RECONNAISSANCE SOIL SURVEY
IN
NORTHERN SURINAM

J. J. VAN DER EYK

STELLINGEN

I. De vaste consistentie en sterke rode vlekking van kleigronden van droge en drassige terreinen in de Surinaamse kustvlakte, zijn een gevolg van de sterke variaties in vochtigheid van deze gronden.

II. De hoge stof-klei verhouding in de bovenste horizonten van de scholgronden van het oude- zeekleilandschap in Suriname is grotendeels, zo niet uitsluitend, veroorzaakt door eluviatie van klei uit deze horizonten.

III. De door D'Audretsch bij boringen rondom Paramaribo aangetroffen gidslaag van groene klei vormt de zeewaartse voortzetting van de afzetting waaruit de door Van Kersen onderscheiden "High level bauxite" en "Low level bauxite" zijn ontstaan.

F. C. d'Audretsch, Recente waterboringen in Suriname. Geologie en Mijnbouw, Nw. S. 15, no. 6, 1953.

J. van Kersen, Bauxite deposits in Suriname and Demarara. Diss. Leiden, 1955.

IV. Brouwer's mening dat bijna alle ritsen in de Surinaamse kustvlakte aan hun oostelijk uiteinde met een oudere rits zijn verbonden, is onjuist. Het door hem geschetste beeld van progressieve oost-west gerichte ontwikkeling van de ritsen is niet in overeenstemming met de werkelijke verhoudingen.

A. Brouwer, Rhytmic depositional features of the East Surinam coastal plain. Geologie en Mijnbouw, Nw. S. 15, no. 6, 1953.

V. De inventarisatie van gemengde tropische natuurbossen met behulp van luchtfoto's dient in de eerste plaats gebaseerd te zijn op de foto-analytische kaartering van bostypen, waarvan samenstelling en houtvolume in het terrein moeten worden bepaald. Het op de luchtfoto's herkennen van individuele boomsoorten en het daarop meten van sluitingsgraden, boomhoogten en kroondiameters is slechts van ondergeschikte betekenis.

VI. Het uitgeven van houtkap- en andere concessies in Suriname dient niet langer gebaseerd te worden op de kaart van Bakhuis en De Kwant, doch op de nieuwe, vanaf fotoplakkaarten getekende, topografische kaarten.

VII. De Bosnegers in Suriname vormen een potentiële arbeidsmarkt, welke tot dusver zeer onvoldoende is benut.

VIII. Voor het verschaffen van werkgelegenheid aan de Creolenbevolking van Paramaribo biedt de landbouw slechts geringe mogelijkheden.

IX. In tegenstelling tot de veelvuldig geuite mening, kunnen fotoplakkaarten ("aerial mosaics") op uiterst eenvoudige wijze stereoscopisch worden bestudeerd.

X. De talrijke voordelen welke, voor de interpretatie van luchtfoto's, een eenvoudige lensstereoscoop biedt boven een normale spiegelstereoscoop, worden onvoldoende beseft, terwijl de nadelen worden overdreven.

RECONNAISSANCE SOIL SURVEY IN NORTHERN SURINAM

Dit proefschrift met stellingen van
JACOB JOHANNES VAN DER EYK,
landbouwkundig ingenieur,
geboren te Den Helder, 27 Juli 1921,
is goedgekeurd door de promotor
Dr Ir C. H. EDELMAN,
hoogleraar in de bodemkunde.

De Rector Magnificus
der Landbouwhogeschool,
W. DE JONG.

RECONNAISSANCE SOIL SURVEY IN NORTHERN SURINAM

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR IN DE LANDBOUWKUNDE,
OP GEZAG VAN DE RECTOR MAGNIFICUS IR W. DE JONG,
HOOGLERAAR IN DE VEETEELTWETENSCHAP,
TE VERDEDIGEN TEGEN DE BEDENKINGEN
VAN EEN COMMISSIE UIT DE SENAAT
VAN DE LANDBOUWHOGESCHOOL TE WAGENINGEN
OP VRIJDAG 12 APRIL 1957 TE 14 UUR

DOOR

J. J. VAN DER EYK

Bij het gereedkomen van dit proefschrift wil ik hen danken die hieraan, direct of indirect, hebben medegewerkt.

Allereerst gaat mijn dank uit naar mijn ouders, die mij in staat stelden de door mij gekozen studie te volgen.

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Hooggeleerde Doeglas, de besprekingen met u over de sedimentologie van Noord Suriname waren voor mijn inzicht hierin van grote waarde.

Hooggeleerde Schermerhorn, voor uw medewerking voor het afdrukken van de luchtfoto's ben ik u zeer erkentelijk.

Waarde Heinsdijk en Cohen, onze samenwerking op het Centraal Bureau Luchtkaartering benaderde naar mijn mening het ideaal van "team-work". Het inzicht in het wezen van de Surinaamse landschappen, waarop dit proefschrift is gebaseerd, werd verkregen tijdens onze gemeenschappelijke tournee's, waaraan ik de beste herinneringen bewaar. Hierbij denk ik ook aan jullie, Emiel, Otti en Johannes, die in ons boswerk een zo belangrijk aandeel hadden.

Hooggeachte De Haan, waarde Hendriks, onze tochten en besprekingen brachten mij in rechtstreeks contact met de landbouwkundige toepassing van de bodemkaartering. Deze samenwerking heb ik bijzonder gewaardeerd.

Een belangrijke aanvulling van het veldwerk vormden de korrelgrootte-analysen, onder leiding van de heren Ir V. K. R. Ehrencron en Dr H. J. Müller, uitgevoerd op het Landbouwproefstation te Paramaribo, respectievelijk het Instituut voor de Tropen te Amsterdam.

Waarde Hoeksema, het enthousiasme waarmede jij je verdiepte in de Surinaamse sedimentatieverschijnselen en je helder oordeel hierover maakten onze besprekingen voor mij zeer geslaagd.

Mevrouw M. E. van Hiel vertaalde het manuscript op vakkundige wijze in het Engels; voor haar werkelijk buitengewone toewijding verdient zij mijn grote erkentelijkheid. De heer J. J. Jantzen ben ik zeer dankbaar voor zijn waardevolle adviezen voor het drukklaar maken van de twee kaarten.

Voorts dank ik Mejuffrouw C. Eykelenboom voor de zorg besteed aan het manuscript, en de heer T. C. Vos, die het teken- en lithowerk voor de gekleurde kaart met veel toewijding uitvoerde.

Zonder de financiële steun van het Welvaartsfonds en het Planbureau Suriname zou het verschijnen van dit proefschrift in deze vorm niet mogelijk zijn geweest. De heer G. van Brakel, Professor Dr R. A. J. van Lier en de heer Dr L. J. Vroon ben ik zeer erkentelijk voor hun medewerking in dezen.

Mieke, het opdragen van dit proefschrift aan jou is maar een zwakke uiting van dank voor de opofferingen die jij je hebt getroost en de steun die je mij hebt gegeven.

CONTENTS

Chapter I.

INTRODUCTION.

Surinam, in the English speaking countries often still called Dutch Guiana, is situated on the North Coast of the South American continent, about half way between the mouths of the Orinoco and the Amazon (2—6° N lat., 54—58° W long.). The country is roughly rectangular in shape; its measurements being about 360 km. in E - W direction and about 420 km. in N - S direction.

In the north, the coast of Surinam is situated on the Atlantic Ocean. The country is bounded on the west by British Guiana, on the east by French Guiana and on the south by Brazil. The capital is Paramaribo.

From 1667 to 1949 Surinam was a colony of the Netherlands. After an interim period, during which time a new juridical status was prepared, the new Statute of the Kingdom of the Netherlands (85) came into operation in 1954. According to this statute Surinam is now an equivalent partner in the Kingdom, having the right to look after its own interests independently.

In order to advance the development of the economic resources of the country, the "Development Fund Surinam" was established by the Netherlands Act of April 1, 1947 (96). This fund would be chargeable to the Netherlands Budget for a period of five years. The "Work-plan of the Development Fund" (95, 50), as required by the Act, was issued on April 8, 1948. This work-plan comprised some twenty subjects, the first one dealing with the aerial survey of a part of the Surinam territory.

In the Explanatory Memorandum to the work-plan, as well as in the annual reports of the Development Fund for the years 1948 to 1953 (92), this subject was divided into two parts, viz. A) the aerial photography by the K.L.M. (Royal Dutch Airlines) and B) the airphoto interpretation and mapping by the C.B.L. (Central Bureau for Aerial Survey).

In these reports the following was stated:

Sub A. In order to get a real basis for the the schemes, intended to raise the level of prosperity, reliable maps and an inventory of the natural resources of Surinam were essential. The only possibility to acquire them within a reasonable space of time was by means of aerial survey. By order of the Development Fund the aerial photography was carried out by the K.L.M. In 1948 the whole part of Surinam north of 4° N lat. had been covered, with an extension southwards along the river Lawa (see fig. 1).

This region, covering an area of over 80,000 square km., is recorded on about 11,000 vertical photos to scale 1 : 40,000 (flying altitude 4,600 m.). Of the coastal region another 7,000 verticals to scale 1 : 20,000 were made (flying altitude 4,200 m.). All photographs (size 18 × 18 cm.) were taken on panchromatic film, the camera being fitted with a dark yellow filter. Exposures were made in east-west running flight lines. In line of flight consecutive photographs overlap approximately 60 per cent.; the overlap between adjacent runs is about 30 per cent..

Moreover, the K.L.M. was charged with the construction of controlled aerial mosaics of the whole area covered by the photographs to scale 1 : 40,000. For ground control the locations of 26 stations, spread all over the region, were determined astronomically. On this geodetic basis the mosaics were constructed by means of combined aero-triangulation and slotted templet methods. They were delivered as reproductions to scale 1 : 40,000 (201 sheets, size 50 × 62.5 cm.) and to scale 1 : 100.000 (56 sheets, size 40 × 50 cm.). The whole project was completed by the K.L.M. in 1951.

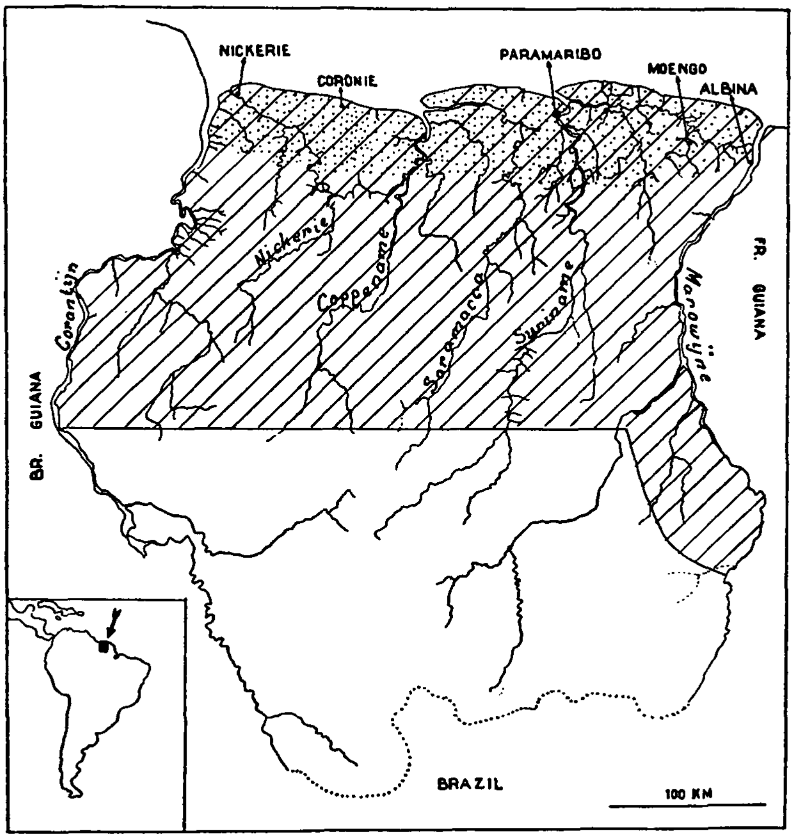

Fig. 1. Surinam. The hatched area is photographed to a scale of 1 : 40.000; the dotted part to a scale of 1 : 20.000.

Sub B. As a necessary consequence of the systematic aerial photography of a part of Surinam, the Central Bureau for Aerial Survey (C.B.L.) was founded in 1948. This bureau, which had its seat at Paramaribo, was in charge of:

1. the supervision of the aerial photography and the judgment of the material supplied by the K.L.M.;
2. the administration of the aerial photographs and mosaics;
3. the systematic interpretation and mapping, and the field work necessary for this purpose.

As a branch of the Development Fund the C.B.L. functioned until January 1954, so for nearly six years. This period was largely spent on the main task of the C.B.L., viz. the airphoto interpretation and the compilation of maps, based on the aerial mosaics. This work was carried out by the "interpretation team", consisting of a forester, a geologist and a soil scientist. By means of investigations in the field so many data were collected regarding topography, vegetation, geology and soils, that in all of these spheres the most important ground features could be recognized on the aerial photographs, and subsequently mapped from the mosaics.

In the course of these six years the C.B.L. produced the following maps:

1. 60 topographical maps (size 50 × 62.5 cm). to scale 1 : 40,000. On them is depicted the north-eastern part of Surinam as well as a few areas in the north-west of the country, altogether covering an area of approximately 3 million hectares. These maps were printed in black and white, but six of them were also issued in five-colour prints.
2. 56 topographical maps (size 40 × 50 cm.) to scale 1 : 100,000, of the whole photographed area (approximately 8 million hectares).
3. About 250 large and small-sized maps to scales ranging from 1 : 10,000 to 1 : 800,000.
   These maps were mostly made for a special purpose, and they depict the ground features important to that purpose (topography, vegetation, geology or soils). Such maps for instance were drawn for the Department of Public Works and Traffic, the Forest Service, the Geological Mining Service and the Agricultural Experiment Station, and also for several timber and mining companies and agricultural enterprises.
4. In behalf of the Forest Service some 20 sylvicultural maps were made to scale 1 : 40,000, covering an area of about 900,000 hectares.
5. In co-operation with the Geological Mining Service a new geological map of the whole of Surinam was made to scale 1 : 1,200,000.
6. In behalf of the Planning Bureau four soil maps were made to scale 1 : 40,000, covering an area of 200,000 hectares.

Some of the results of the field work and the airphoto interpretation were described in 15 publications of the C.B.L. (a.o. 23, 29, 30, 42, 43, 102, 103). Some of these publications were provided with maps, specially designed for the subject involved.

For further particulars on the activities of the C.B.L. during the years 1949—1953, be referred to the annual reports of the Development Fund (92).

From August 1949 to January 1954 the author worked as soil scientist of the C.B.L. interpretation team. In this function he carried out reconnaissance soil surveys in Northern Surinam. A part of the results of these surveys is published in this treatise.

Chapter II.

PRINCIPLES OF SURVEY.

In the modern methods of soil survey ample use is made of aerial photographs. According to the American Soil Survey Manual (83), in the United States almost all soil surveys are nowadays carried out with the aid of aerial photographs. This procedure is recommended by Stephens (86) also for other countries.

However, the application of aerial photographs in this method of mapping has so far developed very one-sided, in that in the main the photos are only used as base material on which the soil boundaries, ascertained in the field, are drawn. This is due to the fact that most of the soil surveys serve for making detailed soil maps, whereby the soil boundaries "are plotted from observations made throughout their course" (83). The marking of these soil boundaries on the aerial photographs is then "largely a matter of keeping oneself properly located with relation to the detail of the photograph, and drawing the soil boundaries in relation to the identifiable images on both the photograph and the ground" (83 p. 87).

In Surinam too, the aerial photographs are put to good use in the above-mentioned way; for the detailed soil surveys, carried out by the Agricultural Experiment Station, the enlargements of the photographs are used as base material. Even so, however, the compilation of these detailed maps is expensive and time-consuming. Consequently these surveys are only carried out in areas already occupied by regular agriculture or intensive forestry, or planned for these purposes in the near future. Areas as such occupy only a small part of Surinam; Zonneveld and Kruyer (103) assess that only 1 per cent. of Surinam's territory is occupied by regular agriculture. So it is clear that these detailed soil surveys alone can contribute but little to making a soil inventory of the whole photographed area, and that thus the aerial photography is only utilized for a minor part.

Therefore, from the very start the C.B.L. has attempted to develop a method whereby the soil mapping of vast areas can be carried out in a short period of time and at low cost by means of the pedological airphoto interpretation. In planning this, the C.B.L. started from the principle that in the Surinam territory, which is so difficult of access, the very expensive and time-devouring field work should be limited to a number of quick reconnaissances, during which the relation between *soil* and *airphoto image* must be determined. The individual soils found in the field must be grouped into soil mapping units, which are to be named and defined, while soil samples are to be taken. This grouping must be done in such a way that the resulting mapping units are recognizable on the aerial photographs. As their boundaries can only be located in some spots in the terrain, it should be possible to follow their course on the photographs, so that by means of airphoto analysis the boundaries can be plotted directly from the photos.

Chapter III.

WORKING METHOD.

In much the largest part of the photographed area the *natural vegetation* and the *relief* are practically the only features that are pictured on the aerial photographs. The vegetation is closely related to the soil conditions, which in their turn depend to a high degree on the parent rock. The relief is determined by the geological formation of the various landscapes. So the airphoto image of any landscape is dominated by three factors, viz. vegetation, soils and geology, which are closely interrelated. For this reason the airphoto interpretation and mapping were carried out, from an *ecological* point of view, in a continuous close co-operation between the members of the interpretation team (forester, geologist and soil scientist).

A. FIELD WORK.

The soil reconnaissances were mainly carried out during 19 trips, totalling 530 field-days. Almost all of the trips were made in heavily forested areas between the rivers Coppename and Marowyne, north of 5° N lat.. West of the Coppename only a few reconnaissances took place.

Further, about 70 day-trips were made from Paramaribo to more easily approachable areas.

The area surveyed east of the Coppename covers about 2 million hectares, of which only a part (600,000 hectares) occurs on the "Reconnaissance Soil Association Map" accompanying this treatise (appendix I). Of the total of c. 600 field days about 200 were spent in this part.

Most of the longer trips were made jointly by the forester, geologist and soil scientist of the interpretation team. The great advantages of team-work, already frequently pointed out (15, 16, 75, 89, 102), were thus utilized to the full. Before starting a trip a rough itinerary was drawn up. While under way, from day to day the survey traverses to be cut through the forest were projected on the controlled aerial mosaics, in mutual consultation. In planning the survey lines, it was taken into account that all geological, soil and vegetation units, occurring in a certain area, would be traversed in characteristic places. This "planned" working, made possible by the application of the aerial photographs, has rendered field work very efficient, so that the inventory of the forest, soils and rock formations could be made up in a rapid way and at utterly low cost (cf. 43).

In order to ascertain the relation between the airphoto image and the landscape in nature, it was essential that the survey lines, once they had been cut, could accurately be marked on the aerial photographs. To this end as starting point of the lines an object was always selected that could unquestionably be recognized on the photo, such as a certain tree on a river bank, a sharp bend in a creek and the like. From this point the traverses were cut through the forest with the help of a Bézard hand compass. At the same time they were measured with a measuring-chain, whereby pickets were placed every 40 metres (= 1 mm. on the aerial photographs). With the aid of this rough knowledge of direction and distances, during the survey a certain sequence of details in the topography or vegetation could be located on the photos. This procedure made it possible, even in this very dense tropical jungle, to *pinpoint* the survey lines on the aerial photos. Since the accuracy of this method could not be improved, the measuring of the lines with a geodetic instrument was superfluous and was therefore never applied. Compared with the older methods this again meant a saving of time and cost.

Most of the lines ran over a distance of 4 to 8 km.; every day one such line could be surveyed. In swamps, however, the tempo was somewhat slower and the lengths of the lines accordingly shorter.

The distances between the survey lines varied widely, so that no average can be given. In the first place this depended on the nature of the terrain and further also on its accessibility. So in vast uniform swamp areas, the photo interpretation of which presented hardly any difficulty, some scattered observations were sufficient, whereas in intricate dry land areas 20 to 40 lines per 100,000 hectares were surveyed.

After the traverses had been cut, all along them the topography, vegetation, geology and soils were studied. For the soil investigations borings took place by means of a soil auger 125 cm. in length. Whenever it was deemed necessary to examine the deeper subsoil, borings were made down to 220 or even 330 cm. by using an auger with extensions. As the aim was in a rapid way to get a general impression of the soils of vast areas, the time-consuming digging and study of profile pits was only seldom applied. The drawback, however, was that thus the structure of the soils could not be ascertained.

The spots of the borings were chosen according to the topography, vegetation and nature of the ground surface; that is, boring mostly took place when a change in one of the above-mentioned factors aroused the supposition that also a change in the soil profile had arisen. Consequently the number of borings per km. survey line depended on the terrain configuration, and normally varied between 4 and 8. In extensive uniform areas borings were made for control purposes every 400 m. at least (cf. 102 fig. 9).

Of each boring the following data were noted down: location (line and picket number), land form, drainage, vegetation and the name of the soil unit found (association, if possible together with the specific soil series). Some striking features of the soil profile involved were added.

Moreover, of every line some characteristic soil profiles were described in detail, whereby of all horizons were mentioned: depth, colour, mottling, consistence, texture, concretions and any other particulars.

Practically the whole area thus surveyed is still covered with its natural vegetation, the character of which proved to be closely related to the soil conditions. Consequently much was profited by the forest investigation, which took place simultaneously, while the geological survey revealed the origin of the landscapes and the relation between the soils and their parent materials.

The day-trips in the populated and more or less reclaimed areas around Paramaribo were often made in co-operation with the geologists or soil scientists of various government services or undertakings, such as the Lelydorp project, the Geological Mining Service, the Agricultural Experiment Station and the bauxite companies. In these areas the orientation on the aerial photographs did not present any difficulty, since it could be done with the help of the existing roads, trenches, houses, scattered groves etc..

Finally it is stated that from 210 borings, scattered all over the survey area, 512 soil samples were collected. Usually profiles were sampled (2 to 5 samples per profile), while in some cases only surface soil samples were taken. The sample spots were carefully selected, on the airphotos as well as in the terrain, so that they indeed represented profiles characteristic of the various soil mapping units.

B. LABORATORY RESEARCH.

The field work could be supplemented with a modest number of grain size distribution analyses, although only a part of the samples collected during our trips could be analysed. Most of the analyses were carried out by the Agricultural Experiment Station at Paramaribo; a smaller number by the Royal Tropical Institute at Amsterdam.

All samples were analysed according to the method described by Hooghoudt (48). However, instead of sodium oxalate, *sodium pyrophosphate* was used as a peptisator; such in order to obtain the maximum dispersion. The analyses show the distribution of the mineral particles smaller than 2 mm. ("fine earth") over 14 individual size groups, with the following size limits: 2 — 16 — 35 — 53 — 74 — 105 — 149 — 210 — 297 — 420 — 590 — 840 — 1190 microns.

The author had at his disposal altogether the granular analyses of 334 samples, taken from 146 soil profiles. These numbers seem very small for a territory of 2 million hectares. However, owing to a careful selection of the sample spots, all soil mapping units were represented in typical profile samples. So this research, however modest, can yet be called representative.

The granular analyses were not only used to determine the textural class names of the soils in question, but also to draw conclusions as to the milieu in which the various sedimentary parent materials were deposited, according to the method applied by Doeglas (24). First of all the analysed soil profiles were grouped according to the soil mapping units mentioned above. Afterwards the analyses of each unit were arranged according to the horizons from which the samples had been taken.

Further, all 334 samples were recorded as summation curves on "probability-paper", as designed by Doeglas and Brezesinska Smithuizen (25). For each set of summation curves of one special horizon within one soil mapping unit one sheet of probability-paper was used. Thus in almost all cases fairly narrow bundles of parallel summation curves arose. The shape of these bundles proved characteristic of the various soil mapping units. A number of these bundles of summation curves has been inserted in this treatise.

C. SOIL CLASSIFICATION.

During the reconnaissance surveys many "individual kinds of soil" (cf. 55 p. 78 and 83 p. 6) were found, which had to be grouped into a limited number of soil mapping units. In Surinam, *detailed soil mapping* is based on distinguishing taxonomic soil series, defined according to their soil morphological characteristics. However, in designing the classification meant here, the underlying principle was that it should be possible to carry out *reconnaissance soil mapping* in a rapid way by means of the aerial photograph interpretation, and independent of the detailed soil mapping. For this purpose the mapping units had to be identifiable on the aerial photographs. It soon became apparent that the only mapping units, that could fulfil this requirement were *soil associations*, each of which consisting of several geographically associated soil series, combined without regard to soil taxonomic principles (cf. 54 p. 256—257).

In order to show the broad geographical relations among these soil associations as well, they were combined into a small number of larger mapping units, referred to as "landscapes". In their turn these landscapes were grouped in the same way into three "belts". So the whole system developed here, comprises units on four different levels: those of the IInd level are the soil associations which serve as the basic mapping units for the airphoto interpretative reconnaissance soil mapping.

In this scheme of soil classification, on the highest three levels ever larger *mapping units* are distinguished. In contrast with the American taxonomic system, based on soil morphological relationships (cf. 7, 55, 83), it may be called a "physiographic system", based on geographical connections between soils (cf. 27, 28). The mapping units of higher levels can be represented on maps of ever smaller scales. Maps representing units of the IIIrd and IVth level can be derived from the basic airphoto interpretative soil association maps by reducing and symplifying them.

All following observations are confined to that part of Surinam situated north of 5° N lat., which for the sake of brevity will further be referred to as "Northern Surinam". This part of the country stretches about 120 km. from north to south and about 360 km. from east to west.

On the highest (IVth) level Surinam is divided into three *belts*. This distinction is based on the age of the most important soils in each of these belts, and on whether their parent materials were transported or not. This grouping roughly divides Northern Surinam into three almost east-west running strips of widely differing north-south dimensions.

On the IIIrd level Northern Surinam is divided into fourteen *landscapes*. In a former publication (29) the mapping unit "landscape" was defined as "an area that as a result of its specific geological origin morphologically forms a unit, characterized by a special rock formation, and a variety of soil conditions and vegetation, typical of this area". In principle the distinction of these landscapes is in accordance with Veatch's (90) division of the state of Michigan into "major land types"; in a later publication Veatch (91) points to the importance of marking out such "pedonomorphical" land types for planological purposes. Many of the landscapes thus differentiated bear much resemblance to the units that Milne (62, 63) designated as "catenas", which units he used in the exploratory soil mapping in East Africa. Since, however, afterwards the notion "catena" was used in a much more limited sense, the word "catena" will not be used here in dealing with these landscapes. The Surinam landscapes are pictured on the accompanying map (appendix II) to scale 1 : 645,000.

Within most of the landscapes two or three smaller units, strongly contrasting in topography, soils and vegetation, occur side by side. These distinct subdivisions are referred to as "landscape elements". Sometimes, however, a landscape consists of one element only. Within each landscape element the soils in a way form a unit, while *as a group* they are sharply outlined against the soils of the other elements. Since these boundaries present themselves on the aerial photographs, the landscape elements may serve as the fundamental mapping units for the airphoto interpretative soil mapping. In principle they correspond to the *soil associations* of the IInd level of the classification system. These soil associations were defined according to the specific properties of the soils involved, which were observed in the field. They include the profile characteristics as well as the horizontal and vertical land forms of the areas occupied by these soils.

As regards the five "factors of soil formation", dealt with by Jenny (51), it may be stated that within each landscape element the differences in climate, time and potential organisms are too small to have caused great differences in soil formation, while the soils have nearly always developed from the same or a similar parent material. Furthermore, within some landscape elements the factor topography is almost uniform. Consequently, through the more or less similar soil formation the soils within the corresponding soil associations have their most important profile characteristics in common.

Within a number of landscape elements, however, great differences in the soils do arise, though yet there will always be a clear relationship between the latter. Sometimes these differences exclusively result from variations in the topography. The soils that may occur within these landscape elements then form a catena, in the limited sense in which the term is now used (37). Not always do all catena members occur together, and so the corresponding mapping units are "catenary associations" (cf. 21, 98). These catenas correspond to the soil groups that Jenny (52) designated as "hydrosequences"; here the differences in the soils exclusively result from variations in drainage conditions.

Within one landscape element the differences in the soils are exclusively caused by the variations in the — as regards its origin, corresponding — parent material. A suchlike group of soils is named by Jenny (52) a "lithosequence".

The soil associations of a part of Northern Surinam are reproduced on the accompanying map (appendix I) to scale 1 : 100,000.

Eventually, on the lowest (Ist) level of the classification system, distinction is made between a number of *soil series* within the soil associations. Such a soil series is " a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material" (83 p. 280).

In order to distinguish and define all soil series within each soil association, it would be necessary to carry out detailed soil surveys, which was beyond the occupations of the C.B.L.. As a result of our reconnaissance surveys, however, it was possible within each soil association to define one or two important soil series. These selected series are not only characteristic, but they occupy the greater part of the various associations as well.

In this way a good, though not complete, image of each soil association can be given, since within most of the soil associations only a few (2 to 5) soil series occur, occupying relatively large areas. This small number of significant series per soil association results from the fact that the soils within most of the associations already have their main characteristics in common, and that they have developed from similar parent material, even though these requirements apply to the separate soil series in a much stricter sense.

The physiographic classification system for the Surinam soils was exclusively designed for mapping purposes. On the lowest level (soil series), however, it was adapted to the American taxonomic system. Although several objections have been raised against the latter (21, 65), it may be stated that this system is gradually developing to a universal classification scheme (cf. 84). The Surinam soils too ought to be classed in it. To this end, on the basis of the soil morphology, the soil series are to be united into taxonomic units of higher categories. In general, however, the data available are not yet sufficient for this taxonomic grouping.

D. INTERPRETATION OF AERIAL PHOTOGRAPHS AND MAPPING METHOD.

Airphoto interpretation is the indirect recognition and naming of those terrain features which are not pictured themselves on the photographs. It results from airphoto analysis, while the actual identification of the terrain features is based on data gathered in the field (cf. 20, 34). Maps produced by means of airphoto interpretation will be called "airphoto interpretative maps".

1. TOPOGRAPHICAL MAPPING.

After a certain catchment area had been surveyed, first of all the topographical maps to scale 1 : 40,000 were drawn. Controlled aerial mosaics to this scale served as base material. Their sizes are 50 × 62.5 cm., which corresponds to a land surface of 50,000 hectares. These mosaics being of the "controlled" type, photogrammetric procedures were irrelevant.

From the controlled aerial mosaics the topographical features were copied on a sheet of kodatrace. This plotting was carried out under a stereoscope, and so it was a matter of projecting the three-dimensional landscape image on the kodatrace cover. It is true that a stereoscopic image of the whole mosaic cannot be obtained at one time; however, a stereoscopic image can be had of each individual photo out of the complete set of rectified alternate photos in the mosaic, in combination with the adjoining loose photos from te same flight line, which are laid over the kodatrace. In this way the stereoscopic image is combined with geodetic accuracy. It seems, curiously enough, that this simple method is applied nowhere else. So the current opinion (also in het Soil Survey Manual (83) repeatedly stated) that aerial mosaics cannot be observed stereoscopically is incorrect. Nor are any extraordinary processes or apparatuses required for this procedure (cf. 41, 87). All maps made by the C.B.L. were drawn by means of simple lens stereoscopes.

They are more satisfactory than the normal mirror stereoscopes in that with sufficient magnification (2 ×) they have a much wider field of vision. Moreover, they are easier to remove over the large mosaics.

Because the interpretation of the photographs was carried out in continual consultation between the members of our team, the knowledge of the ecology of the landscapes jointly acquired, could be expressed in the topographical maps. The natural terrain features, plotted on the maps, include rivers and creeksystems, drainage conditions, land forms, relief and various types of vegetation. As regards the populated areas the following was added: the urban areas, scattered houses, roads, trenches and dams, various crops, „grondjes" and „kapoeweri" *).

As regards *drainage conditions* we must differentiate between *dry land, marshland* and *swamps.*

The distinction between marshes and swamps was already frequently used as the basis for the grouping of the various types of vegetation (10, 11, 32, 59). As criteria were assumed the duration of the annual inundation period and the degree to which the ground dries up in the dry season. However, Heinsdyk (42) already pointed to the fact that the *judgment* of these two criteria is often subjective. Consequently, if applied to topographical and soil mapping, they will be insufficient. Fanshawe (32), for instance, classified some important forest types as marsh forest, although they occur in terrains which, according to his own definition and also from a general topographical and pedological point of view, must be considered swamps. The same appears from Lindeman's (59) grouping. It is obvious that the drainage conditions of some swamps have been misjudged by these vegetation experts.

In very vast forested swamps and marshland areas a systematic investigation of the forest and soil combined was carried out by the C.B.L., in the rainy as well as in the dry season. During these activities particular attention was paid to the drainage conditions. Among other things it appeared that the question swamp or marshland is mainly a matter of relative elevation. In most cases this involves clear differences in the soil profiles and conspicuous differences in the vegetation. On the ground of these criteria a grouping was drawn up, which from the topography, forestry and pedology point of view is deemed satisfactory.

