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An inventory of soils and soil suitabilities in West Irian. II B[1]

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Part II B: Specified information

4.8. Southern part of Vogelkop Peninsula (Object 21)

The part of the Vogelkop south of the line Sorong-Momi is entirely taken up by Neogene sediments which are fringed along the west and south coast by a large swampy belt of alluvial deposits.
In the central part of this Neogene landscape, in a wide area around the Ajamaroe lakes, the youngest Neogene consists of limestones and Globigerina marls.

Object 21: The Ajamaroe-Tebinaboean area (FIG. 11)

In 1958, about 200.000 ha of the above-mentioned Neogene landscape were surveyed on a reconnaissance scale of 1 : 100.000 (Report 21.1). The immediate motive for this survey arose from the evidence that shortage of suitable soils was experienced by the already crowded, but still growing population around the Ajamaroe lakes. Resettlement of volunteering clans in more remote but virgin areas seemed to offer solution of this rather urgent problem.
The soil survey comprised a vast limestone area which reached from Teminaboean eastward to the Kais river and in a northern direction proceeded 10 km beyond the Ajamaroe lakes. The survey also included a smaller area, south of the line Teminaboean-Mos-Aitinjo, which is largely taken up by Neogene shales, marls and sandstones. This area reaches with tongues into the swampy coastal plain of recent alluvium farthermost south.
On FIG. 11 the latter area is indicated as landscape A, which will be left undiscussed because poor drainage and tidal flooding renders these soils unsuitable.
The landscape B that borders on the limestone plateau in the south, was re-surveyed again in some more detail in 1960 (Reports 21.3 and 21.4). It is a dissected, hilly country with low but very steep hills. However, smaller areas which are level or gently undulating are to be found randomized between the hills. The parent materials occurring in this area of about 20.000 ha vary considerably.

1 Continuation of part II A, that, including *figures* 4, 5 a-b, 6, 7, 8, 9, 10 and Annex III (first part), was published in the previous number of the *Neth. J. agric. Sci., i.e.* in Vol. XI (1963) No. 5 (November) p. 387—417.
Part I was published in the last but one number of the Journal, *i.e.* in Vol. XI (1963) No. 4 (August) p. 308—333.
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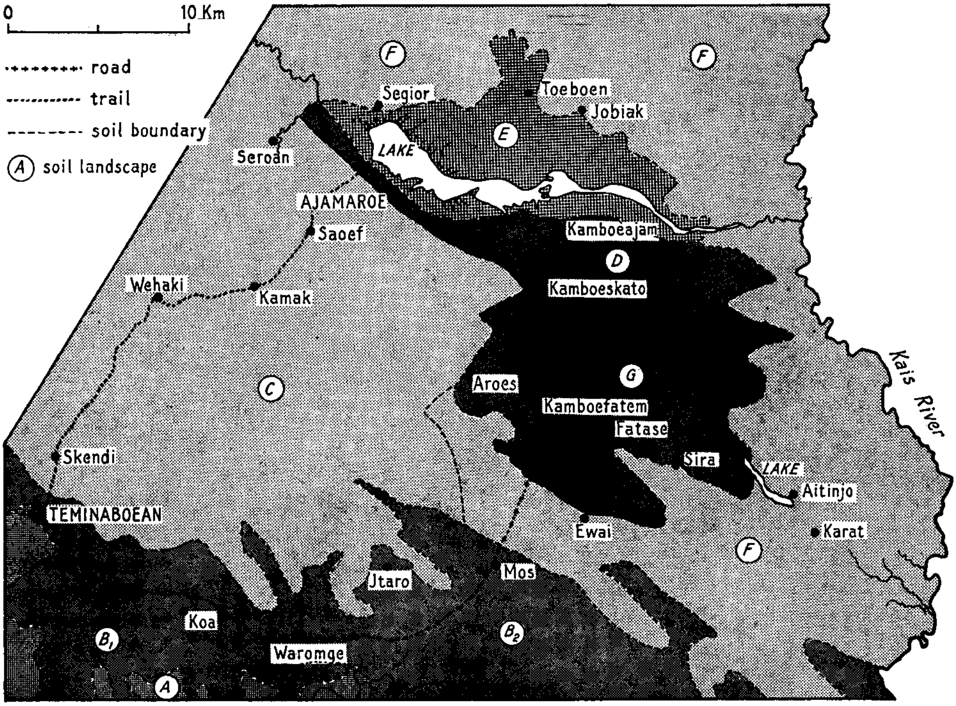
FIG. 11. Physiographical sketch map of the Ajamaroe-Teminaboean area



In the south, transitional to landscape A, a zone of quartizic sandstone and conglomerates is found which reaches with tongues into the coastal alluvium. This old parent material generally carries deep soils which are red (2.5 YR. 4/8) to yellowish-red (5 YR. 5/6–5/8), with heterogeneous textural horizons varying from sandy loams to silty loams which often contain concretionary layers in the subsoil.

These soils are very acid (pH = 5,0—5,5), low in lime and phosphate and suitable only for a tree crop making fewer demands, like rubber. The yellowish-brown variant on conglomerate is mostly very gravelly or stony and extremely acid; it is unsuitable for all cropping purposes.

In between this sandstone zone in the south and the limestone plateau in the north parent materials vary irregularly between soft limestones, marls, marly mudstones, mudstones and shales. Accordingly, four major types of soils are broadly distinguished, *viz.*:

a.1. yellowish, brown, well-drained silty loams of soft limestone with highly calcareous topsoils;

a.2. same, but without free lime being present in the topsoil;

b.1. light olive-brown, poorly drained, stiff, silty loams/clays on marls with calcareous topsoils;

b.2. yellowish-brown, fairly drained, less sticky, silty loams/clays on non calcareous mudstones.

Standard analyses, valid for the averaged composition of the soil between 10 and 70 cm depth (top 10 cm being discarded) are worked out for the sandstone soils (type c) and the soil types a_1, a_2, b_1 and b_2 in the TABLE hereunder.

	Soil suitability				
	good		limited	nil	
Soil type:	a.2	b.2	c	a.1	b.1
Texture					
sand (%)	5	6	34	1	1
silt (%)	52	55	45	53	53
clay (%)	43	39	21	46	46
Soil reaction					
pH-H_2O	6,5	6,1	5,4	8,2	8,2
pH-KCl	5,5	5,0	4,6	7,0	7,0
Free $CaCO_3$ (%)	traces	0	0	23	12
Easily soluble ions					
in 3 % acetic acid					
CaO (p.p.m.)	5.500	4.000	1.000	130.000	60.000
MgO (p.p.m.)	350	300	250	1.400	4.100
K_2O (p.p.m.)	175	125	175	125	155
in Truog extract					
P_2O_5 (p.p.m.)	20	15	10	175	200

In the terrain, the four soil types are very much intermingled and it needs a very detailed survey in order to determine the actual total area of suitable soils which, presumably, lies between 1000 and 2000 ha. Soil depth, the occurrence and the percentage of free lime in the surface soil, slope and drainage conditions are the main criteria to be used in such a detailed survey.

In the karst area of the limestone plateau north of Teminaboean poorly bedded, light coloured autochthonous limestones of (inter) biohermal character are found. The interbiohermal rock type is chalky and powdery on breakage. Its fossil content comprises mainly benthonic Foraminifera and Globigerina of the neritic zone. The interbedded biohermal limestones are harder and are composed of coarser organic remains with a preponderance of corals. Locally, the limestone is almost entirely made up of calcium carbonate whereas in other places the limestones may contain a certain percentage of quartz.

The thickness of the Ajamaroe limestone beds is estimated at a few hundred metres. Post-Tertiary tectonic movements raised the submerged limestone plateau to its present elevation of 300 to 400 m above sea level. Folding and faulting have produced an intersecting, strong joint system with main directions northwest-southeast and northeast-southwest, which are clearly recognizable on the airial photographs. Subsequent erosion and subterranean solution of the limestone resulted in the present karst morphology of the landscape with its conical hills ("sugarloaf topography"), dolines, uvalas, poljes and underground drainage systems.

On the map (FIG. 11), five landscapes C, D, E, F and G are distinguished on account of the relative degree of ruggedness and the type of karst development. The synclinal landscape E is typified by concave relief, the other four by excessive relief.

The 8.600 ha of landscape E comprise two soil complexes of mainly unsuitable soils. One of these consists of very dark-grey (blackish), organic swamp soils on calcareous silt, the other complex is made up of whitish to yellowish quartzitic sands and sandy loams which are very infertile.
In ANNEX III, an averaged analysis of surface soil and subsoil of a deep, yellow quartzitic loamy sand near the kampong of Seta is presented; only the phosphate content is very high, probably because of the relation to the phosphatic soils in the environment.
The landscapes C and F which cover about 130.000 ha in the surveyed area of very rugged, inaccessible, roughly broken rock land, may yield no more than a total of one or two thousand scattered hectares of sufficiently deep soils which are present in the smaller and larger terrain depressions formed by dolines and uvalas. Far less broken, but still rocky, is the plateau-like landscape D, whereas the morphological features of landscape G are intermediate between those of C and D. An estimated total area of 7.000 ha of deep soils are presumably available within the 23.000 ha of the landscapes D and G. These deeper soils are by no means excellent arable soils although they are well drained and possess a friable structure. Besides their general deficiency in potash, practically all soils have the peculiar property in common that they contain extremely high contents of phosphate which may range anywhere from 1 to 25 % P_2O_5. This phenomenon, which we met with already in Biak and Manokwari, is caused by a process of accumulation through which all phosphate, contained in the masses of dissolved limestone, is preserved in the soil thus formed. The same holds true for the large amounts of iron that have accumulated in the same way. Manganese and strontium are other elements which are unusually high in these soils. The bulk of these silty clay loams or silty clays therefore consist of haematite and a clay mineral "crandillite" which is a calcium-aluminium-phosphorus compound. Particulars about these soils and their formation are described by SCHROO (1963).
It is extremely difficult to describe in brief the diversity in colour shades, texture and depth of the soils, as these characteristics are chiefly dominated by the factor relief which is variable from spot to spot. The colours often grade (but not always) in a catenary sequence from purplish and reddish in deep, mature, well-aerated soils on elevated but not eroded sites, towards brownish colours down the slopes and in the terrain depressions. The yellowish-brown colours are found in low sites with poor drainage and in rejuvenated, shallow hill-side soils which still contain undissolved, yellowish calcareous grit and sand.
Some soils contain appreciable quantities of quartzitic sand. Other soils do not. The author holds the opinion that the majority of these soils are suitable only for subsistence cropping and are not suitable for commercial crops like rubber, cocoa and coffee. Anyway, potash deficiency, and probably minor-element deficiencies have to be cured. The natives sometimes take the trouble of gathering wood from other sites in order to burn this material on their cultivation plots for better growth of their crops. After prolonged cropping, the soils degenerate quickly and remain for a long time in fern wilderness. The balance between shifting cultivation and regeneration of the Ajamaroe limestone soils is dealt with by REYNDERS (1961).

