flood-plains of the two Nappis and producing an apparent lower relief within the whole block.

The landform units of this sub-pattern are the same as those of the eastern upland block with slight differences in the landform components (Table VIII). The hills for example, are generally smaller and lower in elevation than those of the eastern block. The relatively higher ones are covered in most parts by coarse gravels from the summit to the sheetwash zones, while the lower ones are dominated by fine gravels on the summit and upper convex sections with sandy loam materials on the straight and lower concave sections.

The most striking difference is provided by the character of the depressions within this block as compared with the eastern block. For instance, circular depressions do not occur, and elliptical ones are very few and restricted to the northeast of Mt. View. On the other hand, linear depressions are found in large numbers in the zone of higher hills and adjacent to the Little Nappi valley.

Blocky laterite surfaces are again met with in this block though less frequently than in the eastern block. The reconsolidated laterites are restricted to the foot slopes and gully sides while the primary laterites are found on the summit flats, slopes and valley flats adjacent to the hills. Massive laterite surfaces also occur, especially on the summits of the higher hills north of Mt. View, some of them carrying small belts of forest and appearing as forest islands. To the northwest of the laterite belts are some valley flats where small patches of massive laterites are exposed. These massive laterites are in all respects similar to those exposed on the flats within the eastern block. Their shining surfaces are virtually bare being surrounded by tall grasses dominated by <u>trachypogon</u>.

The bottomlands occupy the greater part of this central block. Apart from the creek valleys separating the small hills, the Nappi flood-plain accounts for more than 60 per cent of the total area of the block (Fig. 25), and for this reason it will be discussed separately.

<u>The Nappi Lowland</u>:

This is the flood-plain created by both the Nappi and the Little Nappi. It is the only major lowland within the laterite block and the largest flood-plain within the Laterite Uplands. In the middle part, the plain is about five miles in width. Upstream, it narrows to about two miles. Its elevation is generally above 300 feet except where the Nappi approaches the Pirara. In this zone, the plain is barely above 300 feet whereas on the eastern flank near Mt. View, the plain rises to a height above 400 feet as the Kanuku scarp is approached.

This lowland is the product of active erosion by the Nappi, Little Nappi and their tributaries while they were active tributaries of a larger Proto-Berbice River. Both rivers have now stopped active erosion and are steadily aggrading their channels losing their identity in the extensive swamp of the former flood plain.

The soil types of this lowland area vary from sandy loam close to the hills to silty loam, silt and clay in the lowest sections. Around the present stream courses, the soil is sandy but in the flooded depressions, the soil is generally silty with pockets of humic clay. Many of these flooded depressions persist as swamps throughout the year with marshy borderlands whose surface flatness is broken in places by terrawards.

Within the smaller belts of colluvial flats bordering the hills, the soil is generally sandy loam in texture. Some of the flats are dotted by ash-coloured dwarf termiteria which are usually hidden under tall lusty grasses unlike the conspicuous giant termiteria of the summits and slopes of the higher hills of the laterite block.

The general vegetation cover encountered in a traverse from the laterite hills to the Nappi Lowland presents an interesting contrast to that of the eastern upland block. Except where pockets of forest exist in the form of forest islands, the higher hills are areas of open savanna, campo coberto type, while the lower hills are of campo sujo variety. The distribution of the trees often coincides with stands of giant termiteria in some areas such as the northwestern prong. The lowland, on the other hand, is more densely wooded in the colluvial zones than the laterite hills. The well drained parts of the colluvial and alluvial flats have campo coberto while the marshy and swampy zones are areas of campo limpo dominated by sedges, and along the major arteries of the Nappi River are belts of galeria forests especially towards the upper reaches of the tributaries (Fig. 11).

The Western Upland Block.

This upland block is bounded on the east by the Nappi Lowland, on the west by the Takutu flood-plains, on the north by the Marakanata depression, and on the south by the Kanuku colluvium belt and the Sapaika-Sawariwau Lowland (Fig. 25). It consists of gently sloping platforms, depressions and ridges of varying elevations.

The laterite ridges diminish in height westwards. For example, the hills around Nappi settlement attain heights of about 30 feet to 60 feet above their adjacent bottomlands while those around Lethem in the west rise to an average of about 10 to 20 feet above the intervening flats (Plates 22 and 23).

Between St. Ignatius and the Sapaika River on the southwest, the laterite upland is represented by a series of interstream flats with massive laterite intrusions here and there. The Sapaika laterite ridges mark the southernmost extent of laterite within the study area. Immediately to the south of these ridges, a different landform pattern with distinctly different landform units takes over.

Like the two other laterite blocks, this western block is composed of such landform units as gravel surfaces, blocky laterite surfaces, massive laterite surfaces and local bottomlands;and its landform components are the same as in the eastern upland block (Table VIII).

The gravel surfaces are the most common landform units of the sub-pattern. Here too, they are composed of pure laterite gravels and gravels of quartz and flint, but the rounded and oval shaped Roraima cobbles are conspicuously absent even around the high hills near Nappi. These high hills are covered by fine gravels and sands on the summit and slopes with the proportion and size of gravels increasing on the mid slopes, and sands dominating the sheetwash areas. The domed

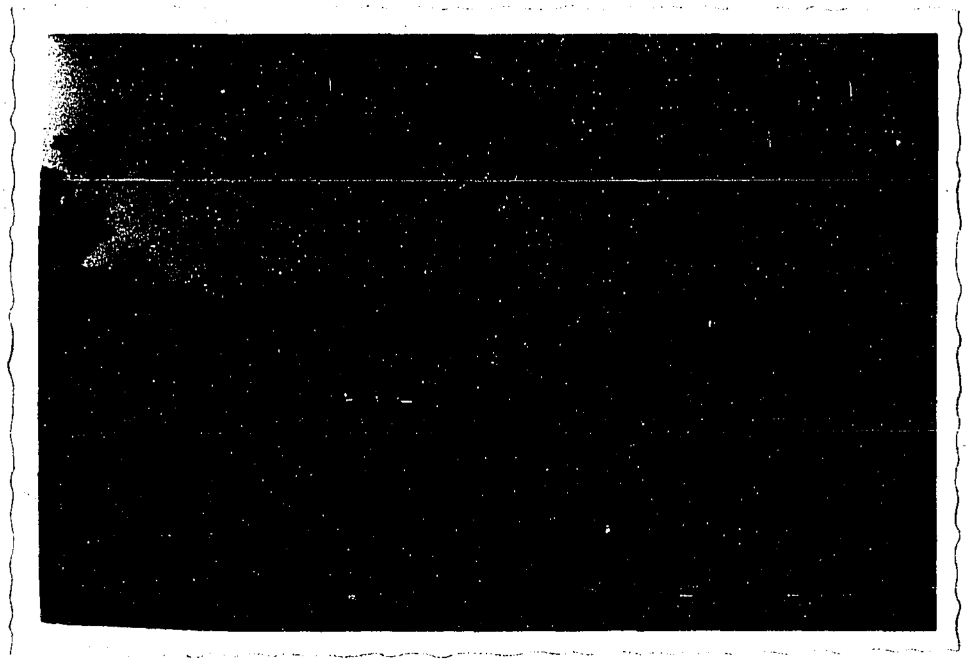


Plate 22: Nappi high hill showing fish-poison trees.
(Photo by Windapo).

Plate 23: Low hills in MocoMoco flat.
(Photo by Windapo).

Plate 22: Nappi high hill showing fish-poison trees. (Photo by Windapo).

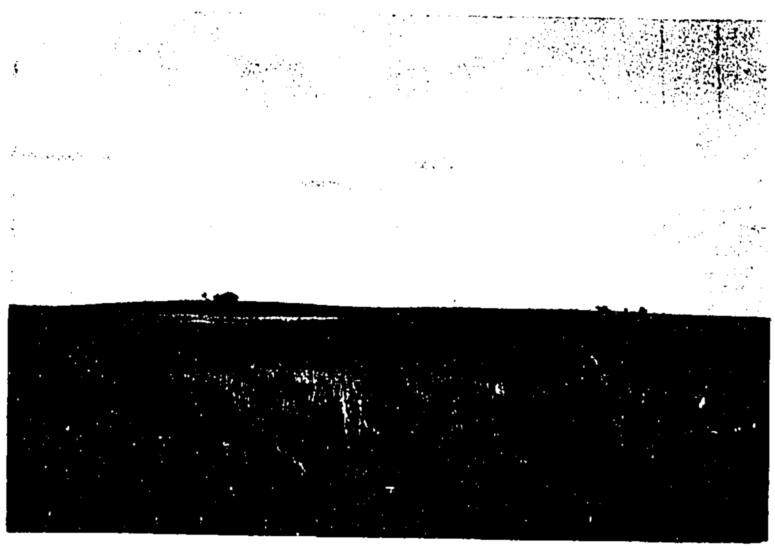


Plate 23: Low hills in MocoMoco flat. (Photo by Windapo).

medium hills around Hiawa, Parika, Manari and MocoMoco, on the other hand, are largely covered by coarse gravels and cobbles from the summit to the lower slopes, leaving a narrow segment of sheetwash composed of gravels and sands at the foot of the hills. The low hills are however, variously covered by coarse and fine gravels, depending on their locations within the sub-pattern. For instance, the low hills around Nappi, Hiawa, Parika and Manari are largely covered by fine gravels and sands, while some of these around MocoMoco and Kumu are covered by coarse gravels grading to fine gravels and sands at the sheetwash zone.

The gravel surfaces are broken by circular, elliptical and linear depressions, all of which are of smaller dimensions than those of the eastern block. Both the circular and elliptical depressions are restricted to the eastern part of the sub-pattern while the linear type is found all over the western block in the zones of high and medium hills adjacent to active creeks as at Komako weather recording site. One conspicuous circular depression is located between Hiawa and Nappi at a distance of about 120 yards from the Lethem-Nappi road (Plate 24).

The gravel surfaces are also interrupted along the lower slopes of the Nappi high hills and the summit and slopes of the medium hills of the sub-pattern by blocky laterite surfaces. These blocky laterite outcrops occur in rows at the foot of some hills especially between Hiawa and Manari bridge and near Johnson's ranch in MocoMoco area

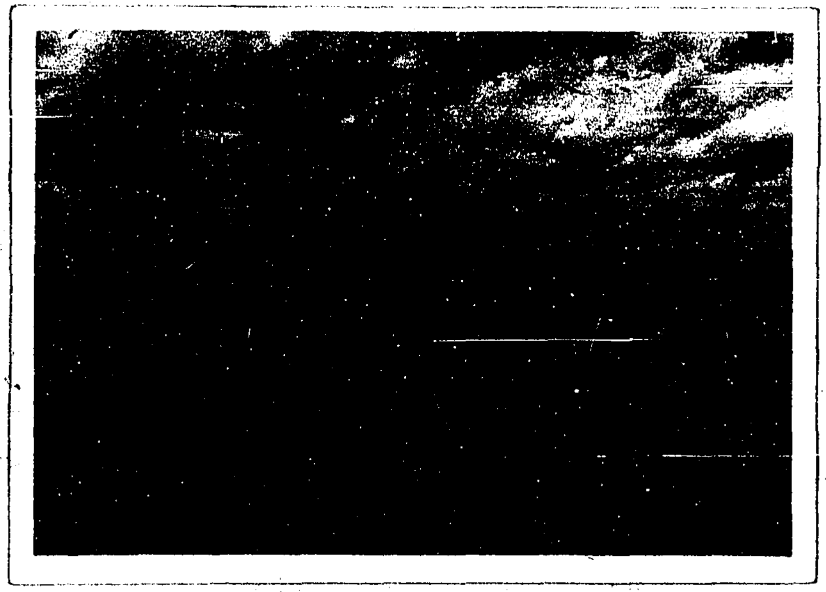


Plate 24: Circular depression between Hiawa and Nappi. (Photo by Windapo).

Plate 25: Blocky laterites near Manari Bridge. (Photo by Windapo).

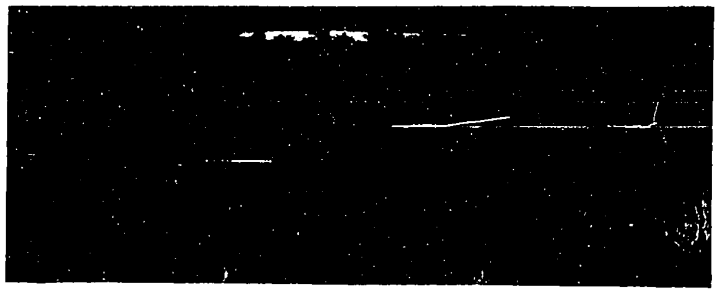


Plate 24: Circular depression between Hiawa and Nap i. (Photo by Windapo).

Plate 25: Blocky laterites near Manari Bridge. (Photo by Windapo).

(Plates 25 and 26). And in many parts of the valley flats, blocky laterites are exposed within sandy loam materials especially along the valleys of Parika, Hiawa, and Manari creeks.

The massive laterite surfaces mainly occupy the summits of the medium hills, but in places, they are found exposed on relatively low hills adjacent to the high flats of Pirara, Manari and Kumu, as well as on valley floors of many of the wide creeks. As in both the eastern and central blocks, some of the massive laterite summit surfaces maintain forest islands, especially on the periphery of Pirara and Kumu flats. One of these forest islands, on the western side of the Lethem-Pirara road, five miles from Pirara, is located on a bed of laterite which stands about three feet above the adjacent sandy loam plain (Plate 27). Those that are exposed on bottom flats are found mainly within the valleys of MocoMoco, Hiawa, Parika and Kumu. These are often bare, with occasional stands of stunted grasses where veneers of soil have developed on the laterite surface.

Apart from the valley flats around many of the streams and creeks, three major lowland areas exist within this sub-pattern. These include the Manari Terrace Belt, the MocoMoco Flat and the Ikuwali-Sapaika Flat which are given special attention below.

The Manari Terrace Belt:

This belt located at the western border of the western upland block extends from near Bon Success to south of Mirichy pond and the surface slopes gently to the banks of the

Plate 26: Blocky laterites near Johnson's ranch in Moc@Moco. (Photo by Windapo).

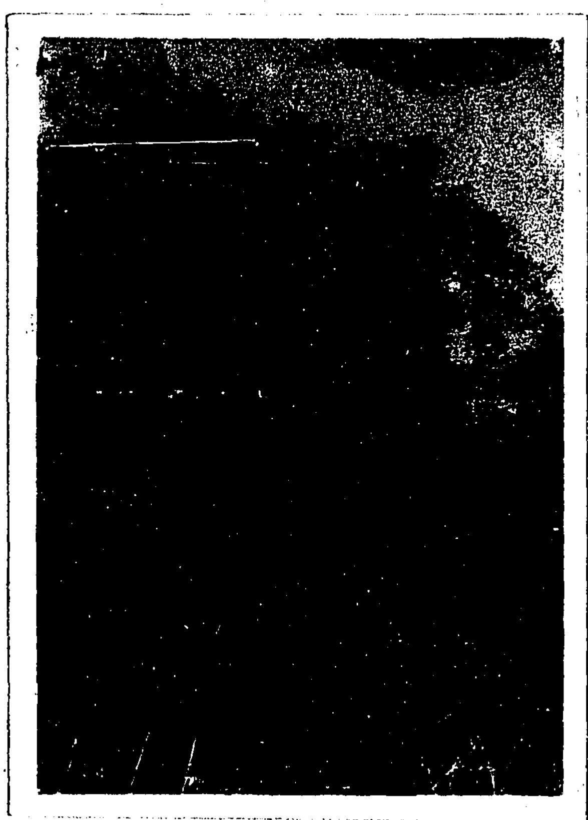


Plate 27: Forest island on raised laterite bed near Pirara. (Photo by Windapo).

Plate 26: Blocky laterites near Johnson's ranch in MocoMoco. (Photo by Windapo).

Plate 27: Forest island on raised laterite bed near Pirara.(Photo by Windapo).

Takutu River. Sand ridges of about 10 to 15 feet dominate the section bordering the Takutu flood-plain, giving way to sandy flats along the Manari River on the eastern borders. The sand ridges seem to have been formed by the dissection of the Manari terrace following the entrenchment of the Manari and the Pig Swamp creek in response to the entrenchment of the Takutu River.

Both the ridges and flats are composed of sandy loam materials which are well sorted as indicated by the grain-size distribution curves for the samples taken near Manari Outstation (Table XVI, Fig. 30). The sand ridges support a densely wooded savanna of campo coberto type, but the flats are almost treeless. These flats are waterlogged in parts for about three months after the rains, and they support clump grasses and sedges with a substratum of forbs.

The MocoMoco Flat:

This sub-unit is bounded by laterite ridges both to the north and south. The MocoMoco River occupies the central part of the flat and the widest portion is found around MocoMoco settlement near the forest edge. This zone narrows downstream of MocoMoco, disappearing almost completely about five miles from St. Ignatius (Fig. 25), giving the flat a pear-shaped outline (Fig. 31). The entrenchment of the river has created a fairly extensive terrace belt near the McGill weather recording site 1. This terrace belt is shown in Fig. 32.

In most parts, the top soil of the flat is composed of fine sands succeeded at depth by sandy clay.

TABLE XVI

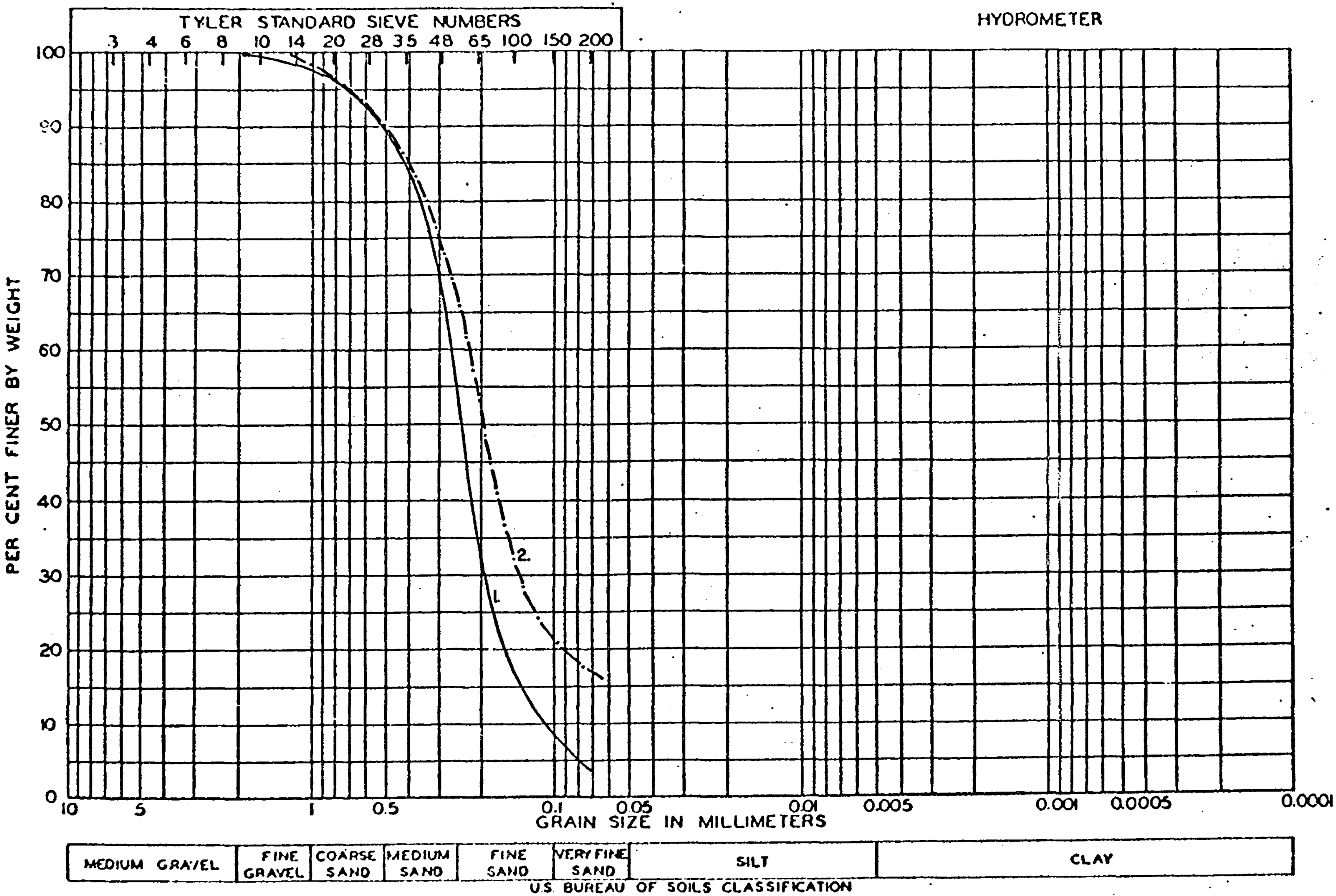
Sieve Analysis of two samples on low sandy ridge and flat near Manari Outstation.

1. Low sandy ridge sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.6	2.5Y
3	-		6/2
2	-		light
1	2		brownish
.5	6		grey
.25	35		
.125	44		
.088	7		

2. Flat surface sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.6	10YR
3	-		
2	-		
1	2		grey
.5	7		
.25	25		
.125	42		
.088	6		

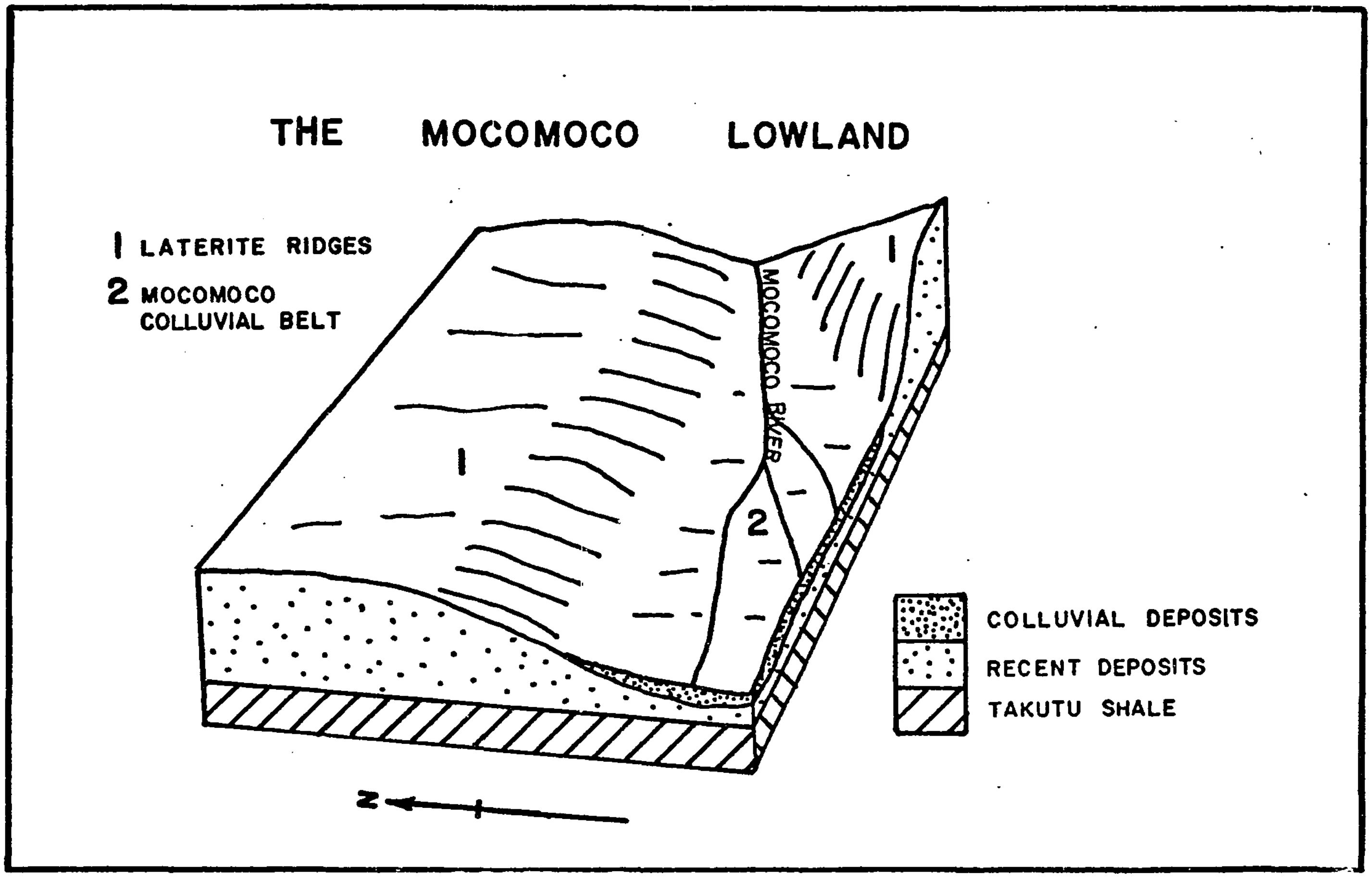


1. Manari Low Sand Ridge

2. Manari Sand Flat

FIG. 30. GRAIN SIZE DISTRIBUTION DIAGRAM: Manari Area.

FIG. 31



Windapo, 1968.

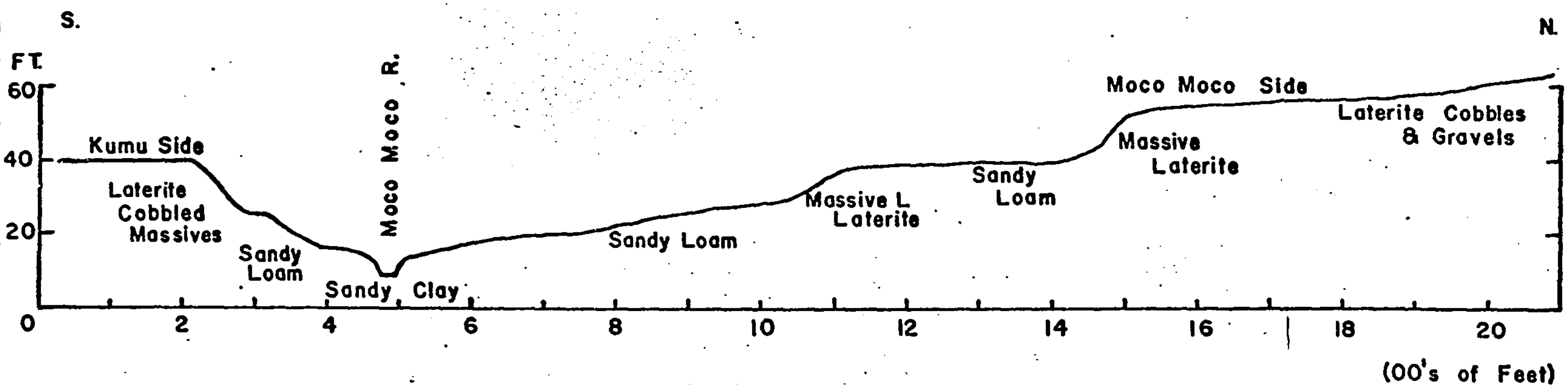


FIG. 32. Surveyed Cross-Profile Showing The Moco Moco Terrace, 5 Miles From St. Ignatius Bridge.

Windapo, 1968.

The soils, mainly of sheetwash origin from both the Kanuku and the adjacent laterite hills,seem to have been laid over an undulating laterite gravel surface as indicated in a profile dug by the author near Squeak's ranch. The site and the composition of each layer of the profile is described in Table XVII.

The sub-unit is moderately well drained though water-logging is experienced in certain parts of the area for short periods after the rains. The vegetation association is variable but campo coberto is the predominant type (Fig. 33). Clumps of trees are not uncommon,especially towards the forest edge, and on abandoned village sites where they constitute forest islands of anthropic origin. In the zones of temporary water-logging, pockets of terrawards are found and the vegetation types vary from campo coberto to campo sujo. Around squeak's ranch however, the campo sujo type is more significant. Here grass is dominant with a substratum of forbs as indicated in Fig. 34.

Along the MocoMoco River itself, galeria forest extends for varying widths succeeded by a belt of dense curatella americana. Within the terraced zone five miles from St. Ignatius, the stand of curatella is dense enough to be classed as campo cerrado (Plate 28, Fig. 35).

The Ikuwali-Sapaika Flat:

Like the MocoMoco Flat, this sub-unit is bounded to the north and south by laterite ridges, and the surface slopes gently southwards. The evolution of the flat can be

TABLE XVII

Profile Site Description:

Location:	MocoMoco Flat, near Squeak's ranch.
Relief:	Flat and level.
Soil Surface:	Fairly firm and even.
Drainage:	Imperfect.
Vegetation:	Campo sujo.

Sieve Analysis of Profile samples:

1st horizon 1' 4" (Medium grained sands)

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.2	10YR
3	-		6/1
2	-		grey
1	2		
.5	25		
.25	30		
.125	29		
.088	6		

2nd horizon 2' 2" (Coarser grained sands)

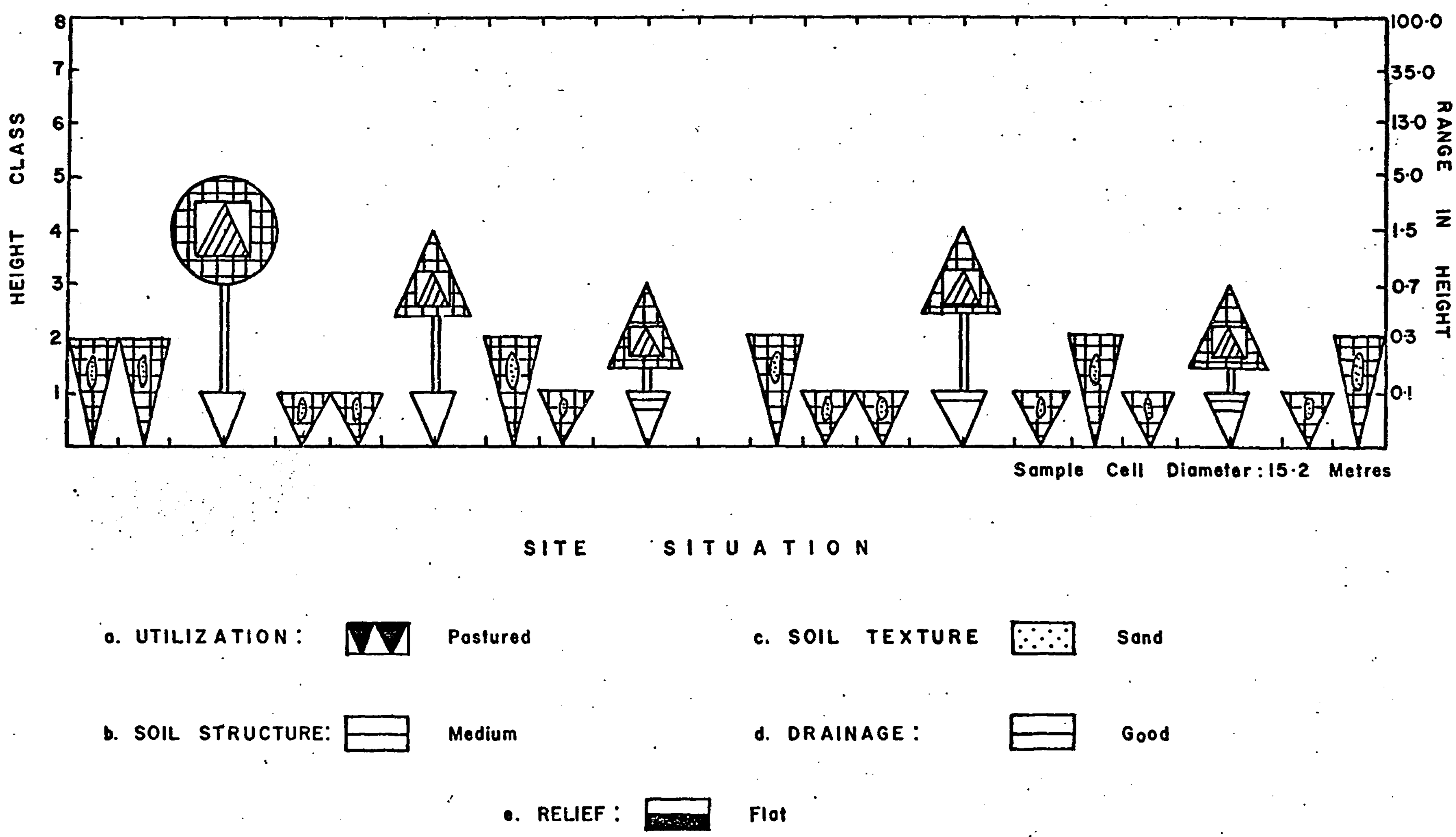
Sieve No.	% of sample above sieve	pH	Colour
5	-	5.8	2.5Y
3	-		7/2
2	1		grey
1	4		
.5	22		
.25	44		
.125	18		
.088	2		

3rd horizon 2' 4" (Mottled Zone with laterite nodules)

Sieve No.	% of sample above sieve	pH	Colour
5	44	6.6	2.5Y
3	10		7/2
2	5		light
1	11		grey
.5	10		
.25	8		
.125	6		
.088	1		

FIG. 33. VEGETATION STRUCTURAL DIAGRAM

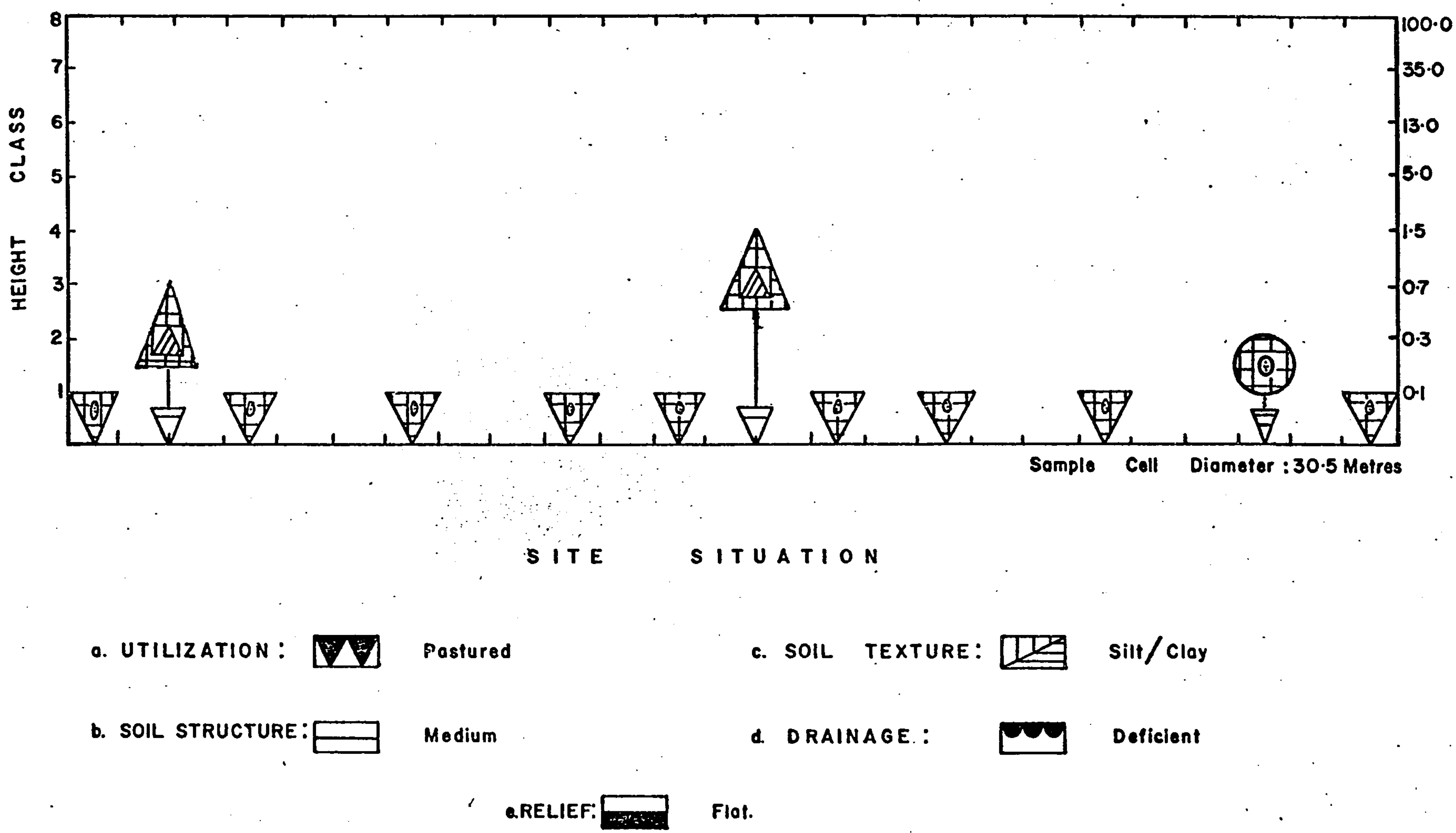
Moco Moco Flat.



