MEDEDELINGEN
VAN DE
STICHTING VOOR BODEMKARTERING

BOOR EN SPADE

XI

VERSPREIDE BIJDRAGEN TOT DE KENNIS VAN DE
BODEM VAN NEDERLAND

AUGER AND SPADE

XI

STICHTING VOOR BODEMKARTERING, WAGENINGEN
DIRECTEUR: DR. IR. F. W. G. PIJLS

Soil Survey Institute, Wageningen, Holland
Director: Dr. Ir. F. W. G. Pijls

1961
H. VEENMAN & ZONEN N.V. - WAGENINGEN

CONTENTS

INHOUD

De pagina-nummers verwijzen naar de Nederlandse samenvatting

INHALTSVERZEICHNIS/TABLE DE MATIÈRES

Die Nummer der Seiten beziehen sich auf die deutschen Zusammenfassungen
Les numéros des pages se réfèrent aux résumés françaises

INTRODUCTORY

Although "Auger and Spade" has for its sub-title "Miscellaneous contributions to the knowledge of the soils of the Netherlands" the editor has thought it fit to publish a volume with an international character, the reason being the fact that several former and also present soil scientists of the Netherlands Soil Survey Institute were or still are active in foreign countries, especially the Tropics and Subtropics. The editor is rejoiced that for the first time some articles on pedological research and survey carried out in Netherlands New-Guinea could be published in this volume. It is deemed appropriate to draw the attention to this work, especially with an eye on international situations. Because of the large number of articles received the editor was compelled to prepare a second volume (XII) in the same way, publication of which will follow as soon as possible.

TER INLEIDING

Hoewel „Boor en Spade" als ondertitel heeft „Verspreide bijdragen tot de kennis van de bodem van Nederland", heeft de redactie toch gemeend een internationaal georiënteerd deel te laten verschijnen. Aanleiding hiertoe is het feit, dat verschillende vroegere en ook huidige medewerkers van de Stichting voor Bodemkartering langere of kortere tijd in het buitenland, vooral in de Tropen en Subtropen, hebben gewerkt of nog werken.

Het verheugt de redactie zeer, dat in dit deel voor het eerst iets gepubliceerd wordt over bodemkundig werk in Nederlands Nieuw-Guinea. Het is goed dat hierop eens de aandacht wordt gevestigd, ook ten aanzien van het buitenland.

Het aantal aangeboden artikelen was zo groot, dat de redactie moest overgaan tot de uitgave van een tweede internationaal deel (XII), waarvan de verschijning zo spoedig mogelijk na XI zal plaatsvinden.

IN MEMORIAM DR. IR. W. N. MYERS

door

M. J. M. Osse

Na slechts luttele dagen bedlegerig te zijn geweest, overleed op 29 januari 1960 te Oosterbeek onze Redactie-Secretaris Dr. W. N. Myers.

De tijding van zijn dood kwam voor ons geheel onverwacht. Als het ware werden wij erdoor overvallen. Enerzijds lag het niet voor de hand ermede te rekenen, dat een zo energiek en sympathiek man als Dr. Myers was, zo plotseling uit ons midden zou worden weggenomen. Van de andere kant zijn de meesten onzer in leeftijd te jong, te gevangen in eigen vitaliteit en eigen streven om werkelijkheden als deze, die niet gewild zijn en waarop door ons geen invloed kan worden uitgeoefend, gemakkelijk te accepteren. Met name viel het moeilijk zich te verzoenen met de idee, dat het leven van Dr. Myers op de toch betrekkelijk jonge leeftijd van 54 jaar eindigen moest. Een tijdspanne overigens, die welbesteed moet worden genoemd; waarin met grote ijver en overgave gewerkt werd en waarin talrijke vriendschapsbanden werden aangeknoopt en onderhouden. Een leven tevens, waarin hem teleurstellingen niet bespaard zijn gebleven, waarbij opvalt, dat de richting, waarin Dr. Myers dit leven leiden wilde vrij sterk bepaald en duidelijk was. Calamiteuze gebeurtenissen als de tweede wereldoorlog en de bezetting van Nederlands Indië door de Japanners, alsook de soevereiniteitsoverdracht en haar gevolgen, hoe onaangenaam dan ook, vermochten niet daarin essentiële wijzigingen te brengen. In grote trekken bleef Dr. Myers in zijn werk Bosbouw en Bodemkunde trouw.

Dr. Willem Nicolaas Myers dan werd geboren op 7 februari 1906 te Meulaboh in Atjeh. Reeds op jeugdige leeftijd kwam hij naar Nederland, waar hij te Utrecht zowel de lagere school als de H.B.S. bezocht. Na zijn eindexamen aldaar studeerde hij vanaf 1924 aan de Landbouwhogeschool te Wageningen, waar hij in 1930 in de toenmalige richting Koloniale Bosbouw afstudeerde. Hij keerde daarop naar Nederlands Indië terug, waar hij zijn eerste werkkring vond bij de Dienst van het Boswezen. Als sectie-chef bij de Bosinrichting legde hij zich krachtig toe op het onderzoek naar de relatie tussen de bodemgesteldheid en de bodemgeschiktheid voor bepaalde houtsoorten. Hij karteerde voor dit doel de houtvesterij Indramajoe en voerde o.a. karteringen uit in Padangan en Gadoengan. Voor de tijd, waarin de bodemgeschiktheid in de praktijk nog voornamelijk werd beoordeeld naar „het gemak, waarmede een stok in de grond kon worden gedrukt" waren deze onderzoekingen tamelijk baanbrekend en nieuw. Zo nieuw stellig, dat lang niet iedereen in zijn omgeving adhesie voor zijn werkwijze kon opbrengen. Verheugend was het daarom voor hem, dat Prof. Edelman, die in 1936 een studiereis door Nederlands Indië ondernam en daarbij ook de kartering Indramajoe bezocht, aan dit werk grote aandacht schonk en daaromtrent zijn waardering uitsprak. Het gevolg ervan was, dat Dr. Myers op 7 december 1937 op het proefschrift: „Groeiplaatsboniteering van Djatiboschgronden in verband met grondkaarteering" bij Prof. Edelman promoveerde.

Hij keerde vervolgens opnieuw naar Nederlands Indië terug en vervulde tot het uitbreken van de oorlog de functie van opperhoutvester op het eiland

Madoera. Na de oorlog, die hij zoals de meesten in een Japans interneringskamp doorbracht, was zijn eerste standplaats Balikpapan. Vandaar werd hij overgeplaatst naar Java, waar hij vanaf 1948 werkzaam was bij de Landinrichting. Na de soevereiniteitsoverdracht trad Dr. Myers in dienst van de Republiek Indonesië. Afgezien van de oorlogstijd werden hiermede wel de meest gelukkige jaren van zijn leven in de tropen afgesloten.

In 1951 immers zag hij zich genoodzaakt het land, zijn geboorteland, dat hij een zo goed hart toedroeg en waaraan hij zovele en zo dierbare herinneringen bewaarde, te verlaten.

Hoewel Dr. Myers, zoals eerder reeds werd gezegd, op een bodemkundig onderwerp promoveerde, moet de aanvangstijd bij ons Instituut toch niet de gemakkelijkste geweest zijn. De bodemkunde hier te lande immers was in de naoorlogse jaren zodanig geëvolueerd, dat het hem ongetwijfeld de grootste moeite moet hebben gekost zich hierin weer enigermate te oriënteren. Bovendien waren sfeer en werkwijze bij de Stichting wel geheel verschillend van die in Ned. Indië of Ned. Nieuw Guinea, terwijl de beoefenaars van deze wetenschap bij de Stichting voor Bodemkartering zonder uitzondering vele jaren jonger waren dan hijzelf. Nog minder gemakkelijk werd het hem gemaakt, toen hij reeds enkele maanden na zijn indiensttreding de verantwoording kreeg over het in vele opzichten vreemde en voor oningewijden wat ondankbare redactie-secretariaat.

Het moet Dr. Myers dan ook tot een grote verdienste worden aangerekend, dat hij na een onopvallende en bescheiden entree zich met behulp van zijn energie, zijn vlug begrip en zijn doorzettingsvermogen snel de bekwaamheden wist eigen te maken, die voor het vervullen van deze functie nodig waren. Spoedig had hij hieruit dan ook een zeer gezaghebbende positie opgebouwd, wat op zijn beurt aanleiding werd hem tevens de leiding over de afdeling Programmering en Planning, die in januari 1958 werd opgericht, toe te vertrouwen.

De taken en werkzaamheden van Dr. Myers waren derhalve velerlei. Indien hieruit niettemin een keuze zou moeten worden gemaakt zou zijn speciale belangstelling voor terminologische problemen en de vertaling van termen en samenvattingen in de Engelse taal moeten worden gememoreerd. Een activiteit, waarin hij op den duur zeer bedreven raakte en die mede in de thans voor U liggende Boor en Spade gedemonstreerd wordt.

Voor het uitvoeren van al deze werkzaamheden waren uiteraard de toegemeten kantooruren geheel onvoldoende. Zonder hiervan te doen blijken, ook zonder dat andere medewerkers bij het Instituut daarvan kennis droegen, was het zijn gewoonte haastwerk en stukken, die een wat rustiger bewerking vergden, thuis af te handelen. In de praktijk kwam dit er weldra op neer, dat vrijwel alle avonduren aan deze werkzaamheden werden besteed. Waaruit in zekere zin tevens blijkt, dat hij na enige tijd in deze redactionele bezigheden veel plezier gekregen had.

Het lijdt dan ook geen twijfel, hoewel Dr. Myers zelve wellicht vele van deze woorden zou hebben geschrapt, dat de Stichting voor Bodemkartering in hem een uitermate toegewijd en intelligent redacteur verloren heeft. Een ijverig en nauwgezet man ook met een scherp gevoel voor organisatie, die om zijn gerijpt en praktisch oordeel en zijn op vele gebieden zeer deskundige raad alom werd gewaardeerd. Een man tevens met een haast onmerkbare autoriteit en een groot besef voor verantwoordelijkheid. Iemand voorts, die naast zijn gevoel van eigenwaarde oog had voor hiërarchische verhoudingen in de organisatie en derhalve de grootheid bezat het eigen oordeel aan dat van zijn superieuren te onderwerpen.

Doch meer dan in het voorgaande trof ons zijn heengaan in het persoonlijke vlak. Velen immers verloren in hem een goede en persoonlijke vriend; een joviaal en geestig man, bij wie men zelden vergeefs om raad of bijstand aanklopte. Men ontving dan een gefundeerde en deskundige mening waarbij men het voordeel had, dat deze niet onder stoelen of banken gestoken werd. Een eigenschap, die vanwege haar emotionele en eerlijke karakter juist van hem aanvaard werd en gewaardeerd.

De verslagenheid, die het bericht van zijn overlijden bij de medewerkers van de Stichting voor Bodemkartering teweegbracht, was dan ook zeer groot. Als het ware werden wij gedwongen om te begrijpen, dat wij zijn stem, zijn stap, zijn schaterlach niet meer zouden horen, zodat het was alsof door zijn heengaan een gedeelte van het eigen wezen mede ten grave gedragen was.

THE NETHERLANDS SOIL SURVEY INSTITUTE. TASKS, ACTIVITIES AND ORGANIZATION

by

M. J. M. Osse *et al.*

I. GENERAL

I.1. *Introduction*

The Soil Survey Institute was founded on 21st August 1945. The founding of the Institute meant the recognition on the value of a method of Soil Survey which had already attracted attention by a number of noticeable successes and thus held out a promise for the future. Moreover developments in agriculture, technology and planning had reached such an advanced stage that further knowledge of the soil of the Netherlands was required.

This method, which was developed during the last war in particular under the direction of Professor Dr. C. H. Edelman, meant that persons with a scientific training went out into the field and examined soil and landscape with trained eyes.

At first the only implement employed was the spade. Profile pits were dug to give an idea of the constitution of the soil. When the auger began to be used as well it also became possible to trace the distribution of the phenomena in a simple and rapid manner. In fact the use of the soil auger made the surveying of the various soil units a practical proposition, enabling the actual mapping to be done much more rapidly.

That this survey work actually started is especially due to the conditions which created interest in this type of inventory work. The time was past when a dressing of fertilizer was regarded as a panacea and it had become obvious that the entire level of production had been raised by the use of the new fertilizers. The traditional differences in evaluation of soils, based on differences in physical properties and plant nutrient content, were emphasized rather than levelled by the use of fertilizers. This development obviously awakened new interest in these physical and chemical characteristics.

Technical progress tended in the same direction. The technical accessories of land improvement operations had become so powerful that there was really no further need to regard the soil as an entirely uncontrollable production factor. It had become possible to make a radical alteration in the location and growing site of the plant. Thereafter it became much more a problem of finance than technique whether or not to apply radical improvements to soils whose profile conditions are unfavourable to plant growth.

The general climate prevailing after the war was also conductive to the development of soil surveying in the Netherlands. The policies envisaged by economic and social authorities required inventarised knowledge and well-arranged material. The planning departments concerned with the planned development of provinces and districts or the extension of towns, showed particular interest in this kind of knowledge and material.

This general interest in soil science soon led to the evaluation of the method followed. Although this evaluation had already been given in 1942 by a departmental commission, it was necessary to wait to the end of the war before it could be organised into an institute. Professor Dr. C. H. Edelman, the great promotor of soil surveying in the Netherlands, was appointed the first director of this institute. In 1955 he was succeeded by his oldest pupil Dr. F. W. G. Pijls.

I.2. *Work and Organization*

In accordance with article 3 of its present Articles of Regulation the work of the Soil Survey Institute comprises:

1. The study of the soil for classification and mapping the soil of the Netherlands.
2. The systematic mapping of the soil of the Netherlands.
3. The evaluation of the suitability and land classification of the areas studied (in co-operation with other institutes).
4. Execution of commissioned soil surveys and land classification work.
5. Publication of the results of the work and making it generally available.

During the initial period following the establishment of the Soil Survey Institute virtually all activity consisted of regional soil surveys, the provision of information and of surveys commissioned by outsiders. This work was done by survey teams in specified districts. The results were recorded in maps and reports. For certain sections of the study the party chief could consult such scientific co-workers as were available for geology, mineralogy, historical geography and archaeology, or else, as was subsequently the case, particular commissions operating in a number of well-defined fields such as the co-ordination of map legends, the evaluation of the suitability of the soil, and hydrology. The provincial departments have grown out of these survey teams.

The surveys carried out by these teams were regarded at the time as preliminary studies for a future national survey. In order to co-ordinate to some extent the results of the teams working practically independently of each other and to be ready whenever a national survey were to be commissioned, a map legend committee was set up whose task was to direct and co-ordinate the various map legends. This process of co-ordination was accelerated by a commission to prepare a soil map of the Netherlands on a scale of 1 : 200.000, the results of which are being published in 1961 and 1962. But in particular it was the commission for the systematic soil survey of the Netherlands on a scale of 1 : 50.000 which caused a change in the existing structure and organization of the Soil Survey Institute. Co-ordination, uniformity and research on a national level were required for carrying out this great survey.

Consequently there grew up from and side by side with the committees the specialist departments which were concerned solely with general research or national co-ordination. This development, which was obviously a gradual one, led in 1957 to a reorganization which defined the national and general soil survey work of the Institute in addition to the former regional work in the organization. Under the present organization these various operations are largely reflected by the titles of the principal departments, these being as follows:

1. Board and Direction
2. Major Department of Regional Soil Survey
3. Major Department of Specialistic Research
4. Department for Publications, Library, Programming and Planning, Map Editing
5. Reproduction Department
6. Department of General Affairs.

OUTLINE OF THE ORGANIZATION OF THE SOIL SURVEY INSTITUTE

BOARD

Direction — Advisor

Major Department of Regional Soil Survey		Major Department of Specialist Research		Publications Department, Library, Programming and Planning	Reproduction Department	Dept. for General Affairs
Dept. Commissioned Surveys	Dept. Noordholland, Zuid-Holland north of the rivers	Dept. for Soil Classification	Dept. for Geology and Palaeobotany	Editorial Staff Reports and Publications	Drawing Room	Accountancy and Administration
Dept. Groningen	Dept. Zuid-Holland south of the rivers	Dept. for Coordination of the 1:50.000 Soil Survey of the Netherlands	Dept. for Diatom Research	Library	Lithography	Archives
Dept. Friesland	Dept. Zeeland	Dept. for Soil-Water Relationships (Hydrology)	Dept. for Vegetation Research	Programming and Planning	Photography	Type Room
Dept. Drente	Dept. Noordbrabant	Dept. for Micropedology	Dept. for Historical Geography	Map Editing	Photo-print	Switchboard
Dept. Overijsel	Dept. Limburg	Dept. for Soil Physics and Chemics	Dept. for Arable Land and Pastures		Drawing Archives	Upkeep
Dept. Gelderland		Dept. for Mineralogy	Dept. for Horticulture			
Dept. Utrecht			Dept. for Forestry			

Technical Archives

I.3. *Board and Direction*

The Soil Survey Institute – as a semi government agency – is represented by a General Board. This Board consists of ten members nominated by the Ministry of Agriculture and Fisheries (4 members), the Ministries of Transport and Public Works and Housing and Building (2 members), by agricultural engineering Offices (2 members), and the Agricultural Corporation Board (2 members). The General Board approves the annual budget, program of work and report as proposed by the Director, and it also submits the budget to the Minister of Agriculture and Fisheries and supervises the financial business of the Institute.

The director is responsible to this Board for implementing agreed policies and the affairs of the Institute.

The initiative for carrying out specific operations is usually threefold in origin. It may come from the Board (e.g. the commission to map the soil of the Netherlands on a scale of 1 : 50.000), from the provincial and specialist departments (proposals for investigations into specific problems) or from outside the Soil Survey Institute (commissioned surveys).

It is the latter in particular that are of great financial importance to the Soil Survey Institute since they represent about a quarter of the total revenue which is further made up of State subsidies and subsidies from a number of institutions.

I.4. *The Major Departments*

The heads of the Major Departments may be regarded as links between the director on the one hand and provincial and specialist departments on the other. Hence their task is to ensure that the responsibilities assumed by the Soil Survey Institute as a whole actually receive attention or are carried out. The heads of the Major Departments therefore have to co-ordinate as far as possible the work of the departments for which they are responsible and ensure a proper balance between this work and the commissions given. They have to designate the order in which the work is to be done or the direction it should take, and also check the quality and progress of the work of the departments.

In this work of directing and checking a useful tool is formed by the work schedules which are drawn up for the departments every year in consultation between the head of the Major Department, the department head concerned and the head of the Programming and Planning Department.

I.5. *Internal Committees*

In addition to the two Major Departments there are 10 internal Committees. Some of these Committees, such as the *Soil Classification Committee*, *the Committee for 1 : 50.000 Map Legend*, the *Land Classification Committee*, the *Horticultural Committee*, the *Hydrological Committee* and the *Committee of Soil Chemics*, generally undertake preparatory and evaluation work such as the discussion and determination of specific problems, and the submission of proposals to the various departments of which the elaboration by the department concerned is again submitted to the committee for judgement. Both the head of the specialist department concerned and a number of heads of provincial departments have a seat on these committees, so that in these internal committees delegations can be seen from all the co-workers of the Soil Survey Institute. This facilitates contact between specialist and provincial departments.

Some other works committees who have a permanent task are the *Terminology Committee*, the *Technical Committee*, the *Non-Graduate Staff Committee*, and *the Committee for Studying the Relationship between Soil Type and Tillage.*

The Terminology Committee co-operates with other committees and departments in matters regarding the terminology of the map legends, the definition of pedological concepts and their English, French and German translation. The *Technical Committee* examines proposals submitted to it on technical questions. It also investigates to what extent certain technical developments may be useful to the work of the Soil Survey Institute.

The *Non-Graduate Staff Committee* is responsible for advising the directors on questions concerning the non-graduate staff; it also drafts proposals regarding promotion, etc..

Some other committees have temporary assignments.

II. THE MAJOR DEPARTMENT OF REGIONAL SOIL SURVEY

II.1. *Introduction*

This major department is responsible for all regional work, for conducting commissioned soil surveys and land classifications, as well as all soil and agricultural surveys begun and carried out by the provincial survey offices (regional soil survey).

This major department is made up of twelve departments, viz. the provincial departments and the department of commissioned surveys.

A university graduate is in charge of each provincial department. He is usually aided by two or three assistants with secondary agricultural schooling, while in certain larger departments a second graduate is engaged.

The Commissioned Surveys Department is led by a university graduate, assisted by two surveyors and 6 to 8 mappers.

This major department has a total staff of 18 graduates and about 40 with secondary and lower qualifications, and in some cases there are 3 to 4 persons in casual employ.

II.2. *The provincial departments*

The provincial departments perform the same work on a regional basis as the Soil Survey Institute on a national one. In the case of the provincial survey offices the work is as follows:

1. Regional soil survey } and research
2. Co-operation in general soil survey } and research
3. Co-operation in national soil survey and the systematic mapping of the Netherlands (on a scale of 1 : 50.000)
4. Conducting and co-operating in commissioned surveys
5. Providing information. Advisory work.

It should not be inferred from the fact that the tasks of the provincial departments are shown in an itemised and schematic form for the sake of clarity that they are so clearly demarcated in practice. Thus certain operations performed by provincial departments may develop into national activities, and in the same way general activities may be concentrated in a particular province. Thus in reality any form of transition is possible between the above five activities.

II.2.1. Regional soil survey

This relates to investigations in which the compilation of a map is not the main objective. These investigations are planned and conducted more or less on the initiative of the staff, in consultation with and on the suggestion of the director, the heads of the major departments, and the heads of the specialist departments concerned.

Hence the object of this type of investigation is not a particular area but actual problems of soil science. For instance, the following subjects have been studied or are still being studied under this heading: the morphology of the pleistocene area in west-central Holland, North Holland and the marginal areas of the IJssel Lake; the „knip"-clay problem (Friesland, islands of South Holland); the initial soil formation in alluvial sediments (physical and chemical „ripening") in North Holland, Zealand, Biesbosch area; the soil formation in the sand soils (Overijssel, Guelderland and North Brabant); the study of tertiary clay strata (Overijssel); black peat survey and toponymical studies (Drenthe); chemical investigation of river clay, the determination of permeability in river clay (Guelderland); soil formation as a result of arable and grassland (Zealand); leaf analysis in connection ion-uptake, the geology of the terraces in Central Limburg, soils with a structure B horizon (Limburg); soils in the peat reclamation areas (Groningen), etc. In these regional studies as far as possible all soil characteristics are investigated. Where necessary for the purpose of the investigation, soil maps are also made. The work is often done in co-operation with other government departments, or with committees set up for specific investigations. The aid of the specialist departments is often enlisted for solving problems in the chemical, geological, mineralogical, hydrological, agronomic, and historical-geographical spheres.

II.2.2. Co-operation in general soil survey

Surveys may be initiated both by the party chiefs and the specialist departments. In such cases the provincial departments provides assistance. In this way co-operative work is undertaken on the investigations on soil structure and humus forms and the differences between river clay and marine clay. Help is also given in surveying and evaluating the suitability for agriculture, horticulture or forestry.

Hence all the tasks described above which cannot always be separated as regards organization, are regional in character. Certain investigations will receive a good deal of attention in one province, depending on the occurrence of the problems, the interests of the survey leader, or the location of the surveys which are begun, whereas in another province these problems will not be studied or perhaps be entirely absent. This shows that there is a considerable amount of differentiation between the various provinces as regards the type of work undertaken.

II.2.3. Co-operation in national soil survey and the systematic mapping of the Netherlands

Up to a certain point all provincial departments assist in this work to an equal degree. Thus all soils had to be described and classified according to a particular system in accordance with the soil classification of the Netherlands. On the basis of this classification a map legend was drafted, under central direction, for the sheet-map survey of the Netherlands on a scale of 1 : 50.000.

All provincial departments co-operate in the experimental surveys for these map legends and their layout, and to some extent they will also be responsible for carrying out this survey. The survey of the Netherlands on a scale of 1 : 200.000 and the land classification based on it was also a combined operation. Co-operative work is also being undertaken in all provinces on the delineation of the hydrological regime on the 50.000 map.

II.2.4. Conducting and co-operating in commissioned surveys

Commissions, given by outside bodies for the survey of a particular area, are undertaken in principle by the provincial departments.

Since these departments are usually fully occupied with the work referred to above and to be mentioned hereafter, and since moreover such commissions often have a well-defined and practical object in view, this type of survey is at present usually undertaken by the Commissioned Surveys Department.

II.2.5. Information. Advisory work

It has gradually become the custom that Dutch institutions concerned with the soil apply to the Soil Survey Institute for advice and information. On a national level this information is generally given by the specialist departments, but by the provincial offices on a regional level. Hence in this sphere there is a good deal of communication with such bodies as the Agricultural and Horticultural Extension Services, the Provincial Land Improvement Departments, the Provincial Public Works Departments, the Land Chambers, municipal and provincial bodies, agricultural engineering Offices, highway construction companies and the like.

As this summary shows, it is not the aim of the Soil Survey Institute to give *direct* information to practitioners.

II.3. *Commissioned Surveys Department*

Before a commission is accepted it is discussed in detail with the customer. In these discussions it is of the utmost importance that the customer should give a clear explanation of the purpose of the survey requested. Once the object had been made clear the head of the department can give advice on the scale of the proposed map, the number and description of derived maps, etc..

The soil maps thus compiled are used for various purposes. They generally serve as a basis for agricultural work. The chief function of soil maps is obviously in connection with re-allotment operations. But in addition commissions are executed for military purposes, for making an inventory of clay stocks on behalf of the brickmaking industry, for water control projects, agricultural instruction, etc..

Generally speaking the soil maps supplied are difficultly readable for the map user who in most cases has no pedological training. For this reason the Soil Survey Institute decided to supply a number of derived maps in addition to the soil map.

Thus the soil map is often accompanied by a soil suitability map showing the suitability of the soils for various purposes. Other derived maps frequently supplied are those which provide hydrological information, maps indicating the texture of the topsoil, the thickness and depth of peat layers, the nature and thickness of the humous topsoil, the occurrence and nature of divergent strata, etc. These surveys are nearly always carried out in co-operation with the provincial departments who naturally have a greater local knowledge than the staff of the Commissioned Surveys Department which operate throughout the country.

It is of the greatest importance to the Soil Survey Institute that pedological knowledge should be examined in the light of practical experience. Hence the requirements of customers or practice occasionally render a new study desirable. In such cases the department refers to the specialist departments who are better equipped for investigation. Thus it is of great benefit to the customer that such a department forms part of the Soil Survey Institute. It is a guarantee that the data and information supplied will be as objective as possible and embody the most recent discoveries of the rapidly developing science of pedology. In fact, after the commission has been executed and payment received the Institute has no financial interest in the use of the map or in the execution of the work for which the map serves as a basis. This is also the reason why the Soil Survey Institute is often called upon to give arbitration awards.