Summing up, the notions swamp and marshland can be described as follows: *Swamps* are terrains which are inundated whether throughout the year or at least during the greater part of it. In the latter case, even in the dry season, the soil will remain moist to close beneath the surface. This goes together with a soft, plastic to friable consistence of the subsoil. Only in extremely dry years will the soil dry up to greater depth. *Marshland* always lies somewhat higher than the adjoining swamp, though somewhat lower than the adjacent dry land. From the swamp to the marshland often an abrupt, though slight rise in the terrain is discernible. The moisture content of the soil is subject to sharp fluctua-

*) "Grondjes" or fields are small-sized plots cut out and burnt down in the forest, where once or twice food crops are grown. After these fields have been abondoned they are grown over by "kapoeweri", i.e. scrub and secondary wood.

tions. In the rainy season the soil is waterlogged, or, for a short period, even inundated. In the dry season the soil completely dries up down to a considerable depth. Marshland usually shows a characteristic micro-aspect with "kawfoetoes" ("hog-wallowed" surface). It is formed by numerous small hillocks, separated by narrow shallow gullies and pits. The soils are tough and compact; the consistence ranges from very plastic via very firm to very hard. Moreover, as a rule these soils are highly mottled with red.

The above-mentioned differences in consistence and mottling do not apply to sand soils; however, here the problem: swamp or marshland, hardly arises.

The marshland is here intentionally not called "seasonal swamp", though it may be submerged periodically. For some swamps are also "seasonal" in that they are not permanently inundated. Nevertheless, they are real swamps, topographically as well as pedologically. There is no abrupt difference in elevation from the permanently inundated terrains, while the strong seasonal drying-up of the soil as well as the very firm consistence and mostly also the abundant red mottling, so characteristic of the marshland soils, are lacking. Because by some authors of earlier days (32, 38, 59) all periodically inundated terrains were grouped together as either "seasonal swamps" or "marshes", they covered a larger acreage than what is at present considered to be marshland.

The *mangrove strips*, occurring all along the coast and the lower courses of the rivers, were separately distinguished as such, and not grouped with the swamps. This was not only done because these areas are mainly influenced by salt or brackish water, but also because here the inundation is neither permanent nor seasonal, but depends on the tides.

During the mapping operations the *drainage conditions* were inferred from the airphoto image of the vegetation, or, in populated areas, from the way of land use. In some forested areas, however, the boundary between marshland and swamp was difficult to discern. On the suggestion by Heinsdyk (42) and in accordance with the experiences gathered in the field, in such cases the palm species *Maximiliana maripa*, which is always recognizabele on aerial photographs to scale 1 : 20,000, was used as an indicator. If this palm is absent, then, with a few exceptions, the terrain is a swamp (cf. 42); if this palm does occur, the terrain is marshland or dry land.

The *relief* was represented by delineating all hills and mountains by means of form lines, drawn by hand under the stereoscope. From a physiographical point of view this way of depicting the hill-shapes was very satisfactory. Moreover, the plotting of accurate contour lines would have been much more time-consuming, as practically no terrain heights were known, whereas even with photogrammetric instruments only the contours of the forest canopy could have been drawn, not those of the terrain surface.

The mapping of the drainage conditions, land forms and relief in this way, in fact meant that a large part of the boundaries between the *landscape elements* (cf. p. 17) was plotted, for these elements are the topographically contrasting terrains to be distinguished within the various landscapes, like dry land as against swamp, hills as against wide plains and narrow marshland valleys etc..

Some of the problems of the topographical mapping by the C.B.L. were dealt with in

(102). However, the form lines represented there in fig. 3 are sketched in a much rougher way than those plotted on the topographical maps 1 : 40,000.

Eventually, from the finished kodatrace sheet a manuscript map was drawn, from which black and white prints were made. In all, sixty topographical maps to scale 1 : 40,000 were issued by the C.B.L.

2. MAPPING OF SOIL ASSOCIATIONS.

The pedological analysis of the aerial photographs revealed that the soil series only present themselves *in groups* on the photos. Mapping was therefore confined to representing these *soil associations,* which in principle correspond to the topographically distinct landscape elements. During the topographical mapping the elements of the various landscapes were, partly or completely, delineated by marking the drainage conditions, land forms and relief. That is to say that in fact a part of the boundaries between the soil associations was already shown on the airphoto interpretative topographical maps. For this reason these maps constitute an extremely suitable base material for the airphoto interpretative soil mapping.
The latter included:

a) the airphoto analysis and the actual identification of all soil associations on the aerial photographs.

b) the plotting of the boundaries between those soil associations which were whether not yet or only incompletely delineated on the topographical base maps.

a) The pedological airphoto analysis is based on three fundamental indicators, which as such are distinguishable in the stereoscopic image, viz. the natural vegetation, the relief and the geographic position. In the cultivated areas the way of land use serves as an indicator instead of the natural vegetation.

1. The *natural vegetation* is the most important indicator, especially in the relatively flat part of the country, i.e. in the two northern belts. Here it sharply accentuates the relief; these differences in elevation are too slight to be discernible themselves in the stereoscopic image.

The vegetation is closely related to the drainage conditions (dry land, marshland or swamp). So the vegetation pattern reflects the shape and possible strike of the landscape elements. These land forms and the consequent drainage pattern are characteristic of the various soil associations; they reflect the nature of the parent material from which each association has developed. Moreover, as regards soils from sandy parent materials, the vegetation indicates the bleached and non-bleached soils. This was demonstrated before in a publication of the C.B.L., illustrated with an aerial photograph (30).

2. In the more dissected terrains, which mainly occur in the southern belt, the *relief* itself is visible in the stereoscopic image. So here the land forms and the drainage pattern reveal themselves directly, through which the nature of the parent materials, which are characteristic of the various soil associations, becomes apparent. In this belt the parent materials may be of residual, colluvial or alluvial origin. Residual parent materials mainly

occur in hills and mountains. From their shapes the nature of the parent rocks can be inferred, as stated before by Simons (81). Examples were given in (102).

3. One of the features of many soil associations is their most specific *geographic position*, which is determined by the origin and the way of sedimentation of the parent materials. So the situation and arrangement of certain landscape elements with respect to the coast line and the river mouths, present-day and former river courses, creeks, hills etc., are indicators as to the soil associations involved.

4. In the cultivated areas, where the natural vegetation has been destroyed entirely or partly, the *mode of land use* is revealed on the aerial photographs. This mainly serves as an indicator to the drainage conditions because the land use in wet terrains naturally differs widely from that of dry land. To this identification the remnants of the natural vegetation, if any, can be of considerable support. The land use too presents a special pattern, from which the shape of the landscape elements appears, so that the soil associations involved can be recognized.

The actual identification of the soil associations on the aerial photographs is based on the *combination* of all these indicators (both the fundamental and the inferred ones), which calls up before one's mind the whole picture of the landscape as it had presented itself during the field work.

The soil associations were defined according to the profile characteristics and land forms of the soils involved, which were observed in the field. *Owing to the fact that during the reconnaisance trips certain combinations of analysis-indicators on the aerial photographs were time an again correlated with specific profile features and land forms, eventually on much the greater part of the airphotos the soil associations concerned could immediately be recognized.* Only in the rather rare questionable cases was it necessary carefully to analyse the various indicators separately. Naturally, the identification of the soil associations was verified with the field data in all those places where reconnaissance lines had been surveyed.

b) On the ground of these field data t h e b o u n d a r i e s b e t w e e n t h e s o i l a s s o c i a t i o n s w e r e p l o t t e d, under a stereoscope, on alternate photographs from which they were transferred to the topographical base maps. First, all survey lines were drawn on the photographs; the way in which this was done has been described on page 14. Along these lines the points were marked indicating the boundaries of the soil associations as found in the field. Starting from these established points, the soil boundaries were traced throughout their course over the entire stereoscopic image, and directly plotted on the photograph involved. Afterwards all other soil boundaries, not intersected by the survey lines, were stereoscopically plotted on the whole photograph in the same way. Finally all boundary-lines were copied on an overlay of kodatrace, and transferred to the topographical base map involved, over a light-table.

These actions were repeated with the following photographs of the same flight line, and further with the photographs of all other flight lines. Naturally, among them were photos, indeed sometimes complete sets of a flight line, which had to be interpreted while showing no survey lines at all. According to the terminology used by Buringh (20) the pedological interpretation of aerial photographs was thus partly carried out according to the method of interpolation, partly according to that of extrapolation.

The alternate photographs from which the soil boundaries were copied on the sheets of kodatrace, were not rectified. However, matching the soil boundaries from the kodatrace to the base maps (derived from the controlled mosaics) did not present any difficulty, as generally part of these boundaries must coincide with the boundary-lines of the drainage conditions, land forms or vegetation, already present on the base maps. For this reason this matching actually was a check as to the right position of the soil boundaries drawn.

As regards the map sheets of the most northern "belt" the procedure was indeed still simpler, since only a few supplementary boundary-lines had to be added. Further, the only thing to be done was to decide which soil associations were represented by the landscape elements, already delineated on the base maps. Here again, this identification resulted from the pedological analysis of the stereoscopic airphoto images, supported by the field data.

It appeared that the airphoto interpretative soil maps, for which the topographical maps (scale 1 : 40,000) served as base material, could be reduced to scale 1 : 100,000. Twelve of such reduced sheets, together covering an area of 600,000 hectares, were linked together to one map, a copy of which is added to this treatise (appendix I). So this map covers only a minor part of the total area surveyed; this part, however, may be considered a highly characteristic north-south "section" through Northern Surinam.

3. MAPPING OF LANDSCAPES.

In order to show the broad geographical relations among the soils of the whole of Northern Surinam, a small-scale map (1 : 645,000) was compiled. The mapping units depicted on this map (appendix II) are not the basic soil associations (landscape elements) but the landscapes as a whole (IIIrd level of the classification system).

This landscape map was prepared two years after the author left Surinam; so, neither aerial photographs nor aerial mosaics were available any more. A minor part of the map could be generalized from the airphoto-interpretative soil association map (scale 1 : 100,000), described above. For the rest, the mapping procedure was different for the eastern and the western part of the map.

As regards the area east of the river Coppename the author had at his disposal all field data, gathered during the reconnaissance trips in this area, and the airphoto-interpretative topographical maps to scale 1 : 40,000. On the ground of the field data the landscapes were delineated on the topographical maps, which again proved their usefulness as base material. As was mentioned before, on these base maps the elements of the various landscapes are represented by the boundaries between contrasting drainage conditions and land forms. On that account the boundaries between the landscapes as a whole could be traced on the base maps by a morphological-pedological analysis of the topographical features already shown. This interpretation and simultaneous delineation were verified with the field data in those places where reconnaissance lines had been surveyed. Afterwards the finished map sheets were reduced to scale 1 : 645,000.

West of the river Coppename only a few reconnaissance trips had been made, while the available airphoto-interpretative topographical maps covered only minor parts of this area. For this reason the boundaries between the landscapes here, were mainly adopted from two earlier small-scale maps, which had been compiled by means of the airphoto analysis without proper field control. This part of the map gives no certainty of all landscape boundaries being plotted correctly.

Since the landscapes were defined according to the land forms and soil characteristics observed in the field, whereas their boundaries were mainly derived from other maps, the notation "exploratory" seems to be the most suitable indication as to the landscape map.

Chapter IV.

CHARACTER OF THE AIRPHOTO-INTERPRETATIVE SOIL ASSOCIATION MAP.

In order to judge a soil map, one ought to ascertain the nature of the soil mapping units shown and the degree of accuracy and detail to which these mapping units are depicted.

In the American Soil Survey Manual the soil maps based on original field observations are divided into "detailed soil maps" and "reconnaissance maps" (83 p. 15—18). The "detailed soil maps" represent practically homogeneous soil types. This requires large-scale mapping, usually scale 1 : 31,680 or larger. In the field the soil boundaries are followed all along their course and plotted on the map, so as to achieve a high degree of accuracy and map detail.

On the "reconnaissance soil maps" usually soil associations are pictured, within which the soil characteristics may vary widely. The scales of reconnaissance maps are usually small; for instance, they may range from 1 : 100,000 to 1 : 500,000. In the field the soil boundaries are often only located by a number of points along the survey lines, between which points the connecting lines, indicating the course of the boundary, are sketched.

Although in the Soil Survey Manual (83 p. 437) about the use of aerial photographs in "reconnaissance soil mapping" it is stated that "they can be used to advantage as supplemental aids in sketching", the possibility of a mapping method as developed by the C.B.L., which to such a high degree depends on the interpretation of aerial photographs, is not mentioned. That this procedure is not in general use may be concluded from the fact that in the experimental soil surveys as described by Belcher (12) and Pomerening and Cline (73), no soil scientists skilled in he interpretation of aerial photographs took part. Belcher, for that matter, remarks that "most practising soil surveyors are reluctant to go into the use of aerial photographs beyond the base map stage". This reluctance obviously refers to the most vulnerable point of the airphoto interpretative mapping: the identification of the soil mapping units on the aerial photographs. With regard to this point, the fact is emphasized that in the procedure pursued by the C.B.L. the soil associations involved were nearly always *at first sight and with certainty identified in the stereoscopic image*. For that matter, this possibility was also mentioned by Bushnell (22), who observed that "a man may say 'that is a certain soil because it looks like it' with no more critical analysis than when he recognizes the picture of a friend".

Indeed, the delineation of the associations was based on the field observations, with which the identification was verified from place to place.

In comparing the two types of American soil maps, mentioned before, with the airphoto interpretative soil map reduced to scale 1 : 100,000, it appears that the latter shows soil associations, each consisting of several similar or contrasting soil series. So in this respect this map is a "reconnaissance map". This also applies to its scale, as well as to the way the field work was carried out. For a reconnaissance map, the scale 1 : 100,000 is rather large. On the other hand, as will be seen below, the intensity of the field work was very low with regard to this comparatively large scale. This paradox makes a closer consideration desirable of both the *accuracy* and the *map detail* of this map. Independent of its scale, a really good reconnaissance map will meet the requirement that, with respect to the topographical features shown on the base map, distinct soil boundaries deviate at most 1 mm. from their right position. With regard to the map detail, each area, shown as one mapping unit, must be so homogeneous that within that area no terrains of another mapping unit may arise, which could readily have been depicted to the scale selected; i.e. with dimensions ranging from a width of 1 or 2 mm. for long-drawn strips to a diameter of 4 or 5 mm. for round spots.

To meet these requirements, in an area like Northern Surinam, which is predominantly heavily forested, partly very hilly and consequently extremely unsurveyable, and the soil survey to scale 1 : 100.000 being exclusively based on field observations, the reconnaissances should be carried out along lines with an average distance between each other of 400 to 500 metres. As to the soil association map enclosed, covering an area of 75 × 80 km., this would mean that the survey lines would total 12 to 15,000 kilometres. Actually the total length of lines and roads surveyed in this area in a period of 200 days was 750 km., so one sixteenth to one twentieth of the number of kilometres mentioned above.

In delineating the soil associations the soil boundaries are naturally observed all along their course in the stereoscopic airphoto image. Hence, it was possible to meet the above-mentioned requirements of accuracy and map detail. Owing to the reduction from the photo and base map scale (1 : 40,000) to the publication scale (1 : 100,000) the admissible deviation in the course of distinct soil boundaries on the topographical base maps was 2½ mm., which is so ample that such a deviation will never have arisen. Indeed, in general distinct boundaries could be traced on the original aerial photographs themselves, accurate already to 1 mm.. From the photos the boundaries could be matched on the base maps (derived from the controlled mosaics) without errors worth mentioning. On the other hand the areas belonging to contrasting soil associations, and varying between long-drawn strips, 2½ mm. in width, and round spots, 10 mm. in diameter, will never have escaped the attention during the photo analysis. *So all soil boundaries which the map ought to present are really there and, by reconnaissance methods, they could not be pictured more accurately or more detailed.*

In fact, since the soil boundaries were traced in the stereoscopic image all along their course, the airphoto interpretative mapping in principle corresponds to the "detailed soil mapping". The only difference is that in the latter procedure the soil boundaries are located in the field. It is, however, incorrect to define this terrestrial mapping as "direct" contrary to the "indirect" photo interpretative mapping, since according to the Soil Survey Manual (83 p. 14) even for terrestrial mapping "excavations or borings are needed chiefly to identify the profile of the soil landscape. The actual boundary can usually be drawn most accurately by careful observations of the landscape". With sufficient experience it will make little difference whether the "observations" are made in the field or on the aerial photographs; and as appears from the working method described, also for the airphoto interpretative mapping borings along the survey lines were carried out in order to identify the soil mapping units. So the only advantage of terrestrial mapping is that, when the course of a boundary is doubtful, a soil profile can immediately be studied on the spot. However, that also in the latter case the outcome is not decisive to the full, was pointed out by Pasto (71), who alleges that "all soil maps have some error because soil boundaries are not finite. Thus there also is inherent in profile examination a degree of error not always predictable".

If the now distinguished soil associations were located in the terrestrial way — for example to a scale of 1 : 40,000 — by following their boundaries all along their course *in the terrain* and meanwhile plotting them, such a map, after being reduced (and consequently simplified) to scale 1 : 100,000, would only slightly differ from the airphoto interpretative soil map.

So the ultimate conclusion must be that this airphoto interpretative soil map to scale 1 : 100,000 is a "reconnaissance soil map" as regards the mapping units it presents. However, with regard to the delineation of these mapping units this map approaches the degree of accuracy and detail of a "detailed soil map" reduced to the same scale.

Chapter V.

TERMINOLOGY AND NOMENCLATURE.

The division of the Surinam soils into three "belts", as earlier mentioned in this thesis, is based on the origin of the parent material and the age of the soils developed from it.

As regards the origin a distinction is made between *residual* or autochtonic parent materials and *sedimentary* or allochthonic parent materials. The former have developed from solid crystalline igneous or metamorphic rocks by weathering *in situ;* the latter have been removed after (partial) weathering of such-like rocks and deposited elsewhere. So sedimentary parent materials consist of sedimentary, usually unconsolidated rocks.

This differentiation, which may very well serve to show the broadest geographical relations among soils, has been applied in Indonesia already for a long time, as appears from (49, 64, 65, 88). Weathering to residual parent material and soil formation take place together as one complicated process; as to sedimentary parent material, after the sedimentation, weathering and soil formation again take place as a second stage. Polynov (72) therefore, in this connection speaks of "monochronogeneous" and "heterochronogeneous" soils.

These two groups of soils are defined by Shaw (79) as "primary soils" and "secondary soils"; these terms are also used by Robinson (76). The Soil Survey Staff (83) too makes a similar differentiation between transported and non-transported parent materials.

To the agricultural valuation of soils, especially in under-developed countries where fertilizers are not used on a large scale, the soil ages are of great significance. This primarily refers to the weathering stage, upon which depends the content of plant nutrients present in the soils. This concerns not only the nutrients that the plants can directly take up, but especially those which are potentially present in the form of readily weatherable minerals, which, through the process of rapid tropical weathering, provide a subsequent supply. Consequently, at least as regards the soils from sedimentary parent materials, a distinction is made between *young* or immature, and *old* or mature soils. Young soils may be rich in plant nutrients directly available, while they still contain readily weatherable minerals. Old soils are practically outweathered; they are poor in plant nutrients. The latter occur almost exclusively as adsorbed ions; however, they may be lacking almost entirely.

This distinction too, has been applied in Indonesia and other countries (cf. 26, 49). A well-known division is the one by Mohr (64, 65), who, between the first and the last stage of the weathering process, distinguishes a juvenile, a virile and a senile stage. This grouping is in accordance with Shaw's (79), whereby the five stages are represented by "recent", "young, "immature", "semi-mature" and "mature" soils. Here the Surinam soils of the first three stages are taken together as young or immature, those of the last two stages as old or mature.

The terms immature and mature further refer to the degree of development of the soil profiles. In "Soils and Men" (37) an immature soil is defined as "a young or imperfectly developed soil", which corresponds to the definition by Robinson (76). According to Marbut (61) the characteristics of the parent material are still predominant with immature soils; mature soils have the "full complement of well-developed features" (60) whereby the characteristics of the solum, resulting from the soil formation, are predominant. In (37) it was added to this statement that a mature soil is "in equilibrium with its environment"; according to Jenny's (51) conception no percolation would take place any more in this stage, which can be the case in the very last stage only. However, here the notion "mature" is not used in this limited sense.

Summing up, the three belts were defined as follows:

A. Northern belt, consisting of landscapes with young soils from sedimentary parent materials.

B. Middle belt, consisting of landscapes with old soils from sedimentary parent materials.

C. Southern belt, consisting of landscapes with soils from residual parent materials.

For the nomenclature of the *landscapes* descriptive denominations were introduced. The latter are derived from the vernacular morphological indication of the principal landscape element (e.g. *"rits"-landscape),* or from the geological origin or rock type (e.g. *old off-shore bar landscape, shist hill landscape* etc.), which are responsible for this morphology. So the "type locality" denominations earlier introduced (29) were discarded.

The names of the *soil associations* developed from sedimentary parent materials were derived from the geomorphological or topographical indications of the landscape elements with which they could be identified, e.g. *river levee soils, swamp soils* etc.. In those cases that within one landscape element two soil associations were distinguished on the ground of important differences in soil characteristics, this differentiation was naturally also expressed in the names, e.g. *bleached* and *non-bleached "dek" soils* etc. The soil associations from residual parent materials were named after the rock-type from which they have developed, supplemented with an indication as to the mode of soil formation, e.g. *schist laterite soils* etc..

This nomenclature does not comply with the demands made in the American Soil Survey Manual (83 p. 17, 303, 439), in which it is said that "the definition of a specific soil association consists of the definitions of its constituent taxonomic units, their proportions and patterns". The Surinam soil associations, however, had to be named while only in two Surinam landscapes the occurring soil series had been defined, and tentatively grouped into taxonomic units of higher categories (30). This made a definition of soil associations, in the way as prescribed in the Soil Survey Manual, impossible for the greater part of the landscapes. For the sake of the homogeneity in the nomenclature, the Soil Survey Manual directives were also abandoned as to the two landscapes, mentioned above.

It was, however, possible within each soil association to define one or more typical *soil series* which are frequent. In accordance with the American nomenclature they were given "type locality" names, derived from the area where the series was first ascertained, e.g. the *Saramacca series*, the *Zandery series*, the *Tempati series* etc.. Objections have frequently been raised towards both the term "series" and the "type locality" nomenclature. Although the objections raised by Bushnell (21) are well-founded in themselves, it would not be reasonable to introduce another term for the notion "soil series", this denomination being quite current in many parts of the world. The descriptive names suggested by Mohr and Van Baren (65) are unusable for the numerous soil series distinguished according to many profile characteristics (cf. 61).

In dealing with the landscapes, landscape elements, soil associations and soil series, terms are frequently used that refer to the land form and drainage conditions. The *land form* is marked by the relief, for which the terms level, undulating (= gently sloping), rolling (= sloping), hilly (= moderately steep) and steep are used. These groups correspond to the "slope classes" dealt with in the Soil Survey Manual (83 p. 163).

The terms dry land, marshland and swamp, used to indicate the *drainage conditions*, were already dealt with in chapter III D.

With regard to the relief and the drainage conditions rough altitude indications will sometimes be given; they are based on Surinam standard level (= "Surinaams Peil" = S.P.). As a comparison the information may serve that the highest water level observed in the river Suriname near Paramaribo is 0.10 m. below S.P.; the lowest 3.50 m. below S.P. and the mean 2.07 m. below S.P. (cf. 2 appendix 2).

As regards the drainage, distinction is made between surface run-off and internal drainage. Both may range from nil to very rapid (83 p. 166—168). As to the total drainage, so the result of the run-off and internal drainage together, the Soil Survey Manual (83 p. 170) distinguishes between seven classes of soil drainage. For the abovementioned terrain types the drainage is about as follows:

swamp	: very poorly drained (class 0)
marshland	: poorly drained (class 1)
marsh to dry land	: imperfectly or somewhat poorly drained (class 2)
dry land	: moderately well to excessively drained (classes 3—6).

The terms concerning the profile horizons, colour, mottling, consistence and texture *), used in the descriptions of soil profiles, are, wherever possible, derived from the normalized American terminology.

1. As the *solum* is designated the upper part of the soil, developed from the parent material through the soil forming processes.

2. For the *profile horizons* the well-known letter nomenclature was used (cf. 83 p. 173). Accordingly:

as *A-horizons* were designated surface horizons of maximum organic accumulation and/or surface or subsurface horizons which are lighter in colour than the underlying horizon, and which have lost clay or iron.

*)Te structure of the soils must, for reasons mentioned on page 14, be left out of consideration.

as *B-horizons* were designated horizons of altered material, characterized by an accumulation of clay, iron or organic matter and/or a stronger or redder colour than that of the A-horizon or the underlying horizons.

as *C-horizon* was designated the layer of unconsolidated material, relatively little affected by the soil forming processes, and presumed to be similar to the material from which the overlying solum has developed.

as *D-layer* was designated any stratum underlying the C or the solum, which is unlike C or unlike the material from which the solum has developed.

In addition, the following subscripts were used:

gg: for horizons of intense reduction, characterized by grey or greyish blue colours, sometimes with yellow or brown mottles.

g: for horizons of seasonal reduction; these horizons are often highly mottled with red.

ir, h or *t:* for accumulations of iron, organic matter or clay respectively.

u: for unconformable inherited characteristics.

3. The *colours* of all soil profiles were described in the field, while in moist or wet condition. Except for the bluish and purplish colours the soil colour names were taken from the Munsell Soil Color Charts (68, also in 83 p. 195).

4. The *mottling* of the soil horizons was described as follows:

a) In the events that the matrix was clearly apparent, e.g. "grey clay, with brown and yellow mottles", or "grey clay, mottled with brown and yellow".

b) If no clear matrix existed, e.g. "mottled grey, brown and yellow clay".

Sometimes indications were added regarding the contrast (faint, distinct, conspicuous) and the abundance of the mottling (slightly, highly) (83 p. 192).

5. The *consistence* of the soils was described in the field. In almost all cases the descriptions deal with the consistence in moist condition, whereby the terms loose, friable and firm were used, which need no further elucidation. Only with swamp soils the consistence was determined in a wet condition, and expressed in terms of stickiness and plasticity (83 p. 232). If, in addition, the consistence was described of soil samples in dry condition, this is stated separately.

6. The term *texture* was exclusively applied in the sense of grain size distribution, i.e. the relative proportions of the various size groups of the individual mineral particles. The judgement of the texture, which took place in the field, was verified with the granular analyses (see chapter III B). First of all a distinction was made between the particles smaller than 2 mm. ("fine earth") and those larger than 2 mm.. In the "fine earth" fourteen fractions were distinguished, which were grouped as follows:

clay		$< 2\ \mu$
silt		2—50 μ
sand	very fine	50—105 μ
	fine	105—210 μ
	moderately coarse	210—420 μ
	coarse	420—840 μ
	very coarse	840—2000 μ

The description of a profile mentions the textural class of every horizon; this is based on the percentages of the fraction-groups sand, silt and clay occurring in the "fine earth". These textural classes were defined according to the triangular graph used in the United States (83 p. 209), from which the textural class names have been derived as well.

Of the textural classes designated as "sand" or "sandy", the size-group of the sand was stated in addition, which was determined according to the median-point of the sand fractions.

The coarse fragments (> 2 mm.) of the soil are subdivided as follows:

gravel	0.2— 7.5 cm.
cobbles	7.5—25 cm.
stones	> 25 cm.

Chapter V.

GEOLOGY, CLIMATE AND VEGETATION OF NORTHERN SURINAM.

A. GEOLOGY.

As was already shown on the geological map by Yzerman (99), in that part of Surinam situated north of 5° N lat., primarily three groups of rock formations are to be distinguished, viz. the *crystalline basement*, the *younger basic intrusives* and the *young sediments*. Schols and Cohen (78) briefly dealt with the latest conceptions about the geology of Surinam. Summing up the following may be stated:

The crystalline basement which constitutes Surinam's interior, covers the southern part of the country, indeed six sevenths of its entire territory. It forms part of the large Guianese shield, which also includes considerable parts of the neighbouring countries British and French Guiana, and further extends to Venezuelan and Brazilian Guiana. It is considered to be of prae-Palaeozoic age and it forms one of the ancient cores of the earth's crust. As such this Guianese shield is of a very complicated composition, while manifold metamorphoses have obscured the original proportions.

At present two metamorphic schist formations are distinguished in this basal complex, viz. the Balling and the Orapu formations. The *Balling formation* is of volcanic-plutonic origin, and consists of metamorphic lavas and tuffs (quartz-(calcite-)chlorite-albite schists) and the dynamometamorphic deeper parts of the volcanic formation (hornblende schists), while the gabbro cores of some mountains too are considered to belong to this formation. The formation was folded during an orogenesis, whereby an intrusion of granite took place. The *Orapu formation*, on the other hand, is of sedimentary-clastic origin, whereby one section (Rosebel) has developed as conglomeratic sandy facies, whereas the other one (Maäbo) as clay facies. The *Rosebel section* mainly consists of sericite quartzites, graywackes and subgraywackes. The *Maäbo section*, within which the degrees of metamorphism vary widely, i.a. consists of phyllites, shales and garnet-staurolite schists. This Orapu formation too was folded during an orogenesis, whereby granitization took place. The intrusions of granite, or the granitization, going together with these two orogeneses are responsible for the occurrence of granito-dioritic rocks of variable composition.

In the area under consideration, the younger intrusives, which broke through the crystalline basement, occur as dolerite dikes. They are often scores of kilometres in length, while their direction is almost north-south.

The young sediments are deposited on the northern border of the crystalline basement, where they form the east-west running coastal strip of Surinam. This strip, which extends to British but hardly to French Guiana (cf. 19 fig. 1), is about 150 km. in width in Western Surinam, and only about 35 km. in the eastern part of the country. Within the young deposits, differentiation is at present made between the Zandery, Coropina and Demerara formations.

The *Zandery formation* includes the oldest non-consolidated sediments, which, however, are not older than Miocene. These sediments form a cover over the northern part of the crystalline basement. They preponderantly consist of coarse sands and (coarse sandy) clays. The origin of this formation is still uncertain. Schols and Cohen (78) mention the possibility of a marine, perhaps littoral origin.

The *Coropina formation* follows the Zandery formation in age, and is presumably of young Pleistocene date. This formation is of marine origin. As already stated before (23, 29, 30) it consists partly of fine sands, which have been deposited as offshore bars, partly of (silty) clays, sedimented in the lagoons on the landside of the offshore bars. After the sedimentation, a regression took place, followed again by a transgression. In this period a considerable part of this formation disappeared through erosion. After the transgression the *Demerara formation* was deposited, which includes the latest (Holocene) sea and river deposits. They mainly consist of clays, sedimented in the form of a tidal flat. Beside the clays fine sands occur, which were deposited as coastal barriers. A minor part of these coastal barriers, however, does not consist of sand, but of shells. These two facies of former coastal barriers, which present themselves in the swampy clay areas as somewhat higher ridges, in Surinam are referred to as "ritsen" (cf. 94). Finally, the layer of peat found in some places in this part of the coastal strip, must also be considered to belong to the Demerara formation.

The distribution of the above-mentioned formations was pictured by Schols and Cohen (78) on the latest geological map of Surinam.

On the highest level of our soil classification system, Northern Surinam, as pointed out in chapter III C, is divided into three belts. This division is founded on the origin of the parent materials and the age of the soils within each of the three belts. As regards this division it may be stated that the southern belt, which in the main embodies soils developed from residual parent materials, is the area where the crystalline basement and the younger intrusives are exposed.

The other two belts, of which the soils have developed from sedimentary parent materials, correspond to the area of the young deposits. The middle belt, mainly consisting of old soils, includes the areas of the Zandery and Coropina formations. The northern belt, with its young soils, corresponds to the area of the Demerara formation.

B. CLIMATE.

The following data are derived from publications by Braak (17), Ostendorf (70) and Hendriks (44). Owing to the location between 5 and 6° N lat., Northern Surinam has a really tropical climate. The t e m p e r a t u r e is high all the year round, namely 26 to 27° C.. The annual variation is slight, ranging from 1.5 to 2.2° C. for the different stations.

As regards the soil temperature only a few data have been published hitherto. Measurements underneath an open grass-field at Paramaribo showed that the mean temperature all over the year hardly differed at depths of 60, 110 and 160 cm. and amounted to a good 29° C.. As to these three depths the differences between the warmest and the coldest months were 2.7, 2.2 and 1.9° C. respectively. In the shade the average soil temperatures for the above-mentioned three depths were 3.9, 3.6 and 3.5° C. lower than the temperatures underneath the open grass-field.

All the year round the trade wind blows with firm steadiness over Northern Surinam, coming from directions almost ENE and E. In the coastal regions the wind is rather strong, but on its way to the interior it rapidly subsides. The average wind-force (measured three times daily) at Coronie (near the coast), Paramaribo and Kabelstation (120 km. inland) was 2.9, 1.4 and 1.1° Beaufort respectively. On the whole, at 2 p.m. the wind-force is stronger than at 8 a.m. and 6 p.m. Heavy winds or gales are rare.

Table 1. Average rainfall in Northern Surinam (in millimetres).

Stations	Nieuw Nickerie	Coronie	Paramaribo	Republiek	Kabelstation
January	150	180	215	186	230
February	115	114	160	125	149
March	153	186	195	147	197
April	176	176	229	225	244
May	249	208	313	301	357
June	265	256	304	291	306
July	241	224	233	215	224
August	143	128	160	154	152
September	63	49	78	79	63
October	44	48	78	65	50
November	78	87	120	105	66
December	163	176	215	204	199
Annual average	1842	1834	2300	2097	2237

In the course of the year the rainfall is subject to much larger variations than the wind. Table 1 shows that four seasons are distinguished, viz. a long rainy season (April—July), a long dry season (August—November), a short rainy period (December—January) and a short dry period (February—March). In the western part of the country June is the wettest month, while in the eastern part it is May. At most of the stations October is the driest month. A secondary maximum usually occurs in December or January; a secondary minimum usually in February.