4.9. Coastal area of Bomberai Peninsula (Objects 22—23)

The Bomberai Peninsula is bordered in the north by the MacCluer Gulf and in the south by the Argoeni Bay. For convenience sake, we may as well include the area

farther south to the Etna Bay in our brief geological description, because limestone bedrock prevails along the entire western coast of the area (see FIG. 3). The smaller subordinated Onin Peninsula in the north and the Koemawa Peninsula in the south of the Bomberai coast are anticlinal areas made up of Miocene limestones and shales with cores of Oligene limestones. The same holds true for the area between Argoeni Bay and Etna Bay. It is reported that these karst areas are largely bare rock and very similar to the landscapes C and F described in the previous paragraph.
The central part of the Bomberai Peninsula is an area of low relief which is taken up by Pleistocene sand, clay, sandy clay and medium to fine gravel. It is bordered to the east and to the west by broad belts of Pliocene sandstone, shale and clay which run in a north-south direction. Unfortunately, no soil surveys have been carried out in this area.

Object 22: FakFak and Coast of MacCluer Gulf

The northern coastal plain along the MacCluer Gulf and Bintoeni Bay east of Kokas, consists of Quaternary deposits which are covered with Mangrove forest. Only a few soil samples have been received from Babo in the past, which were taken from drier sides within the swampy coastal plain. They represent quartzitic loams and clays which have yellowish- and reddish-mottled subsoils, containing iron concretions. Presumably, we are dealing here with old and leached soils, developed on Pleistocene parent material, which reach with tongues from the hinterland into the Quaternary coastal plain.
West of Kokas, the Neogene marls and limestones of the Onin Peninsula reach the coast, and are fringed with recent coral reefs. The small island of Argoeni, north of Kokas, is covered with Eocene limestones, which contain a fair percentage of quartz and do not yield residual soils with high phosphate contents. The phosphatic soils are found on coral limestones near Kokas. Little is known about the soils of the interior of the Onin Peninsula. Only the nearest vicinity of FakFak and also of the nearby kampong Pasar Poetih has been visited by a pedologist (Report 22.1).
Around FakFak the dominant parent rock is a greyish Globigerina limestone of a marly type and platy structure. On weathering, the rock is decomposed along the surfaces of its horizontal and vertical cleavages and cracks, thus forming a brick-work of separate, slightly rounded, flat blocks each of which being covered by a thin layer of decomposed rock or soil. Forest trees, and also nutmeg trees which are grown succesfully here, send their roots into these lamellae of decomposed rock and thrive well, even though the actual solum on top of the limestone is very shallow.
The rock itself is also porous and is leached by rainwater. This facilitates the formation of chalcedonic chert in the lower part of each unit of marly limestone. On weathering, this chert accumulates at the soil surface in those sites, where sheet erosion carries the finer soil particles away. Likewise, hill-side colluvium may be very gravelly, containing abundant amounts of chert.
Depending on the texture of the non-calcareous constituents of these platy limestones, the texture of residual soils and of soil layers may vary within the range of silty loams to silty clays.
In the Pasar Poetih area, sandy loams were found in addition to silty loams and clays. In all instances mineralogical analyses proved that the bulk of the sand separates consists of quartz from which evidence it may be concluded that reserves of nutritive elements are low in these soils. According to quite a number of analyses

made, soils are lacking in potash and phosphate. Locally, also very low values for available magnesia were analyzed.
These deficiencies may account for the fact that "productive years" and "resting years" alternate with regard to the fruiting of nutmeg orchards. A certain amount of plant nutrients is accumulated and contained in the organic matter of the surface layer of the soil. An average analysis of such a layer (uppermost 25 cm) is presented in ANNEX III.

Object 23: Kaimana and Etna Bays

A sketchy survey was carried out in 1960 in the nearest surroundings of Kaimana (Report 22.1). The village is enclosed from the land side by limestone mountains of Paleogene age, which rise steeply from the narrow coastal strip that is built of hillside colluvium and elevated littoral sediments. Besides patches of deep, friable, reddish-brown colluvium derived from mature limestone soils uphill, also rocky detritus is found and juvenile yellowish, shallow loams on limestone rock. Elsewhere, a gently undulating area is found, made up of a deep, yellowish loam which is reddish-mottled and concretionary in its subsoil, and is underlain by a rather imperious, compact layer of greyish silty clay. The fertility of this soil is not high, and its extension is not mentioned.
Further information about soils in this area is very scanty. In the past, poorly described soils have been incidentally sampled by third parties at various sites. For instance, samples have been collected near Mendiwa on the western shore of the Argoeni Bay where, formerly, vast areas have been under shifting cultivation, but are now abandoned and partly covered again by secundary forest. Likewise, a few samples have been received from land, alleged to be suitable for agriculture, near the kampongs of Kembala and Tipoera (Ryklof van Goens Bay). A number of samples have been collected also on the island Poelau Adi, south of Kaimana. All these samples indicate that, in these environments, mostly, soils are to be expected which are developed on limestones, quartz-containing limestones, marls, quartzitic sandstones and coral sand. Soil samples, which formerly have been received from the surroundings of the Etna Bay and the Mboeta Lake north of it, also indicate that limestone soils and quartzitic loams prevail and that soil fertility is generally low. The northern shore of the Argoeni Bay is taken up by steep slopes of the adjacent limestone (karst) area, whereas along the southern shore mainly alluvial lowland is found that continues further southwards all along the western coast.

4.10. The Central Mountains (Objects 24 a-b)

This high mountain system extends in a general east-west direction more than 600 km from Nabiré (Object 11) in the west to the Australian border in the east. Its average width is about 140 km. The highest part of the mountain system, the Snow Mountains, is characterized by sharp peaks, narrow, pocky limestone ridges, very high precipices and deep gorges. Mountains rise up to 5.000 m altitude. Above 2.200 m, valleys are generally U-shaped glacial troughs but below that level river valleys are V-shaped. The south flank of the Snow Mountains drops abruptly, within a relatively short distance, nearly to sea level as follows from FIG. 1. The foothills at this southern margin are high and steep. On the north side the relief decreases more gradually except near the Great Lake Plain where the massif steeply descends from 2.200 down to about 100 m altitude.
Most parts of the region are very difficult of access and were not yet brought under

actual administrative rule, reason why only a few locations have been visited and examined by pedologists. The two main accessible and rather overcrowded centres of population are found around the Wissel Lakes with the Kamoe plain in the west and the Great Baliem Valley with its side valleys in the east. Here, broad reconnaissances have been carried out in order to see if there are possibilities for agricultural development.

The Ok-Sibil valley has also been subject to a cursory pedological examination as it formed a stepping stone for the scientific expedition to the Star Mountains in 1959. The soil-scientific results of this expedition are not yet available at present. Some preliminary results have been published by REYNDERS (1960).

The greater part of the mountain system still forms blanks on the geological map of the country (FIG. 3). The relatively small areas which have been explored so far, reveal a wide variety of rock types ranging from Pre-Devonian to Quaternary in age. The exploratory results suggest that limestones of various geological age, sandstones, shales, slates and other sedimentary rock make up the bulk of all bedrock in these highlands, whereas outcrops of granite, diorite, basic igneous rock, gneiss and mica are only of minor and local importance as far as soil formation is concerned. On weathering and solution of the calcareous components, most of the above-mentioned sedimentary rocks will leave little more behind than quartz particles. From the air, quite often silvery glittering areas of white quartz sand can be seen fringing the base of limestone outcrops. Around the Wissel Lakes as well as in the Baliem Valley, areas of fluviatile sedimentation are found which consist mainly of quartzitic material. No need to say that these soils are almost sterile. They are often scantily covered with a poverty-adjusted, acidophylic vegetation of grasses, ferns, lycopodium and shrubs, sometimes intermixed with Nothofagus and Dacrydium trees. On a poorly-drained, quartzitic sandy loam a thick layer of peat was developed under Dacrydium forest. These type of vegetation has been described by RAPPARD and VAN ROYEN (1959). Peat formation is otherwise quite common in these regions, and may develop on quartzitic as well as calcareous material, wherever low temperature and poor drainage combine and impair the breakdown of organic waste. The occurrence of peat in the highlands has also been mentioned by REYNDERS (1958).

Especially in these mountainous areas, where little is known about bedrock occurring in the upper courses of the rivers and streams, mineralogical analysis of soils found in areas of fluviatile sedimentation, is an important means to assess the potential fertility of such a soil and to make conclusions as to the origin of the material involved. In the latter instance concentration and analysis of the "heavy minerals", which are present in minute quantities in the sand separate, is most helpful. This relationship has been discussed in more detail by SCHROO (1961) in his publication about soils in the Baliem Valley.

