# THE LANDSCAPE IN THE MARO AND KOEMBE RIVER DISTRICT

*(Merauke, Southern Netherlands New Guinea)*


by

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## 1. *Introductory*

During recent decades a number of soil surveys have been carried out in Southern Netherlands New Guinea in the coastal zone between the Bian river and the Papua – Netherlands New Guinea frontier, so that soil conditions of this region became known.

The soil surveys were undertaken in this region on behalf of rice growing and cattle raising. Rice growing potentialities were investigated in the Merauke area as this part of Netherlands New Guinea has a pronounced monsoon climate in which there is a longer period of drought.

Of the above-mentioned coastal district, the part north-west of the Maro river and south-east of the Toranbobe (bobe = swamp) (an extensive swampy creek between the Koembe and the Bian) was selected for further study.

In 1940 Wentholt entered the region south of the Koembe to the east of Merauke for the first soil reconnaissance survey. In the same year Druif carried out a survey from the Merauke area to a point near the Papua-Netherlands New Guinea frontier. They encountered marine clay deposits which were separated by young and old raised beach bars. From the coast inland the marine clay areas were differentiated as young and old marine clays.

The object of these small-scale pre-war surveys was to ascertain to what extent the Meraukese soils were suitable for transmigration. They provided a general view of the area.

After a Bureau of Soils had been established at Hollandia in 1950 it became possible to make an intensive study of the soil.

In 1952 Razoux Schultz surveyed the vicinity of Merauke. In 1953 Buringh, at the I.T.C.[2]) Delft, made an aerial photographic interpretation of the district south-east of the Bian with the aid of information supplied by Wentholt, Druif and Razoux Schultz. Using fairly poor airphotos he compiled his map on a photographic scale of 1 : 40.000 on which details of the morphology of the Meraukese were shown for the first time.

Owing, however, to the lack of terrestrial data Buringh was unable to compile a completely accurate soil map. Buringh's map served as a guide for the Agrarian Commission which visited Netherlands New Guinea in 1953 for the purpose, among others, of investigating the possibilities of establishing a rice plantation. After a visual reconnaissance undertaken by Reynders, Van Soelen entered the region in the same year and surveyed the land between the Toranbobe and the Maro river.

In the first half of 1954 there appeared a survey by Van Loenen on soil

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[2]) International Training Centre for Aerial Survey.

conditions in the area west of the Koembe river in which an experimental rice farm was to be established. A great many analytical data were incorporated in this report. The report shows that old inferior soils were encountered in the north and younger soils of better quality in the south.

In the same year the definitive location was established for the new experimental polders of the future „Koembe" Experimental Farm.

On the basis of cadastral measurements, the nature of the rivers and the information obtained from soil surveys, an experimental farm was planned on either side of the large sand deposit near the abandoned Koerik settlement. The north polder of the experimental farm was planned on the old soils and the south polder on the younger soils. Further investigation was to determine on which soils the future extension of the experimental farm or the ultimate site of a large rice plantation would have to be located.

A further detailed survey of the experimental polder area was started in 1954, but had to be broken off. A brief report by Reynders was published at the beginning of 1955.

In 1954 Razoux Schultz surveyed the coastal strip north-west of Toranbobe to the Bian river.

In 1955 the surface levelling and allotment of the north polder of the experimental farm was undertaken. A part of the north polder was completed first and sown with rice. In the following year a part of the south polder was prepared for production. In 1956 a detailed survey was made by Reynders and Andriesse of the topsoils of the two polders of the experimental farm.

Meanwhile a start had been made on the soil fertility investigation in the field and by means of pot culture experiments and as early as the first year information brought to light that a plan for a large-scale rice plantation on the more recent marine clay soils merited further study.

Hence, in order to pave the way for the examination of further potentialities, the district between Maro and Koembe was mapped in the field by means of a semi-detailed survey undertaken by Reynders and Andriesse with the help of aerial photographs.

Subsequently a soil fertility report on this district was made by Schroo in which a large number of analytical data is provided.

From these reconnaissance surveys and especially the detailed investigations of the site of the experimental farm and the area between the Maro and the Koembe, it was possible to obtain an idea of the soil conditions of the country.

## 2. *Geology*

New Guinea was formed by the uplift of sediments deposited in the geosyncline between a continental plain which must have been situated north of New Guinea and the Australian continent. The northern boundary of the geosyncline is formed inter alia by the Cycloop Mountains near Hollandia. The Australian continent has an edge (the Merauke ridge) which continues beneath Merauke.

When the sediments were lifted still higher, the northern part of New Guinea, i.e. the Central Snow Mountains and mountain chains lying to the north, continued to rise, whereas the south formed a volumetric balance and subsided.

The subsidence can be observed from the many coastal estuaries. In addition many old peat layers in the subsoil are found in borings.

The southern part of the depression formed in this way is dominated by two large rivers, the Digul and the Fly. A curious feature is the twist in the course of both rivers, the Digul towards the west and the Fly towards the east. One gains the impression that the southern part of Netherlands New Guinea is tilting. The river basin, comprised and enclosed by the Digul and the Fly, is situated in the so-called Digul-Fly depression.

As regards landscapes the Dutch part of this Digul-Fly depression may be divided into three extensive areas, viz.:

*a.* the hill area of the Moejoe (Upper Digul)
*b.* the fluviatile modulated higher shield area of the Mappi (Central Digul) and
*c.* the lower shield area of Merauke (south of the Digul).

In addition very extensive low tidal swamp areas are situated along the coast.

The above division is based on soil reconnaissance surveys carried out in the said districts and not further discussed here.

The low shield landscape south-east of the Digul comprises the basins of the Bian, Koembe and Maro rivers.

The catchment area of these rivers is almost entirely surrounded by the Digul and the Fly, so that the Bian, Koembe and Maro are swamp rivers dependent on rain. In the coastal area between the Bian and the Australian frontier it can be seen that the area was formed by marine transgressions and regressions.

Ancient coasts are marked by sand ridges. On either side of the ridges soils are found which show distinct differences in age. These areas of varying age are distinguished as soil landscapes.

### 3. *Division into soil landscapes*

Each of these soil landscapes has a number of typical topographical, vegetational and soil features.