Windapo, 1968.

FIG. 34. VEGETATION STRUCTURAL DIAGRAM

Squeak's Flat



Windapo, 1968.

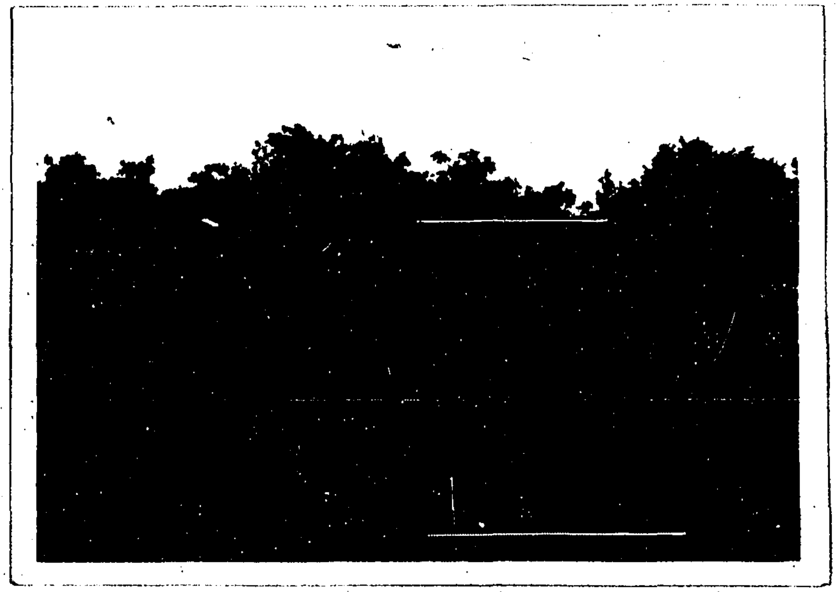


Plate 28: Dense stand of Curatella on MocoMoco terrace belt. (Photo by Windapo).

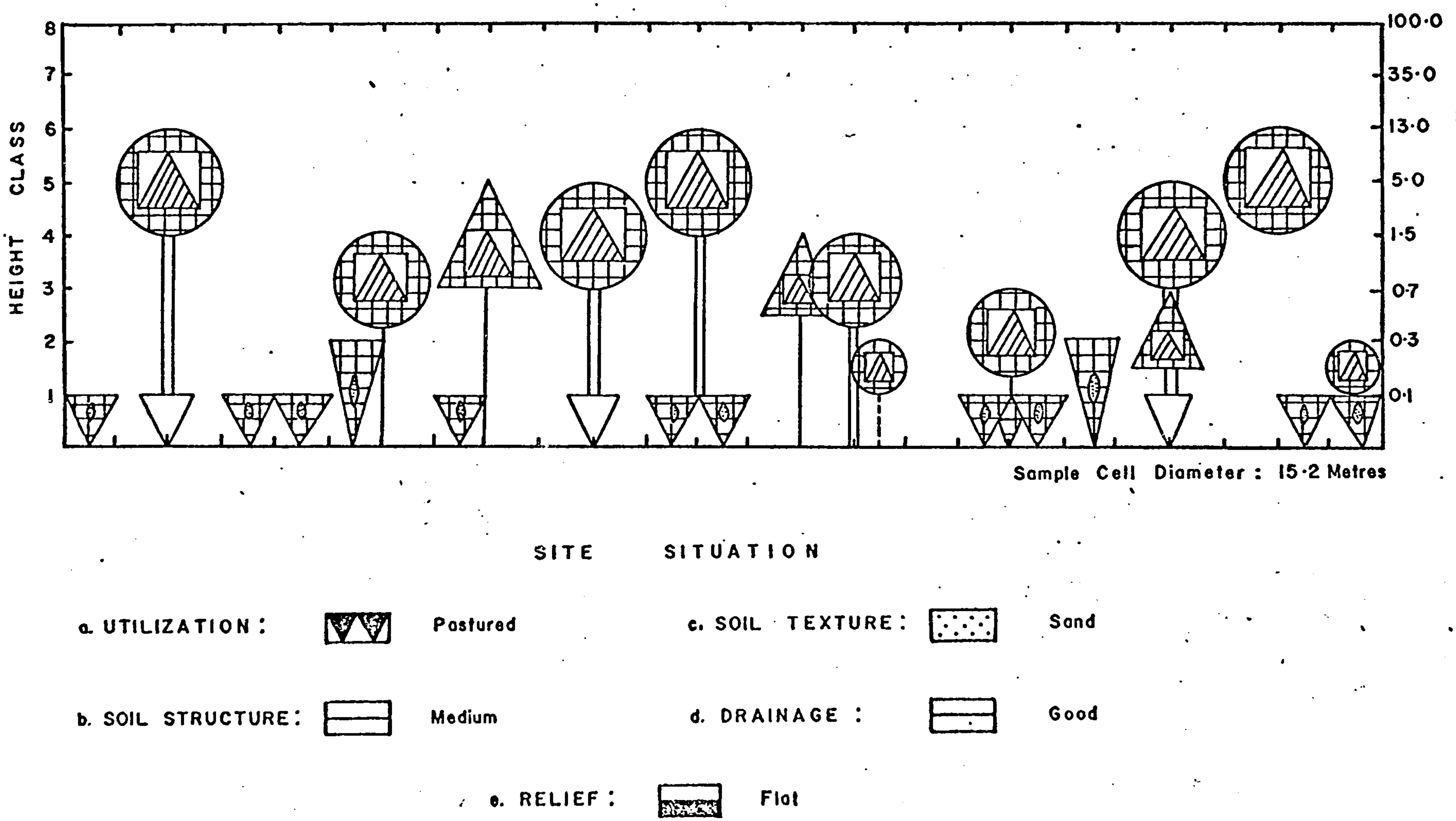
Plate 29: Giant termiteria near Lethem on Pirara road. (Photo by Windapo).

Plate 28: Dense stand of Curatella on MocoMoco terrace belt. (Photo by Windapo).

Plate 29: Giant termiteria near Lethem on Pirara road. (Photo by Windapo).

FIG. 35. VEGETATION STRUCTURAL DIAGRAM

Moco Moco Terrace Belt



Windapo, 1968.

ascribed to the combined erosional forces of both the Ikuwali and the Inaja rivers which removed the laterite cover of the zone.

The surface soil is generally loamy. Between the Ikuwali and Inaja rivers, where the flat is slightly higher, the top soil is composed of loamy sand succeeded at depth by sandy loam and clay loam in sequence. This soil has a higher porosity and is less compacted in the surface horizons than the sheetwash soils of other parts of the western block. The underlying clay loam with relatively higher water retention helps in maintaining adequate water supply to support a densely wooded savanna vegetation (Fig. 36).

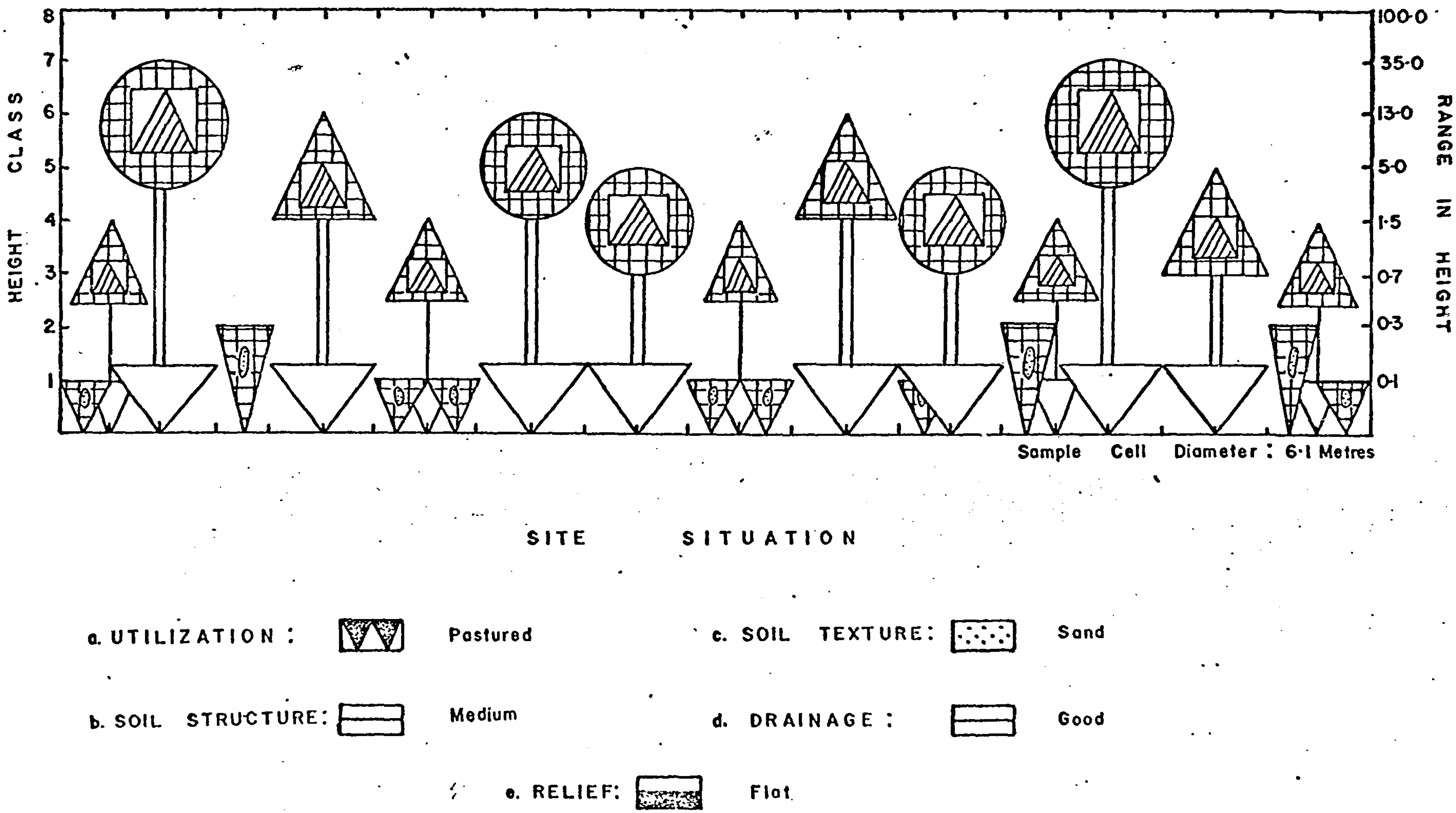
To the south, the loamy soil is greatly influenced by the proximity of the ground-water-table. Areas of swamp exist for some part of the year and within these swamps, the loamy texture of the soil gives way to silt and clay. Here, terrawards are found in large numbers and in varying dimensions. Outside the swamp areas, the vegetation is of campo coberto type while the swamps are zones of grasses and sedges within the generally wooded savanna.

Outside the three sub-units treated above, the soil types are generally lateritic on the hills and where laterite gravels are not dominant, lateritic red and brown earth are found. Such areas of red and brown earth are marked by giant termiteria, especially on the slopes and summits of some medium hills around Lethem, Parika, Hiawa and Nappi (Plates 29 and 30).

Within the creek valleys, the soil varies from

FIG. 36. VEGETATION STRUCTURAL DIAGRAM

Inaja Creek Belt



Windapo, 1968

Plate 30: Giant termiteria near Nappi. (Photo by Windapo).

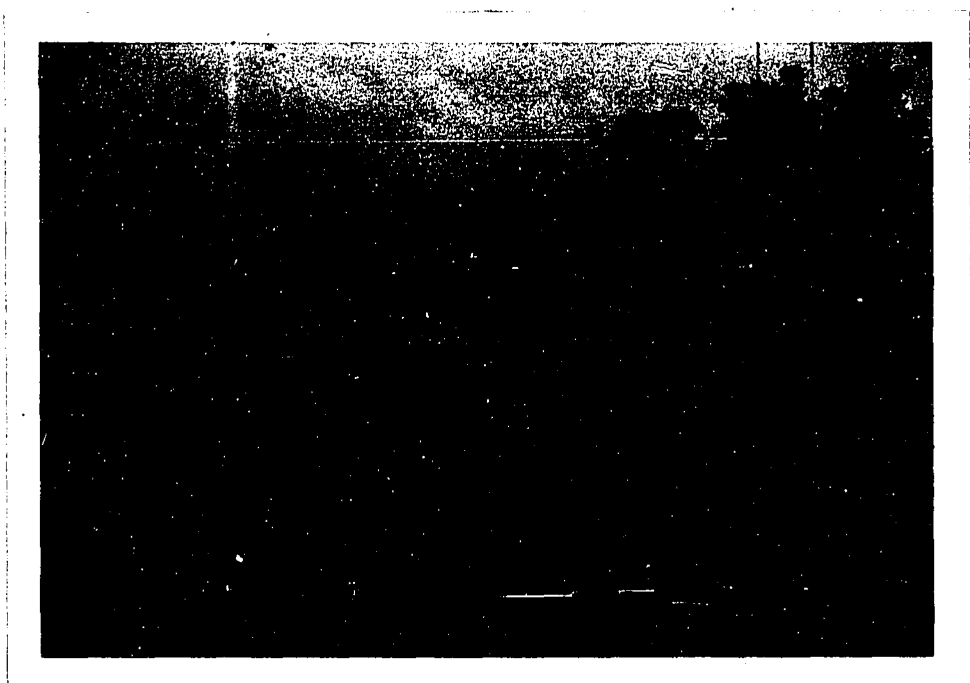


Plate 31: Terraward zone at Komako. (Photo by Windapo).

Plate 30: Giant termitaria near Na[illegible]i.
(Photo by Windapo).

Plate 31: Terraward zone at Komako.
(Photo by Windapo).

sandy loam to silt and clay in the zones of swamp along the valleys. Such sections are characterized by terrawards marked by trees and sedges as along the tributary of Hiawa in Komako area (Plate 31).

The vegetation is generally more open outside the three sub-units except on the Nappi high hills, along some sections of creek valleys, and within the forest islands. The Nappi high hills, for example, are generally densely wooded on the slopes with the Fish-poison trees being the dominant species. Fig. 37 is a profile across the high hills on the way to Nappi and in Figs. 38 and 39 the vegetation differences between the slope and the valley bottom situations are illustrated. From the structural diagrams it can be seen that the slopes are covered with closely spaced slender and tall trees with small leaves, while the creek valley contains shorter larger diameter trees with wide leaves in a random but more open arrangement. The former sample is predominantly of Fish-poison trees, while the other contains curatella americana almost exclusively.

On the hills of Hiawa area, the vegetation is of campo coberto variety. Here too, the wooded species are dominated by Fish-posion trees, but these are concentrated in strips along the closely spaced gullies. And around MocoMoco the hills are sparsely wooded and most of the trees occupy the gullies and upper slopes of the medium sized hills - perhaps marking the zones of seepage moisture (Plate 32).

The creek valleys carry a vegetation which varies from place to place. Some sections are occupied by dense stands

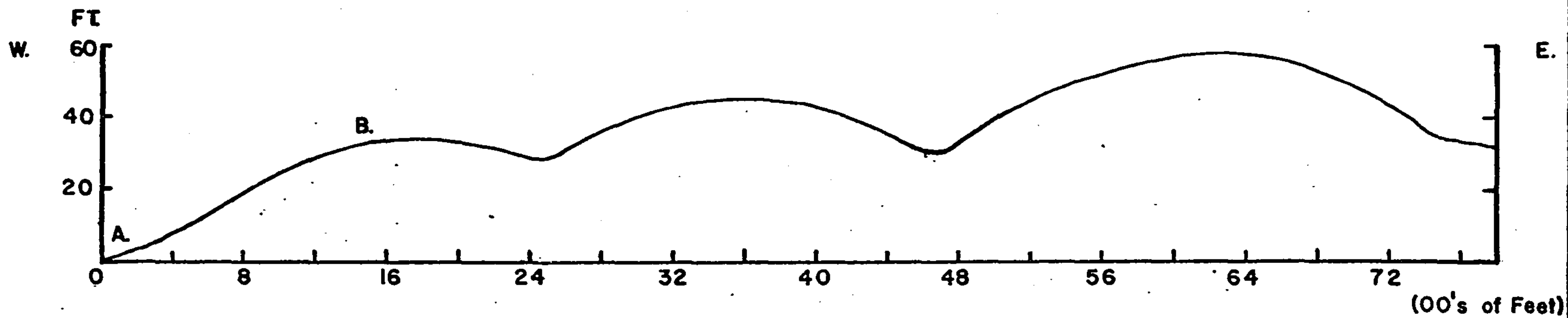


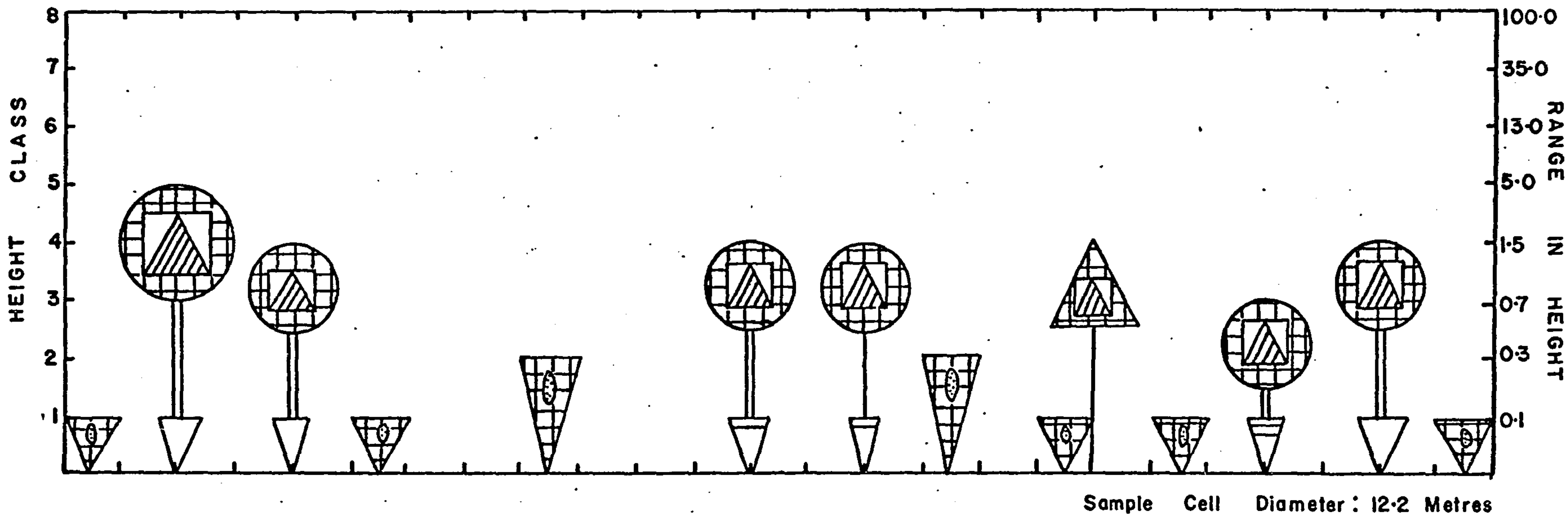
FIG. 37 Profile Of The Nappi High Hills Along The Road.

Note: A. and B. are Vegetation Sample Sites.

Windapo, 1968.

FIG. 38. VEGETATION STRUCTURAL DIAGRAM

Depression Adjacent to Nappi Hills



SITE SITUATION

a. UTILIZATION — Pastured

b. SOIL STRUCTURE — Medium

c. SOIL TEXTURE — Sand

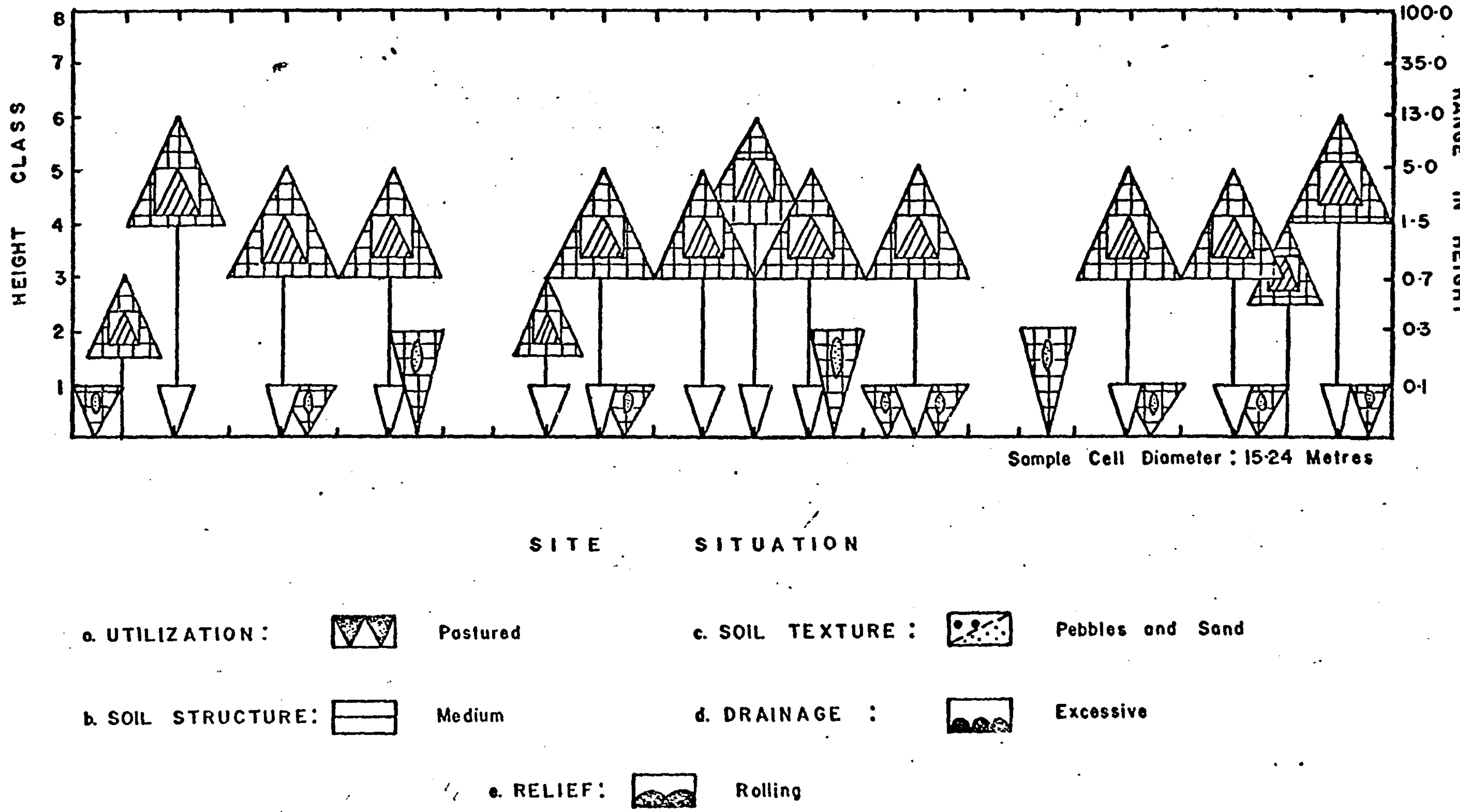
d. DRAINAGE — Good

e. RELIEF — Depressed

Windapo, 1968.

FIG. 39. VEGETATION STRUCTURAL DIAGRAM

Nappi High Hill Slope



Windapo, 1968.

Plate 32: Vegetation along gullies near Komako. (Photo by Windapo).

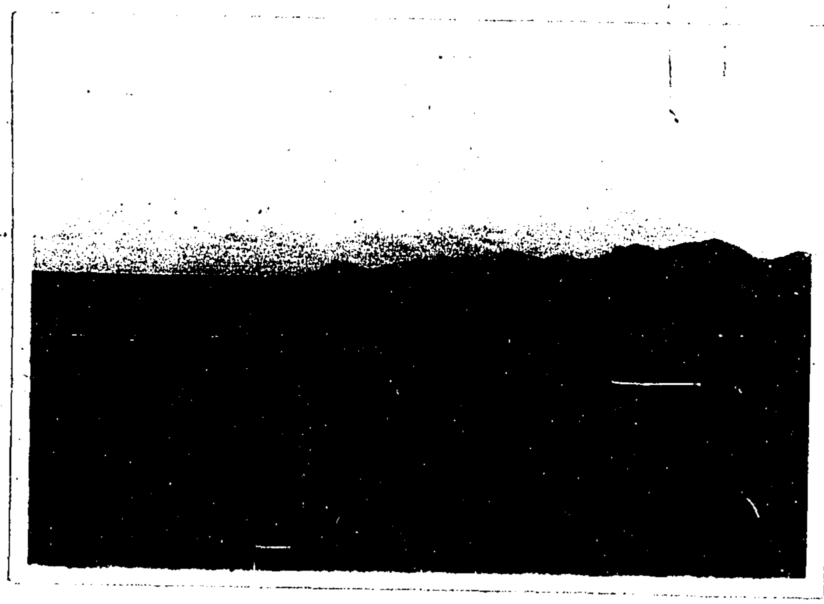


Plate 33: Ite palm swamp at Upper Parika. (Photo by Windapo).

Plate 32: Vegetation along gullies near Komako. (Photo by Windapo).

Plate 33: Ite palm swamp at Upper Parika. (Photo by Windapo).

of <u>curatella</u> as along the Hiawa tributary in Komako. Other sections are occupied by grass and sedge communities, while some other areas are occupied by Ite palms as in the palm swamps of upper Parika (Plate 33).

<u>The Laterite Outliers</u>.

The laterite outliers are found in a discontinuous looping belt to the west, south, and southwestern fringes of the central lowland of the Marakanata depression. They may represent fragments of a former laterite landscape that once extended from the Kanuku borders to the Pakaraima scarp foot but which was breached by the Old Ireng and the Proto-Berbice rivers which removed the laterite cover from the Marakanata lowlands of today.

The largest and most extensive of these laterite enclaves is that stretching from Sunnyside on the Ireng eastwards to a little beyond Meritizero outstation. This belt has been named 'the Meritizero laterite island' by Sinha (1967). It is a belt of higher ground rising to about 60 feet above the surrounding lowlands. It has a core of massive laterites especially towards Sunnyside, and may be adequately described as a laterite ridge. This ridge has been breached by north-south depressions into eastern and western segments. The surfaces of the western segment are largely covered by secondary laterite gravels while lateritic soils - red loams - dominate the surfaces of the eastern segment. The eastern slopes of this eastern segment are, to a considerable extent, buried under sand apparently of aeolian origin (Eden 1964). The hills of this segment are generally broad with gently undulating summits and gentle convex slopes which gradually merge into the surrounding lowland troughs. Fig. 40 is a profile taken across one such hill. Meritizero settlement stands on the eastern wing of this hill.

The minor laterite enclaves are found north of Pirara River and west of Marakanata settlement. These minor remnants are cored with massive laterite which is found close to the surface. They are largely bush-covered on the summits, providing promising farm lands (Plate 34).

The vegetation cover of the laterite enclaves varies from place to place. For example, the western portion of the Meritizero island is well wooded towards Sunnyside, while the eastern segment is mostly treeless. The depth of weathering on the eastern segment seems to have destroyed the laterite aquifer here, hence the deep red loam supports bunch grasses with occasional shrubs only. The minor enclaves support vegetation ranging from campo coberto to thick bush referred to as forest island.

AIR-PHOTO CHARACTERISTICS OF THE LATERITE UPLANDS.

The air-photo characteristics of this landscape can be appreciated from Plates 35, 36 and 37 in which the characteristic associations of landform units and components of the laterite uplands are presented. Plate 35 is representative of the eastern upland block, while Plates 36

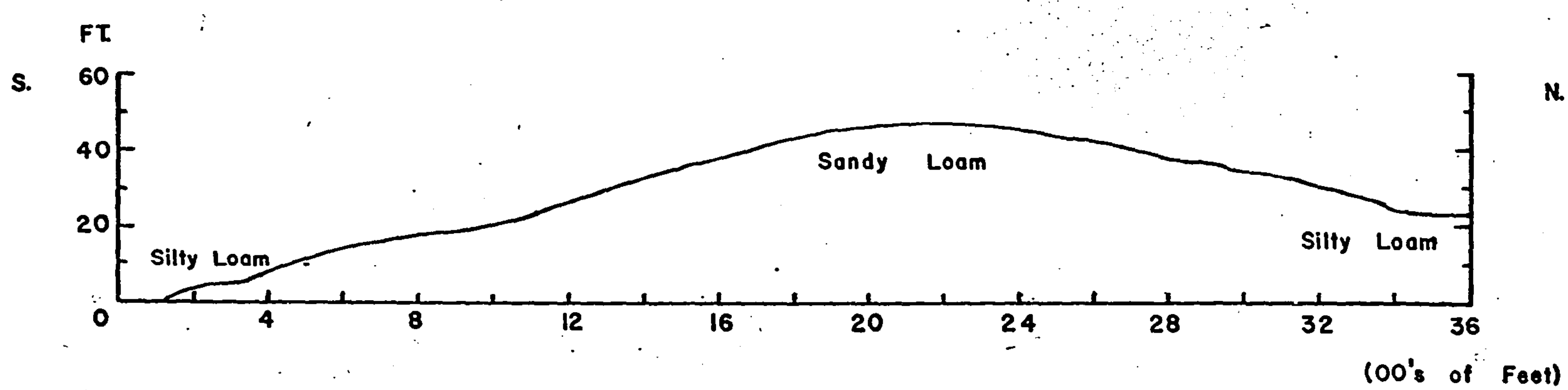


FIG. 40. Meritizero Hill Profile

Windapo, 1968.

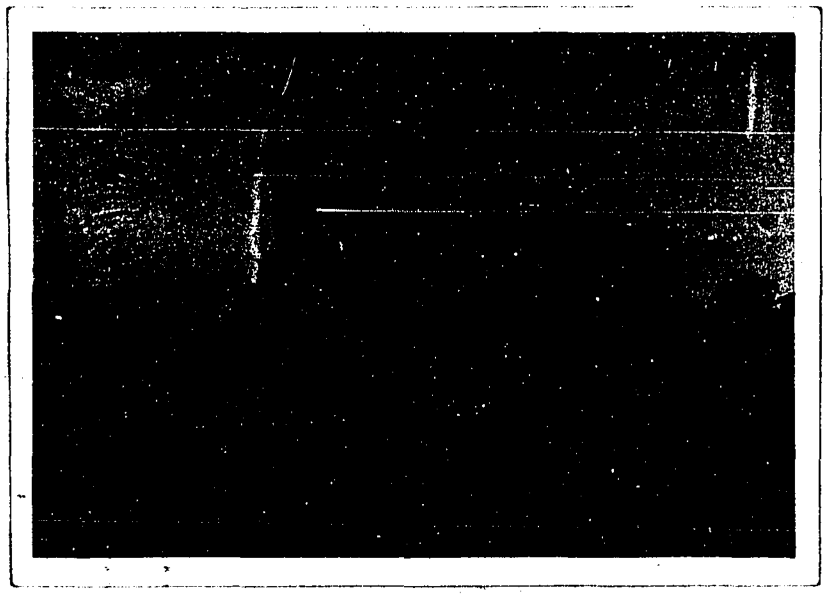


Plate 34: Forest island near Pirara.
(Photo by Windapo).