III. THE MAJOR DEPARTMENT OF SPECIALIST RESEARCH

III.1. *Introduction*

The second major department, that of *Specialist Research*, is responsible for the study of the soil for the purpose of soil classification, the mapping (1 : 50.000) of the soil of the Netherlands, and the evaluation of the suitability of the existing soils and their land classification.

An important factor which led to the establishment of the Major Department of Specialist Research was the increase in national activities resulting from the commissioning of a systematic survey of the soil of the Netherlands on a scale of 1 : 50.000.

This Major Department comprises 13 specialist departments. The staff totals 14 university graduates and 32 others with secondary school and lower education.

III.2. *The specialist departments*

The general tasks of the specialist departments are as follows:

1. the co-ordination of work on national projects
2. giving information, advice and assistance to other departments
3. undertaking its own investigations
4. maintaining contacts with the research workers and assistants of other institutes and government departments

It will be clear that the tasks outlined above do not devolve on all specialist departments to an equal extent. It is just as possible that emphasis will be placed on a different aspect of the work for some time. These shifts of emphasis primarily depend on the stage which the execution of the operations has reached.

Since the Soil Survey Institute is partly decentralised owing to its provincial departments, *co-ordination* is essential in work which extends beyond the provincial boundaries (e.g. for the systematic sheetmap survey on a scale of

1 : 50.000). Examples of specialist departments in which co-ordination work plays a large part are the Map Co-ordination, Soil Classification, Hydrology, Horticulture and Land Classification Departments. The initiative and leadership for these co-ordinating activities generally comes from the specialist departments or from the internal committees concerned.

The second, and likewise earliest work of the specialist departments consists in the giving of information, advice and assistance to the provincial and other departments of the Institute. This is needed because the soil scientist's knowledge of methods to connected or related sciences will usually be insufficient. This is true, for example, of geology, physical and chemical pedology, micropedology, mineralogy and hydrology. It is also true of studies which only incidentally relate to the soil, e.g. agronomy, historical geography, palaeobotany, dating by means of radioactive carbon (C14), and diatom research. Owing to the nature of the work the initiative for this „passive" form of information comes from the provincial departments requiring expert assistance in their field of operations.

The investigations carried out by practically all specialist departments themselves are generally of a more fundamental kind or are concentrated on the research method. This research must obviously be directed towards the compilation of soil maps for practical agricultural purposes.

It is also important for the specialist departments to have contacts with research workers from home or foreign institutes or government departments whose work is the same or touches on that of the specialist departments of the Soil Survey Institute. For carrying out certain types of work co-operation with experts from other institutes is often indispensable. The same may be said with regard to the work of evaluating the suitability of the soil.

III.2.1. The Soil Classification Department

The principal task of this department is the classification of the soils of the Netherlands. For this purpose a system of categories has been evolved on the lines of the new U.S. system. This system came into being after extensive consultations between the various specialist and provincial departments and was carefully tested in the field. Work is still proceeding on the elaboration of the lower categories of this system. This system, accompanied by explanatory notes, will be published in 1960/61. The work of classification will not, however, be completed with this publication, but continued with testing and improvement of the system.

Generally speaking the remaining work of this deparment may be regarded as the preliminaries to the compilation of the classification system, e.g. drafting a scheme (formulation) of profile description (detailed and simple), with the object of standardising it and making it suitable for comparison, drawing up classifications for texture, humus and calcium content based on a large quantity of analytical material and making a survey of C/N ratios in different soils. Attention is also given to the further development and improvement of the profile description technique, e.g. horizon terminology, description of the profiles of heterogeneous soils. Finally, the work includes the co-ordination and summarising of specific investigations undertaken by party chiefs in the sphere of soil classification and profile research.

III.2.2. The Map Co-ordination Department

On the basis of the above classification system the map legends for the sheet-map survey (scale 1 : 50.000) were drafted by the map co-ordination department together with the map legend committee. This work was performed in two stages, viz. a provisional map legend based on experimental surveys, this afterwards being tested by means of a second series of experimental surveys. After the definitive legend has been drafted the work of this department consists in the co-ordination and correlation of the actual survey work done by the survey leaders. This means paying constant attention to recording technique, the density of the record, the map pattern, pedological documentation, and the combination of units into associations. In this connection the work is naturally done in co-operation with the soil classification, hydrology etc. departments and the provincial party chiefs.

III.2.3. The Hydrology Department

The Hydrology Department is responsible for delineating the hydrological regime on the soil map and for classifying the land improvement possibilities. In the first of these tasks particular emphasis is placed on the provision of information on the water tables, especially for the sandy regions. The soils are classified on the basis of estimates into soil water classes with reference to various kinds of profile characteristics which give an indication of the fluctuations in the water tables and are a sufficiently reliable index. In the case of the 50.000 sheet-map survey this is done for each map unit. A great deal of research is done on these profile characteristics, the systematic water table measurements of the Commission for Agricultural Water Utilisation Research in the Netherlands being especially important. As a result of the study of the relationship between specific profile characteristics and water tables it was found possible to make a fairly reliable estimate of the location of the water table. This estimating technique is being continually improved.

The pF research work is likewise important e.g. for typifying the moisture retention, for calculating the amount of moisture available and the water-storage capacity, and finally for gaining an insight into the soil air regime. Owing to the expense of pF determination emphasis is placed on the calculation of the moisture content of a number of typical pF values such as wilting point and field capacity from such readily determined properties as clay content, humus content, etc..

The research programme also includes the permeability of profile horizons (e.g. disturbing strata), the upward movement of capillary moisture, root formation possibilities (estimate method) and the withdrawal of moisture from the profile during periods of drought (gravimetric moisture determination of samples taken from different depths).

III.2.4. The Micropedology Department

Micropedology comprises the microscopic study of the soil. By this means more detailed information is obtained on the nature and arrangement of the various soil components and the proportions in which they occur. They also make an important contribution to widening our knowledge of soil-forming processes. At the same time the phenomena discovered by microscopic examination may provide important indications or supplementary information for research in the sphere of soil physics, soil chemistry, soil biology, microbiology, etc..

The study is based on stereoscopic and microscopic observations of the undisturbed soil, the former being undertaken both in the field and the laboratory. For microscopic research work thin sections are made of the undisturbed soil. In future years attention will be paid to colouring various components in thin sections.

The work comprises:

1. Making a detailed classification of the macrostructures in the Netherlands. This is based on features which are visible under a magnifier not exceeding 4× linear.
2. The study of the humus forms was first undertaken in sandy soils underneath woodlands and heaths where raw humus, moder and dispersed humus are principally found. Many sub-types of these humus forms are distinguished.

The study of the humus forms is very important in the case of the peat soils (these have been largely brought into cultivation and have been substantially drained). Here it is found that the topsoil has often largely moulded. The clay content, pH, fertilisation, drainage, etc. determine which form of humus occurs.

3. Of the numerous other subjects we may mention the study of the relationship between the structure of clay-on-peat soils and the grassland vegetation which revealed a very close correlation in soils between the type of grassland and the nature of the soil structures.
4. In co-operation with the State Horticultural Extension Service and various individual research workers a study is being made of the ripening of soils for horticulture, including the micromorphological differences in „green house soils" in connection with such factors as fuelling, disinfestation, etc. Other studies include the pedological problems of the rhodocultures at Boskoop, the suitability of *„Smoesd" peat* in horticulture, the micromorphology of orchard soils with reference to the soil fauna and root formation, the effect of mulching on profile and root development, and the micromorphological aspects of soil preparation experiments.
5. Experiments on the morphological changes occurring as a function of time in excrements of various soil fauna in different soil types. These experiments will be greatly extended in the future.
6. Such laboratory determinations as water stability measurements (Hénin method), permeability determinations, consistence determinations, granular analyses, qualitative determinations of clay content of excrements of soil fauna, soil-water-air volume determinations, humus and calcium content determinations.

In future intensive study of the development of the humus forms, both by making investigations and conducting experiments will be made. Arable profiles will be micromorphologically studied on a very wide scale and soils with natural vegetation or grass will be used as comparative material. A study of the factors which assist or prevent structural decay, this being important both for soil classification and agricultural, horticultural and forestry practice.

Finally, the programme includes a study of the micromorphological aspects of hydrology (e.g. permeability and moisture stages).

III.2.5. Soil Physics and Chemics Department

The work of this department comprises: Investigations in the sphere of chemistry and clay mineralogy, e.g. for the purpose of typifying the soils of the Netherlands and assisting in research undertaken by the other departments in this sphere.

The activities of this department also include fundamental clay research.

Every main soil type has its own specific chemical and physicochemical properties. These are important both for plant nutrition and for typefying the soil type itself.

Thus the marine clay soils have a high P and K content, whereas the river clay soils are poor in these elements. The SiO_2/R_2O_3 quotient is much higher in marine soils than in highly weathered loess soils.

Gley soils are in a very reduced state, and this property can be measured by determining the oxidation reduction potential.

Rendzinas and plastic soils contain the highly swelling clay mineral known as montmorillonite. When a great deal of this is present the result is a poor structure. The poor structure caused by „open illite", a clay mineral occupying an intermediate position between ordinary non-swelling illite and soil montmorillonite, results in the low potato yields in the basin soils of the river clay area; this used to be wrongly attributed to potash fixation. The occurrence and cause of the irreversibility phenomenon is also being studied as this soil property is likewise very important (cf. the excessive drainage of polders by pumping).

Other subjects studied are a rapid analysis of the soil moisture available to plants, comprising the $pF = 2.2–4.2$ range, in connection with problems of agrarian structure, and also the determination of the internal surface of the soil, since it is precisely this magnitude that determines water absorption rather than the clay content (< 2 mu) or silt and clay content (< 16 mu).

Finally, a detailed study is in progress of the transition from one clay mineral to another, of the formation of particular clay minerals under particular conditions, and of the structure of less well-known but frequently encountered clay minerals such as soil chlorite and soil montmorillonite. For this clay research use is made of X-ray and infrared equipment (Soil Mechanics Laboratory and the Analytical Institute), both at Delft). On the subject of the identification of clay minerals by means of electron microscopy the department co-operates with Dr. Beutelspacher of Brunswick.

III.2.6. Mineralogy Department

The work of the Mineralogy Department comprises the following activities:

1. the study of the mineral composition of the soil in connection with the mineral reserve and soil fertility,
2. investigation of the nature and origin of certain geological deposits where this can be done by mineralogical methods, and the part played by minerals in soil-forming processes.

Thus the humic acids in the A horizon of the podzol profile have a solvent effect on certain minerals. In this manner ancient vegetation horizons can be identified in soil profiles by mineralogical methods.

3. Mineralogical studies relating to the chemical richness of the soil.

High phosphate figures may denote the occurrence of apatite or phosphorite. Boron deficiency may be connected with the distribution of the tourmaline mineral. And the chemical-mineralogical relationship is also clear in the soil profile.

The research programme includes the sphere of silt and fine sand which makes up the greater part of Dutch soils and of which generally speaking, there is still only rudimentary knowledge.

In order to obtain quantitative data it was necessary to develop a special research technique which although not comprehensive would nevertheless be reliable. The gravimetric determination of the minerals in groups is preferred to the conventional method of microscopically determining each of the grain-size fractions.

Although microscopic checking is still required, microscopic counting is replaced by a weighing operation, which means that time is saved. At the present moment no difficulties are encountered in determining the fractions exceeding about 100 microns. The work is done in close collaboration with the staff of the Geological Laboratory of the State Agricultural University of Wageningen.

After the methods have been elaborated it will be examined (e.g. with the aid of statistical methods) to what extent the then known mineralogical reserve of the soil determines soil fertility, and how this factor is correlated with other factors affecting soil conditions.

The relationship between soil fertility and mineral reserve is also being studied by measuring the amount of cations in an aquaous solution that are released in a given period under certain conditions. From the conductivity figures it is then possible to draw indirect conclusions regarding the presence of important mineral reserves.

III.2.7. Geology and Palaeobotany Department

The work of this department is to conduct its own researches and to give advice and assistance on geological questions to other departments (including the publication sphere).

1. Geomorphological maps are compiled on behalf of soil surveys, use being made of such materials as altitude data and aereal photographs. Special attention is paid to micro-relief.
2. The mapping of the glacial deposits and forms. In this way a tectonic map was compiled of the compacted series of the Netherlands and the fluvio-glacial deposits were remapped. At the present moment special attention is being paid to late pleistocene and holocene fluviatile deposits.
3. The problems of the stratigraphy of the Central and Late Pleistocene are receiving attention. The periglacial phenomena are also being investigated and in particular the deposits shifted by solifluction. A study is also made of the periglacial valleys, the valley assymetry and cryoturbate phenomena.
4. A method has been evolved for identifying various deposits from > 2 mm components. The central German river deposits encountered in the north of the Netherlands are being studied in detail.
5. A further part of the work programme of this department consists in studying the relief and origin of the distribution of eolian deposits.

The department co-ordinates and gives advice on sampling for pollen analysis and C-14 research. Palynological research is conducted. The head of the department provides the analysis results with geological comments.

III.2.8. Diatom Research Department

The reason why geologists, palaeobotanists and soil scientists are at present interested in diatom research lies in the possibilities which the diatom association method affords for the determination of environments. Differences in living conditions can be determined from the occurrence of characteristic types. These living conditions provide in turn further information on the nature of the period at which particular sediments came to be deposited.

It is now possible to reconstruct the environment by grouping the types found in the deposits. This so-called association method enables us to establish whether an environment must have had a fresh, brackish or salt character, whether or not the environment was in the vicinity of the sea, whether there was any river influence, whether the water in which the diatoms were deposited was deep or not, whether or not hydrophytes lived in it, and so on. The ecological groups also provide information on the wealth of food, the acidity (pH) and the most probable chlorine content of the environment. Particular type combinations can give a decisive answer to climatic problems (boreal, alpine, tropical, sub-tropical, etc.). In such cases the number of individuals found in the samples is important. The association method is also employed for archaeological investigations, viz. in cases where the material (e.g. potsherds) contains diatoms.

A process in which the diatoms also play a prominent part is the silicon cycle. The „armour" of decayed specimens remain more or less intact in a neutral or acid medium and fossilises slowly. Diatoms have already been discovered for certain in the oldest tertiary strata (Eocene, Oligocene).

In future attention will be given to the study of the characteristic types in different soil strata so as to afford stratigraphic indications and datings and enable Foraminifera, Ostracode and pollen studies to be undertaken. Research will also be carried out on fresh silt.

III.2.9. Vegetation Research Department

There are some reasons for the presence of a vegetation research department in the Soil Survey Institute.

1. Vegetation, whether natural vegetation or one with a marked anthropogenous influence, is an important factor in soil determination. Just as a knowledge of geology is essential for a proper evaluation of the soil, so vegetation in its past and present states can in many respects help in getting an insight in the existing soil conditions.
2. A proper interpretation of the vegetation may be important to the soil scientist in survey work since everything observed in the field should be employed in delineating the soil boundaries. But it is necessary to examine the utility of vegetation-types and type combinations, and this is done in this department.
3. Finally vegetation research may be helpful for establishing the ecological characteristics of various soil types which although pedogenetically different may be ecologically related, and may also display the reverse pattern.

In order to perform this work adequately vegetation is studied as far as possible within the framework of other investigations carried out by the Soil Survey Institute.

There is fruitful co-operation in the sphere of forest soil surveying and hydrology and with various party chiefs. Part of the department's work is done independently; hitherto it has been mainly confined to research.

III.2.10. Historical Geography

Since its inception soil survey work has already been able to make important contributions in the sphere of historical geography. This is chiefly owing to the greatly increased detailed knowledge of the natural landscape and the changes which have occurred in it. The chief subjects to benefit are toponymy, field history and ultimately the history of cultivation.

In many survey areas the still existing names of fields, houses, roads, waters, etc. are assembled on the map during field operations. These data are verified by the Historical Geography Department and then copied on to network maps, transferred to slips, and worked up into lists for each village, hamlet or other unit of settlement. Co-operation with the Sociology and Sociography Department of the State Agricultural University at Wageningen widened the scope of this study in that the social factors were included in the investigation. Knowledge of the former landscape (before the introduction of fertilisers) is obtained from the oldest land register data in particular, i.e. from the so-called minute plans and the first reference tables. The first land register plans may also afford a good impression of the settlement of the country some 150 years ago.

Names, field shapes and village shapes all represent in turn a specific phase in the history of cultivation. By combining these one is enabled to analyse the development of particular settlements.

For help in linguistic problems reference is continually made to the Place-Name Committee of the Royal Netherlands Academy of Sciences.

III.3. *Applications*

The departments engaged in the sphere of the applications of the soil map are the Land Classification (Arable and Grassland), Horticulture and Forestry Departments. These, each in their own sphere, are occupied in studying the relationship between soil and cultivated plants. Hence the aim of this work is to give the soil map an agricultural interpretation directed towards land utilisation and cultivation. This interpretation is recorded in the soil suitability map.

Since in many cases the agricultural merits of different pedological characteristics are not readily apparent these departments also undertake research in this sphere. For this purpose both a knowledge of soil pedology is required and an extensive knowledge of cultivation practices together with some understanding of economics. For these reasons these departments work in close collaboration with the State Extension Services and with the research workers of institutes for the study of plant cultivation, agrarian structure or economics.

III.3.1. The Land Classification Department

The Department of Land Classification for Arable and Grassland Farming is especially engaged in the study of land classification problems relating to agriculture (arable, grassland and mixed farming). Insofar as co-operation with other institutes and government departments relates to national and general activities it is co-ordinated by a Land Classification Working Party of the Ministry of Agriculture and Fisheries. There is regional co-operation with the Extension Services and farmers' organizations via the provincial party chiefs. For the general interpretation of the work the five categories of land classification described by A. B. Lewis have been found very useful. The Soil Survey Institute compiles land classification maps of category III „Land classification in terms of use capabilities". In future it is intended that every soil map will be accompanied by at least one use capability map.

A new category of land classification termed „Soil Quality Classification" has also been distinguished.

The use capability maps for crops may be compiled at various levels of estate management. For the Netherlands this is particularly important in connection with the land improvement projects in course of execution. The lowest level at which a use capability map can be compiled is the actual production level, viz. the average of the results obtained by *all* farmers from the various soil types. The level may be raised by taking into consideration the results obtained by *good* farmers from the various soil types. A third level can be reached by estimating the results which can be archieved by good farmers by means of *the best possible scheme of cultivation.*

The third level is considered the best for typifying the use capabilities of the soil types. For this reason our aim is to obtain as far as possible data at this level for our land classification systems. Experience shows that the suitability of a particular type of soil is determined by the following factors:

yield – production risk – quality of the product – production costs – relative surface area of the soil type or soil pattern.

The intensive form of farming practised in the Netherlands is the reason why in many cases the yield in terms of money is only dependent on the soil types in a very general sense. In many cases the production risk and production costs are more important.

The data are obtained via the methods:

1. group meetings with „good" farmers;
2. seperate interviews with various „good" farmers;
3. collaboration with local experts, e.g. the agricultural extension services;
4. studying the information provided by various experimental farms, etc.;
5. information provided by previous experiments undertaken by other institutes or by the Extension Services;
6. listing the crops (for one or more years) cultivated by the farmers on the various soil types. If the area covered in this way is sufficiently large (at least 5000 hectares) the statistical results thus obtained are important and useful.
7. experimental harvests and crop estimates.

Use is generally made of more than one of these methods in order to obtain the data. Method 3 is invariably employed, sometimes alone but preferably together with one or more of the other groups. The first method proved very important both to the farmers and to ourselves. It was found to be very useful in the three areas in which work has hitherto been done with this method. The second method is less satisfactory than the first and gives less reliable results. With the use of methods 4 and 5 it is possible to obtain a larger number of accurate yield data and hence more quantitative results. Method 6, although it cannot be used independently, has given promising results. Method 7 is costly and can only be used to advantage in specially selected typical areas. In this case certain conclusions can be tested and the results of regional classifications can be placed on a more general level of comparison.

III.3.2. The Horticulture Department

This department of the Soil Survey Institute examines the pedological possibilities afforded by the various soils for carrying on horticulture. There is much co-operation between this department and the State Horticultural Extension Service and various institutes and Experimental Stations, as well as with the other departments of the Soil Survey Institute.

Its work comprises:

1. The assessment of the horticultural possibilities of the various soils. For this purpose a study is made of the development of horticultural plants on these soils.
   The study is preferably made on good establishments. It can be assumed that the plants are properly tended on such establishments, thereby providing a good insight into the potential suitability of the soils.
2. Investigation of the pedological factors causing the differences in soil suitability for the various horticultural plants, methods of cultivation and types of establishments.
   What this study chiefly amounts to is that by comparing detailed profile descriptions of soils of varying suitability an attempt is made to gain a knowledge of the soil suitability factors. Where necessary the profile descriptions are supplemented by various chemical, physical and biological determinations. The study of root formation may be a valuable aid in this type of research.
3. A study of the demands on the soil made by the various horticultural plants, methods of cultivation and types of establishments.
   This study is a corollary to the study of soil suitability factors.
4. A study of the possibilities of improving the soil for horticultural purposes.
   This study is a continuation of the study of the soil suitability factors and the demands on the soil made by the various horticultural plants, methods of cultivation and types of establishment. In order to indicate what possibilities exist for improving the soil it is obviously necessary to know what deficiencies the soil has and what demands are made on the soil.
5. The classification of the soils according to their suitability for horticulture, e.g. on behalf of the Horticultural Settlement Project. This is based on the results of the above-mentioned study. The classification of the soils is generally shown by means of horticultural suitability maps. The suitability classes are descriptive and supplemented by more quantitative data where possible.
6. Giving advice on the suitability of the soil for horticulture to the other departments of the Soil Survey Institute and other bodies.

III.3.3. The Forestry Department

The work of this department consists of:

1. The study of the influence of the soil on the growth of the principal types of timber.
2. The compilation of soil maps and suitability maps derived therefrom.

The study of the relationship between forest and soil is limited to the Scotch pine, Douglas fir and larch production types. During the study the soil of one or more small areas (10 to 30 hectares) is generally mapped. In this area a number of experimental plots are laid out in which the stand of timber is determined. Correlations are sought between the stand and the various soil units, one or more soil characteristics, or combinations of the latter.

When a reasonably good relationship has been found a map legend can be made for the area to be surveyed. With the aid of this legend the soil maps are compiled from which the suitability maps are afterwards derived.

This department chiefly co-operates with the Geology and Palaeobotany Department (relationship between the depth of the root formation and the nature of the deeper strata), the Mineralogy Department (the mineralogical composition of the parent material), the Vegetation Research Department and the Hydrology Department (the relationship between water movement and tree growth). For the suitability study it is sometimes necessary to evaluate the timber stands and to define and name the suitability classes. This work is carried out in close collaboration with the State Forest Administration and the T.N.O. Forestry Experimental Station.

A national study of the Douglas fir is also being undertaken together with the T.N.O. Forestry Experimental Station.

The surveys and research are carried out on the instructions of the State Forest Administration. The survey of the Speulde forest (500 hectares), like that of the State forest areas of Ugchelen and Hoenderlo, may be regarded as study surveys of the Pushed Preglacial. The survey of the State forest area of Kootwijk (2000 hectares) is one of a blown sand area. No generally valid relationship between forest and soil has been found yet in the surveys undertaken in the south of the Netherlands.

Although the amount of knowledge gained is still slight, in many cases it is sufficient to prevent the worst errors of forestry land use. Information on this subject is usually given in the form of courses and excursions for officers of the State Forest Administration and other interested persons.

IV. DEPARTMENT FOR PUBLICATIONS, LIBRARY, PROGRAMMING AND PLANNING, MAP EDITING

IV.1. *Department for Publications*

This department is responsible for publishing the studies made and data assembled.

The following forms of publication are available:

1. *Communications of the Soil Survey Institute.*

These are scientific publications of a somewhat wider scope and consequently less suitable for insertion as articles. These Communications consist of three series two of which also appear in the series entitled Agricultural Research Reports. (Verslagen van landbouwkundige onderzoekingen.)

a. The Soil Survey of the Netherlands.

These are publications relating to research surveys and are therefore accompanied by a soil map. About 20 publications have appeared in this series over the years.

b. Studies on Soil Science.

This series usually contains the results of soil research which is not directly related to a survey or the direct result thereof. This series is started in 1957 when the general national surveys were receiving more attention. To date this series comprises 4 publications.

c. „Boor en Spade" („Auger and Spade").

These publications contain „miscellaneous contributions towards a knowledge of the soil of the Netherlands". They are usually studies which are narrow in scope, rounded-off sections of particular surveys covering a wider sphere, and reprints of articles from other periodicals. These publications also regularly include a survey of the mapping activities of the Soil Survey Institute.

2. *Reports of Commissioned Surveys.*

The soil maps and the maps derived therefrom which are compiled to order are always accompanied by explanatory comments. The latter are supplied to the customer with the maps in the form of a stencilled report.

3. *Preliminary Scientific Communications.*

This series includes the preliminary results of scientific studies and reports on surveys which are not sufficiently rounded off to enable them to be published at once. This obviously means that it is intended to publish these studies at a later date.

Reports of Commissioned Surveys and Preliminary Scientific Communications are not publications in the true sense of the word. The Communications are strictly confidential and solely intended for internal use. Borrowing or quoting from these communications is not allowed without authors' permission. The Reports of commissioned surveys can usually be supplied by the Library on request.

4. *Publications in other periodicals.*

In addition to the above-mentioned publications and reports the editorial department also frequently deals with articles by co-workers for other home and foreign periodicals.

5. *Annual Report, etc.*

This Report, like the surveys or commentaries for „Boor en Spade" or periodicals belonging to other institutions, is compiled by the editorial department.

Other work belonging to the sphere of the editorial department includes the documentation, keeping the minutes of official meetings, general translation work, correcting printers' proofs giving assistance in arranging exhibitions and with public relations.

IV.2. *Library*

The library staff not only perform the usual library work but such tasks as compiling literature lists, and documentation.

IV.3. *Programming and Planning*

This department was set up during the 1957 reorganization. Its work consists in drafting all research and work programmes of the specialist and provincial departments. The heads of departments submit a monthly schedule specifying the time spent. The work progress is posted on a progress chart and work differing or going beyond the programme is noted in good time. In addition quarterly reports are compiled on the work and results. For these purposes a list of items has been drawn up by the Programming Department. This list of items is also the basis of the work programmes and the project administration for which the General Affairs Department is responsible.