For the better demarcation and designation of the various soil landscapes, in this report the sand ridges are given names most of which are derived from the ancient native settlements on the ridges or in the vicinity.

The area in question is divided into four soil landscapes, viz.:

1. the young soil landscape
2. the medium young soil landscape
3. the medium old soil landscape
4. the old soil landscape.

The entire area in question is flat. With the exception of a few higher parts of the coastal dune formations along the coast, the land lies between 2 and 4 metres above sea-level. North of Koerik a part of the soil lies about 6 metres above sea-level.[1])

The differences in age between the soil landscapes are reflected in the soil by such phenomena as the degree of decalcification, the sulphate and gypsum formation in the soil, and the iron mobilisation.

[1]) tide-gauge Merauke.

Before dealing with the individual soil landscapes the sand ridges will be discussed.

## The sand ridges

The sand ridges may be divided into two groups, viz. those containing little or no pea iron concretions, and those in which these concretions are abundantly found in the profile.

The first group of ridges without pea iron concretions form the present-day and former coastlines running parallel to the present coast. The sands were deposited from material derived from the sea. This was brought up by the waves and blown into ridges by the wind.

The other category, that of the ridges rich in pea iron concretions form an angle with the present coastline. They were cast up by the waves which penetrated into the funnel-shaped areas formed during transgressions. The original soil cover was abraded by the sea. The clayey material was selected. The clay fraction remained in suspension in the water, while the heavier parts such as sand and iron concretions were deposited on the side of the transgression in the form of surf-built ridges.

Examples of pea iron concretions containing ridges are the Orambak ridge, the Kapio and Majo ridge, the ridge-fan at Koeprik and the ridge-fan at Merauke.

Examples of ridges having little or no pea iron concretions are the present dune formations and those lying to the rear and the "Wentholt Sand Ridge" (a number of parallel ridges about 5 kilometres from the coast between the Koembe and Maro rivers).

In addition an increasingly red hue is found in the ridges with increasing age. The red hue is caused by a process related to climatic condition in the area. During the wet monsoon the landscape is inundated and the ridges are infiltrated with swamp water. During the dry monsoon the ridges dry up. The organic matter is oxidized. When rain falls the soluble ions are washed downwards. An iron coating remains around each sand particle. The same intensifation of colour can also be observed inland in the sand ridges.

As one leaves the coast the decalcification of the ridges increases. Along the coast the sands have a high shell content. Inland the topsoil becomes increasingly poor in lime to a greater depth. Loose banks of shells are often found in the subsoil; more inland, hard, cemented banks of shells are encountered at greater depht. The Wentholt Sand Ridge and the Koerik ridge have very hard banks. The Orambak, Kapio and Majo ridges are entirely decalcified. They were probably never so rich in free lime as the presentday coastal deposits, and owing to their age the lime has completely disappeared.

The sand deposit at Koerik differs in its general pattern. It is an elongated sand deposit on the transition of an area of which the surface of the clay deposits north of the ridge is about 2 metres higher than the surface of the soils south of the sand deposit. The latter is much wider and higher than the other ridges in the surveyed area.

The north side of the Koerik sand deposit has a number of smaller sand bars running parallel to the main ridge, so that one gains the impression that this is a former coastal dune deposit. The south side has a number of spurs at right-angles to the direction of the main ridge. These were probably formed by water flowing backward and forward and over the surface of the sand deposit. In the west the sand deposit has been partly swept away. Here the Orambak surf ridge is attached to the large Koerik ridge.

In the east the Ephata creek breaks through the Koerik ridge and is then lost in a low-lying swamp basin situated between the Orambak and Koerik ridges. It is not impossible that near Koerik, before the formation of the Orambak surf ridge, a situation was created in which a lagoon was formed into which the sea penetrated at intervals but which was also periodically dry. The Koerik sand deposit was possibly formed by shifting sand from the lagoon. A soil survey of areas more to the east might possibly solve the problem of how this sand deposit fits in the landscape geomorphologically.

## The soil landscapes

In the following discussion the fluviatile soils (F) occurring along the rivers and creeks are not taken into consideration. The several soil landscapes are shown on the soil landscapes map (fig. 1) and the soil map (see appendix).

### Young soil landscape. J 1.

The young soil landscape is situated between the present coastline and the Wentholt Sand Ridge. On the north side of the Koembe river the continuation of these ridges bends towards the coast; in the south-east the landscape is bounded by the Koeprik ridge-fan which adjoins the Merauke ridge-fan on the south side of the Maro river.

The landscape is entirely flat. A number of sand ridges are found in the landscape running parallel to the present coastline; they are generally narrow and interrupted at intervals.

The vegetation is chiefly of the savannah type. Larger and smaller grass plains are separated by belts or forests of Gempol (Nauclea orientalis); Coconut (Cocos) and bamboo (Bambusa spec.) are found on the sand ridges. In earlier times the entire area with the exception of the grass plain north of the mouth of the Maro was laid out in beds. Everyone travelling through this part of the country expresses surprise that thousands of acres here have been reworked foot by foot by the former, now decimated population. Food crops, sago and stimulants ("wati") were formerly grown on these beds. Nowadays they are no longer used and are derelict.

The grass plain north of the mouth of the Maro has apparently never been used, as the sea water had too great an effect here. During the wet monsoon the land is in a marshy state.

The soil consists of a heavy surface clay layer decreasing in thickness in a seaward direction and becoming sandier lower down. Near the Wentholt Sand Ridge the clay layer is about 100 cm thick and at a greater depth it merges into alternating sand and clay layers. Near the youngest sand ridges the clay layer has a thickness of about 50 cm after which it merges into sand layers. On the sea side shell remnants are found in the topsoil; on the land side they only occur at a greater depth.

The question arises as to which soils are representative of this landscape. On the one hand the reworked soils are mixed to a high extent or have a different hydrological regime and on the other hand it can be stated that the not reworked soils of the grass plain were so barren that occupation was impossible, so that neither of these are entirely representative.

For comparison with the other landscapes, however, a profile of the undisturbed soils is given.