According to the classification by Köppen (56) the whole of Northern Surinam belongs to the region of the "tropical rainy climates", and probably the greater part has a "continuously moist rainy climate" Af (see fig. 2). To the region of the "monsoon climates with moderately dry periods" Am belong, besides a strip along the coast, also scattered terrains in the interior. The coastal region near Coronie seems to approach the "periodically dry savanna climate" Aw. However, the time of observation has been short here, while the station Coronie itself has the Am climate.

In individual years rainfall may strongly deviate from the average. So, at Paramaribo the general average for the period 1847—1955 amounts to 2300 mm.. The graph by

Ostendorf (70), in which the annual rainfall is grouped into 100 mm. classes, shows, however, that the classes 2200—2300 mm. and 2300—2400 mm. occurred only ten times, while the classes 1700—1800 mm. and 2700—2800 mm. even occurred seven and eight times respectively. In the driest year fell not more than 1244 mm., in the wettest year 3227 mm., so roughly 50 % less and 50 % more than the average. There are years that the long dry season is severe, whereas in other years it entirely stays away. In individual years the short rainy period and the short dry period too may differ widely in length and intensity; in abnormal years one of them may hold off at all. However, it has

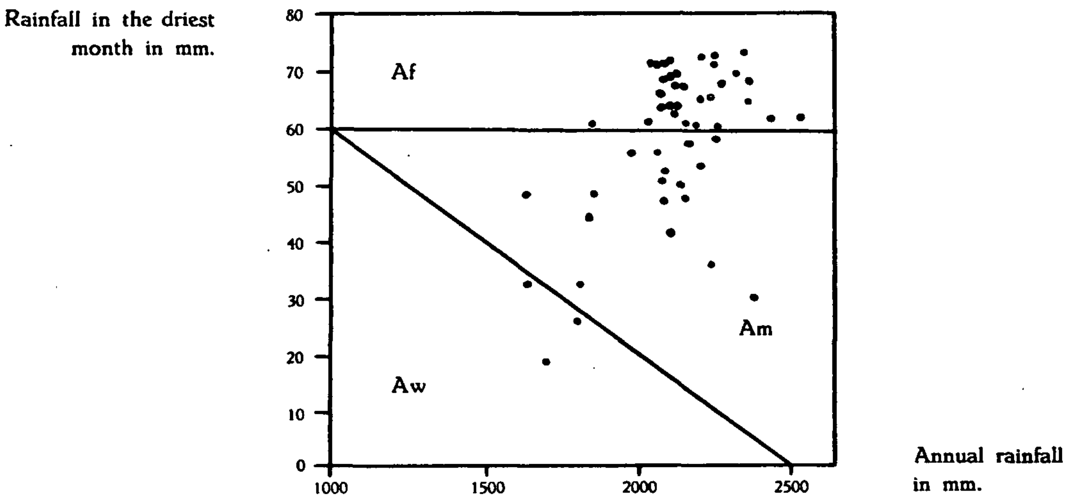

Fig. 2. Mean rainfall of the Surinam stations placed in a Köppen-diagram of the tropical rainy climates. After Bakker (4).

never been observed so far that the long rainy season stayed away, although both its duration and its rainfall may vary.

Years of drought arise when after an abnormally dry or a normal long dry season the short rainy period brings little rain, while subsequently the short dry period is normal or abnormally dry, and moreover, the long rainy season sets in late. So, distinct years of drought are especially characterized by an abnormally poor rainfall during the months December—April. Since 1865 years of severe drought have periodically occurred with intervals of about (though not precisely) fourteen years (cf. 70).

C. VEGETATION.

According to Beard's (10) classification system of the climax vegetations of tropical America, the floristic units (associations etc.) are united in a limited number of physiognomic units (formations), which are further united in six habitat groups. As regards these habitat groups the present author holds the opinion that in Northern Surinam almost all dry land types of vegetation may be considered to belong to Beard's "seasonal formations". The latter occur in "well drained lands with seasonal lack of available moisture, due to ill-distributed rainfall". As will be raised later on, Fanshawe (32) holds a different view in regard to some types of vegetation. The marshland and swamp types of vegetation may be deemed to belong to Beard's "marsh formations" and "swamp formations" respectively, since his definitions on these habitats are practically in accordance with ours.

The physiognomic units are primarily defined according to their "general life form type". In Northern Surinam the following "general life from types" are the most significant:

1. *forest*, usually more than 20 m. high, the trees showing more or less distinct stratification *).
2. *woodland*, a 10—15 m. high vegetation without distinct stratification of the trees*).
3. *scrub*, a more or less dense, woody vegetation 4—8 m. high.
4. *herbaceous vegetation*, in every day life generally designated as "grass", ranging in height from a few decimetres to approximately 4 metres.

The remarkable fact is though, that all four life form types occur in all three types of habitat: dry land, marshland and swamp.

Roughly two thirds of Northern Surinam is covered with primary f o r e s t. The forest occurring in the dry landscape elements of the various landscapes may be considered to belong to the "evergreen seasonal forest". According to Lindeman (59) it is a forest "with three stories of trees, a highly discontinuous stratum of emergent trees reaching 30 m. and more, an almost continuous canopy layer at 15—27 m. and a continuous lower story at 3—12 m.". As a rule it is intensely mixed; Lindeman estimates that "a uniform stand of typical evergreen seasonal forest" contains about 100 tree species. An exception is the walaba forest, in which *Eperua falcata* "may exhibit absolute dominance in the canopy stratum". This forest type, intermediate between the normal mixed forest and the savanna wood, is classified by Fanshawe (32) as "dry evergreen forest", whereas Gonggryp and Burger (38) consider it to belong to the "seasonal evergreen forest", to which view the author subscribes. The various dry land forest types will further be dealt with together with the landscape elements involved (chapter VII).

In general, both marsh forest and swamp forest are lower than, and not so highly mixed as, dry land forest. An important representative of the former group is the forest in the marshland strips along the rivers. The second group includes i.a. the wide-spread matakki *(Symphonia globulifera)* forest, which both Fanshawe (32) and Lindeman (59) unjustly classify as marsh forest. A particular type of the swamp forest is the mangrove *(Avicennia* and *Rhizophora)* forest, which in the main is found in the strips along the coast and the lower courses of the rivers, which terrains are periodically flooded by salt or brackish water.

As w o o d l a n d in the dry land and marshland the so-called savanna wood occurs. It is, according to Lindeman (59) of "a well defined composition", though "physiognom-

*) Definitions according to Lindeman (59).

ically it is very variable, in the best developed form it is a forest with a continuous canopy layer at 10—18 m., consisting of a remarkably large number of thin trees overtopped by a few bigger ones . . . Most trees have micro- to mesophyllous leathery leaves". Characteristic „tree" species are especially savanna mangro *(Clusia nemorosa* and *fockeana)*, blakka beri *(Humiria floribunda* and *balsamifera)*, savanna katoen *(Bombax flaviflorum)* and savanna yzerhart *(Swartzia bannia)*. A peculiar form of the savanna wood is the dakama *(Dimorphandra conjugata)* forest. This forest type is highly inflammable; however, if it is not burnt down prematurely, it can eventually reach a height of about 25 m..

An exemple of woodland occurring in swamps is the non-mixed koffiemama *(Erythrina glauca)* wood.

Among the areas with still lower "life form types" the *savannas* occupy a particular place. Savannas involve dry or marsh land with a vegetation of either mainly grasses and *Cyperaceae*, or more or less dense scrub. In the former case we speak of "grass" or open savannas, in the latter case of scrub savannas. This scrub especially consists of savanna mangro and blakka beri; so those species that grow in the savanna wood as thin trees.

The savanna wood is mainly found around the savannas, where it constitutes the transition towards the surrounding high forest. Elsewhere it may occur separately, in scattered complexes amidst high forest. Most savannas by far are found in areas with unfavourable soil profiles; this is always the case as regards the savanna forest. The scrub savannas and savanna woods on the dry bleached sands of the "dek" landscape are considered by Fanshawe (32) to be "xeromorphic scrub" and "xeromorphic woodland" respectively, and so classified as "dry evergreen formations". Here too the present author thinks a grouping among the "seasonal formations" to be more correct.

There have been widely divergent opinions as to the origin of savannas and savanna woods in a climate where one would expect to find only high forest, except perhaps in the swamps. As already explained in detail (23), these contradictory views mostly resulted from generalizations on the ground of incidental observations, whereby the divergent characters of the different savanna types were neglected. Yzerman (99), for example, in fact has in mind only one — though important — savanna type in the "dek" landscape, when he states that, as a result of intensive leaching, the savanna soils have eventually become so poor that nothing will grow on them any longer. Lanjouw (57) holds that, owing to unfavourable soil conditions, the savanna wood substitutes the high forest; the former is easily destroyed by fire, and may then change into savanna. An extreme stand is taken by Gonggryp and Burger (38), who hold the opinion that all Surinam savannas and savanna wood have arisen through man-made fires. Bakker and Lanjouw (6) attributed the existence of certain savanna types to the occurrence of ortstein pans and claypans. Bakker (4, 5) holds the presence of impermeable layers in the soil profile and the soil erosion responsible for the absence of high forest.

In the before mentioned C.B.L. publication (23) we dealt with all savanna types occurring in the various landscapes. The causes of origin of each of these types — which are of very divergent natures — were traced back. When dealing with the landscapes (chapter VII), this subject will be reverted to.

In the swamps too, the lower "life form types" may consist of either scrub or herbaceous plants. The brantimakka *(Machaerium lunatum)* scrub is a representative of the former, growing especially in brackish swamps. A herbaceous vegetation covers the expansive coastal swamps, designated as "grass" or „open" swamps. Their vegetation mainly consists of *Cyperaceae*, often 2 tot 4 m. in height. Some of these swamps are inundated with brackish or even salt water.

Chapter VII.

THE LANDSCAPES AND SOIL ASSOCIATIONS OF NORTHERN SURINAM.

Table 2 (appendix III) gives a general view of the belts, landscapes and soil associations of Northern Surinam. Of every association one or more characteristic soil series, occupying relatively large areas, have been mentioned. As was stated in chapter III C, the principal criterium in distinguishing the landscapes was their individual morphology, which results from their geological genesis and the nature of the specific rock. This relation between the landscapes and the geological construction of Northern Surinam is also shown in table 2.

The soil mapping units on the IIIrd level (landscapes) are depicted on the accompanying "Map of the Landscapes of Northern Surinam" to scale 1 : 645,000 (appendix II). The mapping units on the IInd level (soil associations) are depicted on the „Reconnaissance Soil Association Map" to scale 1 : 100,000 (appendix I).

The division into the three belts only partly corresponds to the division, formerly used, into the "coastal strip", the "savanna belt" and the "hilly interior" (8, 38, 69), which was derived from Yzerman's division into the fluvio-marine deposits, the continental alluvia and the crystalline basement (99). As follows from the outline on p. 34, our southern belt is identical to the "hilly interior". In the coastal area, however, two parts are distinguished at present. The Holocene northern part, situated directly behind the coast line, is called "young coastal plain", corresponding to our northern belt. The other part, situated farther inland, is of Pleistocene age; it is called "old coastal plain", the landscapes of which belong to our middle belt. The latter further includes the large "dek" landscape, situated even farther inland. On Yzerman's map the boundary between the fluvio-marine deposits to the north, and the continental alluvia to the south, runs right across the old coastal plain. As, however, the entire old coastal plain belongs to the middle belt (see table 2), in many places this belt reaches farther northwards than the boundary between the former "coastal strip" and "savanna belt".

The map by Eysvoogel, Van Beukering and Verhoog (31) presents a better, though most schematic, picture of the three belts. The boundary between the northern two belts is drawn farther northwards than on the map by Yzerman. Unfortunately, the term "old coastal plain" was unjustly used for the whole middle belt. The actual old coastal plain occupies only the northern part of this belt, actually one third of it; the southern part is occupied by the "dek" landscape.

Of the landscapes to be dealt with hereafter, a brief description was published before (29).

A. NORTHERN BELT.

LANDSCAPES WITH YOUNG SOILS FROM SEDIMENTARY PARENT MATERIALS.

This belt, designated as the "young coastal plain", covers that low flat part of Surinam which directly borders on the ocean, and uninterruptedly extends all along the width of the country. Its dimensions inland increase from 8 km. in the east to 50 km. in the west. To the south, however, in innumerable places, this young coastal plain penetrates deep into the adjoining middle belt, in which it forms recesses, which may be 20 km. in width; along the rivers there are still deeper narrow recesses southwards. Consequently, the dimensions inland show great local differences, through which a most capricious course of the southern boundary is formed. This is clearly depicted on the "Map of the coastal plains of Surinam" (30), published before.

In this northern belt three landscapes are distinguished; their acreages, roughly determined with the help of the aerial mosaics, are as follows:

the *river levee landscape*	c. 14,600 square km.
the *young sea clay landscape*	c. 300 square km.
the *"rits" landscape*	c. 1,300 square km.

1. THE YOUNG SEA CLAY LANDSCAPE.

This landscape, only locally interrupted by other landscapes, covers much the larger part of the young coastal plain. It has developed through the sedimentation of clay and silt on the original shallow sea-bed off the coast. Hereby, a tidal flat was formed which, in front of the growing plain, gradually shifted northwards. There is evidence (cf. 19 *)) that at first a considerable accretion of land took place, while in general the sea level remained almost the same or even rose slightly. Later on the sea level, on the whole, sank over 2 or 3 metres, to its present height. This lowering of the sea level may have caused some shrinkage of the upper clay layer of the earlier formed plain.

The whole process of sedimentation was interrupted many times by periodical abrasions, possibly mainly caused by temporarily stronger winds, whether or not combined with temporary slight rises of the sea level.

The resulting clay landscape generally lies roughly 1 to 2½ m. above the present mean sea level. In some places, however, this level has not half been reached. Especially in the before mentioned wide recesses, where the young coastal plain penetrates into the old coastal plain, but in other places as well, occur 1 to 2 m. deep depressions. These depressions, gradually cut off from the sea through the silting-up of the areas north of them, eventually became desalinized. This was followed by a process of peat formation, which has progressed in such a way that at present the surface of the peat areas is only little lower than that of the adjoining clay areas.

It was already observed by Yzerman (99) that a large part of the coast has been in a phase of abrasion of late. This abrasion takes place irregularly; it has caused the formation of small bays, separated by capes, which give the coastline a typical "scalloped" aspect (cf. 35). The strip of land directly adjoining the coastline is silted up about ½ m. higher than the adjacent clay area behind it. All along the abovementioned small bays this heightened strip of land is bordered by a steep cliff 1 to 2 m. high, which ends in a mud flat, visible when the tide is out. Inland the strip stretches from some hundreds of metres to about 5 km..

*) Brouwer (19) unjustly draws the boundary between the young coastal plain and the (higher) old coastal plain near km. 13.5 of the transect described. Actually this boundary lies near km. 10.

According to Zonneveld (101) such erosion takes place along c. 40 per cent. of the entire coastline, whereas c. 20 per cent. is more or less stable. Along c. 15 per cent. occur sand barriers or beaches, of which the formation will be dealt with in the section on the "rits" landscape (p. 51). Along c. 25 per cent., finally, a recent accretion of land is observable, resulting from growing mud flats in front of the formerly abraded cliff coast. Often this former cliff is still distinctly higher than the adjacent oldest part of the tidal flat in front; sometimes the latter is already silted up to the same level, in which case the former coast gradually merges in the tidal flat. After the vegetation, which usually grows on both the heightened strip behind the cliff and the highest silted-up mud flats, these terrains are collectively named the mangrove strip.

Within the young sea clay landscape two landscape elements are distinguished. The most important one by far consists of the vast *swamps*, occupying almost the entire landscape. The second one is the above-mentioned *mangrove strip*, for the most part only inundated during spring-tide.

The *swamps* are level terrains, the majority lying roughly on S.P. to one metre below. The internal drainage of these terrains is negligible, while the run-off is very slow. Therefore, at the end of the long dry season there is often still 5 to 20 cm. water on the surface. It may occur that the surface is not submerged, but even then the soil remains wet to close below the surface, or in any case it will be humid. In the long rainy season the water level will usually rise up tot 50 to 120 cm.; however, in formed river-beds partly silted up, as well as in other depressions, the water may be 2 metres deep or more. The peat swamps are on the whole deeper than the clay swamps. Exceptionally deep is the "swaying swamp" north of Moengo Tapoe, described by Lindeman (59); at the end of the dry season the water was still several metres deep. This swamp, however, occurs as an almost entirely enclosed enclave in the old coastal plain, owing to which fact its water table was about 2 m. higher than that of the swamp situated more to the north. In places were this "swaying swamp" had a depth of more than 1 m., a layer of peat was found, floating on the surface. Whether similar swamps exist in the other parts of Surinam is not known so far.

The larger part of the swamps is inundated with fresh water. Near the coast, however, rather large swamp areas are exposed to the influence of brackish or even salt water. The water of most of these swamps contains less than 10 g. Cl per litre. Locally it may be, at least in the dry season, "polyhalinous" (10—17 g. Cl/1) or even "hyperhalinous" (> 17 g. Cl/1) through the evaporation of the seawater entered at high tide (cf. 59) The percentage of salt strongly declines in the rainy season. All figures published by Lindeman (59) refer to the percentage of salt at the end of the short or long dry season.

The vegetation of the different swamp areas varies widely. Especially in the northern part of the vast swamp region occur extensive *herbaceous swamps*. Their vegetation principally consists of grasses and *Cyperaceae*. They are often characterized by one or a few predominant species, like the *Cyperus giganteus, C. articulatus, Typha angustifolia, Leersia hexandra, Eleocharis intersticta, E. mutata* and others. Some of these swamp types were dealt with in detail by Lindeman (59). In these herbaceous swamps scattered spots of scrub are found, for example consisting of brantimakka *(Machaerium lunatum)*, groves of maurisi palms *(Mauritia flexuosa)* and smaller or larger complexes of swamp wood. The latter may consist of koffiemama *(Erythrina glauca)*, or of bébé *(Pterocarpus officinalis)*, mirahoedoe *(Triplaris surinamensis)* and panta *(Tabebuia spp.)*. Close to the sea, directly adjoining the mangrove strip, occur swamp areas with no vegetation at all, the so-called "pans". These shallow open pools are sometimes several kilometres in length and width. According to Lindeman the original herbaceous vegetation disappeared after creeks had developed, through which sea water could penetrate into these swamps.

High *swamp forest* especially occurs in the swamps situated more to the south. The most wide-spread type of swamp forest consists of the tree species: matakki *(Symphonia globulifera)*, baboen *(Virola surinamensis)*, mirahoedoe and bébé, with a lower story of a great many pina palms *(Euterpe oleracea)*. In another forest type the matakki is mainly mixed with bébé and panta, with as palm species the maurisi. This forest type is especially found in real peat-swamps, where, however, transitions to the firstly mentioned type occur as well.

For mapping, all soils of the swamps were taken together in the following, great association:

Ys. Swamp soils.

Because these soils are submerged all the year round, or at least the greater part of it, an accumulation of organic matter has taken place owing to the slow mineralization of plant remnants. Consequently, in most places an A0-horizon developed above the mineral soil, which horizon consists of peat or muck, in Surinam known under the name of "pegasse".

In much the largest part of the swamp areas the pegasse layer is not more than 25 cm. thick. Here the soils are called swamp clay soils. It was stated before that a thicker layer of peat has developed locally; where the thickness of this layer is more than 50 cm., the soils are referred to as swamp peat soils.

On the surface of the *swamp clay soils* occurring in normal herbaceous swamps, a distinct layer of pegasse is as a rule to be found; its thickness mostly ranges from 5 to 20 cm.. It consists of dark reddish brown, matted fibrous peat, in which many coarse root remains are recognizable. This layer abruptly merges in a dark grey to black A1-horizon, which is rich in organic matter, and, as a rule, not thicker than 5 tot 15 cm..

The clay swamps with the matakki forest, in which the pina palm abounds, vary somewhat in depth. In the shallowest, which are not submerged for several months of the year, the A0-horizon is almost altogether lacking. The surface soil mostly consists of a 10 to 25 cm. thick layer of clay, dark brown to black coloured, and rich in organic matter. In the deeper swamps with a vegetation of the same forest type, a pegasse layer does indeed occur above this A1-horizon. The pegasse layer here consists of dark to very dark brown, fine organic muck, and its thickness usually ranges from 5 to 20 cm..

In some places in these deeper swamps, underneath the A0-horizon the A1-horizon is whether altogether absent, or only a few centimetres thick, and so hardly perceptible. Elsewhere, however, both the pegasse layer and the A1-horizon have considerably better developed than what above was stated as normal. The total thickness of these layers may then be 50 to 70 cm.. These cases, in fact, already indicate transitions to the swamp peat soils.

In most swamps the A-horizons show an abrupt, or at least distinct transition to the underlying reduced horizons. These horizons consist of clay, mostly varying in colour from bluish grey to greyish blue or even very light blue, and, especially between 20 and 60 cm. below the soil surface, they are sometimes slightly, but mostly moderately to highly mottled with yellow to yellowish brown or yellowish red. At a certain depth (sometimes already from 50 cm., but usually only from 100 to 150 cm. downwards) this clay gradually merges in a more grey clay, while the mottling decreases, the colour of the mottles becoming more brown to light olive brown. Eventually, at a great depth (150 to 200 cm.) grey, very soft clay is usually found, whether or not slightly mottled with brown to olive.

In other places, however, occurs a layer of very soft clay, even grey in colour, between the dark surface soil and the greyish blue, mottled clay. Elsewhere the colour of the entire profile is more grey or light grey than greyish blue; the colour of the mottles is then usually brown instead of yellow, although in highly mottled profiles yellow mottling also arises.

Locally greyish blue clay soils are found, which, apart from being mottled with yellow and/or brown, are sometimes mottled with red, especially in the layer at a depth of 30 to 80 cm.. The layers above and underneath, then only show the yellow and brown mottles. Usually this red mottling appeared to arise in the shallowest swamps, which form the transition to the marshland. A pegasse layer is lacking here, but there is a dark A1-horizon. However, even in deeper swamps with a pegasse layer, red mottling may arise.

As already observed by Eysvoogel c.s. (31) in the Nickerie district, the swamp clay soils are very homogeneous as regards their texture. This applies to the diverse horizons of one profile as well as to the profiles of the various swamp areas. All swamp clay soils are characterized by a very high percentage of fine particles. From the results of 200 grain size analyses *) it appeared that the percentage of the fraction $< 2\,\mu$ as a rule amounts to 50 tot 75 % (with two thirds of the samples 60 tot 70 %). The fraction $< 16\,\mu$ usually amounts to more than 85 % (with three fourths of the samples more than 90 %), while the proportion of these fractions usually ranges from 0.6 to 0.8 (with two thirds of the samples from 0.7 to 0.8). The percentage of sand ($> 53\,\mu$) usually does not exceed 2 % and is rarely more than 3 %. **(see fig. 3, p. 52).**

*) Besides the analyses of samples taken by the author himself, a number of analyses, put to his disposal by the "Foundation Mechanical Agriculture", was used, as well as a part of the analyses published by Müller (66) and Eysvoogel, Van Beukering and Verhoog (31).

The following profile descriptions are given of characteristic soil series:

DJAKI SERIES:

Land conditions: moderately deep swamp; drainage very poor (class 0).
Vegetation: swamp forest with much matakki; further baboen, bébé and mirahoedoe; lower story of pina palms.
Profile:

A0	10 cm,.	dark brown, fine organic muck with remnants of leaves and twigs.
A1	0—20 cm.,	very dark brown, sticky, plastic (when dry: hard) clay, rich in organic matter.
C1gg	20—130 cm.,	bluish grey, sticky, plastic (when dry: very hard) clay; with many distinct yellowish red mottles.
C2gg	130—165 cm.,	grey, soft, very sticky, slightly plastic (when dry: very hard) clay; with few distinct, light olive brown mottles.
C3gg	165 m. +,	grey, very soft, very sticky, non-plastic (when dry: very hard) clay.

NICKERIE SERIES:

Land conditions: moderately deep swamp; drainage very poor (class 0).
Vegetation: grasses and *Cyperaceae: Leersia hexandra, Cyperus articulatus.* Locally *Typha angustifolia.*
Profile:

A0	10 cm.,	dark reddish brown "pegasse", in which many coarse root remnants are recognizable.
A1	0—5 cm.,	black, sticky, plastic clay; rich in organic matter.
C1gg	5—35 cm.,	grey, soft, very sticky, slightly plastic clay.
C2gg	35—60 cm.,	greyish blue, sticky, plastic clay; with many distinct, yellow and yellowish red mottles.
C3gg	60—110 cm.,	greyish blue, sticky, plastic clay, with few distinct, yellowish brown mottles.
C4gg	110 cm. +,	bluish grey, soft, very sticky, slightly plastic clay, with few faint, brown mottles.

The above descriptions refer to the profiles of swamp soils in their natural, so wet, position. Further details about these soils, especially as regards their chemical properties and their significance to agriculture, are to be found in (31).

It was especially the clay swamps, where in former ages the large plantations were established. The reclamations of both "grass" and forest swamps go as far back as 1680. The greatest prosperity was reached roundabout 1800, when approximately 500 plantations with an aggregate area of roughly 150,000 hectares, were in full operation for the cultivation of sugar, cacao, cotton, indigo and coffee. It stands to reason that for bringing these swamps into cultivation they had to be drained. In every plantation this was effected by means of dams, drainage trenches and a lock. Each plantation thus formed an individual polder, draining to the river at low tide.

However, most of these plantations were already abandoned in the course of the 19th century; most of them have turned swamps again. A minor part was subsequently parcelled out for small farming, and adapted for rice growing. In 1950 only some ten plantations were under cultivation for coffee, sugar, cacao and citrus.

In the soils of these old plantations, which during the last 2 to 2½ centuries have been deeply drained, the consequent results are sometimes clearly perceptible. It was, for instance, frequently ascertained that the colours of these soils had changed. Moderately well drained soils to a depth of 50 to 60 cm. may be light brownish grey or even greyish brown, mottled with yellowish brown. The underlying clay is then again bluish grey or grey. Well drained soils may be brown to a depth of 40 to 50 cm., while the clay underneath, to a depth of 80 to 100 cm., is light brownish grey with yellow and/or yellowish brown mottles. Further downwards again the bluish grey or grey clay is found. A great many analyses of plantation soils was published by Müller (66) One of the conclusions drawn from them is that for the greater part of these soils, the percentage of the fraction $< 2 \mu$ of the surface soil is somewhat lower than that of the deeper layers, so that the beginning of a textural differentiation into A- and B-horizons is observable.

Especially in the western part of the swamp region (the Nickerie district), but also near Coronie and Paramaribo, polders of a larger acreage have been laid out since roundabout 1900, principally for the cultivation of rice. In the youngest of these polders the drainage takes place by means of a pumping-engine; the older polders drain during low tide without the help of a pumping-engine.

The *swamp peat soils* are characterized by a pegasse layer more than 50 cm. thick. In the central parts of the peat areas, the peat often reaches a thickness ranging from 125 to 250 cm.. Here the vegetation usually consists of matakki swamp forest, in which baboen is rare, but panta frequent. The lower story of pina palms is often absent; the typical palm species is the maurisi. The peat consists of the more or less decomposed litter (including trunks) of this forest; so it is typical forest peat.

Its upper layer, usually 30 to 70 cm. thick, consists of dark to very dark brown, soft, fine muck. Underneath often follows a black layer, mostly 20 to 30 cm. thick; this layer too consists of soft, very fine muck. In some places, however, this horizon is absent, or if present, it has only indistinctly developed. Underneath the black layer follows the third organic horizon, which is the thickest of all; mostly 70 to 160 cm.. It consists of dark greyish brown to dark brown, brittle, coarse peat; the greater part of it is made up of recognizable wood remnants.

The entire layer of peat eventually lies on grey to bluish grey, very soft clay, which is often rich in fine organic fibres.

Lindeman (59) mentions the occurrence of peat swamps with a predominantly herbaceous vegetation. However, our investigations did not include such swamps.

A typical soil series is the earlier (30) described:

KALEBASKREEK SERIES:

Land conditions: deep swamp; drainage very poor (class 0).
Vegetation: swamp forest, mainly consisting of matakki, panta and bébé. Scattered maurisi palms.
Profile

1	0—50 cm.,	dark brown, soft, fine muck.
2	50—70 cm.,	black, soft, very fine muck.
3	70—200 cm.,	dark brown, brittle, coarse peat; for the greater part consisting of wood remnants.
Dgg	200 cm. +,	greyish blue, very soft, very sticky, non-plastic (when dry: very hard) clay; with many fine organic fibres.

Along the borders of the peat swamps, in the transitional zone to the clay areas, often occur profiles consisting of alternate layers of peat and clay, the latter even grey, soft, slightly plastic and very sticky. These layers of clay often contain pieces of peat or a lot of fine organic fibres; sometimes they are not grey but dark brown owing to the presence of organic matter. In other cases the whole profile is built up of mixtures of peat and clay, varying between clayish peat and peaty clay.

The second element of the young sea clay landscape is the m a n g r o v e b e l t, mentioned before. It stretches along c. 85 % of the entire Surinam coast, but as compared with the swamps, the area it covers is only very small. Because of the fact that in the young coastal plain the fall in the large rivers is only slight, the influences of the tides are noticeable far inland. Consequently, in the dry season, when the tide is in, the river water may be brackish at a distance of about 50 km. from the river mouths; the tidal movements themselves are noticeable even much farther up the rivers. The mangrove strip, bending landwards along the estuaries, indeed continues, gradually narrowing, to a considerable distance upstream.

In those places, where along the lower courses of the rivers old plantations or younger reclamations are situated, the mangrove strip is but very narrow, and landwards it is bordered by the front dikes of these polders. This strip of land is designated as "foreland".

The soils of the mangrove strip and the foreland are taken together in the soil association:

Ym. M a n g r o v e a n d f o r e l a n d s o i l s.

Along the coast as well as along the lower courses of the rivers, in fact, two zones, the one behind the other, can be distinguished in the mangrove strip:

a.) *The zone behind the present or formerly abraded coastline,* continuing along the lower courses of the rivers. This zone is silted up to a somewhat higher level than the swamps situated farther inland. It lies above the normal flood level and only at spring-tide is it inundated with salt or brackish water. Its soil consists of firm clay, from grey to brown in colour, in which sometimes yellowish brown to light olive brown mottles and concretions occur. Its vegetation consists of full-grown parwa *(Avicennia nitida)* forest. In many places, however, the landward boundary of this forest was driven back northwards by fires, started in the adjacent "grass" swamps.

b.) *The mud flats in front of the formerly abraded coast,* where now an accretion of land is taking place; they too continue along the estuaries and the lower courses of the rivers as a narrow, sloping, muddy bank on the water-side of the higher parwa-zone, mentioned under a.) The oldest, landward parts of the mud flats are silted up to above the normal flood-level. Seawards their level gradually decreases; the lowest parts, intersected by innumerable winding tidal gullies, are only visible when the tide is out. Correspondingly, the soil varies between a rather firm, greyish brown clay and a very soft, grey mud. The vegetation of those areas lying above the normal flood-level, is young parwa forest, which extends seawards according as the silting-up continues. The sloping muddy bank along the lower courses of the rivers lies in the tidal zone; the vegetation of this soft, grey mud consists of mangro *(Rhizophora mangle)* forest, locally interrupted by patches of brantimakka *(Machaerium lunatum)* scrub.

The foreland of some plantations appeared to be silted up from ½ to 1 m. above the land inside the dikes; it is, however, possible that shrinkage of the endiked land also plays a part in it. This foreland too is only inundated at spring-tide; its soil consists of grey to greyish brown, firm clay, with brown mottles. The plantations being abandoned, the parwa forest could recover on the foreland; in many places it is full-grown again.

An example of this soil association is the

KATKREEK SERIES:

Land conditions: mangrove strip behind the formerly abraded coast; position above the normal flood-level; drainage very poor to poor (classes 0—1).
Vegetation: full-grown parwa *(Avicennia nitida)* forest.
Profile:

1	0—40 cm., brown, sligtly sticky, very plastic clay.
2	40—90 cm., light brownish grey, slightly sticky, very plastic clay.
3	90 cm.+, grey, slightly sticky, very plastic clay.

2. THE RIVER LEVEE LANDSCAPE.

This landscape occupies but a minor place in the young coastal plain. It consists of only one landscape element, the natural river levees. They form the level, definitely marshland terrains along the lower and middle courses of the large rivers and their tributaries. The levees along the lower courses of the rivers are by no means continuous; there are several parts of the rivers, differing in length, where the levees are lacking, so that the swamps on one or both sides reach as far as the river. The levees vary widely in width; this often ranges from some hundreds of metres to approximately 1 km., and rarely exceeds 3 km..

During the rainy season the swamps along the rivers are filled with rain water. When the river level is high, however, the flood water flows across the terrains along the inner bends of the meanders, thus driving the swamp water away and building up the levees with the material it carries in suspension. Accordingly, the levees are widest along these inner bends; along the outer bends they are whether narrow or altogether absent. Along the small branch creeks of the large rivers the levees penetrate farther into the swamp, so that here they will be wider than elsewhere. Not only do they occur along the present courses of the rivers, but also along former river-beds, which are partly silted up again. Especially along the inner bends of the meanders the levees often do not border directly on the river, but lie at some distance from it, owing to the fact that the course of the river has meanwhile shifted outwards.

The level of the levees along the lower courses of the rivers is estimated to be about ½ to 1 m. higher than that of the adjacent swamps. Since even in the rainy season, at high water, the flow of the rivers is too slow to carry sand outside their beds, the levees are almost exclusively built up of clay and silt and contain hardly any sand.