Object 24a: Baliem Valley

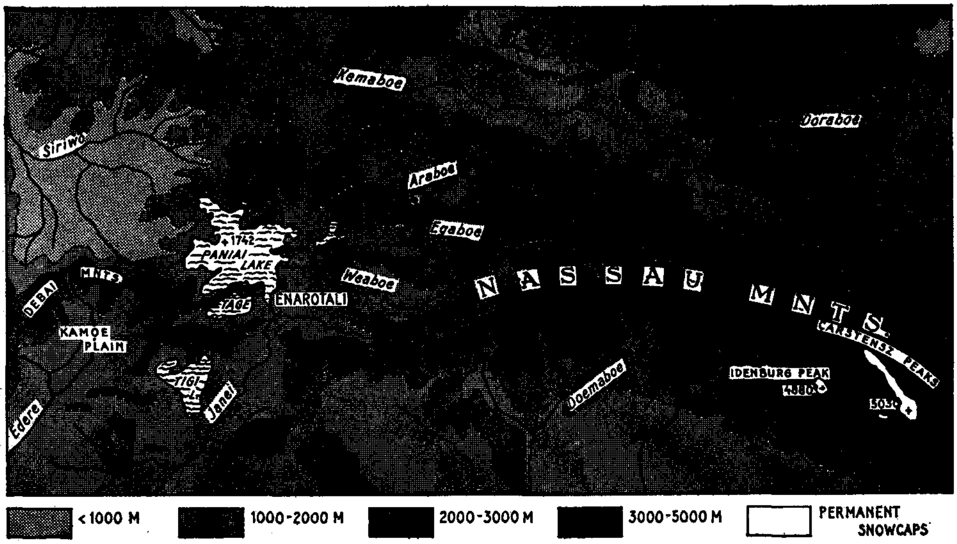
This valley being about 45 km long and on an average 15 km wide, is filled in by erosion material which has been brought down by the Baliem river from the hinterland and also by the tributaries from the adjoining limestone mountains, which border the plain on both sides. The young, short and braided tributaries have deposited coarse material in the valley and are responsible for boulder and gravel beds near or at the soil surface. The Baliem river is a very slow and meandering river which tends to receive more water than can be discharged through the narrow gorges at the southern end of the valley. In the broad flood-plain, which may have been a lake

one time, medium- and fine-textured material of different age is deposited. Consequently, all types of soils conditioned by a meandering river are to be expected in the valley, together with sudden outcrops of limestone hills, soils of alluvial fans, swamp soils and peat soils.
The older Baliem sediments are extremely poor from a mineralogical point of view and they are, in addition, very much decalcified and leached.
The recent Baliem sediments are somewhat richer and contain, besides calcareous concretions, traces of apatite and several percentages of potash-releasing minerals such as orthoclase, biotite, muscovite, glauconite.
An analysis of freshly-deposited river sediment of the Baliem and of an old, leached Baliem sedimentary soil are presented in ANNEX III. The levee soils also become gradually decalcified but remain very fertile when left under natural growth of *Casuarina montana*. It has been proved that this tree is a great accumulator of nutrient elements, particularly for magnesium and phosphorus. Two analyses are presented in ANNEX III which demonstrate this point. Once the Casuarina trees are removed and the soil is cultivated, a rapid decline of its humus fertility sets in under influence of the heavy rainfall, as has been experienced in the horticultural centre near Wamena.
In the marshy areas everywhere in the valley, the natives are practising a self-invented cultivation system of raised planting beds, surrounded by closed drainage ditches. Not only are the beds continuously molded up with plant remains and dirt from the ditches, but the nutrient salts, dissolved and percolating from the beds, are retained in the ditches, and move back into the beds again. Due to the necessity to rest the beds for several years under fallow, each "clan" requires a great deal of land depending on the number of its members and the duration of the fallow period. In many places of the valley acute land hunger exists for this reason. The less fortunate clans, outside the plain, try to maintain a system of planting beds on the slopes of the limestone hills, where a stony, shallow, yellowish-brown to reddish-brown loamy soil type prevails, which is generally poor in organic matter and plant nutrients. Only in terrain depressions and at the foot of the hills, these limestone soils are deeper. On the slopes, all of which are deforested, these shallow soils on permeable parent material, are susceptible to drought during the short spells of dry weather. In some places attempts are made to prevent erosion by crude terracing and contour piling of rock. The crop-yielding capacity of these soils is short-lived, and the natives have to move from one side to another; even the steep inside slopes of the deep conical-shaped dolines are used for cropping purposes, as could be observed from aerial photographs.

Object 24 b: The Wissel Lake area

This area in the western part of the highlands has been described in great detail in the Reports 24.1 and 24.2 and is depicted in FIG. 12. The area comprises the nearest surroundings of the Paniai, Tage and Tigi lakes, situated at an altitude af about 1.750 m, and also the Kamoe plain, which is a former lake, at present covered with several metres of wet peat. The lakes are surrounded on all sides by high mountains with steep slopes, which leave little space between the lake and the mountain sides. Around the Tage lake there is no space for level grounds at all. Around the Paniai lake and Tigi lake some more space is left for alluvial terrains, which are partly alluvial fans and hill-side colluvium, partly clayey and peaty lake-bottom soils. East of the Paniai lake the broad valleys of the Aja and Weja rivers, which feed the lake,

FIG. 12. Physiographical sketch map of the Wissel Lake area in the western Central Mountains



are very wet and covered with thick layers of peat. Depending on the variable level of the water in the lakes, the level terrains bordering the lakes are subject to waterlogging or flooding. Precipitation is very high and fairly even distributed over the year with monthly rainfalls of about 200 mm. Consequently, soils in these highlands are intensively leached.

As far as our knowledge goes, two main groups of parent materials may be distinguished in the surrounding mountains. One group comprises pure, or some quartz-containing limestones, whereas the other group includes the non- or slightly calcareous quartzitic sand- and mudstones. In addition, there are indications that locally, *e.g.* in the Debai Mountains north of the Kamoe plain, outcrops of igneous rock are likely to occur. For this reason, it seems that, on a regional wide base, residual mountain soils could be classified best according to the three main types of parent rock mentioned.

It has been observed, however, that even within a relatively small area, or even along one single slope, calcareous and non-calcareous, sedimentary rock may alternate erratically. From aerial-photographs it is apparent that the composition of the mountain forest does not offer much of a clue as to the type of parent material either. Solifluction along the slopes complicate the issue even more. Another remarkable fact that causes confusion, is the similarity of the final residual soils developed on either type of parent material, provided that the quartzitic particles contained in both materials are of the same texture class. Even the mineralogical analyses do not show much differentiation, quartz being the predominant mineral in both instances. There is, however, a difference in chemical respect, as far as subsoils are concerned. This difference is due to the circumstance that far more limestone must dissolve, in order to produce a certain layer of quartzitic soil than is the case with weathering quartzitic parent material. In the process of dissolving limestone, an element like phosphorus is definitely accumulated in the residual soil and, probably, other elements as well. In the same way, certain weathering-resistant minerals may sometimes be accumulated. This point has been elaborated further by the author in Report 24.2.

From a soil-fertility angle it may be stated that residual soils on limestones are generally the better ones, whereas residual soils on quartzitic parent material are extremely poor, lacking in lime, magnesia, phosphate and potash. Two comparable analyses of limestone soil (Enarotali) and quartzitic soil (Erepakarida) are presented in ANNEX III.

Pilot plots for coffee, which were started on the marginal soils, proved to be a failure, magnesium- and boron-deficiency symptoms being the first to show in this crop.

For temporary cropping purposes (subsistence crops), the soil-fertility factor of paramount importance is a well-preserved organic surface layer. This factor overrules in many instances the effect of difference in parent material. Two analyses of Komopa, presented in ANNEX III, elucidate this principle.

The deeper, sandier phases of the quartzitic mountain soils found on gently sloping terrain display classic features of iron podsols; on steeper slopes truncated profiles may display unexpected bright-orange colours.

There is little need for discussing the coarse-textured, azonal soils found at the upper part of the numerous smaller and larger alluvial fans; nor deserve the soils at the lower end of these fans much more attention, because of their swampiness. The bog soils and half-bog soils are suitable for the growth of tuberous crops (*Ipomoea batatas*) only, to which end the soil is worked into raised beds. Young alluvial soils, which may be suitable for the growing of a mountain-adapted cash crop like coffee, are those having a water table below a depth of at least 50 cm. In the small plains adjoining the lakes, and also in the Kamoe plain, these soils have highly-organic surface layers, most of them being already occupied by the natives for the growing of subsistence crops.

4.11. Southwest coast (Object 25)

The southwest coast of the Mimika and Asmat districts, reaching from the Etna Bay to Agats at the Flamingo Bay, is pedologically rather unknown territory. It is a flat and largely swampy lowland, which reaches southward into the vast Digoel-Fly depression. To the north, this lowland is bordered by extensive piedmont alluvial deposits of Pleistocene age which form a gravelly benchland with altitudes below 120 m, fringing the foothills of the Central Mountains.

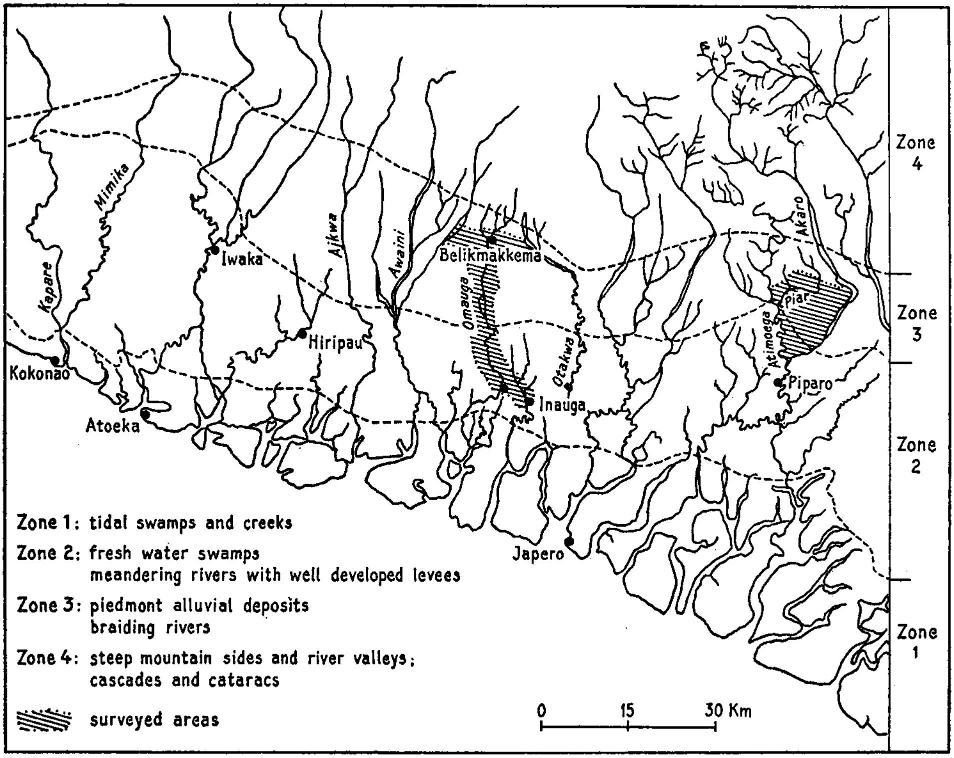
The numerous braiding rivers which traverse this elevated benchland, have cut valleys into their own former deposits and are building new alluvial fans somewhat lower downstream. After having lost the bulk of coarser detritus on entering the actual swampy lowland, the braiding river changes into a meandering stream, a change which may be rather abruptly. In the swampy lowland the meandering rivers are entrenched within fairly high and broad levees, which occasionally overflow.