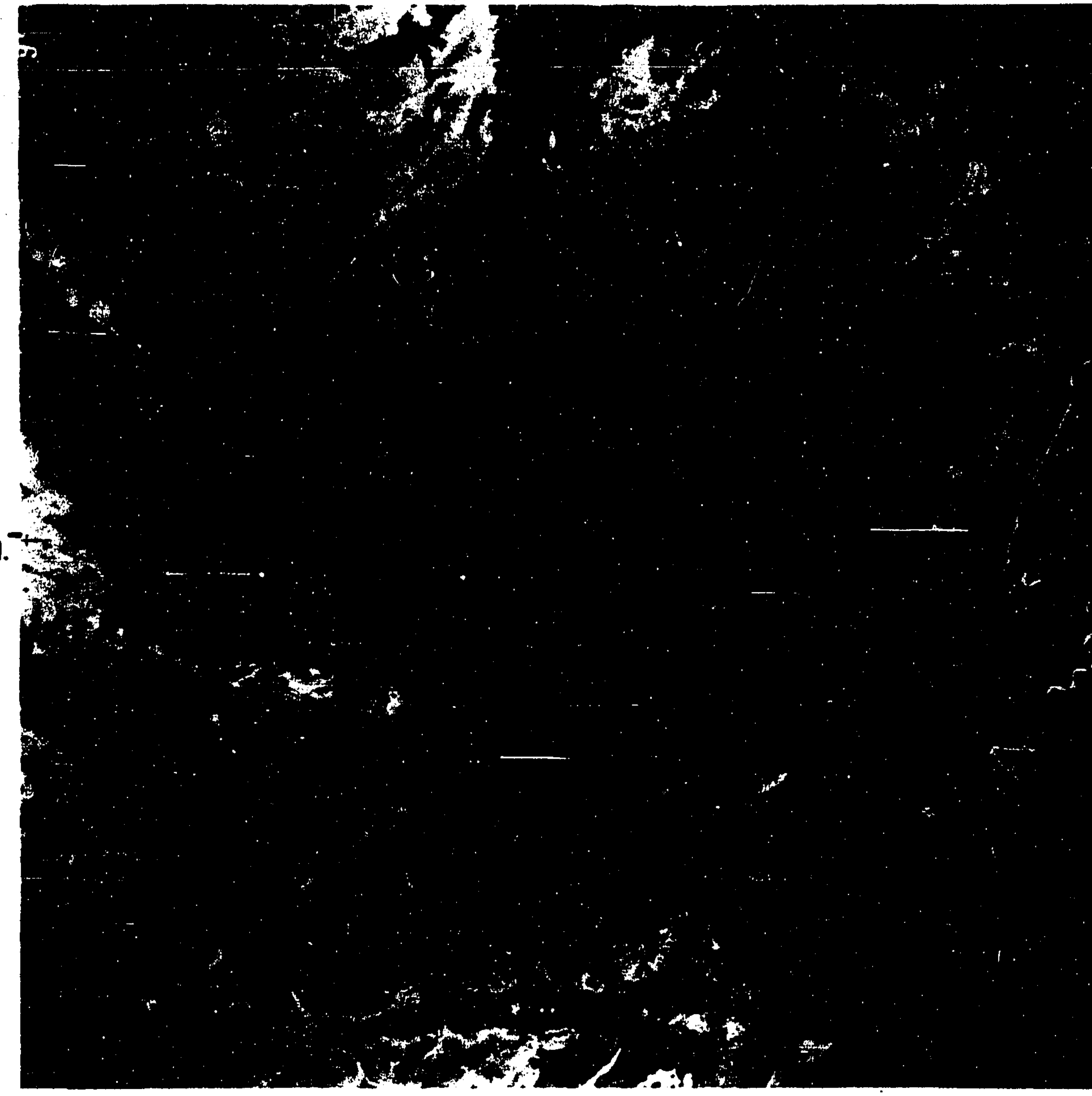
Plate 34: Forest island near Pirara.
(Photo by Windapo).

and 37 represent the central and western blocks respectively.

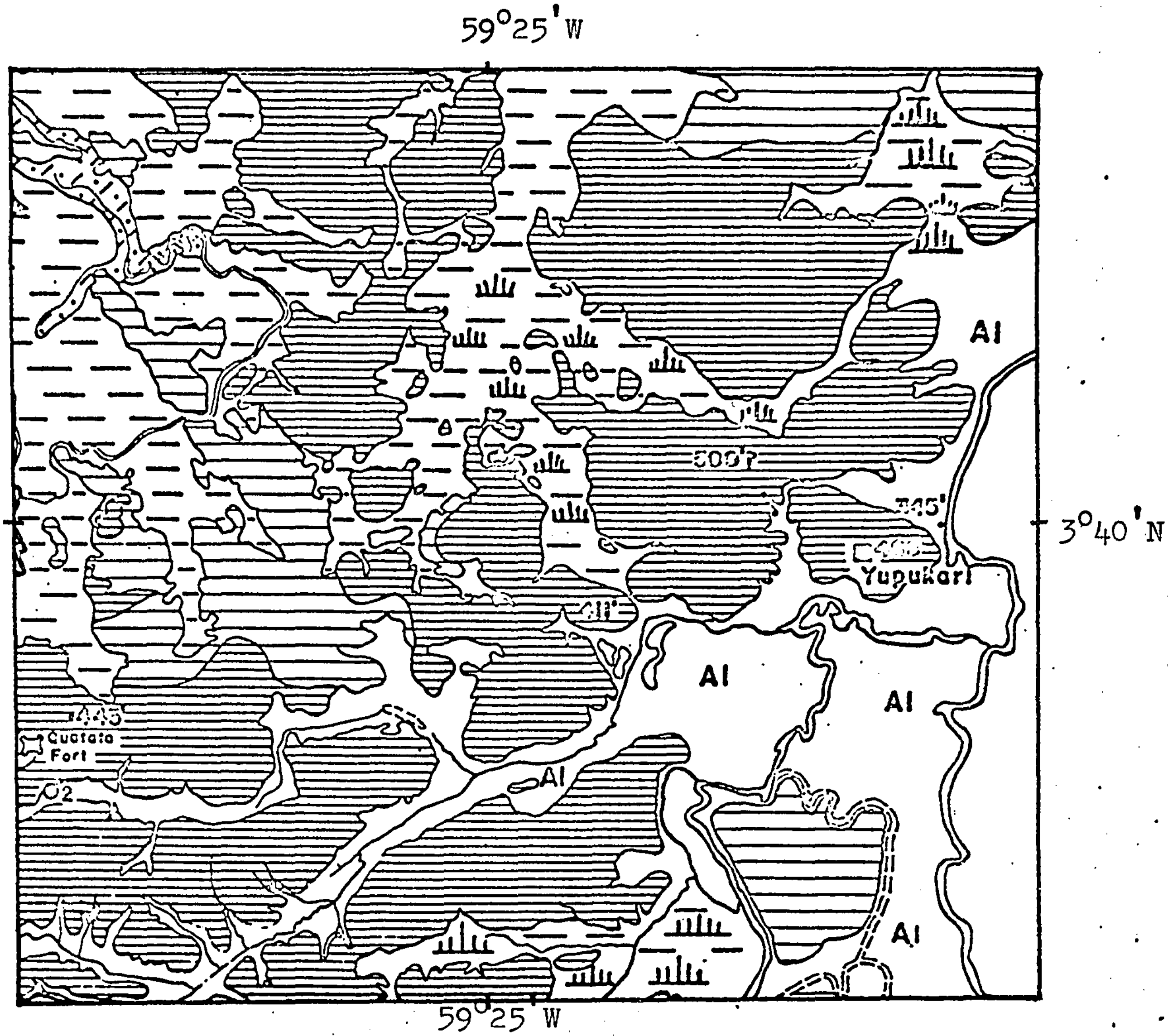
Plate 35 shows laterite ridges wooded in varying degrees and dissected by large creeks which occupy wide valleys - many of which are densely wooded while others are swampy in parts. In such an area, reflectance from the surface varies considerably and there is a corresponding variation in the density of the exposed film and the grey tone values of the prints. A sample transect was made along the line IJ on the Plate and the density variation assessed with the aid of the Munsell neutral value scale. The values are plotted in the form of an amplitude graph shown in Fig. 41. It can be seen that similar features show similar values along this graph and the boundaries separating different features are sharp. For example, the tonal values of the laterite ridges contrast strikingly with those of the creek valleys.

The light toned areas of high surface reflectance shown as (d) on the lower overlay to Plate 35 are open laterite ridges with widely scattered trees. These areas show a range of tonal values between N6 and N8.5, and a surface reflectance of between 30 per cent and 70 per cent. The more densely wooded ridges with lower surface reflectance values show a neutral value range between N4.5 and N6 and are marked (c) on the overlay. The very dark toned portions of the ridges marked (a) are forest islands, and they have tonal values of about N3.5 and a low surface reflectance of about 9.0 per cent.

The creek valleys, on the other hand, are largely areas of low reflectance with tonal values which vary

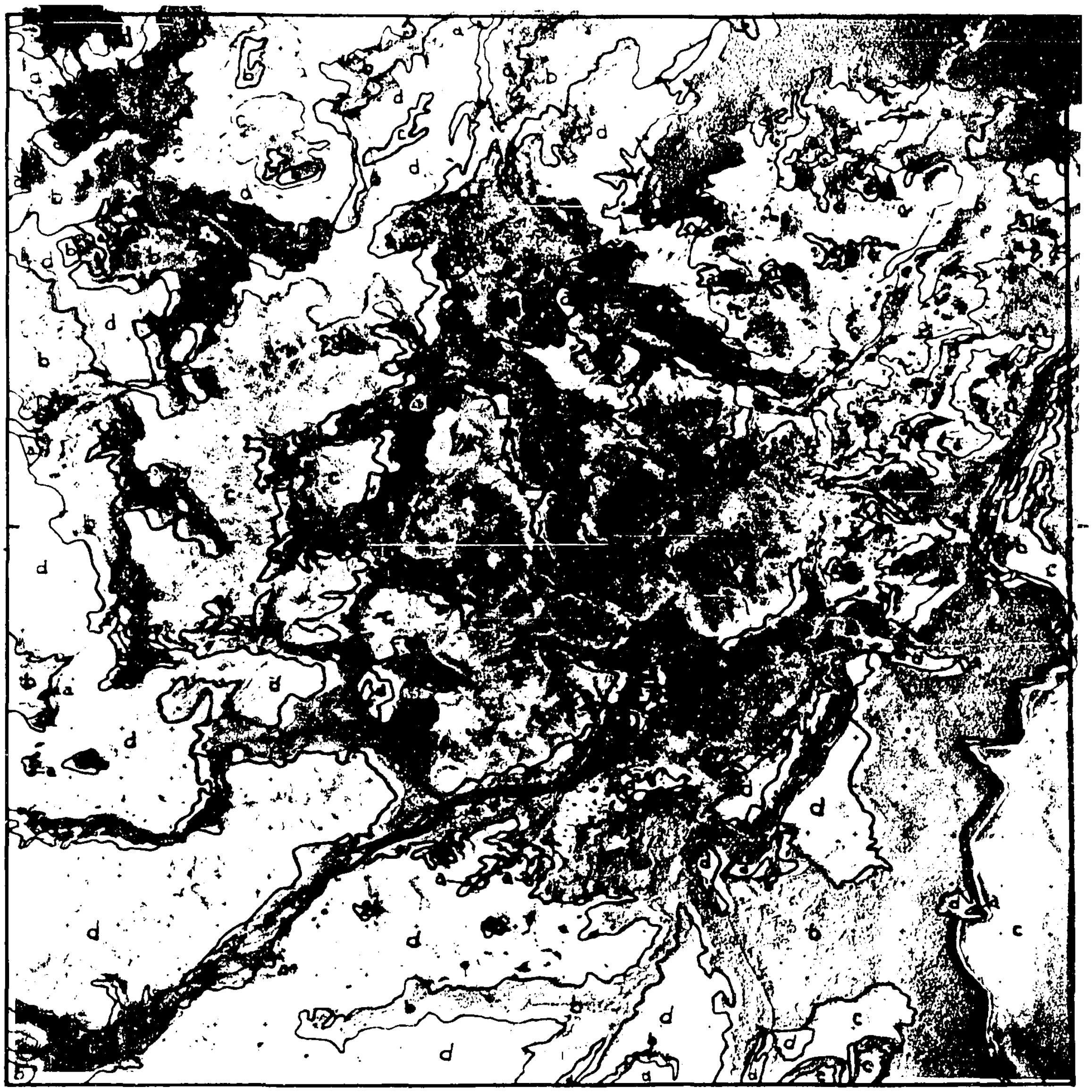


35: Eastern laterite Upland Block. (Photo by Hunting Aerosurveys Ltd..)



(Adapted from Sinha, 1967).

I



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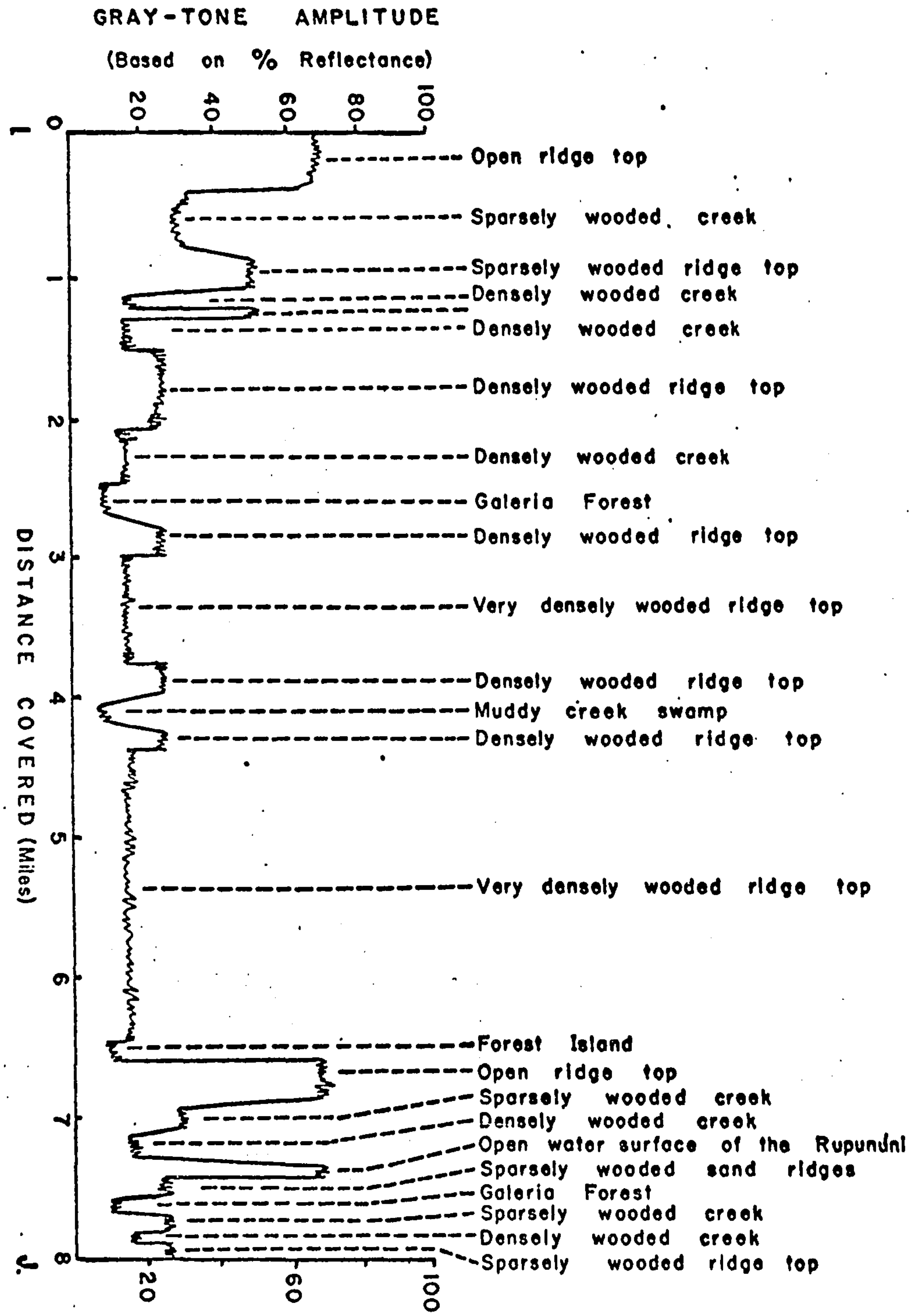


FIG. 41. Graphical Comparison of Gray-Tone Values of Terrain Types of the Eastern Upland Block along Line IJ. on Plate 35.

Windapo, 1968.

fron N3 to N6. The areas marked (a) within these bottomlands are belts of galeria forest and marsh. They show a very low surface reflectance of about 6 per cent. The areas marked (b) are densely wooded sections of the creek valley outside the belts of galeria forest. The moisture condition and the vegetation have combined to effect a dark tone and reduce the surface reflectance to about 30 per cent.

The tonal values are represented in the last column of Table XVIII by neutral value range diagrams. Other characteristics of the terrain, such as drainage and vegetation, deducible from air-photographs, are also shown in the Table.

Part of the central upland block is covered in Plate 36 with adjacent parts of the Nappi lowland and the western uplands. Zone 2 of the top overlay covers the Nappi lowland with a range of tonal values between N3 and N6, while zone 3 represents the area of laterite islands with a range of tonal values between N6 and N8.5. A summary of these tonal variations within the two zones is presented in the Neutral value range diagrams in Table XVIII while the tonal contrasts from zone to zone are shown in Fig. 42 which is a graphical comparison of grey-tone variations representing the terrain variations. Invariably, all the variations show sharp boundaries to one another as can be appreciated from the sampled section on the wave-form graph.

Within the lowland - zone 2 - the areas labelled (a) are areas of galeria forest while those labelled (b) are savanna areas wooded in varying degrees from campo cerrado to

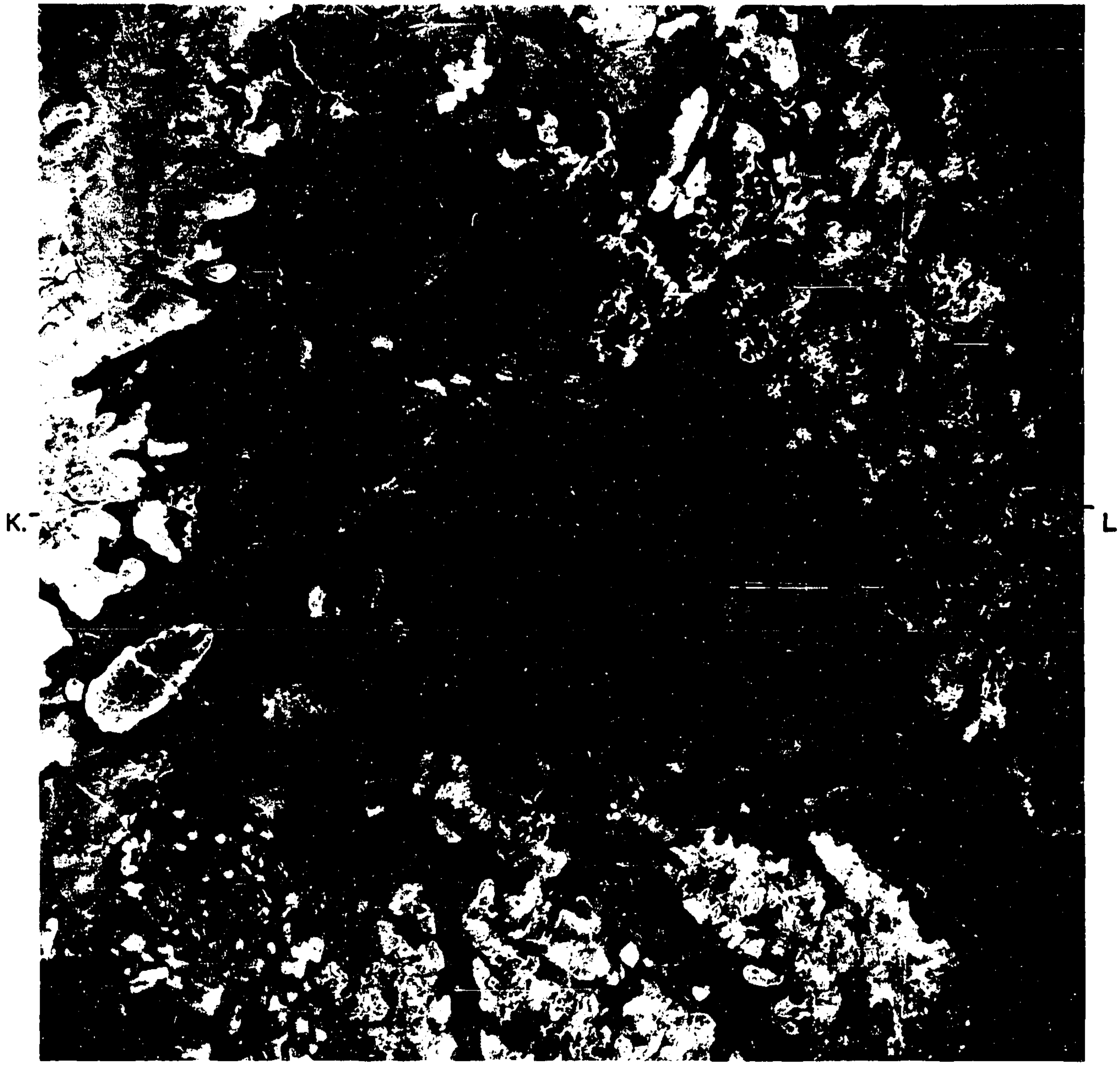
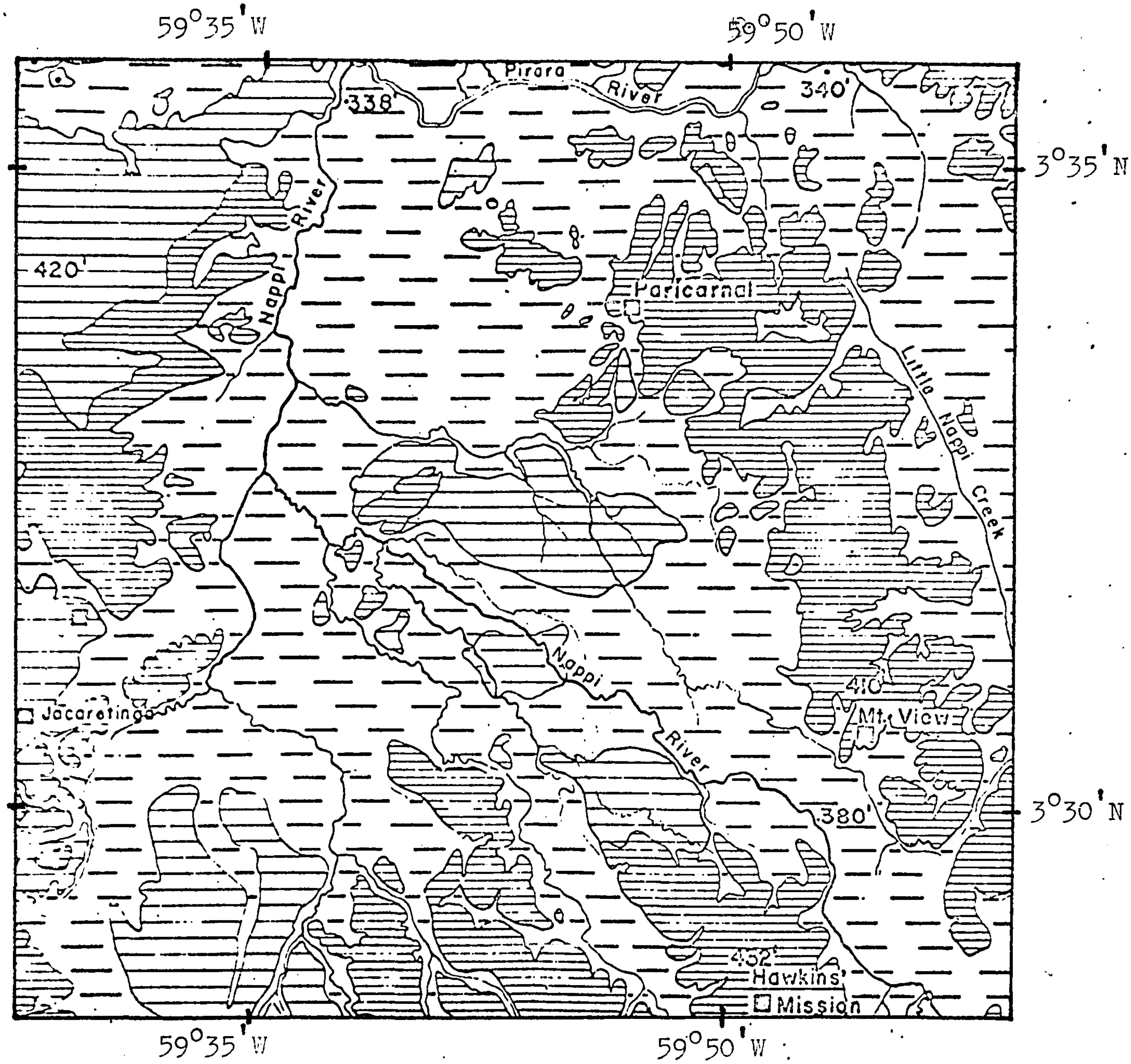
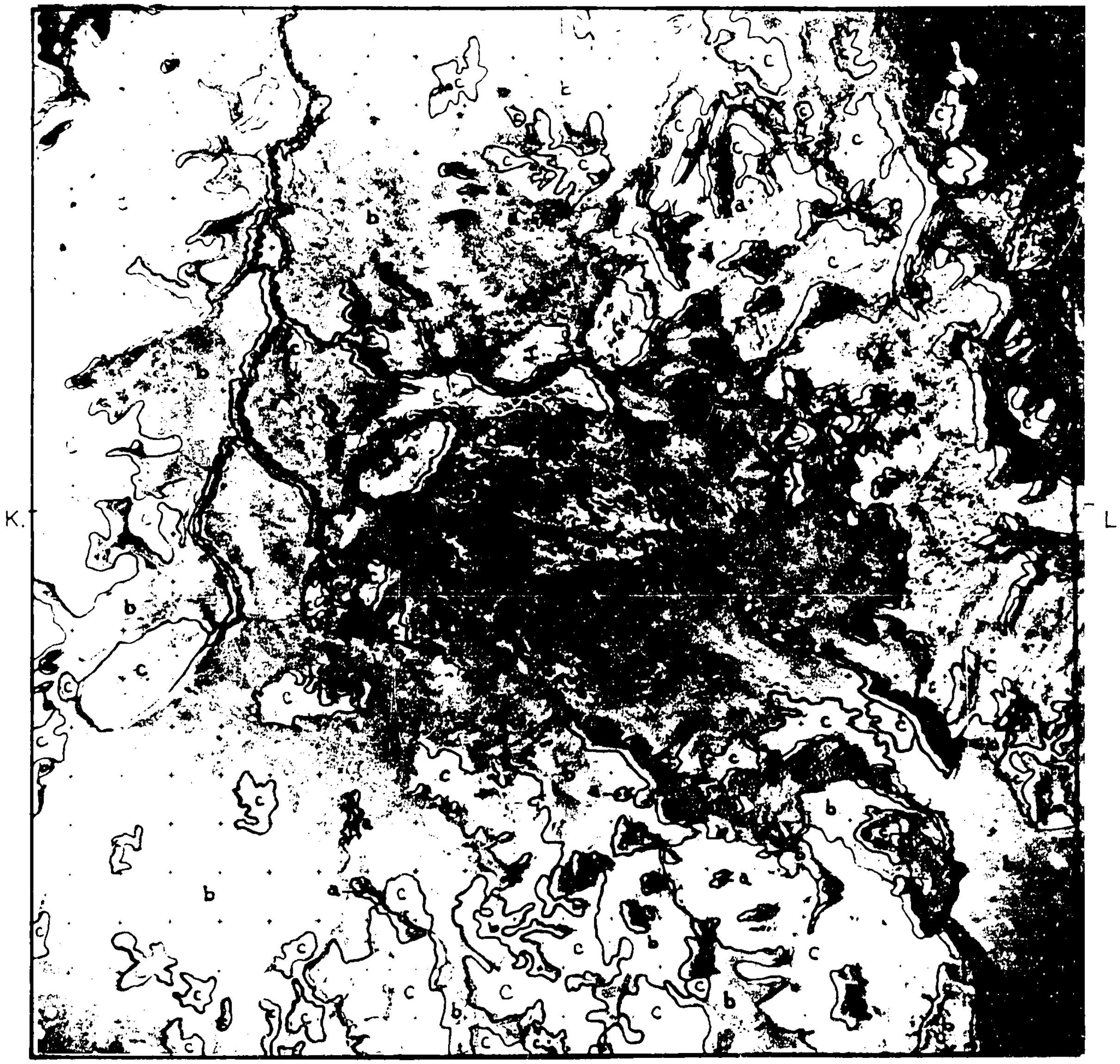


PLATE 36: Central laterite Upland Block. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967)


K.
L.

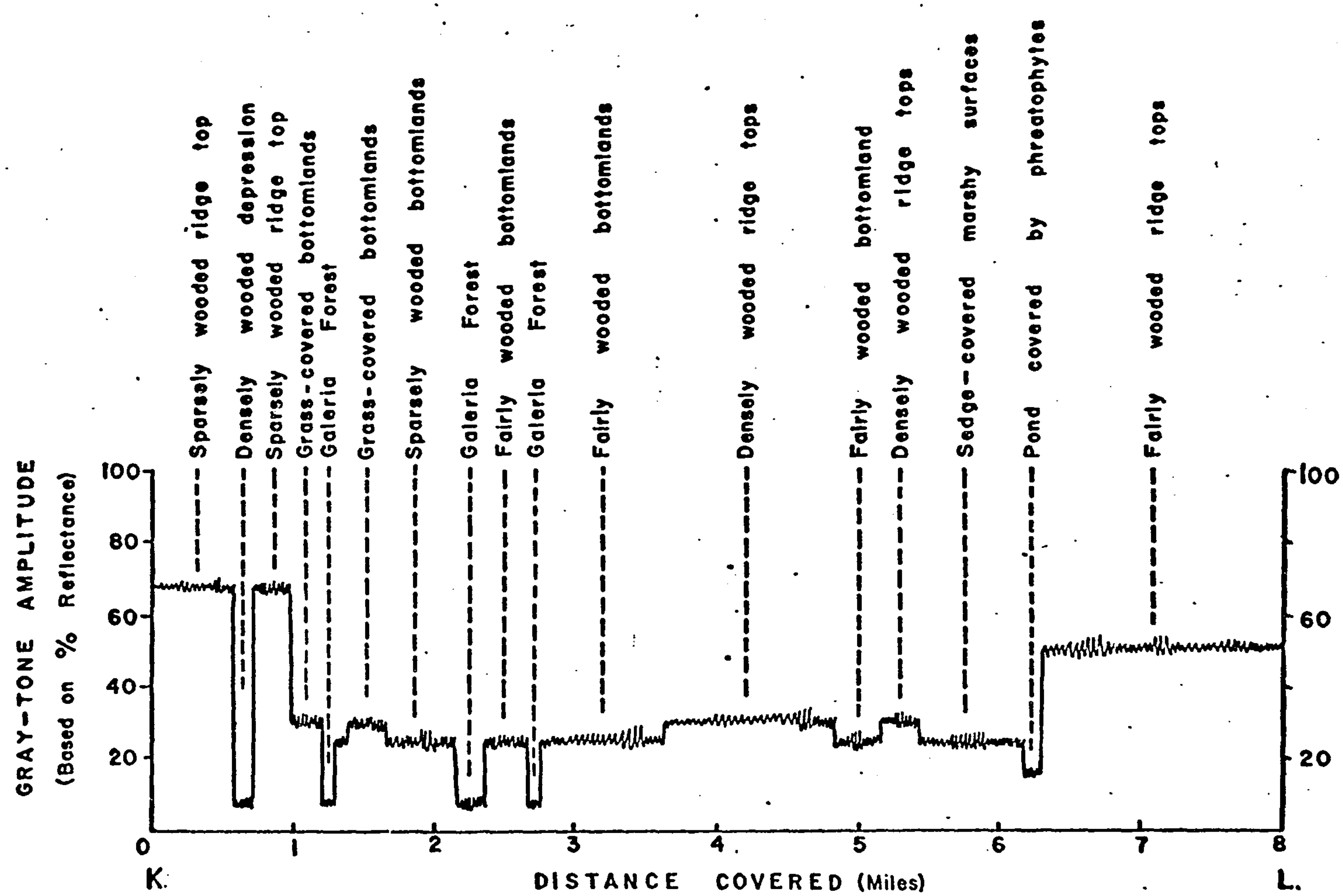


FIG. 42. Graphical Comparison of Gray-Tone Values of Terrain Types of the Central Upland Block along Line KL. on Plate 36.

Windopo, 1968.