Up-stream the levees continue along the sharply meandering middle courses, thus forming the narrow recesses with which the young coastal plain penetrates not only into the middle belt, but also deep into the hilly country of the southern belt. Here these flat marshland flood plains are bordered on either side by an older, higher terrace or by hills. Eventually they gradually pass into the creek valleys, through which the upper feeders of the rivers flow, to be dealt with afterwards (p. 93). The levees in these areas too, mainly consist of clay and silt, but farther up the rivers they contain some sand as well.

The levees have a very characteristic vegetation, namely a type of marsh forest very rich in lianes, for which reason it is known as "tété boesi" (= rope forest). This forest is characterized by the great irregularity in its canopy. Frequent tree species are krappa *(Carapa procera)* and oemabarklak *(Eschweilera corrugata);* viewed from the river the large umbrellas of the kankantrie *(Ceiba pentandra)* crowns are conspicuous. Frequent palm species are maripa *(Maximiliana maripa)* and in the wetter places kiskismakka *(Bactris spp.)*. On the levees in the western part of the country the pure mora *(Mora excelsa)* forest occurs locally.

The soils of the levees are taken together in the soil association:

Ll. River levee soils.

These soils to a high degree present the strong changes in the moisture conditions, so characteristic of marshland soils. Throughout the rainy season they are waterlogged, and for one or more periods, ranging from some days to several weeks, but altogether not longer than 1 to 2 months, they are inundated. The depth of the water then varies between some decimetres and over one metre. On the other hand, by the end of the dry season the levee soils are entirely dried up down to a considerable depth. In many places the micro-aspect with "kawfoetoes" (hummocky surface, see p. 20), another characteristic of marshland, is found. The run-off of the levee soils is slow; their internal drainage slow to very slow.

The profiles show an A1-horizon, which, through the presence of organic matter, is darker in colour than the layers deeper down. This colour may vary between grey and greyish brown or brown, and is sometimes even dark grey or dark brown. In certain cases this layer is slightly to moderately mottled with brown to yellowish red. Its texture is clay or silty clay.

Underneath the profiles consist of very firm, compact clay or silty clay, coloured grey to bluish grey or greyish blue. According to the mottling, several horizons can be distinguished here. Especially the second one of these horizons is most characteristic of the levee soils; it is highly mottled with red and often with brown or yellowish red at the same time, whether or not accompanied by red or brown concretions. Both the depth and the thickness of this horizon vary; its upper boundary usually lies at a depth of 30 to 70 cm., its lower boundary at 60 to 130 cm.. The horizons above it and underneath are slightly to highly mottled with brown and/or yellowish red; the mottles of the lower one are sometimes light olive brown to olive. It may happen that the red mottled horizon directly underlies the A1-horizon. At a varying depth the profile eventually gradually merges in grey clay or silty clay, slightly mottled with brown to olive. In a few cases a number of extremely thin layers of silt were perceived in this subsoil. Elsewhere, underlying the profiles is grey loamy very fine sand, mottled with yellow and brown.

A profile description is given of the

SARAMACCA SERIES:

Land conditions: marshland along inner bend of meander; drainage poor (class 1).
Vegetation: river levee forest.
Profile:

A1	0—15 cm.,	greyish brown, friable, silty clay.
C1g	15—40 cm.,	bluish grey, very firm clay, with few distinct, yellowish red mottles.
C2g	40—110 cm.,	greyish blue, very firm clay, with many distinct, red and yellowish red mottles.
C3g	110—140 cm.,	grey, very firm clay, slightly mottled with brown and olive-brown; mottling diminishing downwards.
C4g	140 cm. +,	grey, very firm clay, with few faint, olive brown mottles.

The above-mentioned description principally involves the levee soils along the lower courses of the rivers. Farther up-stream the colours of the profiles often have pale yellow, yellow or yellowish brown colours, while often a yellowish red, instead of a red, mottling arises. These soils have a higher content of silt, while sometimes they also contain some sand.

3. THE "RITS" LANDSCAPE.

The most important element of this landscape is constituted by the "ritsen". They are the longdrawn ridges mainly built up of sand, which lie more or less parallel to the coast and may rise a few decimetres to some metres (up to a maximum of c. 4 m.) above the surrounding (clay) swamps. These ridges may vary in length from some hundreds of metres to many kilometres, in width from some tens to some hundreds of metres. The transverse section published by Geyskes (36) reveals that the ridges are isolated bodies of sand, lying on a continuous deposit of clay. The cross-section of many a ridge is asymmetric, because of the fact that their summits are not in the middle, but on the seaside. From the summits the landward slopes are gentler than the ones on the seaside. The body of sand, on its landside as well as on its seaside, lies wedge-shaped on the older clay underneath the "rits"; its foot on the seaside is covered by younger clay. The maximum thickness of the sand-body ranges from c. 1 to c. 7 metres; its base is often twice as wide as that part of the body which rises above the clay.

The majority of the ridges are not scattered individually, but they occur in bundles, composed of many individual ridges, the one close to the other. This is distinctly shown on the aerial photographs, elucidated by Simons (82). The component ridges of one bundle are separated from each other by narrow parallel swamps, which as a rule have a bottom of clay. In order to distinguish these narrow swamps from the vast swamps outside the "rits"-bundles, the former are referred to as inter-"rits" swamps; they constitute the second element of the "rits" landscape. Some bundles are almost straight. Many, however, bend landwards, whereby the individual ridges and/or inter-"rits" swamps become increasingly wider, which gives these bundles a fan-shaped aspect. During later transgressions a number of ridge-bundles were cut off slantwise, whereby against the cut-off bundle a new ridge was formed at an angle to the original bundle (see for example 19 fig. 6).

Most ridges are mainly built up of fine or very fine sand. Within the ridge-bodies, however, layers of clay may occur, indicating interruptions in the process of sedimentation of the ridge concerned. Moreover, in some ridges occur layers consisting of shell grit, in widely varying percentages mixed with sand. According to Van der Voorde (94) this is the case with the very long-drawn ridges, which cut off older bundles; they are called shell-sand ridges. Some narrow ridges or parts of them are almost exclusively built up of coarse and fine shell grit; they are refferred to as shell ridges. Another group is formed by those ridges which almost entirely consist of coarse sand. Real bundles belonging to this type only occur in the eastern part of the young coastal plain; elsewhere only the youngest, as a rule very narrow ridges, occurring individually, belong to the coarse-sandy type.

All large ridge-bundles are situated west of the present or former river mouths. From this it may be inferred that the sand of the ridges has been brought down by the rivers concerned. The large rivers Coppename, Saramacca, Suriname and Marowyne have played the leading part in this sand supply. West of each of these rivers lie three to four more or less distinct bundles, roughly north of each other. In general, in the terrains between these bundles, as well as seaward from the most northern bundle, occur only small ridges, or none at all. Perhaps these bundles correspond to an equal number of climatological periods, characterized by a most abundant rainfall. Through the strong erosion and the great transporting capacity of the rivers much sand might then have been brought down; in the intervening periods, as well as in the youngest era, the sand supply has been poor. The smaller rivers too, like the Nickerie, the Coesewyne, the Commewyne and the Cottica, acted as sand suppliers in the past. The distribution of the ridge bundles, which in the central and eastern parts of the young coastal plain occur in so much greater numbers than in the west, is a result of the arrangement of the more and less important rivers.

Leaving the river mouths, the sand was deposited on the mud banks off the (increasing) coast. Consequently, the banks near the estuaries, though still mainly consisting of clay, were richer in sand than those elsewhere. Probably the banks northwest of the estuaries received most of the sand under the influence of the Equatorial Current, directing the outflow of the rivers westwards. The silting-up process, however, was interrupted by short periods of abrasion, perhaps mainly caused by a temporarily stronger dash of the waves (cf. 93). During these abrasions the mud banks were again cleared away, whether entirely or for the greater part of them, whereby the sand was washed out. By the surf, running onto the coast obliquely from the north-east, due to the trade wind, the sand was thrown on shore west of the estuaries, thus building up a ridge there. Afterwards, on the seaside of the ridge, silting-up took place again; the younger clay, deposited here, also covered the foot of the ridge. The repetition of the above process during the periods of ample sand supplies, led to the development of the ridge-bundles, whereby the frequence and duration of the periodical abrasions affected the widths of both the ridges and the inter-ridge swamps.

During the abrasions part of the sand was shifted westwards, and spread over the coast by the oblique surf from the NE. (cf. 101). Hereby, the ridges developed in an E-W direction, or, if the sand was eventually deposited along a bay or estuary farther westwards, in a NE-SW direction. Thus the respective long-drawn, rather straight bundles and the bundles fanning out to the SW were formed. In both cases the sand originated from a river farther eastwards.

Another part of the sand, however, was shifted upstream along the left banks of the very estuaries from which it originated, whereby the tidal stream and the oblique dash of the waves co-operated. Thus the ridges developed in a NW-SE direction, which resulted in the formation of bundles fanning out to the SE. Of the 18 large ridge-bundles 11 preponderantly belong to the former type and the other 7 preponderantly to the latter. Consequently the picture of "progressive east-west development", outlined by Brouwer (19), is by no means in accordance with the real proportions.

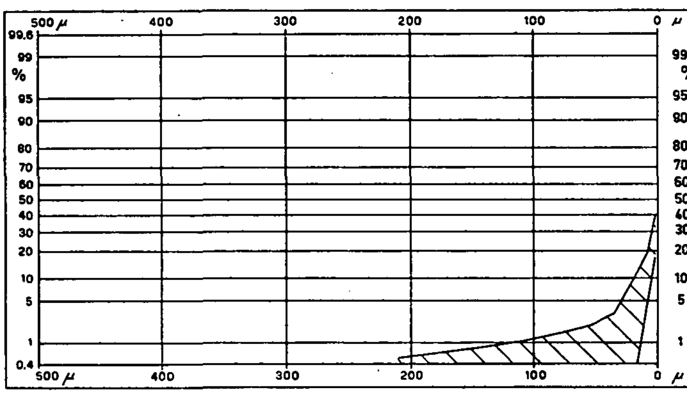

Fig. 3. Bundle of 40 grain-size summation-curves of swamp clay soils (A- and C-horizons).

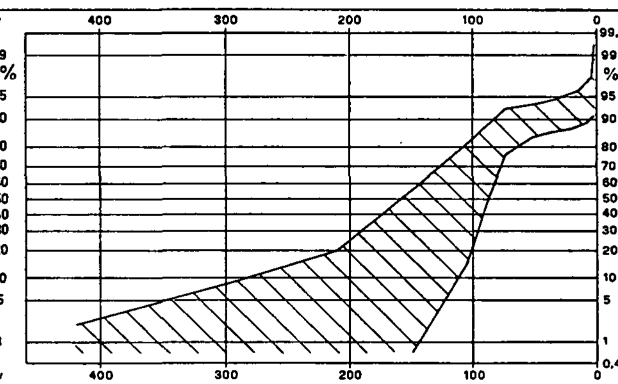

Fig. 4. Bundle of 27 grain-size summation-curves of fine sandy "rits" soils (A-, B- and C-horizons).

As was mentioned before, along c. 15 % of the Surinam coast (mainly W of the Marowyne estuary), small ridges and beaches border the ocean. According to the above, this implies that this part of the coast is not, as Zonneveld (101) supposes, in a stage of accretion, but either stable or receding. Only along a stable or receding coast can the westward movement of the sand, as described above, take place. As soon as growing mud flats develop in front of the coastal ridges, the sand is blockaded.

From the fact that, in general, the ridges in the southern part of the young coastal plain reach greater heights above the present mean sea-level than those in the northern part, Brouwer (19) concludes that the sea-level has sunk. This lowering, however, is not as much as Brouwer suggests (see note, p. 41), Roughly speaking, the oldest ridges maximally rise to 2 or 3 metres above S.P.; the youngest ones at most reach S.P.. Actually, at first the sea-level seems to have been rising slightly, while only later on it sank over 2 or 3 metres.

The granular analysis (fig. 4 and 5) reveal that the material of which the ridges are built up is a mixed sediment. With the normal fine sandy ridges it consists of a component of sand (with a median of 90 to 170 μ) and a silt + clay component, the latter usually totalling 5 to 15 % of the sediment. The median of the sand component of the coarse sandy ridges often ranges from 270 to 420 μ. The summation curves of both groups belong to a type of which Doeglas (24) states: "principally tidal flat sands". Only the most coarse ridge sands (median 600—700 μ) show summation curves which approximate the type among which Doeglas arranges the "beach sands" (cf. 100).

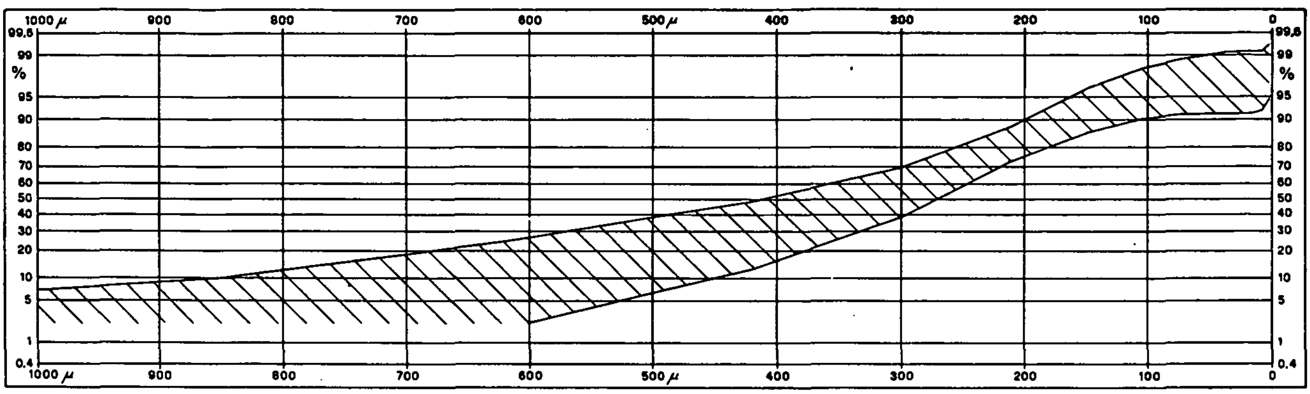

Fig. 5. Bundle of 6 grain-size summation-curves of coarse sandy "rits" soils (A- and B horizons).

As was also observed by Van der Voorde (94), later erosions and transgressions have affected the image of the "rits" landscape. The transgressions caused the before-mentioned oblique cutting-off of the ridge-bundles (see p. 51). Elsewhere bursts through the ridges took place; on either side of such a breach the body of sand is bent landwards; the gully itself is filled with clay (94 fig. 2). During the transgressions clay was again deposited in the inter-ridge swamps. Owing to erosion of the adjacent ridges, and especially to the bursts through the latter during the transgressions, some sand was washed into the inter-ridge swamps as well. Accordingly, in many places the new clay, deposited in these swamps, was mixed with varying amounts of sand.

Of the two landscape elements the ridges in general are dry terrains. Low ridges and the lower parts of higher ridges, however, may be more or less marshy. On the ground of the great differences in texture the soils were grouped in two soil associations, viz. the *fine sandy* and the *coarse sandy "rits" soils.* The inter-ridge swamps are submerged for a great part of the year. They are situated about on a level with, or slightly higher than, the large swamps outside the ridge- bundles, in which they gradually merge without any distinct boundary. Their soils are taken together in the association *inter-"rits" swamp soils.*

Rrf. Fine sandy "rits" soils.

The run-off of these soils ranges from very slow to medium; the internal drainage from slow to medium. They form a clear *hydrosequence* (see p. 17), whereby as to the soil formation, considerable differences present themselves between the well drained soils (drainage class 4) and the imperfectly drained soils (class 2). The former occur in the higher parts of the ridges. In shallow depressions, however, imperfectly drained soils also occur on top of the ridges, as well as in the flat central part of very wide ridges. In the latter case the soils on the edge of such flat tops again are well drained. In this connection Van der Voorde (94) points to the fact that therefore especially the relative altitude is important. Soils situated absolutely high but relatively low, bear a great resemblance to the also absolutely low situated soils of the flanks.

With the imperfectly drained soils, iron compounds have been leached out from the upper horizons, to which process the occurrence of a bleached layer in the profiles is to be attributed. The organic matter has coloured the surface soil greyish brown to dark greyish brown; the colour of the underlying horizon may range from white to grey or light brownish grey. At a depth usually ranging from 30 to 70 cm. this subsurface horizon mostly rather abruptly merges in a B-horizon, predominantly brown to yellowish red or reddish yellow in colour. Immediately underneath the bleached layer, the illuviation of organic matter is often perceptible. Eventually the solum merges in the pale yellow to light yellowish brown, hardly altered parent material. So in these cases it is predominantly podzolization that has taken place. With the well drained soils, podzolization is less marked, or does not arise at all. Here, underneath the brown surface soil, a horizon greyish brown in colour may sometimes occur, but the subsurface and subsoil horizons are mostly coloured (light)yellowish brown, yellowish red or reddish yellow. With the best drained soils the upper horizons present (dark) reddish brown to (dark) red colours, resulting from the relative enrichment of ferri oxides. In these cases the solum usually very gradually merges in the very pale brown to (reddish) yellow substratum. At great depths, where the substratum permanently lies below the ground water level, the colour fades into bluish grey or bluish green in most of the profiles.

The majority of the profiles of the central parts of the ridges have a homogeneous texture of fine or very fine sand. However, as a result of interruptions in the sedimentary process, layers of a heavier texture occur locally, which varies between sandy loam and clay. In between the grains of quartz often occur fine mica plates in conspicuous quantities; they are predominantly colourless in the solum, and black at a greater depth. The lower substratum shows a distinct, fine stratification; many of these thin layers are very rich in dark minerals ("powder"-sand) or in shells or shell-grit. The imperfectly drained soils in the flanks of the ridges often present alternate layers of sand and clay in the subsoil. In the lower parts of the flanks as a rule occurs a strip with a surface soil consisting of sandy loam or even sandy clay loam. Van der Voorde (94) already pointed out that owing to the asymmetrical cross-profile of the ridges the catena of the "rits" soils has mostly better developed on the southern flank than on the steeper northern flank.

Almost everywhere the natural vegetation of the fine-sandy ridges consists of evergreen seasonal forest. Frequent are the tree species foengoe *(Parinari campestris)*, oemabarklak *(Eschweilera corrugata)*, hoepelolie (*Copaifera guianensis)*, krappa *(Carapa* *procera)* and swietie boontje *(Inga spp.)*. In marshy places the big kankantries *(Ceiba pentandra)* are sometimes conspicuous. As regards the palm species, the maripa *(Maximiliana maripa)* occurs frequently and the koemboe *(Oenocarpus)* to a less extent; in marshy places, along with the maripa the pina *(Euterpe oleracea)* is frequent. On some ridge-bundles occur large or small complexes of possentrie *(Hura crepitans)* locally. They constitute an imposing forest, which, however, also (and sometimes even exclusively) extends into the swamp, closely along the ridges. On the ridges krappa abounds in the lower story of the possentrie forest.

Eventually, to illustrate both a poorly and a well drained fine sandy "rits" soil, the descriptions of two soil series are given below. Van der Voorde (94) earlier delivered a description of the *Vredenburg series;* presumably the drainage of the *Perica series* is still somewhat better than that of the *Saron series,* described by him.

VREDENBURG SERIES:

Land conditions: flat top of wide "rits"; rather marshy; drainage somewhat poor (class 2).
Vegetation: "rits" forest, in which, however, pina palms are frequent.
Profile:

A11	0—8 cm.,	dark greyish brown, very friable, very fine sand.
A12	8—15 cm.,	light brownish grey, loose, very fine sand, slightly mottled with brown.
A2	15—50 cm.,	light grey, loose, very fine sand, slightly mottled with brown.
B21	50—80 cm.,	brown, loose, very fine sand; slightly mottled with grey.
B22	80—100 cm.,	strong brown, loose, very fine sand; moderately mottled with yellowish red.
B3	100—140 cm.	brownish yellow, loose, very fine sand; slightly mottled with grey and red.
C	140 cm. +,	pale yellow, loose, very fine sand.

PERICA SERIES:

Land conditions: top of narrow "rits"; dry land; drainage good (class 4).
Vegetation: "rits" forest.
Profile:

A1	0—30 cm.,	dark reddish brown, loose, fine sand.
B1	30—75 cm.,	dark red, loose, fine sand.
B2	75—140 cm.,	yellowish red, loose, fine sand.
B3	140—180 cm.,	reddish yellow, loose, fine sand; moderately mottled with red; with fine mica plates.
C	180 cm. +,	reddish yellow, loose, fine sand; slightly mottled with red and grey; with fine mica plates.

For mapping, both the shell-sand soils and the shell soils were included in the association fine sandy "rits" soils. The former occur in the shell-sand ridges, in those places where the layer, rich in shell-grit, lies on the surface; the latter are found in the real shell ridges (see p. 51).

The shell-sand soils as well as the shell soils present a dark brown to black surface soil, which is rich in organic matter. This surface soil, especially with the shell soils, often reaches as far down as 50 to 80 cm.. Underneath follows a horizon, which, with the shell-sand soils, consists of alternate, very thin layers of shell-grit and fine sand. Owing to the fact that in this horizon lime has dissolved and recrystallized, sometimes a hard breccia may have arisen. The subsoil may consist whether of sand rich in shell-grit, or of alternate layers of clay and shell-sand. With the real shell soils, pale yellow to pale brown coloured, loose shell-grit, varying in coarseness, is found under the dark surface soil.

Rrc. Coarse sandy "rits" soils.

Owing to the fact that the moderately coarse to coarse sand allows of rapid percolation, the higher parts of the ridges are well drained (class 4). Many narrow ridges as well as the marginal strips of the wide ridges, however, are situated but little higher than the surrounding swamp, while here the body of sand above the impermeable substratum of clay is often comparatively thin. These soils are imperfectly to moderately well drained (classes 2 and 3).

The impression is that most of the coarse sandy "rits" soils are podzolized to a more or less extent. Through the occurrence of organic matter the profiles are often brown to dark brown in colour down to a considerable depth (e.g. 40 to 100 cm.); the quartz-grains themselves are white in this layer. The horizons underneath are sometimes white or pale yellow, but they may also be greyish brown or (light) yellowish brown. Frequently, at some depth a yellowish red to dark red coloured horizon was struck upon, into which iron had been illuviated. With many of the low ridges it appeared that the base of the body of sand was formed by a layer very rich in shells or shell-grit, under which the continuous substratum of clay lies.

The natural vegetation of these ridges is a rather poor type of the evergreen seasonal forest. The tree species abounding in this forest are foengoe *(Parinari campestris)*, mappa *(Couma guianensis)* and pakoeli *(Rheedia benthamiana)*. Here too the maripa *(Maximiliana maripa)* is the most frequent palm species.

As an example a description is given of the

WELTEVREDEN SERIES:

Land conditions: top of rather narrow "rits"; dry land; drainage moderately good (class 3).
Vegetation: peanut cultivation.
Profile:

A1	0—50 cm.,	brown, loose, moderately coarse sand (white quartz grains).
A2	50—85 cm.,	greyish brown, loose, moderately coarse sand.
Bir	85—105 cm.,	dark red, through a high content of iron slightly friable, moderately coarse sand.
Cu	105—125 cm.,	pale yellow, loose, moderately coarse sand, rich in coarse shell-grit.
D	125 cm. +,	bluish grey, sticky, plastic clay.

Ri. Inter-"rits" swamp soils.

The internal drainage of these soils is negligible; their run-off very slow. Consequently they are very poorly drained (class 0). The profiles of the wide inter-ridge swamps bear a great resemblance to the swamp clay soils, dealt with before (p. 43). The surface soil, often to a depth of 20 to 35 cm., consists of dark greyish brown to very dark brown or black clay, rich in organic matter. Underlying is a layer of clay, very light grey to grey in colour, often highly mottled with yellow to (olive) brown, the mottling decreasing deeper downwards. Often there are also many yellow concretions. The substratum, e.g. from 150 to 200 cm. downwards, consists of soft clay of a uniform grey to bluish grey colour.

With the narrower inter-ridge swamps the substratum is usually formed by the offshoot of the landward ridge, which offshoot often continues under the clay of the swamp and even farther to underneath the next seaward ridge (cf. 36, fig. 2). So here this substratum consists of sand, not of clay. Further, in many places in the narrow inter-ridge swamps, the clay deposited on top of this substratum was mixed with varying amounts of sand, washed-in from the adjacent ridges (see p. 53). Accordingly, the upper horizons of these inter-"rits" swamp soils may be somewhat sandy. The surface soil usually consists of 5 to 10 cm. greyish brown to very dark brown, soft clay, sandy clay or clay loam, very rich in organic matter; it merges in a dark grey to black, moderately to very firm layer of the same texture. The next horizons are again predominantly light grey, grey or bluish grey, often highly mottled with yellow, yellowish red or (olive) brown. At first their textures correspond to those of the upper layers. However, at widely varying depths (often somewhere between 40 and 120 cm.), they merge via sandy loam in fine or very fine sand. At a great depth, e.g. 140 to 180 cm., the sand is usually of a uniform dark bluish grey colour, while it contains many mica plates and other dark minerals. In some of the narrowest inter-ridge swamps, situated in between two imbricate ridges, no clay has been deposited at all. Therefore, in these swamps the profiles consist of fine to very fine sand directly from the surface downwards.

The natural vegetation of the inter-ridge swamps as a rule consists of swamp forest, in which the principal tree species are: matakki *(Symphonia globulifera)*, baboen *(Virola surinamensis)* and mirahoedoe *(Triplaris surinamensis)*. The lower story mainly consists of pina palms *(Euterpe oleracea)*. Along the borders of these swamps one will often come across some kankantries *(Ceiba pentandra)*. The possentrie *(Hura crepitans)* forest, occurring on some ridges, also stretches over the inter-ridge swamps; in the lower story of this high forest the matakki is frequent.

To illustrate the above a profile description is given of the:

KRAPPA SERIES:

Land conditions: moderately deep, narrow swamp between two ridges; drainage very poor (class 0).
Vegetation: swamp forest (mainly matakki)
Profile:

A11	0—10 cm.,	dark brown, sticky, slightly plastic, peaty clay.
A12	10—25 cm.,	very dark grey, sticky, plastic clay.
C1gg	25—50 cm.,	light grey, sticky, plastic clay; moderately mottled with yellow and brown; with many small, hard, yellow concretions.
C2gg	50—75 cm.,	light grey, sticky, slightly plastic, fine sandy clay loam; highly mottled with
D1	75—160 cm.,	yellow; with many small, hard, yellow concretions.
D2	160 cm. +,	grey fine sand; moderately mottled with yellow and yellowish red.
		dark bluish grey fine sand, with many fine mica plates and other dark minerals.

In the populated areas the ridge-bundles have been reclaimed for the greater part. Most of the inhabitation, inclusive of the farm-yard cultivation is established on the ridges. In the environment of Paramaribo mixed agriculture is practised in the "rits" landscape. The ridges are mainly used as pasture land and for the cultivation of coconut, citrus, bananas etc. In the inter-ridge swamps rice is grown. On the ridges of the Coronie district coconut is cultivated on a rather large scale.

B. MIDDLE BELT.

LANDSCAPES WITH MAINLY OLD SOILS FROM SEDIMENTARY PARENT MATERIALS.

Broadly speaking, this belt stretches south of the young coastal plain. In contrast with the latter, however, this middle belt does not form a continuous east-west strip in Northern Surinam. In some ten places it is broken through by the southward enclaves of the young coastal plain, which, as mentioned before, occur along the rivers. These enclaves cause the capricious northern boundary of the middle belt. Moreover, still farther to the north, so in the midst of the young coastal plain, there are a great many scattered occurrences of this middle belt. Its southern boundary shows a somewhat more regular course. Apart from the interruptions and the isolated occurrences, mentioned above, the belt measures about 60 km. north-south in the western part of the country and about 30 km. in its eastern part. In between the rivers Upper-Nickerie and Tibiti, however, this width differs from the general dimensions, the belt being much narrower here.

This second belt is in the main constituted by three landscapes (see table 2, appendix III), viz.:

the *old offshore bar landscape,* covering	c. 1,500 square km.
the *old sea clay landscape,* covering	c. 2,800 square km.
the *„dek" landscape,* covering	c. 10,000 square km.

The first two landscapes together constitute the so-called "old coastal plain", which occupies the northern part of the belt. It also includes the above-mentioned isolated occurrences, situated north of the belt proper. Geologically this old coastal plain belongs to the Coropina formation. The "dek" landscape forms the southern part of the belt, where the Zandery formation is exposed.

Of less importance is the *river terrace landscape,* which is found along the middle courses of some rivers. These terraces are of Coropina age or older. A minor part of the surface is eventually occupied by the *sedimentary rest-hills.* They are mostly arranged in groups within the area of the old coastal plain. They form part of the Zandery formation.

4. THE OLD OFFSHORE BAR LANDSCAPE.

This landscape is mainly constituted by the remains of a series of former offshore bars, or, according to Shepard's (80) nomenclature, of barrier islands, which are mainly built up of very fine sand. Each barrier island has developed from a great number of imbricate individual ridges and is comparable with a ridge-bundel of the young coastal plain. In contrast with the latter, however, the strips of clay in between the individual ridges forming one bundle, are absent here. So each barrier island originally consisted of one continuous deposit of sand.

The present remains mainly are dry land; some parts, however, belong to the marsh-land. The level of these remains ranges from c. 1 to c. 8 m. above S.P.. They are often 3 to 10 km. in width; some of them, however, are much narrower, for example, about 500 m.. In length they mostly range from 10 to 40 km..

The old offshore bar remains lie in a more or less east-west range, in the main between the Upper-Nickerie and the Marowyne. In the western part of the country they are found about 40 km., and in the east some 10 km. south of the present coastline. In general, not more than one bundle occurs in north-south direction; only in a few places do two barriers occur, the one at some distance behind the other.

The barrier islands, as they are found at present, are not the remains of a, once continuous, "barrier chain" (cf. 80). Instead, each barrier has developed as a separate bundle. Where this development took place along the former estuaries, the barriers, like the young ridge-bundles, are bent landwards. That is why the bundles are not in an even line with each other, and cannot have formed one "barrier chain". From the positions and directions of the old offshore bars it may be inferred that the sand, of which they are built up, was supplied by the rivers, just as happened with the young ridges (cf. p. 51). The most important sand suppliers were the Coppename, the Saramacca, the Suriname, the Commewyne and the Marowyne.

The entire old coastal plain was deposited during a period when the sea level was considerably higher than it is at present. In these circumstances, from the northern boundary of the present "dek" landscape a marine sedimentation took place of mainly clay and silt. Through this process an extensive plain was built up, which in the beginning will have been about on a level with the sea. During periodical abrasions the front part of it was time and again cleared away, while the sand was washed out and thrown up by the dash of the waves into barriers (cf p. 51).

A remarkable fact is that the oldest sandridges were only formed 10 to 30 km. north of the original shore (the northern boundary of the "dek" landscape), while the area landwards of these sandridges silted up without interrupting abrasions. Another point of difference from the young ridge-bundles is that the following abrasions were so heavy and/or lasted so long that time and again the silted-up area in front of the youngest sandridge was nearly always entirely swept away. Owing to the still increasing sea-level every fresh sandridge was deposited not only immediately against, but for the most part of it over the previous sandridge. Thus arose a continuous deposit of sand, which often reached a considerable thickness. From the data obtained by borings, and published by Yzerman (99) and D'Audretsch (2), it appears, for example, that at present the sand thickness near Lelydorp is still 6 to 11 m., and near the Rysdykroad (Lelydorp-project) some 14 m.. Many barriers thus reached a considerable height (at present still 4 to 7 m.) above the adjoining sea clay area farther inland. This clay area eventually formed more or less a lagoon, separating the barriers from the continental "dek" landscape like real "islands".

The granular analyses (fig. 6 and 7) show that the material of the old offshore bars is a mixed sediment, belonging to the E-group of the Doeglas (24) classification. It consists of a sand component, median 75 to 110 μ, and a clay+silt component. The latter made up about 20 to 35 % of the original sediment. Owing to the soil genesis this percentage has much changed in the solum horizons.

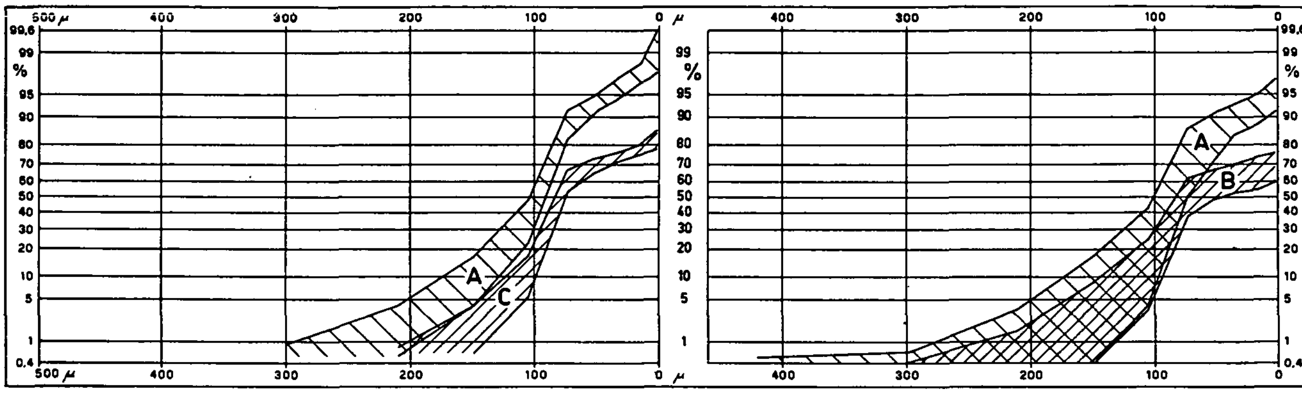

Fig. 6. Two bundles of 6 grain-size summation-curves each, of "wal" soils.
A = A-horizons of strongly podzolized *Rysdyk* series.
C = parent material of various soil series.