Outside the levees, extensive peat bogs covered with forest have developed on top of the finer fluviatile deposits. This layer of topogene peat may attain a magnitude of several metres in the central parts of the peat bog. Here, the peat may eventually rise above flood-level, thus changing gradually into ombrogene peat (see also POLAK, 1950).

Lower down the river course, the fresh-water swamps merge into a broad belt of tidal swamps, which also border the greater part of the coast and are grown with

Mangrove and Nipah forest. Locally, narrow sandy beaches have developed which reach slightly above high spring-tide level and are grown with Casuarina or *Cocos nucifera*. In FIG. 13 the geography of the area and the four belts of fluviatile sedimentation are sketched.

FIG. 13. Geographical sketch map of the Mimika coast



Because most of the rivers originate in the unknown territory of the southern part of the Central Mountains, it may be expected that each of them carries detritus of different mineralogical composition.
This aspect is of importance with relation to the fertility of the higher and dry soils along the rivers. For example, it may be mentioned that a mineralogical analysis of soil samples received from the kampongs of Iwaka and Hiripau indicates the presence of schist in the upper course of the (unnamed) river. The Omauga river, farther south, carries mainly detritus of quartzitic sand and mudstones.
Likewise, in the Akimoega area it was noted that the Akaro river carries calcareous detritus of a dolomitic nature, whereas its confluent, the Akimoega river, only carries schist and other non-calcareous material.

Object 25: Akimoega-Akaro area and Omauga area

Pedological reconnaissance was carried out in 1960 in both areas (Report 25.2). In the first-mentioned triangular area of 10.000 ha, situated in between the Akaro and

Akimoega rivers and traversed by the Piar river, six different soil types were distinguished and mapped on a scale of 1 : 50.000. These soil types were distinguished on account of the characteristics of their topmost layer of 50 cm. They were listed as litosols, sandy loams, silty loams, silts, clayey swamp soils, and (half) bog soils. There is little need to explain that in an area of fluviatile sedimentation where three braiding rivers flow together, soils are heterogeneous and the soil pattern in the field is rather intricate.

Therefore, suffice it to say that soil suitabilities in this area proved to be rather limited with regard to the growing of cash crops like rubber, poor drainage, stoniness and flood hazards being the main limiting factors. It was also ascertained that the land west of the Akimoega river was infertile because this river forms the borderline between calcareous sediments on east and acid, quartzitic sediments on west. The Akaro sediments often contain high percentages of free lime between 20 and 60. Even underneath a well-developed peat layer a very high lime content and a pH = 7,8 are maintained. Two representative analyses of levee soils, one calcareous the other non-calcareous are given in ANNEX III.

As far as the area along the Omauga river is concerned, no real soil survey has been made here, though locally traverses were examined and soil samples were collected along the river in the stretch between the kampongs of Omauga and Belikmakkema. Through lack of aerial photographs, no estimate of the total area of dry soils could be made. However, the general impression was obtained that well-drained sandy loams and loams underlain by boulder beds at various depth prevail in the higher and dry areas. These soils are physically good soils but they are very acid, decalcified and not fertile. Their available-potash contents are often remarkably high (see analysis ANNEX III).

The samples received from the kampongs of Iwaka and Hiripau are all quartzitic silty loams, containing 40—60 % of quartz in their sand separates and about 10 % potash-releasing minerals, such as orthoclase, a little biotite, muscovite and sericite, the remainder being rock fragments. These soils are more fertile, less acidic, having a pH = 5,8 to 6,3, and are reported to produce good subsistence crops.

4.12. Digoel drainage basin (Objects 26—28)

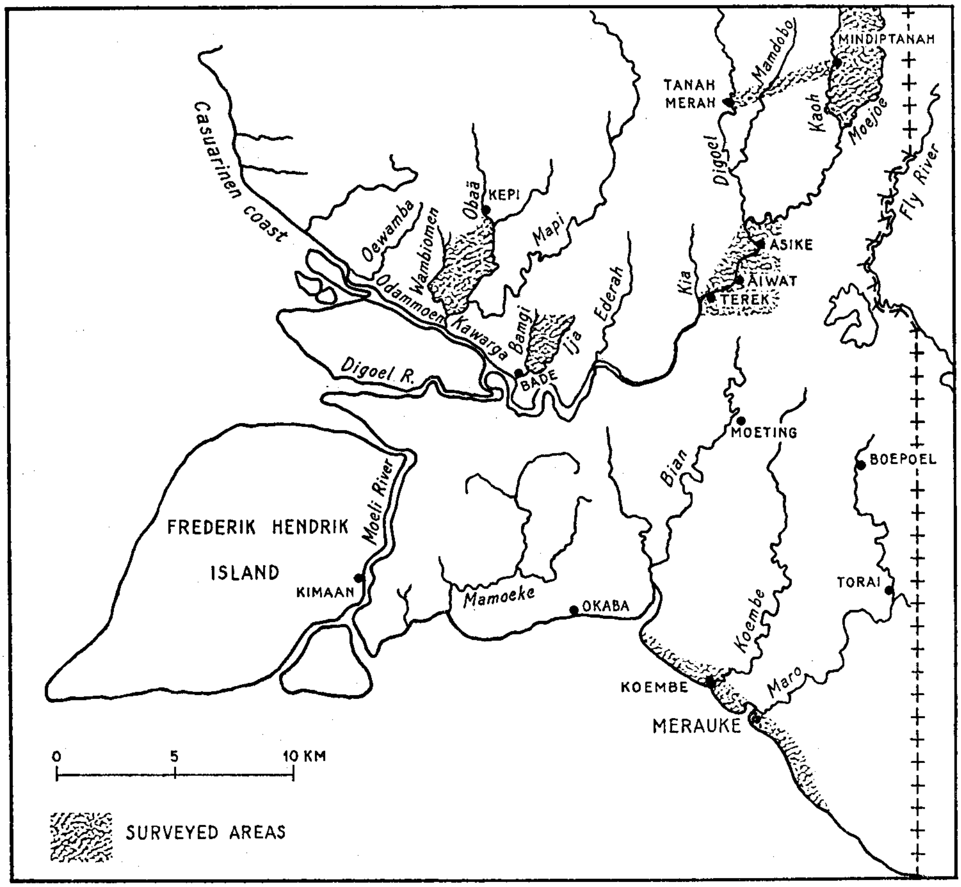
Under this heading the soil surveys will be reviewed which have been carried out in the vast area of the Moejoe-Mandobo and Mappi districts (see FIG. 14). The Digoel is a real mountain river that has its origin far north in the Juliana Mountains. Its length is 670 km measured from the foot of the mountains to the coast. The larger part of the river's course lies in the lowland. This is evident from the fact that the small village of Tanah-Merah, far upstream, lies 18 m above sea level.

Downstream of Tanah-Merah, the Digoel is joined by the smaller Mandobo river. Farther downstream, near the kampong of Getentiri, the Digoel receives at its left bank the Kaoh or Oewimmerah, which is also a real mountain river.

The Moejoe river is an affluent of the Kaoh, the small village of Mindiptanah being the centre of the Moejoe district.

Lower downstream of the confluence with the Kaoh-river, the Digoel receives additional masses of water from the swamp-born northern tributaries Kia, Ederah, Bamgi-Ija and Mappi-Kawarga. An elaborate geomorphological description of the Digoel-catchment area, and the participating rivers was published by HELDRING (1909/1911). As a point of interest and for the proper understanding of the following discussion, it may be briefly mentioned that the Digoel drainage basin is part of a much larger,

FIG. 14. Geographical sketch map of the Digoel area



swampy lowland that extends across the Australian border and is, after VAN BEMMELEN (1949), commonly referred to as the Digoel-Fly depression because of these two big rivers having covered with their sediments the subsided Neogene bedrock in this depression. It is assumed that the subsidence of this area still slowly and intermittently continues, although interperiods of regression must have occurred too. The subsidence of the area is apparent from the many coastal estuaries, whereas the presence of Neogene sedimentary bedrock underneath a thick cover of Quaternary sediments has been proved by borings near Merauke where sandstones and shales were found at a depth of 100 to 230 m. These young Tertiary sediments seem to rest directly on the crystalline floor of the submerged Sahul shelf, which connected the territory of West Irian with the Australian continent in earlier eras.

For more particulars about tectonics and stratigraphy of the area the interested reader is referred to the review of VISSER (1962).

In the northern part along the mountain front, the area is occupied by terrace gravels (by VAN BEMMELEN named Post-tectonic molasse) which dip at a very low angle towards the south, and present three or four terraces at various levels above the river. These gravel terraces can be observed as far south as Tanah-Merah and Mindiptanah. Still farther to the south, the zone of coarse alluvial detritus gradually merges into a zone of finer sediments. It is assumed that in old Quaternary times, a piedmont alluvial plain stretched far southward to the former coastline. After regression, this plain was even farther extended through the emerging of a coastal plain. This proceeding simultaneously initiated renewed erosion. The thick layers of fine sands, silts and clays, covering this old Quaternary constructional plain, have been intensively weathered. These red, yellowish red- or red-mottled old Digoel soils consist mainly of quartz and iron ores, zircon and turmaline being the main recognizable accessary minerals.