TABLE XVIII: AIR-PHOTO CHARACTERISTICS OF LATERITE UPLAND PATTERN

Sub Patterns	Plates & Zones	Sub pattern variants	Approx. % coverage	Drainage	Vegetation	Soils	Darker Lighter Neutral Values 1 5 10
The Eastern Upland Block	Plate 35.	Laterite Ridges	80	Generally excessively well drained Long gullies channel surface water	Campo cerrado on high hills depleting to campo coberto on the lower ones with pockets of forest islands.	Laterite gravels and laterite red and brown loams.	
		Bottom-lands	20	Poorly drained with swamps in places	Galeria forests and campo coberto on fairly well drained flats. Campo limpo sedge and palm swamps in poorly drained sites.	Sandy loam grading to silt and clay in poorly drained sites	
The Central Upland Block	Plate 36 Zone 2	The Nappi Lowland	65	Poor internal drainage in places but generally moderately well drained with dendritic surface pattern	Stretches of galeria forest. Campo coberto and sedge dominated campo limpo.	Sandy loam grading to silt and clay.	
	Plate 36 Zone 3	Laterite Islands	35	Generally well drained with gullies channelling surface water	Campo coberto mainly	Laterite gravels and lateritic red and brown loam	
The Western Upland Block	Plate 37 Zone 1	Laterite Hills	70	Generally excessively well drained with gullies channelling surface water	Campo sujo dominant with few belts of campo coberto, and campo cerrado.	Laterite gravels with lateritic red and brown loam.	
		Local Bottom-lands	25	Poorly drained in parts generally moderately well drained	Galeria forests with belts of capo cerrado by some creeks. Campo cerrado depleting to campo limpo on some flats. Pockets of palm swamps too.	Sandy loam with pockets of silt and clay	
	Plate 37 Zone 2	MocoMoco Flat	2	Moderately well drained generally with pockets of poorly drained areas	Galeria forests with some zones of campo cerrado along creeks. Campo coberto dominant with belts of campo sujo and campo limpo.	Sandy Clay with pockets of silt and clay	

□ Dominant Values
< > Range of Values
. Mean Value

campo limpo, but which are all influenced greatly by the abundance of moisture causing the low reflectance. On the other hand, (c) mark laterite enclaves within the lowland. These are fairly bare laterite gravel hills with high reflectance value of about 60 to 70 per cent.

Within zone 3 - the laterite islands - the dark toned areas marked (a) are forest islands and galeria forests on the upper courses of creeks. The lighter toned areas (c) occupy the greater part of the zone. These areas cover the wooded laterite ridges with a surface reflectance of about 30 per cent in the most densely wooded sections, 60 per cent in the unmappable few areas of open woodland and 70 per cent in the very few and tiny bare spots. Other characteristics of this sub-pattern are also presented in Table XVIII.

The western upland block is represented by zones 1 and 2 on the top overlay to Plate 37. Here the tonal values range from N2.5 with a reflectance of about 5 per cent along the extensive galeria forests of MocoMoco River to N9.5 with a surface reflectance ofabout 90 per cent on some bare laterite ridges. Zone 2 is the MocoMoco flat. Within this flat, the belt of MocoMoco galeria forest is very conspicuous and occupies all the areas labelled (a) on the lower overlay. The areas labelled (c) and (d) represent open savanna surfaces with (c) having more wooded species than (d). In zone 1 however, the areas marked (a) are narrow stretches marking belts of galeria forests of some creeks with a tonal

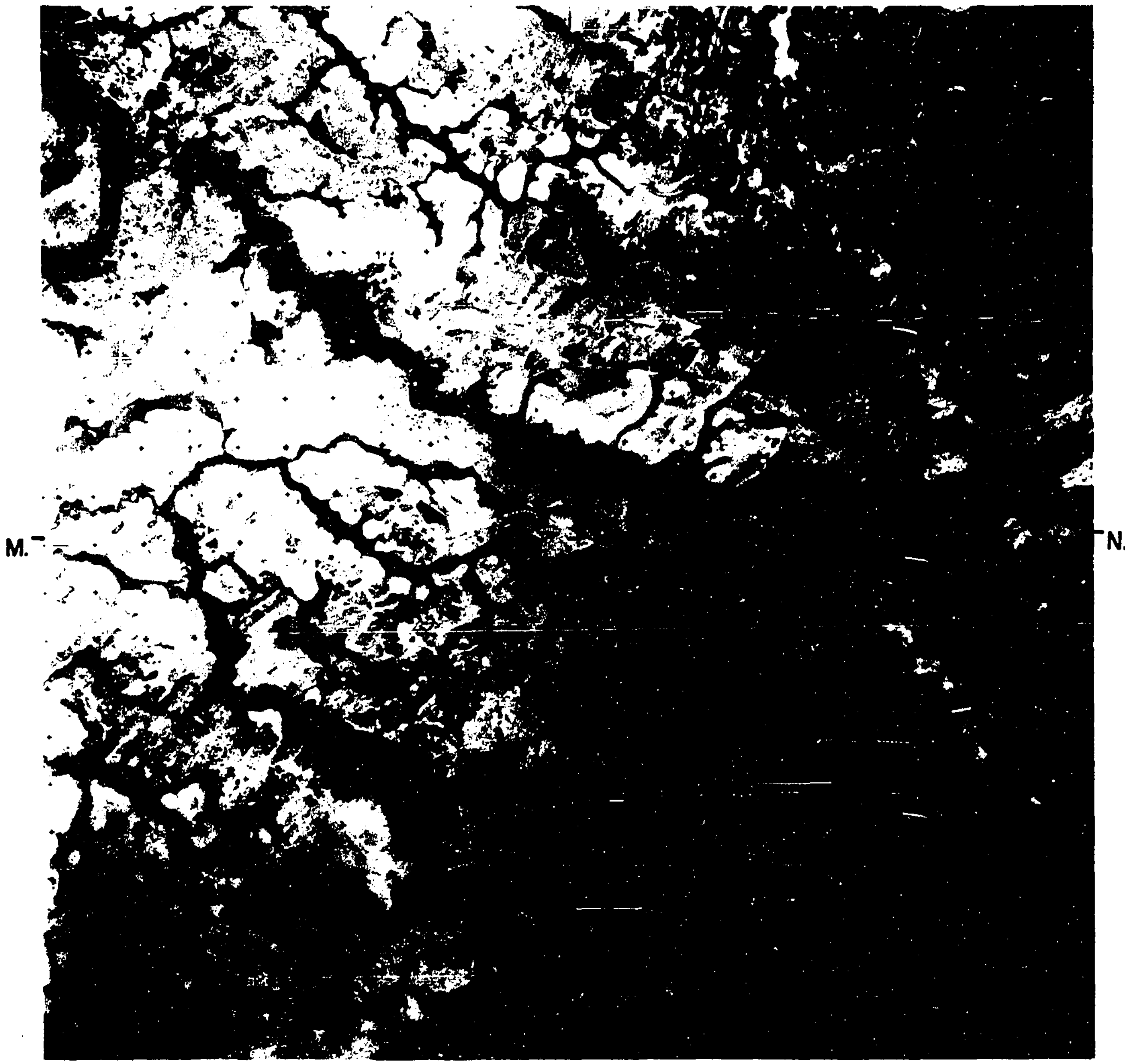
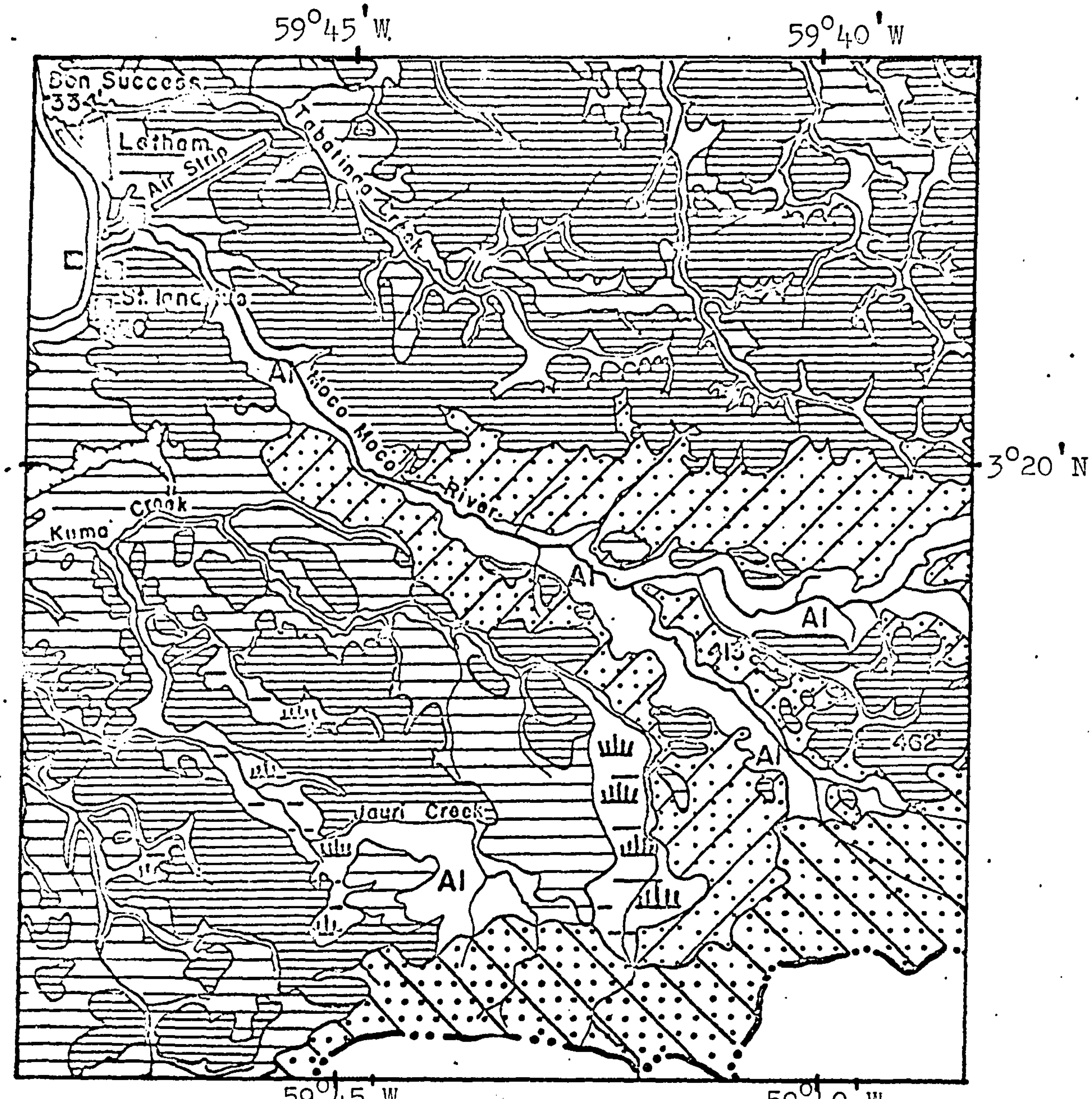
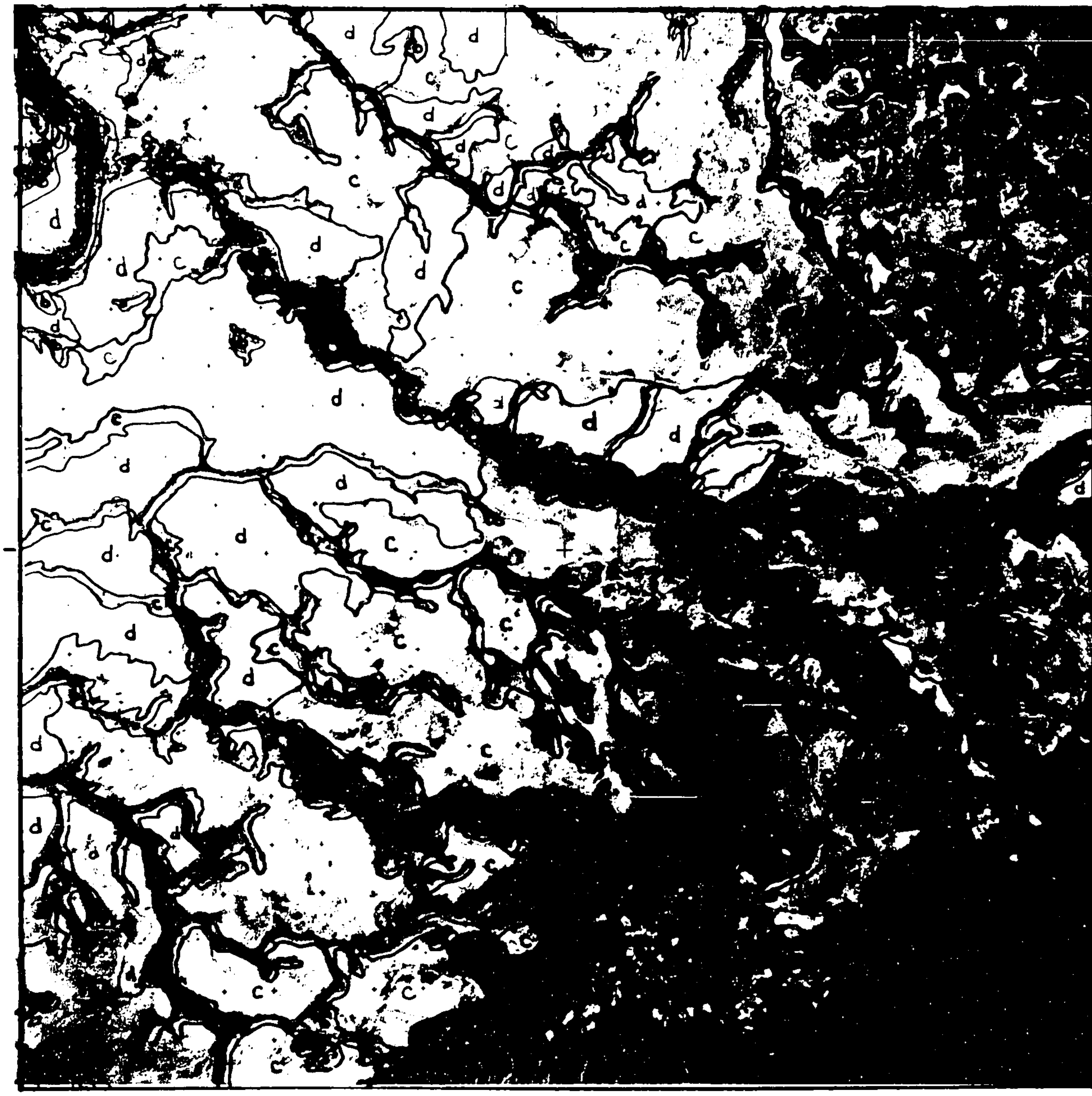


PLATE 37:. Western laterite Upland Block. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967)

M.  N.

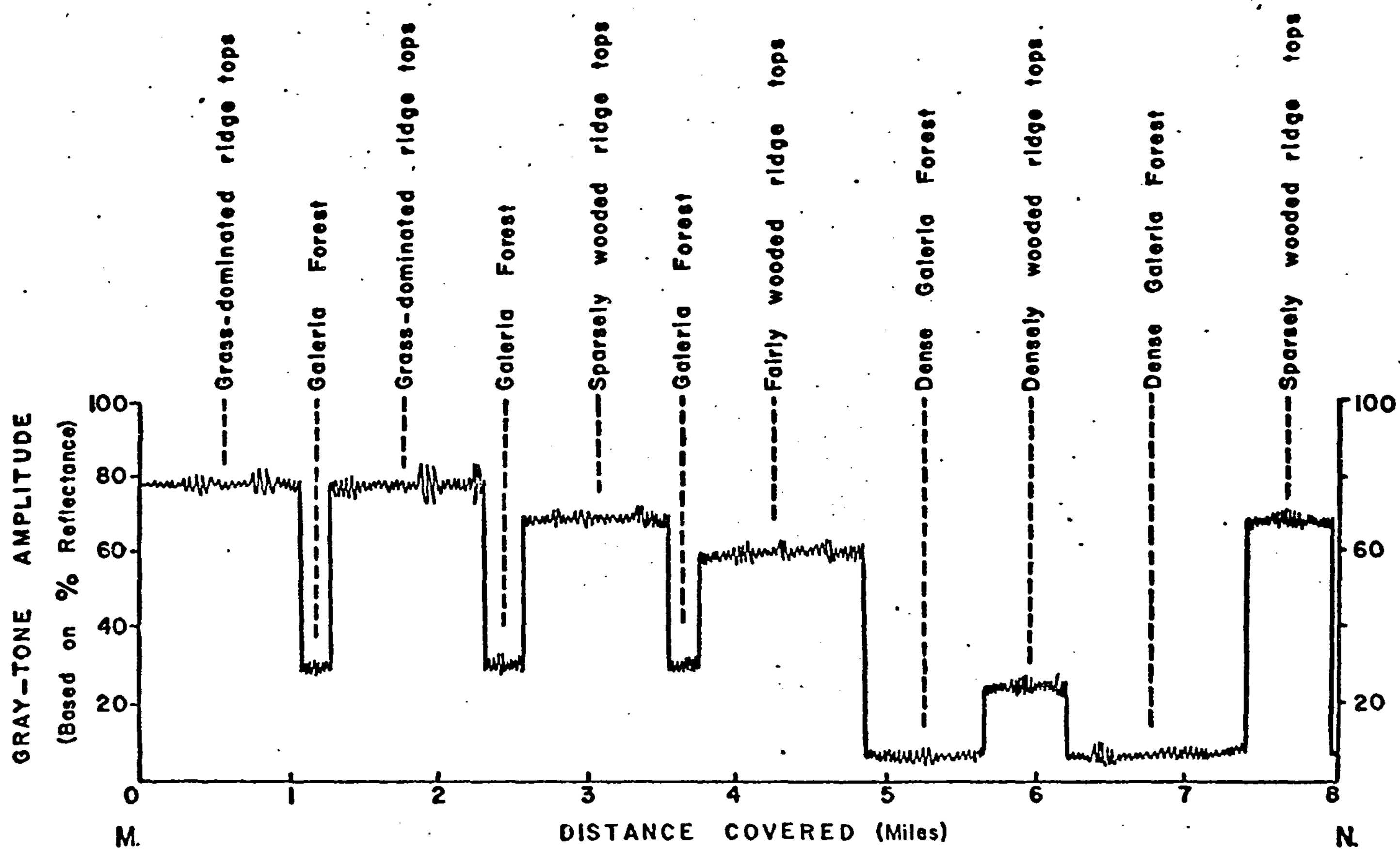


FIG. 43. Graphical Comparison of Gray-Tone Values of Terrain Types of the Western Upland Block along Line MN. on Plate 37.

Windapo, 1968.

value range of between N3 and N4. The fairly well-wooded and imperfectly drained creek areas (b) where moisture conditions have reduced the surface reflectance value are dark toned with a neutral value range of between N4 and N5. The areas marked (c) correspond to densely wooded areas of campo coberto with a tonal value of N6 and a reflectance of about 30 per cent, while those areas marked (d) are open ridge tops with a range of tonal values between N8 and N9.5 and a high surface reflectance ranging between 60 per cent and 90 per cent. All these tonal values show sharp boundary contrasts as shown in Fig. 43 and the range of variation is summarized in neutral range diagrams in Table XVIII.

CHAPTER VI

THE KANUKU SCARPLANDS

The land pattern formed by the Kanuku Scarplands is found along the northern and southwestern margins of the Western Kanuku Mountains (Fig. 9). The north-facing scarp rises to a varying elevation of between 1,500 to 2,500 feet above the adjacent laterite uplands (Fig. 44). The fault-scarp consists of three component parts that have been laterally displaced along NE-SW faults as shown in Fig. 4. This displacement is perhaps responsible for the down-faulting of the Takutu shale and the overlying recent sediments in the direction of the Kanuku scarps. Evidence of such down-faulting has been found along the Takutu River west of the mountain, six miles upstream from San Jose, where the sedimentary rocks have been down-faulted relative to the gneisses exposed slightly further upstream (Morris, 1962). The southern section of the scarp is not as prominent as that to the north because the western Kanuku mountain block gradually decreases in elevation towards the Southern Savannas. It is however bounded by a relatively straight scarp trending ESE-WNW as shown in Fig. 4.

The major landform units found within the pattern include scarp faces, pediments and scarp foot slopes with a number of outliers particularly on the south-facing side (Table VIII). Unlike the Pakaraima scarp, deep chemical weathering could be observed all along the Kanuku scarp faces though

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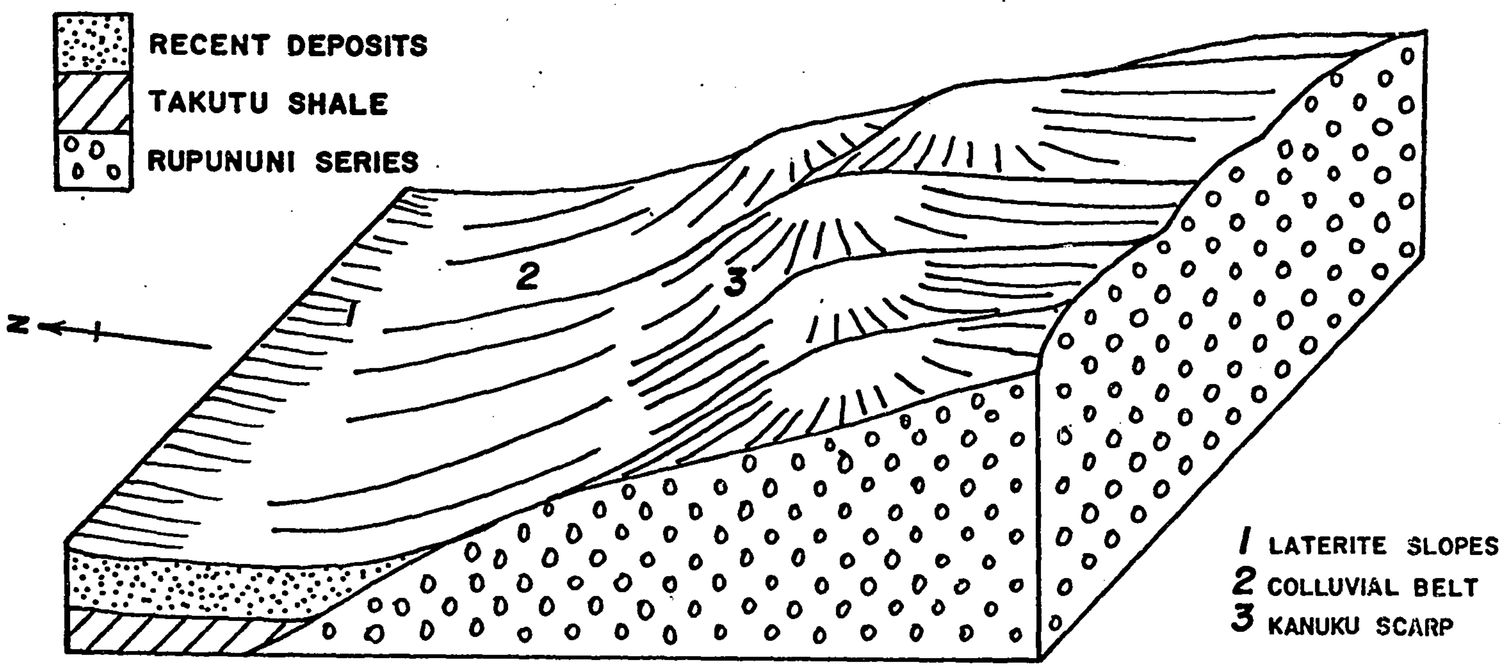
FIG. 44. THE KANUKU SCARPLAND



Windapo, 1968.

unweathered granite exposures occur in places, some protruding as rock ledges. Thus, both mantled and bare-rock slopes can be found along the scarps which are carved up by slash-gullies in places, especially along the northern face.

In both northern and southern sections, the pediments are areas of deep weathering as well as deposition with protruding granite rocks in places. On the north-facing side, there is evidence of laterization especially along the banks of the major streams traversing the zone - MocoMoco being a typical example.

Within the colluvial scarp foot of the northern face too, laterite bodies occur and are particularly noticeable along stream courses where they have been exposed. Such laterite bodies are conspicuously absent within both the pediment and the scarp foot of the southern scarp face. This can be attributed to the poorer drainage condition of the pediment and scarp foot of the southern scarps as revealed by the occurrence of many backswamps - an equivalent of which is not found within the better drained north-facing section.

The soil of the scarp foot is generally colluvial sandy loam which has developed from weathering and rottening of granites and gneisses of the Kanuku scarps. This sandy loam belt forms the most fertile belt in the whole of the study area, and it is consequently the most exploited for arable farming. Important farming areas of this zone include Inaja, Kumu, MocoMoco, Hiawa and Nappi (Plate 38). Table XIX shows the sieve analysis of a soil sample taken within this

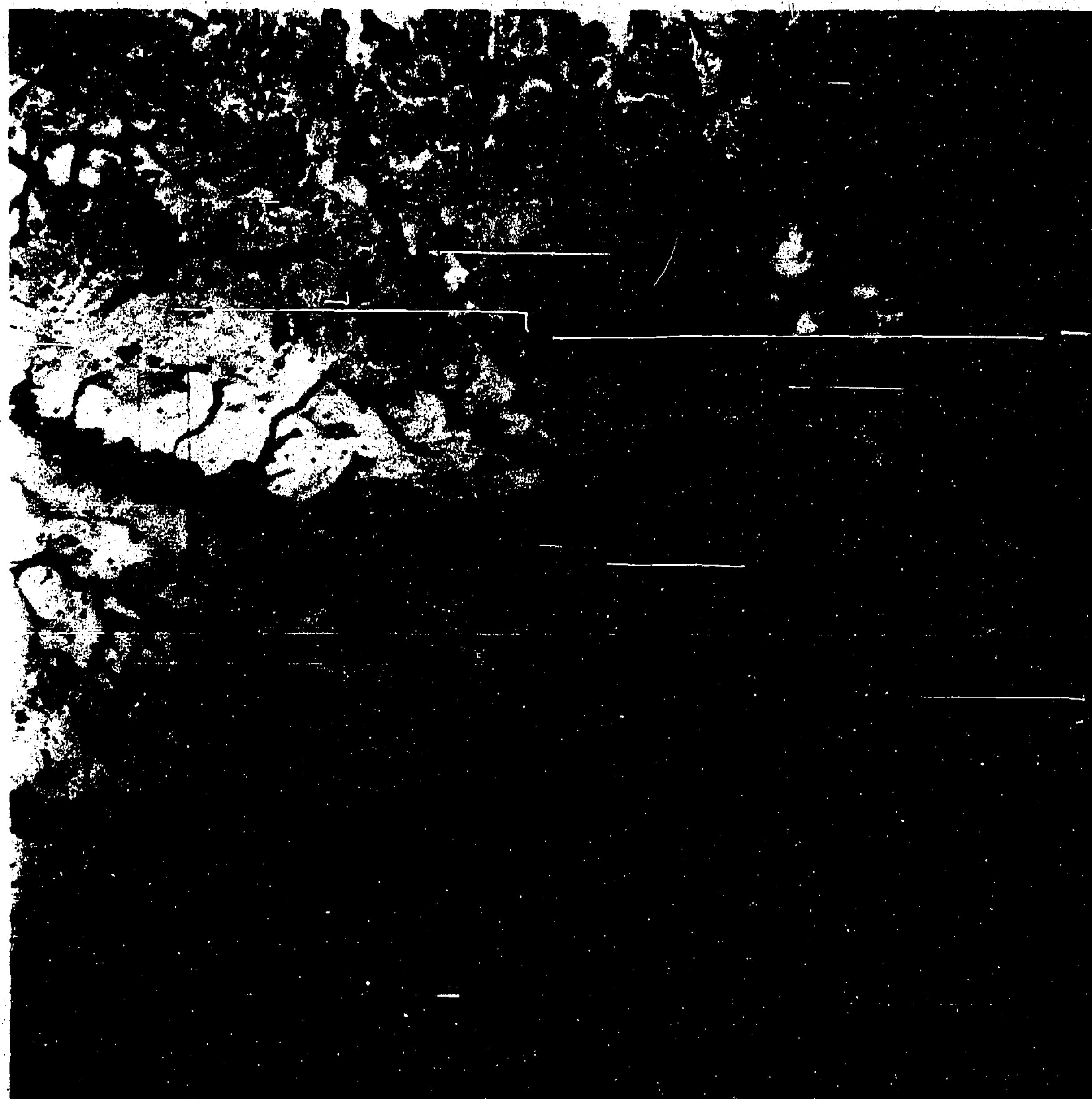


PLATE 38: Cultivation sites within the Kanuku colluvial forest belt. (Photo by Hunting Aerosurveys Ltd.)

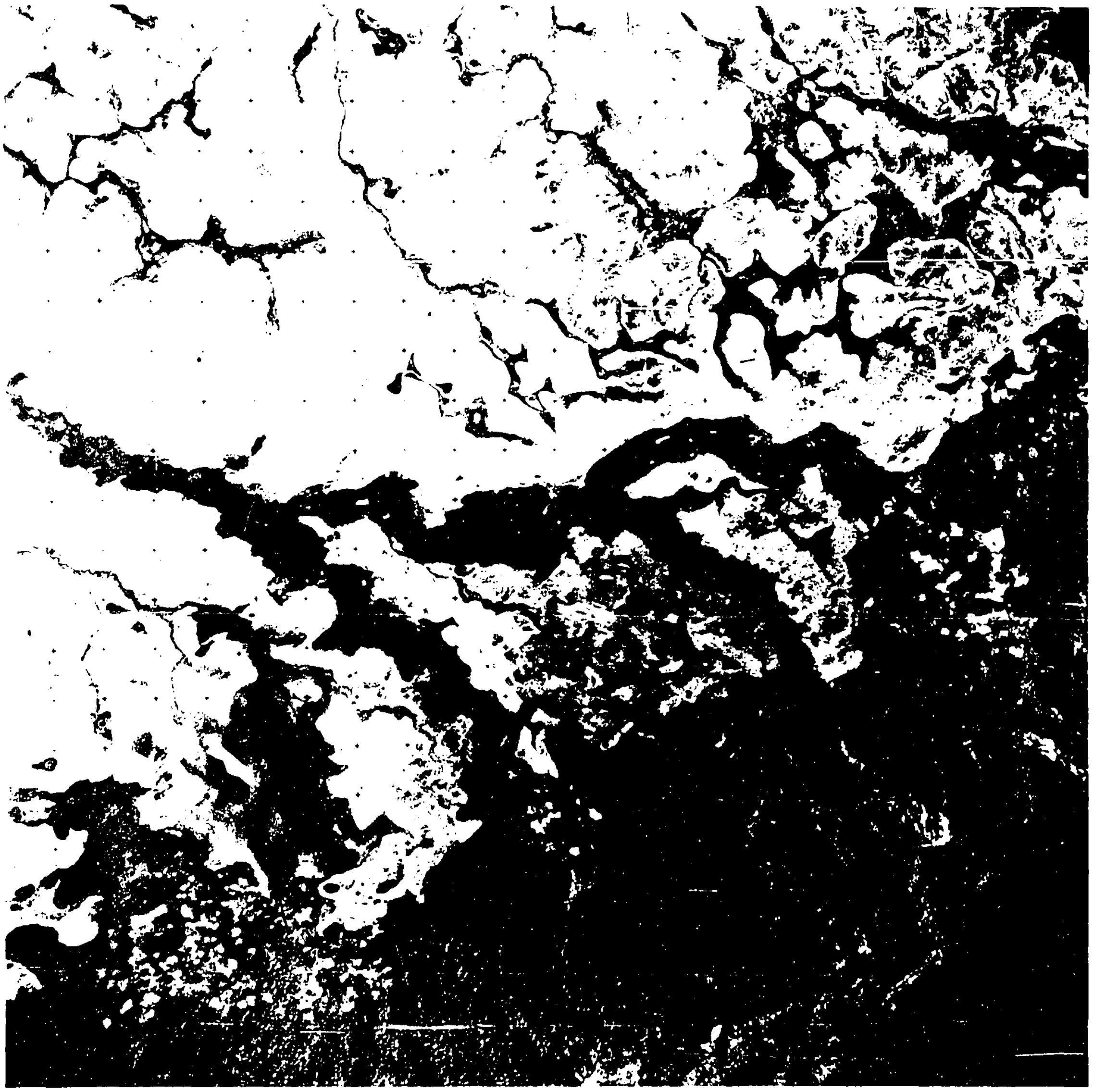


TABLE XIX

Sieve Analysis of Soil from Kanuku Colluvium Belt.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.8	10YR
3	-		5/3
2	1		brown
1	2		
.5	11		
.25	57		
.125	17		
.088	3		

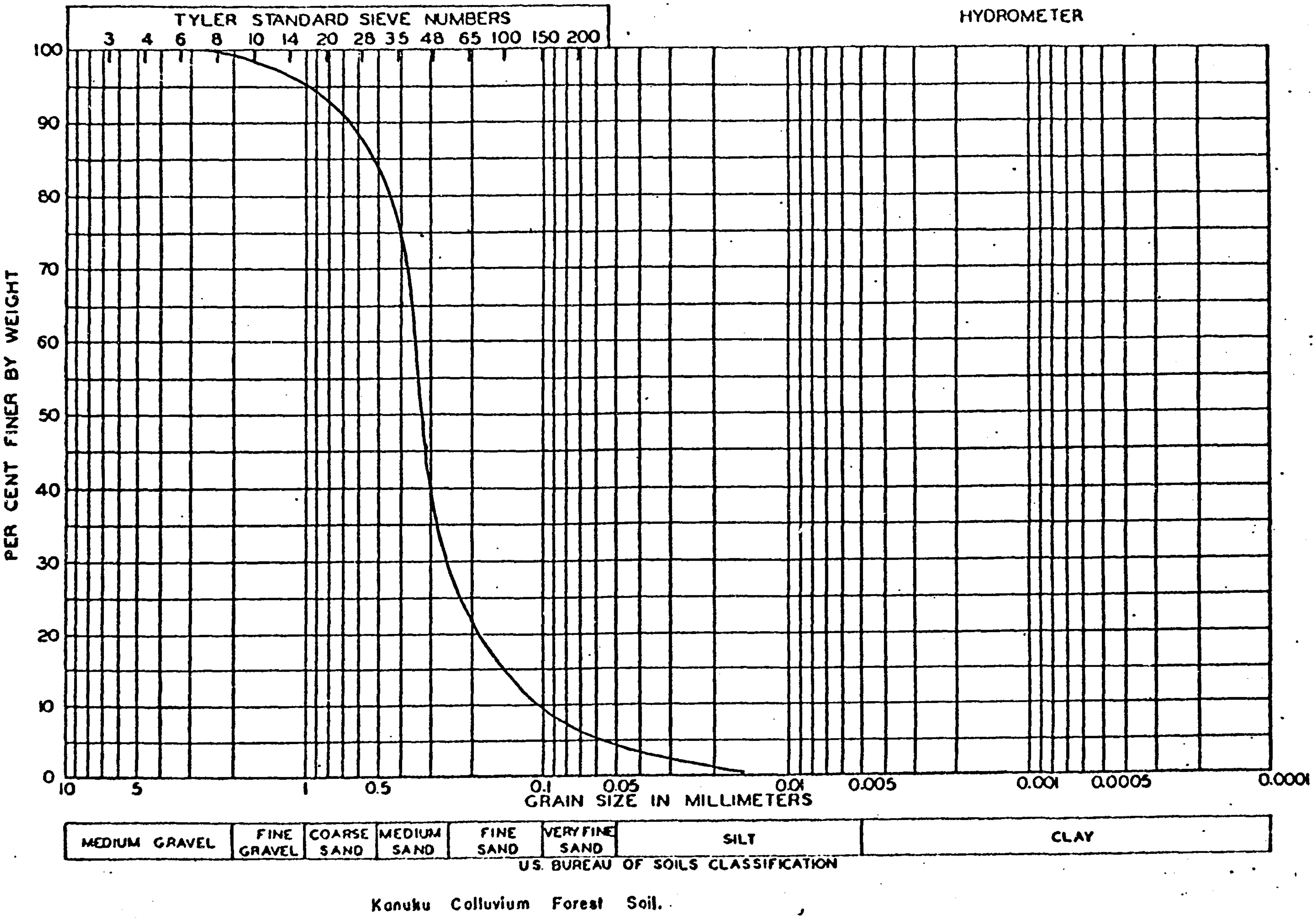


FIG. 45. GRAIN SIZE DISTRIBUTION DIAGRAM: Kanuku Colluvium Belt.

zone while Fig. 45 presents the grain-size distribution curve of the sample.