Profile description (1)[1]

| | |
|---|---|
| 0– 10 cm | moist, crumbly to friable, brownish black (10YR 3/2) silty clay with a high organic matter content; well rooted; gradually merging into: |
| 10– 30 cm | stiff, moist dark grey (10YR 4/1) clay with scattered yellow to yellowish brown (10YR 5/6) mottles and scattered whitish loamy, well rooted; gradually merging into: |
| 30– 80 cm | moist to wet, greenish light grey (5Y 6/1–6/2) silty clay containing shell remnants. Scattered yellow and small rust mottles as well as soft iron concretions; gradually merging into: |
| 80–110 cm | ditto with loamy lenses. The colour gradually changes into light grey (5Y 5/1), scattered black iron concretions at 110 cm. |

The soils situated on the northern bank of the Maro along the coast are still flooded by the sea at the present day. These most recent accretion soils are discussed in the following paragraphs as J O separately from the J 1 soils.

Medium young soil landscape. J 2.

This landscape is situated inland behind the young landscape. Its greatest extension is found on either side of the Koembe river, south of the Orambak ridge and west of the Kapio and Majo ridge.

North-east of the Wentholt Sand Ridge occurs a very narrow strip of medium young soils tapering out over the medium old landscape. A part of the medium young soils is also found east of the Merauke ridge-fan.

The medium young landscape has the morphological pattern of a river estuary. Such forms can also be found both near the Koembe and the Maro. It is a flat landscape in which a few small undulations occur. Most of it is usually flooded during the west monsoon (wet period). In the east monsoon (dry period) the lower parts only remain dry after several months.

The vegetation of this landscape chiefly consists of kaju putih (Melaleuca) forests on the higher parts of the land, alternating with extensive non-wooded lower lying areas.

Rahai (Acacia spec.) is found on the highest undulations and Gempol (Nauclea orientalis) along the deeper depressions and creeks.

On the western side of the Koembe river large parts have been laid out in beds in a zone about 5 kilometres from the coast. Only a narrow zone of beds about 1 kilometre in width is found in the area between the Koembe and the Maro. No parallel ridges are found as in the young landscape.

The soils in this landscape fall into two principal groups, viz. the soils of the undulations or shields and those of the basins and depressions situated at a somewhat lower level. Gypsum formation occurs in the higher parts. The profile description is as follows:

Profile description (2)

| | |
|---|---|
| 0– 25 cm | dry, black, humic clayey silt with tongues grading into: |
| 25– 60 cm | moist, grey, silty clay with scattered yellow mottles increasing with depth; merging into: |
| 60–100 cm | moist, grey silty clay, merging with depth into loamy clay with scattered gypsum crystals and shell remnants; the yellow mottling decreases with depth; merging into: |

[1]) All descriptions bear on profiles in the dry season.

| | |
|---|---|
| 100–120 cm | moist, grey, loamy clay with scattered iron concretions and yellow mottles; merging into: |
| >120 cm | moist, grey loamy clay with many yellowish brown iron concretions. |

In the lower parts gypsum formation occurs less frequently. The profile is as follows:

Profile description (3)

| | |
|---|---|
| 0– 20 cm | moist to wet, black humic clayey silt to silty clay, with tongues grading into: |
| 20– 70 cm | wet, grey, clayey silt with many yellow mottles in places soft iron concretions scattered at a depth of about 40 cm; merging into: |
| 70– 90 cm | wet, grey loam with sand lenses and shell remnants; yellow mottles also occur in places. |
| 90–110 cm | ditto but with scattered iron concretions. |
| >110 cm | wet, grey, fine sandy loam with sand and loam lenses. |

Medium old soil landscape. O.1.

The medium old landscape is found in the east of the area east of the Wentholt Sand Ridge and between the Koeprik and the Kapio-Majo ridges.

The flat landscape consists of a number of fairly extensive undulations with interlying shallow depressions with silted-up creek systems. A large part of the landscape is permanently in a marshy to swampy state.

The vegetation consists of kaju putih (Melaleuca spec.) forests in which Rahai (Acacia spec.) occurs scattered on the highest parts. A line of Gempol (Nauclea) trees are found along the creek systems. Abandoned bed systems are found on the borders of the area, and here and there sago plantings are still found in use.

The soil generally consists of a humic, greyish clay overlying a grey clay with intense red mottles. In the deeper subsoil a strongly humic to peaty clay is found in various marshy sites at a depth of 100 cm and deeper. Underlying this layer a soft, wet intense yellow mottled clay containing free calcium is found. One gains the impression that this is an old swamp landscape covered by clayey sediments. These deposits are total decalcified. The swamp soils along the banks of the creeks contain free calcium in the subsoil at a depth of less than 100 cm. This may probably explain the occurrence of the Gempol (Nauclea) on these soils. Except on the borders of the old soil landscape, Gempol does not occur in marshy or swampy basins not situated along the creeks.

In this landscape a number of soil units were distinguished, of which the most important are referred to below. A part of the gently undulating plain has the following soil profile:

Profile description (4)

| | |
|---|---|
| 0– 10 cm | moist to wet crumbly to friable dark brown (10YR 2/2) humic clayey silt; merging into: |
| 10– 30 cm | wet, dark brown, friable, clayey silt with rust stains; merging with tongues into: |
| 30– 50 cm | wet, light grey (10YR 6/1) yellow and red mottled clay; gradually into: |

| | |
|---|---|
| 50–100 cm | wet, grey clay with less mottling than the previous layer; merging into: |
| > 100 cm | wet, grey to meat-coloured (5YR 5/2) humic clay. |

The following profile is found in the lower marshy to swampy parts:

Profile description (5)

| | |
|---|---|
| 0– 5 cm | wet, black (5YR 5/1) strongly humic to peaty silty clay; merging into: |
| 5– 20 cm | wet, black, humose silty clay; merging into: |
| 20– 60 cm | wet, light grey (5YR 5/2) clayey silt with yellow and red mottling; merging into: |
| 60–100 cm | wet, brownish (5R 3/2) humose to peaty clay with many yellow mottles. |

The old landscape. O.2.

This landscape was encountered north of the Orambak ridge. It consists of a number of undulations or shields with interlying wide, shallow depressions.

The land gradually slopes down in the direction of the Toranbobe. During the wet season the lower parts are marshy. At high water of the Toranbobe the land is flooded.

The higher shields are covered with moderately high forests in which a great deal of Melaleuca and Palmea occurs and a higher Acacia vegetation. The depressions often only have a grass vegetation.