The old Quaternary landscape has been partly eroded away during eras of regression and a general lowering of the erosion-base level of the rivers. More inland, the remaining elements of that old landscape still cover large areas, forming plateaus, ridges and hills, which may reach heights of 30 m. Nearer to the coast, these elevated and isolated remnants of the old landscape become fewer, more widely dispersed and of lower heights, the young fluviatile sediments being the dominating type.

Quoting VISSER (1962) in his review of the plains of South New Guinea, he says on page 188:

> locally remains of river terraces occur, forming flat-topped, narrow hills, composed of sandy material with small well-rounded pebbles. They are especially prominent along the Digoel and lower Mappi rivers, where they are the site of villages. In the lower reaches of these rivers they are about ten metres high; going upstream along the Digoel their height increases to a few tens of metres.

It has been supposed by HELDRING (1911) that part of the old Quaternary landscape has been temporarily submerged, being covered by marine sediments of quartzitic composition during that period. This assumption is not unlikely because, nearest to the coast, red-mottled clays are found underneath marine sediments. Subsequent regression of the sea must have proceeded with intervals according to a system of retreating shorelines (marked by sand ridges), which have been mapped by this geologist. His theory has not been checked by pedologists.

In reviewing the results of the relatively few and scattered soil surveys that have been carried out in this vast and inaccessible area of the Digoel-Fly depression, the lack of trustworthy local information about Quaternary geological data and of a region-wide pedological reconnaissance are badly felt.

The exact interpretation and amalgamation of observed pedological facts in this region was therefore often impossible.

Object 26: Moejoe-Kaoh-Mandobo area

An area near Mindiptanah of about 60.000 ha, bordered by the Kaoh river in the west and the Moejoe river in the east, was surveyed in 1954 on a reconnaissance scale of 1 : 250.000. The greater part of this area is dissected hilly country with excessive relief, which forms the watershed between the two rivers.

From the Kaoh it is known that this river cuts in his upper course through extensive formations of tuffaceous sandstone, tuffaceous mudstone, and conglomerate beds, containing calcareous and volcanic rock from the Central Mountains. The lower aggradation terraces of the Kaoh, which are found south of Mindiptanah, are therefore very fertile. The mineralogical composition of these loamy terrace sands warrants a rich miscellanea of nutrient-releasing minerals. However, these good soils (soil type No. 3, in Report 26.1) are subject to occasional flooding.

The soils in the hilly country are formed on a parent material of old fluviatile origin, which is a greyish-red and yellow-brown mottled, gravelly silty clay. The soils are yellowish-brown (silty) clays, which are mostly not deeper than 30 to 60 cm, and seldom rooted by forest trees to a greater depth than 50 cm. The surface layer is friable and contains gravel and flat fragments of limonite-cemented quartz. The subsoil becomes more compact, less permeable and is reddish mottled. In the deeper layers, beneath the solum, pieces of platy sandstone are sometimes found. In higher sites the soils are often truncated, whereas in lower sites the profiles are covered with hill-wash.

These yellowish-brown silty clays (soil type No. 1, in Report 26.1) are very poor and support forest of mediocre quality. When used for the growing of food crops in the native system of shifting cultivation, these soils are completely exhausted in two years time and are left fallow for twenty years and more. This type of soil also occurs on the other side of the Kaoh river and across the Mandobo river, and is believed to cover most of the area lying between Mindiptanah and Tanah-Merah. An averaged analysis of seven surface soils (0—25 cm) and seven corresponding subsoils (25—50 cm) sampled east of Mindiptanah, are presented in ANNEX III. Because of its large extension and the good physical properties of the deeper phases, this soil received considerable attention from agronomists who wished to grow cocoa on it in order to boost economic developments in this very backward district. On account of analytical evidence and, the more so, because the use of fertilizers was rejected as an unworkable proposition for native cash cropping, the present author advised against cocoa growing on this soil.

The extremely acid, decalcified soils are lacking in magnesia and potash. They are also very deficient in phosphate and their phosphate-fixing capacity is high, as has been proved by pot tests and in the laboratory.

Basic slag or rock phosphate are the recommended fertilizers for this soil. Its suitability for the growing of rubber has also been under consideration in later years, and pilot schemes for testing rubber on these soils have been started near Mindiptanah and Tanah-Merah in 1961. It is the author's opinion that even for this tree crop which makes fewer demands the suitability of this soil is marginal without the use of phosphatic fertilizers. Furthermore, it should be noted that this type of soil is very susceptible to erosion and requires great care and protection when used for native rubber planting in terrains which are not level.

Object 27: Digoel-Bian area

In 1961, a practically unknown and uninhabited area of 100.000 ha situated east of the Digoel and south of the confluence of the Digoel and Kaoh rivers, was surveyed on a reconnaissance scale of 1 : 200.000.

The western part of the area is taken up by the very broad flood-plain of the meandering Digoel river. The plain measures 10 km in width but is marshy to very swampy. Small areas of suitable soils, which will remain undiscussed, are found here only on the river levees which are 20 to 100 m wide.

East of the Digoel an elevated plateau is found which is a remnant of the old Quaternary landscape. The plateau, which has an altitude of about 30 m above sea level, is more or less flat in its central north-south stretched zone.

Its western side towards the Digoel and its eastern side towards the Bian are badly dissected and eroded.

Because the main purpose of the Digoel-Bian survey was the evaluation of soils in relation to rubber planting, soil suitabilities will be considered according to this relationship. The prevailing type of soil in this area is very similar to that of Mindiptanah and Tanah-Merah because it has been developed on the same whitish to greyish, quartzitic material. Here, the soils have been studied in greater detail. Although in the plateau landscape three soil series were distinguished, these series should actually be regarded as three variants of one single series. After the kampong Aiwat at the eastern bank of the Digoel, the soil might be named *Aiwat, old, red loamy clay series.* The author holds the opinion that this is a Red-Yellowish Podsolic soil.

The averaged, normal standard profile is composed of a brown (10 YR. 5/3), humic, eluvial surface horizon which seldom attains a thickness of more than 20 cm. This surface horizon is followed by illuvial layers, which may be divided into about 50 cm of a homogeneously red-coloured (5 R. 4/6) illuvial B_{ir}-horizon in which all quartzitic soil particles are iron-coated, and an underlying red- and yellow-mottled B_{2t}-horizon of about 40 cm, which gradually merges into a puplish-stained, whitish $B_{3(t)}$-layer. The enrichment of the B-layer with sesquioxides at the expense of the A-layers becomes lesser and more localized with increasing depth. Due to the moister soil climate, also yellowish-brown mottles of hydrated iron oxide form in the deeper subsoil, whereas in the upper B-horizons the red, homogeneous colouring with dehydrated oxides of iron and manganese prevails. Deep down into the profile, the infiltration of colouring agent from the surface horizon becomes lesser and only purplish stains of manganese hydroxide remain.

It is difficult to assess the transition from the horizons B_3 to C, because the texture of the soil profile is variable, due to the original differences in texture occurring in the various layers of the sedimentary parent material. For the same reason it might happen that these primary fluctuations of the texture completely overrule and mask the secundary differences of texture of pedogenetic horizons, such as a B_{2t}-horizon. Quite often layers have been found in the subsoil, containing white, rounded quartzitic gravel which sometimes may crumb and desintegrate completely upon pressure or rubbing.

Another characteristic feature of this soil is the formation of plinthite in the B_2-horizon which is so much enriched with finely-dispersed iron and humic compounds. The plinthite forms, initially as soft earthy nodules, lumps or platy sheets in the deeper and moister B-layers. The gradual induration of these concretionary accumulations is most apparent in the transitional A_3/B_1-layer, which also assumes an intermediate reddish-brown colouring. Here the plinthite has hardened already.

Under prevailing conditions of heavy rainfall, the soil profiles are subject to continuous rejuvenation. That means that the surface layers are carried away through sheet erosion and that the underlaying B-horizons are transformed anew into eluvial A-horizons, provided that the soil remains under forest. This explains why the A-horizons are often found to be cramped with plinthite fragments which have been formed into the original B-horizon. Sheet erosion only carries away the lighter soil particles. In extreme cases the soil surface is littered with these plinthite fragments. Also numerous oölithes, accumulate in this way at or near the soil surface. They are made up of siliceous material cemented by limonite and are shaped like crooked, solid pipes which form around small roots in the subsoil. In many instances the root passage is still open.

The principle of dynamic profile development is little known outside the forested areas of the humid tropics where loose sedimentary parent material is simultaneously subject to pedogenesis and sheet erosion. In extreme cases, soil profiles are entirely

truncated whereas other profiles are buried by erosion material from uphill.
The various modifications of the standard, normal soil profile (No. 2 in the original Report 27.1) can be grouped and represented by the standard profiles from the two other soil variants mentioned.
In the much better soil variant (No. 1) the red, friable B_{2ir}-horizon is well developed and attains a thickness of 100 cm. The physical properties of this variant are good and render this type of soil suitable for a deep-rooting tree crop like rubber.
Quite unsuitable is the third soil variant (No. 3) which has been truncated down to the mottled layer. The red B_{2ir}-horizon has completely disappeared and a new thin eluvial layer has developed straight from the mottled layer. When not covered with a forest vegetation, the bare, mottled or whitish soil surface of such a truncated profile remains unchanged as soil genesis has practically come to a stop. In some places, these truncated profiles may be buried under thick layers of brown, sandy material from uphill surface layers. Such a layer should not be mistaken for an A-horizon developed in situ.
Apart from the good physical properties of the deep variant (No. 1), the chemical properties are very unsatisfactory, like those of the Mindiptanah soil.
In ANNEX III an averaged analysis is presented of the A-, B_1-, B_2- and B_3-layers which show very little mutual difference as far as soil reaction and available nutrients are concerned. The deeper sub-layers seem to contain a larger content of total potash because of a slight increase of the mineral orthoclase. The phosphate status of the soil including the humic surface layer is extremely poor. The cation-exchange capacity varies between 8 and 12 milli equivalents, 10 m.e. being the average. The saturation degree amounts to 20 %, which means that 100 g of air-dry soil contains no more than 2 m.e. cations on an average.
Returning to the over-all results of this survey, it has been estimated that almost two third of all plateau soils are unsuitable because of excessive relief and erosion damage. An area of 20.000 to 30.000 ha of relatively level and little broken terrain, carrying soil variants 1 and 2, is judged suitable for the growing of rubber, provided that due attention is paid to the necessity of soil conservation and soil amendment.
It is evident that this type of soil, prevailing in the old Quaternary landscape of the Moejoe-Mandobo-Digoel-Bian area, occupies even much larger areas than have been met with during this survey.