The work programmes are drawn up annually by consultation between the head of the major department concerned, the departmental heads and the head of the Programming Department. If necessary this programme may be subject to interim changes.

IV.4. *Map Editing*

At this department the draft maps and drawings are recorded and prepared for the drawing office. This department consults the text editors in order to ensure that the definitive form of the map legends and letterpress agrees with that of the report or publication. Where necessary these texts are translated (usually into English).

To add to their clarity the map legends are shown in tabular form where this can be suitably done. This means a considerable gain in clarity and scope.

In consultation with the author and the drawing office fairly detailed instructions are given on the colours and shading to be used.

The object is to show the differences and correspondences between the delineated units in their relation to each other and to obtain a certain degree of uniformity, at any rate within each report or publication. As far as possible esthetic appearance and technical feasibility is also borne in mind. A slight change of method may sometimes greatly facilitate the work. The method of working is definitively established in consultation with the head of the drawing office, and the drawings, together with the necessary instructions, are passed on to the drawing office.

Problems which arise during or after drawing or colouring are solved, if necessary in consultation with the department for Publications or the author.

In order to prevent the same problems from occurring whenever the colours or shadings are selected a colour scheme and a collection of shadings have been assembled. In co-operation with the drawing office, the photographic department and the lithographic department, the appropriate technique has gradually been further developed so as to provide a still wider selection in the future and satisfy the increasing number of demands.

V. REPRODUCTION DEPARTMENT

This department, which with its staff of 23 is certainly the largest one in the Soil Survey Institute, includes the drawing office, lithographic, photoprinting and photographic sub-sections, as well as the records departments for soil maps, topographical maps, transparencies, photographs and blocks.

This department undertakes all the reproduction work of the Soil Survey Institute for both internal and external use.

V.1. *Drawing Room*

The task of the drawing office is to reproduce all text figures and field maps of outdoor staff for the publications. The data are transferred to transparent material. Non-dimensional stable photo-printing material is used for report maps and exclusively dimensional stable material for maps which will appear in print. After the drawing work has been completed a print is made on dyeline paper. This print is coloured by hand with transparent water colours.

After the first coloured specimen has been passed the required number of copies of the report map (maixmum 15) are coloured. This is also a manual operation.

In the case of a map intended for a printed publication the above method takes an entirely different form. One copy is actually coloured, but after being passed it is sent to the lithographic subsection.

V.2. *Lithographic sub-section*

This sub-section works the map up sufficiently to enable it to be immediately copied on an offset plate and printed.

The Soil Survey Institute has a colour scheme by means of which a total of 195 shades can be obtained from the three colours yellow, red and blue in successively superimposed screens. From these shades a selection can be made for the soil types.

For the drawing on dimensional stable material three uniform blueprints are made, one for all yellow shades, another for all shades of red, and the last blueprint for all shades of blue.

A coloured map having 150 shades, for example, is completely analysed into the three main colours yellow, red and blue. In the subsequent stage all shades are applied by ink, transparent red foils, and line or point screens. These foils or screens are made on stripping film in the photographic subsection and given an adhesive wax coating. Where necessary the stripping film is stuck to the blueprints and then carefully cut off along the soil types.

After the three blueprints have been treated in this way they are copied on to a sensitive plate at a printing office together with the black drawing.

V.3. *Photographic sub-section*

In this sub-section work is performed for both outdoor and indoor staff. For the outdoor staff the work comprises making black-and-white or colour photographs of profiles, differences in growth, landscapes, etc. Although practically every party chief has a camera it is sometimes necessary for a professional photographer to take the photographs, for instance in cases where colour enlargements on paper are required. In addition, all field maps for the map which is to be supplied are photographically reduced or enlarged to the required scale.

For indoor staff, the work is chiefly in connection with the drawing office and lithographic and photo-printing sub-sections. Master maps, texts, copies in black-and-white or maps and screens can be prepared with the aid of a large reproduction camera.

In addition, black-and-white or coloured lantern slides are prepared for lectures. Microscopic photographs are also taken for the Micropedology Department.

The experiments in reproducing soil maps, etc. by means of colour photography have raised hopes that it might be possible to employ this photographic method instead of the above-mentioned colouring by hand. The laborious task of colouring by hand could then be confined to the colouring of a single good model.

V.4. *Photo-printing sub-section*

In close co-operation with the photographic sub-section, this sub-section undertakes all photo-printing work for the entire outdoor and indoor staff.

VI. GENERAL AFFAIRS DEPARTMENT

This department has a permanent staff of 14, supplemented by the office management staff and a housekeeper.

Its chief functions are the control and administration of the receipts and expenditure, budgetting and the budget audit, the costprice calculations, the inventory administration and all other matters relating to finance.

The work connected with staff matters is also fairly extensive. This department is also responsible for typing and stencilling work, the central mailing and records departments and the telephone and messenger departments.

It is also in charge of the cleaning of the offices and other maintenance work, permanent installations, inventory and garden.

TAAK EN ORGANISATIE VAN DE STICHTING „INSTITUUT VOOR BODEMKARTERING"

1. INLEIDING

De Stichting „Instituut voor Bodemkartering" werd op 21 augustus 1945 opgericht. Daarmede kreeg een werkwijze gestalte, die reeds enige opvallende resultaten had bereikt. Deze werkwijze – vooral tijdens de laatste oorlog ontwikkeld onder leiding van Prof. Dr. C. H. Edelman – bestond uit het onderzoek van de aard en de verbreiding van de min of meer blijvende eigenschappen van de bodem door daarin gespecialiseerde onderzoekers. Het gebruik van de grondboor, naast de spade, maakte een snelle inventarisatie van de bodemverschillen mogelijk. De algemeen bestaande interesse in de kennis van de eigenschappen van de bodem en hun regionale verbreiding leidde spoedig tot erkenning van de gevolgde werkwijze.

De grote promotor van de bodemkartering Prof. Dr. C. H. Edelman werd de eerste directeur van het nieuwe Instituut. Hij werd in 1955 opgevolgd door zijn oudste leerling, Dr. F. W. G. Pijls.

2. TAAK EN ORGANISATIE

Het werk van de Stichting „Instituut voor Bodemkartering" omvat volgens art. 3 van de statuten:

1. De bestudering van de grond ten behoeve van de classificatie en de kartering van de bodem van Nederland.
2. De systematische kartering van de bodem van Nederland.
3. De geschiktheidsbeoordeling en landclassificatie van de bestudeerde gronden (in samenwerking met andere instituten).
4. Het in opdracht uitvoeren van bodemkarteringen en landclassificaties.
5. Het publiceren en algemeen beschikbaar stellen van de uitkomsten der werkzaamheden.

Aanvankelijk bestond het werk vrijwel uitsluitend uit regionaal bodemkundig en aansluitend landbouwkundig onderzoek, uit opdrachtkarteringen voor derden en uit voorlichting. Deze werkzaamheden werden uitgevoerd door karteringsploegen onder leiding van een in de bodemkunde gespecialiseerde landbouwkundig ingenieur. Hieruit zijn later de provinciale afdelingen gegroeid.

Voor bepaalde onderdelen kon de karteringsleider te rade gaan bij enige specialisten, b.v. voor geologie, mineralogie, historische geografie en archeologie. Daarnaast ontstonden coördinerende commissies, die op bepaalde afgebakende gebieden werkzaam waren, b.v. coördinatie van de legenda, geschiktheidsbeoordeling en hydrologie.

Het proces van coördinatie werd verhaast door de opdracht tot het vervaardigen van een bodemkaart van geheel Nederland, schaal 1 : 200.000, waarvan de resultaten in druk zijn. Vooral echter door de opdracht tot een systematische bodemkartering op schaal 1 : 50.000 werd coördinatie, uniformiteit en onderzoek op landelijk niveau noodzakelijk.

Deze ontwikkeling leidde in 1957 tot een reorganisatie, waarbij de landelijk, algemeen bodemkundige taak naast de bestaande regionale werkzaamheden haar vorm kreeg.

Het organisatie-schema werd van toen af:

ORGANISATIESCHEMA VAN DE STICHTING VOOR BODEMKARTERING

BESTUUR

Directie — Adviseur

Hoofdafdeling Regionaal Bodemkundig Onderzoek en Karteringen	Hoofdafdeling Specialistisch Onderzoek	Afd. Redactie, Bibliotheek en Programmering en Planning	Afd. Reproductie	Afd. Algemene Zaken
Afd. Opdrachtkarteringen Afd. Groningen Afd. Friesland Afd. Drente Afd. Overijsel Afd. Gelderland Afd. Utrecht Afd. Noordholland, Zuid-Holland ten noorden van de rivieren Afd. Zuid-Holland beneden de rivieren Afd. Zeeland Afd. Noordbrabant Afd. Limburg	Afd. Bodemclassificatie Afd. Kaartcoördinatie Afd. Hydrologie Afd. Micropedologie Afd. Chemische Bodemkunde Afd. Mineralogie Afd. Geologie en Paleobotanie Afd. Diatomeeën-onderzoek Afd. Vegetatiekunde Afd. Historische Geografie Afd. Landclassificatie Afd. Tuinbouw Afd. Bosbouw	Redactie rapporten en publikaties Bibliotheek Programmering en Planning Redacteur kaarten	Tekenkamer Lithografie Fotografie Lichtdrukkerij Tekeningenarchief	Boekhouding en Administratie Archieven Typekamer Telefoon Onderhoud

Technische Archieven

3. BESTUUR EN DIRECTIE

Het bestuur bestaat uit 10 leden, benoemd door de Minister van Landbouw en Visserij op voordracht van de Minister van Landbouw en Visserij (4), de Ministers van Verkeer en Waterstaat en Volkshuisvesting en Stedebouw (2), het bedrijfsleven en het Landbouwschap (4). Het bestuur voert het financiële beheer van het Instituut en stelt op voordracht van de directeur o.a. het werkplan vast. De directeur is aan het bestuur verantwoording verschuldigd aangaande het beleid en de gang van zaken bij het Instituut. Hij wordt bijgestaan door een adjunct-directeur.

De initiatieven tot uitvoering van bepaalde werkzaamheden zijn van drieërlei oorsprong. Zij kunnen afkomstig zijn van het bestuur (kaartbladenkartering), van de provinciale en specialistische afdelingen (onderzoek van bepaalde bodemkundige problemen) en van buiten de dienst (opdrachtkarteringen). Deze laatste zijn van groot belang, omdat hieruit – naast Rijksbijdrage en subsidies van enkele instellingen – rond een kwart van de inkomsten verkregen wordt.

4. DE HOOFDAFDELINGEN

De hoofdafdelingen vormen de schakel tussen de directie en de provinciale en specialistische afdelingen. De hoofden ervan stemmen de afdelingen op elkaar en op de opgedragen taken af. Zij hebben een dirigerende en controlerende functie. Het jaarlijks op te stellen werkprogramma voor de verschillende afdelingen wordt in overleg met het hoofd van de betrokken hoofdafdeling opgesteld.

5. INTERNE COMMISSIES

Er bestaan 11 interne commissies, o.a. de Commissie voor Bodemclassificatie, de Commissie voor de legenda van de 50.000-kaart, de Landclassificatiecommissie, de Tuinbouwcommissie, de Hydrologische Commissie en de Chemische Commissie. Zij verrichten voorbereidende en toetsende werkzaamheden, doen voorstellen aan de diverse afdelingen betreffende het onderzoek van bepaalde problemen en toetsen de uitwerking. Naast het hoofd van de betreffende specialistische afdeling hebben in deze commissies enige hoofden van provinciale afdelingen zitting.

Daarnaast bestaan enige werkcommissies, zoals de Terminologiecommissie (formulering van begrippen, termen), Technische Commissie (toepassing van technische ontwikkelingen op bodemkundig werk), Commissie Middelbaar Personeel (adviezen over het personeel).

6. DE HOOFDAFDELING REGIONAAL BODEMKUNDIG ONDERZOEK EN KARTERINGEN

Hieronder vallen taken met een regionaal karakter, de uitvoering van opdrachten voor derden en dat gedeelte van het onderzoek, dat door de provinciale afdelingen regionaal en zelfstandig wordt uitgevoerd.

De hoofdafdeling bestaat uit de provinciale afdelingen en de afdeling Opdrachten. De bezetting wordt gevormd door 18 academici en ca. 40 middelbare en lagere krachten.

De provinciale afdelingen

Alle afdelingen staan onder leiding van een academicus, meestal bijgestaan door 2 assistenten. In enkele grote ambtsgebieden is een tweede academicus werkzaam.

De provinciale afdelingen hebben de volgende taken:

1. Regionaal bodemkundig onderzoek
2. Medewerking aan algemeen bodemkundig onderzoek
3. Medewerking aan landelijk bodemkundig onderzoek en de systematische kartering van Nederland (schaal 1 : 50.000)
4. Uitvoering van en medewerking aan opdrachtkarteringen
5. Voorlichting.

In het kader van het *regionaal bodemkundig onderzoek* werden onderzocht of zijn nog in onderzoek b.v. de morfologie van het pleistocene oppervlak in westelijk Midden-Nederland; het knipkleiprobleem (Friesland en Zuidhollandse eilanden); de fysische en chemische rijping (Noordholland, Zeeland, Biesbosch); bodemvorming in zandgronden (Overijsel, Gelderland, Noordbrabant); zwartveenonderzoek (Drente); bodemvorming onder invloed van bouwland en grasland (Zeeland); veenkoloniale gronden (Groningen); vorming van een z.g. textuur-B (Limburg).

Medewerking aan *algemeen bodemkundig onderzoek* (uitgevoerd door de specialistische afdelingen) wordt o.a. verleend aan het onderzoek van structuur- en humusvormen, de verschillen tussen zee- en rivierklei, geschiktheidsbeoordeling voor akkerbouw en tuinbouw.

Aan het *landelijk bodemkundig onderzoek* is door alle provinciale afdelingen medegewerkt bij de beschrijving van de gronden ten behoeve van de bodemclassificatie van Nederland.

Voor de *systematische kartering, schaal 1 : 50.000*, zijn door alle afdelingen proefkarteringen uitgevoerd voor het vaststellen van de legenda. Ook de uitvoering van deze kartering zal grotendeels door de provinciale afdelingen geschieden.

De *uitvoering van opdrachtkarteringen* geschiedt in principe door de provinciale afdelingen. Omdat deze karteringen vaak een scherp omlijnd, praktisch doel hebben (ruilverkaveling, stadsuitbreiding, tuinbouwvestiging) en de afdelingen overbelast zijn, worden deze karteringen meestal door de afdeling Opdrachtkarteringen uitgevoerd, soms samen met de provinciale afdelingen.

Voorlichting aan instanties die met de bodem te maken hebben, wordt op regionaal niveau door de provinciale bureaus gegeven. *Directe* voorlichting aan de praktijk wordt niet gegeven. Dit geschiedt door de land- en tuinbouwvoorlichtingsdiensten.

De afdeling Opdrachtkarteringen

Deze wordt geleid door een academicus, bijgestaan door 2 opzichters, 6–8 karteerders en enig personeel in los verband.

Aan de hand van de doelstelling worden kaartschaal, legenda, te vervaardigen afgeleide kaarten, enz. vastgesteld. Meestal is de doelstelling van landbouwkundige aard. Het belangrijkste zijn bodemkaarten ten behoeve van ruilverkavelingen. Ook worden vele opdrachtkarteringen uitgevoerd voor uitbreidingsplannen, waterbeheersingsplannen, inventarisatie van kleivoorraden (baksteenindustrie), militaire objecten, e.d..

Naast de bodemkaart worden veelal afgeleide kaarten gemaakt, die de niet-bodemkundig geschoolde gebruikers een beter overzicht van bepaalde facetten van de bodem geven. Zo worden dikwijls geschiktheidskaarten voor bepaalde vormen van bodemgebruik vervaardigd. Herhaaldelijk zijn ook kaarten samengesteld, waarop gegevens betreffende de waterhuishouding, de zwaarte van de bovengrond, de dikte en diepte van veenlagen, voorkomen en aard van afwijkende lagen, e.d. staan aangegeven.

7. DE HOOFDAFDELING SPECIALISTISCH ONDERZOEK

Hieronder ressorteren de algemene en landelijke taken, zoals de studie ten behoeve van de bodemclassificatie, de systematische kartering van Nederland en de geschiktheidsbeoordeling van de gronden.

De hoofdafdeling omvat 13 specialistische afdelingen met 14 academici en 32 middelbare krachten.

De specialistische afdelingen

De algemene taken van de specialistische afdelingen zijn de volgende:

1. Coördinatie van landelijke projecten
2. Geven van voorlichting, adviezen en assistentie aan andere afdelingen van het instituut
3. Verrichten van eigen onderzoekingen
4. Onderhouden van contacten met onderzoekers en medewerkers van andere instituten en diensten
5. Wetenschappelijke hulp bij publikaties van de Stichting voor Bodemkartering.

Aangezien de Stichting voor Bodemkartering gedeeltelijk gedecentraliseerd is, is *coördinatie* bij werkzaamheden, die over de provinciegrenzen reiken (zoals bij de systematische kaartbladenkartering op schaal 1 : 50.000), noodzakelijk. Specialistische afdelingen met een sterk coördinerende taak zijn o.m. de afdelingen voor Kaartcoördinatie, Bodemclassificatie, Hydrologie, Tuinbouw en Landclassificatie.

Het geven van voorlichting en adviezen binnen de dienst is een belangrijke taak o.a. voor de afdelingen Geologie, Fysische- en Chemische Bodemkunde, Micropedologie, Mineralogie, Hydrologie, Vegetatiekunde, Paleobotanie, Historische Geografie.

De eigen onderzoekingen van de specialistische afdelingen zijn veelal fundamenteel of toegespitst op de methodiek van het onderzoek.

Afdeling Bodemclassificatie

De voornaamste taak is de classificatie van de Nederlandse gronden. Hiervoor is een categorieënschema ontworpen in de geest van het nieuwe U.S.A.-systeem. Aan de uitwerking van de lagere categorieën wordt nog gewerkt. Daarnaast wordt aandacht besteed aan de standaardisering van de profielbeschrijvingen, de indeling van textuur, humus- en kalkgehalten, ontwikkeling en verbetering van de beschrijvingstechniek (horizontbenamingen), e.d..

Afdeling Kaartcoördinatie

De taak bestond in eerste instantie uit het opstellen van de legenda voor de systematische kaartbladenkartering. Bij de opname van de kaartbladen is de hoofdtaak coördinatie en correlatie van de uitvoering door de provinciale afdelingen.

Afdeling Hydrologie
Taak is bestudering van de weergave van de waterhuishouding op bodemkaarten en de cultuurtechnische classificatie van de gronden. Bij de eerstgenoemde taak staat het geven van informatie over de grondwaterstanden met behulp van profielkenmerken op de voorgrond. Hieraan is veel onderzoek verricht met behulp van de systematische grondwaterstandsmetingen in Nederland (C.O.L.N.-gegevens). Ten behoeve van de kaartbladenkartering 1 : 50.000 is een indeling van de gronden in grondwaterklassen opgesteld.

Daarnaast zijn van belang: pF-onderzoek, doorlatendheid (o.a. van storende lagen), bewortelingsmogelijkheden van bodemhorizonten, wateronttrekking aan het profiel in droge perioden.

Afdeling Micropedologie
Basis van het onderzoek vormen stereoscopische en microscopische waarnemingen aan ongestoorde grond. Voor het microscopisch onderzoek worden slijpplaatjes vervaardigd. Er wordt aandacht besteed aan het kleuren hiervan. Door dit onderzoek wordt inzicht verkregen in de aard, de onderlinge rangschikking en het procentuele aandeel van de verschillende bodemcomponenten. Het levert o.a. een aandeel in de kennis van de bodemvormende processen.

De werkzaamheden omvatten:

1. De classificatie van macro-structuren van de grond.
2. Studie van de humusvormen, o.a. bij veengronden.
3. Het verband tussen de structuur van klei-op-veengronden en de graslandvegetatie.
4. Rijpmaken van gronden voor tuinbouw, o.a. micromorfologische verschillen in kasgronden in verband met stoken, grondontsmetting, e.d.. Micromorfologie van boomgaardgronden in verband met bodemfauna en beworteling; toepassing van doorgevroren zwartveen (tuinturf) in de tuinbouw; invloed van mulchen op profiel- en wortelontwikkeling.
5. Morfologische veranderingen in excrementen van bodemdieren in verschillende bodemtypen.
6. Uitvoeren van laboratoriumbepalingen als: waterstabiliteitsmetingen (methode Hénin), doorlatendheidsbepalingen, consistentiebepalingen, e.d..
7. In de toekomst staan op het programma: intensieve studie van de humusvormen, onderzoek naar de oorzaken van structuurverval en structuurstabiliteit, micromorfologische aspecten van de hydrologie.

Afdeling Chemische Bodemkunde
Deze heeft tot taak het verrichten van onderzoek op chemisch en klei-mineralogisch gebied en het fundamentele klei-onderzoek, zoals de overgang van het ene kleimineraal in het andere, de omstandigheden waaronder bepaalde kleimineralen ontstaan, de structuur van minder bekende kleimineralen. Voor dit onderzoek wordt gebruik gemaakt van röntgen- en infrarood apparatuur. Op het gebied van de elektronenmicroscopie voor de identificatie van kleimineralen wordt samengewerkt met Dr. Beutelspacher (Braunschweig.)

Daarnaast wordt onderzoek verricht naar een snelle analyse van beschikbaar bodemvocht (pF 2,2–4,2) en voorts de bepaling van het inwendig oppervlak van de grond.

Afdeling Mineralogie

De werkzaamheden omvatten:

1. Onderzoek van de mineralogische samenstelling van de gronden.
2. Onderzoek naar aard en herkomst van bepaalde afzettingen.
3. Het aandeel van de mineralen in de bodemvorming.
4. Mineralogisch onderzoek in verband met de chemische rijkdom van de grond.

Voor het verkrijgen van kwantitatieve gegevens is een speciale onderzoektechniek ontwikkeld: de groepsgewijze gewichtsanalytische bepaling van mineralen. Deze verdient de voorkeur boven de microscopische determinatie van elke korrelgrootte-fractie.

Het verband bodemvruchtbaarheid-minerale reserve wordt tevens bestudeerd door het meten van de hoeveelheid kationen in waterige oplossing die in een bepaalde tijd onder bepaalde omstandigheden vrijkomen.

Afdeling Geologie en Paleobotanie

De afdeling verricht eigen onderzoek en geeft advies en assistentie op geologisch gebied aan andere afdelingen:

1. Het vervaardigen van geormorfologische kaarten voor bodemkarteringen met speciale aandacht voor het microreliëf.
2. Het karteren van glaciale afzettingen en -vormen.
3. Er wordt aandacht besteed aan de jong pleistocene en holocene fluviatiele afzettingen, de stratigrafie van het Midden en Jong Pleistoceen; studie van door solifluctie verplaatste afzettingen, periglaciale dalen, dalasymmetrie en kryoturbate verschijnselen.
4. Er werd een methode ontwikkeld tot het herkennen van verschillende afzettingen aan de hand van bestanddelen $>$ 2 mm. In dit verband worden de afzettingen van de middenduitse rivieren in Noord-Nederland bestudeerd.
5. De studie van het reliëf, de herkomst en de verbreiding van eolische afzettingen.
6. Coördinatie en advisering bij bemonstering voor pollenanalytisch en 14C-onderzoek en het voorzien van de uitkomsten hiervan met geologische commentaar.

Afdeling Diatomeeënonderzoek

De reconstructie van het afzettingsmilieu van sedimenten is mogelijk door het groeperen van diatomeeënsoorten die in de afzettingen worden gevonden. Deze z.g. associatiemethode geeft de mogelijkheid dat met zekerheid kan worden vastgesteld of een milieu zout, brak of zoet geweest is, of de sedimentatie al dan niet in de buurt van de zee heeft plaatsgevonden, of het water waarin de afzetting heeft plaatsgevonden diep was of niet, enz. Tevens geven de ecologische groepen inlichtingen omtrent voedselrijkdom, pH en chloorgehalte van het milieu.

Afdeling Vegetatiekunde

De vegetatie is een belangrijke factor bij de bestudering van de bodem. Een juiste interpretatie van de vegetatie is bij karteringswerk (o.a. herkenning van bodemgrenzen) een grote steun. Het vegetatie-onderzoek kan van belang zijn voor het vaststellen van ecologische eigenschappen en onderlinge verschillen van verwante bodemeenheden.

Er wordt nauw samengewerkt met de afdelingen Boskartering en Hydrologie.

Afdeling Historische Geografie

De bodemkartering heeft belangrijke bijdragen geleverd op het gebied van de historische geografie. Het historisch-geografisch onderzoek, met name naar de ontginningsgeschiedenis, is van groot belang voor het bodemkarteringswerk.

In vele karteringsgebieden zijn en worden perceelsnamen, namen van huizen, wegen, wateren, e.d. verzameld. Deze worden geïnventariseerd en bestudeerd. De studie van de perceelsvormen gaf aanleiding tot een indeling van de kaveltypen in verband met de ontginningsgeschiedenis. De onderscheiden vormen worden thans in detail bestudeerd. Uit de kadastrale plans krijgt men een goede indruk van de bewoning van ± 150 jaar geleden. In enkele dorpen in de zandgebieden werd de dorpsvorm onderzocht.

Namen, kavelvormen en dorpsvormen vertegenwoordigen ieder een bepaalde fase uit de ontginningsgeschiedenis. De combinatie maakt het mogelijk de ontwikkeling te analyseren.

Toepassingen

De afdelingen, die op het gebied van de toepassingen werkzaam zijn, houden zich bezig met het verband tussen bodem en cultuurgewas. Hun doel is dus een op het landgebruik en de teelt gerichte interpretatie van de bodemkaart te geven, neergelegd in een bodemgeschiktheidskaart. Hiervoor is behalve bodemkundige kennis tevens een grote teelttechnische kennis nodig. Er is daarom een intensieve samenwerking met de consulentschappen en met de instituten die de plantenteelt, de cultuurtechniek en de economie tot object van onderzoek hebben.

Afdeling Landclassificatie

Deze afdeling bestudeert de landclassificatie voor akker- en weidebouw en het gemengde bedrijf. De landelijke samenwerking met andere diensten wordt gecoördineerd door een Werkgroep Landclassificatie van het Ministerie van Landbouw en Visserij.

Voor verschillende niveaus van bedrijfsuitvoering kunnen geschiktheidskaarten worden gemaakt. Het beste niveau voor de landbouwkundige karakterisering van de bodemtypen wordt verkregen door het bepalen van de resultaten die door goede boeren bij zo gunstig mogelijk bouwplan kunnen worden behaald.