Apparently native burning and the high water of the Toranbobe have forced the vegetation back to the higher undulations.

The soils are totally decalcified and there is also a low concentration of monovalent and other bivalent ions.

One gains the impression that this is an old clay landscape over which, in a later period, more recent clays have been deposited. A fairly rapid transition in colour of the soil matrix is found everywhere at a depth of about 60 to 100 cm. The underlying layer has a dark grey matrix. The following two soil types predominate in the areas directly north of the sand ridge near Koerik.

In this landscape two characteristic soil profiles are again described, viz. one from the higher and one from the lower parts.

The following profile occurs in the higher parts:

| | |
|---|---|
| 0– 10 cm | dry, light brownish grey (10YR 6/2), rooted, silty loam consisting of hard, friable aggregates; fairly rapidly merging into: |
| 10– 35 cm | dry, light yellowish brown (10YR 6/4) rooted, sandy loam with irregular vertical cracks and consisting of hard friable aggregates, with yellow and red mottles; the wavy transition merges fairly rapidly into: |
| 35– 60 cm | ditto but with numerous iron concretions, even of fist size. When the soil of this horizon dries up, small reddish aggregates are formed having a somewhat irregular platy structure; this form is due to the abundance of iron hydroxides. |
| 60–100 cm | moist, light grey (10YR 7/2) clayey silt with red mottles. |

The following profile occurs in the lower parts:

| | |
|---|---|
| 0– 15 cm | moist, dark greyish brown (10YR 3/2) friable, rooted, clayey silt gradually merging into: |

15– 40 cm moist, grey (10YR 5/1), friable to crumbly, clayey silt with scattered yellow mottles gradually merging into:
40– 60 cm moist, light grey (10YR 5/1) clayey silt with irregular vertical cracks, with orange-yellow and red mottling; scattered, hard to earthy, small iron concretions occur, rapidly merging into:
60–100 cm moist, dark grey (7.5YR 4/0) compact silty clay with irregular vertical cracks with laminae-like red mottles.

## Decalcification

In the various landscapes an increasing decalcification occurs when passing from recent to old. This decalcification is due to calcium carbonate being attacked by organic and other soil acids. Under the periodically swampy conditions prevailing in the tropics this process will be more rapid than in temperate zones (fig. 2).

An average of 20% of free calcium (see table 1) is found in soils in process of accretion (see J.0).

TABLE 1.

| Sample | Depth | % free lime |
|---|---|---|
| 1722 | 0–25 cm | 20.3 |
| 3493 | 0–25 cm | 19.0 |

The acidity of these topsoils is in the range pH 7–8.5. The free calcium was determined according to Scheibler.

In the *young landscape* J.1. the profile contains no free lime down to an average depth of 25 to 30 cm. In the underlying horizons the soil, unlike the still accreting soils, is partially decalcified; this is shown in table 2. The samples referred to are all taken from soils which have not been reworked into beds. No free calcium was found in the sample taken from the overlying horizons. The same applies to table 3.

TABLE 2.

| Sample | Depth | % free calcium |
|---|---|---|
| 3384 | 20–30 cm | 3.5 |
| 3473 | 20–40 cm | 11.6 |
| 3475 | 15–30 cm | 0.7 |
| 3476 | 30–50 cm | 12.0 |

The average acidity of the topsoils from this area is in the range pH 6–8. The high pH values are due both to the calcium ions present and Na and a large amount of Mg.

The *medium-young soils* J.2. are decalcified to an average depth of 60 to 80 cm. The average percentage of free calcium found in the horizon lying at this depth is lower than in the recent landscape. Some figures are given in table 3.

TABLE 3.

| Sample | Depth | % free calcium |
|---|---|---|
| 3425 | 60– 80 cm | 8.0 |
| 3419 | 80–100 cm | 4.7 |
| 3516 | 80–100 cm | 10.6 |

Fig. 2 Fig. 3

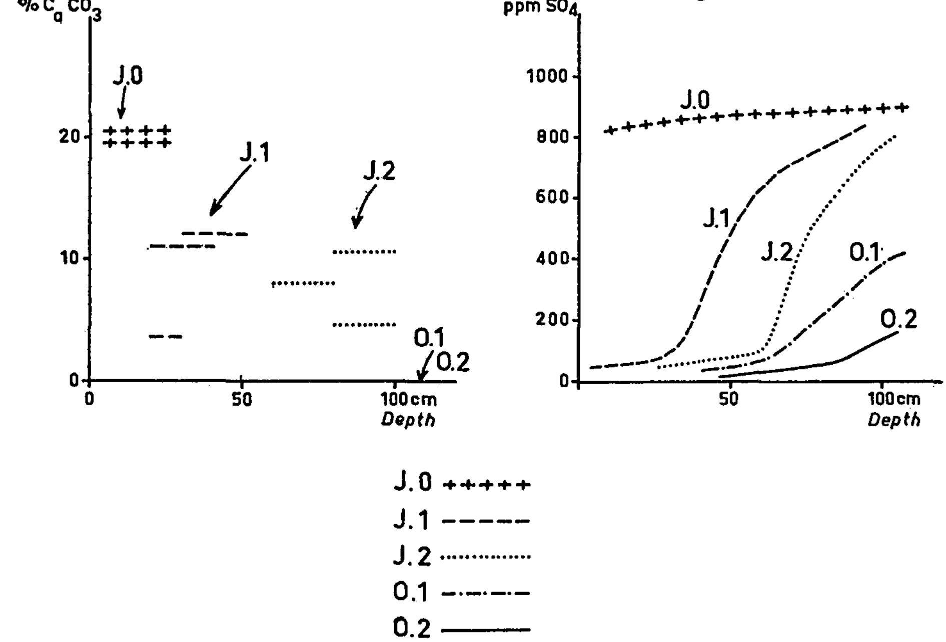



Fig. 2.
Approximate percentage free $CaCO_3$ in the topmost horizon of profiles in the landscapes as recognized.

Fig. 3.
Approximate $SO_4$ content (in Morgan-Venema extract) in profiles of the landscapes as recognized.

The acidity of these soils varies from pH 5–6.