The whole landform pattern is generally forested, but the cultivated areas have lost their original forest cover, maintaining only secondary forests in fallow. The patches of lighter tones within zone 3 of Plate 37 represent such cultivated areas of MocoMoco and Hiawa within the forested scarpland.

AIR-PHOTO CHARACTERISTICS OF THE PATTERN.

Generally, the Kanuku scarplands are thickly forested, and this forest has acted as a mask hiding the terrain variations under a dark tone imposed by the vegetation. It is only in the cultivated patches of the colluvial scarp foot that variations of tone are appreciable, as within the areas marked (e) in zone 3 of Plate 37. In the uncultivated forests marked (a) on the lower overlay, the range of tonal values varies only between N2.5 with a surface reflectance of about 5 per cent and N3.5 with a surface reflectance of about 10 per cent. Within the cultivated patches of the scarp foot on the other hand, the tonal value ranges from N4 with a surface reflectance of about 12 per cent to N8 with a surface reflectance of about 60 per cent. A summary of these tonal variations is presented by means of neutral value range diagrams in Table XX where the general terrain characteristics of the landform pattern are shown.

TABLE XX: AIR-PHOTO CHARACTERISTICS OF THE KANUKU SCARPLAND PATTERN

Sub Pattern	Plates & Zones	Sub pattern variants	Approx. % coverage	Drainage	Vegetation	Soils	Darker Lighter Neutral Values 1 5 10
The North-facing Section	Plate 37 Zone 3	Collu-vial Belt	60	Well drained internally. Surface drainage channelled into stream courses and their side gullies.	Mainly thick forest with patches of secondary bush in cultivated areas.	Mainly sandy loam.	
		Scarp Faces	40	Freely drained by stream channels with a dendritic pattern.	Thick forest	Pockets of thin sandy loam layers separated by bare rocks.	
The South-facing Section	Plate 39 Zone 5	Collu-vial Belt	70	Generally well drained with pockets of backswamp. Surface drainage channelled into stream courses and side gullies	Thick forest with patches of bush	Mainly sandy loam	
		Scarp Faces	30	Freely drained by streams with dendritic pattern.	Thick forest	Thin mantle of sandy soil interrupted by bare rock surfaces.	

□ Dominant Values

< > Range of Values

• Mean Value

CHAPTER VII

THE SAPAIKA - SAWARIWAU LOWLAND

This Landform Pattern occupies the south-western part of the study area. It is bounded on the north by the Sapaika River, on the south by the Sawariwau River, on the east by the Kanuku mountain scarp, and on the west by the flood-plains of the Takutu river. Within this belt, the laterite terrain has completely disappeared, giving place to a complex juxtaposition of ponds, swamps and sand dunes (Plate 39). Most of the dunes are found on the western section where they increase in height towards the Takutu flood-plains. Around Jacare and Central, they attain heights of about 25 - 35 feet above the intervening flats and swamps. Fig. 46 is a profile taken about half a mile east of Central settlement; it represents one of the highest sand hills of the belt. Eastwards, the dunes lose heights, becoming small mounds rising slightly above the swamps in the centre of the zone. Further eastwards from the centre, the land begins to gain in elevation towards the Kanuku scarpfoot as depicted by the block-diagram in Fig. 47.

Although there is a uniform morphological assemblage of swamps and dunes all over the pattern area, two major zones are recognizable. The first covers all areas of higher dunes. This zone stretches from north to south adjacent to the Takutu flood-plains with a small looping belt stretching eastwards parallel to the northern banks of the Sawariwau River to form a crude L-shaped pattern. The longer north-south axis covers

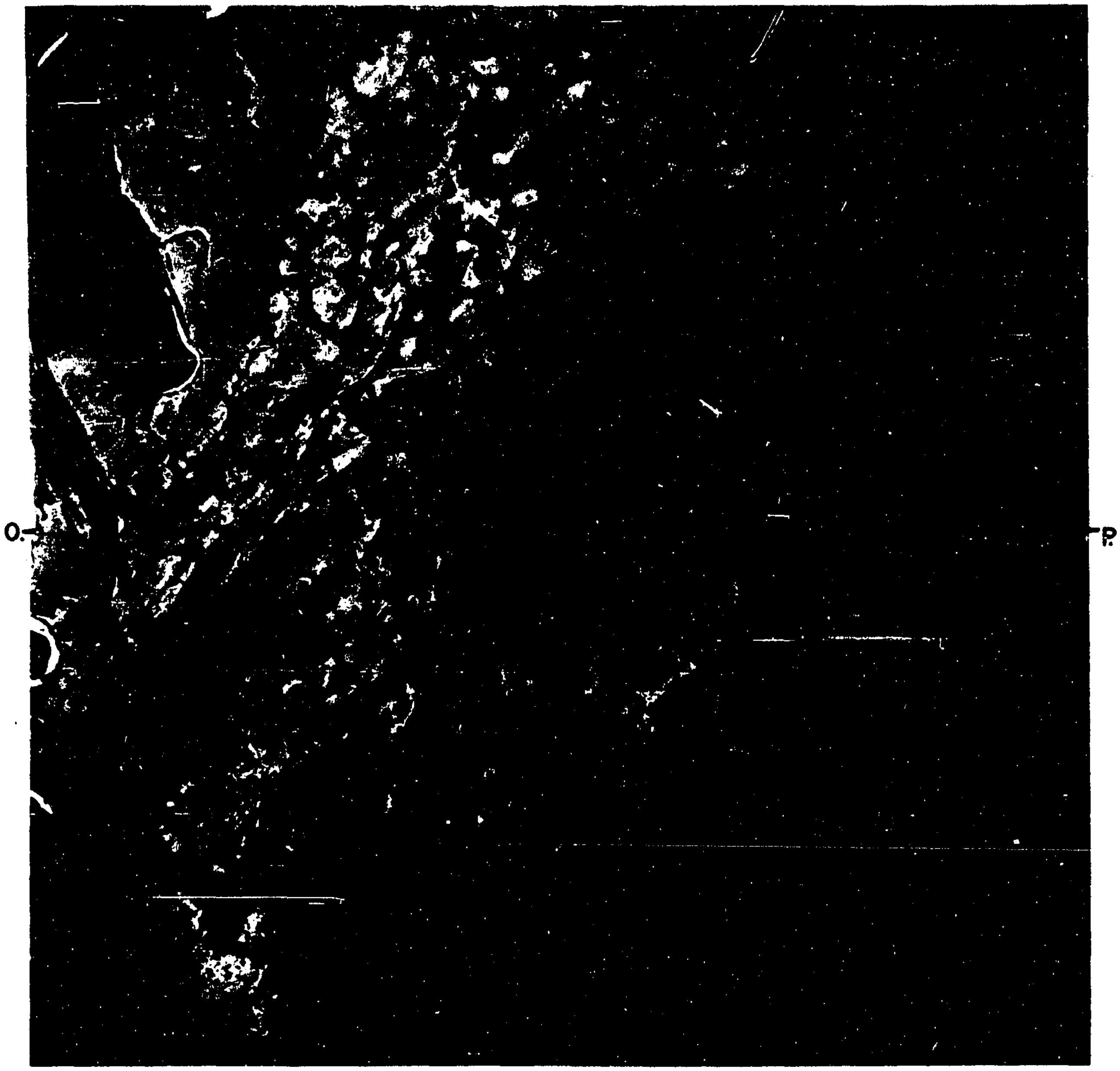
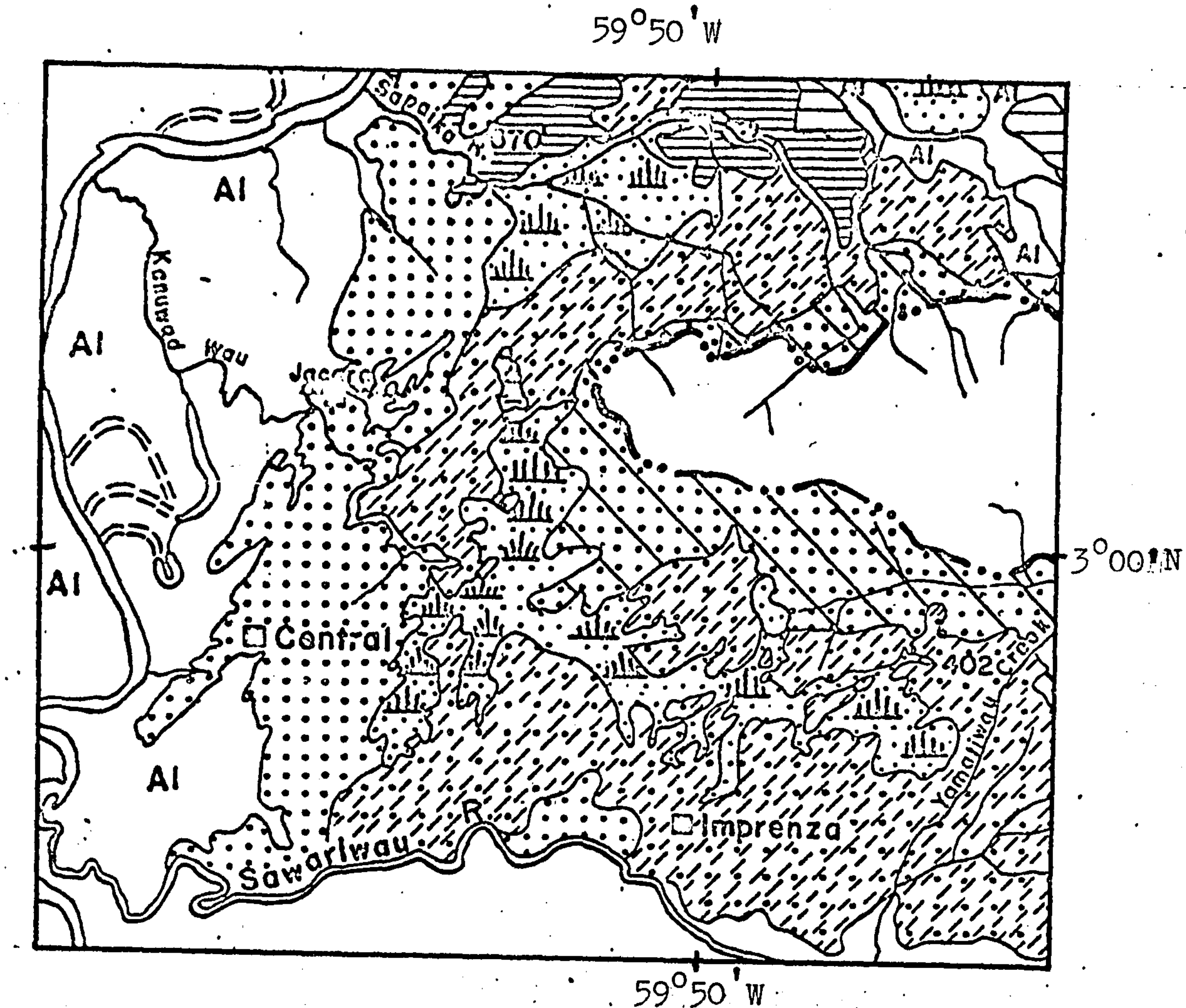


PLATE 39: Sapaika-Sawariwau Lowland. (Photo by Hunting Aerosurveys Ltd.)



(Adapted from Sinha, 1967)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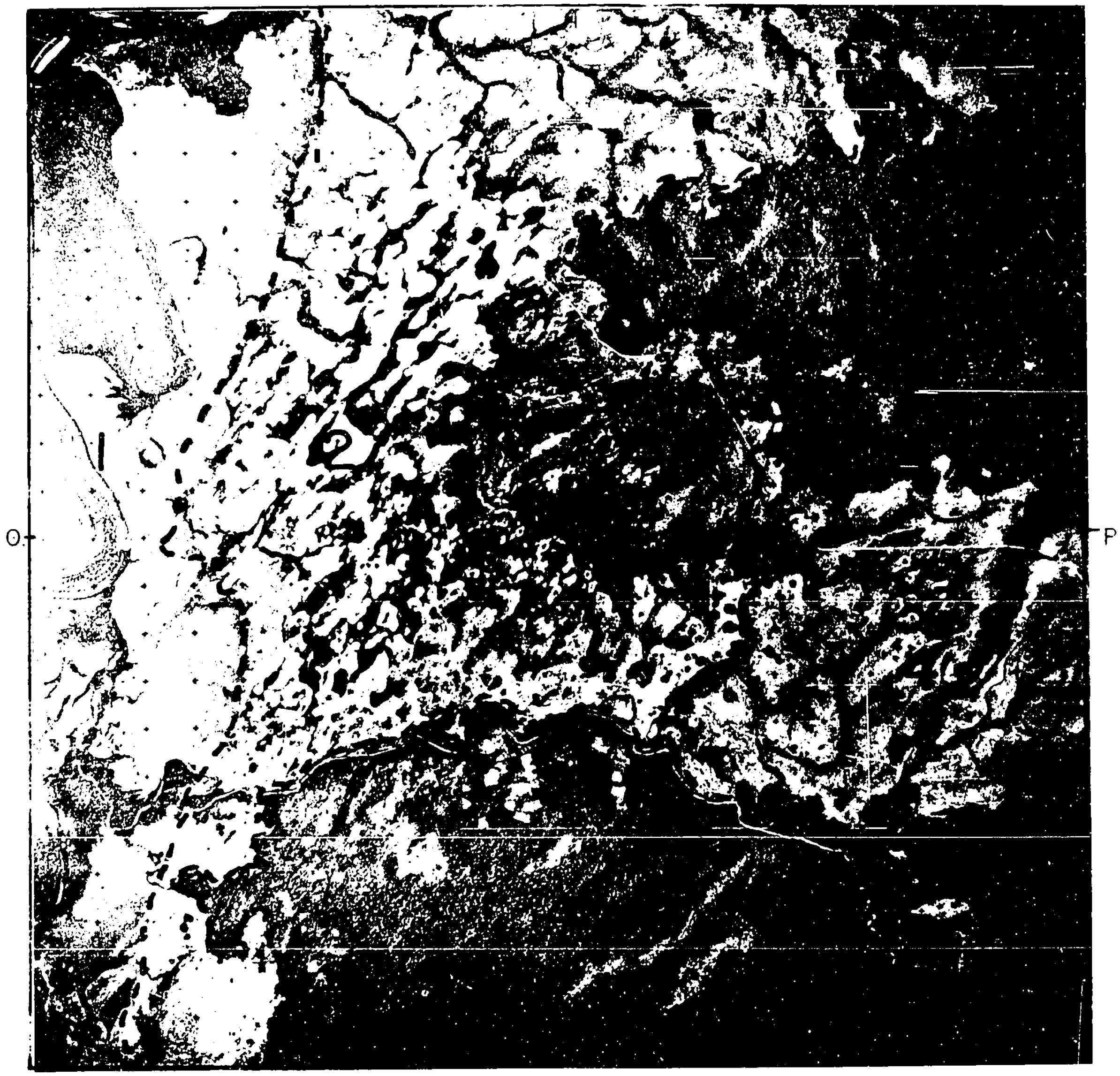
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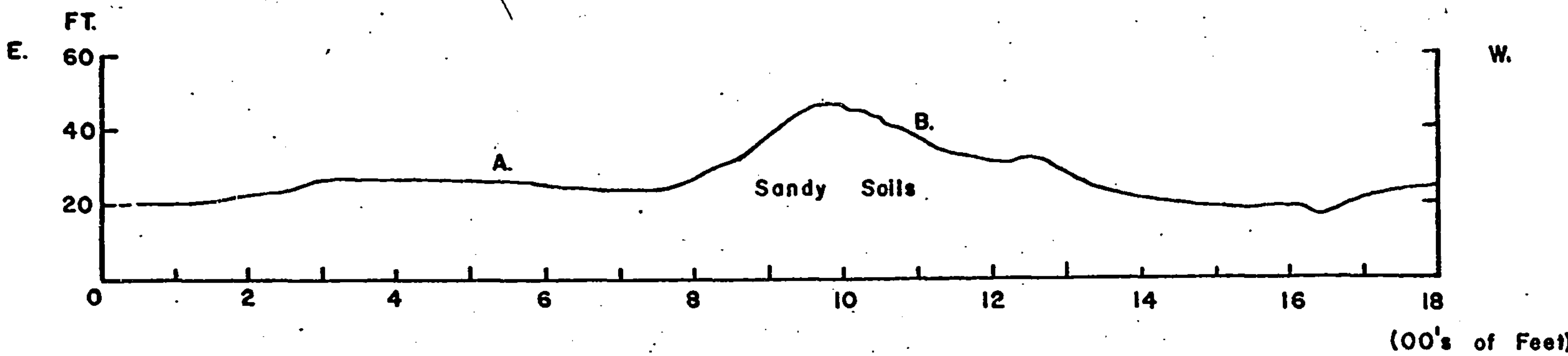


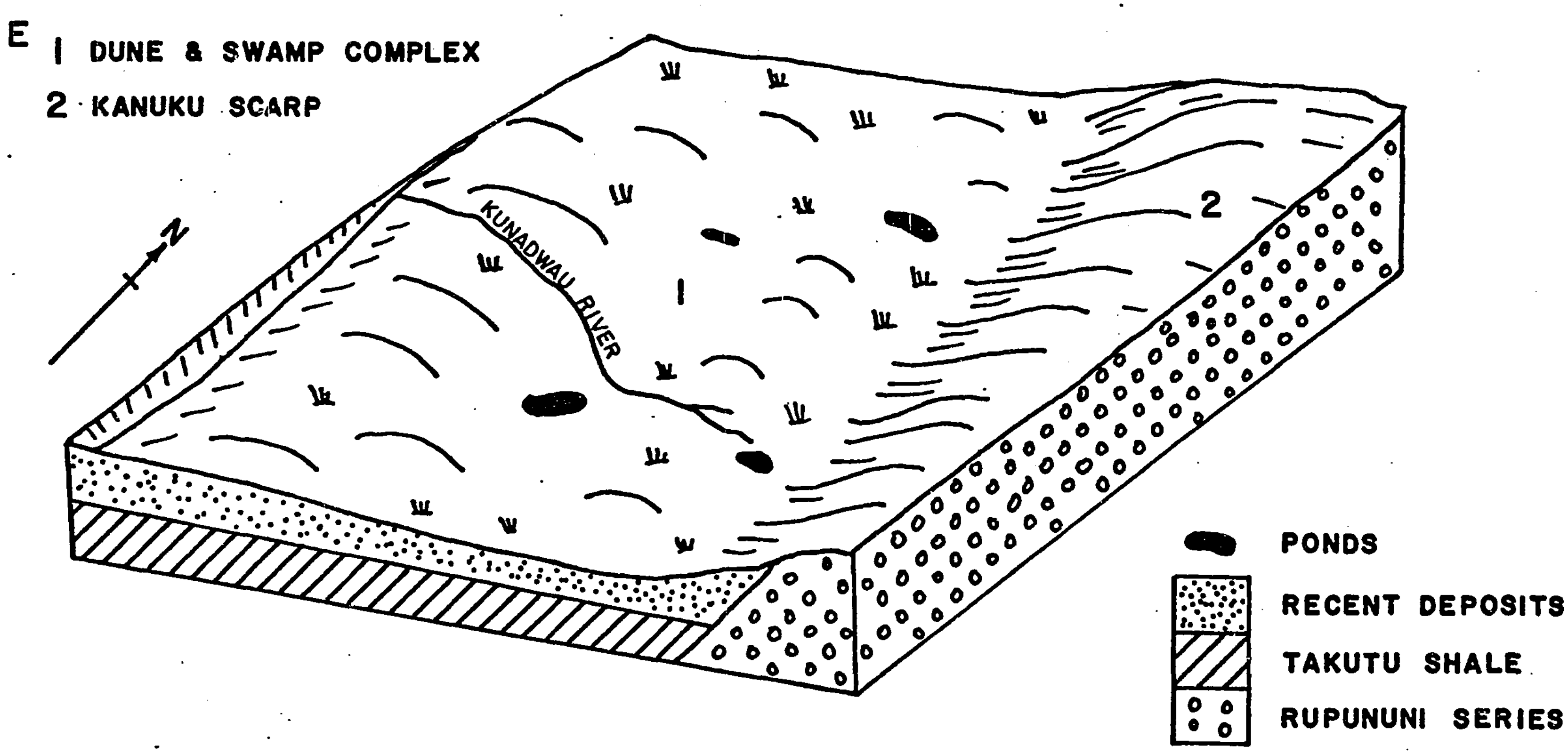
FIG. 46. Profile Across A Sand Ridge Half-Mile East Of Central.

Note: A. and B. are Soil Sample Sites.

Windapo, 1968.

E

FIG. 47 THE SAPAIKA - SAWARIWAU DUNE & SWAMP COMPLEX



Windapo, 1968.

such important areas as Jacare and Central, while the shorter west-east axis centres around Imprenza. Although Sinha (1967) has mapped the Imprenza area as belonging to a different soil series as shown in the map of surficial deposits, accompanying Plate 39, the author regards this area as part of the same soil group found around Jacare and Central. All these areas are covered by structureless sands of medium grains on the hills and silty loam in the depressions. The only apparent difference is that the west-east axis is relatively more dissected than the north-south axis. Also, all the dunes of the two axes are aligned in a northeast-southwest direction as shown in Plate 39, but while the north-south axis extends for about three miles from the banks of the Takutu to the western borders of the second zone of smaller and lower sand dunes, the shorter west-east axis maintains a width of about two miles from the banks of the Sawariwau to the southern borders of the second zone.

The major landform components of this zone comprise high dunes, sand flats, silty depressions, marsh flats, swamps and drainage ways. The high dunes are composed of well sorted structureless sands with medium grains in the greatest proportion as shown in Table XXI and presented diagrammatically in Fig. 48. These dunes are generally excessively drained internally and consequently carry a very open campo sujo type of savanna.

On the other hand, the sand flats dominated by medium grains (Table XXI, Fig. 48) are well drained areas and

TABLE XXI

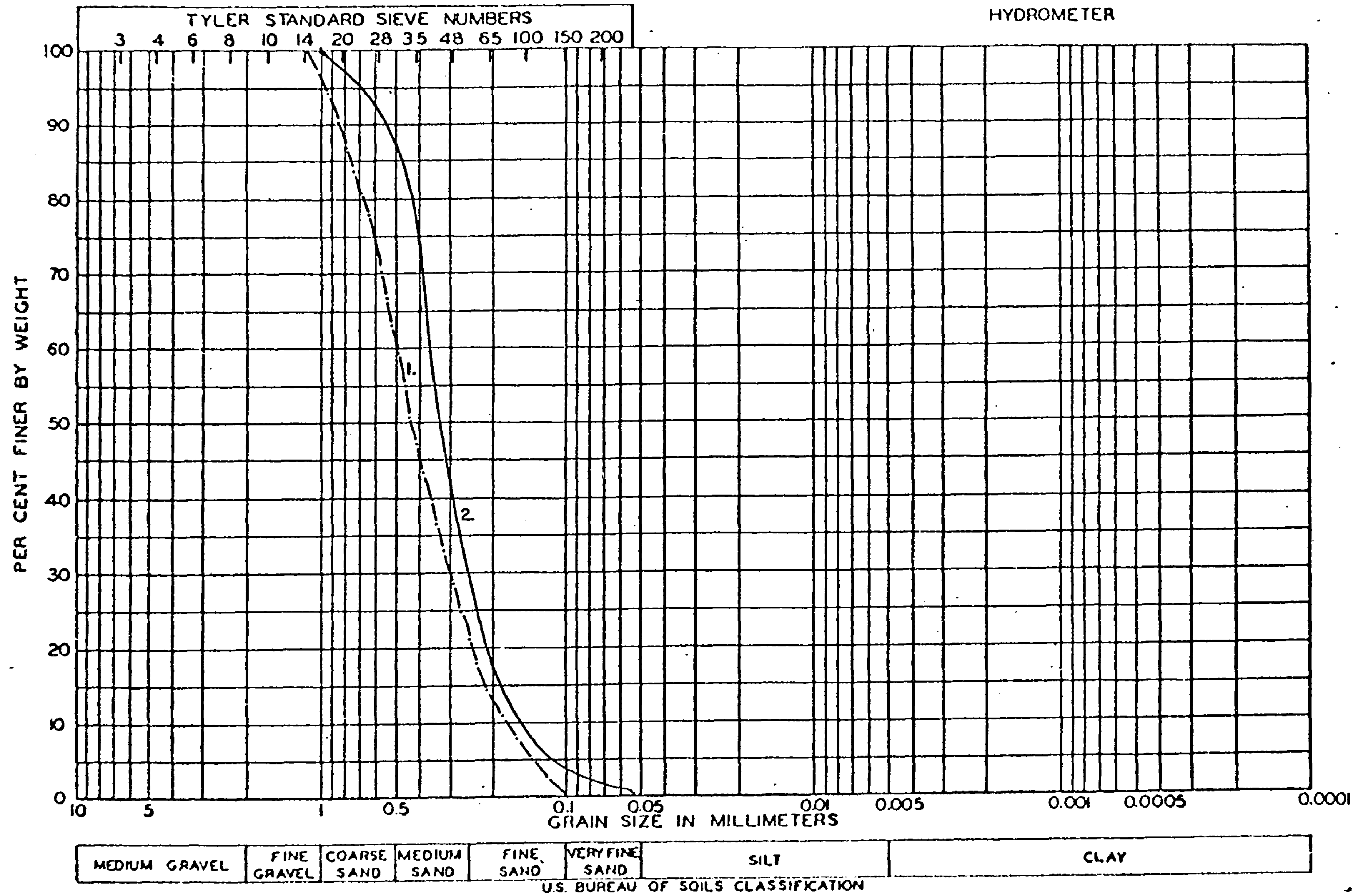
Sieve Analysis of samples on high Dune and flat near Central.

1. High dune Soil Sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	10YR
3	-		6/2
2	-		light
1	3		brownish
.5	36		grey
.25	40		
.125	17		
.088	-		

2. Flat Surface Soil Sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	10YR
3	-		5/1
2	-		grey
1	-		
.5	11		
.25	57		
.125	23		
.088	2		



1. Central: Hill Slope Soil.

2. Central: Sand Flat.

FIG. 48. GRAIN SIZE DISTRIBUTION DIAGRAM : High Dune Complex

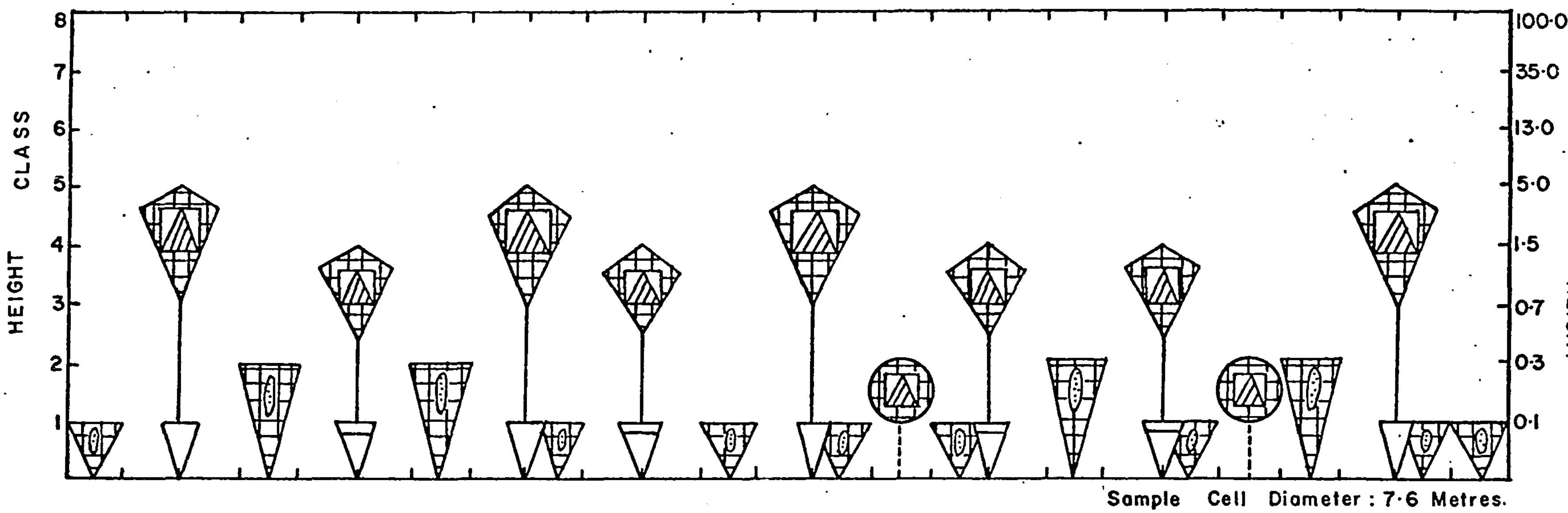
are relatively densely wooded, maintaining a campo coberto type of savanna dominated by such trees as Byrsonima crassifolia, Baudichia Sp. and curatella americana. Fig. 49 is a structural diagram of a sampled cell on the flat adjacent to the high hill half a mile from Central ranch settlement. The dominant tree in the sampled area is a type of Baudichia locally referred to by the Amerindians as Murukpure.

The marsh flats and the swamps are generally areas of silty loam materials and they maintain only campo limpo savanna composed of sedges and grasses in the marshy areas and pure sedge communities in the swamps. Within both the marshes and swamps could be found belts of terrawards masked by tall grasses. Where local depressions occur, pockets of ponds are not uncommon, creating cooling grounds for the pigs of the local farmers in the dry season as at Central and Imprenza.

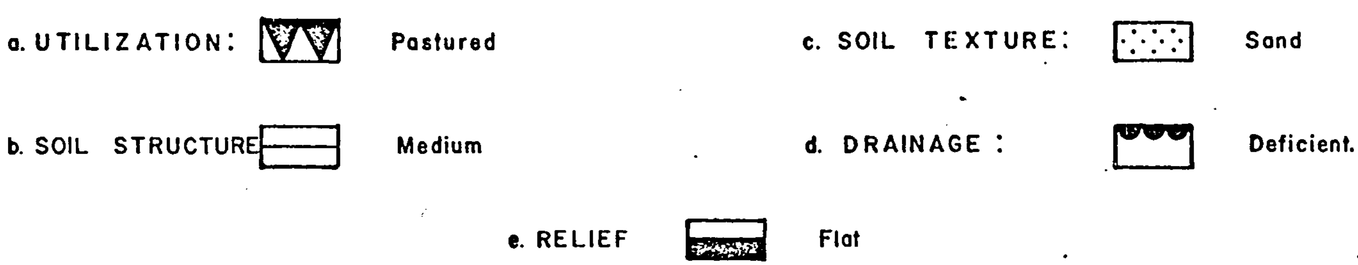
The second zone is found to the east of the longer north-south axis of the first zone. It is referred to as the eastern dune complex under the landform units of Table VIII. The major landform components of this unit comprise low dunes, sand flats, silt-clay depressions, marsh flats, swamps and drainage ways. The low dunes are generally well drained with coarser sand grains. Table XXII shows the sieve analysis of a sample taken on a low hill about four miles east of Central and Fig. 50 presents the grain-size distribution curve of the sample. The coarseness of the sand could be attributed to the

FIG. 49. VEGETATION STRUCTURAL DIAGRAM

Sandy Flat East of Central.



SITE SITUATION



Windapo, 1968.