Object 28: Mapi-Ederah area

In its lower course the Digoel is joined by the Ederah, Bamgi and Ija rivers. Still further downstream, the Digoel river branches and part of its waters flow through the Kawarga and Oedammoen towards the ocean. In this northern branch the Mapi river, with its tributaries Obaä and Nambiomen, flow into the Digoel. All tributaries mentioned are true swamp-born rivers which contain clear, siltless tea-brown water and do not form levees.
In 1957, reconnaissance soil surveys were carried out in the nearest surroundings of the small village Kepi, along the Nambiomen, Bamgi and Ija rivers. Through lack of proper aerial photographs and because of difficult access to the swampy terrains, these surveys have yielded a rather fragmentary information about prevailing soil types because the old-fashioned system had to be followed of mapping soils in a narrow strip of land, along traverses and native trails.
Here, in the lower course of the Digoel, the elevated remnants of the old Quaternary landscape are widely dispersed and form "islands" in the otherwise marshy and

swampy lowland. During the wettest months of the year the low-lying terrains are completely inundated and travelling in all directions can easily be done by prahu. During the drier months of July, August and September, part of the marshy terrains fall dry and the vegetation of grasses, sedges and shrubs are set afire in wide surroundings. These terrains are recognizable on aerial photographs because of the presence of "gelam forest" (*Melaleuca leucadendron*), which does not suffer from the fires. The gelam forest, however, does not thrive in permanently wet areas, where swamp forest prevails and also *Metroxylon sago* grows well.

The soils in this vast area can be grouped best into three soil complexes according to the hydrological conditions of the terrain, *i.e.* permanently dry, permanently wet and periodically dry terrains.

The permanently dry, irregularly-shaped hills and ranges which rise 5 to 10 m high above the surroundings, are built of quartzitic fine sand and silt, presumably resting on a continuous substratum of clay.

A vertical cross section through such a hill would reveal quite a variation of texture, due to the fluviatile or lacustrine sedimentary character of this material. Consequently, the texture of the dry-land soils will vary from one site to the other according to the textural layer which turns up nearest the surface. Ten different soil types were distinguished within the complex of permanent dry soil.

They differ in texture of surface soil and subsoil, and range from sandy soils to silty soils. Generally, their subsoil is finer textured and may be a silty clay loam or silty clay due to a downward migration of dispersed clay particles. These soil types also differ in colour which may be yellowish-brown, brown, reddish-brown or red. However, all soils are characterized by very high acidity (pH = 4,5 to 5,5) and extremely low values for readily soluble lime, magnesia, potash and phosphate. In some soil types the potash content is somewhat better.

Perhaps the best physical type is soil No. 4 (Report 27.1) which is a very deep, reddish-brown (5 YR. 4/4-5/6), humic, fine-sandy loam. This soil covers considerable areas in the Mambiomen and Bamgi-Ija areas. Its profile characteristics are similar to those of the Digoel-Bian soil type and may be used for the growing of rubber with the aid of phosphatic fertilizers. An averaged characteristic analytical is presented in ANNEX III.

Although the organic-matter content of the upper 25 cm of soil is high (C = 4,4 %) and a corresponding high cation-exchange capacity of 18,6 m aeq. per 100 g of soil is measured, the S-value is no more than 5,3 %. This fact clearly demonstrates the extreme base deficiency of this soil through leaching. In the low swampy terrains only one type of soil has been distinguished (No. 10).

It is a greyish, heavy clay with a dark-grey (10 YR. 3/4) surface layer of organic sludge. Due to contamination or burying with hill-side material, the texture of the upper layers may vary from (silty) clay loam to (silty) clay. The soil's acidity is extremely high (pH = 4,0—4,5) and di-valent bases are lost through prolonged leaching. Only potash is sufficiently present, probably because the aquatic vegetation accumulates this element in the plant tissues. After decay of the plant remnants the potash is released, and is re-absorbed by the organic absorbing complex of the surface soil.

4.13. Southern coastal plain (Objects 29—31)

Individual sections of the coastal strip of land, that is 5 to 10 km wide and reaches from the Bian southwards beyond Merauke, has been surveyed in the past by a number of soil surveyors and at various mapping scales.

An attempt was made in 1961/62 to synthesize these individual surveys and to produce a complete map of the area with a single legend. This work was carried out by the soil surveyor SCHWAN and his report (36.1) with map 1 : 100.000 could be finished just before the Bureau of Soil closed in October 1962. A very instructive description with maps of the middle section, *i.e.* the coastal plain situated between the Maro and Koembe estuaries, was published in English by REYNDERS (1961). The interested reader is referred to this publication and the report 31.6 for more detailed information, as the scope of the present review only permits a brief description of the most important soil types.

It has been mentioned before that, according to HELDRING's (1909) treatise, the lowland comprised between the Digoel and Fly rivers has been built up through sedimentation of quartzitic sands, silts and clays during a very long period of slow subsiding of the sediments, a testimony of which is found in the presence of peat layers which were found in deep borings near Merauke.

This period was followed by marine regression, the stages of which are marked by sand ridges occurring far inland along ancient coastlines.

It is not certain whether the marine regression was continuous or that it was interrupted by periods of transgression, *i.e.* negative movements of the land surface.

It seems that the previously mentioned, elevated, old reddish Digoel soils are present mostly in the deeper subsoil of this coastal area. Near the coast at a depth of a few metres, or, sometimes at the surface, and farther inland at many metres below the surface, a heavy whitish to greyish clay is found which is dark yellow- to bright red-mottled over a considerable depth. These bright-red, earthy, iron accumulations are real plinthite and harden to brick-like concretions when exposed to the air or when in contact with sea water. It is evident that these accumulations of dehydrated tri-valent iron cannot form in deep soil layers at great depth but must have been formed in ancient times near the surface of a soil that was exposed to alternating wetting and drying, and that cracked deeply during pronounced dry seasons. This means that in the coastal region of today the ancient land surface has been submerged again and consequently has been covered with fresh sediments. At present, only these recent uppermost sediments of quartzitic sands, silts and clays are soil-forming parent materials. Part of these sediments are distinctly of marine origin and are found nearest to the present coast. Their calcareous character contrasts sharply with poor, acid, quartzitic sediments of lacustrine or fluviatile origin which are found farther inland. Here, old marine clays containing large crystals of gypsum are found underneath at a greater depth. The azonal soils of recent estuary and flood-plain sediments may be reckoned to the recent marine soils because these sediments are calcareous and have settled in salty to brackish water.

The marine soils may be divided according to their age: the younger ones being calcareous and even saline up to the surface soil, whereas the older ones are non-saline and are decalcified to varying depth. The younger soils are azonal but the older ones have well-developed profile characteristics. Each of these stages of soil formation occupies a distinct area, *i.e.* a "soil landscape" which is often separated from the other by sand ridges.

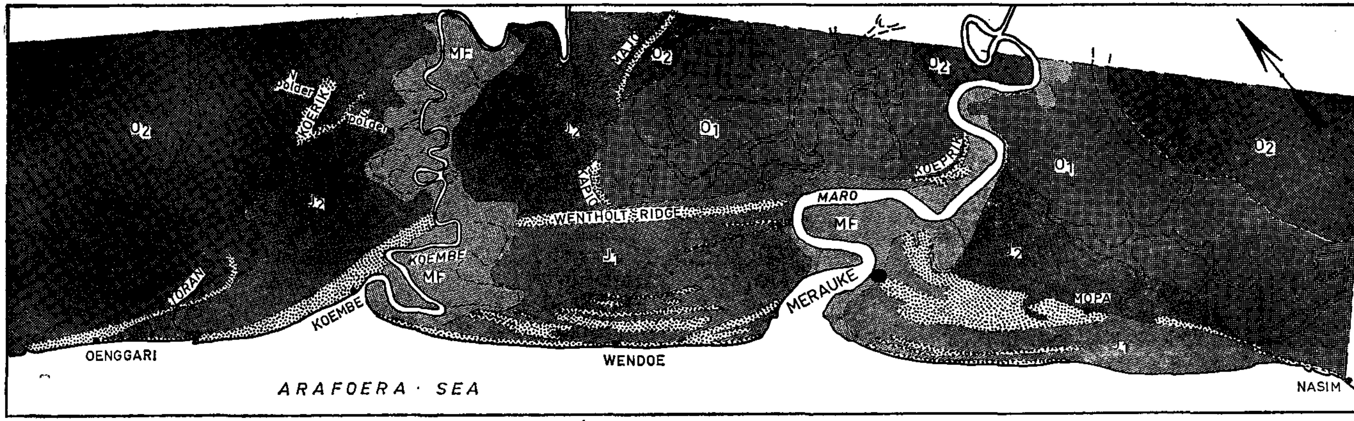
The old fluviatile soil landscape begins at a distance of 5 to 10 km inland from the coast and its numerous soil variants have not been studied intensively yet because

most of these soils are unsuitable for agricultural use.
It must be noted that the morphology of the coastal area is rather intricate because, in the past, the rivers shifted their estuary and their meandering, lower course from site to site. The rivers involved, *i.e.* the Bian, Toran, Koembe and Maro, are all swamp-born rivers, carrying non-calcareous quartzitic silt from the hinterland. The morphology of this area is further complicated by the strong surf of sea currents, which engulfed large portions of the coastal plain at one place, and caused the formation of new land at other places. This accounts for the experience that a regular sequence from younger to older soil landscapes in a direction perpendicular to the present coastline is seldom found. Locally, the old fluviatile landscape may even border the sea, as it is the case between the Bian and Toran rivers.
The young, most fertile marine clays are found south of the Koembe river and farther southwards beyond the Maro river. In order to complete the above general picture of the coastal plain, it should be mentioned that its greater part is marshy to swampy during the wet season because the general drainage of the flat terrains is poor and is obstructed by the sand ridges. From May to November the plain is dried by the strong dry winds from the Australian continent and large areas of the grass, shrub, and tree savannas are on fire.