No free calcium is found in the soils of the *medium-old landscape O.1* down to a depth of 100 cm. The ionic calcium content of these soils is also very low. The average acidity of these soils in the entire profile down to a depth of 100 cm is pH 4.5–5.5. Free calcium is found in places at a greater depth of about 200 cm.

No free calcium occurs in the soils of the *old landscape O.2*. The ionic calcium content of these soils is very low.

## Sulphate formation

Van der Spek's article (1950) on "Katteklei" (cat clay) can be closely followed with regard to the reduction of sulphates to sulphides and the subsequent oxidation of sulphides in marine deposits.

A great deal of sulphate occurs in soils deposited by the sea. This sulphate is derived from sea water and micro-organisms and molluscs. Organic matter partly derived from organisms is also found in tidal flat soils.

Under anaerobic conditions the sulphates are reduced by sulphate bacteria since owing to the dehydrogenation of organic matter hydrogen is released, which hydrogenates sulphate.

The calcium sulphate present is also reduced to calcium sulphide in this way. During subsequent conversions the iron and calcium compounds present are converted into iron sulphide and calcium carbonate.

The various reactions are either elemental or combined.

The above mentioned phenomenon is also found in the soils of the Meraukese (fig. 2). The young tidal flat soils (see J.0) contain a fair amount of sulphate, viz. 600 to 1000 ppm in the whole profile. These determinations were made by the Morgan-Venema extraction method, use being made of a sodium acetate extract having a pH of 4.8. Unless otherwise stated, the extractions referred to below were carried out in the same way.

In the next stage, the soils in the young landscape, a lower sulphate content is found, viz. in these soils the sulphate has already been converted. However a part of the sulphate or sulphur in these soils will still be bound in a complex manner by micro-organisms. When these soils become more mature these sulphur compounds are gradually released.

In the top horizons, from 0 to 30 cm, of the recent landscape, the sulphate content is very low. The values are usually below 50 ppm. Below an average depth of 30 cm the sulphate content increases to very high values, viz. 600–1000 ppm.

When the marine soils become dry as a result of embanking or by enclosure by a row of dunes, air is enabled to enter the profile and conditions are favourable to the oxidation of the sulphides formed.

Van der Spek describes the formation of water-insoluble ferri-sulphates and basic ferri-sulphates which are responsible for the yellow colour and yellow mottles in the soil.

"Katteklei" is not formed in the presence of free lime, since iron sulphate reacts with calcium carbonate and leads to an irreversible reaction in which iron hydroxide or iron oxide are formed.

In profile 1 these phenomena are found in the yellow mottled horizon at a depth of 10 to 30 cm. Extractions with 10% hydrochloric acid show that some sulphate is actually present in the upper layers of the profile. Free lime is only found underneath this horizon (see table 2).

In this underlying horizon the yellow and brown rust stains found are also remarkable. The profile therefore closely resembles that described by Van der Spek as overlying neutrally reacting "katteklei".

As stated above, the sulphate content increases in the subsoil as a result of the formation of calcium sulphate.

Since the soils are still young and are flushed by periodic semi-annual floods and the subsoil remains sufficiently moist, the sulphate content is not high enough to lead to the formation of gypsum.

The process is, however, somewhat more complicated than as described above. The periodic, half-yearly inundations repeatedly cause anaerobic conditions in the soil. Owing to the inundation a swampy condition arises as a result of which the low vegetation dies off and the organic matter or humic acids penetrate into the soil. Disperse humus is formed in the topsoil.

The organic matter is again hydrated in the upper horizons and the sulphates present are reduced. Owing to this process there is also a decrease in content of the water-soluble sulphates present.

Various processes may occur simultaneously in the dry season as well. The yellow patches occur from place to place. Concentration differences apparently occur in the soil over short distances. Ferri-sulphate accumulates in the yellow patches. In the grey parts of the soil adjoining the yellow patches the sulphate content is lower (cf. also Van der Spek), so that it is not impossible that $CO_2$ is released in this grey soil (e.g. by plant roots). This is probably also the case in the overlying horizon. Since a fairly large amount of magnesium occurs in the Meraukese soils this leads to the formation of magnesium carbonate.

In the *medium-young landscape* very low sulphate contents, all below 100 ppm are found in the upper horizons. These upper horizons are entirely decalcified (see table 3).

At a depth of from 60 to 100 cm there is a considerable increase in the sulphate content which is often in the range 300 ppm to 1000 ppm. The latter value is very high. Since a fair amount of calcium is present in the profile at this depth, gypsum formation occurs in the dry season where there are high calcium sulphate concentrations.

From the point of view of soil chemistry these soils constitute an older phase of the young soils. The soil is decalcified to a greater depth. The patches of "katteklei" are encountered over a wider zone (see profile 2). The sulphate formation took place over a longer period. Owing to the soil being decalcified to a greater depth leaching is less. Since free lime is found in the soil at depths of 60 cm or more, gypsum formation occurs with high calcium sulphate concentrations.

In the *medium-old landscape* the sulphate content is usually less than 100 ppm in the upper horizons up to a depth of 50 cm. In the deeper horizons, 50 to 100 cm, the sulphate content rise to values in the range 300 to 600 ppm; very high values of 1000 ppm of sulphate occur incidentally. Free lime is not found down to a depth of 100 cm. Down to this depth the entire profile shows the yellow "katteklei" patches.

From the description it might be assumed that this medium-old landscape overlies a landscape which is thereby preserved in a medium-young state. A fairly large amount of gypsum is found in places at a depth of 150 to 250 cm. This gypsum has crystallized as large plates, pieces of which can be raised with an auger.

In the *old landscape* the sulphate content of the topsoil is very low, and in the subsoil the contents are only moderate, increasing to maximum values of from 100 to 300 ppm. In this landscape most of the ions have been leached, so the soil is poor.

Only iron hydroxide and iron oxide have been left. These have been increasingly dehydrated in the course of time, as a result of which bright red mottling occurs in the soil and iron concretions are formed at a still later stage.

## Determination of the age of the area

The Koembe and Maro swamp rivers exhibit a number of typical forms in their meander pattern. Numerous old meander turns (oxbows) are found in the soils along the river. Their form, closeness and sequence, differs in the young marine area from the old landscape of the hinterland.

In the coastal zone so-called bottleneck patterns are found in the former and present-day river beds. The beds have straight sections.