De gegevens worden verkregen via:

1. groepsvergaderingen met „goede" boeren;
2. afzonderlijke ondervraging van „goede" boeren;
3. samenwerking met plaatselijke deskundigen;
4. bestudering van gegevens van verschillende proefboerderijen;

5. gegevens van vroegere proeven, uitgevoerd door andere instituten of door consulentschappen;
6. opname van de gewassen die op de verschillende bodemtypen verbouwd worden;
7. proefoogsten en gewassentaxaties.

Afdeling Tuinbouw
Deze afdeling onderzoekt de mogelijkheden die de verschillende gronden bieden voor de tuinbouw. Zij onderzoekt de bodemkundige factoren die de geschiktheid voor de diverse gewassen, teeltmethoden en bedrijfstypen veroorzaken aan de hand van de eisen die de gewassen stellen. Er wordt onderzoek gedaan naar de mogelijkheden van grondverbetering. De afdeling voert tuinbouwclassificaties uit o.a. ten behoeve van het Tuinbouwvestigingsplan en geeft adviezen aan andere afdelingen van de Stichting voor Bodemkartering en andere instanties.

Afdeling Bosbouw
De taak van de afdeling is:

1. Het onderzoek naar de invloed van de bodem op de groei van de voornaamste produktie-houtsoorten: grove den, lariks en douglas.
2. Het maken van bodemkaarten en hiervan afgeleide geschiktheidskaarten.
3. Het geven van bodemkundige voorlichting.

De voor het geschiktheidsonderzoek noodzakelijke beoordeling van houtopstanden wordt uitgevoerd in nauwe samenwerking met het Staatsbosbeheer en het Bosbouwproefstation. Samen met dit laatste wordt een landelijk douglasonderzoek uitgevoerd.

8. AFDELING REDACTIE, BIBLIOTHEEK, PROGRAMMERING EN PLANNING, KAARTREDACTIE

Redactie
Deze heeft tot taak het openbaar maken van verrichte studies en verzamelde gegevens. Gepubliceerd worden:

1. De Bodemkartering van Nederland
Publikaties van studiekarteringen, vergezeld van een bodemkaart. Verschenen: 19 afleveringen.

2. Bodemkundige Studies
Resultaten van bodemkundig onderzoek dat niet direct op karteringen betrekking heeft. Verschenen: 4 afleveringen.

3. Boor en Spade
Studies van kleinere omvang over de bodemkunde van Nederland, afgeronde gedeelten van bepaalde onderzoekingen en stand van de werkzaamheden. Publikaties ca. 1 × per jaar.

Voorts verschijnen nog z.g. *Interne Rapporten:* verslagen van opdrachtkarteringen in gestencilde vorm, afgeleverd aan de opdrachtgever en enkele instanties van het Ministerie van Landbouw.

Tot de overige taken van de redactie behoren het samenstellen van het jaarverslag, documentatie, verzorgen van tentoonstellingen, enz..

Bibliotheek
Verzorgt de boekerij, stelt literatuurlijsten en documentaties samen.

Programmering en planning
Zij stelt alle onderzoek- en uitvoeringsprogramma's van de overige afdelingen samen. Door middel van maandstaten wordt door de diverse afdelingshoofden de bestede tijd verantwoord. Deze maandstaten worden verwerkt.

Ieder kwartaal verschijnt een verslag betreffende de voortgang van de werkzaamheden aan de hand van een objectenlijst. Deze lijst is tevens basis voor de werkprogramma's en de projecten-administratie van de afdeling Algemene Zaken.

Kaartredactie
Hier worden de ontwerpkaarten en -tekeningen gereed gemaakt voor afwerking. Er worden richtlijnen gegeven voor de te gebruiken kleuren en harceringen. Hierbij wordt gestreefd naar het tot uitdrukking brengen van verschillen en overeenkomsten van de afgebeelde eenheden. Ter vereenvoudiging van keuze zijn een kleurenschema en een collectie harceringen samengesteld. De hierbij behorende techniek wordt verder ontwikkeld om aan de steeds toenemende eisen te kunnen voldoen.

9. REPRODUKTIE AFDELING

Hieronder ressorteren de onderafdelingen tekenkamer, lithografie, lichtdrukkerij en fotografie, alsmede de archieven van bodemkaarten, topografische kaarten, diapositieven, foto's en clichés.

De afdeling omvat 23 man personeel en verzorgt al het reproduktiewerk.

Tekenkamer
De cartografische gegevens van de buitendienst worden op transparant materiaal overgenomen, op lichtdrukpapier afgedrukt en met waterverf ingekleurd. Daarna wordt voor interne rapporten de oplaag (tot 15 exemplaren) met de hand ingekleurd. Voor kaarten, die gedrukt worden, wordt één exemplaar ingekleurd dat op de onderafdeling lithografie verder wordt behandeld.

Lithografie
Hier worden de in kleuren te drukken kaarten zover gereed gemaakt, dat deze door de drukker op een offsetplaat gekopieerd en gedrukt kunnen worden.

Er bestaat een kleurenschema, waarmede in 3 kleuren (geel, rood en blauw) in oplopende dekking van rasters 195 tinten verkregen kunnen worden. Iedere ingekleurde kaart wordt geheel in de 3 hoofdkleuren ontleed. Daarna worden alle tinten aangebracht met inkt, transparante rasters (strippingfilm), lijn- of puntrasters.

Fotografie
Bij deze onderafdeling wordt al het fotografische werk van de dienst vervaardigd of afgewerkt. Door middel van een grote reproduktiecamera kunnen basiskaarten, teksten, kopieën van kaarten en rasters worden gemaakt.

Lantaarnplaatjes in zwart-wit en kleur alsmede microscopische opnamen worden hier vervaardigd.

Men heeft succesvolle proeven genomen om door middel van kleur-fotografie bodemkaarten te reproduceren. Dit zou het tijdrovende inkleurwerk kunnen gaan vervangen.

Lichtdrukkerij

Deze verzorgt alle lichtdrukwerk voor de dienst.

10. AFDELING ALGEMENE ZAKEN

Deze afdeling omvat 14 personeelsleden, aangevuld met huishoudelijk personeel en een concierge. Tot haar taken behoren het beheer en de administratie van ontvangsten en uitgaven, budgettering en budgetcontrole, kostprijsberekeningen, administratie van de inventaris en personeelszaken. Daarnaast is de afdeling belast met type- en stencilwerk, post- en archiefzaken, telefoon- en bodediensten en onderhoudswerkzaamheden.

AUFGABE UND ORGANISATION DER STIFTUNG „INSTITUT FÜR BODENKARTIERUNG"

1. EINLEITUNG

Die Stiftung „Institut für Bodenkartierung" wurde am 21. August 1945 gegründet. Damit nahm eine Arbeitsweise Gestalt an, die bereits einige auffallende Ergebnisse gezeitigt hatte. Diese vor allem während des letzten Krieges unter Leitung von Prof. Dr. C. H. Edelman entwickelte Arbeitsweise bestand aus der Untersuchung der Art und der Verbreitung der mehr oder weniger bleibenden Eigenschaften des Bodens durch Untersucher, die sich hierin spezialisiert hatten. Die Verwendung des Grundbohrers neben dem Spaten ermöglichte eine rasche Inventarisierung der Bodenunterschiede. Das allgemein vorhandene Interesse an der Kenntnis der Eigenschaften des Bodens und ihrer regionalen Verbreitung führte rasch zur Anerkennung der befolgten Arbeitsweise.

Der große Promotor der Bodenkartierung Prof. Dr. C. H. Edelman wurde der erste Direktor des neuen Institutes. Sein Nachfolger wurde 1955 sein ältester Schüler, Dr. F. W. G. Pijls.

2. AUFGABE UND ORGANISATION

Die Arbeit der Stiftung „Institut für Bodenkartierung" umfaßt nach Art. 3 der Statuten:

1. Das Studium des Bodens zugunsten der Bodenklassifikation und -Kartierung in Holland.
2. Die systematische Kartierung des Bodens in Holland.
3. Die Bodeneignungsklassifikation und Landklassifikation des untersuchten Grundes (in Zusammenarbeit mit anderen Instituten).
4. Das auftragsgemäße Ausführen von Bodenkartierungen und Landklassifikationen.
5. Das Publizieren und zur Verfügung stellen der Ergebnisse der Tätigkeiten.

Anfänglich bestand die Arbeit fast ausschließlich aus regionaler bodenkundiger und anschließend landbaukundiger Untersuchung, aus Auftragskartierungen für dritte und aus Aufklärung. Diese Arbeiten wurden durch Kartierungsgruppen unter Leitung eines in der Bodenkunde spezialisierten Diplomlandwirtes durchgeführt. Hieraus sind später die provinzialen Abteilungen entstanden.

Wegen bestimmter Einzelheiten konnte der Kartierungsleiter einige Spezialisten um Rat fragen, z.B. für Geologie, Mineralogie, historische Geographie und Archeologie. Daneben entstanden koordinierende Kommissionen, die auf bestimmten abgegrenzten Gebieten tätig waren, z.B. Koordinierung der Legenden, Eignungsklassifikation und Hydrologie.

Der Prozeß der Koordinierung wurde beschleunigt durch den Auftrag, von ganz Holland eine Bodenkarte im Maßstab 1:200.000 herzustellen; die Ergebnisse hiervon sind im Druck. Vor allem jedoch durch den Auftrag zu einer systematischen Bodenkartierung im Maßstab 1:50.000 wurde Koordinierung, Uniformität und Untersuchung auf ländlichem Niveau erforderlich.

Diese Entwicklung führte in 1957 zu einer Reorganisation, wobei die ländliche, allgemein bodenkundige Aufgabe neben den bestehenden regionalen Tätigkeiten Gestalt erhielt. (Sehe Organisationsschema).

3. LEITUNG UND DIREKTION

Die Leitung besteht aus 10 Mitgliedern, die vom Minister für Landbau und Fischerei auf Vorschlag des Ministers für Landbau und Fischerei (4), die Minister für Verkehr und Wasserbau, Wohnung und Städtebau (2), durch Personen aus dem Wirtschaftsleben und den Wirtschaftsverband für die Landwirtschaft ernannt wurden. Die Leitung sorgt für die finanzielle Verwaltung des Institutes und stellt auf Vorschlag des Direktors u.a. den Arbeitsplan fest.

Der Direktor muß der Leitung Rechenschaft ablegen über die Geschäftsführung und den Verlauf der Dinge im Institut. Ein Direktionsassistent hilft ihm.

Die Initiativen zur Ausführung bestimmter Tätigkeiten sind dreifachen Ursprungs. Sie können stammen von der Leitung (Kartenblätterkartierung), von den provinzialen und spezialistischen Abteilungen (Untersuchung bestimmter bodenkundiger Probleme) und von außerhalb des Dienstes (Auftragskartierungen). Diese letzteren sind von großer Bedeutung, weil hieraus – neben Reichsbeiträgen und Subsidien von einigen Instanzen – rund ein Viertel der Einkünfte erhalten wird.

4. DIE HAUPTABTEILUNGEN

Die Hauptabteilungen bilden die Verbindung zwischen der Direktion und den provinzialen und spezialistischen Abteilungen. Die Leiter stimmen die Abteilungen aufeinander und auf die aufgetragenen Aufgaben ab. Sie erfüllen eine dirigierende und kontrollierende Funktion. Das jährlich aufzustellende Arbeitsprogramm für die verschiedenen Abteilungen wird nach Beratung mit dem Leiter der jeweiligen Hauptabteilung zusammengestellt.

5. INTERNE KOMMISSIONEN

Es gibt 11 interne Kommissionen, u.a. die Kommission für Bodenklassifikation, die Kommission für die Legende der 50.000-Karte, die Landklassifikationskommission, die Gartenbaukommission, die Hydrologische Kommission und die Chemische Kommission. Sie verrichten vorbereitende und überprüfende Tätigkeiten, machen den verschiedenen Abteilungen Vorschläge über die Untersuchung bestimmter Probleme und prüfen die Auswirkung. Neben dem Leiter der betreffenden spezialistischen Abteilung befinden sich in diesen Kommissionen einige Leiter der provinzialen Abteilungen.

Daneben bestehen einige Arbeitskommissionen, wie die Terminologie-Kommission (Formulierung der Begriffe und Termen), die Technische Kommission (Anwendung technischer Entwicklungen auf bodenkundige Arbeit), die Kommission für Personal mit höherer Schulausbildung (Gutachten über das Personal).

ORGANISATIONSSCHEMA DER STIFTUNG „INSTITUT FÜR BODENKARTIERUNG"

LEITUNG

Direktion — Berater

Hauptabteilung für regionale bodenkundige Untersuchung und Kartierungen	Hauptabteilung für spezialistische Untersuchung	Abteilung Redaktion, Bibliothek, Programmgestaltung und Planung	Reproduktionsabteilung	Abteilung Allgemeine Angelegenheiten
11 provinziale Abteilungen Abt. Auftragskartierungen	Die Abteilungen: Bodenklassifikation, Kartencoördination, Hydrologie, Mikropedologie, Chemische Bodenkunde, Mineralogie, Geologie und Paläobotanik, Diatomeenuntersuchung, Vegetationskunde, Historische Geographie, Landklassifikation, Gartenbau, Waldbau	Redaktion Bibliothek Programmgestaltung und Planung Kartenredaktion	Zeichenzimmer Lithographie Photographie Lichtpauserei Archiven	Buchführung und Administration Allgemeine Archiven Schreibmaschinenzimmer Telephon Unterhalt

Technische Archiven

6. DIE HAUPTABTEILUNG FÜR REGIONALE BODENKUNDIGE UNTERSUCHUNG UND KARTIERUNGEN

Hierunter fallen Aufgaben mit regionalem Charakter, die Ausführung von Aufträgen für dritte und der Teil der Untersuchung, die von den provinzialen Abteilungen regional und selbständig ausgeführt wird.

Die Hauptabteilung besteht aus den provinzialen Abteilungen und der Abteilung für Aufträge. Ihr gehören 18 Akademiker und ca. 40 Kräfte mit höherer und Volksschulbildung an.

Die provinzialen Abteilungen

Alle Abteilungen stehen unter Leitung eines Akademikers, dem meist 2 Assistenten zur Seite stehen. In einigen großen Amtsgebieten ist ein zweiter Akademiker tätig.

Die provinzialen Abteilungen haben die folgenden Aufgaben:

1. Regionale bodenkundige Untersuchung
2. Mitarbeit an allgemein bodenkundiger Untersuchung
3. Mitarbeit an ländlich bodenkundiger Untersuchung und der systematischen Kartierung von Holland (Maßstab 1:50.000)
4. Ausführung von und Mitarbeit an Auftragskartierungen
5. Aufklärung.

Im Rahmen der *regional bodenkundigen Untersuchung* wurden untersucht oder sind noch im Untersuchung, z.B. die Morphologie der pleistocenen Oberfläche im westlichen mittleren Holland; das Knickproblem (Friesland und Südholländische Inseln); die physische und chemische Reifung (Nordholland, Zeeland, Biesbosch); Bodenbildung in Sandgrund (Overijsel, Gelderland, Nordbrabant); Untersuchung von schwarzem Torf (Drente); Boden-Bildung unter Einfluß von Bauland und Grasland (Zeeland), Moorkolonien (Groningen); Entstehung der Parabraunerden (Limburg).

Mitarbeit an *allgemein bodenkundiger Untersuchung* (ausgeführt durch spezialistische Abteilungen) wird u.a. geleistet bei der Untersuchung der Strukturtypen und Humusformen, der Unterschiede zwischen See- und Flußton, bei der Bodeneignungsklassifikation für Ackerbau und Gartenbau.

An der *bodenkundigen Untersuchung* haben alle provinzialen Abteilungen mitgearbeitet u.zw. bei der Beschreibung des Grundes für die Bodenklassifikation von Holland.

Für die *systematische Kartierung, Maßstab 1:50.000* haben alle Abteilungen Probekartierungen zwecks Feststellen der Legende durchgeführt. Auch die Ausführung dieser Kartierung wird größtenteils durch die provinzialen Abteilungen erfolgen.

Die *Ausführung von Auftragskartierungen* geschieht im Prinzip durch die provinzialen Abteilungen. Da diese Kartierungen häufig genau umrissen sind, ein praktisches Ziel haben (Flurbereinigung, Stadtausbreitung, Gartenbau) und die Abteilungen überbelastet sind, werden diese Kartierungen meist durch die Abteilung Auftragskartierung durchgeführt, manchmal zusammen mit den provinzialen Abteilungen.

Instanzen, die mit dem Boden zu tun haben, werden auf regionalen Niveau durch die provinzialen Büros beraten. *Direkte* praktische Aufklärung wird nicht erteilt. Dies geschieht durch die Land- und Gartenbauberatungsdienste.

Die Abteilung Auftragskartierungen

Diese wird von einem Akademiker geleitet, dem 2 Aufseher, 6–8 Kartierer und etwas Personal in losem Verband zur Seite stehen.

Anhand der Zielstellung werden der Kartenmaßstab, die Legende, die herzustellenden abgeleiteten Karten usw. festgestellt. Meist ist die Zielstellung landbaukundiger Art. Am wichtigsten sind Bodenkarten für Flurbereinigungen. Auch werden viele Auftragskartierungen für Ausbreitungspläne, Wasserbeherrschungspläne, Inventarisierung von Tonvorräten (Backsteinindustrie), Militärische Objekte u. dergl. ausgeführt.

Außer der Bodenkarte werden häufig abgeleitete Karten gemacht, die den nichtbodenkundigen Gebrauchern eine bessere Übersicht über bestimmte Aspekte des Bodens geben. So werden häufig Eignungskarten für bestimmte Formen des Bodenbenutzung hergestellt. Wiederholt wurden auch Karten zusammengestellt, auf denen sich Angaben über den Wasserhaushalt, die Schwere des Oberbodens, die Dicke und Tiefe der Torflagen, das Vorkommen und die Art abweichender Lagen u. dergl. befinden.

7. DIE HAUPTABTEILUNG FÜR SPEZIALISTISCHE UNTERSUCHUNG

Hierunter fallen die allgemeinen und ländlichen Aufgaben, wie das Studium der Bodenklassifikation, die systematische Kartierung von Holland und die Eignungsklassifikation des Bodens.

Die Hauptabteilung umfaßt 13 spezialistische Abteilungen mit 14 Akademikern und 32 Kräfte mit höherer Schulausbildung.

Die spezialistischen Abteilungen

Die allgemeinen Aufgaben der spezialistischen Abteilungen sind die folgenden:

1. Koordinierung der ländlichen Projekte
2. Erteilung von Auskünften, Ratschlägen und Hilfe an andere Abteilungen des Institutes.
3. Durchführung eigener Untersuchungen
4. Das Unterhalten von Verbindungen mit Untersuchern und Mitarbeitern von anderen Instituten und Dienststellen
5. Wissenschaftliche Hilfe bei Publikationen der Stiftung für Bodenkartierung.

Da die Stiftung für Bodenkartierung teilweise dezentralisiert ist, ist Koordinierung bei Tätigkeiten, die über die Provinzgrenzen hinaus reichen (wie bei der systematischen Kartenblätterkartierung im Maßstab 1:50.000) erforderlich. Spezialistische Abteilungen mit einer stark koordinierenden Aufgabe sind u.a. die Abteilungen für Kartenkoordination, Bodenklassifikation, Hydrologie, Gartenbau und Landklassifikation.

Die Erteilung von Auskünften und Ratschlägen innerhalb des Dienstes stellt eine wichtige Aufgabe dar, u.a. für die Abteilungen Geologie, Physische und Chemische Bodenkunde, Mikropedologie, Mineralogie, Hydrologie, Vegetationskunde, Paläobotanik, Historische Geographie.

Die eigenen Untersuchungen der spezialistischen Abteilungen sind häufig grundlegend oder der Methodik der Untersuchung angepaßt.

Abteilung Bodenklassifikation

Die wichtigste Aufgabe ist die Klassifikation des holländischen Bodens. Zu diesem Zweck hat man ein Kategorienschema im Geist des neuen U.S.A.-Systems entworfen. An der Ausarbeitung der niederen Kategorien wird noch gearbeitet. Man interessiert sich außerdem für die Standardisierung der Profilbeschreibungen, die Einteilung der Parabraunerden, die Humus- und Kalkgehalte, die Entwicklung und Verbesserung der Profilbeschreibung (Horizontalbezeichnung) u. dergl.

Abteilung Kartenkoordination

Die Aufgabe bestand in erster Linie aus dem Aufstellen der Legende für die systematische Kartenblätterkartierung. Bei der Aufnahme der Kartenblätter besteht die Hauptaufgabe in der Korrelation der Ausführung durch die provinzialen Abteilungen.

Abteilung Hydrologie

Die Aufgabe besteht in der Wiedergabe des Wasserhaushaltes auf Bodenkarten und in der kulturtechnischen Klassifikation des Bodens. Bei der erstgenannten Aufgabe steht die Erteilung von Auskünften über die Grundwasserstände mit Hilfe von Profilkennzeichen im Vordergrund. Auf diesem Gebiet hat man viele Untersuchungen mit Hilfe der systematischen Grundwasserstandsmessungen in Holland (C.O.L.N.-Angaben) durchgeführt.

Für die Kartenblätterkartierung 1:50.000 hat man die Bodenarten in Grundwasserklassen eingeteilt.

Daneben sind von Bedeutung: pF-Untersuchung, Durchlässigkeit (u.a. von störenden Schichten), Bewurzelungsmöglichkeiten von Bodenhorizonten, Entwässerung des Profils in Trockenperioden.

Abteilung Mikropedologie

Die Basis der Untersuchung bilden stereoskopische und mikroskopische Beobachtungen am ungestörten Grund. Für die mikroskopische Untersuchungen werden Dünnschliffe hergestellt, die sorgfältig gefärbt werden. Durch diese Untersuchung erhält man Einblick in die Art, die Anordnung und den prozentualen Anteil der verschiedenen Bodenkomponenten. U.a. lernt man die bodenbildenden Prozesse kennen.

Die Tätigkeiten umfassen:

1. Die Klassifikation der Makrostrukturen des Bodens.
2. Das Studium der Humusformen, u.a. bei Torfböden.
3. Der Zusammenhang zwischen der Struktur von Ton-auf-Torfböden und der Graslandvegetation.
4. Das Reifmachen von Bodenarten für den Gartenbau, u.a. mikromorphologische Unterschiede in Treibhauserden im Zusammenhang mit Heizen, Bodendesinfektion, u. dergl.. Mikromorphologie von Obstgartenerden im Zusammenhang mit der Bodenfauna und Bewurzelung; Anwendung von durchgefrorenem Schwarzerde (Gartentorf) im Gartenbau; Einfluß der Streubedeckung auf Profil- und Wurzelentwicklung.
5. Morphologische Veränderungen in Exkrementen von Bodentieren in verschiedenen Bodentypen.
6. Ausführung von Laboratoriumsbestimmungen wie: Wasserstabilitäts-

messungen (Methode Hénin), Durchlässigkeitsbestimmungen, Konsistenzbestimmungen u. dergl.
7. In der Zukunft stehen auf dem Programm: intensives Studium der Humusarten, Untersuchung der Ursachen der Bodenstrukturdegradation und -stabilität, mikromorphologische Aspekte der Hydrologie.

Abteilung Chemische Bodenkunde

Ihre Aufgabe besteht in der Durchführung von Untersuchungen auf chemischen und tonmineralogischem Gebiet und in der fundamentalen Tonuntersuchung, wie der Übergang des einen Tonminerals in das andere, die Umstände, unter denen bestimmte Tonminerale entstehen, die Struktur weniger bekannter Tonminerale. Zu dieser Untersuchung verwendet man Röntgen- und Infrarot-Apparaturen. Auf dem Gebiet der Elektronenmikroskopie zwecks Identifizierung der Tonminerale wird mit Dr. Beutelspacher (Braunschweig) zusammengearbeitet.

Daneben werden Untersuchungen durchgeführt, um die verfügbare Bodenflüssigkeit rasch zu analysieren (pF 2,2–4,2) und ferner die Bestimmung der inneren Oberfläche des Bodens.

Abteilung Mineralogie

Die Tätigkeiten umfassen:

1. Untersuchung der mineralogischen Zusammensetzung der Böden.
2. Untersuchung der Art und Herkunft bestimmter Ablagerungen.
3. Der Anteil der Minerale an der Bodenbildung.
4. Mineralogische Untersuchung im Zusammenhang mit dem chemischen Reichtum des Bodens.

Zur Erhaltung quantitativer Angaben hat man eine spezielle Untersuchungstechnik entwickelt, die gewichtsanalytische Bestimmung der Minerale in Gruppen. Diese ist der mikroskopischen Bestimmung jeder Korngrößenfraktion vorzuziehen.

Der Zusammenhang Bodenfruchtbarkeit-Mineralreserve wird gleichzeitig untersucht, indem die Menge Kationen in wässriger Lösung gemessen werden, die in einer bestimmten Zeit unter bestimmten Umständen freikommen.

Abteilung Geologie und Paläobotanik

Die Abteilung führt eigene Untersuchungen durch und erteilt Rat und Hilfe auf geologischem Gebiet an andere Abteilungen:

1. Herstellung geomorphologischer Karten für Bodenkartierungen wobei dem Mikrorelief besondere Aufmerksamkeit geschenkt wird.
2. Kartieren glazialer Ablagerungen und Formen.
3. Man interessiert sich für die jungpleistozenen und holozenen fluviatilen Ablagerungen, die Stratigraphie des Mittel- und Jungpleistozens; Studium der durch Solifluktion verlagerten Ablagerungen; der periglazialen Täler, der Tal-asymmetrie und der Frostzerrungserscheinungen.
4. Es ist eine Methode entwickelt worden, um verschiedene Ablagerungen anhand von Bestandteilen von > 2 mm zu erkennen. In diesem Zusammenhang werden die mitteldeutschen Flüsse in Nordholland untersucht.

5. Studium des Reliefs, der Herkunft und der Verbreitung äolischer Ablagerungen.
6. Koordinierung und Beratung bei der Probeentnahme zur pollenanalytischen und 14C-Untersuchung und das Versehen der Ergebnisse mit geologischem Kommentar.