Fig. 7. Two bundles of 6 grain-size summation-curves each, of "wal" soils.
A = A-horizons of slightly or not podzolized *Onverdacht* and *Guldenvlies series.*
B = B-horizons of the same profiles.

The highest parts of the old offshore bar remains roughly lie about 8 m. above the adjacent swamps, that is roughly 4 to 6 m. higher than the oldest ridges of the young coastal plain, and roughly 7 to 8 m. higher than the youngest ones. This difference in level is expressed in the cross-section of the traverse Wiawia bank- Moengoe Tapoe, published by Lindeman (59) and Brouwer (19). However, Brouwer's suggestion that the oldest ridges of the young coastal plain should reach about the same height as the old offshore bars, is incorrect. Actually, the sandridges under consideration here do not belong to the young coastal plain any more; they are the most northern old offshore bars of the old coastal plain (see note p. 41). Taking into account the later erosion of the old barriers, and the shrinkage of the underlying clay, it becomes evident from the difference in level mentioned above, that in the period of the development of the old offshore bars, the sea-level was about 10 to 12 m. higher than it is at present. The accurate dating of this period has not taken place as yet; hypothetically it may be assumed that this depositing took place during the Risz-Würm (Sangamon *)) interglacial age.

According to this assumption, the sea-level sank considerably during the following Würm (Wisconsin *)) glacial age. This decline of the sea-level will have caused some shrinkage of the clay deposit underlying the old offshore bars. Further, the erosion of

*) Probable equivalence of European and American Pleistocene ages as suggested by Leverett (58) and maintained by Flint (33).

these bars set in. In the Holocene age the sea-level rose again, temporarily reaching a level that was even 2 to 3 metres above the present one, though still staying about 7 to 10 metres below the level prevailing when the old coastal plain was originally being built up. In this period, the — then marine — erosion assumed enormous proportions. As the supplemented maps show, considerable parts of the original offshore bars were altogether cleared away. Another part was highly dissected and "dissolved" into a great number of remnants, left behind in groups and separated by deep tidal erosion gullies.

In the complexes less heavily impaired, for instance the area south of Lelydorp, the constituent ridges of the old bundles were much levelled down. The depressions, lying in between, were whether entirely or partly filled up with the sand washed down from the adjacent crests. At present the remains of these depressions are still to be found here and there as small, often long-drawn, shallow fens. Owing to their origin these small, high-level swamps often occur in long ranges, in a direct line with one another. They constitute the second element of this landscape. The original relief thus largely got lost. On the other hand, in these larger complexes too, deep erosion gullies developed, through which another rather strong relief arose.

Eventually, in between the groups of old offshore bar remains, and in the erosion gullies, young marine clay was deposited, which is similar to the clay of the large swamps of the young coastal plain. In the landscape as it is at present, these gullies form narrow, much branched, meandering swamps; they are the third landscape element. So most of these gully-swamps have a bottom of clay; in the deepest gullies a layer of peat developed afterwards.

In accordance with what was stated above, three soil associations were distinguished in this landscape, viz. the *"wal" soils* (Dutch wal = bar) in the old offshore bar remains, the *fen soils* in the small, high-level swamps on some of these remains, and the low level *gully swamp soils.*

Bw. "W a l" s o i l s.

As appears from the earlier published classification of these soils (30), together they may be referred to as the "*Rysdyk - Onverdacht - Guldenvlies* association", after the most important soil series involved. The soil geneses of these series are widely different, dependent on the drainage conditions, which again are closely related to the relief. Consequently the association is a *hydrosequence* (cf. 52).

Hendriks and Glavimans (45) already pointed to the occurrence of extensive, almost level plateaux on the one hand, and narrower ridges with a rolling relief on the other hand. On top of the plateaux (slope class A) the run-off is either nil or very slow. Moreover, because of the slowly impermeable layers arising in the profiles, which with the low plateaux go side by side with a high ground-water-table, the soils are poorly to somewhat poorly drained (classes 1 to 2). The percolation, originally being still strong, caused an almost complete eluviation of the clay, and at a greater depth the development of a layer rich in clay. Above this layer an intense podzolization took place.

There is sometimes a thin layer of dark reddish brown to dusky red, loose litter on the surface. The organic matter has coloured the surface soil dark brown, dark grey or black. The underlying layer is highly bleached and consists of light grey or white, fine or very fine sand. This layer is thickest on those plateaux that are situated high above the surrounding swamps. The soils of these high plateaux contain a hardpan, 20 to 40 cm. thick, mostly at a depth of 90 to 150 cm.. Usually the sand is cemented, in the main by organic matter, and to a less extent by iron oxides. The upper part of the hardpan is often dark brown or black in colour, while its lower part is mottled yellow, brown and/or yellowish red. Elsewhere the entire hardpan is dark brown in colour, sometimes mottled with yellow and brown. It may happen that two hardpans are found, the one above the other, separated by a layer of light grey (very) fine sand. The lower one is then often a yellow to yellowish red iron pan. This (lower) hardpan often lies on top of the already mentioned layer rich in clay (mostly sandy clay loam or sandy clay), which as a rule is pale yellow, yellow or reddish yellow in colour. Eventually the latter gradually merges in pale yellow or yellow sandy loam.

The low lying plateaux, as well as the flat feet of the flanks of the plateaux and ridges, lie only little higher than the swamps around them. Here the podzolization has gone less deep. The bleached horizon usually reaches as far down as 40 to 80 cm.. Underlying it is often a thin layer, dark coloured by illuviation of organic matter, but this layer does not form a hard, impermeable pan. In other cases the white, (very) fine sand lies directly over pale yellow to (light) grey sandy clay, which is sometimes highly mottled with yellow, red and/or yellowish red.

On the narrow ridges and on the sloping flanks of the high plateaux (slope classes B to C) the run-off varies from slow to rapid. The soils are on the whole moderately well to well drained (classes 3 to 4). Here again a layer rich in clay has developed at some depth. However, in the horizons above it usually still 5 to 10 per cent. of clay has remained behind. The podzolization dominates to a much less extent, or does not arise at all.

Down to a considerable depth (e.g. 40 to 70 cm.) the soils are dark in colour through the presence of organic matter. Withe well drained soils these upper horizons consist of dark brown to brown loamy (very) fine sand. Underneath follows a yellow, brownish yellow or reddish yellow horizon of the same texture. This horizon, mostly at a depth of 70 to 150 cm., lies over yellow to reddish yellow sandy clay loam or sandy clay. Eventually the latter merges in pale yellow to yellow sandy loam. With the moderately well drained soils the upper horizons are predominantly dark grey to greyish brown in colour. Here directly overlying the pale yellow to reddish yellow horizon rich in clay. is a clearly bleached horizon of grey, pale yellow or pale brown, loamy (very) fine sand.

The soils on top of the highest summits of the landscape are somewhat excessively drained (class 5). These profiles present a predominant laterization. An accumulation of organic matter is discernible down to 60 to 100 cm.. The upper horizons consists of (very) fine sand, varying in colour from dark reddish brown to dusky red, which deeper downwards fades into strong brown to red. This sand gradually merges in loamy (very) fine sand, yellowish red to red in colour, fading into reddish yellow at a greater depth.

Apart from the sand soils already dealt with, on the flanks of the ridges and plateaux there are also soils of a heavier texture. These soils have mainly developed from layers that originally lay deeper downwards. The relative acreages occupied by these soils differ widely in the various parts of the old offshore bar landscape, dependent on the degree of erosion. Locally these heavier soils may even dominate. High up the flanks are the well drained soils, developed from former subsoils by renewed soil formation. The profiles consist of dark brown sandy loam or sandy clay loam, merging in yellow to red sandy clay loam or sandy clay. At the bottom of the flanks occur imperfectly drained soils, with a surface soil that is mainly constituted by colluvial material. This surface soil consists of brown to greyish brown sandy loam or loam. The subsoil is a grey (silty) clay loam or (silty) clay, highly mottled with red, yellow and/or yellowish red; it has developed from the upper part of the deposit that forms the foundation of the old offshore bars.

The natural vegetation of much the largest part of the "wal" soils consists of richly mixed evergreen seasonal forest. Frequent tree species in this forest type are the foengoe *(Parinari campestris)*, oemabarklak *(Eschweilera corrugata)*, hoepelolie *(Copaifera guianensis)*, alatta *(Minguartia guianensis)* and swietie boontje *(Inga spp.)*. Conspicuous among the big trees of this forest are the cederkwarie *(Qualea)*, injipipa *(Couratari spp.)* and soemaroepa *(Simarouba amara)*. Frequent palm species are the maripa *(Maximiliana maripa)*, koemboe *(Oenocarpus)* and paramakka *(Astrocaryum paramacca)*; the latter was never found on the young "ritsen".

However, where the water household is worse, quite different types of vegetation arise. On some high summits of dry reddish brown sand, for example, the walaba *(Eperua falcata)* is predominant in the canopy of the forest. Less favourable are the conditions in that part of the highly bleached "wal" soils which, through the occurrence of an ortstein or clay pan, is alternately very wet and very dry. A fairly luxuriant forest type here, is that in which the foengoe *(Parinari campestris)* dominates in the canopy (cf. 59). Where the ortstein pan is well developed, the walaba forest is found locally; more frequent, however, is the savanna wood with the palm species obé *(Acrocomia)*. Extremely unfavourable conditions arise in the bleached "wal" soils north of the Wanekreek, where Bakker (5, 6) found a quite impermeable ortsteinpan, 70 cm. thick. Here are open savannas, which we classified as the "Watamaleo" savanna type (23).

To illustrate the above, hereafter the profile descriptions will be given of two soil series, which were already defined before (30).

RYSDYK SERIES:

Land conditions: marshland on top of high level plateau; drainage somewhat poor (class 2).
Vegetation: savanna wood with obé palms.
Profile:

A0	5 cm.,	dark reddish brown, loose litter.
A1	0—10 cm.,	dark greyish brown, loose, very fine sand.
A2	10—105 cm.,	white, loose, very fine sand.

B2h 105—±120 cm., very dark brown, very fine sand; cemented into a hardpan with irregular lower boundary.
B2ir ±120—±130 cm., mottled yellow, brown and yellowish red, very fine sand; cemented into a rather hard pan with irregular boundaries.
B2t ±130—265 cm., yellow, firm, very fine sandy clay, with many reddish yellow mottles; this horizon very gradually merges in:
C 265 cm. +, pale yellow, friable, very fine sandy loam, with few brown mottles.

GULDENVLIES SERIES:

Land conditions: dry land on top of a ridge; drainage good (class 4).
Vegetation: evergreen seasonal forest.
Profile:
A11 0—25 cm., dark brown, very friable, loamy very fine sand.
A12 25—60 cm., brown, loose, loamy very fine sand.
A2 60—95 cm., yellow, loose, loamy very fine sand.
Bt 95—245 cm., reddish yellow, firm, very fine sandy clay loam; with red mottles and red concretions; it very gradually merges in
C 245 cm. +, pale yellow, very friable, very fine sandy loam, with few red mottles and small red concretions.

Part of the "wal" soils south of Paramaribo has been reclaimed. The habitation has been established on the old offshore bars, as is the case on the ridges in the young coastal plain. Further the "wal" soils are in the main used for the cultivation of coconut, citrus, cassava, bananas etc.. An image of this non-intensive husbandry is given in the account on the agricultural inquiry, carried out by Hendriks and Joosten (46) in 1953. In 1950 a pilot scheme of some 500 hectares was started in this area, the so-called Lelydorp-project, financed by the Development Fund (cf. p. 9). The aim was to examine the possibility of establishing miscellaneous farms, each 5 to 11 hectares large. Besides cattle-breeding these farms include tree crops (oilpalm, coconut, cacao, citrus) and less long-lived crops (pine-apple, cassava, peanut, banana). The development and results of the Lelydorp-project were described by De Haan and Hendriks (39) and by Hendriks (44).

Bf. Fen soils.

The fens are small, moderately deep, often long-drawn swamps. They are found on the high plateaux, amid highly bleached sand soils, so on a much (some 3 to 6 m.) higher level than that of the large swamps of the young coastal plain.

These fens have no water-outlet; their run-off is entirely ponded. As a result of the eluviation process an almost clayless horizon arose, under which a slowly permeable layer formed, rich in clay. Consequently the fen soils are very poorly drained; they are submerged for the greater part of the year.

Owing to these predominantly anaerobic conditions, a layer of very dark grey to black organic muck has formed on the surface. The surface soil is coloured dark to very dark grey through the presence of organic matter. From the somewhat higher environment (the adjacent crests of the sandridges) fine material (especially silt) has been washed down; for this reason the texture of the surface soil varies from sandy loam to silt loam. Underneath, the above-mentioned eluvial horizon is found, which is highly bleached, consisting of white or light grey, fine to very fine sand. The underlying illuvial horizon usually consists of pale yellow to very pale brown, (very) fine sandy clay loam.

In the fens a mainly herbaceous vegetation is found, containing *Jussieua* and ferns, together with some kiskismakka *(Bactris)* palms.

In the classification of these soils (30) only one soil series was distinguished; its profile description is following below:

GROENHART SERIES:

Land conditions: moderately deep, narrow swamp on high plateau; drainage very poor (class 0).
Vegetation: mainly Jussieua and ferns.
Profile:

A0	30 cm.,	black organic muck.
A1	0—30 cm.,	dark grey, friable silt loam.
A2	30—85 cm.,	white, loose, very fine sand.
Bt	85 cm. +,	pale yellow, firm, very fine sandy clay loam.

Bg. Gully swamp soils.

The erosion gullies constitute much branched, mostly rather narrow, but deep swamps. They lie about on a level with the large swamps of the young coastal plain (roughly 0 to 1 m. below S.P.), into which they, gradually widening, debouch.

The gully swamp soils are very poorly drained (class 0). Since they are submerged almost all the year round, often a strong accumulation of organic matter has taken place. Normally, these soils have profiles as follows:

1. a pegasse (A0) layer of dark brown to black organic muck.
2. an A1 horizon of dark grey to black clay, rich in organic matter.
3. a Cgg horizon of light grey, grey or bluish grey clay, often mottled with yellow, brown and/or yellowish red.

These profiles bear a great resemblance to the clay soils of the large swamps of the young sea clay landscape described on p. 43, for example, the *Djaki series*. In the gully swamps, however, the A0 and A1 layers are often more developed. The total thickness of these layers may reach 35 to 70 cm., or even more. An example of such a profile is the *Arapappa series*, of which a description is given below. In the deepest gully swamps also occur real peat soils, similar to the swamp peat soils, described on p. 46, e.g. the *Kalebaskreek series*.

Before the young clay was deposited in them, some of the erosion gullies were less deep indented than they normally are. Light grey, (loamy) very fine sand of the old offshore bars may then sometimes occur in the soil profile underneath the clay. The substratum may also be the upper part of the deposit that forms the foundation of the old offshore bars. In these cases it consists of grey to white, firm (silty) clay .loam or (silty) clay, often mottled wih red and yellow.

The natural vegetation of the gully swamps usually consists of matakki *(Symphonia globulifera)* swamp forest. On the clay soils this tree species is especially mixed with baboen *(Virola surinamensis)* and mirahoedoe *(Triplaris surinamensis)*, while there is a lower story of pina palms *(Euterpe oleracea)*. On the peat soils occur, along with the matakki, mainly the panta *(Tabebuia aquatilis)* and bébé *(Pterocarpus officinalis)*, with the palm species maurisi *(Mauritia flexuosa)*.

Sometimes a herbaceous vegetation occurs in the gully swamps, principally consisting of *Cyperaceae* and mokomoko *(Montrichardia arborescens)*.

ARAPAPPA SERIES:

Land conditions: deep swamp in erosion gully; drainage very poor (class 0).
Vegetation: matakki swamp forest.
Profile:

A01	20 cm.,	dark brown organic muck.
A02	15 cm.,	black organic muck.
A1	0—30 cm.,	black, sticky, plastic clay.
C1gg	30—135 cm.,	grey, sticky, plastic clay, with many brown and yellow mottles and small brown concretions.
C2gg	135 cm. +,	grey, very sticky, slightly plastic clay, with few brown mottles.

5. THE OLD SEA CLAY LANDSCAPE.

This landscape is mainly constituted by the remains of the vast plain, mainly built up of clay and silt, on the northern part of which the old offshore bars were formed. These remains are referred to as "schollen" (Dutch schol = flat terrain, slightly higher than its surroundings); they are the main element of this landscape. These level or nearly level terrains belong partly to the dry land, partly to the marshland. They roughly lie 1 tot 3 metres above S.P.; this is about 1 to 3 m. above the adjacent swamps of the young coastal plain. The strip in which these "schollen" occur, with the exception of some interruptions, stretches all across Surinam, from east to west, directly north of the "dek" landscape. Along the rivers and creeks these "schollen", in a southward direction, penetrate deep into the "dek" landscape.

During the period of the high sea-level, mentioned before, the old sea clay ("Coropina clay") was deposited in the shallow part of the sea off the northern boundary of the present "dek" landscape. Along the above boundary lies the Coropina clay wedge-shaped upon the Zandery formation. Since at present the level of the "schollen" is still 4 to 7 m. below the tops of many old offshore bar remains, the rising of the sea-level must have gone faster than the building-up of the old sea clay plain by the sedimentation. Large parts of this area eventually formed a sort of lagoon, situated on the landside of the old offshore bars.

When subsequently the sea-level declined considerably, the area ran dry and thereupon shrinkage of the clay set in. When the sea-level rose again, up to 2 to 3 metres above the present level, the area was heavily affected by marine erosion. In consequence the "schollen" proper arose, being the remains of the original plain, mostly occurring in groups. In between these remains deep tidal erosion gullies developed. Eventually these erosion gullies were partly filled up with young clay, belonging to the Demerara formation The erosion gullies, at present much branched, meandering swamps, are the second element of this landscape. In the deepest of these gully swamps a layer of peat developed.

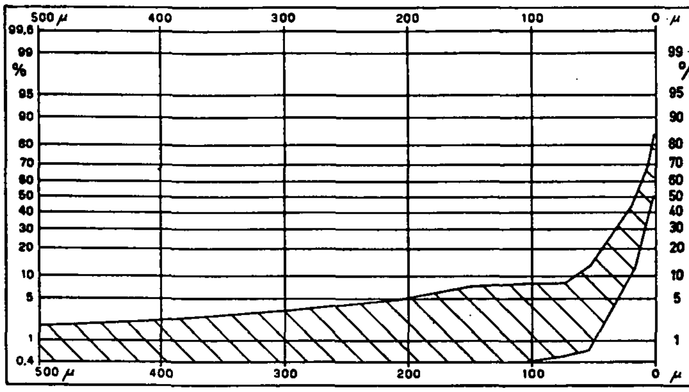

Fig. 8. Bundle of 16 grain-size summation-curves of "schol" soils (A-horizons).

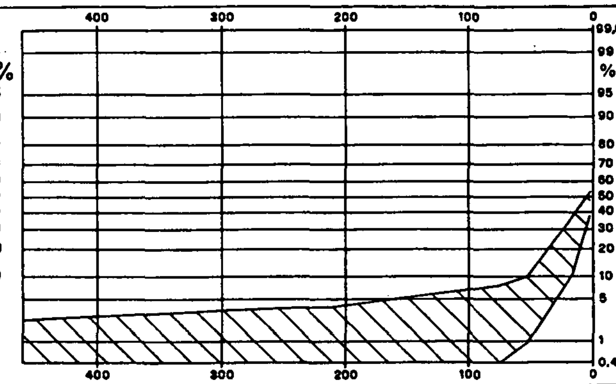

Fig. 9. Bundle of 10 grain-size summation-curves of "schol" soils (B- and C-horizons).

With the exception of the upper soil horizons, the granular composition of the old sea clay in principle corresponds to that of the young sea clay (see fig. 9). There is a high percentage of fine particles.

The fraction $< 2\ \mu$ usually amounts to 45 to 65 %, the fraction $< 16\ \mu$ to 70 to 90 %, the ratio between these fractions being 0.6 to 0.8. The material as a rule contains a tiny bit of very fine sand (median 75—105 μ), similar to that of which the old offshore bars are built up. In addition, however, it often contains some coarser sand as well. Consequently the total content of sand normally varies between 2 and 15 per cent., whereby the median of the sand fractions ranges from 75 to 200 μ.

In the vicinity of the offshore bars the content of very fine sand may increase to some 30 %, in the surface soil even to about 60 %. These "schollen", rich in very fine sand, form a transition to the old offshore bars; locally they may cover a relatively large acreage. On the whole the percentage of coarser sand increases towards the "dek" landscape. Close to the "dek" landscape the content of sand may increase to 60 per cent. or more, the median of the sand fractions being between 200 and 600 μ. The inference is that this coarser sand has come from the Zandery formation. Via numerous creeks it has been washed into the old sea clay. In those places where high percentages of sand, as mentioned above, arise, the percentages of the fractions $< 2\ \mu$ and $< 16\ \mu$ are lower than normally. However, this does not affect the ratio between these fractions, which is nearly always 0.6 to 0.8.

The surface and subsurface soils, however, present a different image (see fig. 8). In here the fraction $< 2\ \mu$ normally ranges from 20 to 50 %, the fraction $< 16\ \mu$ from 60 to 90 %, the ratio between these fractions being only 0.3 to 0.6. In comparison with the deeper horizons and with normal marine deposits in general, these upper horizons show a shortage of clay particles. For this reason Bakker (5) holds that the old sea clay was deposited in brackish water and is comparable with the "sloef" layers, occurring in the bottom of the Netherlands Zuiderzee (Dutch sloef = fine silt, namely the fraction 2—16 μ).

In these "sloef" layers the ratio between the fractions $< 2\ \mu$ and $< 16\ \mu$ is usually 0.30 to 0.45, against 0.65 to 0.70 in normal marine clay deposits. Muller and Van Raadshoven (67), Zuur (104) and Wiggers (97) explain the shortage of clay in the "sloef" layers by assuming that the originally flocculated material of normal composition, brought in by the sea, was again dispersed owing to the low percentage of salt in the Zuiderzee. This hampered the deposition of the particles $< 2\ \mu$.

Something similar arises with the S- (and MS- resp. BS-) sediment types, rich in silt, distinguished by Van Andel and Postma (1) near the mouths of the Orinoco, in the bottom of the Gulf of Paria. The material here is of fluviatile origin, and originally non-flocculated. In this S-clay, which presumably is much alike the Surinam old sea clay, the ratio $< 2\ \mu : < 16\ \mu$ is in general lower than 0.6; farther away from the estuary, where the water is salter, the ratio is usually 0.6 to 0.7. The difference is explained to have been caused by the "progressive sorting" (cf. 77) within the fraction $< 16\ \mu$, which arises in brackish water, where flocculation is of minor importance.

The topmost layer of the old sea clay might have been deposited in brackish water during the before-mentioned lagoon stage, when the old offshore bars were already well developed. The deeper layers would then have been deposited in an entirely marine milieu, before the offshore bars had formed. This would explain the different values for the ratios $2\ \mu : < 16\ \mu$ in the top layer (0.3 to 0.6) and in the deeper layers (0.6 to 0.8). It is, however, doubtful whether even in the lagoon stage the percentage of salt had ever been low enough so as to impede the flocculation of the clay to such a degree that, for instance, the above- mentioned ratio could drop to 0.3 or 0.4. For, as appears from the supplemented maps, the offshore bars have never formed one more or less continuous *"nehrung"*, but they always occurred as separate bundles. In between them the sea has always had ample access to large parts of the old sea clay area. Furthermore, there are also a few small "schollen", occurring on the seaside of the old offshore bars. Although here the water could hardly have been brackish, ratios of 0.30 and 0.45 occur in the top layer.

In general the top layer, short of clay, is but a very thin one. The ratio $< 2\mu : < 16\mu$ mostly outweighs the value 0.6 already at a depth of 30 to 60 cm. This small depth leads the idea towards the soil genesis. In the author's opinion the low value for the abovementioned ratio in the upper horizons should mainly, if not entirely, be attributed to the eluviation of clay. That clay eluviation also arises in such heavy clay soils, was already ascertained by Müller (66) in the profiles of the young sea clay soils of the plantations (see p. 46). These plantation soils, reclaimed from swamps, have been drained only for 2 to 2½ centuries past, so a very short period in comparison with the space of time that the eluviation could affect the old sea clay. Apparently, on these flat "schollen" the sheet erosion has in general not been strong enough as to wipe out the effect of the eluviation.

The soils of the old sea clay landscape were grouped in two soil associations, viz. the *"schol" soils* and the *gully swamp soils.*

Os. "S c h o l" s o i l s.

From the classification earlier drawn up (30), it appears that these soils together may be referred to as the *Cassewinica-Waycaribo* association. The "schollen" are generally level or nearly level areas (slope class A). Their run-off is slow as a rule. There may also occur undeep depressions, where the run-off is entirely ponded. Owing to the bad permeability of the subsoil, the internal drainage is slow to very slow. Most of the "schollen" still belong to the dry land; their soils are somewhat poorly drained (class 2). Along the borders of these "schollen", however, often runs a lower strip of land, which is marshland, as are the above-mentioned undeep depressions. The lowest "schollen" as a whole belong to the marsland. In all these cases the soils are poorly or even very poorly drained (class 1 or 0). These variations in the drainage conditions go together with clear differences in the profile developments. So this soil association too is a *hydrosequence* (cf. 52).

With the somewhat poorly drained soils the surface soil down to 5 to 10 cm. is often coloured dark brown, brown or greyish brown through the presence of organic matter. In some places no A1-horizon is to be perceived at all; somewhere else it has developed more than normally, and for instance, may reach 15 to 25 cm..

Underneath follows a horizon predominantly yellowish brown, pale brown or light brownish grey in colour, in places mottled with brown. These upper horizons normally consist of very friable to friable silt loam or silty clay loam. The next horizon, usually occurring from a depth varying between 20 and 50 cm., is already much firmer in consistence, greyish brown to grey in colour, often mottled with yellow, brown or yellowish red. This horizon is a transition to the subsoil. Mostly at a depth between 40 and 80 cm. it merges in very to extremely firm silty clay or clay, most conspicuously mottled red (to purple), white (to grey) and yellow (to reddish yellow). Often many hard, red or purplish red concretions occur in it.

With the poorly to very poorly drained soils the surface to a high degree presents the micro aspect with "kawfoetoes" (hummocky surface). The usually 10 to 20 cm. thick A1-horizon is dark grey to dark brown in colour. The underlying horizon consists of light grey, friable silt loam or silty clay loam. The firmer transitional layer is also light grey in colour, often mottled with yellow or brown. Here again the subsoil consists of very firm silty clay or clay, also most conspicuously mottled white, red and reddish yellow.

The very fine sandy soils in the vicinity of the old offshore bars are mostly somewhat poorly drained. They from the transition to those "wal" soils occurring in the lower parts of the flanks of the old offshore bar remains. The surface soil consists of brown to greyish brown, very friable to friable, silt loam to loam, or even sandy loam. The subsoil, here again highly mottled white, red and reddish yellow, consists of very firm (silty) clay loam or (silty) clay.

In the neighbourhood of the "dek" landscape moderately coarse to coarse sand in variable quantities has mixed with the "schol" soils. Consequently the textures of these soils differ widely. In places with a high percentage of coarse sand the surface soil, often down to a considerable depth, e.g. 40 to 80 cm., is coloured dark brown to dark greyish brown through the presence of organic matter. This surface soil then consists of friable sandy loam or sandy clay loam. Where the percentage of coarse sand is lower, all kinds of transitions occur, ranging from loam or clay loam to silty loam or silty clay loam. Downwards in the profile the percentage of sand always decreases. The subsoil generally consists of very firm clay loam to (silty) clay, and here again it is highly mottled red, white and reddish yellow. It may, however, sometimes consist of layers alternately poor and rich in coarse sand.

The dry land "schollen" have a natural vegetation of mixed evergreen seasonal forest: Frequent tree species in it are the manbarklak and oemabarklak *(Eschweilera longipes* and *corrugata* respectively), kopi *(Goupia glabra)*, foengoe *(Parinari campestris)* and hoepel-olie *(Copaifera guianensis)*. Conspicuous for their heigth are especially the tree species red locus *(Hymenaia courbaril)* and injipipa *(Couratari spp.)*. Frequent palm species are the paramakka *(Astrocaryum paramacca)* and the maripa *(Maximiliana maripa)*. The typical "schol" forest has not developed luxuriantly. Its under story often consists of a great number of very thin trees. Owing to this, the forest recalls the aspect of a luxuriant savanna wood. This relatively poor forest vegetation may result from the slowly permeable subsoil and the consequent poor water household. However, on the "schol" soils in the south, which are rich in coarse sand, very luxuriant forests do occur, in which as palm species the paramakka abounds, along with the boegroemakka *(Astrocaryum)*.

The vegetation of the strips of marshland around many of the dry land "schollen", consists of foengoe *(Parinari)* forest with very few palm trees. In the depressions with ponded run-off, as wel as on the real marshland "schollen", often occur savanna wood, scrub savanna or open savanna. These savannas were classified (23) as the "Welgelegen" savanna type, wet variation. Here the absence of high forest must be attributed to the impermeability of the subsoil, along with the relatively low position. In consequence the humidity of the soil is most variable; the latter may be entirely dried up in the dry season, and flooded in the rainy season. Bakker (5) pointed out the influence of the depth at which this subsoil claypan arises; savannas would occur in those places where the claypan lies less than 50 to 60 cm. deep.

Open savannas are also found here and there on the dry land "schollen" ("Welgelegen" savanna type, dry variation). They are, however, of man-made origin. They have developed through the shifting cultivation, whereby the forest, after repeatedly being burnt down, finally did not recover.

Two characteristic soil series, already earlier defined (30), are the following:

CASSEWINICA SERIES:

Land conditions: dry land "schol"; drainage somewhat poor (class 2).
Vegetation: evergreen seasonal forest.
Profile:

A1	0—10 cm.,	brown, very friable silt loam.
A2	10—45 cm.,	yellowish brown, very friable silt loam.
B1	45—70 cm.,	greyish brown, firm, silty clay loam, with many strong brown mottles.
B2g	70—140 cm.,	mottled light grey, yellowish red and purplish red, very firm silty clay, with small, hard, red concretions. Mottling very conspicuous.
Cg	140 cm. +,	mottled light grey, yellowish red and purplish red, very firm silty clay loam, with small red concretions.

WAYCARIBO SERIES:

Land conditions: marshland "schol" with "kwafoetoes"; drainage poor (class 1).
Vegetation: savanna wood.
Profile:

A1	0—15 cm.,	dark grey, very friable silty clay loam.
A2g	15—30 cm.,	light grey, friable silty clay loam.
B1g	30—65 cm.,	light grey, firm silty clay; with many reddish yellow mottles.
B2g	65 cm., +,	white, extremely firm clay, with many reddish yellow and red mottles and few small, hard, red concretions. Mottling very conspicuous.

Og. Gully swamp soils.

In the gully swamps of this landscape occur clay and peat soils, similar to the gully swamp soils of the old offshore bar landscape (association Bg). For the description of these soils and the types of vegetation involved, be referred to p. 65.

6. THE RIVER TERRACE LANDSCAPE.

In several places along the middle courses of some of the large rivers, one or two terraces were found. All terrace occurences were together grouped into the river terrace landscape. These terraces, in fact, form southward offshoots of the middle belt, which along the rivers penetrate rather deep into the southern belt.

The terrace areas are of limited dimensions. Along the inner bends of the rivers concerned, they may reach a width of some 5 km., whereas along the straight parts of the rivers they are only narrow, e.g. up to about 2 km.. In front the terraces usually border on the marshland strips (flood plains), through which the middle courses of the rivers meander, and which are the continuations of the river levees along the lower courses (see p. 49). In the back the terraces border on the hilly land of the southern belt. The terrace occurrences form flat to slightly undulating terrains, lying dry all the year round. Only in a few places were two distinct terraces discerned, the one above the other. The impression is that the lower terrace lies 2 to 4 m., and the higher one 4 to 6 m. above the flood plain in front of them. The material of which the terraces are built up, mostly contains 60 to 85 % of moderately coarse to coarse sand (median usually 300 to 500 μ), and 10 to 35 % of clay. It was deposited in the Coropina age or earlier on. During the low sea-level, following the Coropina age, the rivers cut through this sediment, thus forming the terraces proper.

The soils of these terraces are comparatively uniform. They were grouped in one soil association:

Tt. River terrace soils.

On the whole these soils are well drained(class 4). The surface soil, down to 10 to 30 cm., usually consists of brown to dark (yellowish) brown, (loamy) coarse sand or coarse sandy loam. In the profile downwards the colour grows increasingly lighter and the texture increasingly heavier. The subsoil, from a depth ranging from 40 to 80 cm. being mostly yellowish brown to yellow or reddish yellow in colour, as a rule consists of firm coarse sandy clay loam or coarse sandy clay. In some relatively low lying places this subsoil is mottled with light red (or pink) and white (to grey).

The natural vegetation of the terraces is evergreen seasonal forest. In many places this was cleared for the shifting cultivation, so that at present "kapoeweri" (secondary wood) is found there.