In many cases these elongated sections follow the continuation of former coastlines, in this case the sand ridges.

In its meandering the river apparently comes up against a topsoil, the sand deposit, which determines the direction of the new stream. On the other hand a discontinuity in the subsoil layers is probably to be found in this place as a result of which the river continues its course for some distance or makes no further cutting-in in a lateral direction. It is not impossible that the tidal effect may reinforce this phenomenon. Only a few meander turns are found in the young landscape.

A much larger number of old beds is found in the medium-young landscape and in many cases these have rounded forms and intersect at right-angles at various places.

It may be concluded from these forms and the closeness and sequence of the meander pattern that the most recent marine deposits must be fairly young.

At the present the coast between the Maro and the Koembe is in a state of abrasion. Aged natives recount stories of their houses which at the beginning of their lifetimes stood on top of a row of dunes which have now been engulfed by the sea. Heldring (1909) also reports this phenomenon. During the past 75 years, i.e. since about 1885, three series of dunes have been washed away. Heldring states, however, that about 1860 the population lived on a raised beach corresponding to a ridge which is now situated some 300 metres inland. It follows that five sand ridges have been formed in the course of 25 years.

At a period previous to 1860 the native population must have lived on the sand ridges which now form the Wentholt Sand Ridge. This is witnessed by the old settlements of Serapoe, Karanan, Deramat and Kwandi. Hence the ridge which was settled in 1860 formed a temporary interruption in a regression period of the sea. The ridges situated between this ridge and the Wentholt Sand Ridge are very narrow and interrupted in several places.

Since the soils between the ridges in the young landscape show no substantial differences of age and the meander pattern indicates a young landscape and five sand ridges may be formed in 25 years during a regression, it seems likely that the entire young landscape remained dry in the course of the 19th century. Previously the area must have been a tidal flat landscape. The great transgression in the Meraukese must have taken place in previous centuries.

We are still ignorant as regards the age of the other landscapes.

(Submitted December 1958.)

## SUMMARY

After mentioning the various soil surveys carried out in the area between the river Bian and Papua-New Guinea frontier a short review is given of the geological conditions of the area treated. A more detailed description is given of the pedological phenomena of the transgression-regression landscape near the mouths of the rivers Koembe and Maro. Based on topography, vegetation and soil conditions four landscapes are distinguished, viz.: the young J.1, the medium-young J.2, the medium-old O.1 and the old landscape O.2. These landscapes are separated by sand ridges which mark the various regression periods. These sand ridges can be divided into two groups, viz. those rich in pea iron concretions deposited along the funnelshaped river mouths and those deposited parallel to the present-day coast line and which are poor in iron concretions. An increasing decalcification of the ridges with growing age has been established whereas also the older ridges show a more intensive reddish colour. A description is given of the distinguished landscapes and

their typical profiles. With growing age an increasing mobilisation of iron hydroxide and initially an increasing, afterwards decreasing mobilisation of sulphates takes place.

Next the decalcification of the landscapes is reviewed. It appears that with growing age free $CaCO_3$ is not only found deeper in the profile but also that the free $CaCO_3$ content of these horizons decreases. (See fig. 2).

The occurrence of sulphate formation in these marine and marshy soils and the profile descriptions show a great similarity with "cat clay" soils in the Netherlands. When the topsoil dries gypsum is formed above the groundwater level if free lime is present. (See fig. 3).

With the aging of the soils sulphate content of the topsoil as well as of the subsoil decreases. In an intermediary period gypsum formation occurs at a depth of 1 metre in the medium-young landscape J.2. In relation with the above mentioned decalcification of the younger landscapes, a possible dating is worked out. Surveys and historical data point to the young landscape getting its present-day shape during the last 150 years probably originating from an extensive sand bar and tidal marsh area.

The various sand ridges which mark the transgressions make it likely that, formely, a river system existed of greater importance than the present Maro-Koembe system.

## SAMENVATTING

Na een uiteenzetting van de verschillende karteringen die in het gebied tussen de Bian en de grens van Papua and New Guinea hebben plaatsgehad, is een kort overzicht van de geologie gegeven. Meer in het bijzonder is ingegaan op de bodemkundige verschijnselen van het transgressie-regressie landschap aan de mondingen van de Koembe- en Maro-rivieren. Op grond van topografie, vegetatie en bodemkundige kenmerken worden 4 landschappen onderscheiden, t.w. 1. het jonge landschap; 2. het medium-jonge landschap; 3. het medium-oude landschap en 4. het oude landschap. Deze landschappen zijn door zandwallen, welke de verschillende regressies markeren, van elkaar gescheiden. De zandritsen blijken in twee groepen verdeeld te kunnen worden, nl. de ijzerconcretierijke ritsen die langs de trechtervormige mondingen zijn afgezet en de ritsen die evenwijdig aan de huidige kustlijn zijn afgezet en arm zijn aan ijzerconcreties.

Met toenemende ouderdom van de ritsen valt een ontkalking te constateren, terwijl de oudere ritsen eveneens een intensievere roodkleuring vertonen.

Van de verschillende landschappen zijn een terrestrisch beeld en een typerende profielbeschrijving gegeven. In deze profielen komt met toenemende ouderdom een toenemende mobilisatie van ijzerhydroxyde en een eerst toenemende en daarna weer afnemende sulfaatmobilisatie tot uiting. Vervolgens is de ontkalking van de gronden van de verschillende landschappen behandeld. Bij het ouder worden der landschappen blijkt niet alleen vrije kalk steeds dieper in het profiel voor te komen, doch het gehalte ervan in de desbetreffende horizont wordt ook geringer.

Het optreden van sulfaatvorming in deze mariene en moerassige gronden evenals de profielbeschrijvingen, toont een grote overeenkomst met katteklei-gronden. Bij het uitdrogen van de bovengrond wordt bij aanwezigheid van

vrije kalk gips gevormd boven het grondwater. Bij het ouder worden der gronden blijkt het sulfaatgehalte in de bovengrond zowel als naar beneden in het profiel af te nemen. In een tussenperiode komt in het medium-jonge landschap J.2 op een diepte van 1 meter gipsvorming voor.