TABLE XXII

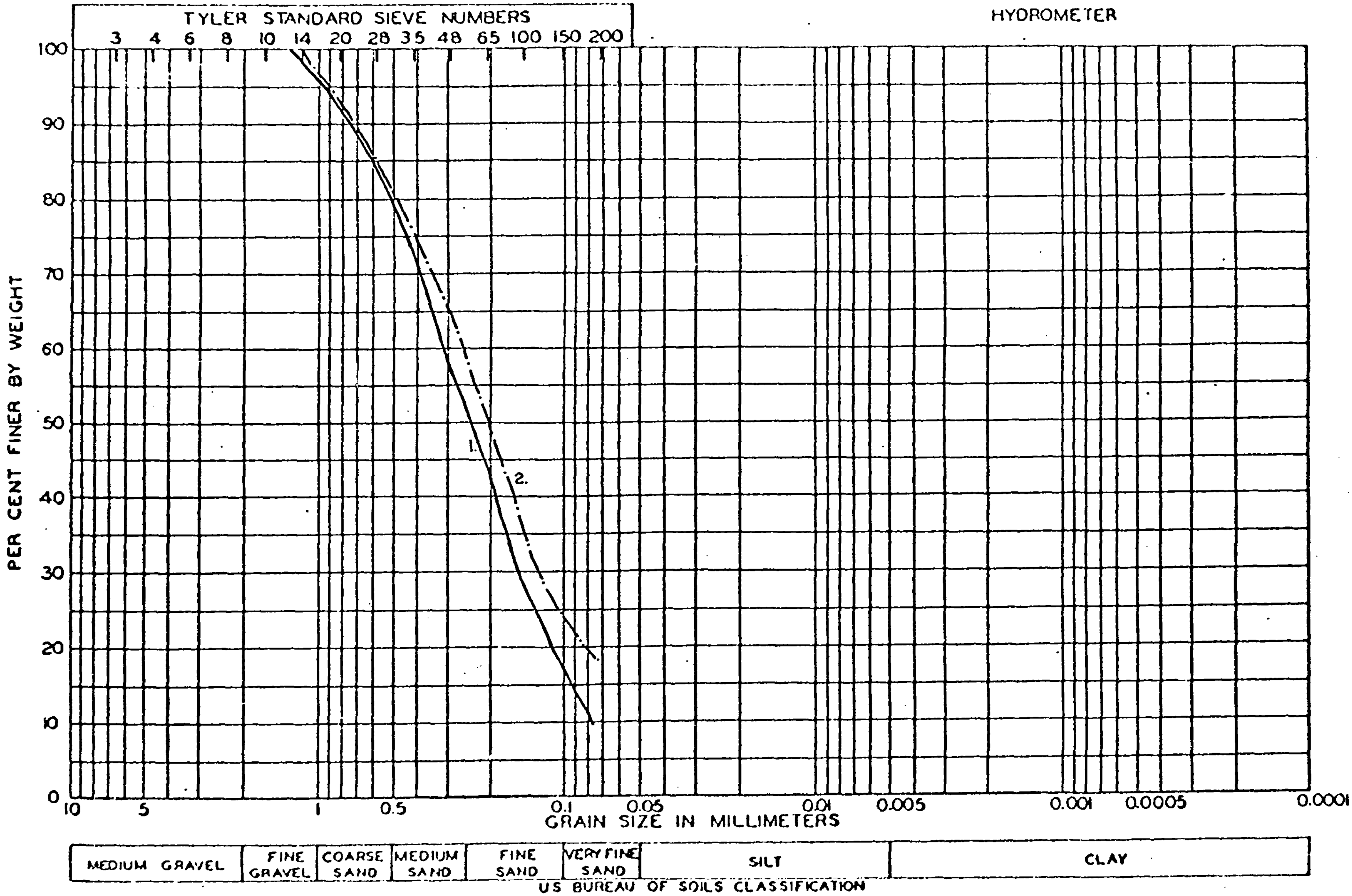
. Sieve Analysis of samples on low dune and flat four miles of Central.

1. Low dune soil sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.2	10YR
3	-		6/2
2	-		light
1	3		brownish
.5	16		grey
.25	30		
.125	36		
.088	4		

Flat surface soil sample.

Sieve No.	% of sample above sieve	pH	Colour
5	-	5.4	10YR
3	-		6/2
2	-		light
1	3		brownish
.5	16		grey
.25	22		
.125	31		
.088	4		



1. Low Sand Hills 4 Miles East of Central

2. Sand Flat Adjoining Low Hills 4 Miles East of Central.

FIG. 50. GRAIN SIZE DISTRIBUTION DIAGRAM : Low Dune Complex

sifting effect of water at flood times. As the water laps on the sandy hills, finer materials are washed into the depressions leaving the dunes coarser than those of the first zone which were able to stand above the flood waters. Since they are close to the ground water-table due to their heights above the seasonally flooded flats, they are able to maintain a densely wooded *campo coberto* savanna type all over the zone. The dominant tree species include *Baudichia Sp*. and *curatella americana*.

The sand flats composed of silty loam materials are only moderately well drained in parts. Where they are close to creeks, they maintain dense *campo cerrado* type of savanna with *Baudichia* and *Byrsonima crassifolia* in dominance. Adjacent to the swamps are poorly drained marsh flats which are only sparsely wooded with dense substratum of clump grasses and sedges. They are dotted in parts by closely spaced huge terrawards which are often densely grown with clump grasses.

The fairly depressed swamps constitute pockets of herbaceous *campo limpo* sedge-dominated savanna within the eastern zone. Unlike the swamps of the first zone, they retain surface water throughout the year. Consequently only the hardy phreatophitic sedges inhabit these areas.

AIR-PHOTO CHARACTERISTICS OF THE PATTERN.

Zones 2 and 3 of Plate 39 cover the Sapaika - Sawariwau Lowlands and these two zones display varying air-photo characteristics as could be appreciated from the tonal patterns marked on the second overlay to the Plate. Zone 2 represents the high dune belt. Within this belt are dunes covered in varying degrees by vegetation, and breached by many flats and depressions dotted by swamps and ponds. All these landform components with their different tonal values have thus combined to give the zone its mottled appearance which is so striking on the air-photograph.

Within this zone, the areas marked (a) show the darkest tonal values of between N2.5 and N3.5 with a very low reflectance between 5 per cent and 9 per cent. These are areas of ponds and swamps within the bottomlands, and enclaves of thickets on some of the sand dunes of the west-east axis. The areas marked (b) with a tonal range between N4 and N5 are mainly restricted to the bottomlands. They mark the densely wooded flats and creek valleys in many parts of the zone. But in a few places, they reflect the moisture condition rather than vegetation cover, especially in areas of semi-permanent swamps. The few areas marked (c) are the fairly densely wooded dunes towards the margins of the zone as it merges into the second zone of lower and smaller dunes. The areas marked (d), on the other hand, occupy the greatest proportion of the zone, and cover the sparsely wooded high dunes. Their tonal values range between N8 and N9 with high reflectance values of between 60 per cent and 80 per cent.

The second zone marked (3) on the first overlay shows fewer tonal variations than the first zone. The few areas marked (a) show a tonal value of N3.5 and a reflectance of

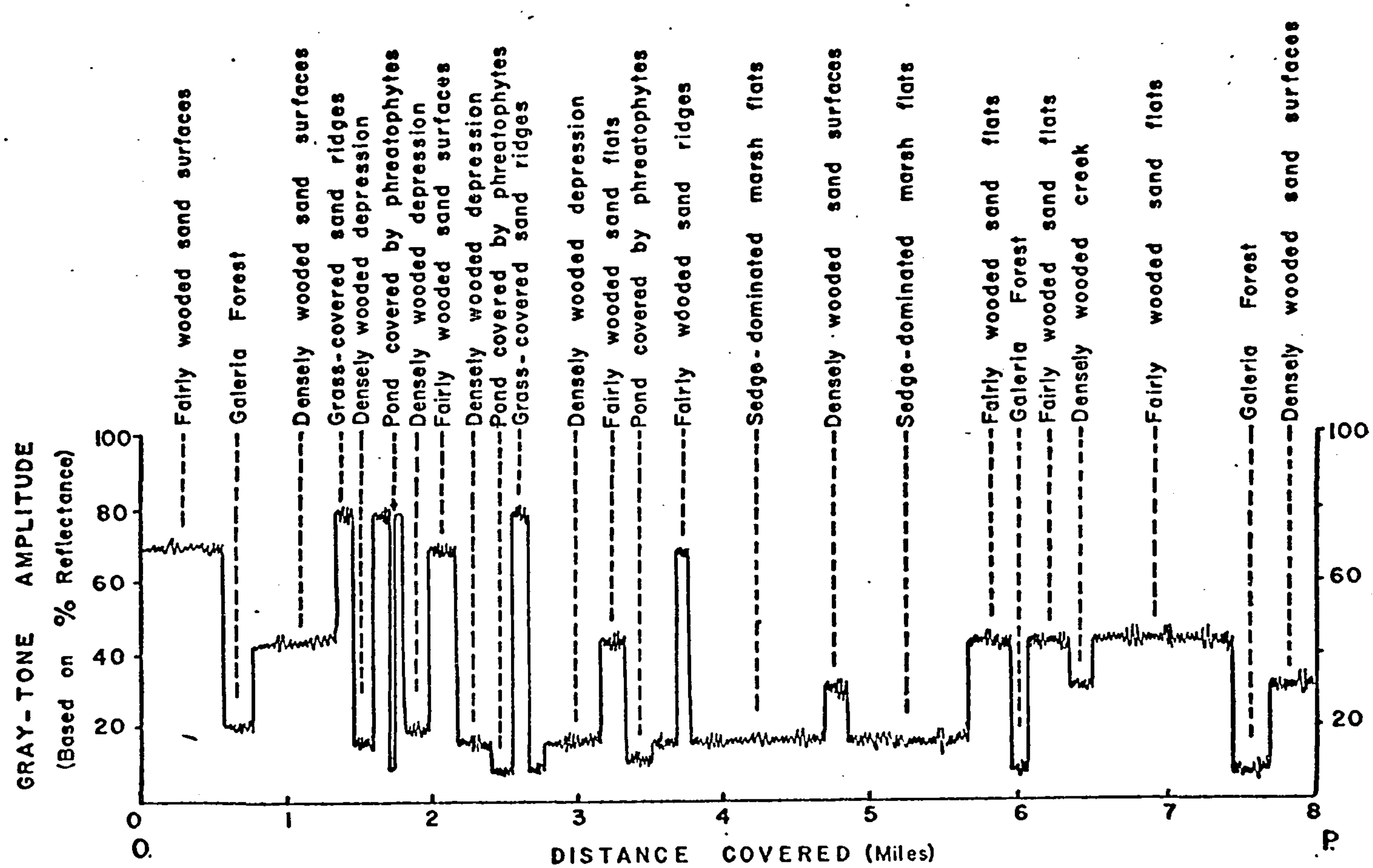
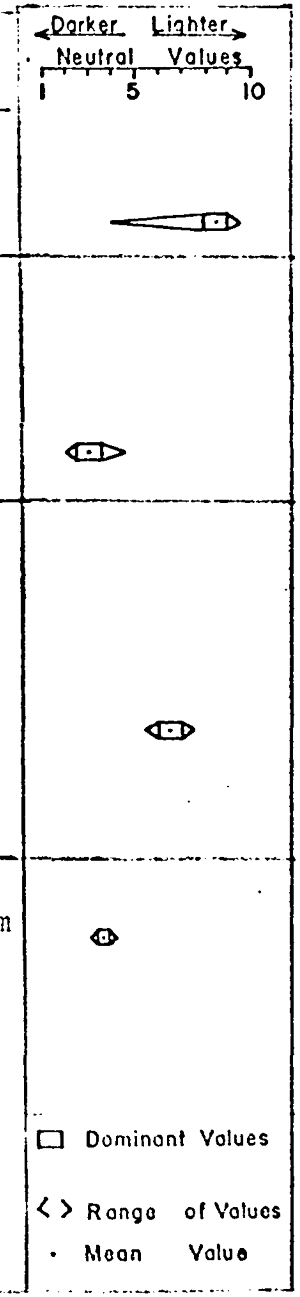


FIG. 5I. Graphical Comparison of Gray-Tone Values of Terrain Types of the Sapaika-Sawariwau Lowlands along Line OP. on Plate 39.

Windapo, 1968.

TABLE XXIII: AIR-PHOTO CHARACTERISTICS OF THE SAPAIKA-SAWARIWAU LOWLANDS

Sub Pattern	Plates & Zones	Sub pattern variants	Approx. % coverage	Drainage	Vegetation	Soils
Western Section	Plate 39 Zone 2	High dune surfaces	70	Excessively drained internally	Mainly Campo sujo	Structure-less sands
		Bottom-lands	30	Poorly drained. Many swamps and ponds	Campo limpo sedge dominated	Silty loam
Eastern Section	Plate 39 Zone 3	Low dune surfaces	30	Moderately well drained	Campo cerrado depleting to campo coberto	Structure-less coarse sands when dry.
		Bottom-lands	70	Poorly drained	Campo limpo sedge-dominated	Silty-loam to clay loam



9 per cent. These are the belts of galeria forests along creek valleys. The largest portion of the zone comes under areas marked (b), and these areas cover the extensive flats and swamps which are mainly of herbaceous campo limpo savanna. Their darker tones of between N4 and N5 are not a reflection of vegetation cover, but an indication of the moisture condition.

Towards the borders of the zone are also found few areas marked (c). These coincide with the densely wooded dunes that have managed to rise above the swamps of the zone. They present tonal values of between N6 and N7 with a reflectance of about 30 - 40 per cent. With these sand mounds dotting the generally darker swamps, the whole zone presents a speckled texture and looks relatively darker than the first zone. This contrast can be appreciated from the wave-form graph (Fig. 51) taken across the two zones from O to P on Plate 39. The western section of the graph largely reflects the grey-tone amplitude and frequency of the first zone, while the eastern part is more representative of the second zone. A summary of the tonal values for both zones is presented diagrammatically in the last column of Table XXIII which shows the overall air-photo characteristics of the landform pattern.

CHAPTER VIII

THE MAJOR FLOODPLAINS

This landform pattern is associated with areas subjected to seasonal flooding by the major rivers. Within this pattern are recognized two sub-patterns - western and eastern sections - on the basis of permanence of flooding and maturity of the landform units. Forming the western subpattern are such landform units as the Ireng Flood-plain and the Takutu Flood-plain, while the eastern sub-pattern is formed solely by the Rupununi Flood-plain. Common to all these landform units are such landform components as ox-bow lakes, sand flats, levees, backswamps, over-flow scars, abandoned channels, and entrenched channels (Table VIII).

The Ireng Flood-plain.

The Ireng Flood-plain starts north of Moreiru and extends along the river to its confluence with the Takutu within a distance of about 60 miles in the study area. Within the Marakanata Lowlands and the laterite landscape, the flood-plain extends in varying dimensions, with the maximum width in the Marakanata depression where the plain stretches across the Rego River - a legacy of the Old Ireng - to join the flood-plain of the Rupununi in the height of the rainy season.

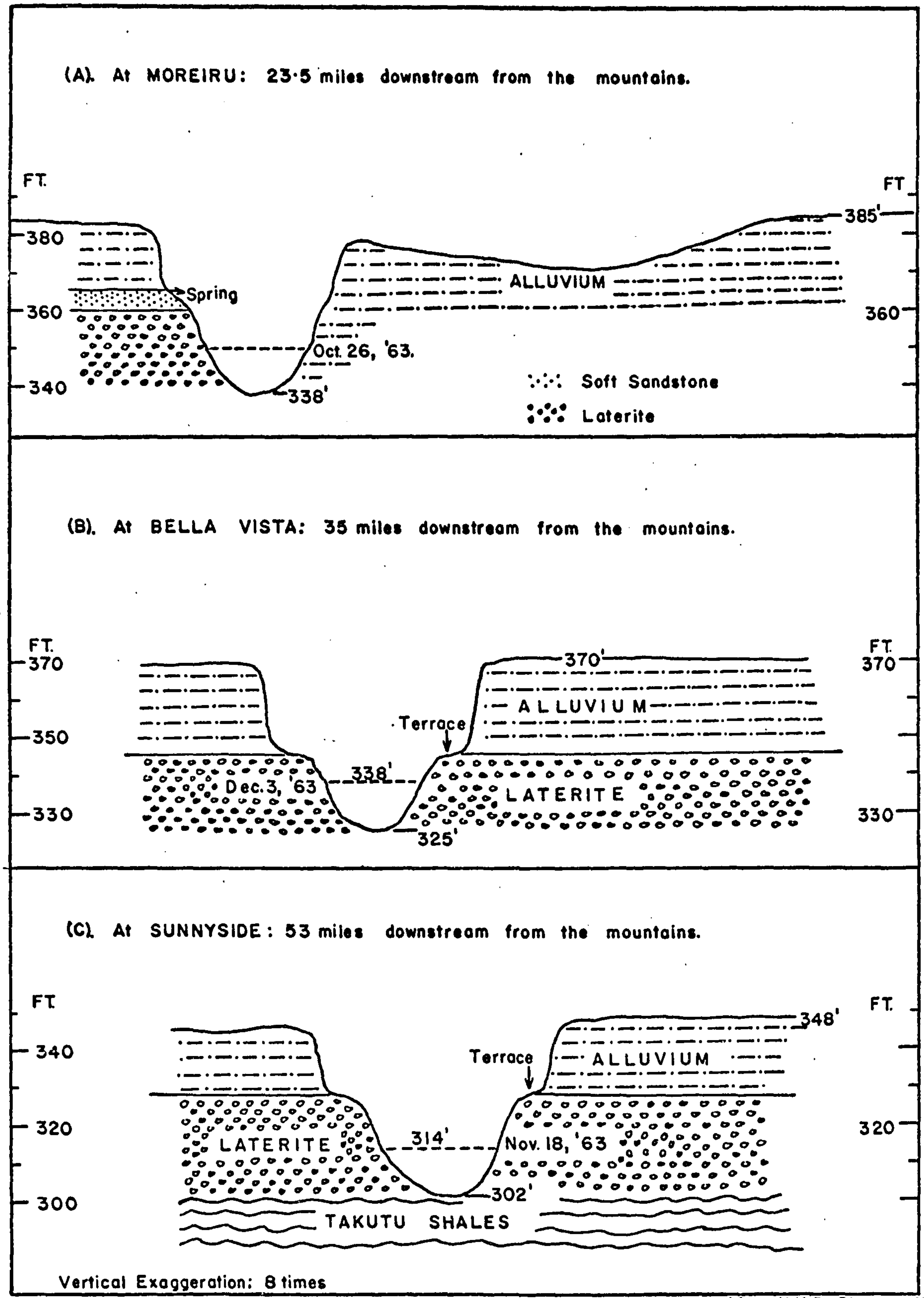
The Ireng River as it exists today in the area of the Northern Rupununi shows evidence of rejuvenation. From the

Karasabai Landing about 15 miles upstream from Moreiru, to its confluence with the Takutu, the river is marked by an entrenched channel which is particularly striking in the zone of laterite landscape where an entrenchment of about 45 feet could be measured at Bella Vista and Sunnyside (Fig. 52). Between Good Hope and Karasabai, the entrenched channel is flanked by point-bar deposits, large meander cut-offs and discarded channels.

The Ireng River in its new course is susceptible to what has been described as flash flooding (Rutherford, 1957). This behaviour derives from the heavy rainfall in the Pakaraimas. The river quickly overflows its banks, inundating extensive portions of the lands on either side of its banks. With a pause in the rains, the river level quickly drops and the flooded areas quickly drain back into the river channel.

The flash-flooding greatly affects the hydrology of the flood plains. At each flooding, water is trapped within the many saucer-shaped depressions reminiscent of the large meander cut-offs of the river's former course. Some of these depressions remain as lakes almost throughout the dry season when the surrounding sandy belts are very dry.

The soils along this flood-plain belong to old alluvium. This is because the entrenched river is unable to maintain permanent flooding whereby it could add more recent alluvium to the old terraces along its banks. These soils vary from dark-grey to pale brown silty loam. In the depressions where pockets of dark-grey clays occur, the

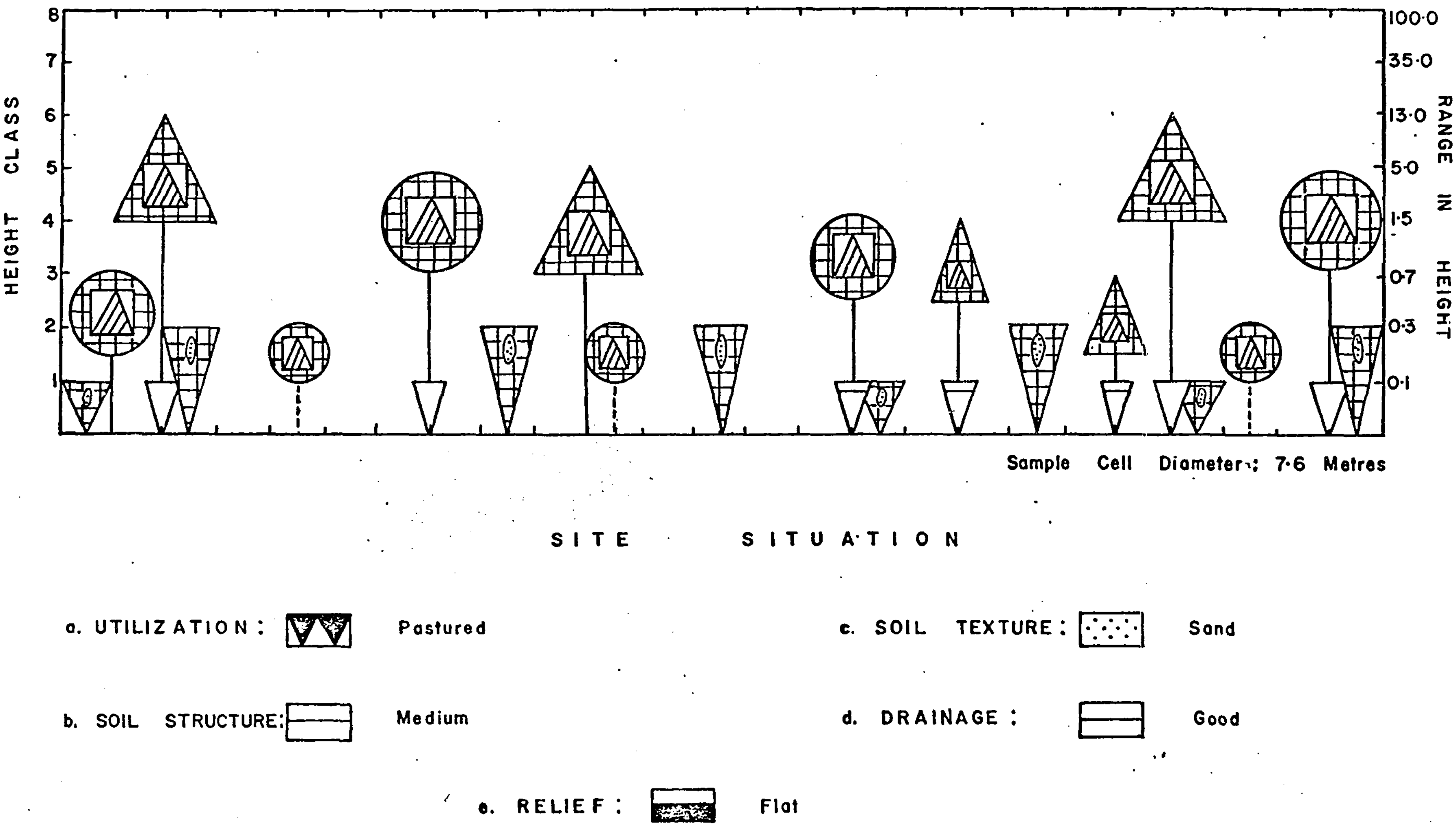


After N.K.P. Sinha, 1967

FIG. 52. PROFILES ACROSS THE IRENG RIVER
SHOWING TERRACES and ENTRENCHMENT.

FIG. 53. VEGETATION STRUCTURAL DIAGRAM

Near Good Hope Police Station



Windapo, 1968.

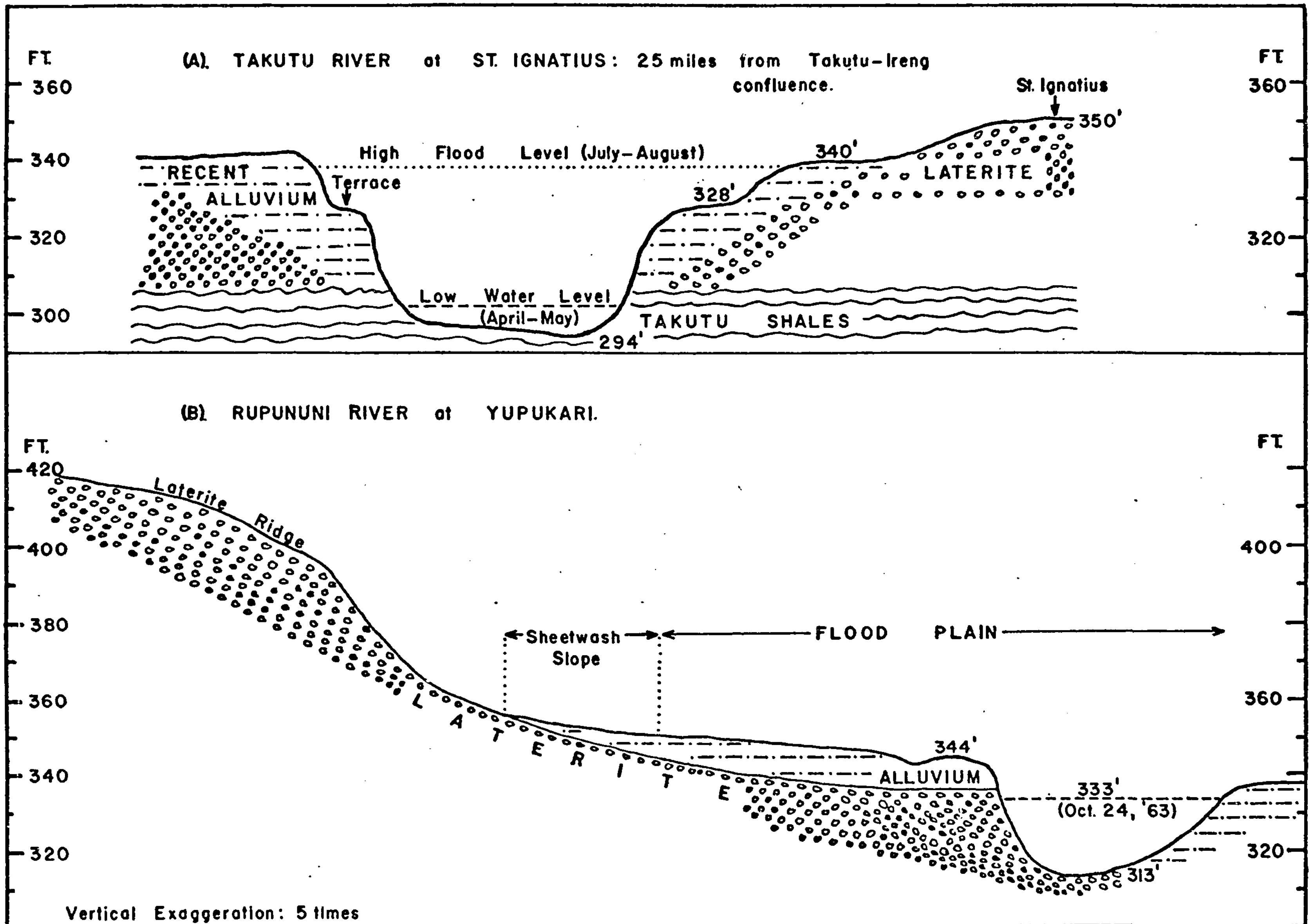


FIG. 54. PROFILES ACROSS (A). THE TAKUTU and (B). THE RUPUNUNI RIVERS, SHOWING TERRACES and ENTRENCHMENT.

After N.K.P. Sinha, 1967.

surfaces of the clay crack up exhibiting angular blocky structure.

The vegetation of this plain is mainly wooded savanna - campo cerrado - semi-orchard in appearance, with curatella americana in dominance. Fig. 53 is a structural diagram of a sampled cell near the Ireng, south of Good Hope Police Station. Discontinuous belts of galeria forests are also found along the river banks in varying widths, especially towards its confluence with the Takutu River.

The Takutu Flood-plain.

This flood-plain occurs in varying widths along the Takutu River from its Sawariwau confluence to that with the Ireng. Generally, the plain is less than three miles wide, and in places, it narrows to a few yards as around St. Ignatius where laterites protrude close to the river banks. Like the Ireng, the Takutu is deeply entrenched within its narrow flood-plain marked in several places by ox-bow lakes (Fig. 54). The ox-bow lakes mark the former broader and shallower course of the Takutu (Fig. 55). As along the Ireng, they hold back flood waters whenever the river overflows its present banks.

Influenced by its entrenchment, the river inundates its flood-plain only at the height of the rainy seasons. During the dry season the level of the river drops considerably and the soils of the flood-plain readily dry up. Much of the flood-plain is however covered by recent alluvium in contrast to the Ireng flood-plain (Appendix B). Texturally, the

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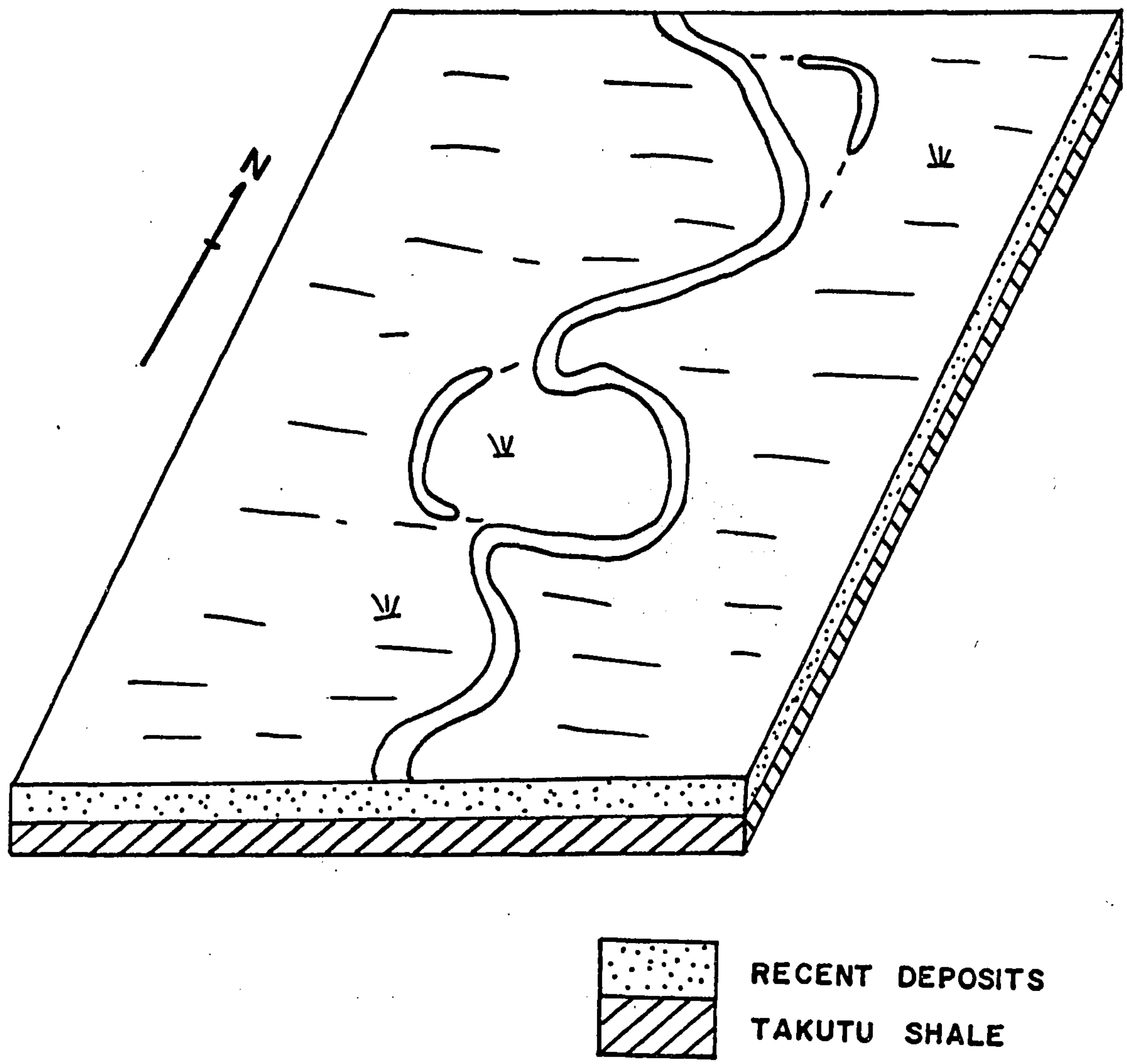
FIG. 55. THE TAKUTU FLOOD - PLAIN



Windapo, 1968.

alluvium is largely composed of sandy materials. Along the depressions, the deposits are sandy clay while along the banks and ox-bow lake rims, the materials are mainly sandy.

As a result of the seasonal fluctuation in moisture content, the flood-plain maintains a belt of galeria forest which varies in dimensions with site situation. Where the land adjacent to the bank is low and harbouring ox-bow lakes and other depressions, the forests cover a considerable width of the flood-plain. But where the adjoining land is high and freely drained, the forest tract is very narrow, even disappearing in places at St. Ignatius. Thus, most of the Takutu flood-plain is covered by savanna vegetation of varying density from a dense campo cerrado - orchard savanna - to a more open campo coberto type.

The Rupununi Flood-plain.

This is the widest and generally most distinct of the major flood-plains of the study area. It begins from about a mile north of the gorge separating Eastern and Western Kanukus, and continues along the whole length of the river within the study area. The river itself is less incised than either the Ireng or the Takutu (Fig. 54). As a result, it floods a considerable part of the land along its banks. Thus it maintains a broad and ill-drained flood-plain within which the river has changed course creating a number of ox-bow lakes and braided channels. The flood-plain attains a maximum width of about four miles north of Kwaimatta, where it floods the lower courses of the Bunoni River.

Unlike the Ireng, the Rupununi flood-plain is affected by a more permanent flooding, as a result of which the soil does not experience the same degree of seasonal dessication as along the Ireng. The soils are however more heterogeneous with sand banks occurring side by side with mud banks. While soils of the sand-banks are texturally sandy, those of the mud-banks are dark-grey humic clays.

As a result of its moisture regime, the flood-plain is largely forested with very few tracts of savanna vegetation (Fig. 11). Where drainage is greatly impeded, zones of swamp communities occur dominated by coarse rank grasses and wild rice. A common feature associated with zones of swamp within the plain is the occurrence of terrawards, some of which are closely spaced.

AIR-PHOTO CHARACTERISTICS OF THE LANDFORM PATTERN.

The Major Flood-Plains present the least varied air-photo patterns within the Takutu Province. This is because the areas are all covered by recent deposits which have been grown partly with forest and partly with savanna vegetation. It is only along both the Rupununi and the Takutu rivers that two belts of deposits could be recognized - one older and more compact than the other. But even here, the belt of younger alluvium is usually under forest cover and consequently renders no appreciable change in the general air-photo patterns of the flood-plains.