Abteilung Diatomeenuntersuchung

Die Rekonstruierung der Ablagerungsmilieus von Sedimenten ist möglich durch das Gruppieren der Diatomeenarten, die in den Ablagerungen gefunden werden. Diese sogen. Assoziationsmethode bietet die Möglichkeit, daß mit Sicherheit festgestellt werden kann, ob ein Milieu salzig, brack oder süß gewesen ist, ob die Sedimentation in der Nähe des Meeres stattgefunden hat oder nicht, ob das Wasser, in dem die Ablagerung stattfand tief war oder nicht etc. Gleichzeitig geben die ökologischen Gruppen Auskünfte über Nahrungsreichtum, pH und Chlorgehalt des Milieus.

Abteilung Vegetationskunde

Die Vegetation ist ein wichtiger Faktor beim Studium des Bodens. Eine richtige Deutung der Vegetation ist bei der Kartierungsarbeit (u.a. Erkennung der Bodengrenzen) eine große Hilfe. Die Untersuchung der Vegetation kann von Bedeutung sein für die Feststellung der ökologischen Eigenschaften und die Unterschiede verwandter Bodeneinheiten.

Es besteht eine enge Zusammenarbeit mit den Abteilungen Waldkartierung und Hydrologie.

Abteilung Historische Geographie

Die Bodenkartierung hat wichtige Beiträge auf dem Gebiet der historischen Geographie geliefert. Die historisch-geographische Untersuchung, vor allem der Geschichte der Urbarmachung, ist von großer Bedeutung für die Bodenkartierung.

In vielen Kartierungsgebieten wurden und werden Namen von Parzellen, Häusern, Wegen, Gewässern u. dergl. gesammelt. Diese werden inventarisiert und untersucht. Das Studium der Parzellenformen war der Anlaß zu einer Einteilung der Parzellentypen im Zusammenhang mit der Geschichte der Urbarmachung. Die unterschiedenen Arten werden zur Zeit ausführlich studiert. Die Katasterpläne verschaffen einen guten Eindruck von der Bewohnung vor ungefähr 150 Jahren. In einigen Dörfern in den Sandgebieten wurde die Dorfsform untersucht.

Namen, Parzellenformen und Dorfsformen stellen je eine bestimmte Phase aus der Geschichte der Urbarmachung dar. Die Kombination ermöglicht es, die Entwicklung zu analysieren.

Anwendungen

Die Abteilungen, die auf dem Gebiet der Anwendungen tätig sind, beschäftigen sich mit dem Zusammenhang zwischen Boden und Kulturgewächsen. Ihr Ziel ist also, eine auf die Landverwendung und den Anbau gerichtete Deutung der Bodenkarte zu geben, was in einer Bodeneignungskarte seinen Niederschlag findet. Hierzu ist außer Kenntnissen in der Bodenkunde eine große zuchttechnische Kenntnis erforderlich. Aus diesem Grunde besteht eine intensive Zusammenarbeit mit den Beratungsdiensten und mit den Instituten, die den Pflanzenanbau, die Kulturtechnik und die Ökonomie zum Ziel ihrer Untersuchung haben.

Abteilung Landklassifikation

Diese Abteilung studiert die Landklassifikation für den Acker- und Weidenbau und den gemischten Betrieb. Die ländliche Zusammenarbeit mit anderen Diensten wird durch eine Arbeitsgruppe Landklassifikation des Ministeriums für Landbau und Fischerei koordiniert.

Für verschiedene Niveaus der Betriebsausführung können Eignungskarten gemacht werden. Das beste Niveau für die landbaukundige Charakterisierung der Bodentypen erhält man durch die Bestimmung der Ergebnisse, die von guten Bauern bei möglichst günstigem Bauplan erzielt werden können.

Die Angaben erhält man via:

1. Gruppenversammlungen mit „guten" Bauern.
2. Einzelbefragung „guter" Bauern;
3. Zusammenarbeit mit örtlichen Fachleuten;
4. Studium der Unterlagen von verschiedenen Versuchsbauernhöfen;
5. Angaben von früheren Versuchen, die durch andere Institute oder Beratungsdienste durchgeführt wurden;
6. Aufnahme der Gewächse, die auf den verschiedenen Bodeneinheiten angebaut werden;
7. Probeernten und Gewächstaxierungen.

Abteilung Gartenbau

Diese Abteilung untersucht die Möglichkeiten, die die verschiedenen Böden für den Gartenbau bieten. Sie untersucht die bodenkundigen Faktoren, auf die die Eignung der Böden für die verschiedenen Gewächse, Zuchtmethoden und Betriebstypen zurückzuführen ist, anhand der Anforderungen, die die Gewächse stellen.

Man untersucht die Möglichkeiten, der Bodenmelioration. Die Abteilung führt Gartenbauklassifikationen durch u.a. für den Gartenbaugründungsplan und erteilt anderen Abteilungen der Stiftung für Bodenkartierung und anderen Instanzen Ratschläge.

Abteilung Waldbau

Die Aufgabe der Abteilung ist:

1. Die Untersuchung des Einflusses des Bodens auf das Wachstum der wichtigsten Holzarten: Kiefer, Lärche und Douglasfichte.
2. Die Herstellung von Bodenkarten und hiervon abgeleiteten Eignungskarten.
3. Die Erteilung bodenkundiger Informationen.

Die für die Eignungsuntersuchung erforderliche Beurteilung der Holzbestände erfolgt in enger Zusammenarbeit mit der Staatsforstverwaltung und der Forstlichen Versuchsanstalt. Zusammen mit dieser letzteren wird eine örtliche Untersuchung der Douglasfichten durchgeführt.

8. ABTEILUNG REDAKTION, BIBLIOTHEK, PROGRAMMGESTALTUNG UND PLANUNG

Redaktion

Diese hat die Veröffentlichung der durchgeführten Studien und der gesammelten Angaben zur Aufgabe. Veröffentlicht werden:

1. *Die Bodenkartierung von Holland*
Publikationen von Studienkartierungen zusammen mit einer Bodenkarte. Erschienen: 19 Ausgaben.

2. *Bodenkundige Studien*
Ergebnisse von bodenkundigen Untersuchungen, die sich nicht direkt auf Kartierungen beziehen. Erschienen: 4 Ausgaben.

3. *Bohrer und Spaten*
Studien kleineren Umfangs über die Bodenkunde von Holland, abgerundete Teile bestimmter Untersuchungen und Stand der Tätigkeiten. Publikationen ungefähr 1 × pro Jahr.

Ferner erscheinen noch sog. *Interne* Berichte: Berichte von Auftragskartierungen im Schablonendruck. Wird dem Auftraggeber und einigen Instanzen des Landbauministeriums geliefert.

Zu den übrigen Aufgaben der Redaktion gehören das Zusammenstellen des Jahresberichtes, der Dokumentation, die Sorge für Ausstellungen etc.

Bibliothek

Sorgt für die Bücherei, stellt Literaturverzeichnisse und Dokumentationen zusammen.

Programmgestaltung und Planung

Sie stellt alle Untersuchungs- und Ausführungsprogramme der übrigen Abteilungen zusammen. Durch Monatsberichte legen die verschiedenen Abteilungsleiter Rechenschaft über die verwandte Zeit ab. Diese Monatsberichte werden verarbeitet. Jedes Quartal erscheint ein Bericht über den Fortgang der Tätigkeiten anhand eines Objektverzeichnisses. Dieses Verzeichnis ist gleichzeitig die Basis für das Arbeitsprogramm und die Projektverwaltung der Abteilung Allgemeine Angelegenheiten.

Kartenredaktion

Hier werden die Entwurfskarten und -zeichnungen für die Ausarbeitung fertig gemacht. Es werden Richtlinien gegeben für die zu verwendenden Farben und Schraffierungen. Hierbei strebt man danach, Unterschiede und Übereinstimmungen der abgebildeten Einheiten zum Ausdruck zu bringen. Zur Vereinfachung der Wahl hat man eine Farbtafel und eine Kollektion Schraffierungen zusammengestellt. Die hierzu gehörende Technik wird weiter entwickelt, um den stets zunehmenden Anforderungen entsprechen zu können.

9. REPRODUKTIONSABTEILUNG

Hierunter fallen die Unterabteilungen Zeichenzimmer, Lithographie, Lichtdruck und Photographie sowie die Archive der Bodenkarten, topographischen Karten, Diapositive, Photos und Klischees.

Die Abteilung umfaßt 23 Personalangehörige und sorgt für alle Reproduktionsarbeit.

Zeichenzimmer
Die kartographischen Angaben des Außendienstes werden auf transparentem Material übernommen, auf Lichtpausmaterial abgedruckt und mit Wasserfarbe eingefärbt. Danach wird die Auflage (bis zu 15 Exemplaren) für interne Berichte mit der Hand eingefärbt. Für Karten, die gedruckt werden, wird ein Exemplar eingefärbt, das auf der Unterabteilung Lithographie weiterbehandelt wird.

Lithographie
Hier werden die in Farben zu druckenden Karten soweit fertiggestellt, daß diese vom Drucker auf eine Offsetplatte kopiert und gedruckt werden können.

Es besteht eine Farbtafel, mit der in 3 Farben (gelb, rot und blau) in zunehmender Deckung der Raster 195 Farbtöne erhalten werden können. Von jeder in Farben zu druckenden Karte werden von Hand drei Farbauszüge gemacht. Die benötigten Deckungen werden mit Hilfe von Abdecktusche und transparenten Kleberastern liniiert oder punktiert (Strippingfilm mit Wachsschicht) angebracht.

Photographie
Bei dieser Unterabteilung wird die ganze photographische Arbeit des Dienstes erledigt oder vollendet. Mit Hilfe einer großen Reproduktionskamera können Basiskarten, Texte, Kopien von Karten und Raster gemacht werden. Lichtbilder in Schwarz-weiß und Farben sowie mikroskopische Aufnahme werden hier hergestellt.

Man hat mit Erfolg versucht, um mit Hilfe der Farbphotographie Bodenkarten zu reproduzieren. Dies könnte die zeitraubende Einfärbearbeit ersetzen.

Lichtpauserei
Diese sorgt für alle Lichtdrucke des Dienstes.

10. ABTEILUNG ALLGEMEINE ANGELEGENHEITEN

Diese Abteilung umfaßt 14 Personalangehörige sowie Haushaltsangestellte und ein Hausmeister. Zu ihren Aufgaben gehören die Verwaltung der Eingänge und Ausgaben, die Budgetierung und Budgetkontrolle, Kostenpreisberechnungen, Verwaltung des Inventars und der Personalsachen. Außerdem hat die Abteilung für die Schreib- und Schablonenarbeit, Post- und Archivsachen, Telefon- und Botendienste und Unterhaltsarbeiten zu sorgen.

L'INSTITUTION PÉDOLOGIQUE NÉERLANDAISE, SON ORGANISATION, SA TÂCHE ET SES ACTIVITÉS

1. INTRODUCTION

L'Institution de la Cartographie des sols a été fondée le 21 août 1945. Elle concrétisait une méthode de travail qui avait déjà fourni quelques résultats remarquables. Cette méthode – principalement mise au point durant la dernière guerre sous la direction du professeur Dr. C. H. Edelman – consistait dans l'étude de la nature et de la distribution des propriétés plus ou moins permanentes du sol, étude effectuée par des experts dans ce domaine. L'emploi de la sonde en plus de la bêche a permis un inventaire rapide des différences entre les sols. L'intérêt généralement attaché à la connaissance des propriétés du sol et à leur distribution régionale a bientôt fait adopter généralement la méthode appliquée.

Le grand promoteur de la cartographie pédologique, le professeur Dr. C. H. Edelman, a été le premier directeur du nouvel Institut. En 1955, son plus ancien élève, le Dr. F. W. G. Pijls, lui a succédé.

2. OBJECTIFS ET ORGANISATION

Suivant l'article 3 des statuts, les objectifs de l'Institution de la Cartographie des sols comprennent:

1. L'étude des terres en vue de la classification et de la cartographie du sol des Pays-Bas.
2. La cartographie systématique du sol des Pays-Bas,
3. L'appréciation d'aptitude et la classification des terres étudiées (en collaboration avec d'autres Instituts).
4. L'exécution sur commande de mises en carte et classifications de terres,
5. La publication et la mise à la disposition de tous des résultats des travaux.

Au début, les travaux se composaient presque exclusivement de l'étude pédologique, puis agronomique à l'échelle régionale, de cartographie sur commande de tiers et de travaux d'information. Ces tâches étaient exécutées par les équipes de cartographie sous la direction d'un agrégé de l'Université d'Agriculture, spécialisé en pédologie. De là se sont développées plus tard les sections provinciales.

Pour certains sujets, le chef de l'équipe de cartographie pouvait consulter quelques experts, par exemple en géologie, en minéralogie, en géographie historique et en archéologie. De plus, il s'est formé des commissions de coordination actives dans un domaine déterminé, par exemple l'uniformisation des légendes, de l'appréciation de la convenance des sols et de l'hydrologie.

Le processus de coordination a été accéléré par la commande d'une carte pédologique de tout le territoire des Pays-Bas au 200.000e, dont les résultats sont sous presse. Mais c'est surtout l'ordre d'une mise en carte systématique au 50.000e qui a rendu la coordination, l'uniformité et l'étude à l'échelle nationale indispensables.

Cette évolution a été cause en 1957 d'une réorganisation où l'activité pédologique générale à l'échelle nationale a reçu sa forme définitive à côté des travaux régionaux existants.

Depuis ce temps, l'organisation présente la structure suivante:

L'ORGANISATION SCHÉMATIQUE DE L'INSTITUT DE LA CARTOGRAPHIE DES SOLS

BUREAU

Direction — Conseiller

Département des recherches et des cartographies pédologiques régionales	Département des recherches specialisées	Section de rédaction, bibliothèque programme et planification	Section de Reproduction	Section des affaires générales
11 Sections provinciales La section de mise en carte sur commande	Les sections de Classification des Sols, Coördination cartographique, Hydrologie, Micropedologie, Pédologie Chimique, Minéralogie, Géologie et Paléobotanie, Recherches sur les Diatomées, Végétation, Géographie historique, Classification des terres pour l'Agriculture, l'Horticulture et la Sylviculture	Rédaction Bibliothèque Programme et planification Rédaction des Cartes	Salle de dessin Lithographie Photographie Diazocopie	Comptabilité et Administration Les archives générales Salle de dactylographie Téléphon Entretien

Les archives techniques

3. BUREAU ET DIRECTION

Le bureau se compose de 10 membres, nommés par le ministre de l'Agriculture et du Ravitaillement sur présentation du ministre de l'Agriculture et du Ravitaillement (4), du ministre des Ponts et Chaussées et du ministre du Logement et de l'Urbanisme (2), des milieux professionnels et de l'organisme de droit public pour l'agriculture, dit „Landbouwschap". (4). Le bureau exerce la gestion financière de l'Institut et fixe entre autres les programmes des travaux sur présentation du directeur. Le directeur rend compte au bureau de sa direction et de la marche des affaires dans l'Institut. Il est assisté d'un directeur adjoint.

Les initiatives d'exécution de certains travaux proviennent de trois sources différentes.

Elles peuvent venir du bureau (mise en carte sur feuilles détachées), des sections provinciales et spécialisées (étude de certains problèmes pédologiques) et de l'extérieur du service (mise en carte sur commande). Cette dernière catégorie est de haute importance parce q'elle fournit – en plus de la subvention gouvernementale et des subventions de quelques institutions – environ un quart des revenus.

4. LES DÉPARTEMENTS

Les départements forment le lien entre la direction et les sections provinciales et spécialisées. Les chefs des départements accordent les sections entre elles et également à leurs tâches. Ils ont une fonction directrice et vérificatrice. Le programme annuel des travaux de chaque section est établi de concert avec le chef du département intéressé.

5. COMMISSIONS INTERNES

Il existe 11 commissions internes, parmi lesquelles la Commission de Classification des sols, la Commission pour la légende de la carte au 50.000e, la Commission de classification des terres, la Commission Horticole, la Commission Hydrologique et la Commission Chimique. Elles procèdent à des travaux préliminaires et à des vérifications, soumettent aux différentes sections des propositions concernant l'étude de certains problèmes et en vérifient les résultats. Outre le chef de la section spécialisée en question, quelques chefs de sections provinciales siègent dans ces commissions.

Outre cela, il existe quelques commissions d'étude, telles que la commission pour la terminologie (formulation de notions, définition de termes), la commission technique (utilisation des perfectionnements techniques dans les travaux pédologiques), la commission du personnel secondaire (conseils concernant le personnel).

6. LE DÉPARTEMENT DES RECHERCHES ET DES CARTOGRAPHIES PÉDOLOGIQUES RÉGIONALES

Celui-ci remplit les tâches de caractère régional, l'exécution de commandes de tiers et la partie des recherches à exécuter d'une façon indépendante par les sections provinciales.

Le département se compose des sections provinciales et de la section des commandes. Son personnel se compose de 18 personnes à formation universitaire et d'environ 40 personnes à formation secondaire ou primaire.

Les sections provinciales

Toutes les sections sont dirigées par un chef à formation universitaire, le plus souvent aidé de 2 assistants. Dans quelques ressorts étendus, elles ont un second membre à formation universitaire.

Les sections provinciales ont les tâches suivantes:

1. Recherches pédologiques régionales.
2. Collaboration aux recherches pédologiques générales.
3. Collaboration à l'étude pédologique nationale et à la mise en carte systématique des Pays-Bas (au 50.000e).
4. Exécution de mises en carte sur commande ou collaboration à leur exécution.
5. Renseignements.

Dans le cadre des *recherches pédologiques régionales* on étudie ou a étudié par exemple la morphologie de la surface pléistocène du centre-ouest des Pays-Bas; le problème de l'argile compacte des sols marécageux (Frise et îles de la Hollande méridionale); la maturation physique et chimique (Hollande septentrionale, Zélande, Biesbosch); la formation du sol dans les terrains sablonneux (Overijssel, Gueldre, Brabant septentrional); les tourbes hautes fortement dégradées (Drenthe); la formation du sol sous l'influence des champs et prairies (Zélande); les terres de la région des tourbières (Groningue); la formation d'une texture-B (Limbourg).

La collaboration aux *recherches pédologiques générales* (exécutées par les sections spécialisées) concerne entre autres les recherches sur la classification des éléments structuraux et des types d'humus, les différences entre les argiles marines et fluviatiles, l'appréciation de la convenance à l'agriculture et à l'horticulture.

Toutes les sections provinciales ont collaboré aux *recherches pédologiques nationales* pour ce qui est de la description des terres servant à la classification des sols des Pays-Bas.

Pour la *cartographie systématique au 50.000e*, toutes les sections ont exécuté des mises en carte d'essais pour composer la légende. L'exécution de ces travaux sera également assurée pour une grande part par les sections provinciales.

L'exécution des mises en carte sur commande se fait en principe par les sections provinciales. Comme ces travaux ont souvent un but pratique nettement déterminé (remembrement, extension urbaine, établissement d'une exploitation horticole) et que les sections sont surchargées de travail, ces commandes sont le plus souvent exécutées par la section de Cartographie sur commande, parfois en collaboration avec les sections provinciales.

Les renseignements aux organismes intéressés aux questions du sol sont fournis à l'échelon régional par les bureaux provinciaux. Il n'est pas pratiqué de *vulgarisation directe* aux utilisateurs du sol. Cela se fait par les conseillers agricoles et horticoles.

La section de mise en carte sur commande

Cette section est dirigée par un chef à formation universitaire avec ses 2 assistants, 6–8 cartographes et quelque personnel provisoire.

Selon le but que l'on se propose, on fixe l'échelle de la carte, de la légende, les cartes dérivées à dresser, etc. Le plus souvent, le but de la cartographie est de nature agricole. Les cartes pédologiques les plus importantes sont celles devant servir aux remembrements. En outre, bien des mises en carte sont exécutées sur commande pour des projets d'extension, des projets hydrologiques, l'inventaire des réserves d'argile (briquetrie), des ouvrages militaires, etc.

Outre la carte pédologique, on dresse souvent des cartes dérivées donnant aux utilisateurs non-experts en pédologie une meilleure vue d'ensemble de certains aspects du sol. Ainsi, on dresse souvent des cartes indiquant la convenance de certains sols à différents usages. A plusieurs reprises aussi, il a été dressé des cartes indiquant des données sur l'hydrologie, la texture des couches supérieures, l'épaisseur et la profondeur des couches de tourbe, l'existence et la nature de couches exceptionnelles etc.

7. LE DÉPARTEMENT DES RECHERCHES SPÉCIALISÉES

Ce département s'occupe des tâches générales et nationales, telles que l'étude à l'usage de la classification du sol, la cartographie systématique des Pays-Bas et l'appréciation de l'aptitude des terres.

Le département comprend 13 sections spécialisées avec un personnel universitaire de 14 personnes et secondaire de 32 personnes.

Les sections spécialisées

Les tâches générales des sections spécialisées sont les suivantes:

1. coordination des travaux concernant le pays entier,
2. renseignements, conseils et assistance fournis aux autres sections de l'Institut,
3. propres recherches,
4. entretien du contact avec les chercheurs et collaborateurs d'autres instituts et services,
5. assistance scientifique aux publications de l'Institution de la Cartographie des sols.

Attendu que l'Institution de la Cartographie des sols est partiellement décentralisée, la *coordination* des travaux dépassant les frontières provinciales (comme dans la mise en carte systématique au 50.000e sur feuilles détachées) est indispensable. Certaines sections spécialisées, telles que les sections de coordination cartographique, de classification des sols, d'hydrologie, d'horticulture et de classification des terres ont une fonction coordinatrice importante.

Une tâche importante consiste à fournir des renseignements et conseils à l'intérieur du service, entre autres pour les sections de géologie, de pédologie chimique, de micropédologie, de minéralogie, d'hydrologie, de végétation, de paléobotanique, de géographie historique.

Les propres recherches des sections spécialisées sont souvent de nature fondamentale ou orientées sur la méthodologie de l'étude.

Section de classification des sols

Sa tâche principale est la classification des sols des Pays-Bas. A cet effet, il a été élaboré un système de catégories dans le genre du nouveau système américain. La mise au point des catégories inférieures est encore en cours. De plus, il est accordé de l'attention à la normalisation des descriptions des profils, la classification des textures et des teneurs en humus et en chaux, à la mise au point et du perfectionnement de la technique de description (nomenclature des horizons) etc.

Section de coordination cartographique

La tâche de cette section consistait en premier lieu dans l'établissement de la légende pour la mise en carte systématique sur feuilles détachées. En ce qui concerne le lever cartographique, la fonction principale est d'assurer la coordination et la liaison entre les exécutions dans les sections provinciales.

Section d'hydrologie

Celle-ci a pour tâche de décrire l'hydrologie sur les cartes de sol et de classer les terres au point de vue du génie rural. Dans la première fonction, la nécessité de fournir des renseignements sur les niveaux des eaux souterraines à l'aide des caractéristiques des profils s'impose. A cet effet, une étude importante a été faite au moyen de mesures systématiques du niveau des eaux souterraines aux Pays-Bas (données C.O.L.N.). A l'usage de la mise en carte au 50.000e sur feuilles détachées, il a été établi une classification des terres selon le niveau des eaux souterraines.

Autres sujets importants: étude du potentiel capillaire, perméabilité (entre autres de couches pertubatrices), possibilités d'enracinement des horizons du sol, pertes d'eau du profil dans les périodes sèches.

Section de micropédologie

L'étude stéréoscopique et microscopique du sol intact forme la base des recherches. Des plaques minces sont préparées pour l'étude microscopique. Ces plaques sont colorées avec le plus grand soin. Cette étude fait connaître la nature, la disposition et la proportion des différents éléments du sol. Elle contribue entre autres à la connaissance des processus de formation des sols.

Les travaux comprennent:

1. La classification des macrostructures du sol.
2. L'étude des formes d'humus, entre autres dans les sols tourbeux,
3. Le rapport entre la structure des sols d'argile sur tourbe et la végétation des prairies.
4. La maturation des sols pour l'horticulture, entre autres les différences micromorphologiques dans le sol des serres en conséquence du chauffage, de la désinfection du sol etc.
   La micromorphologie des sols des vergers à cause de la faune du sol et de l'enracinement; l'utilisation de la tourbe noire profondément gelée (tourbe pour jardins) dans l'horticulture; l'influence de l'emploi d'une couche-écran sur le développement du profil et de l'enracinement.
5. Modifications morphologiques des excréments des animaux du sol dans les différents types de sols.
6. Exécution de mesures en laboratoire: stabilité de structure hydrologique (méthode Hénin), mesures de la perméabilité, de la consistance, etc.
7. Pour l'avenir, le programme comprend l'étude approfondie des formes d'humus, la recherche des causes de la dégradation et de la stabilité des structures, les aspects micromorphologiques de l'hydrologie.

Section de pédologie chimique

Cette section procède aux recherches dans le domaine chimique et sur la minéralogie des argiles ainsi qu'à l'étude fondamentale des argiles, concernant par exemple la transformation d'un minéral argileux en un autre, les conditions dans lesquelles certains minéraux argileux se forment, la structure de minéraux argileux peu connus. Ces recherches sont effectuées à l'aide d'un équipement à rayons X et infrarouges. Dans le domaine de la microscopie électronique pour l'identification des minéraux argileux, la section collabore avec le Dr. Beutelspacher (Brunswick).

De plus, la section recherche des méthodes d'analyse rapide du contenu en eau dans le sol (pF 2,2–4,2) et de détermination de la surface totale des grains du sol.

Section de minéralogie

Les travaux comprennent:

1. L'étude de la composition minéralogique des sols.
2. L'étude de la nature et de l'origine de certains sédiments.
3. L'étude de la contribution des minéraux à la formation du sol.
4. L'étude minéralogique par rapport à la richesse chimique du sol.

Une méthode spéciale de recherche a été élaborée pour l'obtention de données quantitatives: l'analyse quantitative des minéraux par groupes. Cette méthode est préférable à la détermination microscopique de chaque fraction granulométrique.

De même, le rapport entre la fertilité du sol et la réserve minérale est étudié par mesure de la quantité de cations en solution aqueuse qui se libèrent en un temps déterminé dans des conditions déterminées.

Section de géologie et de paléobotanie

La section procède à ses propres recherches et fournit ses conseils et son assistance dans le domaine géologique aux autres sections:

1. Dressement de cartes géomorphologiques pour la cartographie pédologique accordant une attention spéciale au microrelief.
2. La mise en carte de dépôts et formes glaciaires.
3. L'attention est dirigée sur les dépôts fluviatiles du Néopléistocène et de l'Holocène, à la stratigraphie du Pléistocène moyen et du Néopléistocène, à l'étude des dépôts déplacés par solifluction, des vallées périglaciaires, de l'asymétrie des vallées et des phénomènes de cryoturbation.
4. Il a été élaboré une méthode permettant de reconnaître les différents dépôts à l'aide d'éléments de grosseur inférieure à 2 mm. Sous ce rapport, les dépôts des rivières d'Allemagne centrale dans le Nord des Pays-Bas ont été étudiés.
5. L'étude du relief, de la provenance et de la distribution des dépôts éoliens.
6. Coordination et conseils dans le prélèvement d'échantillons pour l'analyse pollinique et le dosage du carbone 14 et interprétation géologique de leurs résultats.