Ten slotte wordt, mede in verband met de hiervoor behandelde ontkalking van de jongere landschappen, een mogelijke datering van het landschap aangeduid. Op grond van terrestrische gegevens en geschiedkundige data moet het jongste landschap in de laatste 150 jaar gevormd zijn. Voordien zal hier een zandbanken- en slikkengebied gelegen hebben.

De verschillende zandwallen, die transgressies markeren, doen een riviersysteem van grotere importantie uit een vroegere periode vermoeden, dan het huidige Maro-Koembe systeem.

## ZUSAMMENFASSUNG


Nach einer Erörterung der verschiedenen ausgeführten Bodenkartierungen im Gebiete zwischen dem Bian-flusz und der Papua-New Guinea Grenze folgt ein kurzer geologischer Überblick.

Besonders die bodenkündlichen Erscheinungen in der Transgression-Regression Landschaft an den Mündungen der Maro und Koembe Flüsze werden erörtert. Auf Grund topographischer, floristischer und bodenkündlicher Merkmale sind 4 Landschaften ausgeschieden worden, d.h. 1. die junge Landschaft J.1; 2. die mittel-junge Landschaft J.2.; 3. die mittel-alte Landschaft O.1 und 4. die alte Landschaft O.2. Diese Landschaften sind von einander getrennt durch Sandrücken welche die verschiedenen Regressionen markieren.

Die Sandrücken sind in zwei Gruppen ein zu teilen, d.h. entlang der trichterförmigen Mündungen abgelagerte, Eisenkonkretionen führende Rücken und Rücken welche parallel der heutigen Küstenlinie abgelagert sind und wenig Eisenkonkretionen aufweisen.

Mit zunehmenden Alter ist eine Entkalkung fest zu stellen während auch ältere Rücken eine intensivere Rotfärbung zeigen.

Die verschiedenen Landschaften sind beschrieben und von jeder ist eine Beschreibung eines typischen Bodenprofils gegeben. Mit steigendem Alter tritt in diesen Profilen eine anfänglich zunehmende und nachher wieder abnehmende Sulphatmobilisation auf. Weiter ist die Entkalkung der Böden der den verschiedenen Landschaften erörtert. Beim altern der Landschaften zeigt sich dasz freier Kalk ($CaCO_3$) nicht nur tiefer im Profil vorkommt, sondern auch der Kalkgehalt der bezüglichen Horizont zurück geht.

Die Sulphatbildung in diesen marinen und sumpfigen Böden wie die Profilbeschreibungen, zeigt grosze Ähnlichkeit mit Pulvererde in niederländischen Böden. Beim Austrocknen des Oberbodens bildet sich bei Gegenwart freiem Kalke, Gips oberhalb des Grundwassers. Beim Altern der Böden zeigt sich eine Senkung des Sulphatgehalts im Oberboden sowie tiefer im Profil. In einer Zwischenperiode bildet sich in der mittel-jungen Landschaft J.2 Gips in einer Tiefe von ungefähr 1 Meter.

Schlieszlich ist eine etwaige Datierung der jüngeren Landschaften auch im Zusammenhang mit der oben angedeutete Entkalkung angegeben. Auf Grund terrestrischer und geschichtlicher Daten ist die Entstehung der jüngsten Landschaft auf die letzten 150 Jahre zurück zu führen. Vorher lag an

dieser Stelle eine Wattengebiet. Die verschiedenen Sandrücken deuten auf einem früheren Fluszsystem von gröszerer Bedeutung als das heutige Maro-Koembe-System.

## LITERATURE


*Heldring, O. G.*, 1909: De Zuidkust van Nieuw Guinea, Jaarboek van het Mijnwezen in Nederlandsch Indië.

*Spek, J. van der*, 1950: Katteklei. Versl. Landbouwk. Onderz. no. 56.2.

Various unpublished Soil Survey Reports of the Bureau of Soils, Netherlands New Guinea.