TABLE XXIV: AIR-PHOTO CHARACTERISTICS OF THE MAJOR FLOOD-PLAINS.

Sub-Pattern	Units	Sub-pattern variants	Approx. % coverage	Drainage	Vegetation	Soils	Darker ← Neutral Values → Lighter (1 … 5 … 10)
Western Section	Ireng Flood-plain	Zone of younger deposits	15	Generally well drained except at flood period	Very narrow belts of galeria forest	Silty loam	
		Zone of younger deposits	85	Moderately well-drained with pockets of ill-drained backswamps	Extensive savanna varying from campo cerrado to campo sujo	Mainly silty loam with clay in depressions	
	Takutu Flood-plain	Zone of younger deposits	40	Generally well-drained except at **flood period**	Galeria forests of varying widths	Generally sandy loam	
		Zone of older deposits	60	Generally well-drained except at flood-period with pockets of poorly-drained backswamps	Extensive savanna varying from campo cerrado to campo coberto with pockets of campo limpo in backswamps	Structure-less sands except in the areas of swamps where silty clay are also found	
Eastern Section	Rupununi Flood-Plain	Zone of younger deposits	75	Moderate to poor even in the dry season	Extensive galeria forests punctuated by pockets of campo limpo savanna in swamps	Sandy loam with pockets of silt	
		Zone of older deposits	25	Moderate to poor	Narrow belts of campo cerrado savanna succeeded by campo coberto away from the galeria forests, and campo limpo in the swamps	Sandy loam with pockets of clay.	

☐ Dominant Values
< > Range of Values
· Mean Value

Two ranges of tonal values dominate the flood-plains, and these derive from the vegetation covers - a belt of galeria forests fringed by a savanna belt. This arrangement is typified along the Takutu flood-plain as represented in zone (1) of Plate 39. Within this zone, the areas marked (a) represent belts of galeria forests with a tonal value of between N3 and N4 and a surface reflectance ranging from 6 per cent to 12 per cent. The areas marked (c) represent the savanna belts fringing the galeria forests, on older alluvium. They show a tonal value between N6 and N7 with a reflectance ranging between 30 per cent and 40 per cent, due to variations in vegetation density. The very few and narrow belts marked (d) within the flood plain represent open clear water surfaces with a tonal value of between N9 and N9.5 and a high surface reflectance of about 80 - 90 per cent. These tonal characteristics are summarized in neutral value range diagrams in Table XXIV in which the general air-photo characteristics of the landform pattern are presented.

P A R T   T H R E E

CHAPTER IX

THE DEVELOPMENT TREND OF THE LANDSCAPE

Part II of this thesis has been devoted entirely to treating the landform patterns found within the study area. These patterns however have evolved through the interplay of many factors as reflected in changes both in drainage and vegetation of the study area.

The Role Of Rivers.

The present landscape of the Rupununi graben has been greatly influenced by changing drainage conditions. Following the filling of the graben with iron-rich deposits derived from the Pakaraima and Kanuku scarp faces, the Proto-Berbice River worked its way across the deposits of the graben in early Pleistocene times. The river captured the Takutu, Ireng and Rupununi which were the major rivers flanking the graben. It became the dominant river and the base-level of erosional activities from the Pliocene to Middle Pleistocene times during which it influenced both the formation and later dissipation of laterites in the study area.

As it lowered its bed, it induced progressive lowering of the water-table in the surrounding areas. Former springs flowing into the river and its tributaries also responded to the lowering by working back into and dissecting the laterite uplands. Such former springs developed into streams and creeks which in turn induced rill gully drainage channels as they cut into the landscape. The erosional activities of the Proto-Berbice River ultimately carved out the Marakanata depression while those of the tributary streams and creeks have created wide flat-bottomed valleys in the laterite landscape.

With the capture of the Proto-Berbice River by the Rio Branco towards the close of the Pleistocene, deposition began within the Marakanata depression. As the tributaries continued to bring in eroded materials from the adjacent higher areas into the depressed valley, the channel of the Proto-Berbice was soon chocked and the valley started to fill up. This filling is still in progress today and is particularly observable in times of excessive flooding. With loss of gradient and lack of clearing at the mouth of streams, their eroding activities within the laterite terrain considerably decreased and the materials brought down by the gullies from the surrounding hills in turn started filling up the stream valleys, and consequently building up wide flat-bottom valleys. With further filling, some of such valleys have developed zones of swamps. Here too, the process of filling can still be observed. The Takutu and the Ireng, now regaining their identities as separate rivers, started drifting across the Marakanata Lowlands constantly changing and choking their courses in the process.

But with the close of the Pleistocene, the Rio Branco

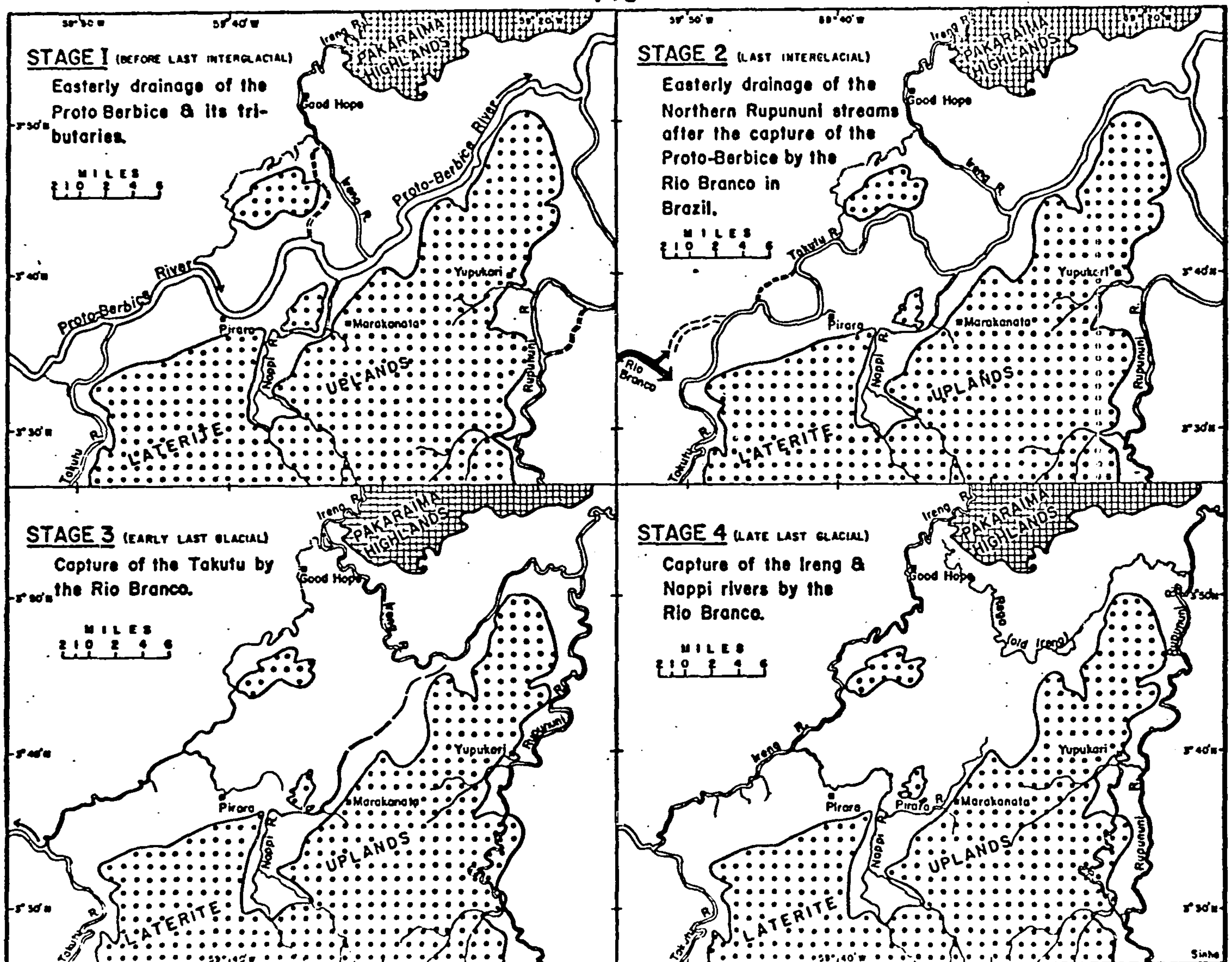
River rapidly worked its way from Brazil towards the Marakanata depression, and on gaining the former channel of the Proto-Berbice, recaptured both the Ireng and the Takutu, and consequently diverted a large portion of the Northern Rupununi drainage westwards into the Amazon River system. This capture started a new phase of accelerated erosion and incision by the captured rivers and their tributaries which have consequently developed valley-in-valley forms and shoulders. Fig. 56 mapped by Sinha (1967) shows the stages through which the Northern Rupununi streams have evolved.

The recent entrenchment of many of the streams like the MocoMoco, The Parika and the Manari has, however, not advanced far enough to induce headward erosion into many of the swamps and flats, and start a new phase of active erosion within the laterite terrain. However the entrenchment has ended a long period of quiescence in the sculpture of the landscape and initiated a new phase in the evolution of the graben's terrain.

The trend in vegetation changes:

The dynamic evolution of the Rupununi landscape is also reflected in its vegetation. Before the Proto-Berbice phase of erosion, the whole graben was said to have been thickly forested, but with the dissection of the landscape and the progressive drop in the water-table, the soil-moisture equilibrium which sustained the forests was upset. As the laterite landscape was breached, the laterite aquifer was

FIG. 56



RECENT CHANGES IN THE COURSES OF THE NORTHERN RUPUNUNI STREAMS. (Sinha,1967) destroyed and the laterite crusts started to break down. This resulted in the disappearance of forests from the laterite plateaus. The forests have been replaced by savanna vegetation in various grades of degeneration. In well drained zones with higher moisture content, the thickly wooded campo cerrado type of savanna is dominant as between Ikuwali and Sapaika rivers. In excessively drained areas, the savanna has depleted from campo coberto to campo sujo while in very poorly drained areas of swamps, the campo limpo herbaceous savanna is dominant.

Few legacies of former forests can however be found within the landscape in form of forest islands. These are restricted to the summits of some of the laterite ridges. Other types of forest islands are also found within the landscape, but these are of secondary origin. Some are found isolated within some big and deeply incised gullies where the forests are able to draw on a lower water-table for their moisture requirements. Others are found on former village sites where they have been initiated by man, as anthropic forest islands. And others are yet growing in old river courses with favourable moisture conditions while some swamps are gradually being inhabited by trees to form nuclei of future forests. The colonization of such swamps has been initiated largely by Ite Palms.

The Ite Palm is said to be greatly instrumental in the reclaiming of swamps as a result of its high transpiration potentials. It is on this account that the Government of Guyana has legislated against indiscriminate cutting of the palm in the Rupununi. On appearing in the swamps, it soon creates favourable conditions for other tree species to grow around it. Thus it forms a nucleus of forest around the edges of swamps and ultimately reclaims the areas for forest regeneration.

CHAPTER X

THE TASKS AHEAD

So far the evolution of the Rupununi landscape has been traced with special attention to the terrain types that have subsequently evolved. In the course of the study, some localized forms of terrain development have been observed especially in forms of terrawards and termiteria. Little is known about these forms, and consequently, the author regards them as important areas of future research into the Northern Rupununi terrain.

The first - the terrawards - are closely spaced earth mounds rising to between one foot and two feet above marshes and seasonal swamps. Their occurrence is not restricted to any particular landform pattern. Rather, they occupy sites with unique hydrological conditions. For example, they are associated with soils possessing high silt and clay contents, and in marshy areas that are never completely submerged by water to any great depth and for long.

The origin of these mounds has been a point of controversy though generally attributed to earth worms. It has been suggested that they are built up by earthworms in their struggle to reach above flood-waters for respiratory purposes (Rutherford 1957). This however, is because earthworms are usually found within the mounds. But the origin could be due to differential erosion especially around vegetation bases and this may explain the presence of trees on some terrawards as at Hiawa where each terraward is marked by a stand of <u>curatella americana</u>. The differential erosion may also follow cracks on dried clayey surfaces. Once initiated, the earthworms could then colonize the zones free from running water and help build up the mounds by moving soft clays from areas under water to the free areas as they carry out their vital processes. However, no specific effort has yet been directed to the study of these terrain features. Future efforts could therefore be directed to finding out conditions under which they develop, and their significance within the Northern Rupununi terrain.

The second which are termite mounds, occur in scattered locations especially within the laterite uplands of the Northern Rupununi Savanna. Two types have been noticed by the author: the dwarf type and the giant type. The dwarf ones are found as small mounds of about a foot high on the flats (Plate 40). They occur in very few numbers and at great distances apart, on such flats as the MocoMoco, Manari and Nappi. Unlike the giant termiteria, they tolerate wet locations and are restricted to areas with silty and clayey loam soils hence their colour is usually grey.

The giant termiteria, on the other hand, are restricted to the laterite upland areas. They occupy well-drained sites on the upper and middle slopes of laterite ridges. On the medium hills between Lethem and MocoMoco, very tall termite mounds with heights ranging from eight to twelve feet are found occupying the whole crest right down to the middle

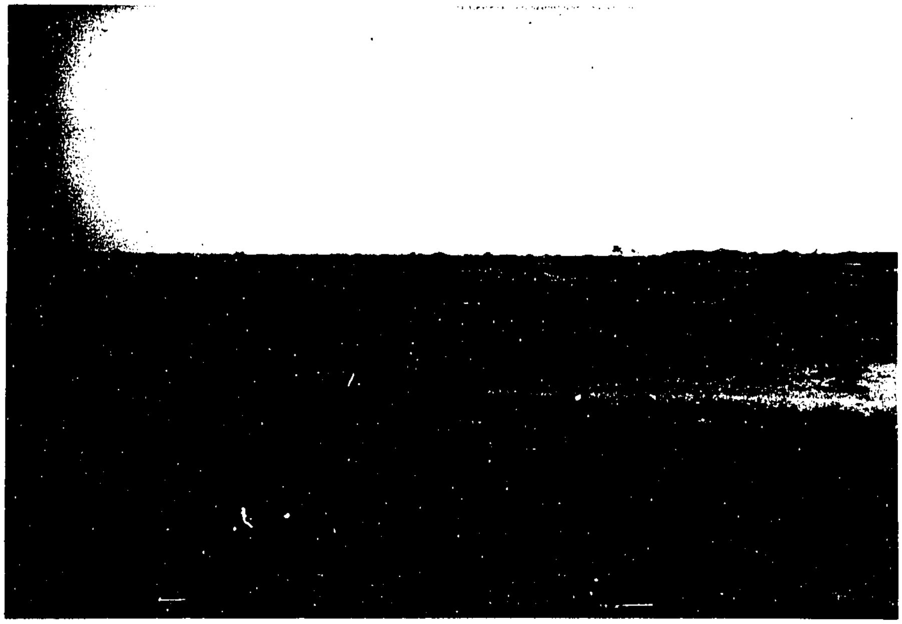


Plate 40: Dwarf termite mounds on MocoMoco flat. (Photo by Windapo).

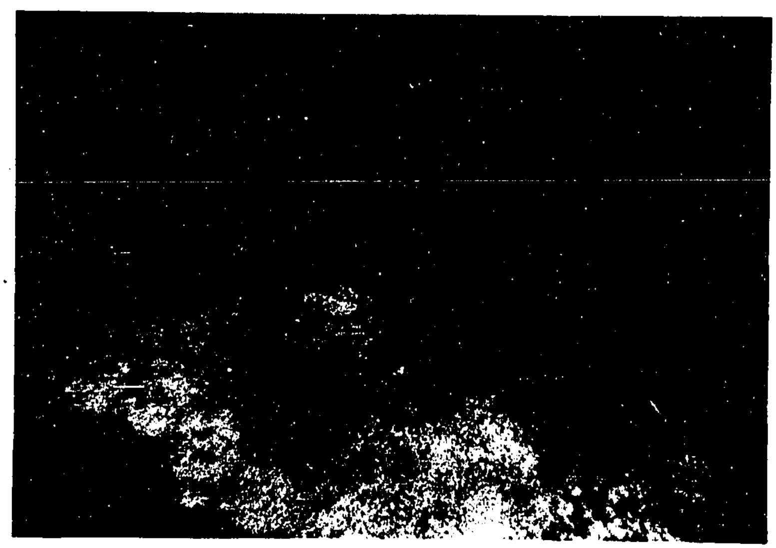


Plate 41: Dwarf termite mound at close view. (Photo by Windapo).

Plate 40: Dwarf termite mounds on MocoMoco flat.
(Photo by Windapo).

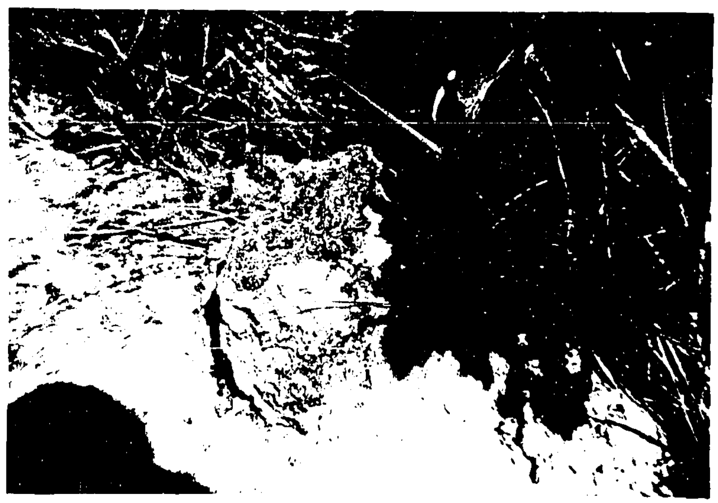


Plate 41: Dwarf termite mound at close view.
(Photo by Windapo).

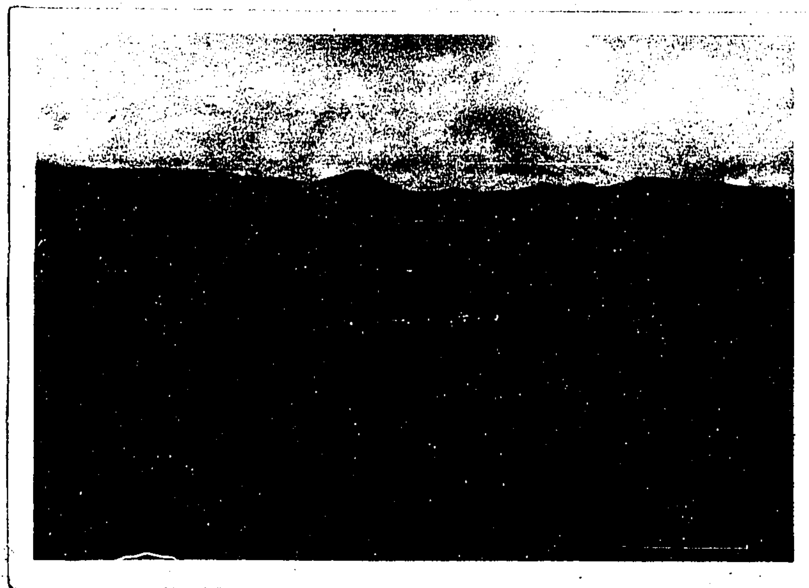


Plate 42: Giant termite mounds near Lethem on MocoMoco road. (Photo by Windapo).

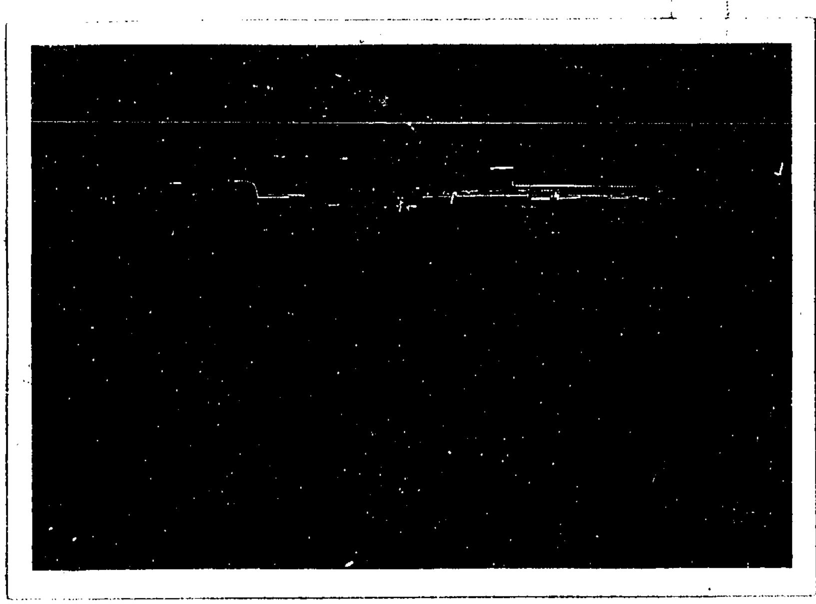


Plate 43: Giant termite mounds near Hiawa. (Photo by Windapo).

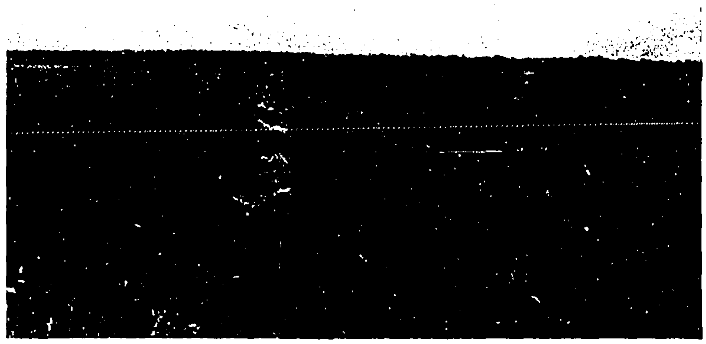


Plate 42: Giant termite mounds near Lethem on MocoMoco road. (Photo by Windapo).

Plate 43: Giant termite mounds near Hiawa. (Photo by Windapo).

slopes (Plate 42). This pattern of distribution is also found on some medium hills between Hiawa and Nappi (Plate 43), and on the Meritizero low hills though with reduced height of between three and ten feet. On the Nappi high hills on the other hand, the tops are avoided and the mounds seem to grade down-slope with the taller ones on the upper slopes and the shorter ones on the middle slopes.

What the author has stated so far is based on general observation on the field. No particular attention was paid to patterns of distribution. The author feels that these features are interesting enough to merit specialized research which would take into consideration: (a) the types of termites responsible for both the dwarf and the giant termiteria, (b) the life cycle of the termite types, (c) the pertinence of their life cycle to the site situation adaptability, (d) distribution by site, (e) sizes of mounds with regards to height and base - circumference dimensions, (f) rate of growth and (g) their influence on soil types.

P A R T   F O U R

CHAPTER XI

CONCLUSIONS

Under the 'Geologico-Morphological Setting' in Part I of this work, the author sets out his observations concerning the laterite forms in the Northern Rupununi Savanna. Three levels of laterite crusts have been observed as legacies of the Pleistocene laterization within the graben, and these include the high-level laterites, some of which carry forest islands, the low-level laterites exposed on some bottomlands as at Komako, and the basal laterites topping the Takutu shale and exposed at points along the banks of the major rivers like the Takutu and the Rupununi. These crusts exist in two forms as a result of their media of formation: pisolitic in coarse materials and vesicular in fine materials.

In the main body of this work, the author examined the physiography of the Northern Rupununi Savanna and provided a detailed interpretation permitting the erection of a hierarchy of regional divisions which can be related to the photo patterns. Thus, six landform patterns have been demarcated within three geological provinces which include:

(1) the Mazaruni Province,

(2) the Takutu Province, and

(3) the Rupununi Province.

Of the six landform patterns, one - the Pakaraima Scarp Complex - is associated with the Mazaruni Province, another one - the

Kanuku Scarplands - belongs to the Rupununi Province, while the remaining four which include the Marakanata Lowlands, the Laterite Uplands, the Sapaika-Sawariwau Lowlands, and the Major Flood-plains have all developed within the Takutu Province. Each land system is depicted on a block diagram and its identification features are shown in Appendix B. The various landform units together with their landform components have been listed out to details along with the local forms as shown in Table VIII. This system is basic to any regional study since it provides the fundamental understanding of the landscape and its development.

Within each land system, attention was paid to morphology, vegetation, soil and economic activity. Under morphology, slope inclination, slope form and drainage characteristics both internal and external were studied with regards to their influence on air-photo appearance of each system.

The variations in vegetation from one land system to another were studied with particular attention to physiognomy and density of cover types. The universal system for recording vegetation was employed to give a visual impression of changes in vegetation from site to site.

With regards to forest/savanna conditions, the author is of the opinion that the edges of the existing forest islands provide evidence to maintain the argument that the forest belts are receding, while at the same time, enough evidence can be found along the swamps already colonized by Ite Palms and other tree communities to support the argument that as long as draining continues within such swamps, there is the possibility of future forest belts growing on such sites.

Variations in soils were examined by means of grain-size distribution analyses presented in graph forms, and their compactness, structure, acidity and horizon development were also studied from unit to unit.

Also noted were the predominant economic activities within each land system. In general ranching is the main economic pursuit, but some arable farming is done in the forest belts. The major ranching zones are the bottomlands where grasses manage to keep green in the dry season.

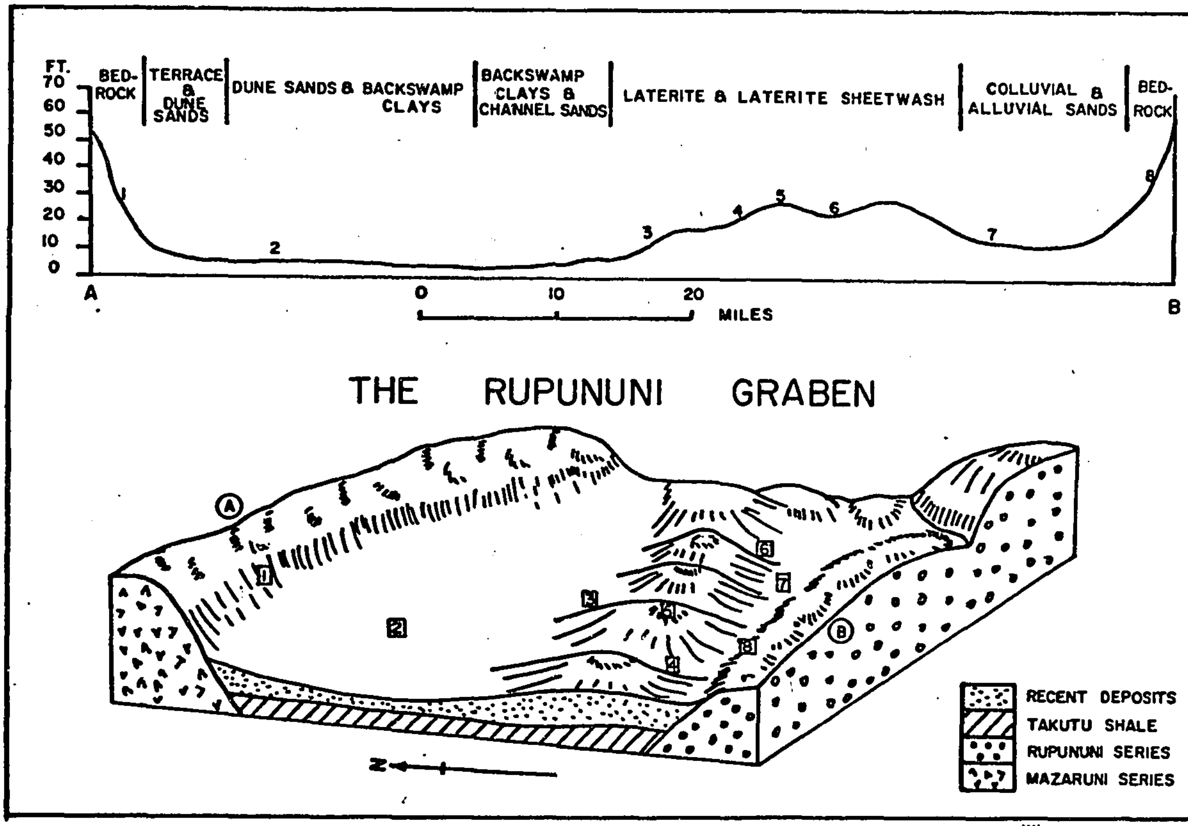
The prevalence of extensive bottomlands seem to point out that the study area is an old landscape, but as pointed out in Part III of this work, the author is of the opinion that the area is a developing landscape. The recent entrenchment of the streams and creeks may subsequently lead to the draining of many of the present water-logged bottomlands. Such draining is likely to induce changes in the moisture regime of the higher grounds adjacent to the bottomlands, as well as cause changes in vegetation association. With this in mind, the author expects changes to occur in air-photo characteristics of the landform patterns as the recent entrenchment matures.

On the whole, however, the author has found the present exercise of terrain analysis with the aid of air-photographs a very useful undertaking. By building a hierachy of regional divisions on their air-photo characteristics, the author has established a more systematic approach to the study of the Northern Rupununi terrain. Such a system permits direct extrapolation in adjacent areas of South America,and is a contribution to the study of laterite landscapes which are such an important part of the Sub-tropical lands.

APPENDIX A: INDEX OF TERRAIN CLASSIFICATION AND DESCRIPTION

Stage in Classification	Relevant Factors	Factors suitable for quantification	Quantification Techniques	Terrain Factors expressed Descriptively	Methodology of Description	Factors expressed in Maps
LAND PROVINCE	Distinct physiographic units with constant geology at group level	Relief Amplitude	Measured on the field	Geology	Background information from geology maps and publications. Preparation of block diagrams and maps	Geology, relief, drainage soils and vegetation
LANDFORM PATTERN	Constant geomorphology within units, distinct pattern on air-photos	Stream frequencies	Measured on air-photos by counting streams in terms of stream order	Geomorphology	Geomorphological reconnaissance and extrapolation from air-photo interpretation	Geology
		Channel depths of incision	Measured on the field	Soil	Profile and surficial deposits analysis-grain size and acidity	Soil and
		Soil composition	Measured in laboratory - sieve analysis & pH	Vegetation	Structural diagram	Vegetation
LANDFORM UNIT	Distinctive soil variation	Grain size of soil	Measured in the laboratory by sieve analysis	Soil characteristics i.e. compactness	Table of characteristics	Soil and
	Distinctive vegetation association	pH of soil	Determined in the laboratory	Vegetation association	Structural diagrams along profiles	Vegetation
		Colour of soil	Determined in the field through the use of Munsell colour chart			
LANDFORM COMPONENT AND MICRO RELIEF	Enigmatic features and zones of anomaly	Size dimensions i.e. height and width	Measured on the field	Soil	Table of characteristics.	
				Vegetation	Structural diagrams	

APPENDIX B (i)



Windopo, 1968

(a) GENERAL

CLIMATE	ROCK	MORPHOGENESIS	SOIL	VEGETATION	ALTITUDE	RELIEF
Tropical with distinct dry and wet seasons	Precambrian Basement Complex: Rupununi Group in the Kanuku, Mazaruni Group in the Pakaraimas. Deeply weathered granites producing laterite.	A Graben with undulating interior variously capped by massive laterite and boulders, cobbles and gravels below which are long hill slopes leading to aggraded and frequently swampy villages.	Gravels Lateritic red and brown loam. Sands and silty clay.	Mainly savanna with varying density of trees. Forests restricted to the scarps, stream valleys and crests of some laterite ridges as forest islands	Above 1000' in scarps, dropping to 450'-300' in the laterite belt.	Variable Mt.scarp swamps, laterite ridges and flats

(b) TRANSECT FROM THE PAKARAIMA SCARP (A) TO THE KANUKU SCARP (B) AS SHOWN ON BLOCK DIAGRAM.

1. Pakaraima Scarp: Abrupt and sloping.	Metamorphic rocks; mainly schist. Generally above ground water influence. No soil profile, slope wash and gullies.	Forest with savanna element
2. Marakanata Depression: Low with imperceptible slopes. Main width about 4 miles.	Soils derived from recent sediments covering the Takutu shale. These include terrace sands, back-swamp clays and channel fill sands. Poorly drained; influenced by ground water.	Mainly grass and sedges in swamps. Dense to sparse stands of trees on terrace stands. Forests along stream courses in discontinuous belts.
3. Convex interfluve slopes in laterite st steepening to about 7°. Lower and mid slopes mainly straight.	Laterite and lateritic sheetwash. Reddish brown densy loam. Well drained; above ground water influence.	Wooded savanna along lower slopes though with stunted trees in many places. Mainly grass on hill crest.
4. Broad valleys with flat bottom.	Lateritic sheetwash and alluvial deposits. Brown to grey sandy loam. Within ground water influence.	Wooded savanna varying from campo cerrado to campo sujo Occasional forest belts along major streams, and campo limpo swamps.
5. Convex interfluve slopes in laterite, steepening to about 9°. Lower and mid slopes mainly straight.	Massive laterite exposures, cobbles and coarse gravels, at the crest and mid slopes. Gravels on lower slopes grading to sheetwash in adjacent valleys. Gully drainage channels. Generally freely drained and above ground water influence.	Savanna with varying densi of trees. Strip vegetatio along gullies significant.
6. Broad flat bottomed v valleys fed by narrow V-shaped valleys and gullies.	Sands with gravels as well as mottled clay. Poorly drained in parts.	Fairly dense stand of tre broken by belts of grass sedge and palm swamps.
7. Broad alluvial flats flooded by streams with incised channels.	Sandy loam to sandy clay in zones of seasonal swamps. Generally moderately drained.	Fairly dense stand of tree varying to sparsely wooded campo sujo. Belts of camp limpo grows dominated.
8. Kanuku Scarp. Abrupt and steeply sloping	Colluvium sandy loam. Well drained. Rocky Scarp faces with no soil profile.	Densely forested.

DISTINCTIVE FEATURES.

(1) Scarp.

(i) Very steep rocky slope.
(ii) Thin stony clay among rocky exposures.
(iii) Fast flowing short streams with rocky beds
(iv) Forest with savanna characteristics.