Object 29: The coastal area between the Bian and Koembe rivers (FIG. 15)

The northern section of this area, which is situated between the Bian and Toran rivers was surveyed in 1955 (Report 29.2). This coastal area is less than 6 km in width and is bordered in the north by deep swamps. It can be reached on foot only along the narrow beach at low tide. The old reddish-brown quartzitic sand ridges, which elsewhere form a more or less continuous strip of high and dry ground parallel to the coast, are here merely present as scattered, isolated, narrow strips which stretch in varying directions.
There are a few limited areas of fertile, juvenile marine silty clays and silts bordering the Bian river. However, they are saline and not really protected against high spring-tide floods by recent beach walls. The larger part of the area is occupied by a reddish-grey (5 YR. 5/2), quartzitic, loamy sand soil. This soil is very much leached and has a yellowish- to reddish-mottled subsoil, containing soft and hard plinthite. The soil belongs to the oldest landscape (O_2) which formerly must have been parted from the sea by a broad zone of new land that has now disappeared. The soil is inundated in the wet season and suffers from drought in the dry season. Its surface shows a typical sort of "gilgai" micro relief of pits and mounds which is found in many other savannah areas in the old fluviatile soil landscape. The occurrence of high termitaries is also characteristic for this particular soil type.
It is no use paying further attention to this area because of the complete absence of soils suitable for agricultural use.
East of the small, insignificant Toran river and west of the impressive Koembe river, a more interesting area is found, where much soil research has been devoted in aid of the experimental pilot scheme for mechanical rice growing which was started near the kampong of Koerik in 1955.
This pilot scheme comprises two polders, each measuring 100 ha in size, which are situated on the north and on the south side of the Orambak and Koerik sand ridges. These ridges also denote the borderline between the old fluviatile soil landscape on north and a medium-young marine soil landscape on south.

FIG. 15. Physiographical sketch map of the Koembe-Maro coast



Sand ridges of various age

Old river courses in various stages of silting-up

Soil landscapes

MF = Very young marine/fluviatile landscape, with salty and calcareous clays in flood-plains and estuaries

J_1 = Young soil landscape, with young calcareous marine clays

J_2 = Medium-young soil landscape, with old to very old marine clays

O_1 = Medium-old soil landscape, with quartzitic sandy and silty loams

O_2 = Oldest soil landscape, with quartzitic sandy and silty loams and old, reddish-mottled clays with plinthite layers

It stands to reason that in the flat, northern soil landscape the texture of the prevailing quartzitic soils may vary considerably. Especially the surface soils may vary from sandy loams to silty loams, but all of them possess a clayey, mottled subsoil. One gets the impression that, apart from primary textural differences which are characteristic for transported soils, also a secondary differentation into light-textured surface soils and heavier subsoils are induced by podsolic pedogenesis. It has been noted that in several localities these surface layers form very loose structures which lost their cementing clay by leaching, and behave like quicksand.
When wet, this surface soil easily succumbs under pressure of heavy machinery and turns into a liquid paste. The critical upper limit of plasticity proved to be 35 %. Silty clays with a plasticity limit above 35 % did not flow away under pressure. Notwithstanding textural differences, the analytical characteristics of these so-called "north-polder soils" vary little. These very much leached, decalcified, quartzitic soils are extremely acid and infertile, as may follow from the standard analysis of a representative silty loam (ANNEX III). Its cation-exchange capacity is 17,6 m.e. which is partly due to the high organic-matter content. The saturation degree of the absorbing complex is only 0,9 % which means that absorbed mono- and di-valent bases are practically absent, being replaced by hydrogen- and aluminium ions. The high exchange acidity also involves decomposition of the organic absorbtion complex and release of aluminium which is partly washed down into the B-horizon. According to the author's opinion, it is this very loss of clay in the surface horizon by both mechanical and chemical processes, that is also responsible for the formation of gilgai micro relief on these marshy quartzitic soils.
In the bare, shallow depressions in between the ilumps of grass, rainwater accumulates and percolates into the soil during the greater part of the year. Consequently, it is in these spots that removal of clay is accelarated and that the soil surface gradually subsides. The mounds are leached less, whereas the grass roots keep the soil in its original volumetric status. In this way the discrepancy between pits and mounds slowly increases.
The extreme infertility of these tropical podsols makes them unsuitable for normal agricultural use. However, this type of soil seemed to appeal to the initial supporters of the mechanized rice scheme, because of its occurrence in vast areas of almost flat terrain and because of its impervious clayey subsoil. This soil type was believed to offer ideal conditions for mechanisation and for perfect water control within the polder. More than 3.000 ha of this soil type were available with a view to the eventual extension of the pilot scheme.
The use of the fertilizers was accepted as a necessary condition for successful cropping. However, continued research and field experiments proved that the choice of this soil type was not a very lucky one, as many failures and disappointments cropped up in nearly every aspect of cultivation and crop production. One of the most outstanding features was the occurrence of soil-induced toxicity in physiological disease of susceptible rice varieties. Extreme acidity, unfavourable redox conditions and the presence of toxic ions and organic compounds may be summed up as the dominant harmful factors inherent to this soil type. Tillage can be practised succesfully only within a rather narrow range of soil-moisture conditions.
In the medium-young marine soil landscape in which the southern polder is situated, a partly decalcified marine silty clay is found as the main type of soil. It occupies the entire area between the Orambak ridge and the coastal ridges and it borders in the east on the recent deposits of the present flood-plain of the Koembe river. About

2.000 ha of this soil was estimated to be available for paddy growing if properly empoldered.
According to the meso relief of the terrain, decalcification of the surface soil and the formation of gypsum in the subsoil is more advanced in the higher than in the lower spots. In the terrain depressions the influence of brackish ground water, containing harmful concentrations of chloride and magnesia is apparent in the wet season outside the polder. The effect of brackish ground water increases when coming nearer to the lower-situated terrains near the Koembe river and near the coast.
The light-grey, yellowish-stained, stiff clay, which lies underneath the dark-grey, rusty-mottled, humic, surface layer, proved to be somewhat toxic to paddy when ploughed up in the polder.
The heavy soil becomes very hard and shrinks when dried. The clay consists of 30 % montmorillonite, 50 % illite, 15 % kaolinite and 5 % quartzite. Incidentally, it may be mentioned that a very young marine clay found near the coast is made up of practically the same composition. Contrary to this composition, the soils of the northern polder possess a kaolinitic clay fraction, which contains only 10 % montmorillonite.
An analysis of a surface soil which is representative for the southern polder is given in ANNEX III. It is a silty clay with high organic-matter content, which possesses a cation-exchange capacity of 33 m.e., and a saturation degree of 52 %. The soil is deficient in available phosphate, and good crop response is obtained from phosphatic fertilizing. The occurrence of physiological disease is weakly present on this soil type, and is believed to be related to toxic products of anaerobic decomposition of organic matter. After a few years of empoldering this effect wears off.

Object 30: The coastal area between the Koembe- and Maro rivers (FIG. 15)

This area is divided into an older and a younger marine soil landscape by a long-stretched series of sand ridges, running parallel to the present coast. This ancient beach-wall is called "sand ridge of WENTHOLT" and forms a serious obstacle to the drainage of the older landscape in the north, which is very marshy to swampy. The Kapo and Majo sand ridges, which branch off from the WENTHOLT ridge, divide this area into a western and an eastern part. The western part, bordering the Koembe river is taken up by the same medium-young marine clay that is typical for the southern polder on the other side of the Koembe river. The eastern part, bordering the Maro river is older and is described by REYNDERS as a "medium-old landscape". Of more interest is the young, marine clay landscape which lies south of the WENTHOLT sand ridge. This flat area is separated from the sea by a dune-like beach-wall, whereas narrow sand ridges of older origin are found more inland, marking a former gradual retreat of the sea from this young coastal plain.
The drainage of this area towards the sea is naturally poor. In earlier days large parts of the area were worked into a system of raised beds and ditches by the former, now decimated Marind people. In the eastern part of the plain, close to the Maro river, the open grassy terrain is largely undisturbed by this type of human activity.
The prevailing soil consists of a heavy, silty, clay layer, decreasing in the thickness in a seaward direction and becoming sandier lower down. On the sea side, shell remnants are found in the surface soil, but on the land side these remnants are only found deeper down in the subsoil.
During the dry season the soil shrinks considerably, and becomes hard like concrete. It cracks prismatically with wide fissures reaching down to a depth of about 45 cm.

Each year the grassy vegetation of the savannah is burnt up completely. When the rains set in, organic matter, ashes and charcoal are washed down into the fissures, which slowly close again. The churning properties of this heavy clay result in a black, humic surface layer, underlain by a transitional layer in which the actual mixing of the bluish, yellow-mottled subsoil with the blackish surface material takes place. Accordingly, the transitional layer may be divided into an upper part, which is predominantly dark with light-greyish mottles, and a lower part, which is a blackish-stained subsoil. A standard analysis which is typical for the upper 25 cm of soil in the grassy plain is presented in ANNEX III.
In areas where the soil has been anthropogenically disturbed, the surface layer may be more sandy and more calcareous because of contamination with material from the subsoil. It should also be mentioned that nearer to the coast the influence of brackish surface water and ground water becomes more apparent. A very detailed study of this soil type, carried out at different sites in the said grassy plain near the Maro, is published in the English language by SCHROO (1961). For the many details concerning ground-water movements, salinization and de-salinization during the monsoonal periods, the reader is referred to that publication.
Finally, it may be mentioned that all soil investigations which have been carried out in the field, the greenhouse and the laboratory in support of the intended Mechanized Rice Scheme, have been reviewed by the present author in the Dutch-written Report 30.7.