Section de Recherches sur les diatomées

La reconstruction du milieu de formation des sédiments est possible par groupement des espèces de diatomées trouvées dans les sédiments. Cette méthode dite d'association permet de déterminer avec certitude si un milieu a été salin, saumâtre ou doux, si la sédimentation a eu lieu dans le voisinage de la mer ou non, si l'eau dans laquelle la sédimentation s'est effectuée était profonde ou non, etc. De plus, les groupes écologiques renseignent sur la richesse en substances nutritives, le pH et la teneur en chlore du milieu.

Section de végétation

La végétation est un facteur important de l'étude du sol. L'interprétation correcte de la végétation donne un appui important dans les travaux de mise en carte (entre autres pour la détermination des limites des sols). L'étude de la végétation peut avoir de l'importance pour la détermination des propriétés écologiques et des différences de sols apparentés.

Les travaux sont effectués en étroite collaboration avec les sections de cartographie forestière et d'hydrologie.

Section de géographie historique

La mise en carte des sols a contribué dans une mesure importante à la géographie historique. L'étude de la géographie historique, notamment celle de l'histoire des défrichements, est de grande importance pour la cartographie pédologique.

Dans bien des régions à mettre en carte, les noms de parcelles, de maisons, de routes, de cours d'eau etc. sont rassemblés. Ces données sont inventoriées et étudiées. L'étude de la forme des parcelles a donné lieu à une classification des types de parcelles en rapport avec l'histoire des défrichements. Les différentes formes sont actuellement étudiées d'une façon détaillée.

Les plans cadastraux donnent une bonne idée de l'occupation il y a quelque 150 ans. Dans quelques villages des régions sablonneuses, les types de villages ont été étudiés.

Les noms, les formes des parcelles et des villages représentent chacun une phase déterminée de l'histoire des défrichements. L'association de ces différents aspects permet d'analyser l'évolution.

Applications

Les sections actives dans le domaine des applications s'occupent du rapport entre le sol et les plantes cultivées. Leur tâche est donc de fournir dans une carte d'aptitude des sols une interprétation de la carte pédologique pour l'utilisation du sol et la culture. Pour cela il faut non seulement des connaissances pédologiques, mais encore une connaissance importante de la technique des cultures. C'est pourquoi ces travaux sont effectués en collaboration étroite avec les conseillers et les instituts de recherches sur les cultures, le génie rural et l'économie.

Section de classification des terres pour l'Agriculture

Cette section s'occupe de la classification des terres pour l'exploitation agricole, l'exploitation en prairies et l'exploitation mixte. La collaboration avec d'autres services à l'échelon national est coordonnée par la Commission Technique de Classification des Terres du Ministère de l'Agriculture.

Les cartes d'aptitude des sols peuvent être dressées pour différents niveaux d'exploitation. Le meilleur niveau pour la caractérisation agricole des types de sols est obtenu en enregistrant des résultats obtenus par de bons cultivateurs suivant un programme de culture aussi favorable que possible.

Les données sont obtenues par:

1. Les réunions avec les „bons" cultivateurs.
2. Les entretiens personnels avec les „bons" cultivateurs.
3. La collaboration avec les experts locaux.
4. L'étude des données fournies par différentes fermes pilotes.
5. Les données résultant d'expériences ultérieures, exécutées par d'autres Instituts ou par les conseillers.
6. L'examen des cultures pratiquées sur différents types de sols.
7. Les récoltes d'essai et les taxations des cultures.

Section d'horticulture

Cette section étudie les possibilités de pratiquer l'horticulture sur les différentes terres. Elle étudie les différents facteurs pédologique qui influencent l'aptitude du sol à différentes cultures, méthodes de culture et types d'exploitation suivant les conditions requises par les cultures.

La section étudie les possibilités d'amélioration du sol. Elle procède à des classifications horticoles, entre autres à l'usage du Plan d'établissement horticole, et fournit des conseils à d'autres sections de l'Institution de la Cartographie des sols et à d'autres organismes.

Section de sylviculture

Celle-ci a pour tâche:

1. L'étude de l'influence du sol sur la croissance des principales essences productrices: le pin, le mélèze, et le sapin de Douglas.
2. la préparation de cartes pédologiques et de cartes dérivées concernant l'aptitude des sols aux différentes destinations.
3. Les renseignements pédologiques.

L'examen des peuplements, nécessaire pour l'étude de l'aptitude des sols, est exécuté en étroite collaboration avec l'Administration Nationale des Forêts et la Station Expérimentale de Sylviculture. Une étude concernant le sapin de Douglas dans le pays entier est exécutés avec cette Station.

8. SECTION RÉDACTION, BIBLIOTHÈQUE, PROGRAMME ET PLANIFICATION, RÉDACTION DES CARTES

Rédaction

La rédaction est chargée de la publication des études exécutées et des données rassemblées. Elle publie:

1. La cartographie des Pays-Bas

Publication de mises en carte d'étude, accompagnées d'une carte pédologique. Ont paru: 19 fascicules.

2. Etudes pédologiques

Résultats de recherches pédologiques n'ayant pas directement trait à des mises en carte. Ont paru: 4 fascicules.

3. Sonde et Bêche

Etudes sur une plus petite échelle concernant la pédologie des Pays-Bas, des parties indépendantes de certaines études et la position des travaux. Edité une fois par an environ.

En plus de cela, il est encore établi des „rapports internes": rapports polycopiés de mises en cartes sur commande. Remis au commettant et à quelques organismes du Ministère de l'Agriculture.

Les autres tâches de la rédaction comprennent l'établissement du rapport annuel, de la documentation, l'organisation d'expositions, etc.

Bibliothèque

Prend soin de la bibliothèque, dresse des listes bibliographiques et établit des documentations.

Programme et planification

Compose tous les programmes de recherches et d'exécution des autres sections. Les différents chefs de section répondent du temps utilisé au moyen de bordereaux mensuels. Il est procédé au dépouillement de ces bordereaux mensuels.

Chaque trimestre, il paraît un rapport concernant l'avancement des travaux suivant une liste des objectifs. Cette liste constitue aussi la base des programmes de travail et de l'administration des projets par la section des Affaires Générales.

Rédaction des cartes

C'est ici que la finition des projets des cartes et des croquis est préparée. Des directives sont fournies concernant l'emploi de couleurs et de hachures. Par ce moyen, on s'efforce d'exprimer les différences et les concordances des unités représentées. Pour simplifier le choix, une gamme de couleurs et une collection de hachures ont été composées. La technique de ces travaux est constamment perfectionnée pour pouvoir satisfaire aux exigences toujours plus hautes.

9. SECTION DE REPRODUCTION

Celle-ci comprend les subsections suivantes: salle des dessinateurs, lithographie, diazocopie et photographie, ainsi que les archives de cartes pédologiques et topographiques, de diapositifs, de photographies et de clichés.

La section a un personnel de 23 personnes et exécute tous les travaux de reproduction.

Salle de dessin

Les données cartographiques fournies par le service extérieur sont portées sur des feuilles transparentes, diazocopiées et coloriées à l'aquarelle. Pour les rapports internes, tous les exemplaires (15 au maximum) sont coloriés à la main. Pour les cartes à imprimer, un seul exemplaire est colorié pour être traité ensuite par la subsection de lithographie.

Lithographie

Ici, les cartes à imprimer en couleurs sont préparées de manière à ce que l'imprimeur puisse les copier sur une matrice off-set et les imprimer.

Il existe une gamme de couleurs dans laquelle 195 teintes sont obtenues par surimpression des trois couleurs primaires (jaune, rouge et bleu) avec des trames graduées. Chaque carte coloriée est analysée en trois couleurs primaires, après quoi toutes les teintes sont exécutées avec de l'encre et des trames linéaires, pointillées ou transparentes (stripping film).

Photographie

Cette subsection exécute ou finit tous les travaux photographiques du service. Un grand appareil de reproduction photographique permet de confectionner des cartes de base, des textes, des copies de cartes et des trames. On confectionne ici les diapositifs en noir et en couleurs ainsi que des microphotographies.

On a effectué avec succès des expériences de reproduction de cartes pédologiques par la photographie en couleurs. Celle-ci pourrait remplacer le coloriage, qui prend beaucoup de temps.

Diazocopie

Cette subsection exécute tous les travaux de diazocopie pour le service.

10. SECTION DES AFFAIRES GÉNÉRALES

Cette section comprend un personnel de 14 personnes, complété du personnel domestique et d'un concierge. Sa tâche comprend la gestion et l'administration des recettes et dépenses, l'établissement et le contrôle du budget, le calcul des prix de revient, l'administration de l'inventaire et les affaires du personnel. De plus, la section se charge des travaux de dactylographie et de polycopie, du courier et des archives, du service téléphonique et des transports ainsi que des travaux d'entretien.

METHODS OF SOIL SURVEYING IN USE AT THE NETHERLANDS SOIL SURVEY INSTITUTE

by

Ir. G. G. L. Steur *et al.*

By soil surveying is meant the compilation of maps on which various permanent features of the soil are depicted. Hence a soil map is a map designed to show the horizontal distribution and limits of pedological units. Although the work of the Soil Survey Institute covers a wider sphere than the compilation of soil maps and the study of the soil, it is useful to follow the procedure adopted in making a soil map.[1])

Since the soil is a three-dimensional body, for the purpose of surveying it is necessary to know the vertical structure of the soil and the situation of the soil units in the horizontal plane. Augers and spades are employed for this purpose. Profile studies by themselves give no information on the essential third dimension, the horizontal extension of the soil unit. For this purpose a survey is required. In this survey it is usually possible to distinguish four important phases:

1. Preparatory work;
2. Reconnaissance and investigation;
3. Field work;
4. Processing the information.

1. Preparatory work

Once it has been settled that a survey is to be made in a given district and its boundaries have been determined, the preliminary work can be commenced.

In the Soil Survey Institute this work is usually done by the department in whose province the district in question falls. These departments coincide with the geographical provinces and are headed by a survey party chief trained at the Agricultural University of Wageningen and who specialized in soil science. The party chief is helped by assistants who are responsible for a great deal of the field work. These assistants are secondary school-trained staff with an elementary or secondary agricultural schooling. Moreover they followed a course of practical training as well as an extension course in theory of which the chief aspects are soil science and soil hydrology. Much of the day-to-day management of the actual survey can be entrusted to the best members of this corps as overseers. It is probably owing to the good preliminary training given in the Netherlands that this work can be performed in this country by staff with a secondary schooling only; elsewhere it has hitherto proved impossible to carry out the work in this way. If necessary the field party is helped by a number of assistants of whom no special pedological or agricultural knowledge is required.

The equipment of such a field party consists of the various boring and

[1]) For a description of the work of the Soil Survey Institute reference may be had to this volume, chapter 2.

digging implements (fig. 1), drawing and writing materials, a working file for holding the map material, a Munsell Soil Color Chart for measuring colours, a Scheme for profile description containing standardised categories of humus and lime contents, texture, structure, etc., a loose-leaf standard notebook for recording data on the soil profile (fig. 3), a dropping flask containing dilute hydrochloric acid for determining the carbonate content, a magnifying glass or a sand ruler (fig. 2) as a means of estimating the grain size, and in certain cases a simple pH-meter (Hellige-Truog).

A good basic map is required for carrying out the field-work and this is usually available in the Netherlands. Different basic maps are employed, according to the type of survey. It may be laid down as a general rule that a map to be published is surveyed on a scale twice the size. In surveying use is generally made of land register maps of a 1 : 5,000 or 1 : 10,000 scale which have usually already been brought up to date and supplemented by other departments, so that all fields and field boundaries are shown on the map. For a part of the country topographical maps are available on the scale of 1 : 10,000. These sheets are rapidly increasing in number. The 1 : 50,000 soil map of the Netherlands which is in course of compilation, will be surveyed, using the plain sheets of the topographical map on a scale of 1 : 25,000 as field maps. In addition to topographical and land register maps, increasing use is being made of aerial photographs as basic material. This is necessary in areas where a location cannot be determined with sufficient accuracy in the field by means of topographical maps (fig. 4 and 5). In regions where good maps are available the aerial photograph is not so necessary as a basis. It is less used owing to certain drawbacks, such as sensitivity to moisture, difficulty of writing on, and the difficulties of transferring it to the definitive basis.

Besides the map required as a basis for field work and the definitive soil map, all other kinds of maps in existence of the district are extremely important. Obviously the geological map is an important document. Moreover an expert soil scientist is able to draw a very great number of conclusions about the probable soil pattern from the topographical maps showing the shape of fields, vegetation indications, land use, watercourses, field names, and the like. In the cultivated landscape of the Netherlands, so greatly influenced by man, old maps in particular are very valuable. They provide much more information on the natural pattern of the soil via the former land use than maps made subsequent to the large-scale reclamations during the 19th and 20th century. The analysis of aerial photographs can also provide a great deal of pedological information. In the flat country of the Netherlands stereoscopic analysis cannot play a very important part. Its importance has only been proved in South Limburg and certain blown-sand regions.

2. *Reconnaissance and investigation*

Having gained a rough idea from maps as to what may be encountered in the area to be mapped and what types of landscape occur therein, the next stage is to enter the terrain oneself. On the most typical locations the surveyor then tries to obtain a general view of the chief differences in the soil with the use of profile holes and the auger. Once this stage has been reached there follows the detailed investigation required for making a map legend. It will be clear that in surveying areas closely related to other known areas, it is possible to reduce the time spent on reconnaissance and even on investigation and that sometimes it can be omitted altogether.

Reconnaissance is followed by the preliminary investigation. This mainly depends on the knowledge already existing of related or same soils and the degree of accuracy with which the survey is to be made. When working in a district for which a reasonably good soil classification has already been made, one's activities can be limited to a mainly morphological study of profiles in profile holes, supplemented by borings. In addition a number of physical and chemical determinations are made in the laboratory. Should considerable differences be found to exist, making it impossible to work with the existing classification, or should such a classification be entirely lacking, a more detailed examination will be required. The data derived from this investigation will have to be fitted into the Netherlands system of soil classification which works with taxonomic, morphometrically defined units. This kind of investigation provides the material required for an improvement and further extension of the Netherlands soil classification system.

There is a special form of investigation which enables the soil scientist to study the spatial relationships of soil units before he starts on the actual survey. This is the *detailed experimental survey* which is carried out in each of the distinguished landscapes of the area to be surveyed, as determined in the reconnaissance. In this experimental survey it is possible to start from well-defined soil units characterized by a large number of features which were distinguished in the profile studies. It is, however, also possible to follow various features individually, watch their horizontal course and notice how they are spatially correlated with other features, i.e. not only in the vertical plane observed in the profile pit. The study of the soil in the horizontal plane is all too often neglected, especially by pedologists who are not surveyors. The technique of surveying with the detailed experimental survey is substantially the same as that of general surveying, except that the work is carried out more exactly with less interpreting form such indirect data as vegetation, relief, etc.

The party chief plays an active part in the field work involved in profile description and the experimental survey, although a considerable part of the work is done by assistants, their share varying according to their knowledge and experience. Knowledge of the morphometrically defined soil units of which the spatial distribution is verified by the experimental survey is the basis of the next step of the investigation, i.e. compiling the map legend. The starting point of the latter consists of the basic units of the soil classification, the cartographic representation of the unit on the scale concerned being the decisive factor. On very large scales it will be possible to employ the lowest units of the soil classification as mapping unit. It has been found, however, that as the scales become smaller, important units of the classification are so complex that they have to be introduced in the legend as associations. This is found to be the case even in the 1 : 10,000 scale. The scale of the map is determined by the extent of the detail which is still necessary to show in the lowest units of the legend and the degree of accuracy with which the boundaries should or can be defined.

Hence the map scale greatly depends on the object of the survey; the larger the scale, the greater is the detail which can and should be given, and the greater the accuracy with which the units are defined and the denser the necessary observation-network and the lower it is possible to reach in the categories of the soil classification system. The scales of soil maps normally used are discussed in § 5.

3. Field work

This is generally carried out by the assistants, in some cases helped by workmen for boring and/or digging profile pits. In areas where ordinary augers can be used, viz. in practically all fairly light clay soils, sands and loess soils, an assistant surveyor is generally unnecessary in routine surveying.

The surveyor goes out into the field alone with auger and map, he drills, classifies the profile, gives a short description in the note-book, notes it in code on the field map and determines the boundaries of the mapping units by means of boring. This has proved a very satisfactory method in not too heavy terrain and where the hands are not too much dirtied by boring. The field map used is an aerial photograph or a good map. Its scale depends on the scale on which the map has to be published. In practice the field map selected is twice the scale of the definitive map, since accuracy is increased by the reduction in size. Much larger scales than double are undesirable as they have the effect of making one work in excessive detail without noticing it (this is particularly the case in free surveying). Generally speaking it seems to be more difficult to force oneself to work more or less roughly than to carry out detailed work. The characteristic of practically every inexperienced surveyor is to work in excessive detail. Broadly speaking, two methods of surveying may be distinguished:

a. Baseline surveying.
b. Free surveying.

This division also shows the order in which there is an increase in the interpretation from derived features and a decrease in direct observation from the profile. Moreover it can be said in general that the scale on which the survey is carried out also becomes smaller, viz. more approximate in this order. All transition forms occur between these two forms of surveying. They will be successively discussed below.

a. Baseline surveying

Surveying with the auger is the most efficient method in landscapes having few solid and hard soils. This is the method exclusively followed in the Netherlands. In most cases a boring depth of 120 cm is sufficient.

Occasionally greater depths are required where there are greater possibilities of root penetration or where deviations occur in the deeper subsoil affecting the hydrology of the upper layers. When very few differences in the soil can be observed at the surface, e.g. no relief or vegetation in which differences in growth can be observed, etc., surveying has to be carried out by means of a baseline network (fig. 6). The soil is then examined at fixed intervals.

A distance of, say 30 to 50 metres between two borings, is a reasonable standard in surveys on a scale of 1 : 10,000. Generally speaking, the distances can either be measured or estimated (this is certainly the case when good maps are available). A compass is a valuable help in terrain difficult to view as a whole. The soil boundaries are filled in at once or at a later period, the latter when there is nothing to be observed on the surface. If one knows or has reason to believe that more differences in the soil may be expected in one

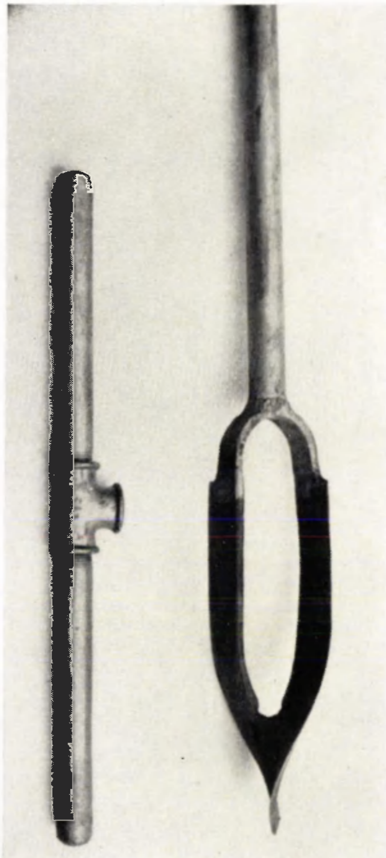


Foto Stiboka nr. 7217

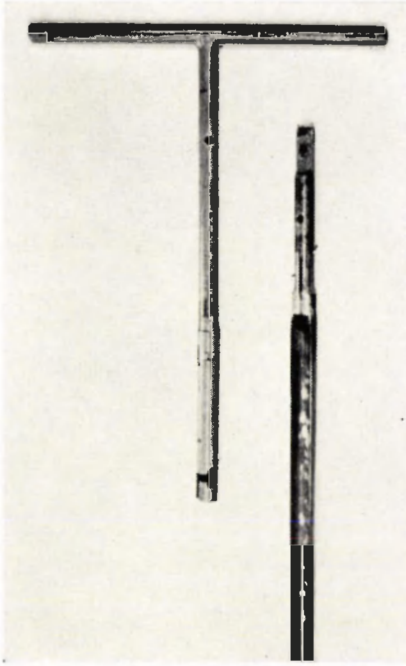


Foto Stiboka nr. R 21-10

Fig. 1. Soil augers
Left: auger used in sand and clay soils
Right: auger used in peat

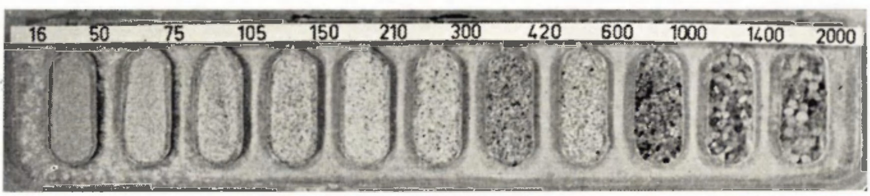
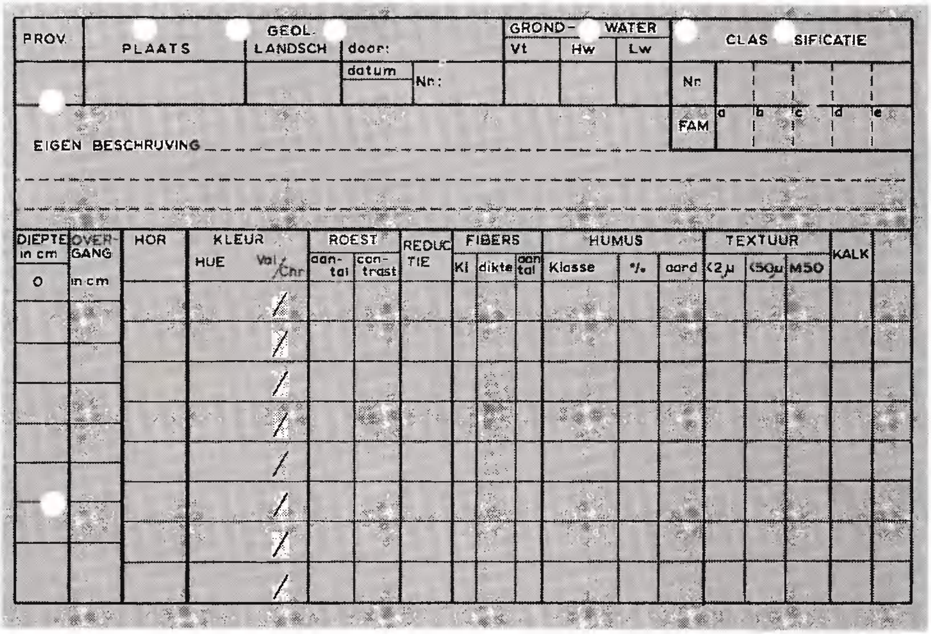


Foto Stiboka nr. 7210

Fig. 2.
The "sand ruler" for estimating particle-size of sand



PROV.	PLAATS	GEOL. LANDSCH	door:		GROND- WATER Vt	Hw	Lw	CLAS SIFICATIE
			datum	Nr:				Nr
								FAM a b c d e

EIGEN BESCHRIJVING

DIEPTE in cm	OVER-GANG in cm	HOR	KLEUR HUE	KLEUR Val/Chr	ROEST aan-tal	ROEST con-trast	REDUC TIE	FIBERS Kl	FIBERS dikte	FIBERS aan tal	HUMUS Klasse	HUMUS %	HUMUS aard	TEXTUUR <2 μ	TEXTUUR <50μ	TEXTUUR M50	KALK	
0				/														
				/														
				/														
				/														
				/														
				/														
				/														
				/														

Fig. 3. Page of a note-book

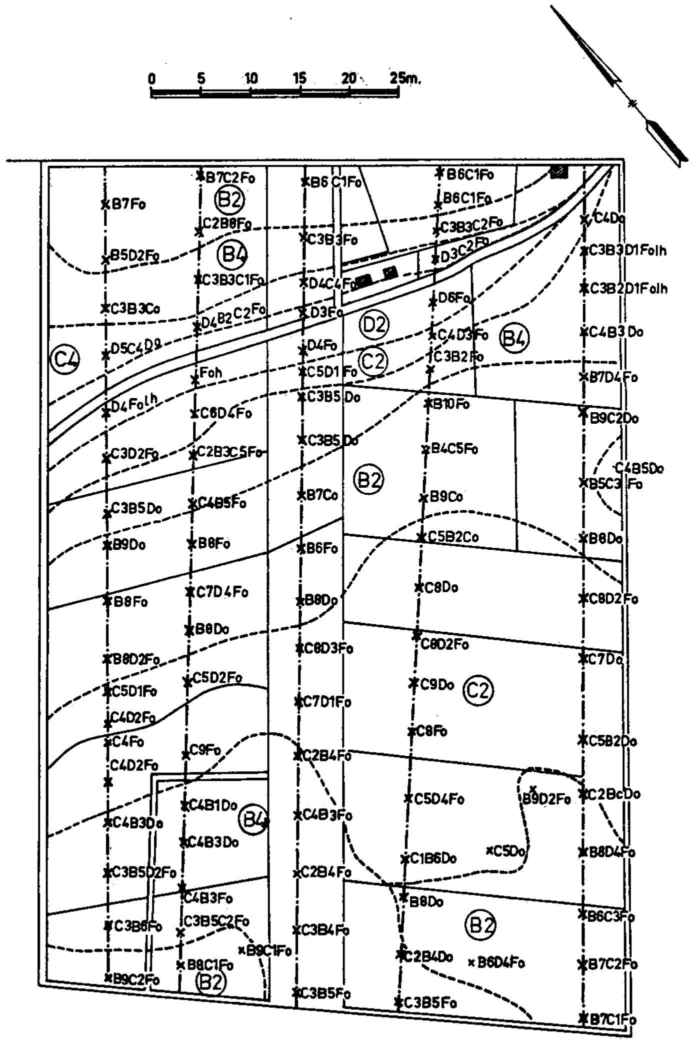
Appr. scale 1:29,170 *Luchtfotoarchief Topografische Dienst, Delft*

Fig. 4. Where orientation in the field is difficult aerial photos bring relief. Hilly grounds near Gronsveld, South Limburg.