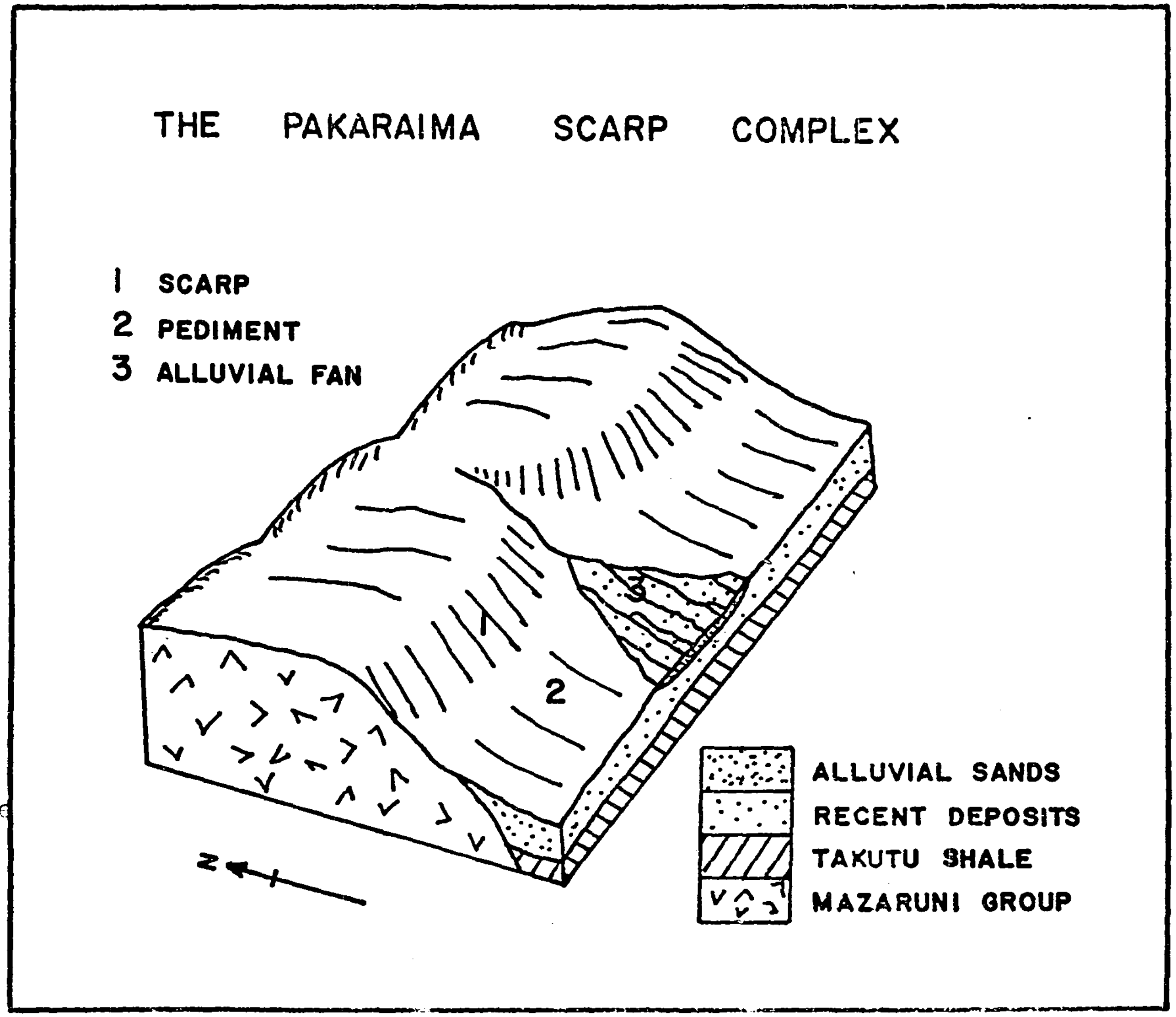
(2) Pediment.

(i) Gentle slope; zone of deposition.
(ii) Stony clay.
(iii) Short creeks with stony beds.
(iv) Wooded savanna (orchard type) dominated by Curatella americana.
(v) Grazing.

(3) Alluvial Fans.

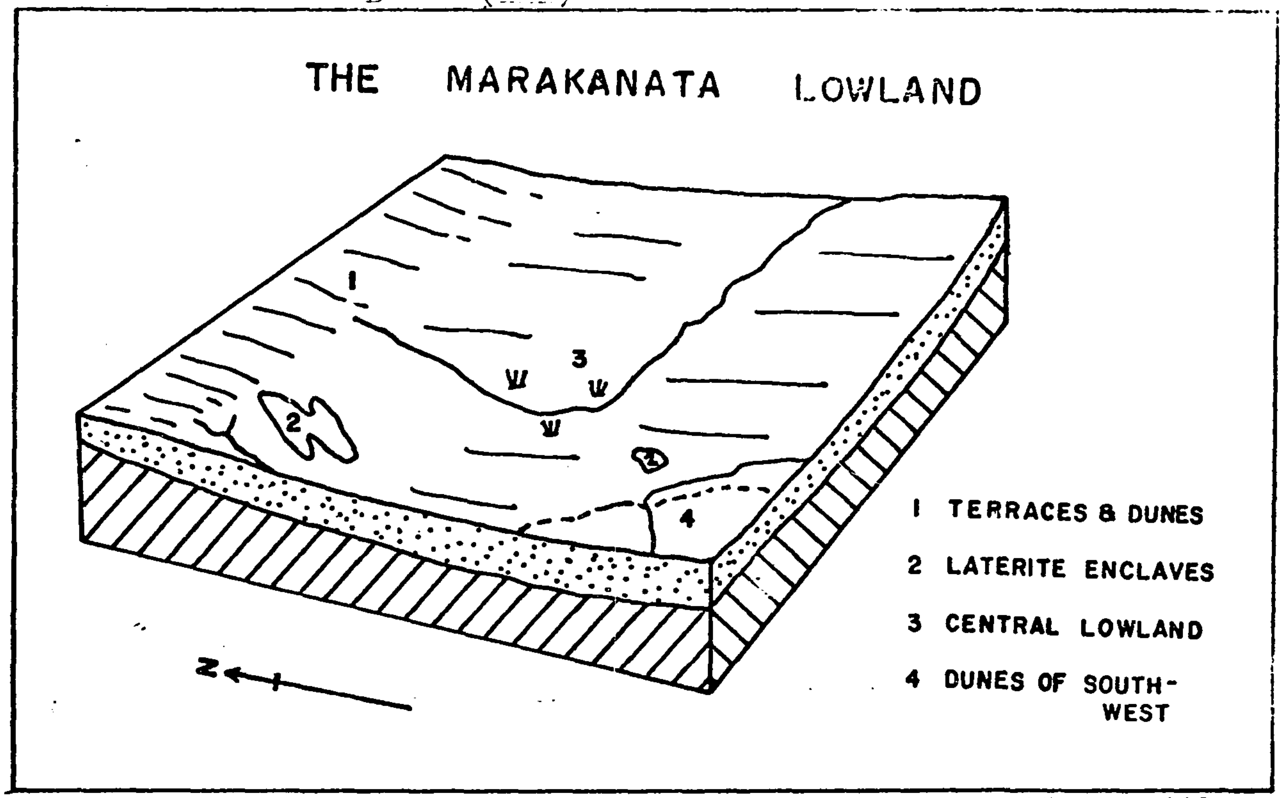
(i) Gentle slope; zone of deposition.
(ii) Sandy soil.
(iii) Free drainage - fan-like surface channels.
(iv) Open savanna - campo coberto.
(v) Grazing.

B (ii)



Windepo, 1968.

DEFINITIVE FEATURES. B (iii)



Windapo, 1968.

(1) Terraces and Dunes:

(i) Undulating surfaces.
(ii) Sandy soils.
(iii) Free to impeded drainage.
(iv) Wooded sand ridges and grassy depressions.
(v) Grazing.

(2) Laterite Enclaves:

(i) Convex slopes about 5-9°.
(ii) Massive laterites; lateritic red and brown loam.
(iii) Well drained
(iv) Campo coberto depleting to campo sujo.
(v) Grazing. Cropping in forest islands.

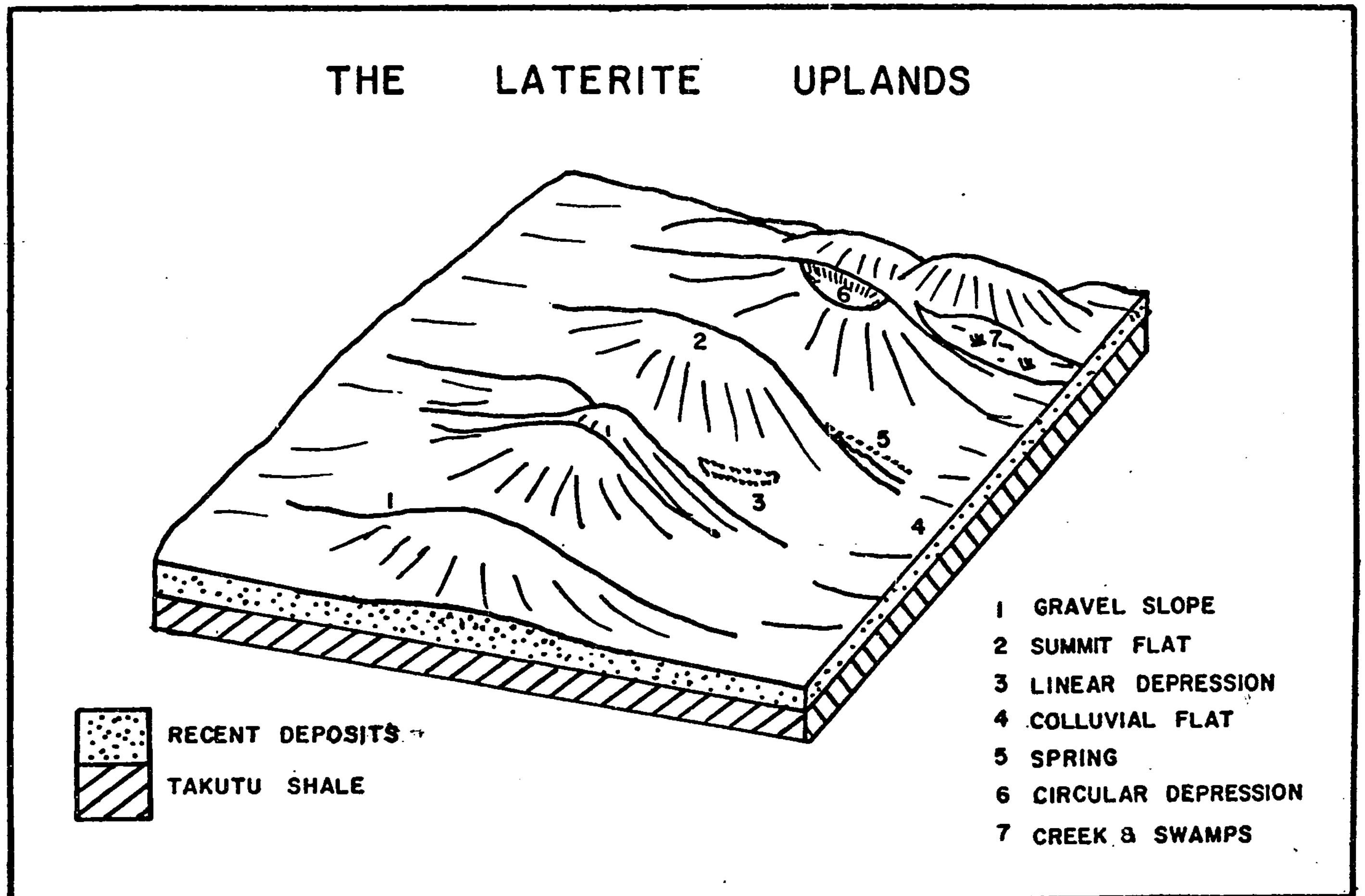
(3) Central Lowland:

(i) Depressed surfaces broken by channel fills.
(ii) Silty soils dominant.
(iii) Poorly drained; lakes, ponds and swamps.
(iv) Campo limpo dominant.
(v) Grazing.

(4) Dunes of Southwest.

(i) Undulating surfaces.
(ii) Sandy soils.
(iii) Free to impeded drainage; lakes, ponds and swamps.
(iv) Wooded sand ridges and grassy depressions.
(v) Grazing.

B (iv)



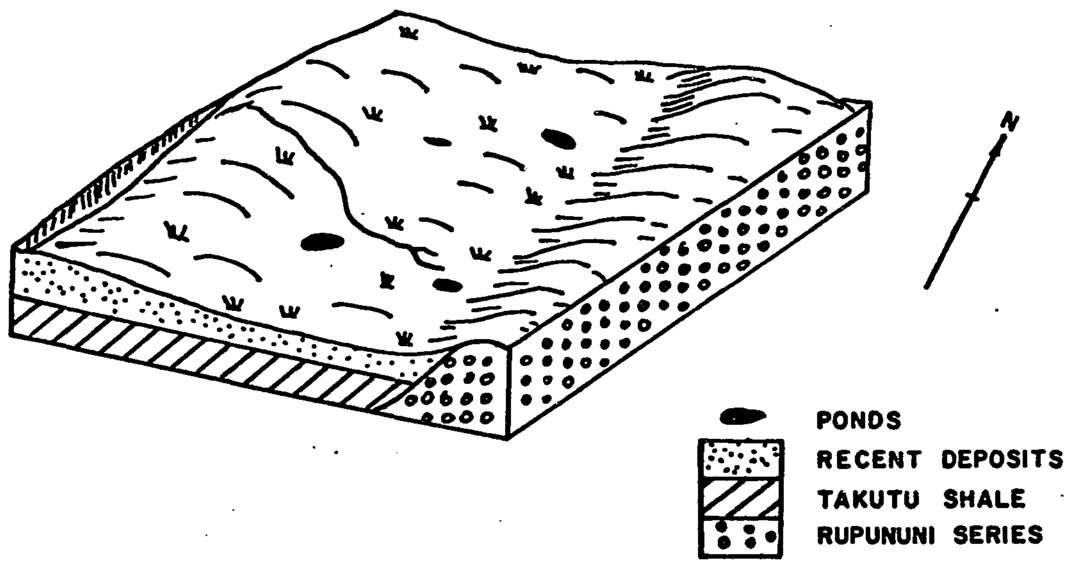
Windapo, 1968.

DEFINITIVE FEATURES

(i) Steep to undulating surfaces dominated by convex slopes.
(ii) Massive laterites and gravels to lateritic red and brown sands and silts in the depressions.
(iii) Excessively drained to poorly drained in flats and depressions: lakes and swamps.
(iv) Forest islands. Campo cerrado depleting to campo sujo, and campo limpo in some flats and swamps.
(v) Grazing.

B (v)

THE SAPAIKA - SAWARIWAU DUNE & SWAMP COMPLEX



Windapo, 1968.

DEFINITIVE FEATURES

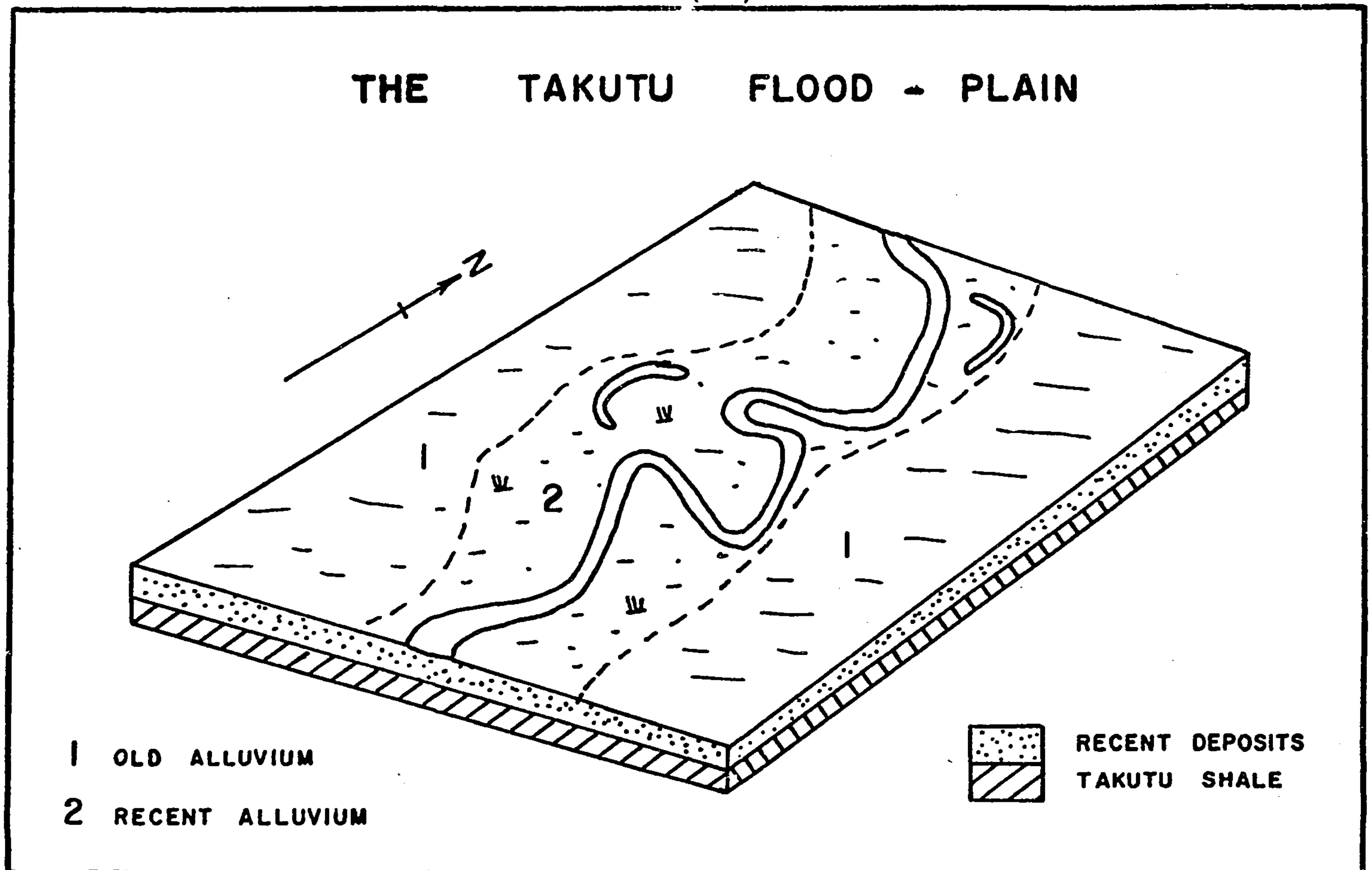
(1) Higher Dune Surfaces.

- (i) Moderately steep sand ridges and depressions.
- (ii) Generally sandy soils.
- (iii) Free to impeded drainage: Ponds and swamps.
- (iv) Campo coberto depleting to campo limpo in the depressions
- (v) Grazing.

(2) Lower Dune Surfaces.

- (i) Undulating surfaces and depressions.
- (ii) Generally sandy loam.
- (iii) Poorly drained: many ponds and extensive swamps.
- (iv) Campo coberto depleting to campo limpo in the swamps.
- (v) Grazing.

B (vi)

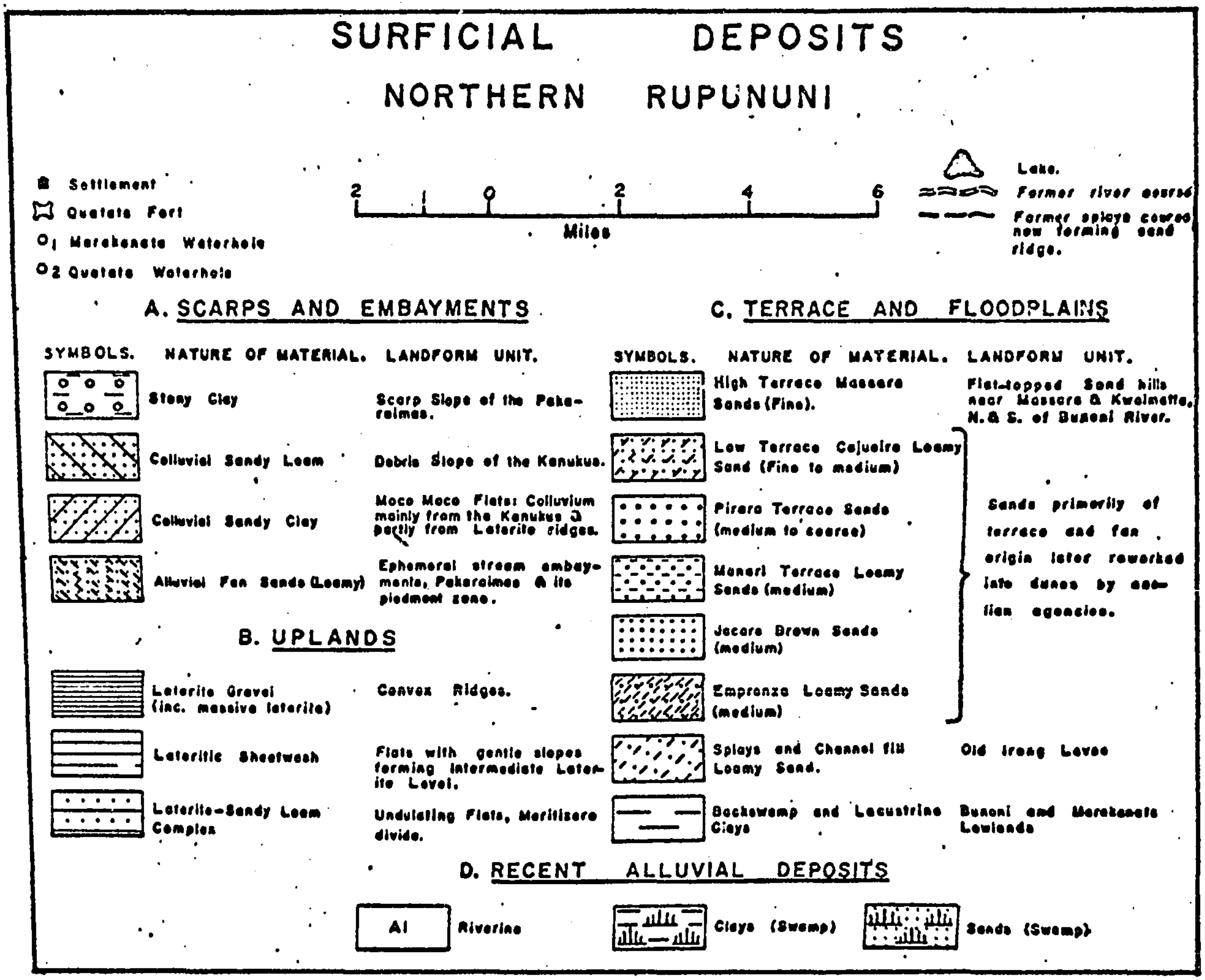


Windapo, 1968.

DEFINITIVE FEATURES

(i) Flat to gently sloping surfaces.
(ii) Generally sandy loam soils.
(iii) Free to impeded drainage: Ox-bow lakes, overflow scars and abandoned channels.
(iv) Galeria forests, and campo cerrado broken by belts of campo limpo in swamps.
(v) Grazing and cropping.

APPENDIX C



(Adapted from Sinha, 1967.)

APPENDIX D

In collecting data for the construction of the structural diagrams, the following steps were taken:

(a) Sample cells were selected with varying diameters depending on site and density of trees. (The diameter of each cell is indicated at the bottom right hand corner of each structural diagram).

(b) The highest tree within a cell was used as the cell determinant.

(c) The tree height, diameter, branching level and types of leaves were taken into consideration and types of stem arrangement within the cell were also noted. The included data sheets, I and II, were used as guides in the collection of information on the vegetation association within each cell.

In drawing the structural diagrams, the percentage coverage of each vegetation class is used in determining its coverage on the diagram. Vegetation types with less than 4 per cent coverage are not included in the diagram since each square grid is 4 per cent on the scale.

All plant symbols are drawn to touch the line representing their height class. As the height of the plants being represented decreased, the symbols correspondingly decreased vertically and horizontally. The ratio of height of crown to width of crown for the various crown shapes are as shown below:

VEGETATION DATA SHEET - 1

Location: ______________ Site No: ___ Veg. Region: ____________ Pattern: ___ Facet: ___ Date: __________ Season: ______

Notes: ____ Veg. Grade: _____ Cell Diameter ___ ft

PLANT TYPE	CELL-DETERMINANT	HEIGHT CLASS (meters) I 0 - 0.1	II 0.1 - 0.3	III 0.3 - 0.7	IV 0.7 - 1.5	V 1.5 - 5	VI 5 - 13	VII 13 - 35	VIII 35 - 100		CROWN SHAPE ○ Round	◇ Flat	△ Pointed	Spindle	Tabular	% coverage		LEAF CHARACTERISTICS SHAPE Needle	L-flat	△ B-flat		TEXTURE Filmy	Papery	Hard	Su		SIZE sq. cm 0 - 1	□ 1 - 150	○ 150 up		LIFE FORM Absent	Dead-clinging	Lvs. Green	Twig fr.-no l	Fungi
ERECT WOODY PLANTS																																				
STEM ONLY																																				
ERECT NON-WOODY PLANTS											woody Lianas st. ep.		non-woody Vines st. epi.																							
▽ CLIMBING																																				
▽ AIR ○ non-woody woody SPRAWLING ○ non-woody woody																																				

cation: ______________ SiteNo: ___ Veg. Region: __________ Pattern: ___ Facet: ___ Date: ____________ Season: ____

tes: ____ Veg. Grade: ________ Cell Diameter: ___ ft ___

PLANT	CELL DETERMINANT	STEM DIAMETER centimeters						BRANCHING DIVERGE (meters)				BRANCHING HORIZ (meters)				STILT ROOTS (meters)				ENLARGED BASE stem. diam.			ENLARGED BUTTRESS (meters)				ANNOYANCE					DISTRIBUTION						PLATEAU DIAMETER	RESISTANT TRUNK SPACING
		0 – 2.5	2.5 – 7.5	7.5 – 15	15 – 30	30 – 60	60 up	0 – 0.3	0.3 – 0.6	0.6 – 2	2 up	0 – 0.5	0.5 – 1.5	1.5 – 3.0	3 up	0 – 0.3	0.3 – 0.6	0.6 – 2.0	2 up	0 – 2X	2 – 4X	4X up	0 – 1	1 – 2	2 – 4	4 up	Multiple	Spines	Stinging	Cutting	Poisons	Random	Clumps	Patches	Grid	Rows	Strips		
ERECT WOODY PLANTS																																							
STEM ONLY																																							
ERECT NON WOODY PLANTS		FIELD SIZE Boundary etc								LAND USE																													
CLIMBING																																							
AIR non-woody		Refs																																					
AIR woody																																							
SPRAWLING non-woody																																							
SPRAWLING woody																																							

Crown Shape

Height Class	Round Flat-topped Pointed		Spindle		Tabular	
	Height	Width	Height	Width	Height	Width
8	3	3	3	1.5	1.5	3
7	2.5	2.5	2.5	1.25	1.25	2.5
5 & 6	2	2	2	1	1	2
3 & 4	1.5	1.5	1.5	0.75	0.75	1.5
1 & 2	Always drawn with round crown symbol					

Height and width stated in units of basic grid.

The branching habits of the plants are represented on the diagrams according to the scale shown under D(i) while the foliage characters placed in the centres of the crown shapes are selected according to D (ii). The stem diameter symbols used and the height at which they were measured are also in accordance with D (iii).

Site conditions of the sample cell are also shown under the structural diagrams. The overall legend to these site conditions is shown in D (iv).

APPENDIX D (i)

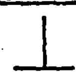
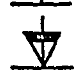
Basic Plant Symbols -- Branching Habits

Symbols used only on plants more than 0.3 meter tall; only on woody plants.

DIVERGING BRANCHES: Plants which divide into multiple upward-trending branches.

Symbol	Height Aboveground at Which Branching Occurs
	More than 2 meters (no alteration in stem symbol)
	0.6 to 2.0 meters
	0.3 to 0.6 meter
	Less than 0.3 meter

HORIZONTAL BRANCHES: Plants which send out branches essentially horizontally.

Symbol	Height Aboveground at Which Branching Occurs
	More than 3 meters (no alteration of stem symbol)
	1.5 to 3.0 meters
	0.5 to 1.5 meters
	Less than 0.5 meter

(Adapted from Dansereau, 1958).

D (ii)

Basic Plant Symbols -- Foliage Characteristics

Symbols	Definitions
LEAF SHAPE:	
⬭	Shaped like a needle or awl; twigs covered with small scales are included.
⬯	Long and flat; more than five times as long as it is broad.
△	Broad and flat; less than five times as long as it is broad.
LEAF TEXTURE:	
no symbol	Filmy, translucent: newsprint can be seen through the leaf if placed close to it.
⁘	Papery or membranous; thin and flexible; will not break or permanently deform if wrapped around a pencil.
////	Hard and stiff; will break or permanently deform if wrapped around a pencil.
□	Succulent; thick and fleshy; leaf more than 2 millimeters thick.
LEAF SIZE:	
no symbol	Less than 1 sq cm in area.
□	Between 1 and 150 sq cm in area.
○	More than 150 sq cm in area.
PRESENCE OR ABSENCE OF LEAVES:	
no symbol	Leaves absent at time of inspection.
||||||	Leaves dead, but still clinging to plant at time of inspection.
▦	Leaves present and green at time of inspection.
▩	Leaves absent, but twigs and/or branches green at time of inspection.
▭	Leaves absent; use only for fungii (plants which are never green).

(Adapted from Dansereau, 1958).

D (iii)

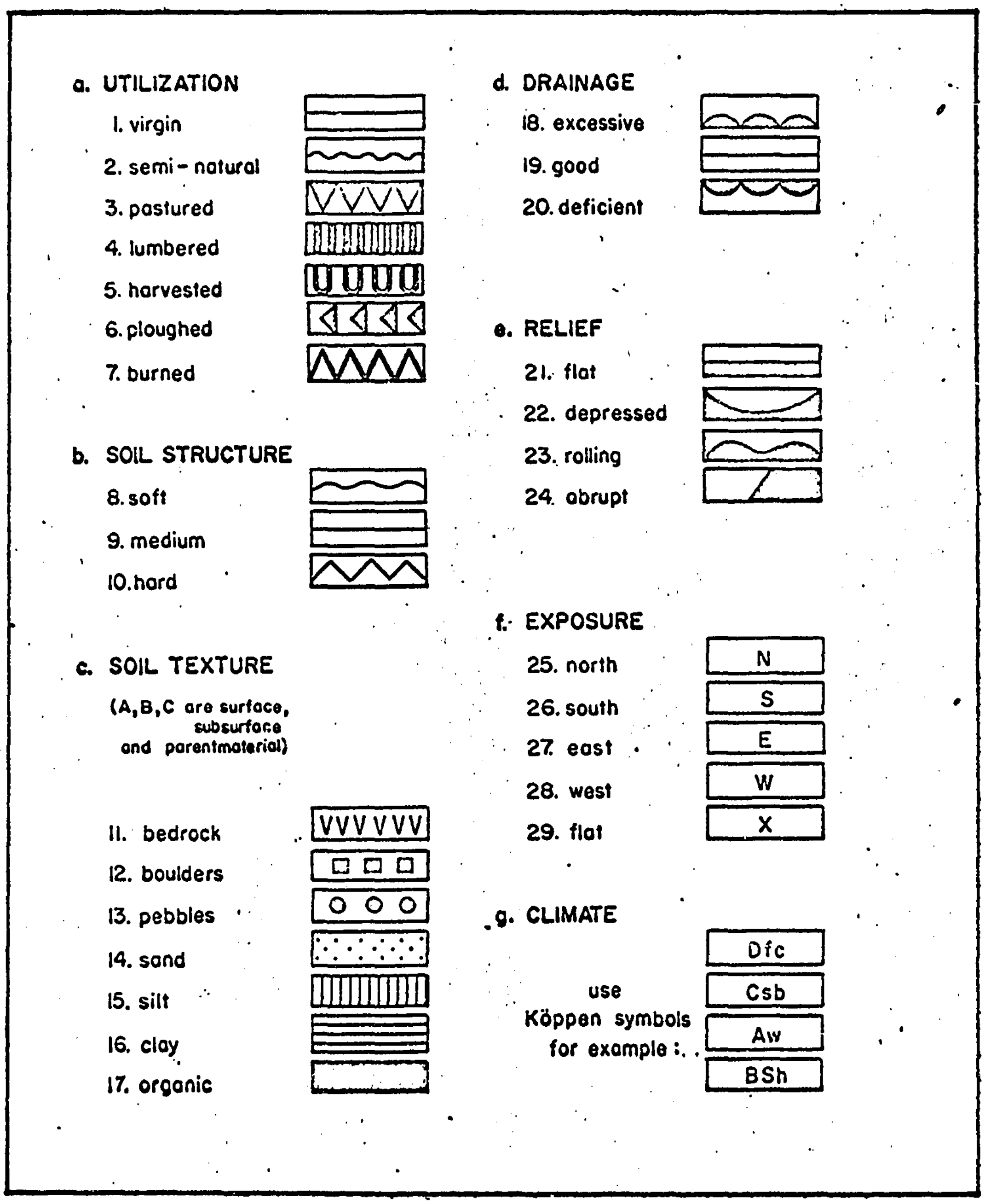
Basic Plant Symbols -- Stem Diameters

Height Class	Height at Which Stem Diameter Is Measured
6 - 8	1.5 meters
5	1.0 meter
4	0.3 meter
3	0.1 meter
2	Ground level
1	No stem diameter symbol used

Stem Size Symbol	Range of Values
	Less than 2.5 cm in diameter
	2.5 to 7.5 cm in diameter
	7.5 to 15 cm in diameter
	15 to 30 cm in diameter
	30 to 60 cm in diameter
	More than 60 cm in diameter

(Adapted from Dansereau, 1958).

APPENDIX D(iv) Categories and symbols for recording site conditions (from Dansereau, 1958, Table V, pg. 35).



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