A characteristic soil profile is presented by the

ABANNA SERIES:

Land conditions: dry terrace; drainage good (class 4).
Vegetation: secondary wood.
Profile:

A1	0—15 cm.,	dark brown, loose, moderately coarse sand.
A2	15—40 cm.,	yellowish brown, friable, loamy moderately coarse sand.
B1	40—65 cm.,	brownish yellow, firm, moderately coarse sandy loam.
B2	65 cm. +,	reddish yellow, very firm, moderately coarse sandy clay loam, slightly mottled with red.

7. SEDIMENTARY REST HILLS.

This "landscape" is only mentioned for completeness' sake. The hills of this landscape vary in height from some 10 m. to about 60 m.. They occur mostly in groups in the midst of the old coastal plain or close to the northern boundary of the "dek" landscape. The best known groups are those near Paranam on the river Suriname and those near Moengo on the river Cottica.

From the investigations by Van Kersen (53) it became apparent that these hills are the last remnants of an alluvial plain, which formed the youngest clay facies of the Zandery formation. During the Pleistocene era, on its surface a continuous ferrite-bauxite weathering mantle developed, lying over kaolin. This bauxitized plain was almost entirely gnawed away by erosion, arising in a later period. Eventually the comparatively low lying northern remmants were covered with Coropina sediments (during the Riss-Würm

(Sangamon *)) interglacial age?). This buried bauxite is designated as "Medium level bauxite" (53). The southern remmants, lying on a somewhat higher level, constitute the rest hills now under consideration; they rise above the old coastal plain. The overlying bauxite mantle is referred to as "High level bauxite". Characteristic of these hills are their flat tops and very steep flanks.

In the legend of the soil association map (appendix I), the soils of these bauxite hills were designated as:

Hl. "Sedimentary" laterite soils.

The operations of our team did not extend to an investigation of these soils. Van Kersen (53) described some profiles of characteristic hills. They presented a "soil cover" down to a depth of about 1.5 m., described as "iron beans and small stones together with some material rich in humus".

Underlying this "soil cover" is the ferrite-on-bauxite mantle, varying in thickness from about 1 to some 8 metres. After a 1 to 2 m. thick, transitional zone follows the kaolin, which may reach a thickness of over 20 metres.

Despite the ferrite-bauxite mantle the natural vegetation of these hills consists of normal, mixed, evergreen seasonal forest.

From a number of these hills, the High level bauxite is being exploited (9); on a few hills the mining is already finished. The Medium level bauxite, found in the vicinity of these hills, is also being mined (13).

8. THE "DEK" LANDSCAPE.

This landscape covers the southern part of the middle belt. Some interruptions along the rivers excepted, it stretches all along the width of Surinam, from east to west. Its north-south dimensions range from 60 to 70 km. in the western part of the country to only 5 to 10 km. in the eastern part of it. South of the proper area of the landscape several small, isolated occurrences of it are found in the midst of the southern belt.

The landscape comprises level to undulating plains, which, especially in the west, are very vast. It is on the whole dry land, but parts of marshland may occur locally. The altitude varies from 6 to 10 m. above S.P. in the northern part of the landscape, to some 70 m. above S.P. in the most southern part where the isolated occurrences of it are found. The plains are dissected by a great number of creek valleys, forming a rather regular drainage pattern. In some places they are but shallow gullies, whereas in other places they may form 10 to 15 m. deep valleys. The flat bottom of such a valley consists of a narrow strip of swamp or marshland on either side of the creek.

We already pointed out (23) that the formerly much used term "savanna belt" is unsuitable for the "dek" landscape. For the savannas, occurring in this landscape, occupy not more than 7 per cent. of the entire landscape acreage; the rest of it is forest or wood-

*). See note p. 60.

land. Moreover, 30 per cent. of the total savanna acreage of Surinam is situated outside the "dek" landscape.

The material of which the "dek" landscape is built up, forms the "sand" facies of the Zandery formation. These oldest non-consolidated sediments are of Miocene to Pliocene ages (cf. 53). The material at present constituting the upper few metres of the deposit, is much affected by processes of soil formation.Especially the eluviation or illuviation of clay and the homogenization by living organisms (cf. 47) conceal the granular composition of the original sediment. Depending on the soil series and the profile horizon involved, 45 to 100 % of the material consists of moderately coarse to coarse sand, median 200 to 600 μ (mostly 300 to 500 μ). It contains less than 5 % of silt and up to 50 % of clay. Deeper downwards the substratum predominantly consists of moderately coarse to coarse sand, alternated with more or less pure clay layers of variable thickness. The name of the landscape was derived from the fact that this sediment lies as a cover (Dutch: dek) over the crystalline basement. In some places this cover is only thin, namely a few metres or even less than one metre. In many places the foundation of the cover is formed by a layer of rounded gravel.

There is still uncertainty as to the depositing procedure of the Zandery formation. Yzerman (99) speaks of "continental alluvia". Bakker (3, 4, 5) deems Yzerman's criteria not decisive. Zonneveld (100) holds the view that the sediment was deposited by rivers. Schols and Cohen (78) suggest a marine, perhaps littoral origin.

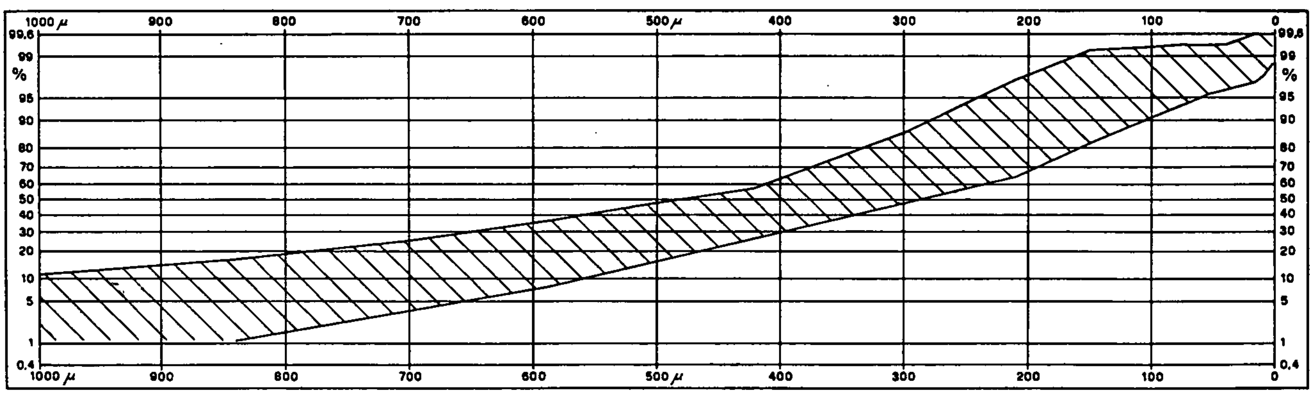

Fig. 10. Bundle of 12 grain-size summation-curves of bleached "dek" soils (A-horizons).

The author graphically worked up 61 granular analyses of soil samples selected from the entire landscape. The summation curves (fig. 10 and 11), though curving very faintly, give the impression that a mixed sediment is involved. However, these analyses represent the upper few metres of the deposit, which, like the deep substratum, originally may have consisted of alternate layers of sand and clay. Such a stratification could have disappeared completely through the proces of homogenization, this process being quite effective as appears from the numerous big heaps of "parasol" ants *(Atta sexdens* and *cephalotes)*.

So the shape of the summation curves is not decisive as to the mixed character of the original sediment. However that may be, both the curves of the entire material and those of the sand and clay components separately, are very similar to the curves of the river deposits, published by Doeglas (24). So the origin is probably fluviatile. This supposition is supported by the fact that Van Kersen (53) repeatedly observed a distinct cross-bedding in the sands of the White Sand series in British Guiana, this geological series being identical with the Zandery formation in Surinam. It is possible that the sediment was deposited by a great number of south-north running, relatively short, braided river systems.

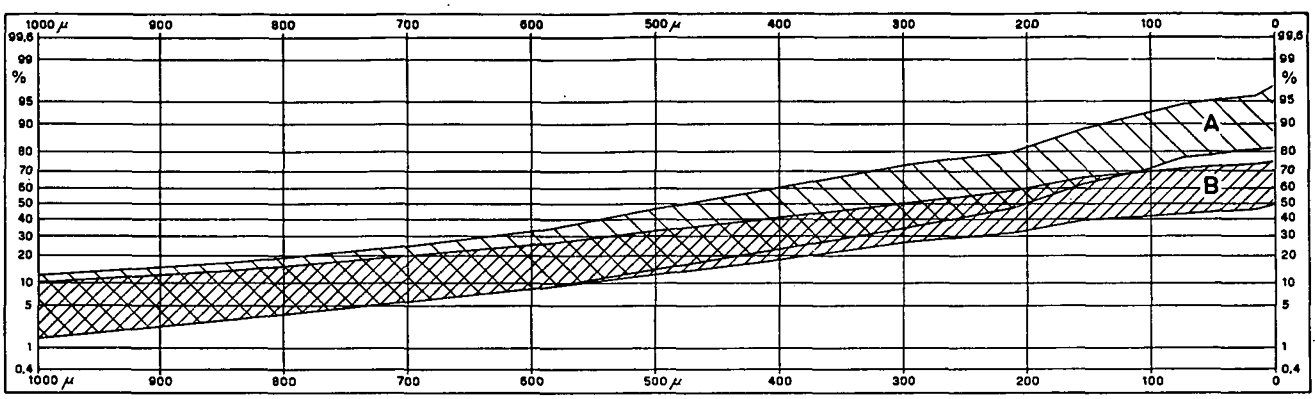

Fig. 11. Two bundles of 12 grain-size summation-curves each, of non-bleached "dek" soils. A = A-horizons, B = B-horizons of the same profiles.

From the original parent material widely different soils have developed, often under topographically similar circumstances. Part of these soils, down to a great depth, is completely bleached white owing to a very strong podzolization. These A-horizons contain less than 2 % of clay (mostly less thans 1 %). Elsewhere the soils are predominantly brown to yellow or reddish yellow in colour, the A-horizons containing 3 to 25 % of clay (mostly 5 to 20 %). Based on these facts two soil associations were distinguished, viz. the *bleached* and the *non-bleached "dek" soils.* In general, this great difference in soil genesis is not obviously linked with variations in drainage conditions, which arise in either association.

Apparently, the strong bleaching only arises where the A-horizons contain less than 2 to 3 % of clay. Probably the difference between bleached and non-bleached soils was caused by a difference in the clay content of the parent material. Where this clay content had been already relatively low, it subsequently dropped below the critical value of 2 to 3 % owing to the eluviation of clay, and consequently bleached soils developed here. Where the original clay content had been relatively high, it has not (yet) dropped below the critical value afterwards; so non-bleached soils (still) occur here. Therefore, on the whole the soils of the two associations together would form a lithosequence (cf. 52).

Locally, the topography, ruling the drainage conditions, may have been the decisive factor of soil formation. Here, narrow strips of poorly drained, bleached soils occur, bordering on large areas of well drained, non-bleached soils relatively poor in clay, which may have developed from identical parent material.

Apart from the two soil associations mentioned, the soils of the marshy or swampy valley bottoms were grouped in a third association, the *creek valley soils.*

Ccb. Bleached "dek" soils.

The profiles of these soils present variations, which are related to the differences in drainage and vegetation. The latter may consist of:

a) a poor vegetation of mainly *grasses and Cyperaceae.* In the higher parts occur groups of shrubs; on the marshy spots groves of maurisi palms *(Mauritia flexuosa)* and sabanne kiskismakka *(Bactris sp.).* These "open" savannas were described before (23) and classified as the "Zandery" savanna type.

b) more or less dense *scrub* of mainly *Humiria* and *Clusia.* These scrub savannas were classified as the "Cassipora" type (23).

c) *savanna woodland* (see p. 37), with on the marshy spots the palm species obé *(Acrocomia sp.).* A particular facies is presented by the almost pure dakama *(Dimorphandra conjugata)* wood or forest.

d) evergreen seasonal *forest,* in which the walaba *(Eperua falcata)* dominates in the canopy. In this forest type occur only few palms, usually scattered specimens of the savanna maripa *(Maximiliana sp.?)* and koemboe *(Oenocarpus spec.).*

In the *open savannas* a sequence of well to poorly drained soils is observable. The well to imperfectly drained soils (classes 4-2) cover the greatest area. Their profiles present a thin top layer, only a few centimetres thick, which consists of white to light purplish grey, moderately coarse or coarse sand. Underlying it is a horizon, coloured dark brown to greyish brown, sometimes only light brownish grey, through the presence of organic matter. Conspicuous are the white (bleached) grains of quartz in this horizon, which, usually at a depth of 30 to 80 cm., gradually merges in white, (moderately) coarse sand. This A2-horizon often reaches down to 2 metres or more. That is why during our reconnaissances the underlying B-horizon was mostly not reached. Where we did strike upon it, it proved to be at a depth of 2 to 3 m., and to consist of a dark brown to black hardpan, 15 to 30 cm. thick. The organic matter had cemented the sand in here. In some places two, and rarely even three, similar ortstein pans were observed, the one above the other, and separated by layers of white sand. In all profiles observed the (lowest) pan was found overlying the weathered crystalline rock of the basal complex, sometimes separated from it by a layer of rounded gravel.

A smaller part of the open savannas is occupied by poorly drained soils (class 1). They occur in relatively low, distinctly marshy spots. Their surface presents the well-known kawfoetoes (hummocks). The thin white layer on the surface is absent here. The surface soil, rich in organic matter, consists of dark brown to black, often somewhat peaty, (moderately) coarse sand. Usually from a depth ranging from 50 to 100 cm. the white A2-horizon is found. These profiles are very wet for a part of the year.

Scrub savannas occur on soils that, at least in the upper metre of the profiles, are somewhat excessively drained (class 5). For the rest, in the main the profiles are similar to those of the well drained open savannas.

The *savannawood* too mostly occurs on soils, of which the topmost part is somewhat excessively drained (class 5). On the surface a 5 to 10 cm. thick layer of dark red matted or fibrous "mor" is often found. This is scarcely mixed with sand, and very rich in fine and larger roots. The A1-horizon consists of (moderately) coarse sand, through the presence of organic matter often characteristically coloured dusky red, in which, however, the white quartz grains are conspicuous. Further downwards the colour soon grows lighter, and usually at a depth of 40 to 80 cm. this horizon gradually merges in the white A2-horizon, which here too reaches a great depth, probably seldom less than 3 metres below the surface. In some places, however, at a depth of 60 to 90 cm., it is interrupted by a dark grey horizon, in which organic matter has accumulated. Underneath this illuvial horizon, the layer of white sand again continues downwards. The marshland savannawood occurs on soils similar to those of the poorly drained open savannas.

The *dakama wood* or *forest* occurs under drainage conditions varying between somewhat excessive and somewhat poor. The soils here are covered with a layer of loose litter, downwards merging in a more or less greasy "mor". This organic horizon often reaches a total thickness of 40 to 60 cm., which makes this forest type highly inflammable.

The *walaba forest* occurs under conditions equal to those of the dry land savannawood. Here, however, the "mor" layer, overlying the A1-horizon, is mostly absent.

The, on the whole, poor vegetation of the bleached "dek" soils primarily results from the unfavourable soil profiles. Presumably the strong drying-up process in the long dry season, from which all these soils commonly suffer, is the main cause of the normally mixed evergreen seasonal forest being lacking here. A second factor is the extreme poorness in plant nutrients of these soils. Moreover, the vegetation of part of the savannas may have changed through fires. Owing to these fires some savannas could extend at the expense of the surrounding savannawood or walaba forest.

As an example, below the description of a profile is given of the:

ZANDERY SERIES:

Land conditions: nearly level plain; dry land; drainage moderately good (clas 3).
Vegetation: poor state of mainly *Cyperaceae* (open savanna).
Profile:

A11	0—2 cm.,	white, loose, moderately coarse sand.
A12	2—30 cm.,	greyish brown, loose, moderately coarse sand, in which the white grains of quartz are conspicuous.
A13	30—55 cm.,	light brownish grey, loose, moderately coarse sand, gradually merging in
A2	55—285 cm.,	white, loose, moderately coarse sand.
Bh	285—305 cm.,	very dark brown, moderately coarse sand, cemented into a hardpan by organic matter.
Bu	305—310 cm.,	very dark brown, moderately coarse sand with rounded gravel, constituting the lower part of the hardpan.
D	310 cm. +,	greyish brown, non-sticky, plastic clay, rich in very fine mica plates. Weathered schist.

Ccn. Non-bleached "dek" soils.

The drainage of these soils is closely related to their textures, which may vary. Most of the non-bleached "dek" soils are moderately well to well drained (classes 3—4). Locally, however, there are soils with profiles of which the topmost 1½ metres consist of rapidly permeable, moderately coarse to coarse sand, poor in clay. The drainage here is somewhat excessive (class 5). Furthermore, especially along the northern boundary of the "dek" landscape, profiles are found with a slowly permeable subsoil rich in clay; these soils are somewhat poorly drained (class 2).

On the surface of the non-bleached "dek" soils often occurs a very thin (a few mm. to a few cm.) layer, consisting of pink to light (yellowish) brown, clayless, (moderately) coarse sand. In other places, however, this thin layer is absent.

The depth down to which the profiles are dark in colour, through the presence of organic matter, differs widely. In some places occur characteristic profiles which, down to 50 to 75 cm. or still deeper, are coloured grey to dark brown or dark yellowish brown by humus. In other places the humus colouring reaches a depth of only 10 to 20 cm.. There are also profiles with so little accumulation of organic matter that the surface soil colours are considerably lighter than the above-mentioned.

The texture of the surface soil is mostly whether or not loamy, moderately coarse to coarse sand, or (moderately) coarse sandy loam. In most profiles by far, downwards there is an increasing percentage of clay, while the colour grows lighter. Differentiation can be made between the profiles of red and those of yellow tinges. The colour of the subsurface soil in the one case fades into yellowish red or reddish yellow, in the other case into brownish yellow or yellow. The textures of these horizons usually vary between loamy (moderately) coarse sand and (moderately) coarse sandy clay loam.

The above-mentioned variation in colour continues in the subsoil, of which the upper boundary usually occurs from a depth ranging from 60 to 100 cm.. In some profiles this subsoil is light red or reddish yellow in colour; in others yellow, pale yellow or nearly white. The subsoil in the profiles rich in clay may be moderately to highly mottled, the colours of the mottles being red, light red or reddish yellow. The consistence and texture of the subsoil vary between friable (moderately) coarse sandy loam and very firm (moderately) coarse sandy clay.

Especially along the northern boundary of the "dek" landscape occur profiles with a subsoil showing the characteristics of a slowly permeable pan. In spite of their high positions (some 6 to 10 m. above the neighbouring swamps), these soils are somewhat poorly drained. The subsoil then consists of very to extremely firm sandy clay, highly mottled white (to grey), red (to light red) and yellow (to reddish yellow).

With those soils where the surface soil contains less than about 5 per cent. of clay, downwards there will be either none or but slight increase in the percentage of clay. The surface horizon of these poor-in-clay profiles usually presents but a small accumulation of organic matter. It is often brown, greyish brown or light yellowish brown in colour. Often some bleaching of the quartz grains is observable, in which cases the soils are transitional between the bleached and the non-bleached "dek" soils. The deeper lying horizons are usually light red, reddish yellow or brownish yellow in colour. Even at a depth of, for instance, 1½ m. the texture is still (moderately) coarse sand or, at best, loamy ditto sand. These soils are somewhat excessively drained.

The natural vegetation of the non-bleached "dek" soils, consisting of evergreen seasonal forest, has often developed very luxuriantly. As was mentioned before by Heinsdyk (42), the abundant occurrence of the giant tree wane *(Ocetea rubra)* often gives this forest its specific character. The basralocus *(Dicorynia paraensis)* too may be present in great numbers. Other regularly occurring tree species are: the foengoe koko *(Licania)*, djadjidja *(Sclerolobium melenonii)*, kopi *(Goupia glabra)*, several kwarie species *(Qualea)* and injipipa *(Couratari)*, the latter being conspicuous for its bigness. The walaba *(Eperua falcata)* is abundant locally, especially on the somewhat excessively drained soils poor in clay. On the soils richer in clay this tree type may be altogether absent. On the soils rich in clay the palm species growing in the lower story of the forest, are especially the paramakka and boegroemakka *(Astrocaryum paramacca* and *sciophilum* respectively). On the soils poor in clay the main palm species is the savanna maripa *(Maximiliana?)*.

In some places occur open savannas on non-bleached "dek" soils. They were classified as the "Coesewyne" savanna type (23). These savannas are of man-made origin. They have resulted from the shifting cultivation, because the forest did not recover from repeatedly being burnt down.

Two frequent soil series are the following:

COESEWYNE SERIES:

Land conditions: nearly level terrain; dry land; drainage moderately good (class 3).
Vegetation: luxuriant evergreen seasonal forest.
Profile:

A11	0—1 cm.,	light brown, loose, moderately coarse sand.
A12	1—60 cm.,	dark brown, friable, moderately coarse sandy loam.
A2	60—85 cm.,	reddish yellow, firm, moderately coarse sandy loam.
B	85—165 cm.,	light red, very firm, moderately coarse sandy clay, with some red and yellow mottles.
C	165 cm. +,	reddish yellow, firm, moderately coarse sandy clay loam, with few light red mottles.

COSTERI SERIES:

Land conditions: nearly level terrain; dry land; drainage good to somewhat excessive (classes 4-5).
Vegetation: rather poor, evergreen seasonal forest.
Profile:

A1	0—15 cm.,	yellowish brown, loose, coarse sand.
A2	15—65 cm.,	brownish yellow, loose, coarse sand.
A3	65—135 cm.,	yellow, loose, coarse sand.
B	135 cm. +,	reddish yellow, very friable, loamy coarse sand.

Cv. Creek valley soils.

The largest creeks of the "dek" landscape run through rather wide and deep valleys; the smaller creeks and tributary streams through narrow undeep gullies. This soil association includes all soils occurring in the narrow strips of young alluvium or colluvium along these creeks. Mainly owing to seepage from the adjacent areas, lying on a higher level, these strips consist of swamp or marshland. All these soils are very poorly to poorly drained (classes 0—1). Almost everywhere these wet conditions have caused a strong accumulation of organic matter. Further the profile characteristics of the creek valley soils depend on the material deposited in these valleys, either by the creeks or as colluvial wash. In a great many places this material consists of completely bleached, moderately coarse to coarse sand. In those places which are submerged throughout the year or a great part of it, a layer of dark (reddish) brown fine "muck" has formed over this sand. The thickness of this organic layer may vary widely, for example from 10 to 20 cm. to over 1 metre. Underneath this muck the sand is dark brown to greyish brown in colour through the presence of organic matter, but the quartz grains themselves are white. Downwards this dark coloured sand gradually merges in light grey to white, mostly coarse to very coarse sand, sometimes rich in gravel.

In the only seasonally flooded places no layer of organic "muck" has formed on the surface. The sand here, mostly down to a depth ranging from 20 to 70 cm., is also dark brown or black in colour through the accumulation of organic matter. Here again this layer dwonwards merges in light grey to white sand.

Those creeks which run, whether entirely or partly, through the (clay containing) non-bleached "dek" soils, have deposited in their valleys not only sand, but, from time to time and locally, also material of a heavier texture. Accordingly, in the marshland strips along the creeks, the textures of the surface soils, as well as those of the substrata, may vary widely, and rather independently of each other. The dark brown surface soil may consist of coarse sand, or of sandy loam, sandy clay or even clay. In each of these cases the substratum underneath may vary between white coarse sand and light grey to pale yellow, sandy loam or sandy clay. Eventually there are also profiles completely consisting of clay, which down to a considerable depth may be rich in organic matter.

In so far as the creek valleys consist of swamps with muck-over-sand or mucky clay profiles, they will bear a vegetation of swamp forest. In this forest the matakki *(Symphonia globulifera)* is the principal tree species, while pina palms *(Euterpe oleracea)* mainly from the lower story.

The marshland strips, with their profiles of bleached coarse sand, mostly have a savanna-woodland-like vegetation, with many obé palms *(Acrocomia)*. In the open savannas of the bleached "dek" soils, the marshland strips are characterized by a vegetation of scrub, savanna kiskismakka *(Bactris)* and groves of maurisi palms *(Mauritia flexuosa)*.

In the marshland strips with soils consisting of loam or clay, marshland forest will be found, in which usually the oemabarklak *(Eschweilera corrugata)* abounds.

To give an example, below a description will follow of the frequent:

BLAKKAWATRA SERIES:

Land conditions: narrow strip of swamp along creek; drainage very poor (class 0).
Vegetation: swamp forest.
Profile:

A0	65 cm.,	dark reddish brown, fine organic "muck".
A1	0—40 cm.,	dark brown, moderately coarse sand, rich in organic matter. The quartz grains totally bleached. This layer very gradually merges in.
A21	40—65 cm.,	light brownish grey, moderately coarse sand.
A22	65 cm +,	light grey, gravelly, very coarse sand.

C. SOUTHERN BELT.

LANDSCAPES WITH MAINLY SOILS FROM RESIDUAL PARENT MATERIALS.

Broadly speaking, this belt stretches south of the "dek" landscape. It occupies all of the remaining part of Surinam, so six sevenths of the country.

In contrast with the two belts dealt with before, the principal elements of the landscapes in this southern belt are not built up by the deposition of loose sediments, but they have developed from solid crystalline rocks. So the parent materials of the soils of these landscape elements have *in situ* formed from these rocks. Almost everywhere this transformation took place through a lateritic weathering process, reaching down to a great depth. The soils that developed here, are generally rich in ironstone gravel. Consequently they are designated as "laterite soils", which name, however, does not refer to a "great soil group". In these landscape elements, besides the ironstone gravel, a hard laterite surface crust or large loose laterite boulders may occur locally. In the Guianas the ferruginous material, of which these crusts and boulders consist, is referred to as "ferrite" (cf. 53).

The rock formations, from which the landscapes of this belt have developed, belong to the "crystalline basement" and the "younger instrusives" (cf. p. 33). So the abovementioned laterite formation has taken place on geologically old formations (precambrian to Mesozoic); a phenomenon observed in many parts of the world (cf. 65, 74). Both the morphology of the diverse landscapes and the properties of their soils, are related to the nature of the rock formation involved. Altogether six landscapes were distinguished in this southern belt, conveniently grouped as follows: *dolerite dikes, granite landscapes* and *schist landscapes* (see table 2, appendix III).

In the area under consideration, so that part situated north of 5° N.lat., the schist landscapes cover the largest acreage by far. They occupy almost the entire eastern part of this belt, so the area between the rivers Tibiti and Marowyne. In the smaller western part, situated between the rivers Upper Nickerie and Tibiti, the granite landscapes predominate. The dolerite dikes have but a small acreage; they mainly run through the (eastern) schist area.

9. DOLERITE DIKES.

The dolerite dikes manifest themselves partly in very long-drawn narrow hills, partly in frequently interrupted ranges of more or less long-drawn hills. They stretch in an almost north-south direction, and may extend over some tens of kilometres. Usually the dikes are steep and in height they range from some tens to about 100 metres. Amidst the surrounding schist or granite hills the dolerite dikes are often conspicuous for their greater height.

Geologically the dolerite dikes belong to the younger intrusives. They are supposed to be of Mesozoic (post-Triassic) age.

The soils of the dolerite dikes were classified as the association:

DI. Dolerite laterite soils.

Despite the steep slopes these soils have a medium run-off, owing to their dense forest vegetation and moderate permeability. The internal drainage too is medium. In the whole these soils are well drained (class 4).

Ironstone gravel, mostly in the shape of glossy round beans, nearly always abounds on the surface. In addition there are often many laterite cobbles and stones; the latter may be a cubic metre or more in size. In some places the laterite cobbles form one uninterrupted layer on the surface.

The profiles usually have a surface soil, which, down to a depth of 5 to 20 cm. is coloured brown to (dark) reddish brown through the presence of organic matter. This surface soil consists of very friable clay, as a rule very rich in ironstone beans. Sometimes this gravel constitutes the main substance, the spaces in between being filled up with clay. There are places in the surface soil where no accumulation of organic matter is noticeable at all; so here the A1-horizon is absent.

The subsurface soil usually consists of yellowish red, red or dark red, friable clay. As a rule this horizon too is still rich in ironstone gravel. Mostly from a depth of 40 to 80 cm. downwards the profiles show a still redder colour ("hue"); this may vary between light and dark red. This subsoil also consists of friable clay. Downwards a clear decrease in the percentage of ironstone gravel is often observable. The parent rock of the dolerite dikes is only found at a depth of several metres. A remarkable fact is that in some dikes on the surface, besides the before-mentioned laterite stones, numerous loose boulders of non-weathered dolerite are found as well. These boulders often present a characteristic rounded prismatic shape.

As to the ironstone gravel and cobbles now occurring on the surface, it may be assumed — in accordance with the most current opinion (cf. 65, 74, 76) — that they have formed at some depth in the profile. The originally overlying horizons have disappeared through erosion. Subsequently continued erosion resulted in the accumulation of the ironstone gravel on the surface. The same process took place with the boulders of fresh rock now on the surface. These boulders remained intact during the weathering of the surrounding rock material.

The vegetation of the dolerite dikes consists of highly mixed evergreen seasonal forest. On some dikes this forest has developed very luxuriantly.

Typical soil profiles are offered by the

LUCAS SERIES:

Land conditions: high and steep dolerite dike; drainage good (class 4).
Profile: the surface abundant in ironstone gravel (beans) and laterite cobbles; numerous boulders of fresh dolerite.

A1	0—15 cm.,	reddish brown, very friable gravelly clay, the gravel consisting of rounded-off, smooth ironstone beans.
B2	15—70 cm.,	yellowish red, friable gravelly clay. A very high percentage of ironstone beans in the higher parts, gradually decreasing downwards from 50 cm.
B3	70 cm. +,	Red, friable clay. Percentage of ironstone beans further decreasing.

10. GRANITE LANDSCAPES.

These landscapes have developed on granito-dioritic rocks of variable composition. These rock formations belong to the "crystalline basement", and they are of pre-cambrian age. In the area where soil investigations took place (i.e. east of the river Tibiti), they cover but a a small acreage. Here distinction was made between two landscapes, which morphologically as well as pedologically differ widely.

The first landscape to be dealt with includes level to gently undulating terrains. The soils occurring in these areas are not red in colour, nor do they contain ironstone gravel. They were grouped in the following association:

Gy. Granite yellow earths.

As a rule these soils are moderately well drained (class 3). Through the presence of organic matter the profiles are brown to dark brown in colour, usually down to a considerable depth, e.g. 40 to 70 cm.. In some places, however, the dark colouring goes much less deep. The texture of the surface soil is mostly loamy coarse sand or coarse sandy loam. Downwards the colour grows lighter and the texture heavier. In some places the subsoil is reddish yellow or yellow in colour, whereas in other places it is pale yellow, very pale brown or almost white. Owing to the variable proportion of quartz in the parent rock the texture of the subsoil may vary widely. The latter mostly consists of (coarse sandy) clay loam or (coarse sandy) clay.

A striking feature of these soils is that from variable depths downwards they are mica-containing. Fine colourless mica plates may already be found in the subsurface soil. The subsoil usually contains both fine and coarser colourless and/or black mica plates, sometimes in very large quatities.

The parent material that is found, for example, from 1½ m. downwards entirely shows the structure of the parent rock (granite, gneiss or diorite). The feldspar crystals of the rock are *in situ* quantitatively converted into white kaolin-like clay. The quartz and (predominantly black) mica crystals are embedded in this ground mass.

The natural vegetation of the granite yellow earths is normal evergreen seasonal forest.

A typical soil profile is that of the

PHEDRA SERIES:

Land conditions: gently undulating plain; drainage moderately good (class 3).
Profile:

A1	0—50 cm.,	brown, friable, coarse sandy loam.
A2	50—75 cm.,	light brownish grey, friable, coarse sandy loam, with fine colourless mica plates.
B	75—145 cm.,	yellow, firm, coarse sandy clay, with yellowish red and light red mottles; rich in colourless mica plates.
Cg	145 cm. +,	white, friable, coarse sandy clay rich in mica plates. In the upper part of this layer many yellow and light red mottles; mica colourless. From about 350 cm. downwards no mottling any more; mica black.

The other granite landscape mainly comprises numerous hills. The latter are seldom higher thans some tens of metres, while their slopes are moderately steep. Probably they have developed through the dissection of an old-tertiary peneplain (cf. p. 86). In contrast with the previous group the soils of these hills are red in colour, and may contain ironstone gravel. They were referred to — perhaps somewhat inaccurately — as the association:

Gl. Granite laterite soils.

These soils are well drained (class 4). On the surface ironstone gravel may abound. These concretions are often partly made up of quartz grains, cemented by iron oxides. In other cases the ironstone gravel is altogether absent. This difference is probably caused by variations in the composition of the parent rock. This, to a certain extent, would be in accordance with the conclusion to which Hardy and Follett Smith (40) came, that in British Guiana the acid rocks, like granite, do not yield laterite.

The surface soil, often showing whether none or but little accumulation of organic matter, is mostly reddish yellow or yellowish red in colour. Downwards the colour grows increasingly redder, the subsoil being red or light red in colour. The profiles as a rule have a homogeneous texture of (coarse sandy) clay loam or (coarse sandy) clay. These soils too, often contain much mica, in the upper horizons in utterly fine fragments, at a greater depth in fine and somewhat coarser black plates.

These granite hills often have a vegetation of low, poor evergreen seasonal forest.

Profiles without ironstone gravel are found with the

MAIKABOEKA SERIES:

Land conditions: low, moderately steep hill; drainage good (class 4).
Profile:

A1	0—4 cm.,	brown, very friable, coarse sandy clay loam.
B1	4—35 cm.,	yellowish red, friable, coarse sandy clay loam; rich in extremely fine mica fragments.
B21	35—80 cm.,	light red, friable, coarse sandy clay loam, rich in black mica plates.
B22	80 cm. +,	red, friable, coarse sandy clay loam, rich in black mica plates.