Appr. scale 1:21,700

Photo: K.L.M.-Aero-carto

Fig. 5.
Where orientation in the field is difficult aerial photographs bring relief.
Environments of Belt (Overijssel). A: sand soils; B: Area where peat has been dug, the open water being filled with floating mats of vegetation; C: Lake Beulaker Wijde.



Legend

B2 Symbol of soil unit

C4B3Do Symbol of profile

Boundary between soil units

Base line

Site of augering

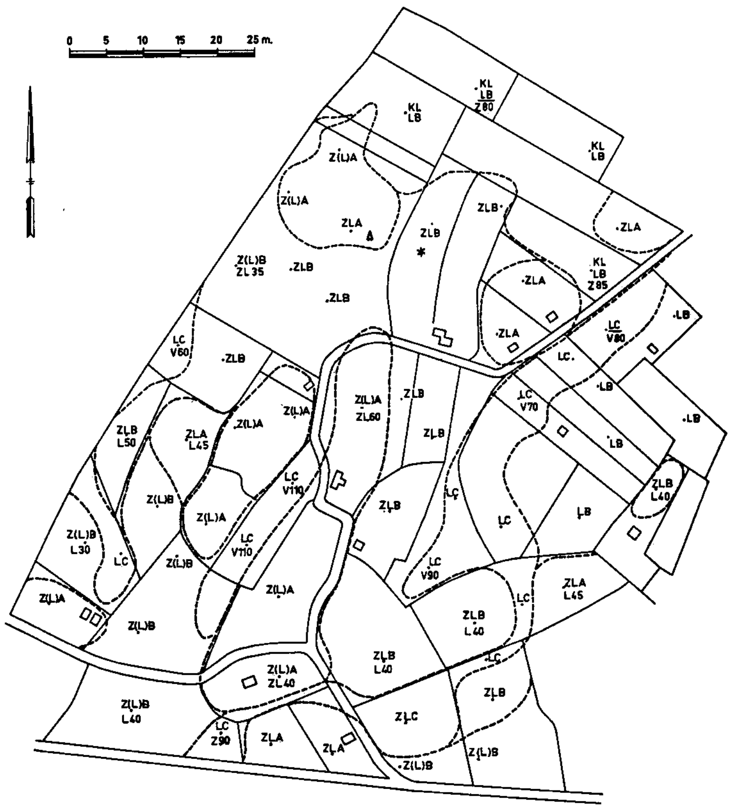
Fig. 6.
Part of field map, baseline survey. Baselines perpendicular to the main differences in soil units. Survey by M. A. Bazen, 1949.

direction than in the other, the square network may be departed from. A comparatively greater number of borings is then taken in the direction in which the most rapid succession of soil differences is anticipated (fig. 6). Hence where soil types are zonally situated, e.g. along rivers, shores of lakes, etc., it is always necessary to proceed at right-angles to the boundaries anticipated.

b. Free surveying

When one is confronted with soils in which a great many differences can be indirectly read on the surface from micro- or even macrorelief, or from the differences in natural vegetation or the reaction of the plants to soil conditions, it is possible to change from the baseline method of surveying to free surveying, provided one has a good basic map (fig. 7).

In this method the main procedure is to walk the boundaries which can be more or less followed on the surface from all manner of secondary features.



Legend

· Site of augering

---- Boundary between soil units

Z(L)B Symbol of soil unit

Fig. 7.
Part of a field map, free survey. Survey by J. J. Vleeshouwer, 1954.

By regularly boring on both sides of the boundary its course can be checked and the real nature of the differences also determined. For a proper determination of the units on both sides of the boundary it is necessary to make an occasional observation in the centres of the concrete soil units.

As a surveyor gains more experience he will be able to employ a free survey sooner than a worker who is not so fully trained and requires distinct surface features to guide him. But if the surveyor is without a good detailed basic map he will still have to walk along the baselines starting from points which are recognizable on the map. If he does not do this he will not know how to fill in the boundaries. This method also has to be employed in dense woodland where the view is restricted and it is difficult to find one's bearings. The same applies to other terrains difficult of access, such as swamps, where the surveyor is unable to walk about as he likes.

The great advantage of free surveying is that work can be done more rapidly as less boring is required. A danger is that more interpretation is involved, with the result that there is a greater risk of making systematic errors. A further drawback is that the borings shown on the map are not regularly distributed over the terrain but mainly concentrated along the soil boundaries. This restricts the use of these data for other purposes (including such information as the precise values, observed in situ, of layer thickness, etc.).

c. Changeover from baseline surveying to free surveying

A middle course is to distribute the drillings fairly regularly, if necessary still on baselines, but to fill in the boundaries by the free surveying method. This is undoubtedly the most accurate method, even if not the most rapid one. A knowledge of the exact layer thicknesses, etc. and their variation within a mapping unit is precisely what is required as a basis for land improvement works. In such a case the use of this method is obligatory.

In most cases it will be possible to show in code on field maps the principle information at each boring point. If a great deal of information has to be shown the surveyor can work with numbered forms and denote the points by corresponding numerals on the map. Another method is to make a somewhat more extensive profile description at every one in 10 or 20 borings. This is especially important when surveying in areas where little preliminary investigation has been carried out. It is also necessary in the case of inexperienced surveyors who need additional supervision. Generally speaking, however, the most efficient way is only to show the information on a field map. When carrying out free surveying, or at any rate filling in the boundaries in the field, the surveyor has to show both the code of the various features and the symbol of the legend unit derived from it.

Even in the most mechanical form, as in baseline surveying, soil surveying is anything but a mechanical operation. There is always a certain amount of interpretation involved which increases as the scale becomes smaller and the survey more approximate as a result.

To be able to perform this work, and particularly general surveys, well-trained staff should be available who are capable of working independently both in the pedological sphere and as regards a sense of responsibility. A party chief should himself go out into the field regularly (especially when it is a question of surveying a new area), both in order to supervise his staff and to keep himself informed of the progress being made in the soil investigation and provide the necessary leadership.

In general, however, he will rarely visit each field assistant more frequently than once a week. Hence for the remainder of the time these assistants will be working entirely on their own.

4. Processing the information

The data shown on the field maps should be transferred to a cumulative map, the so-called network map, preferably in the evening immediately after being recorded, or in any case at the end of the week. For this purpose use is made of a map of transparent material, known as a calque, on which a topographical basis has already been printed. By placing this on the field map the boundaries can immediately be taken over from the latter. Photo prints can be continually taken from this transparent sheet so as to build up a set of shadow records. Owing to the great amount of field work carried out on the sections already recorded, the loss of any of them is a very costly affair. The field maps are coloured to give a better idea of the arrangement of the various soil units, thus providing a far better insight into the pedological structure of the area investigated. The latter is very important, as a good survey can only be made if the surveyor understands the soil pattern of the area. Moreover colouring brings to light more or less automatically any errors of demarcation and conjunction.

The report belonging to the soil map is made from the brief reports given with the field maps and the analytical data, as well as from the processing of all the rest of the investigation. This report contains both a general chapter on such technical matters as boundary definition, acreage, object of the survey, time and method of the survey, at least a detailed description of the map legends employed, supplemented by the analyses of the profiles sampled, and a description of the soil map in which attention is drawn to the distribution of the soil units and their cause. This chapter generally also includes certain details which are not explicitly shown on the map. In addition the report should serve as an account of the entire investigation carried out in the course of and on behalf of the survey. Moreover it has to provide further information on certain applications which may have been included via derived maps. In many cases this will relate to land classification maps and maps for land improvement applications, e.g. maps showing sand depths, peat depths and thicknesses, and the like. The report is usually drawn up by the party chief with the help of the assistants who performed the field work. The map and text are then completed in draft, after which the editorial board and the drawing office make them suitable for distribution, either in stencilled form with hand-coloured maps as an internal report intended for the principals and a small circle of other interested parties, or else in printed form as a publication in the series of Reports on Agricultural Investigations[1]) or Communications of the Soil Survey Institute[2]) intended for a wider circle of readers.

5. Map scales

The largest scale soil maps made in the Netherlands are the so-called farm-plan soil maps. These are compiled with a view to soil suitability, soil im-

[1]) Verslagen van landbouwkundige onderzoekingen.
[2]) Mededelingen van de Stichting voor Bodemkartering: for sale at the Soil Survey Institute.

provement, etc. They are obviously most detailed in the case of intensive horticulture and least detailed in the case of forestry.

Except for the forestry survey maps, which are compiled by a special department of the Soil Survey Institute, the compilation of farm-plan maps is the task of the extension services who have a special advisory bureau for the co-ordination of this work, viz. the State Horticultural Advisory Bureau for Matters relating to the Soil, and the State Agricultural Advisory Bureau for Soil and Fertilization. The scales of the farm-plan maps vary from 1 : 1,000 to 1 : 10,000 according to their purpose (the extremes being intensive horticulture and forestry) and the complexity of the soil pattern. The number of observations (borings) varies from 10 to 20, sometimes 30 or more per hectare, to 4 to 5 per hectare. Generally speaking these maps do not yet link up with the Netherlands soil classification system already drafted. The map legends employed are in many cases taken from the old morphogenetic system, but emphasis is placed on slight differences in profile structure which may be important for the purpose of the survey. An exception is formed by the forestry survey maps which, being the newest branch of the „farm-plan" surveys, are much more closely linked to the Netherlands soil classification system.

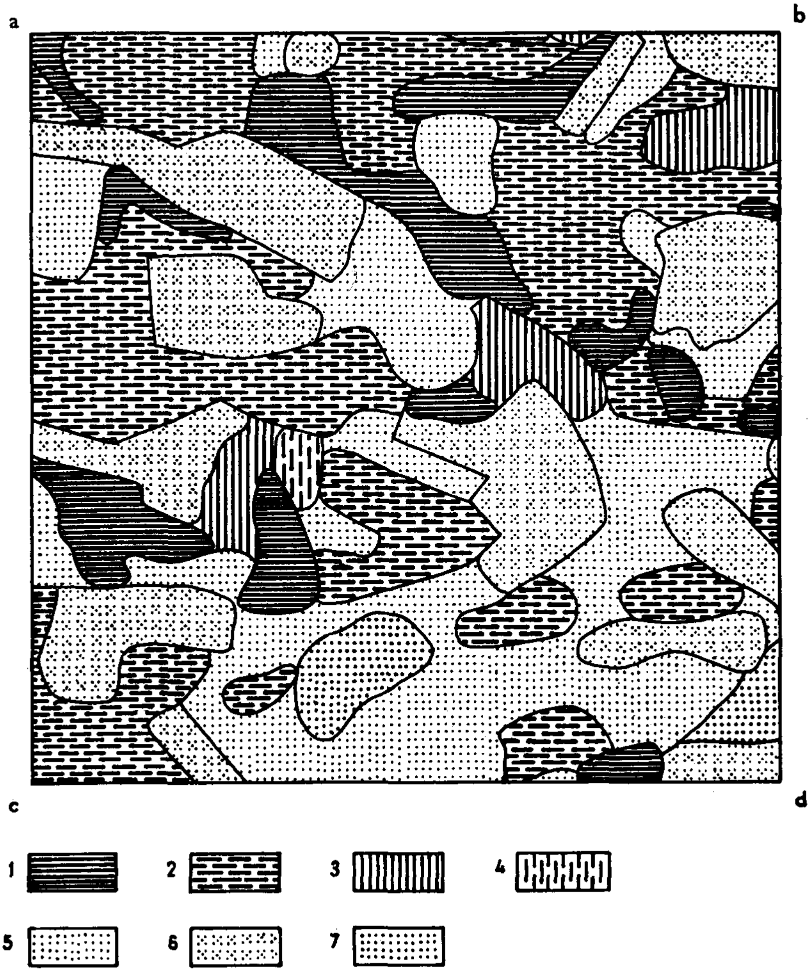
Detailed soil maps compiled in the Netherlands by the Soil Survey Institute have a scale of 1 : 10,000 (fig. 8). They are surveyed at a density of 2 to 3 to 6 to 8 observations per hectare. The maps already published[1]) are all based upon the morphogenetic system. The map legend is worked out separately for each map. Although these maps are surveyed on the same general principle of classification according to landscape, they differ from each other to a greater or lesser extent owing to differences in detail and the lack of a general soil classification at the time of the survey. This is particularly true of the lower levels of the map legend. Since the soil classification system forms the basis of the new 1 : 10,000 surveys, it may be expected that in future there will be a considerable increase in the comparability of the detailed maps. There is not likely to be a complete correlation between the various detailed maps. Each new survey and each new investigation contributes to a better knowledge of the soil. If the practical use of the soil maps is to increase, it will be necessary to incorporate this knowledge in the soil classification. The question as to when soil surveying will cease altering its classification and nomenclature must be answered in Kellogg's words: „When we shall have ceased to learn about soils".[2])

General soil maps are on the scale of 1 : 25,000 and were surveyed with an observation network of about 1 per hectare to 1 per 2 to 3 hectares. For special reasons some maps have been brought out on different scales. The maps already published are based on the morphogenetic system. The map legends vary from area to area, but the mutual correlation is greater than in the case of the detailed maps.

The semi-detailed map or detailed general map occupies an intermediate position between the detailed map and the general map. The scale of these maps varies from 1 : 10,000 to 1 : 25,000, depending on the degree of detail. In the south-west of the country a number of maps of a semi-detailed description have appeared on a scale of 1 : 16,667. Both the density of the

[1]) Verslagen van landbouwkundige onderzoekingen.

[2]) Kellogg, Ch. E., 1955. Soil surveys in modern farming. J. of soil and water conservation, *10*, 6, 271–277.



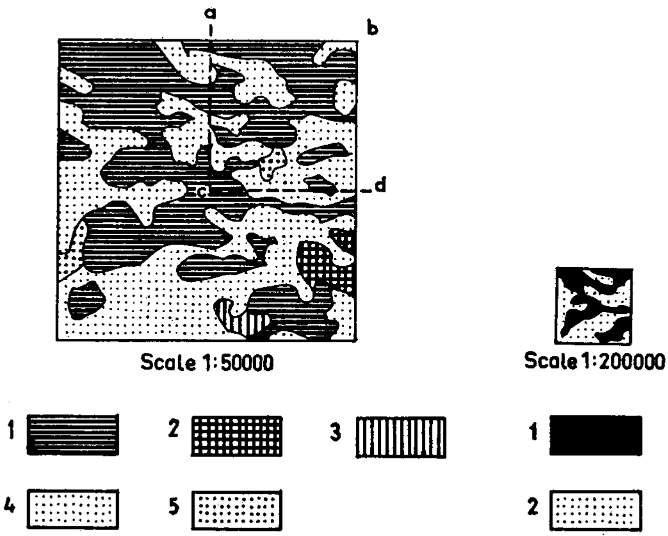
Legend

1. Black gley soils, groundwater level between . . . . 0– 75 cm
2. Ditto . . . . 15–120 cm
3. Brown gley soils, groundwater level between . . . . 15–120 cm
4. Ditto . . . . 40–170 cm
5. Humus podzols, organic matter favourable, groundwater level between . 15–120 cm
6. Ditto, groundwater level between . . . . 40–170 cm
7. Humus podzols, organic matter unfavourable, groundwater level between 15–120 cm

Fig. 8.
Soil map on scale 1 : 10,000.

observation network and the scale are intermediate between the general and detailed maps.

Small-scale maps are compiled for various purposes, especially for town and country planning. The scales vary from 1 : 50,000 to 1 : 100,000 (fig. 9). The composition of the mapping units and the density of the observation network



Legend 1 : 50,000 soil map

1. Black gley soils
2. Complex of black and brown gley soils
3. Brown gley soils
4. Humus podzols, organic matter favourable
5. Humus podzols, organic matter unfavourable

Legend 1 : 200,000 soil map

1. Gley soils
2. Humus podzols.

Fig. 9.
Soil maps of the same area of which a part (a, b, c, d) is pictured in fig. 8. Details of legend and soil pattern disappear when map scales are reduced.

bears the very strong impression of the purpose for which the map was compiled. This type of soil map is known as a r e c o n n a i s s a n c e m a p.

Two other small-scale maps are made which provide a general picture of the soil pattern of the entire country. These are:

a. The provisional soil map of the Netherlands, scale 1 : 400,000, published on the occasion of the IVth International Soil Science Congress at Amsterdam in 1950. This map was surveyed with a minimum of field work. All pedological data known up to that date from many different sources are summarised on it. The map layout is highly geogenetic.

b. The soil map of the Netherlands, „Nebo" map, scale 1 : 200,000. The layout of this map is also entirely geogenetic, but the units are fairly well defined from the morphometrical stand-point. A great deal of field work was done for the survey, but it was not systematic. Pedological knowledge assembled since 1950 is, of course, entirely incorporated in this map.[1])

The systematic survey of the Netherlands on map sheets on the scale of 1 : 50,000 deserves special mention. Work on this map has just begun. A uni-

[1]) This map will be published in printed form in 1960.

form map legend, based on the morphometric units of the taxonomic soil classification, has been developed. This map will be completed in 20 to 25 years.

SAMENVATTING.

Een bodemkaart geeft een indruk van de horizontale verbreiding en begrenzing van bodemkundige eenheden. Profielstudie verschaft slechts gegevens omtrent de verticale opbouw van het bodemprofiel. Door kartering wordt de horizontale uitbreiding van de eenheid vastgesteld.

De bodemkartering heeft 4 belangrijke fasen.

1. Voorbereiding.
2. Verkenning en onderzoek.
3. Veldopname.
4. Afwerking.

1. Voorbereiding

Deze gebeurt door de provinciale afdelingen in wier gebied het te karteren object ligt. Het werk staat onder leiding van een karteringsleider, opgeleid aan de Landbouwhogeschool (Wageningen) en gespecialiseerd in bodemkunde. Hij wordt bijgestaan door bodemkundig geschoolde assistenten met elementair of middelbaar landbouwonderwijs. Deze assistenten voeren een belangrijk deel van het veldwerk uit.

Het veldwerk wordt opgenomen op een basiskaart, die de dubbele schaal heeft van de definitieve kaart. In het algemeen zijn dit kadasterkaarten 1 : 5000 of 1 : 10.000 of topografische kaarten 1 : 10.000. Ook luchtfoto's worden als basis gebruikt. Studie van oude topografische kaarten en luchtfoto's kan reeds veel inlichtingen verschaffen omtrent de te verwachten bodemgesteldheid.

2. Verkenning en onderzoek

Dit gebeurt in het terrein door op typische plaatsen te boren of profielkuilen te graven. Zo verkrijgt men een globaal overzicht van de voornaamste bodemverschillen. Daarna volgt het vooronderzoek. Meestal wordt dit uitgevoerd als een gedetailleerde proefkartering. Deze wordt gelegd in elk van de onderscheiden landschapseenheden, die bij de verkenning werden onderkend.

De kennis van de morfometrisch gedefinieerde bodemeenheden is de basis voor de samenstelling van de kaartlegenda. Deze is afhankelijk van de vereiste mate van gedetailleerdheid en dus van het doel van de kaart. Ook de schaal van de kaart wordt daardoor bepaald (zie § 5).

3. Veldopname

Deze wordt uitgevoerd door de assistenten. Zij werken gewoonlijk alleen. Er kunnen 2 manieren van karteren onderscheiden worden:

a. de raaienkartering,
b. de vrije kartering.

a. Raaienkartering

Wanneer aan de oppervlakte bijzonder weinig bodemverschillen zijn waar te nemen, b.v. geen reliëf of geen groeiverschillen in natuurlijke vegetatie of gewas, moet men karteren volgens een raaiennet (fig. 6). Er wordt op vaste afstanden geboord. Bij een schaal 1 : 10.000 zal de afstand tussen twee boringen liggen op 30 à 50 m. De boordiepte bedraagt als regel 1,20 m. Indien in een bepaalde richting meer bodemverschillen worden verwacht dan in de andere, wijkt men van het vierkantsnet af. In die richting, waarin de snelste opeenvolging van bodemverschillen wordt aangetroffen, neemt men relatief meer boorpunten (fig, 6). Men loopt dus loodrecht op de te verwachten grenzen.

b. Vrije kartering

Wanneer de bodemgrenzen in het terrein direct of indirect (b.v. via een reactie van het gewas) kunnen worden waargenomen, kan men overgaan tot een vrije kartering (fig. 7). Hierbij loopt men min of meer de grenzen af. Deze soort kartering eist veel ervaring. Een groot voordeel is, dat men veel sneller kan werken. Nadelen zijn de grotere mate van interpretatie uit indirecte kenmerken en het feit, dat de boringen voornamelijk rond de grenzen zijn geconcentreerd.

c. Overgang tussen raaienkartering en vrije kartering

Dit is een tussenvorm, waarbij de boringen vrij regelmatig over het terrein zijn verdeeld, maar waarbij de grenzen volgens de vrije kartering worden nagegaan. Deze methode is minder snel, maar maakt een betere interpretatie van de eenheden mogelijk. Dit is vooral van belang, wanneer exacte gegevens van vlakken nodig zijn, b.v. van dikten van bepaalde lagen, zoals vaak voor cultuurtechnische toepassingen (grondverbetering, ontwatering, e.d.) het geval is.

4. *Afwerking*

De gegevens van de veldkaarten worden op een z.g. netkaart overgebracht. Men gebruikt hiervoor doorzichtig materiaal, een z.g. calque, waarop de topografische basis is voorgedrukt.

Uit de bij de veldkaarten behorende beschrijvingen, de analyseresultaten en de verwerking van het overige onderzoek ontstaat het bij de bodemkaart behorende rapport.

Dit rapport omvat technische gegevens als doel, wijze en tijd van uitvoering, begrenzing en oppervlakte van de kartering. Daarnaast wordt een uitgebreide beschrijving van de legenda gegeven, aangevuld met analyseresultaten van bemonsterde profielen. Bovendien worden de resultaten van alle onderzoekingen, die ten behoeve van de kartering zijn verricht, vermeld. Meestal bevat het rapport ook toelichtingen omtrent toepassingen, die eventueel via afgeleide kaarten worden voorgesteld. In vele gevallen betreft dit de geschiktheid van de bodemeenheden voor land-, tuin- of bosbouw en kaarten voor cultuurtechnische toepassingen, zoals zanddiepte-, veendiepte- en diktekaarten, e.d..

Het rapport wordt door de karteringsleider opgesteld. Het concept wordt door de redactie en de tekenkamer geschikt gemaakt voor verspreiding. Kleine rapporten verschijnen in gestencilde vorm met handgekleurde kaarten. Publikaties voor een bredere lezerskring verschijnen gedrukt als Verslagen van Landbouwkundige Onderzoekingen of Mededelingen van de Stichting voor Bodemkartering.

5. *Kaartschalen*

Op de grootste schaal worden bedrijfskaarten vervaardigd. Deze variëren al naar de doelstelling (intensieve tuinbouw en bosbouw) en de gecompliceerdheid van het bodempatroon tussen schaal 1 : 1000 en 1 : 10.000. Het aantal waarnemingen ligt tussen 10 à 20, soms 30 en meer, tot 4 à 5 per ha.

De detailkaarten hebben een schaal 1 : 10.000 en zijn opgenomen met 2 à 3 tot 6 à 8 waarnemingen per ha.

Overzichtskaarten hebben een schaal 1 : 25.000 en zijn opgenomen met een waarnemingsnet van 1 per ha tot 1 per 2 à 3 ha.

Semi-detailkaarten of gedetailleerde overzichtskaarten staan tussen detail- en overzichtskaart in. De schaal is afhankelijk van de mate van detaillering en ligt tussen 1 : 10.000 en 1 : 25.000. Een aantal van deze kaarten is op schaal 1 : 16.667 gepubliceerd.

Verkenningskaarten zijn op verschillende schalen van 1 : 50.000 tot 1 : 100.000 vervaardigd, meestal ten behoeve van de regionale planologie.

Er zijn nog 2 kaarten van kleine schaal vervaardigd.

a. De voorlopige bodemkaart van Nederland, schaal 1 : 400.000 (1950). Hiervoor is weinig veldwerk verricht. De kaart is sterk geogenetisch.

b. De bodemkaart van Nederland, schaal 1 : 200.000 (1960). Deze kaart is geogenetisch van opzet, doch vrij goed morfometrisch gedefinieerd. Er is vrij veel veldwerk voor verricht.

Het ligt in de bedoeling in de komende jaren een systematische kartering van Nederland uit te voeren, uit te geven op kaartbladen schaal 1 : 50.000. Deze kaart heeft een uniforme legenda, gebaseerd op de morfometrische eenheden van het taxonomische Nederlandse systeem van bodemclassificatie.

ZUSAMMENFASSUNG.

Eine Bodenkarte gibt einen Eindruck von der horizontalen Ausdehnung und Begrenzung bodenkündlicher Einheiten. Das Studium des Profils ergibt nur Daten über den vertikalen Aufbau des Bodenprofils. Durch Kartierung wird die horizontale Ausdehnung einer Einheit festgestellt und festgelegt.

Die Bodenkartierung hat 4 wichtige Phasen:

1. Vorbereitung.
2. Orientierung und Untersuchung
3. Feldaufnahme.
4. Ausarbeitung.

1. *Vorbereitung*

Diese besorgen die Provinzialabteilungen, in deren Gebiet das zu kartierende Gelände liegt. Die Arbeit steht unter Leitung eines an der Landwirtschaftlichen Hochschule in Wageningen ausgebildeten Kartierungsleiters, der sich auf Bodenkunde spezialisiert hat. Bodenkündlich geschulte Assistenten mit elementarer oder mittlerer Landwirtschaftsausbildung stehen ihm bei. Diese Assistenten führen einen bedeutenden Teil der Feldaufnahme durch.

Das Ergebnis der Feldaufnahme wird auf einer Basiskarte angegeben, deren Maszstab doppelt so grosz ist wie der der endgültigen Karte. Als Basiskarten benützt man im allgemeinen Katasterkarten 1 : 5000 oder 1 : 10.000 oder topographische Karten 1 : 10.000 oder auch Luftbilder. Das Studium von alten topographischen Karten und Luftbilder kann über die vermutliche Bodenbeschaffenheit schon vieles lehren.

2. *Orientierung und Untersuchung*

Die erste Orientierung erfolgt im Gelände, indem man an charakteristischen Stellen bohrt oder Profilgruben gräbt. So erhählt man eine allgemeine Übersicht von den bedeutendsten Bodenunterschiede. Dann folgt die Voruntersuchung, meistens in Form einer detaillierten Probekartierung, die in jeder der bei der Orientierung erkannten Landschaftseinheiten durchgeführt wird.

Die Kenntnis der morphometrisch definierten Bodeneinheiten ist die Grundlage für die Zusammenstellung der Kartenlegende. Sie hängt von der verlangten Detailliertheit und somit vom Zweck der Karte ab. Auch der Maszstab der Karte bestimmt sich danach (siehe 5).