Object 31: Coastal area south of Merauke (FIG. 15)

In this area the long sand ridge, which reaches from the broad fan-shaped ridge near Merauke via Mopa towards the kampong Nasim, may be compared with the WENTHOLT Sand Ridge on the other side of the Maro river because both ridges form the dividing line between the younger and the older marine clays.
The young marine clay which covers the coastal area southwest of the Mopa ridge has practically the same characteristics and analytical features as the young marine clay in the grassy plain of Paal Poetih. The soil is slightly younger as follows from the thinner development of the organic surface layer, and also from the presence of free lime in that layer. In the past, this soil was used succesfully by the local population for the growing of paddy which use is still continued nowadays in the part of the plain nearest to Merauke.
Under paddy cultivation, the surface layer of the soil has been homogenized and all free lime has been dissolved down to the slightly-condensed plough sole, due to the action of carbon dioxide which is produced in the plough layer by decomposing plant remains. The old paddies may be recognized by this feature and by the growth of different reed grasses. Incidentally, it may be relevated that rice growing in the rain-fed paddies of this entire area is rather risky. The prevailing monsoonal climate is whimsical because the onset and duration of the rainy period vary from one year to the other.
Irrigation water is not available because the river becomes brackish as far as 180 km upstreams and supplies of fresh water from nearby swamps also dry up in the dry season. During that season, nothing can be grown in the brick-hard, salty clay of the drought-stricken Merauke plains. Subsistence crops are then grown on the Mopa sand-ridge where some water is still available from wells. When the dry season is very severe, even this water becomes brackish.
Residential quarters and the airfield are also accomodated on this ridge so that

there is not much room left for agricultural enterprise. This is probably the main reason why part of the paddy-growing population moved across the river to the Koeprik sand ridge where paddy is grown on the older marine clays, and food crops thrive well on the sandy to loamy soils of the ridge.

The coastal plain southwest of the Mopa ridge is separated from the sea by a recent beach-wall, followed by a strip of land which is 250 to 500 m in width and by a sub-recent beach-wall, which runs as a rather narrow sand ridge parallel to the coast. The very young clay found in the strip of land in between these two sand ridges is saline and often covered with a layer of brackish water.

In the soil landscape on the land side of the Mopa ridge, older marine clays are found. These are more de-calcified and more affected by fluviatile influences as they occur farther inland. As far as can be concluded from evidence derived from aerial photographs and soil surveys, there are no distinct sand ridges in this area which denote the boundaries between a regular sequence of medium-young (J_2), medium-old (0_1), and old (0_2) soil landscapes. The transition from one soil landscape to the other is rather gradual and, locally, very irregular, due to the presence of ancient river courses, creeks and other terrain depression which have been silted up under swampy conditions.

Even within the J_2-landscape at least two types of marine clay soils of different age can be distinguished. Both soils, which merge gradually into each other, have been described for the environment of Mopa by VAN SOELEN (Report 31.4). It has been ascertained by this soil surveyor that, adjacent to the Mopa sand ridge, and also in between the numerous subordinated smaller sandy ridges northeast of it, about 650 ha of the younger clay is found, which contains free lime derived from shell fragments at a depth of about 50 cm. Its surface soil is often mixed with sand which is washed from the protruding sand ridges. More inland and farther away from the Mopa ridge the other type predominates in the lower terrains of this area. Its blackish surface layer is thicker, and gypsum is formed in the subsoil. About 750 ha of this clay soil have been comprised into the said survey. The entire area of 1.300 ha is suitable for grazing purposes, and part of it has already been used by the cattle-breeding station near Mopa. The clay soils occurring in the soil landscape 0_1 are comparable with those west of Koeprik on the other side of the Maro river.

The soil generally consists of a humic, greyish clay overlying a layer of grey clay with intense red mottles and showing a platy structure. The red mottling becomes stronger at a depth of 70 to 90 cm at which depth also gypsum crystals are found. Nearer to the 0_2-landscape the soil becomes lighter in colour, more silty and less clayey, whereas also the pronounced shrinkage properties of the true marine clay become lesser and lesser. The old fluviatile landscape (0_2) is comparable with that of the north polder landscape. The extremely infertile quartzitic soils vary greatly in texture and are grown with a poor type of Eucalyptus-Melaleuca forest.

In the eastern part of this area, ancient river courses, probably branches of the Fly river, have been recognized. These so-called "bobes" contain a peaty type of soil and are entrenched by levee soils. The latter show a regular textural sequence of sandy, via loamy to silty quartzitic soils occurring in an outward direction from the "bobe". On the sandy quartzitic soil, which is often grown with bamboo, a classical type of iron podsol may be found which is very similar in appearance to the podsol of the temperate climatic zones elsewhere. According to soil samples obtained from third parties and collected much farther inland along the trail from Boepoel

(Maro river) to Moeting (Bian river), the same type of poor quartzitic soil also prevails in that region.
From the above discussion of the Objects 29 to 31 it may be concluded that the availability of fertile alluvial soils in the coastal area south of the Bian river are rather limited. Their suitability for agricultural purposes, including paddy growing, is further restricted by undesirable drainage conditions during the wet season and by drought during the dry east-monsoonal period. Reclamation of these soils for permanent agricultural use will require large-scale and costly measures of land improvement. Further inland, the same unfavourable external factors combine with a general infertility of the prevailing old quartzitic soils so that there the occurrence of suitable soils will be very much localized.

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ANNEX III (continuation of previous issue, p. 416/417)

No. Object	Standard soil type and layer of sampling	pH H_2O	pH KCl	Free lime $CaCO_3$ %	Total carbon C %	Easily soluble nutrients (in 3 % acetic acid) CaO ppm	MgO ppm	K_2O ppm	(Truog) P_2O_5 ppm	Total contents P_2O_5 %	K_2O %
21	*Seta, yellow, deep, quartzitic sandy loam*										
	0—25 cm	5,1	4,7	0,0	1,20	300	< 50	50	70	0,380	0,06
	25—50 cm	5,2	5,0	0,0	0,35	200	< 50	20	85	0,600	0,06
	Kamboefatem, dusky-red, residual clay on limestone										
	0—15 cm	6,0	5,3	0,0	2,31	750	110	170	380	8,60	0,070
	15—50 cm	6,6	6,2	0,0	0,50	1.100	240	190	500	9,40	0,040
22	*Fak-Fak, yellowish-brown, undeep, residual silty loam on quartzitic limestone*										
	0—25 cm	6,2	—	0,0	1,50	6.000	100	75	10	—	—
24a	*Tulem, old Baliem silty clay loam*										
	0—25 cm	**4,1**	3,9	0,0	4,17	400	60	100	8	—	—
	Tulem, recent Baliem silty clay loam (on levee under Casuarina forest)										
	0—25 cm	6,4	5,8	0,0	6,84	7.400	550	150	260	—	—
	Wamena, recent Baliem silty clay loam (on levee under Casuarina forest)										
	0—25 cm	7,3	6,5	0,1	4,64	5.700	370	240	80	—	—
	Fresh Baliem river sediment										
	(silty loam)	7,9	7,0	6,7	1,20	30.000	1.200	100	3	—	—
24b	*Enarotali, mountain clay loam on limestone*										
	0—25 cm	6,2	5,5	0,0	2,50	5.000	200	180	40	0,175	0,700
	Erepakarida, mountain silty loam on quartzitic sandstone										
	0—25 cm	4,7	3,5	0,0	1,55	500	50	90	8	0,035	0,300
	Enaro, alluvial silty loam (L.V.D. experimental field)										
	0—25 cm	4,3	3,7	0,0	2,30	600	60	70	30	0,065	0,185
	25—50 cm	4,5	3,8	0,0	0,45	400	< 50	50	15	0,136	0,440
	Komopa, mountain sandy loam on quartzitic sandstone										
	0—25 cm	4,6	4,0	0,0	—	300	< 50	45	7	—	—
	ibid. but under Casuarina cover:										
	0—25 cm	5,6	4,7	0,0	2,00	1.800	1.100	85	13	—	—

25	*Akaroe, silty-loamy levee soil*										
	0—25 cm	7,8	—	20,0	1,20	45.000	24.000	130	12	0,075	—
	Agimoega, silty-loamy levee soil										
	0—25 cm	6,5	—	0,0	2,20	3.200	1.450	120	6	—	—
	Omauga, sandy-loamy levee soil										
	0—25 cm	5,1	—	0,0	1,60	1.400	180	360	30	—	—
26	*Mindiptanah, yellowish-brown, silty loam* (No. 1)										
	0—25 cm	4,8	4,3	0,0	3,15	440	100	110	< 5	0,140	0,130
	25—50 cm	4,9	4,3	0,0	0,90	320	< 50	50	0	0,121	0,143
27	*Aiwat, red, old loamy clay*										
	0—25 cm (A)	5,0	4,4	0,0	1,60	200	150	100	< 5	0,040	0,120
	25—50 cm (B_1)	4,9	4,4	0,0	0,40	200	150	50	< 5	0,030	0,180
	50—90 cm (B_2)	5,1	4,4	0,0	0,30	150	150	65	< 5	0,030	0,340
	below 90 cm (B_3)	5,0	4,2	0,0	0,15	100	150	55	< 5	0,030	0,520
28	*Bamgi-Ija, reddish-brown, old, humic, fine-sandy loam*										
	25—50 cm	5,1	4,1	0,0	4,40	130	< 50	125	< 5	0,030	0,160
	0—25 cm	5,0	4,3	0,0	1,70	135	< 50	90	< 5	0,010	—
29	*Koerik, old, quartzitic silty loam* (Average, north-polder surface soil)										
	0—25 cm	4,9	4,2	0,0	1,70	100	< 50	50	140	0,020	—
	Koerik, medium-young, marine silty clay (Average, south-polder surface soil)										
	0—25 cm	5,7	4,5	0,0	3,50	2.300	260	140	< 5	0,045	—
30	*Paal Poetih, young marine silty clay* (Average surface soil grassy plains of J_1-landscape)										
	0—25 cm	7,2	6,2	0,0	2,900	4.400	2.500	160	7	0,090	1,040