11. SCHIST LANDSCAPES.

These landscapes almost entirely cover that part of the southern belt situated east of the river Tibiti. The metamorphic rock formations, from which these landscapes have developed, belong to the "crystalline basement", and they are of pre-cambrian age.

Distinction was made between three landscapes, widely different in morphology, soil conditions and vegetation. This grouping in the main proved to correspond to the three main groups, in which these rock formations were subdivided, namely the Rosebel and Maäbo schists (together constituting the Orapu formation) and the Balling schists (cf. p. 33).

From the Orapu formation two landscapes have developed, viz. the *subgraywacke landscape* in the Rosebel area and the *schist hill landscape* in the Maäbo area. Near Bosland on the river Suriname, however, occur to small areas of the Balling formation, which in the main also belong to the schist hill landscape. As against this, from the rest of the Balling formation the *schist mountain landscape* has developed. In this third landscape, for that matter, locally also occur Maäbo schists.

THE SUBGRAYWACKE LANDSCAPE.

This landscape presents itself most characteristically in that area which is situated E of the river Saramacca, S of Santigron. The soil association map (appendix I) does not cover this landscape; therefore it will not be dealt with in this thesis. For descriptions be referred to two former publications (23, 29).

THE SCHIST HILL LANDSCAPE.

North of 5° N lat. this is by far the most important landscape of the southern belt. It extends almost uninterruptedly from the river Suriname to the Marowyne, while a part of the belt, between the Suriname and the Upper Nickerie, also belongs to this landscape.

The principal element of this landscape is made up by the *schist hills*. The majority of them range in height from less than ten metres to about sixty metres. Their slopes are mostly moderately steep to steep, their tops being dome-shaped or pointed. A number of hills, however, reach greater heights, the maximum being about 200 metres. These higher hills often occur in groups. They mostly have steep or very steep slopes and dome-shaped summits. A few of these higher hills, however, have flat tops. The latter form relatively small, almost horizontal plateaux, covered with a more or less uninterrupted laterite ("ferrite") surface crust. The brinks of these ferrite caps form almost vertical escarpments in some places four metres or more in height. On the slopes of these ferrite-capped hills big loose ferrite boulders abound.

The ferrite caps are composed of a conglomerate of ironstone pisolites, cemented by hard ferruginous material. In between, however, very hard and massive lumps of limonite may occur. The ferrite caps are generally very porous. As was already stated by Bleys (14) a good deal of the rain water runs through and collects underneath the caps. Thus underground creeks develop, emerging at the edges of the plateaux from under the ferrite caps.They carry away the clay from under the caps, where, in consequence, they form grottos, which undermine the caps. This again results in the crumbling away of the ferrite caps along their edges. Thus the very steep escarpments have formed on the brinks of the plateaux. The ferrite boulders occurring on the slopes and in the small ravines at the feet of the plateaux are the remnants of the crumbled-off ferrite caps, which originally must have been much larger in size.

Similar plateaux with laterite caps occur in may parts of the world (cf. 65, 74, 76). It is generally assumed that the present surface crusts have developed at a certain depth under the influence of fluctuating ground-water. This development is supposed to be confined to peneplain conditions of poor drainage. After a relative land-rise, resulting in a fresh erosion process, the ferruginous hardpans are believed to have come on the surface.

According to this hypothesis the Surinam schist hills with their ferrite caps may be regarded as the last remnants of a peneplain, which had stretched over a large part of the Guianas. Probably not everywhere in this peneplain did a ferruginous hardpan form, but a number of scattered occurences of more or less local significance developed. It is possible that these laterite hardpans developed in the same peneplain as the British Guiana bauxite layers, classified by Van Kersen (53) as the "Low level bauxite". According to Bracewell (18) the latter bauxite, developed *in situ* from the bedrock, once formed part of a peneplain, large parts of which disappeared through erosion. In a later period the remnants were covered with sediments of the White Sand series (= Zandery formation). From the above Van Kersen drew the conclusion that this bauxite is of old or middle tertiary age, which, mutatis mutandis, might also apply to the laterite crusts of the Surinam schist hills.

The countless hills and hillocks of the present schist hill landscape have developed from this (old tertiary) peneplain as a result of intense dissection. The exposed laterite crusts went on crumbling away owing to their being continuously undermined. It is only the few high plateaux existing at the present time that have withstood the destruction. In those places where in between the schists, granito-diorites are embedded, the granite hills developed, dealth with on p. 84.

In the upper metres of their profiles the schist hills are made up of the residual weathering product of the schists. Apart from the ironstone and/or quartz gravel occurring in certain horizons, usually 40 to 70 % of this material consists of clay. (see fig. 12). It contains 10 to 30 % of silt and 5 tot 50 % of fine to moderately coarse sand, the median of the sand ranging from 100 to 300μ (mostly 150 tot 200 μ).

The second element of the schist hill landscape is constituted by the *foot plains*. They are level or nearly level terrains, which are classified partly as dry land, partly as marshland. Within the schist hill landscape proper the foot plains are mostly but relatively small areas, lying all around the hills. Northwards, however, the aspect of the schist hill landscape gradually changes towards the much more level "dek" landscape. Here, the large schist hill complexes gradually merge in terrains with scattered separate hillocks, the foot plains in between the latter covering increasingly larger parts of the landscape. Along the northern boundary of the schist hill landscape the foot plains eventually form an uninterrupted strip, up to a few kilometres wide, where only here and there a minute schist top emerges. Similar terreins also occur locally within the schist hill landscape proper, like more or less basin-shaped terrains surrounded by hills.

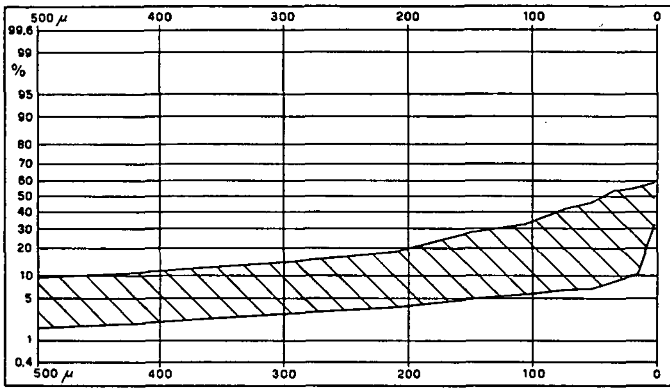

Fig. 12. Bundle of 8 grain-size summation-curves of schist laterite soils (A- and B-horizons).

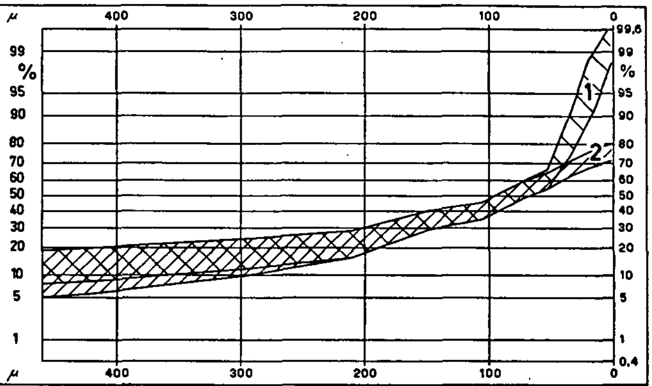

Fig. 13. Two bundles of 6 grain-size summation-curves each, of foot plain soils (A-horizons)
1 = strongly podzolized *Bosland* series
2 = not podzolized soils.

The foot plains are built up of colluvial and alluvial material, which has come from the schist hills. Normally 45 to 70 % of this material consists of poorly assorted sand, median 100 tot 300 μ (mostly 150 to 200 μ). It contains 10 to 45 % of silt and up to 30 % of clay (see fig. 13). As compared with the residual weathering product of the schists, a relative enrichment of sand and a decrease of the proportion of clay can be ascertained. Of the residual material, brought down from the hills by the surface run-off and via gullies, it was especially sand and silt that was deposited at the feet of the hills, and but little clay.

The colluvial deposit, however, is only thin. In most places it is but ½ to 1½ m. thick; a thickness of over 2 metres is rare. The deposit lies over the residual weathering product of schists, which here is composed of kaolin-like material.

In most places in between the colluvial deposit and the residual "kaolin" occurs a boundary layer, made up of very coarse sand and/or gravel. This gravel has formed from the numerous quartz veins running through the original rock. In the period preceding the deposition of the colluvium, these veins were naturally also exposed according as the valleys between the hills deepened and widened. Owing to continued erosion the quartz gravel arisen from the exposed veins, accumulated on the surface of the weathering material of the schists, and spread like a more or less uninterrupted "erosion pavement" all over these low lands in between the remaining hills. In a later period the colluvial and alluvial material, at the present time occurring on the surface of the foot plains, was deposited over this layer of gravel. In the largest foot plains emerge small outcrops of the residual subsoil, which are not covered with colluvium. The same quartz gravel lies on the surface here.

The entire schist hill landscape is dissected by a great many small and big creeks. They form a dendritic drainage pattern. Along almost all creeks a narrow strip of marshland is found, lying on an even slightly lower level thans the adjacent foot plains. These marshland strips were designated as the *creek valleys;* they are the third element of the schist hill landscape.

For some time of the year these creek valleys are flooded. They consist of young alluvial material, deposited by the creeks. From the foot plain to the creek valley a distinct descent of about 1 to 2 metres is observable in many places.

In accordance with the above, three soil associations were distinguished in the schist hill landscape, viz.: the *schist laterite soils* in the hills, the *foot plain soils* in the colluvial plains around the hills, and the *creek valley soils* in the marshland strips along the creeks.

Sl. Schist laterite soils.

Owing to the dense vegetation and the moderate permeability of these soils, they mostly have a medium run-off, despite the steep slopes. The internal drainage being medium too, the soils are generally well drained (class 4).

Although almost everywhere the profiles contain much ironstone gravel at some depth, in many places this gravel is altogether absent on the surface and in the upper horizon(s). In other places, however, ironstone gravel already abounds on the surface, mostly in the shape of more or less rounded-off smooth pisolites. A small proportion of the ironstone pebbles, however, is more angular in shape, and displays a distinct very fine layering, in which the structure of the original rock is still visible. Especially overlying the crests of the hills there may occur a continuous layer of bigger laterite cobbles and stones, made up of a conglomerate of pisolites, cemented by ferruginous material. Further, locally much angular-shaped quartz gravel is found on the surface, originating from the numerous quartz veins which run through the rock. Besides, large quartz boulders are found as well. Big laterite boulders mainly occur on the slopes of the few hills bearing an uninterrupted laterite cap. In all these cases the surface soil too, contains a high percentage of ironstone gravel, whether or not mixed up with quartz pebbles. The percentage may be so high that the gravel makes up the main mass, the spaces in between being filled up with brown (fine sandy) clay.

The surface soil of the — probably even more frequent — profiles which contain ironstone gravel only at some depth, is usually brown or reddish brown in colour through the presence of organic matter. However, the dark colouring mostly does not reach deeper thans 5 to 15 cm.. In some places no accumulation of organic matter is observable at all, so that in these cases there is no A1-horizon. The surface soil mostly consists of very friable, fine sandy clay, clay loam or clay.

The subsurface soil may vary in colour from strong brown or reddish yellow to red or dark red, and as a rule consists of very friable clay loam or clay. In many places, already immediately beneath the A1-horizon, this subsurface soil is rich in ironstone gravel. In other places there is first a gravelless subsurface horizon. This, however, will seldom reach deeper than 40 to 50 cm., below which depth in these profiles too ironstone arises. Furthermore, the subsurface soil often contains extremely fine sericite plates, through which the clay feels somewhat "greasy".

Downwards the profiles grow redder in colour. Normally the subsoil is red or purplish red, in some places yellowish red in colour, while it also consists of friable clay loam or clay. Below 40 to 100 cm. the profiles mostly do not contain ironstone gravel any more. However, there is often an increasing percentage of sericite, owing to which the subsoil feels very "greasy", and displays a "silky" gloss. At a great depth, for example 2 metres or more, the profiles are usually highly mottled with purple, red, yellow and white. Here again the friable clay often contains a great many extremely fine sericite plates.

From the above it appears that the depth of the ironstone gravel layer, which occurs almost everywhere, may be somewhat variable. In normal profiles the upper boundary of this layer will lie between 0 and 40 cm., its lower boundary between 40 and 100 cm.. Consequently, as this gravel in many cases does not occur on the surface, it cannot possibly be a remnant of the ferrite caps, dealt with before, the disintegration of which took place only after their being exposed. Obviously the gravel formed in a later period than that in which the ferrite crusts arose; so it must be the product of a younger weathering cycle. At some depth in the profile the rounded-off, smooth pisolites have developed as concretions, from unconsolidated weathering products. The angular, layered iron pebbles, however, evidently have formed directly from rock fragments, in which *in situ* the iron containing minerals are converted into iron oxides.

The gravel layer, which in many places has not yet been exposed by erosion, does occur within the root zone of the forest vegetation. The proces of exposure is at present accelerated by trees being blown down. Whenever this happens, the gravel occuring amid the root system, is brought up together with fine earth. The fine earth is washed out and away by rain; the gravel is left behind and accumulates on the spot on the surface. Innumerable mounds of ironstone indicate the places where in former days trees had fallen.

The vegetation of the schist hills is highly mixed evergreen seasonal forest. Heinsdyk (42) divided this forest into two associations. In the one association the tree species walaba *(Eperua falcata)* abounds; in the other one it is absent. The two barklak species *(Eschweilera longipes* and *corrugata)* and the basralocus *(Dicorynia paraensis)* regularly occur in either association. The walaba-barklak-basralocus association covers by far the largest acreage; the barklak-basralocus association forms but a narrow strip along the northern boundary of the schist hill landscape.

For forestry purposes Heinsdyk subdivided both associations in a number of forest types, in which, besides the trees mentioned, one or more of the following tree species are frequent: kopi *(Goupia glabra)*; injipipa (*Couratari spp.)*, several kwarie species *(Qualea spp.)*, yzerhart *(Swartzia spp.)*, wane *(Ocetea rubra)*, salie *(Tetragastris sp.)* and djadjidja *(Sclerolobium melenonii)*. The palmspecies of this forest are especially the paramakka *(Astrocaryum paramacca)* and the boegroemakka (*Astrocaryum sciophilum)*.

On the small plateaux covered with ferrite caps, a low savana-wood-like vegetation is found.

Characteristic soil profiles are offered bij the

TEMPATI SERIES:

Land conditions: steep hill; drainage good (class 4).
Vegetation: evergreen seasonal forest ("Eperua-Eschweilera-Dicorynia association").
Profile:

A1	0—10 cm.,	reddish brown, very friable, fine sandy clay.
B1	10—25 cm.,	yellowish red, very friable clay.
B2	25—70 cm.,	red, very friable, gravelly clay. The gravel consists of irregularly shaped, smooth ironstone pisolites. A small proportion of minute sericite particles, the proportion increasing downwards.
B3	70 cm. ±,	red, friable clay, rich in extremely fine sericite particles. It feels greasy, and displays a silky gloss.

Sp. Foot plain soils.

The run-off of these level terrains is slow or very slow. Owing to a relatively lower or higher position, and the whether or not occurrence of slowly permeable layers in the profiles, the internal drainage varies widely, namely from very slow to medium. On the whole most of the soils are poorly or somewhat poorly drained (classes 1-2); a minor part is moderately well drained (class 3).

These variations in drainage have caused considerable differences in the development of the profiles. The poorly drained soils are highly podzolized; according as the drainage conditions are better, podzolization arises to a less extent or not at all.

Not only did the variations in drainage conditions result from the differences in the relative elevations between the soils, but also from the variations in the textural composition of the parent material. In the highly podzolized profiles the A-horizons contain less than 5 % of clay and 30 tot 45 % of silt; in the slightly or non-podzolized profiles these horizons contain 20 to 30 % of clay and only 10 to 20 % of silt. In both cases the content of sand ranges from 45 to 70 % (see fig. 13). These considerable differences in texture cannot have been brought about exclusively by the eluviation of clay in the highly podzolized soils; they must largely already have existed in the colluvial parent material. Apparently, owing to the high ratio between the percentages of silt and sand of the poor-in-clay colluvium, a compact horizon of a very close packing could develop closely above the residual "kaolin". Through the very slow permeability of this layer the drainage became so poor as to cause the strong podzolization.

The depth at which the slowly permeable residual "kaolin" occurs, has a similar influence on the drainage conditions and the profile development, though to a less extent. The colluvial deposit over this "kaolin" may vary in thickness between c. 50 cm. and over 2 m.. In the later case the soils are moderately well drained, and only slightly or not podzolized.

With the poorly drained soils a 5 to 10 cm. thick layer of reddish brown organic "mor" may occur on the surface; however, often this A0-horizon is absent. The proportion of organic matter in the surface soil is widely variable. This horizon may be (dark) brown or (dark) greyish brown in colour; in many profiles, however, it is only light brownish grey or pale brown in colour. The surface soil mostly consists of fine sandy loam, as a rule reaching down to 15 to 40 cm.. The underlying horizon is highly bleached, and usually grey to white in colour. This horizon too is mostly made up of fine sandy loam. Especially its lower part presents a very close packing and a compact consistence, but the consistence of the material is friable, once dug out. Probably, this compact layer complies with the definition of a "fragipan" (cf. 83 p. 243).

At a depth ranging from 40 to 90 cm. the profiles usually show a strong, at least distinct, illuviation of organic matter and/or iron compounds, through which in many places a hard ortstein pan has formed. Its upper part mostly consists of a dark (reddish) brown pan 10 to 30 cm. thick, cemented by organic matter. In other places this upper illuvial horizon consists of non-cemented dark brown or greyish brown "silt loam". The lower part of the pan is in the main cemented by iron oxides; it is mostly 5 to 20 cm. thick, and (reddish) yellow in colour, or highly mottled yellow, brown and grey. This latter iron pan may also occur in those profiles in which the overlying horizon, though dark brown through the illuviation of humus, is not cemented. In other profiles, on the contrary, it is the yellow lower pan that is absent. The high "silt" percentage of these illuvial horizons has presumably resulted from the colluvial material having mixed with the underlying residual weathering product of the schists. Owing to this mixing these horizons may also abound in fine sericite particles.

In some profiles, underlying the ortstein pan, first may arise a light (brownish) grey or pale yellow horizon, also consisting of "silt loam". Usually this horizon gradually merges in the very coarse sand and gravel containing boundary layer, which lies over the kaolin-like weathering product of the schists. In other places the illuvial horizons lie directly over the coarse sandy layer. Often this boundary layer too is absent; the pan will then occur directly overlying the residual "kaolin".

The latter is mostly found from a depth ranging from 70 to 130 cm.. It is usually mottled white (to pale yellow) and (yellowish) brown, and in many cases contains much fine sericite.

With the less poorly drained soils the surface soil is usually coloured (dark) brown to (dark) greyish brown through the presence of organic matter. This horizon varies widely in thickness; it mostly reaches 15 to 40 cm., however, it may even reach 50 to 60 cm..

With the still somewhat poorly drained soils the following horizon is more or less bleached. It may vary in colour from (light) grey or light brownish grey to (very) pale brown or pale yellow. With the moderately well drained soils, however, it is usually yellow or brownish yellow in colour, in some places even yellowish red. With the former soils these horizons mostly have a texture of fine sandy loam or loam; with the latter the texture is often fine sandy clay loam.

Down from 40 to 100 cm. a gradual merging in the residual substratum is often observable. This merging is characterized by an increasing addition of coarse or very coarse sand, here and there together with quartz gravel. This transitional layer usually has red or reddish yellow mottles, while fine sericite particles may already occur in here.

The underlying boundary layer itself, mainly consisting of very coarse sand and/or quartz gravel, is mostly found from a depth of 50 to 110 cm. downwards. It may vary in thickness from less thans 10 to over 50 cm.; in some profiles, however, it may be altogether absent. The sand and gravel may to a high degree be mixed with a kaolin-like material; the layer then being pale yellow or yellow in colour, mottled with red and reddish yellow. This mixture often contains a good deal of fine sericite. Close to the schist hills, ironstone gravel may occur in this boundary layer.

Eventually, the residual weathering product of the schists is mostly found from a depth of 70 to 130 cm. downwards; with the moderately well drained soils it may lie at a greater depth, e.g. 150 to 200 cm.. It is usually white, but it may be very pale yellow in colour, often mottled with red and reddish yellow. In its upper part there is often still some coarse sand and/or gravel, which is not the case at greather depth. The material gives a kaolin-like impression. It usually feels "greasy" because of the great proportion of fine sericite it contains. This percentage may be so high as to give the material a "silky" gloss. According to the granular analyses, the texture is "silt loam", the proportion of "silt" amounting to 70 to 85 %. However, presumably these analyses results are influenced by the fine sericite plates, the ratio between silt and clay, in fact, being much lower. Wherever this suspicion arose, in the above the terms silt and silt loam have been put between quotation marks.

The vegetation of the foot plains varies widely. On the poorly drained, podzolized soils with ortstein pans savanna wood, scrub savannas or open savannas are found. The latter were classified as the "Bosland" savanna type (23). These types of vegetation also arise on podzolized soils without ortstein pans, if the slowly permeable residual "kaolin" lies at a small depth.

The somewhat poorly drained soils have a vegetation of mixed evergreen seasonal forest. In these forests grow in the main the same tree species as in the adjoining forests of the schist hills. The trees, however, being thin and not high, form but one story. This gives the forest a somewhat savanna-wood-like aspect. The undergrowth is characteristic; it mainly consists of maripa palms *(Maximiliana maripa)*, paloeloe *(Ravenala guianensis)* and pingowierie, while the obé palm *(Acrocomia sp.)* occurs locally. On these soils complexes of walaba *(Eperua falcata)* forest are also found.

The moderately well drained soils, little or non-podzolized, bear evergreen seasonal forest, which hardly differs from that of the adjacent schist hills (see p. 89).

Two characteristic soil profiles are the following:

BOSLAND SERIES:

Land conditions: level marshland plain amidst schist hills; drainage poor (class 1). Surface with "kawfoetoes" (hummocks).
Vegetation: scrub savanna.
Profile:

A1	0—30 cm.,	greyish brown, very friable, fine sandy loam.
A21	30—45 cm.,	white, very friable, fine sandy loam.
A22	45—65 cm.,	white, fine sandy loam of very close packing. This "fragipan" has a compact consistence, but, once dug out, the material is of a very friable consistence.
B2h	65—85 cm.,	dark reddish brown hardpan, consisting of sericite containing "silt loam", cemented by organic matter.
B2ir	85—95 cm.,	reddish yellow hardpan, consisting of sericite containing "silt loam", cemented by iron oxides. Many brown and grey mottles.
D	95 cm.+,	mottled white and brown, kaolin-like "silt loam", rich in sericite; feels greasy and displays a silky gloss. Some very coarse sand in the upper part.

ANJOEMARA SERIES:

Land conditions: level plain; dry land to marshland; drainage somewhat poor (class 2).
Vegetation: poor, low, evergreen seasonal forest; in the undergrowth many maripa palms, paloeloe and pingowierie.
Profile:

A1	0—25 cm.,	brown, friable loam.
A2	25—60 cm.,	light brownish grey to pale yellow, friable loam.
AD	60—80 cm.,	pale yellow, friable, very coarse sandy loam, with reddish yellow mottles.
D1	80—110 cm.,	light grey, loamy and gravelly very coarse sand, mottled with yellow and reddish yellow. It contains some fine sericite. It gradually merges in
D2	110 cm., +,	white kaolin-like "silt loam", rich in sericite; many reddish yellow and few red mottles. It feels greasy and has a silky gloss.

Sv. Creek valley soils.

These soils, occurring in the strips of marshland along the creeks, are submerged in the rainy season. Generally they are poorly drained (class 1). In these strips also occur patches of swamp; their soils are very poorly drained (class 0).

The foundation of the young creek sediments is composed of sand and gravel. Distinction can be made between those soils, in which this layer occurs deep down, for instance, 150 cm. or more below the surface, and those in which this layer already occurs at a depth of 50 to 120 cm.. The former soils are found especially along the larger creeks; they form a transition to the soils of the flood plains along the middle courses of the rivers (see p. 49). In the dry season these soils entirely dry up down to a considerable depth. The secondly mentioned soils are the more common ones. They occur along almost all small tributary-streams, as well as along some of the larger creeks. In the dry season, these soils dry up to a less extent.

The firstly mentioned group has profiles, of which only the upper 5 to 10 centimetres are coloured brown through the presence of organic matter. The underlying horizon is mostly yellow to brownish yellow, in some cases even reddish yellow, in colour. At most varying depths, sometimes already from 20 cm. downwards, but mostly from depths ranging from 40 to 80 cm., this horizon shows red or reddish yellow mottles.

Downwards the profiles grow lighter and lighter in colour, while the mottling increases. The subsoil, mostly from a depth varying between 60 to 100 cm., is highly mottled grey to pale yellow, red, reddish yellow and/or yellow. All horizons above the layer of gravel are rather homogeneous in texture. They usually consist of (silty) clay loam or (silty) clay, which, except in the very friable surface soil, is of a firm to very firm consistence.

The profiles in which the sand-and-gravel layer occurs less deep, are usually (dark) brown to (dark) greyish brown in colour down to 10 to 50 cm.. The underlying horizons are mostly grey, light grey or even light bluish grey in colour, and often mottled with yellow, brown and/or reddish yellow. In some profiles, however, down to 30 to 80 cm., the subsurface soil is still pale brown or light brownish grey in colour.

Above the gravel layer the texture of all horizons within each profile is mostly fairly homogeneous. However, the profiles vary widely among themselves; they may consist of fine sandy loam as wel as of silty clay or clay. On the whole these soils are of a friable consistence, in contrast with the former group.

The sand and gravel layer mostly occurs at a depth ranging from 50 to 120 cm.. Often first a layer of fine sand is found overlying (very) coarse sand and gravel.

The vegetation of the creek valleys consists of marshland forest, in which the oemabarklak *(Eschweilera corrugata)* is a frequent tree species. The maripa *(Maximiliana maripa)* is the frequent palm species of this forest; in the wettest places, however, it is the pina palm *(Euterpe oleracea)* that abounds.

To give an example, below the soil profile is described of the:

MAPANE SERIES:

Land conditions: marshland strip along creek; drainage poor (class 1).
Profile:

A1	0—35 cm.,	dark brown, friable, fine sandy clay loam.
Cgg	35—80 cm.,	grey, friable, fine sandy clay loam, with small brown mottles, gradually merging in
D1	80—100 cm.,	light grey, fine sand.
D2	100 cm. +	white, very coarse sand and gravel.

THE SCHIST MOUNTAIN LANDSCAPE.

To this landscape belongs a number of mountains and their nearest surroundings, situated between the rivers Tibiti and Marowyne, somewhat north and somewhat south of 5° N.lat.. The most well-known of them are Brownsberg and the Nassau Mountains.

The soil association map (appendix I) does not cover this landscape. A description was given in two former publications (29, 53), to which be referred.

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Table 2. Geology, belts, landscapes and soil associations of Northern Surinam.

BROAD GEOLOGICAL GROUPING	GEOLOGICAL FORMATIONS	NATURE OF ROCKS	BELTS	LANDSCAPES		SOIL ASSOCIATIONS		REPRESENTATIVE SOIL SERIES
Young sediments	Demerara	clay, peat, fine sand, coarse sand, shells.	Northern belt, with young soils from sedimentary parent materials	Young coastal plain	Young sea clay landscape	Ys	Swamp soils	Djaki Nickerie Kalebaskreek
						Ym	Mangrove- and foreland soils	Katkreek
					River levee landscape	Ll	River levee soils	Saramacca
					"Rits" landscape	Rrc	Coarse sandy "rits" soils	Weltevreden
						Rrf	Fine sandy "rits" soils	Vredenburg Perica
						Ri	Inter-"rits" swamp soils	Krappa
	Coropina	fine sand, silty clay, clay.	Middle belt, with mainly old soils from sedimentary parent materials	Old coastal plain	Old offshore bar landscape	Bw	"Wal" soils	Rysdyk Guldenvlies
						Bf	Fen soils	Groenhart
						Bg	Gully swamp soils	Arapappa
					Old sea clay landscape	Os	"Schol" soils	Cassewinica Waycaribo
						Og	Gully swamp soils	Arapappa
				River terrace landscape		Tt	River terrace soils	Abanna
				Sedimentary rest hills		Hl	"Sedimentary" laterite soils	—
	Zandery	coarse sand, coarse sandy clay, clay.		"Dek" landscape		Ccb	Bleached "dek" soils	Zandery
						Ccn	Non-bleached "dek" soils	Coesewyne Costeri
						Cv	Creek valley soils	Blakkawatra
Younger intrusives		dolerite	Southern belt, with mainly soils from residual parent materials	Dolerite dikes		Dl	Dolerite laterite soils	Lucas
Crystalline basement		granito-diorites		Granite landscapes		Gy	Granite yellow earths	Phedra
						Gl	Granite laterite soils	Maikaboeka
	Orapu: Rosebel	sericite-quartzites, graywackes, subgraywackes a.o.		Schist landscapes	Subgraywacke landscape	—		—
	Orapu: Maäbo	phyllites, shales, garnet-staurolite schists a.o.			Schist hill landscape	Sl	Schist laterite soils	Tempati
						Sp	Foot plain soils	Bosland Anjoemara
						Sv	Creek valley soils	Mapane
	Balling	quartz- (calcite-) chlorite-albite schists, hornblende schists, gabbros			Schist mountain landscape	—		—

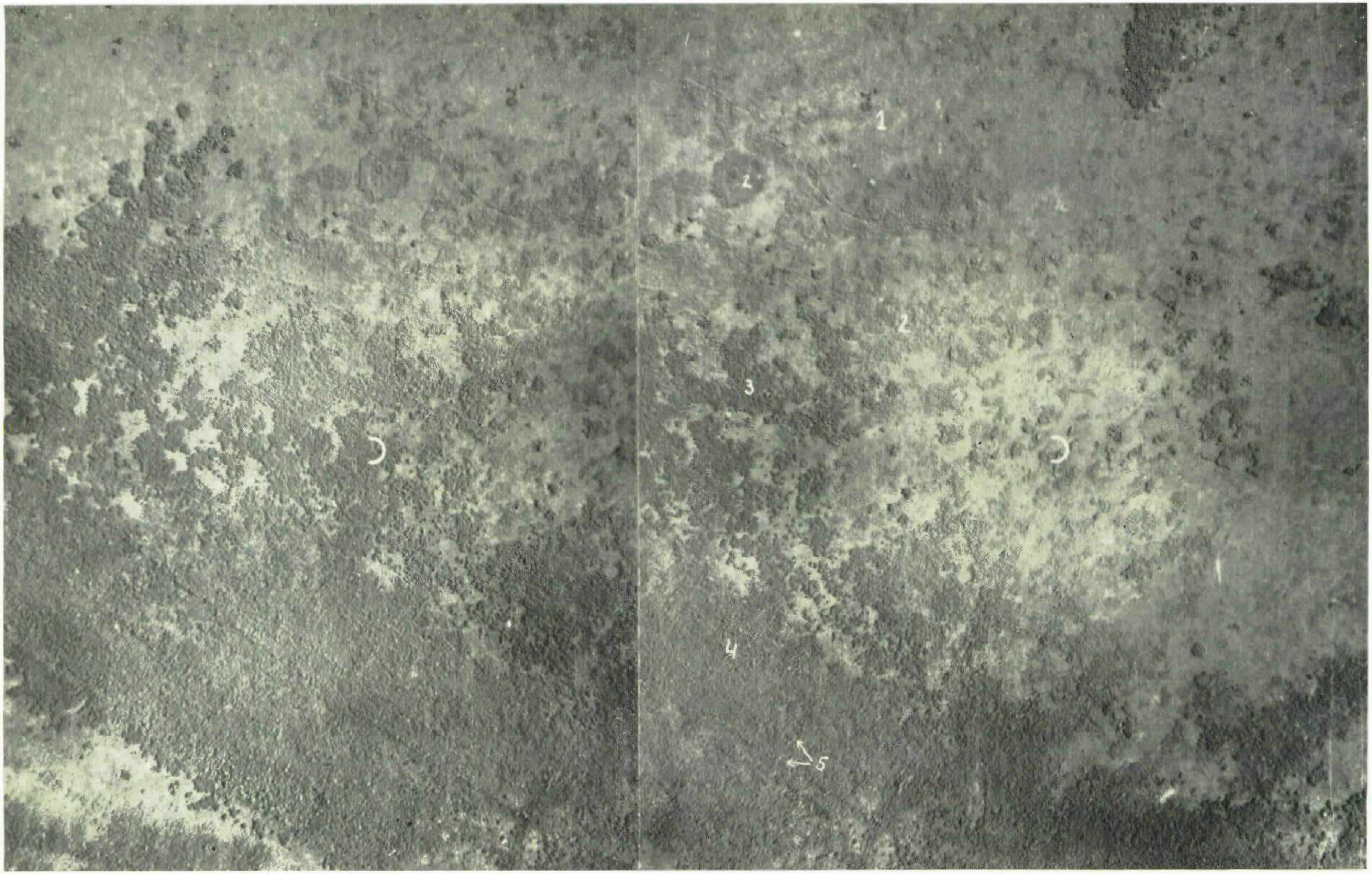

Plate 1. Stereo pair of vast swamps of the young sea clay landscape.
1: Herbaceous swamp. 2: Swamp scrub. 3: Swamp woodland of koffiemama (Erythrina glauca). 4: Swamp forest. 5: Indications of levees along former river course. Scale 1 : 40,000.