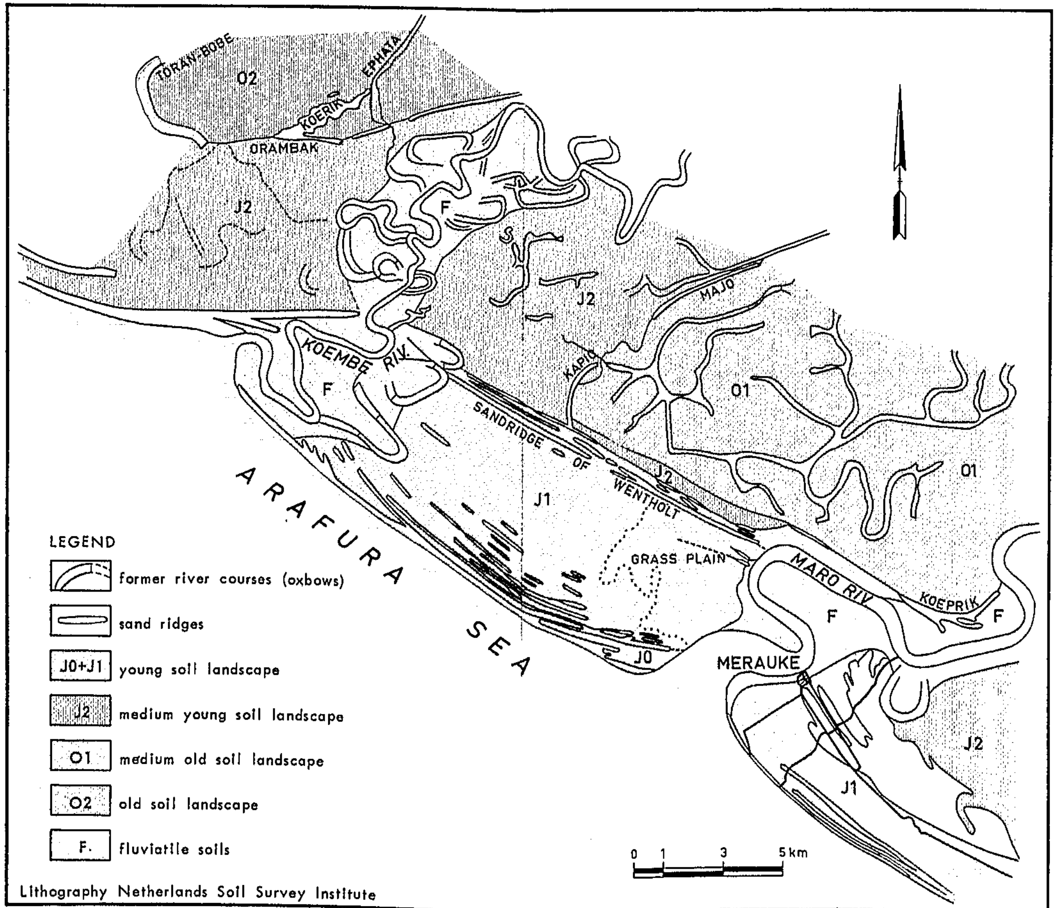
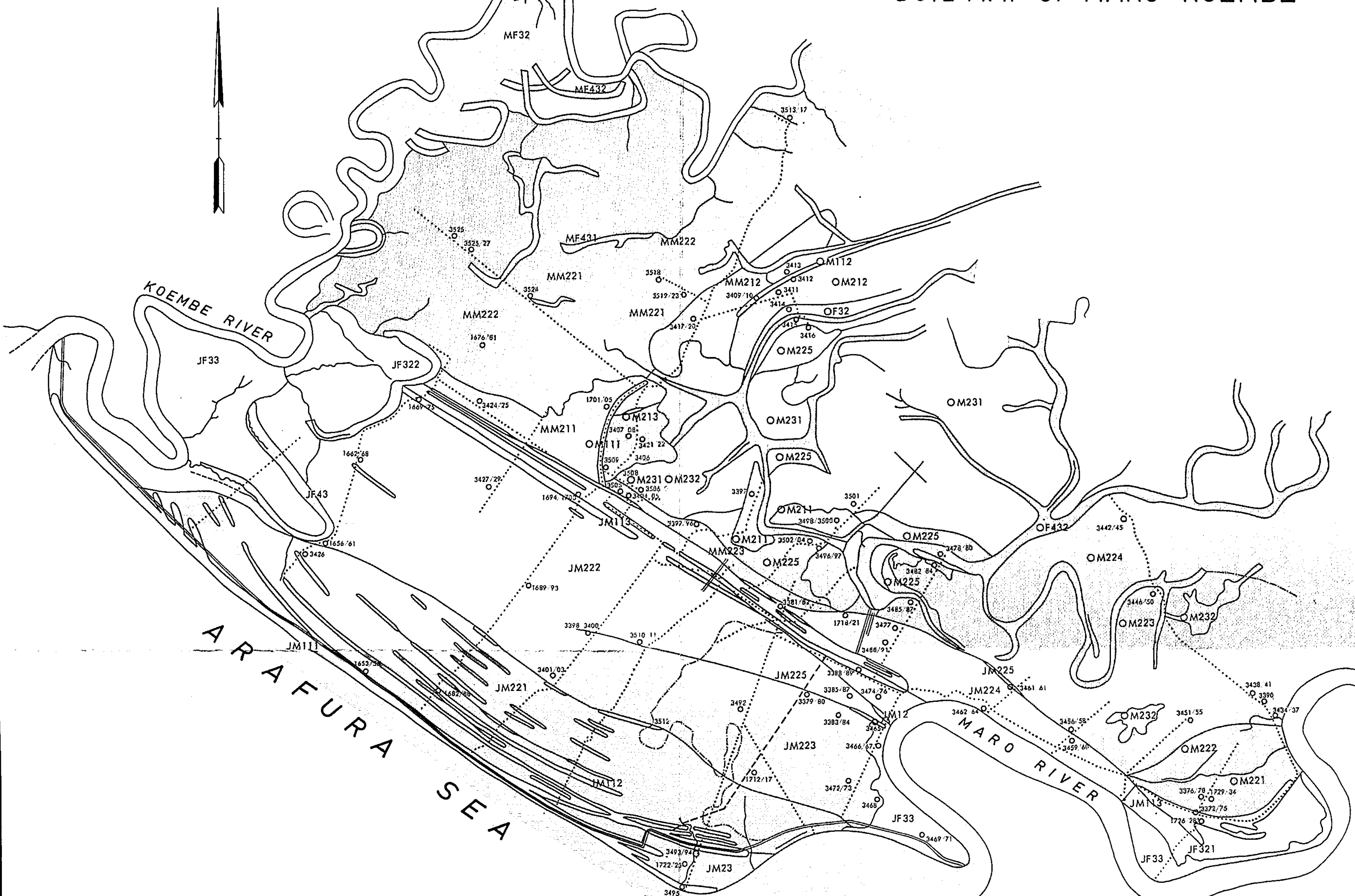



**Fig. 1 Soil landscapes of Maro-Koembe**
Scale 1:250.000 reduced from 1:100.000
Agricultural Experiment Station, Hollandia.
Netherlands New-Guinea

DRUK MPS DEN HAAG

Auger and Spade XI.1
J.J.Reynders
Appendix 1

# SOIL MAP OF MARO-KOEMBE




LEGEND

| SOIL LANDSCAPE | YOUNG | | MEDIUM YOUNG | | MEDIUM OLD | |
|---|---|---|---|---|---|---|
| | sub-series | phases | sub-series | phases | sub-series | phases |
| MARINE DEPOSITS | | | | | | |
| Sand ridges | | | | | | |
| dry soils | JM 11 | JM 111/3 | | | OM 11 | OM 111/2 |
| Level clayey deposits | | | | | | |
| dry soils | | | MM 21 | MM 211/2 | OM 21 | OM 211/3 |
| periodically inundated | JM 22 | JM 221/5 | MM 22 | MM 221/3 | OM 22 | OM 221/5 |
| continuously inundated | JM 23 | | | | OM 23 | OM 231/2 |
| FLUVIATILE DEPOSITS | | | | | | |
| Levee soils | | | | | | |
| periodically inundated | JF 32 | JF 321/2 | MF 32 | | OF 32 | |
| continuously inundated | JF 33 | | | | | |
| Channel soils | | | | | | |
| continuously inundated | JF 43 | | MF 43 | MF 431/2 | OF 43 | |

o location of sampling pits

scale 1:100.000
reduced from 1:50.000

0 1 3 5km

Agricultural Experiment Station
Hollandia Netherlands New-Guinea

Lithography Netherlands Soil Survey Institute