Plate 2. Young sea clay landscape.
1: Coffee plantation "Peperpot" on the river Suriname. Regular pattern of koffiemama shadow-trees. 2: Former plantation "Meerzorg", parcelled out for small farming. 3: Road and houses on a "rits". Scale 1 : 20,000. (cf. appendix I).

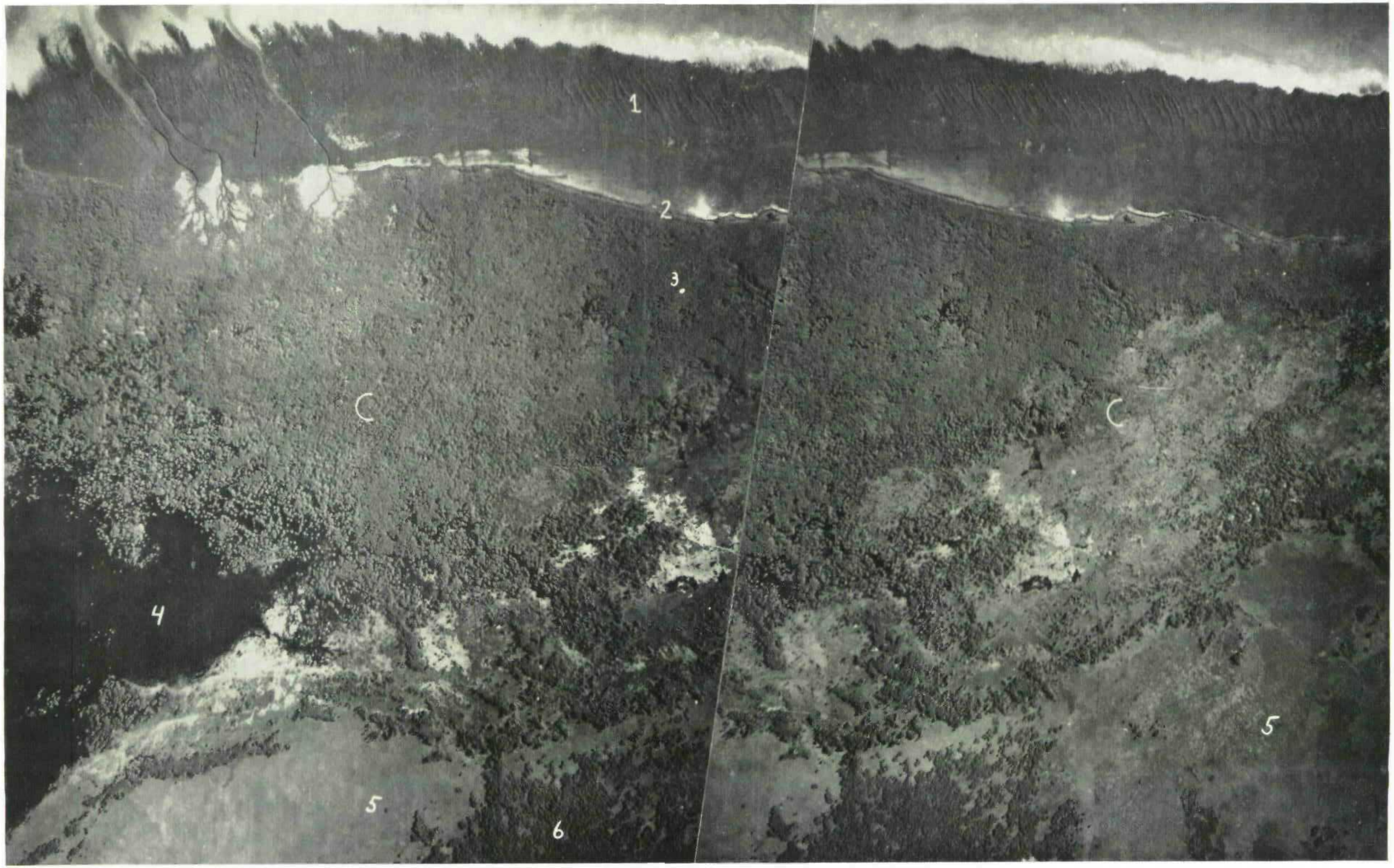

Plate 3. Stereo pair of mangrove strip of the young sea clay landscape.
1: Growing mud-flat with young parwa (Avicennia nitida) vegetation. 2: Former shore-line. 3: Full-grown parwa forest. 4: Shallow pool without vegetation ("pan"). 5: Herbaceous swamp. 6: Swamp woodland. Scale 1 : 40,000.

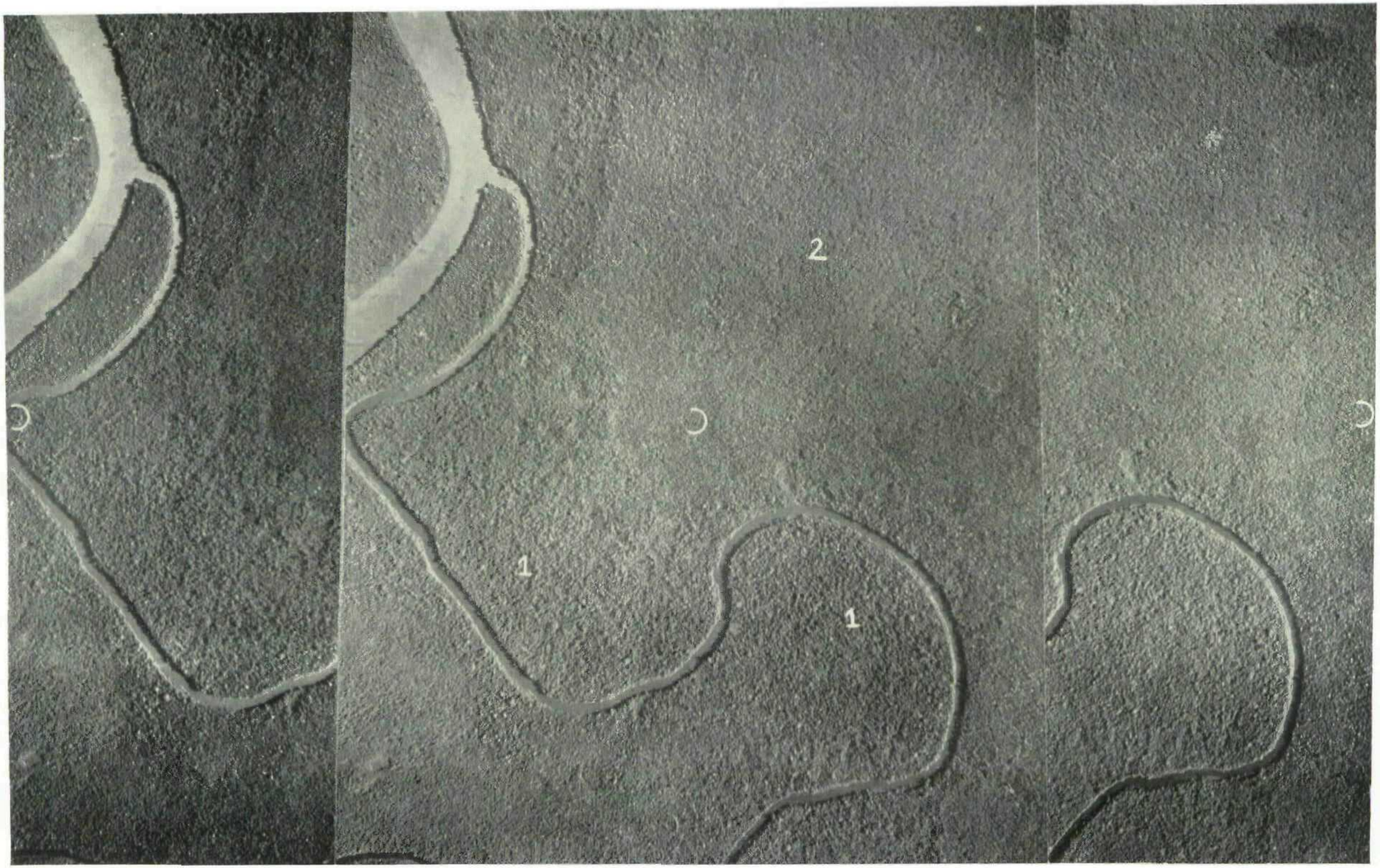

Plate 4. Stereo triplet of the river levee landscape.
1: River levees along inner bends of meanders. Marshland forest with very irregular canopy. 2: Swamp with monotonous matakki (Symphonia globulifera) swamp forest. Scale 1 : 40,000.

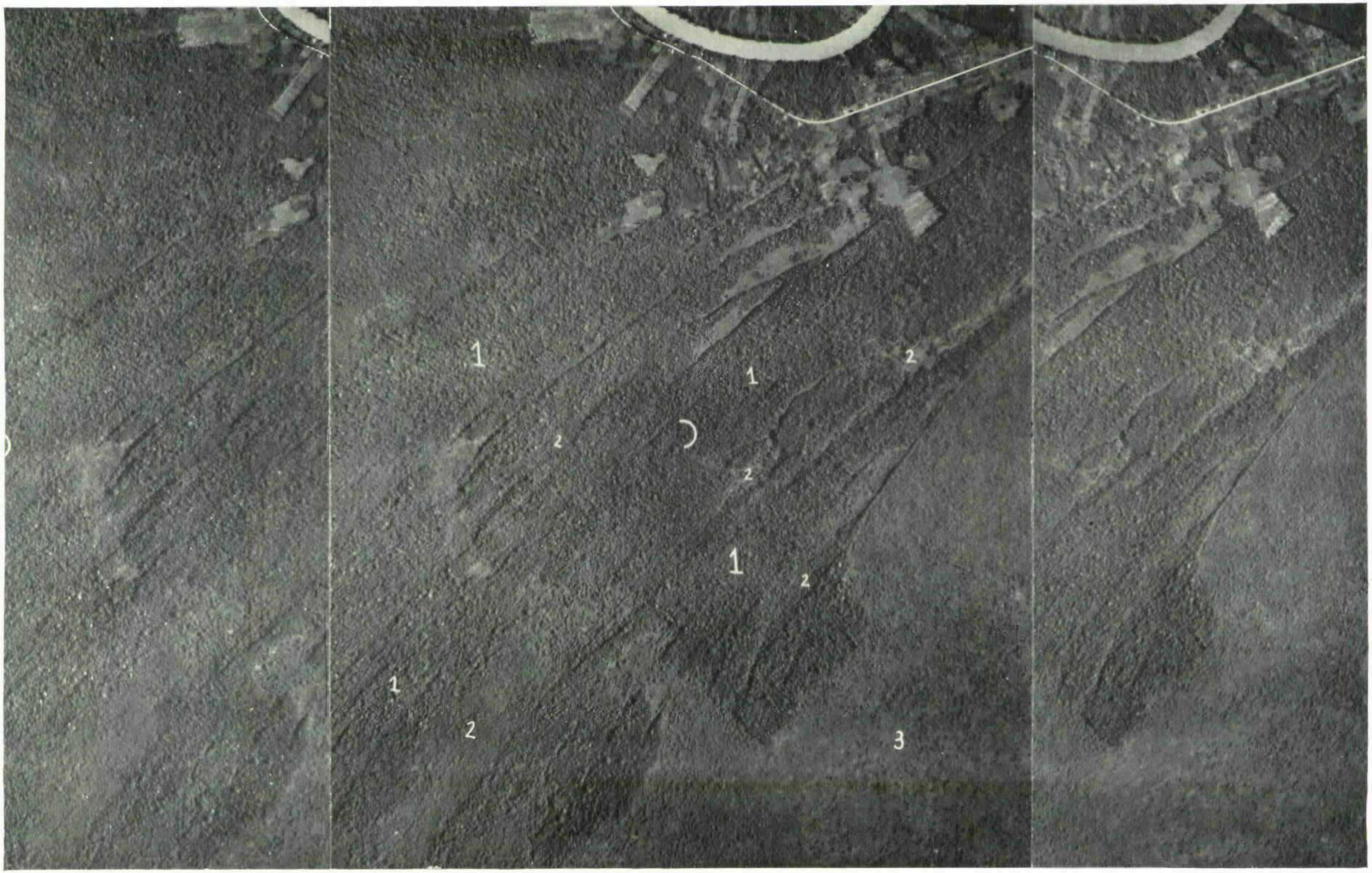

Plate 5. Stereo triplet of a fan-shaped "rits" bundle.
1: "Ritsen" with high forest. 2: Inter-"rits" swamps with swamp forest or herbaceous vegetation. 3: Vast herbaceous swamp with shrubs. Scale 1 : 40,000. (cf. appendix I, S of Groningen).

Plate 6. Stereo triplet of reclaimed "rits" landscape.
1: "Ritsen" with roads, houses and dry land farming. 2: Inter "rits" swamps with rice fields. Scale 1 : 20,000. (cf. appendix I, NNW of Lelydorp).

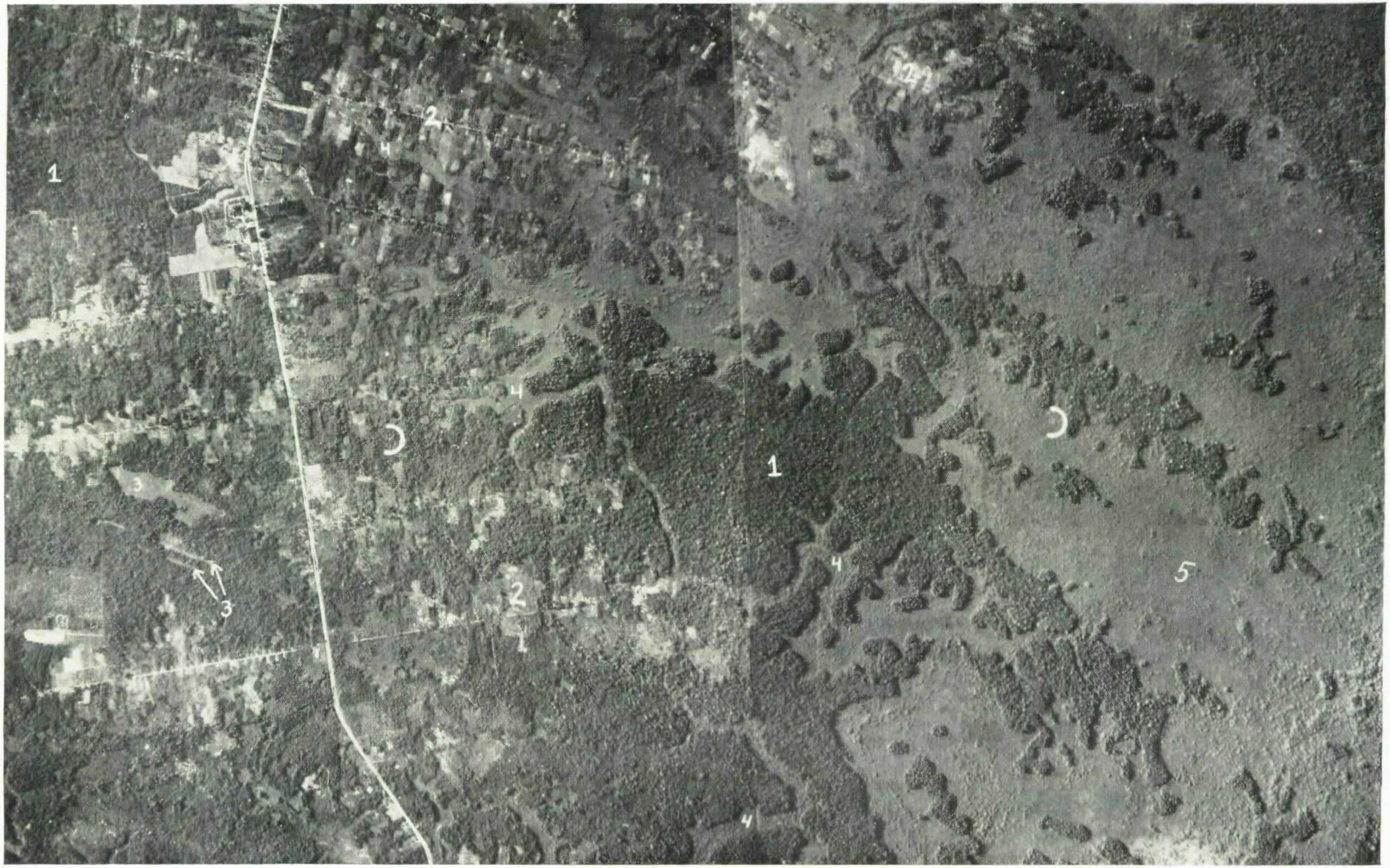

Plate 7. Old offshore bar landscape.
1: "Wal" soils with high forest. 2: The same, reclaimed. 3: Small, long-drawn "fens". 4: Gully swamps with herbaceous vegetation. 5: Swamp of the young sea clay landscape. Scale 1 : 40,000. (cf. appendix I, near Lelydorp Plan).

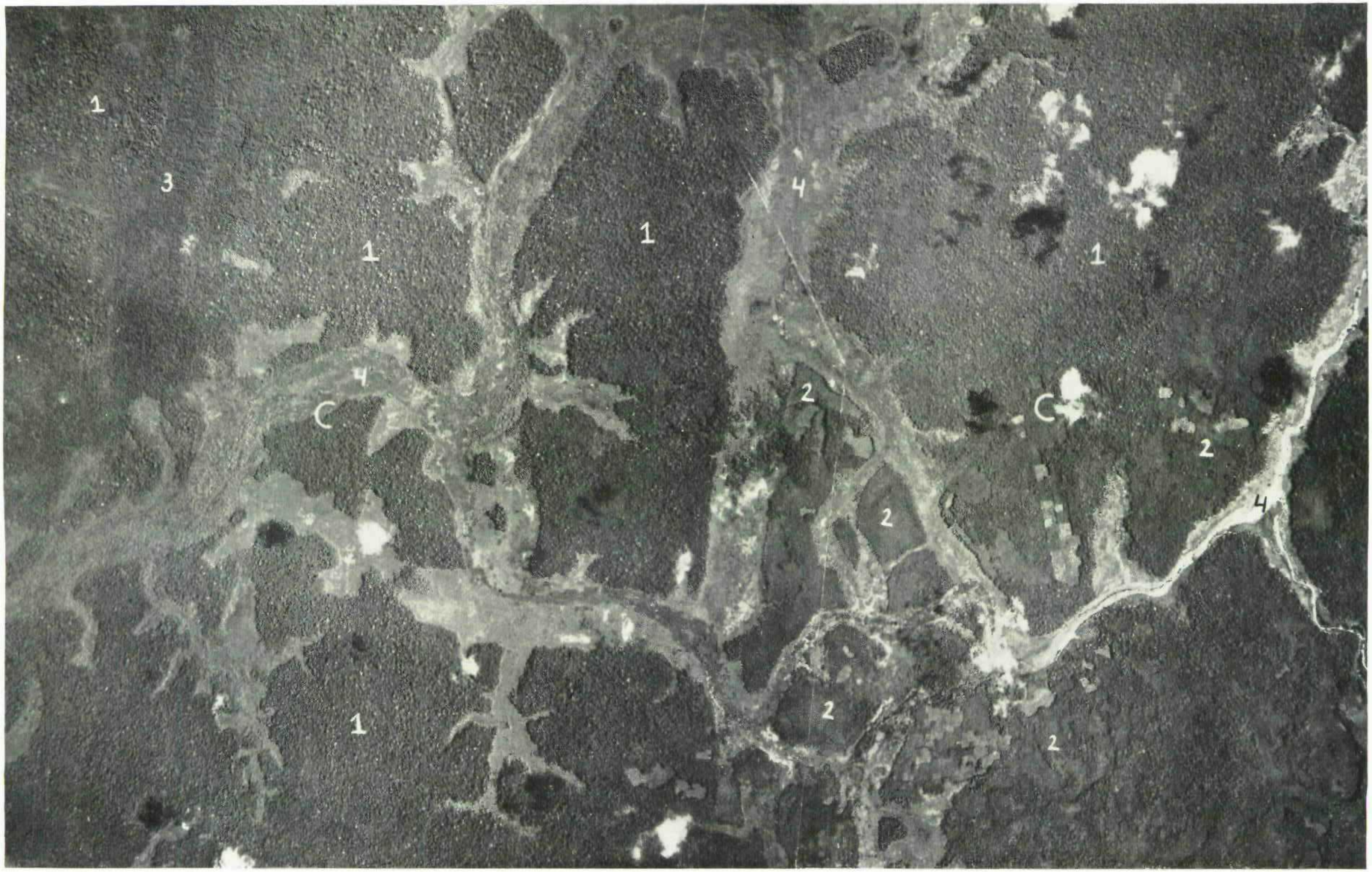

Plate 8. Old sea clay landscape.
1: "Schol" soils with primary forest. 2: The same, with shifting cultivation. Second-growth of various ages. 3: Gully swamp with swamp forest. 4: The same, with herbaceous vegetation. Scale 1 : 40,000. (cf. appendix I, WNW of Republiek).

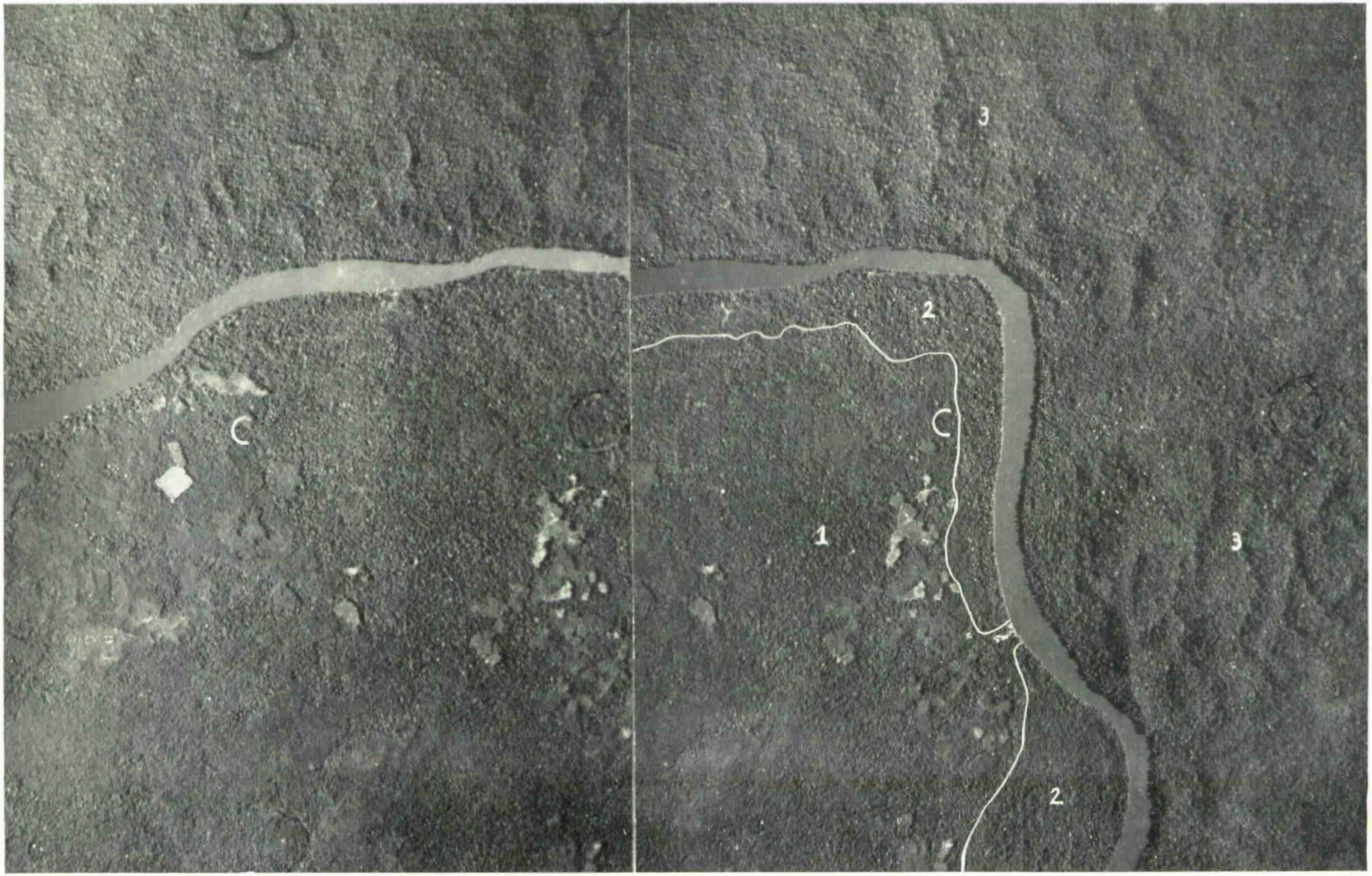

Plate 9. Stereo pair of the river terrace landscape.
1: River terrace with high forest and shifting cultivation. Second-growth of various ages. 2: Marshland strip (flood plain). 3: Schist hill landscape.
Scale 1 : 40,000.

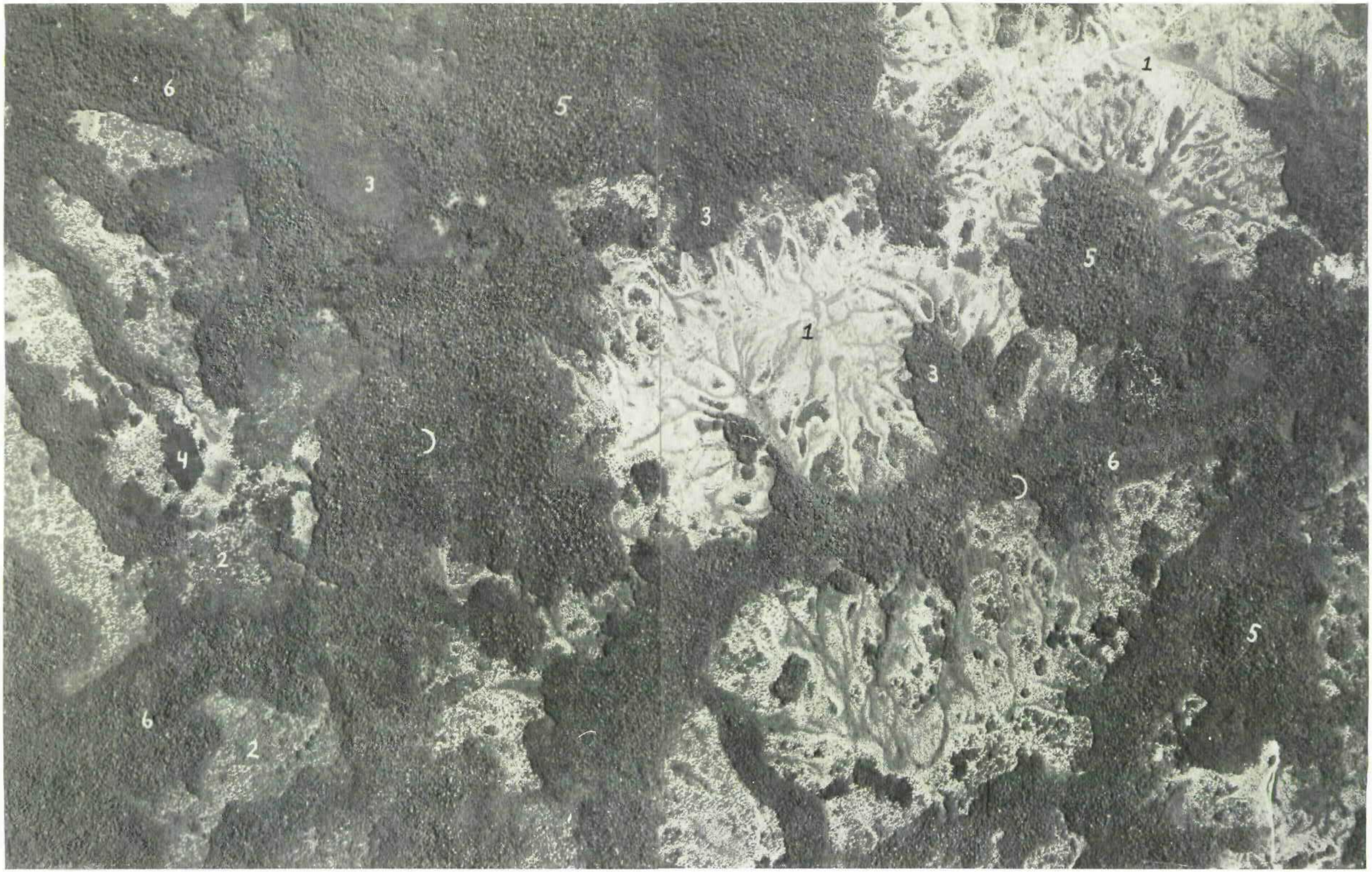

Plate 10. "Dek" landscape.
Bleached "dek" soils with various types of vegetation. 1: Open savanna. 2: Scrub savanna. 3: Savanna woodland. 4: Dakama (Dimorphandra conjugata) wood. 5: Non-bleached "dek" soils with high forest. 6: Creek valleys. Scale 1 : 40,000. (cf. appendix I, WSW of Berlijn).

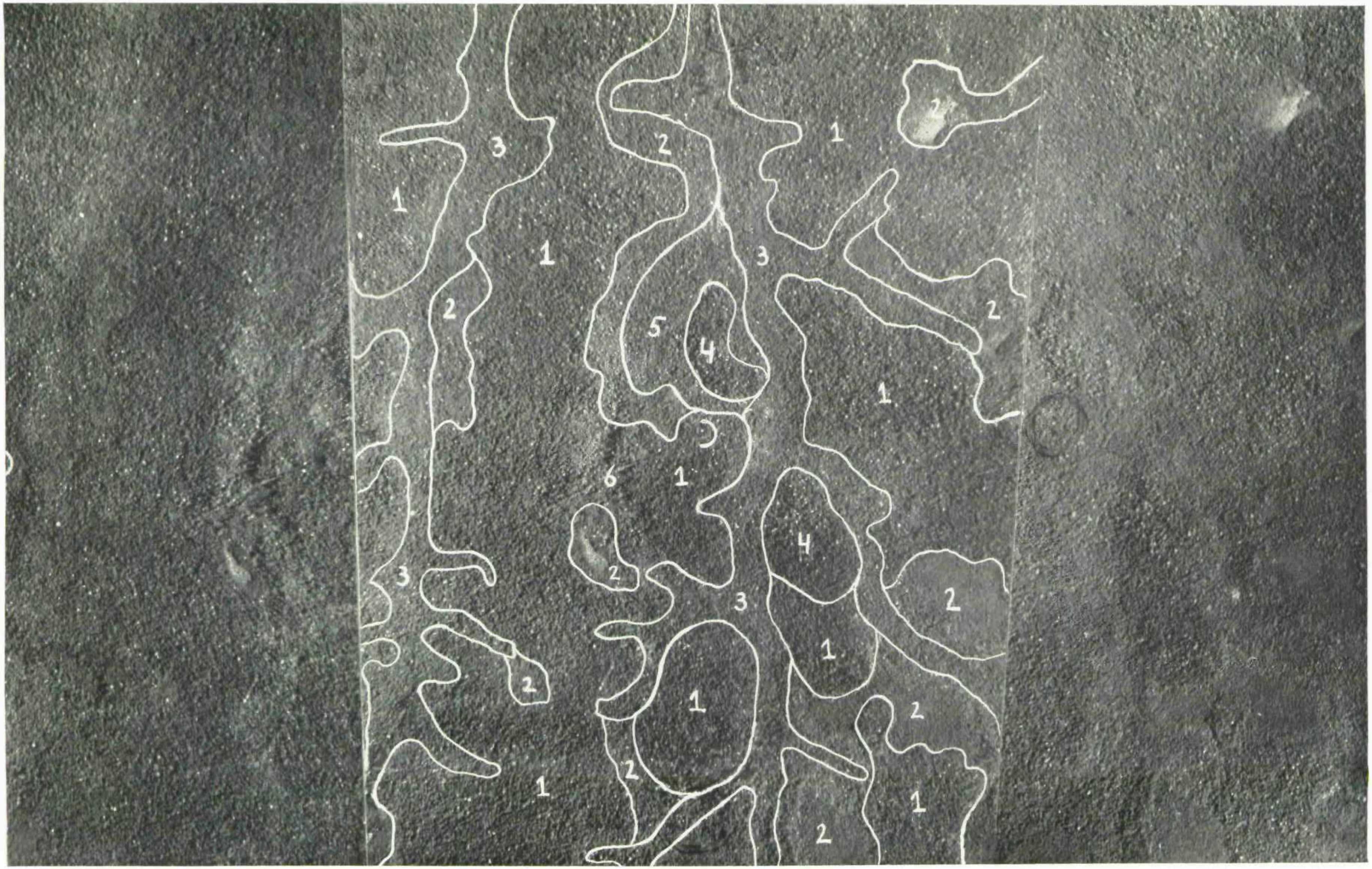

Plate 11. Stereo triplet of the "dek" landscape.
1: Non-bleached "dek" soils with high forest. 2: Bleached "dek" soils with savanna woodland or savanna. 3: Creek valleys. 4: Exposed schist hills. 5: Foot plain with low forest. 6: Damage by wind. Scale 1 : 40,000. (cf. appendix I, S of Gran Poika).

Plate 12. Stereo triplet of the schist hill landscape.
1: Schist hills. 2: Foot plains with low forest or woodland. 3: The same with scrub savannas. 4: Creek valleys. Scale 1 : 40,000.