3. *Feldaufnahme*

Diese führen die Assistenten durch. Sie arbeiten gewöhnlich allein. Man kann zwei Verfahren unterscheiden:

a. die gradlinige Kartierung,
b. die freie Kartierung.

a. Gradlinige Kartierung

Wenn man an der Oberfläche sehr wenig auf Bodenunterschiede Hindeutendes wahrnimmt, z.B. kein Relief und keine Wachstumsunterschiede in der natürlichen Vegetation oder in Bestände von Kulturpflanzen, musz man nach einem Netz aus rechteckigen Maschen kartieren (Abb. 6). Die Entfernung zwischen zwei Bohrlöcher in einer Linie ist jeweils die gleiche. Bei einem Maszstab 1 : 10.000 beträgt der Abstand zwischen zwei Bohrungen 30 bis 50 m. Die Bohrtiefe ist in der Regel 1,20 m. Erwartet man in einer Richtung mehr Bodenverschiedenheiten als in der andern, so wählt man die Maschen nicht viereckig, sondern bringt mehr Bohrlöcher an in der Richtung, in der sich der Boden schneller ändert (Abb. 6). Man bewegt sich also senkrecht zu den zu erwartenden Grenzen vorwärts.

b. Freie Kartierung

Wenn man die Bodengrenzen im Gelände direkt oder indirekt (z.B. am Verhalten des Bestandes) wahrnehmen kann, ist eine freie Kartierung möglich (Abb. 7). Dabei folgt man mehr oder weniger den Grenzen. Diese Kartierungsart erfordert viel Erfahrung. Ein groszer Vorteil ist, dasz man viel rascher Arbeiten kann. Nachteile sind, dasz man mehr aus indirekten Merkmalen interpretieren musz und dasz die Bohrungen hauptsächlich um die Grenzen konzentriert sind.

c. Übergang zwischen gradliniger und freier Kartierung

Bei dieser Zwischenform sind die Bohrungen ziemlich regelmäszig über das Gelände verteilt, an den Grenzen aber häufiger. Dieses Verfahren ist weniger schnell, ermöglicht aber eine genauere Kenntnis von den Einheiten. Das ist besonders wichtig, wenn exakte Angaben über Flächen nötig sind, z.B. über die Mächtigkeit bestimmter Schichten, wie es oft für kulturtechnische Anwendungen (Bodenverbesserung, Entwässerung u.dgl.) der Fall ist.

4. *Ausarbeitung*

Die Angaben der Feldkarten werden auf eine sog. Netzkarte übertragen. Man benutzt dazu eine (transparante) Tochterpause, auf dem die topographische Grundlage vorgedruckt ist.

Aus den zu den Feldkarten gehörenden Beschreibungen, den Analysenergebnisse und der Auswertung der übrigen Untersuchungen entsteht der zu der Bodenkarte gehörige Bericht.

Dieser Bericht enthält technische Angaben wie Zweck, Art und Zeit der Durchführung, Begrenzung und Flächeninhalt der Kartierung. Daneben wird die Legende ausführlich beschrieben unter Erwähnung der Ergebnisse der Analysen von Profilproben. Auszerdem werden die Ergebnisse aller Untersuchungen erwähnt, die im Rahmen der Kartierung angestellt worden sind. Meistens enthält der Bericht auch Erläuterungen über Anwendungsmöglichkeiten, die gegebenenfalls auf abgeleiteten Karten dargestellt werden. In vielen Fälle handelt es sich dabei um die Eignung der Bodeneinheiten für Landwirtschaft, Gartenbau oder Forstwirtschaft und um Karten für kulturtechnische Anwendungen, wie Sandtiefen-, Moortiefen- und -dickenkarten u.dgl.

Der Kartierungsleiter stellt den Bericht auf. Die Redaktion und die Zeichenabteilung machen das Konzept zur Verbreitung geeignet. Kleine Berichte erscheinen als Schablonendruck mit handgefärbten Karten. Veröffentlichungen für einen gröszeren Leserkreis erscheinen auf dem Wege des Hochdrucks in der vom Landwirtschaftsministerium verlegten Reihe: „Verslagen van Landbouwkundige Onderzoekingen" oder als „Mededelingen van de Stichting voor Bodemkartering".

5. *Kartenmaszstäbe*

Den grószten Maszstab haben Betriebskarten. Sie schwanken je nach dem Zweck (für intensiven Gartenbau einerseits und für Forstwirtschaft anderseits) und der Kompliziertheit der Bodenlage von 1 : 1000 bis 1 : 10.000. Die Zahl der Beobachtungen je Hektar beträgt 10 bis 20, überschreitet mitunter die 30, beträgt aber mindestens 4 oder 5.

Detailkarten haben den Maszstab 1 : 10.000 und die Zahl der dafür angestellten Beobachtungen beträgt 2 à 3 bis 6 à 8 je Hektar.

Übersichtskarten haben den Maszstab 1 : 25.000; die Zahl der Beobachtungen schwankt von 1 je Hektar bis 1 je 2 à 3 Hektar.

Semidetailkarten oder detaillierte Übersichtskarten stehen zwischen den Detailkarten und den Übersichtskarten. Der Maszstab hängt von der Detailliertheit ab und beträgt höchstens 1 : 10.000 und mindestens 1 : 25.000. Eine Anzahl dieser Karten sind im Maszstab 1 : 16.667 veröffentlicht worden.

Orientierungskarten hat man in verschiedenen Maszstäbe von 1 : 50.000 bis 1 : 100.000 hergestellt, meistens für die regionale Raumplanung.

Zwei Karten haben einen noch kleineren Maszstab:

a. die vorläufige Bodenkarte der Niederlande im Maszstab 1 : 400.000 (1950); für diese hat man wenig Feldarbeit verrichtet; die Karte ist stark geogenetisch,
b. die Bodenkarte der Niederlande im Maszstab 1 : 200.000, die 1960 erscheinen wird, ihre Grundlage ist geogenetisch, sie ist aber ziemlich gut morphometrisch „definiert". Für diese Karte ist verhältnismäszig viel Feldarbeit verrichtet werden.

In den nächsten Jahre will man die Niederlande systematisch kartieren. Die Kartenblätter sollen im Maszstab 1 : 50.000 erscheinen; sie erhalten alle dieselbe Legende, die sich auf die morphometrischen Einheiten des taxonomischen niederländischen Systems der Bodenklassifikation gründet.

RÉSUMÉ.

La carte pédologique fournit une représentation de l'étendue et limitation horizontales des unités pédologiques. L'étude des profils ne nous renseigne que sur la structure du profil du sol en sens vertical. La mise en carte détermine l'étendue horizontale de l'unité.

La cartographie pédologique connaît 4 phases importantes:

1. Préliminaires.
2. Exploration et étude.
3. Lever sur le terrain.
4. Mise en oeuvre.

1. Préliminaires

Les travaux préliminaires sont effectués par les sections provinciales dans le domaine desquelles est situé le terrain à mettre en carte. Les travaux sont dirigés par un chef de travail formé à l'Université d'Agriculture (Wageningen) et spécialisé en pédologie. Il est aidé par quelques assistants ayant reçu une formation pédologique après l'enseignement agronomique élémentaire ou moyen. Une part importante des travaux sur le terrain est confiée à ces assistants.

Les données recueillies sont enregistrées sur une carte de base à échelle double de celle de la carte définitive. Il s'agit en général de cartes cadastrales au 5000e ou au 10.000e ou de cartes topographiques au 10.000e. On utilise également comme base des photographies aériennes. L'étude d'anciennes cartes topographiques et photographies aériennes peut déjà fournir bien des renseignements sur la nature probable du sol.

2. Exploration et étude

Celles-ci se font sur place en sondant des trous ou en creusant des puits en des endroits caractéristiques. On obtient ainsi une vue d'ensemble des principales variations du sol. Ensuite, on procède à l'étude préliminaire, le plus souvent sous la forme d'une *mise en carte détaillée d'essai.* Cela se fait dans chacune des unités de terrain distinguées lors de l'exploration.

La connaissance des unités pédologiques morphométriquement définies constitue la base de l'élaboration de la légende de la carte. Celle-ci dépend du caractère plus ou moins détaillé de la carte demandée, et par là du but

auquel elle doit servir. C'est également de cette destination que dépend l'échelle de la carte (voir paragraphe 5).

3. Lever sur le terrain

Le lever est exécuté par les assistants, qui travaillent ordinairement seuls. La mise en carte peut se faire selon deux méthodes différentes:

a. lever en lignes,
b. lever libre.

a. Lever en lignes

Lorsque peu de variations du sol paraissent à la surface et que, par exemple, l'on ne voit pas de variations du relief ou de la croissance de la végétation naturelle ou cultivée, on procède au lever selon un réseau de lignes (fig. 6), les sondages sont effectués à intervalles réguliers. Pour une carte au 10.000e, les sondages seront espacés de 30 à 50 m. La profondeur du sondage est généralement de 1 m 20. Si l'on s'attend à trouver plus de variations du sol dans un sens que dans l'autre, on s'écartera du réseau à carrés. Les sondages seront plus serrés dans le sens où les variations se succèdent le plus rapidement (fig. 6). On se dirige donc en angle droit vers les limites présumées.

b. Lever libre

Lorsque les limites pédologiques sont directement ou indirectement visibles (par une réaction de la végétation, par exemple), on peut procéder au lever libre (fig. 7). Dans cette méthode, on suit plus ou moins les limites. Un lever de ce genre demande beaucoup d'expérience. Cette méthode offre le grand avantage d'être beaucoup plus rapide. Elle a l'inconvénient de comporter plus d'interprétations de données indirectes et de concentrer principalement les sondages aux environs des limites présumées.

c. Forme mixte du lever libre et du lever en lignes

On applique une méthode intermédiaire, selon laquelle les sondages sont répartis assez uniformément sur le terrain, les limites étant cependant étudiées selon la méthode du lever libre. Cette méthode est moins rapide, mais permet une meilleure interprétation des unités. Cet avantage est surtout important quand il faut des données exactes sur des surfaces, comme sur l'épaisseur de certaines couches, ce qui est souvent le cas pour les projets de génie rural (mise en valeur des sols, drainages, etc.).

4. Mise en oeuvre

Les données fournies par les cartes dressées sur le terrain sont transférées sur une carte „au net". On utilise à cet effect un papier transparent (calque) sur lequel la base topographique est imprimée d'avance.

Le rapport annexé à la carte pédologique est dressé à partir des descriptions accompagnant les levers, des résultats d'analyse et des autres données fournies par l'étude.

Ce rapport comporte des données techniques telles que le but, le mode et le temps d'exécution, les limites et la superficie de la mise en carte. A cela s'ajoute une description détaillée de la légende, complétée des résultats d'analyses de profils échantillonnés. Le rapport comprend encore les résultats de toutes les études faites pour la mise en carte. Le plus souvent, il donne des exposés sur les utilisations possibles, éventuellement illustrés de cartes secondaires. Dans bien des cas, il s'agit ici des qualités rendant les différentes unités appropriées à l'agriculture, à l'horticulture ou à la sylviculture et de cartes servant aux travaux de génie rural et indiquant par exemple la profondeur des sables ou de la tourbe, les épaisseurs, etc.

Le rapport est établi par le chef de travail. La rédaction et les dessinateurs le mettent au point pour la publication. Les petits rapports sont polycopiés, avec des cartes coloriées à la main. Les publications destinées à un plus grand public paraissent imprimées comme V.L.O.[1]) ou comme Bulletin de l'Institut de la Cartographie des Sols.

5. *Echelles*

La plus grande échelle est celle des *cartes d'exploitation.* Selon le but (horticulture intensive ou sylviculture) et le plus ou moins de variation du sol, ces cartes sont dressées à des échelles variant du 1000e au 10.000e. Le nombre d'observations varie entre 10–20 (parfois même 30 ou plus) et 4–5 par hectare.

Les *cartes de détail* sont dressées au 10.000e au moyen de 2–3 à 6–8 observations par hectare. *Les cartes d'ensemble* sont au 25.000e. On suit ici un réseau d'observations de 1 par ha à 1 pour 2–3 ha.

Les *cartes semi-détaillées* ou *cartes d'ensemble détaillées* sont l'intermédiaire des *cartes de détail* et des *cartes d'ensemble.* Leur échelle dépend du caractère plus ou moins détaillé et varie du 10.000e au 25.000e. Un certain nombre de ces cartes a été publié au 16.667e.

Les *cartes exploration* sont dressées à différentes échelles du 50.000e au 100.000e, le plus souvent à des fins de planologie régionale.

Deux cartes ont encore été dressées à une échelle plus réduite:

a. La carte pédologique provisoire des Pays-Bas, au 400.000e (1950). Pour cette carte, peu de travaux ont été effectués sur place. La carte est nettement géogénétique.

b. La carte pédologique des Pays-Bas au 200.000e (1960). Cette carte est géogénétique dans l'ensemble, mais d'assez bonne définition morphométrique et dressée à l'aide d'un assez grand nombre d'études sur le terrain.

Le projet existe de procéder dans les années à venir à une mise en carte systématique des Pays-Bas, à publier sur des planchettes au 50.000e. Cette carte a une légende uniforme, basée sur les unités morphométriques du système taxonomique néerlandais de classification des sols.

[1]) Verslagen van Landbouwkundige Onderzoekingen.

SOIL SURVEY IN NETHERLANDS NEW GUINEA

by

Ir. J. J. Reynders [1])

Already before World War II soil surveys of a number of areas in Netherlands New Guinea were carried out by the Soil Survey Institute at Buitenzorg (Java). In the first place the soil survey expeditions of F. A. Wentholt (1932–1940) are to be mentioned. When considering that present-day soil surveys in New Guinea with better communications and contacts still bear the character of expeditions, Wentholt's achievements command the greatest respect. A summary of pre-war surveys is given by Van Beusechem (1948). Afterwards Van Baren (1954) and Van Loenen (1954) gave descriptions and data of New Guinea soils.

As the economic potentialities of New Guinea were principally to be looked for in the field of agriculture, Ir. F. C. van Loenen was commissioned by the Government of Netherlands New Guinea, after the transfer of the sovereignty of Indonesia, to establish a Bureau of Soils in Hollandia.

In order to begin the survey of various areas as soon as possible, two experienced soil surveyors[2]) of the former Netherlands East-Indian Soil Survey were appointed (1951–1952). In 1952 a mineralogist[3]) was appointed and a soil scientist (Ir. J. J. Reynders) for the establishment of a laboratory for soil chemical and physical research. In 1953 a young assistant soil surveyor joined the service[4]) in order to safeguard a certain rejuvenation of the field staff.

Till 1956 the activities of the Bureau of Soils were carried out by 3 sections viz.

1. Soil Survey and Mapping
2. Mineralogical Research
3. Soil Physical-Chemical Research

In the period 1951–1955 various surveys were carried out by Van Soelen, Razoux Schultz and Andriesse, occasionally also by Reynders and Mouthaan. In 1954 the Bureau of Soils was transformed into the Agriculture Experimental Station which was in 1954 divided into two departments for soil and agricultural research respectively. In 1956 Ir. H. Schroo was appointed Head of the soil department which was subdivided into:

1. Soil Survey and Mapping – Head: Ir. Reynders
2. Soil Fertility Research – } Head: Ir. Schroo
3. Laboratory – }

In 1957 the Director Ir. Van Loenen retired and was succeeded by Mr. J. G. Rozenboom. In that year the staff consisted of two assistant soil surveyors[5]) and in 1958 a soil scientist (Ir. G. Hekstra) was appointed while the oldest soil surveyor was excused from field duties in consideration of age.

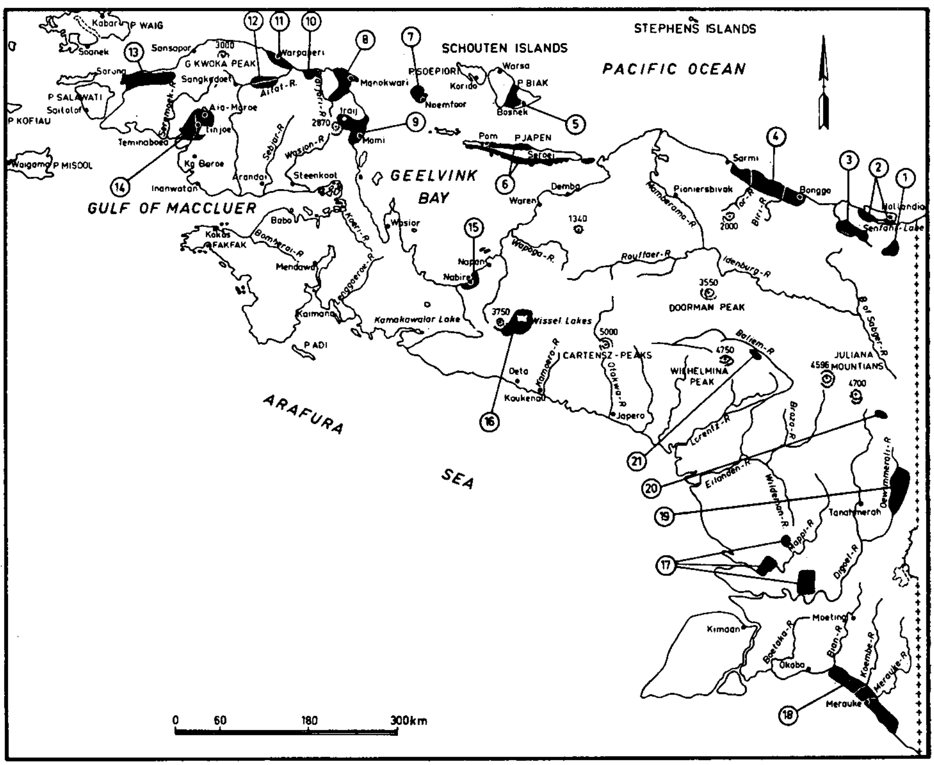
[1]) Formerly Soil Scientist Bureau of Soils, Hollandia, Netherlands New Guinea. At present: Mineralogical and Geological Institute of the University of Utrecht.
[2]) W. J. van Soelen and F. H. N. Razoux Schultz.
[3]) W. P. J. L. Mouthaan.
[4]) P. J. Andriesse.
[5]) B. Schlette and R. H. de Bock.

Three periods of soil survey activities in Netherlands New Guinea can be distinguished viz.:

a. before 1950
b. from 1950 to 1956
c. 1956 to 1958 inclusive.

Before 1950 soil surveys were generally restricted to small scale reconnaissance surveys. The years following (b) were dedicated to organisation and constitution of the soil survey. As reliable maps were not available in most cases in addition to soil mapping also topographical mapping was necessary. In 1955 Mr. Razoux Schultz and Mr. Reynders, during leave, attended a course in pedological aerial photographic interpretation at the International Training Centre for Aerial Survey at Delft (Netherlands). By application of aerial photographic interpretation the soil survey could be founded on modern lines (1956–1958).

In table 1 and fig. 1 a summary is given of the surveyed areas in Netherlands New Guinea. As for the map scales three categories are distinguished viz.:



▬ mapped areas / *gekarteerde gebieden*

Fig. 1.
General map of Netherlands New Guinea scale 1 : 600,000 indicating areas of which soil surveys have been carried out. Numbers refer to table 1 (page 82 and 83).
Overzichtskaart van Nederlands Nieuw Guinea schaal 1 : 600.000 aangevende de gebieden waarin bodemkundige karteringen zijn uitgevoerd (zie tabel 1, pag. 82 en 83).

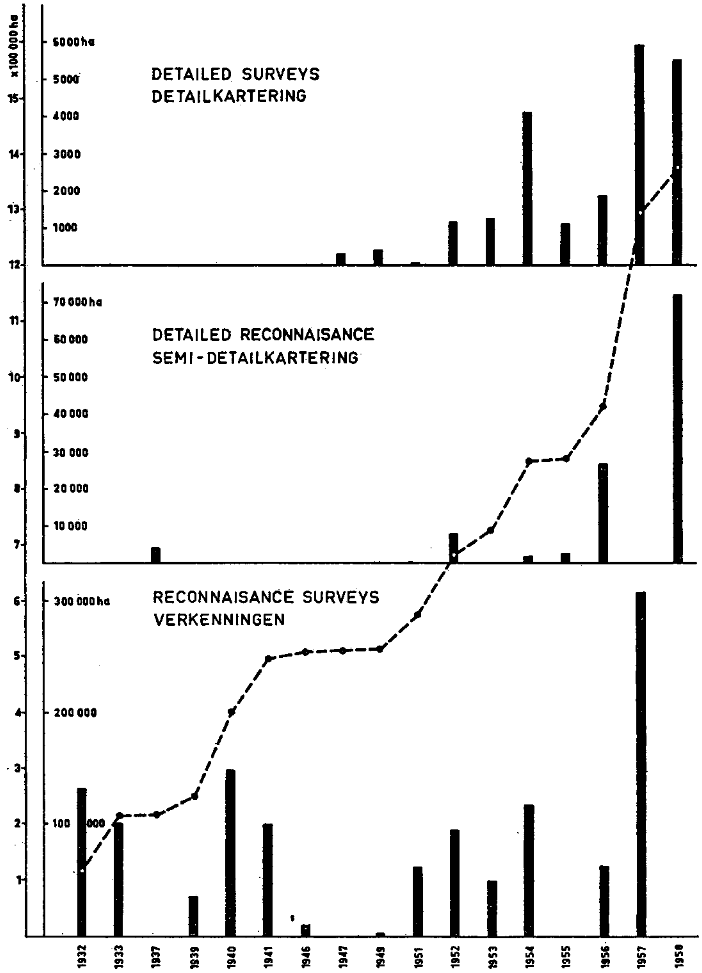


Fig. 2.
Graph representing surveyed areas in Netherlands New Guinea. The broken line (accumulation curve) indicates the increase of the total surveyed area.
Grafische voorstelling van de gekarteerde oppervlakte in Nederlands Nieuw Guinea. De sommatiecurve geeft de stijging van de totale gekarteerde oppervlakte.

a. Reconnaissance maps on scales 1 : 63.360, 1 : 100.000 and 1 : 200.000
b. Detailed reconnaissance maps on scales 1 : 25.000 and 1 : 50.000
c. Detailed maps on scale 1 : 20.000 and larger.

From various areas so-called visual reconnaissance was made in some cases followed by a closer survey.

In fig. 2 a graphical summary is given. In this figure the three categories are separately represented while also an accumulation curve of the surface area of the surveyed regions is given. Conspicuous in the continuously ascending line from 1951 to 1958 is the sudden change of direction in 1954/55 as at the time most of the soil surveyors were on leave. The strong ascent of the line after 1955 is a consequence of the use of aerial photographs. This is strongly confirmed by each of the graphs separately. In 1957 the surface area of the reconnaissance surveys increased to more than threefold the preceding yearly average.

Not only the surface area of the detailed reconnaissance surveys has increased but also areas which before 1955 could only be mapped on a 1 : 100.000 scale are being mapped on a 1 : 50.000 scale after 1955.

Data obtained by aerial photographic interpretation proved to be very valuable also for detailed surveys.

It must be observed that it is quite natural that by an increasing knowledge of the soil and of the agricultural potentialities of the various areas of a country the surface area surveyed and mapped on a large scale increases greatly. In Netherlands New Guinea of a total surface area of 1.375.480 ha, soil surveys were carried out of which 1.200.000 ha for the first time. The first figure corresponds with ca. 3.5% of the total surface area of Netherlands New Guinea, or by a very rough estimation after a deduction for rugged mountainous and swamp areas, with ca. 10% of the area having agricultural potentialities.

A summary of the area surveyed in the three above mentioned periods is given here.

Period	Detailed surveys ha	Detailed reconnaissance surveys ha	Reconnaissance surveys ha	Total ha
1932/50	700	4.000	510.100	514.800
1950/55	7.605	12.200	323.900	343.705
1955/58	13.270	98.675	405.030	516.975
Total	21.575	114.875	1.239.030	1.375.480

(Submitted December 1958.)

SAMENVATTING

Een overzicht is gegeven over de organisatie en stand van de bodemkartering in Nederlands Nieuw-Guinea tot en met 1958.

ZUSAMMENFASSUNG

Die Abhandlung gibt einen Überblick von der Organisation und dem Stande der Bodenkartierung in Niederländisch Neu-Guinea.

LITERATURE

Beusechem, D. van, 1948: Korte bijdrage tot de kennis van de bodemgesteldheid en de landbouwkundige waarde van een veertiental geëxploreerde gebieden in Nederlands Nieuw Guinea. Landbouw *20,* 210–229.

Baren, F. A. van, 1954: In: Nieuw-Guinea, de ontwikkeling op economisch, sociaal en cultureel gebied. Dl 2.

Loenen, F. C. van, 1954: Idem.

TABLE 1. SURVEYS/*Karteringen*

Year *Jaar*	Surveyed areas *Gekarteerde gebieden*	No. on map *Nr. op kaartje*	Detailed *Detail* (ha)	Detailed reconnaissance *Semi-detail* (ha)	Reconnaissance *Verkenning* (ha)	Visual reconnaissance *Visuele verkenning* (ha)	Map scales *Kaartschalen*	Soil surveyor *Karterings-leider*
1932	Hollandia-Sentani-Depapré	2			20.000		1:100.000	Wentholt, F. A.
	Momi-Ransiki-Angimeren	9			55.000		1:100.000	Wentholt, F. A.
	Omgeving Manokwari	8			40.000		1:100.000	Wentholt, F. A.
1933	Amberbaken	11			25.000		1:100.000	Wentholt, F. A.
	War Samson	13			75.000		1:100.000	Wentholt, F. A.
1937	Ransiki	9		4.000			1: 25.000	Wentholt, F. A.
1939	Grimé-Sekoli	3			35.000		1:100.000	Wentholt, F. A.
1940	Legari	15			8.000		1:100.000	Wentholt, F. A.
	Merauke (west)	18			140.000		1:200.000	Wentholt, F. A.
1941	Merauke (oost)	18			100.000		1:200.000	Druif, J. H.
1946	Soegroen-Arso	1			10.000		1: 63.360	Soelen, W. J. van
1947	Manggoapi-Wosi	8	300				1: 10.000	Soelen, W. J. van
1949	Amban	8	400				1: 20.000	Es, F. W. J. van
	Achterland Sorong	13			2.100		1:100.000	Es, F. W. J. van
1950	Dojo	2				V.V.		Loenen, F. C. van
	Omgeving Enarotali	16				V.V.		Loenen, F. C. van
1951	Z.O. hoek Humboldtbaai	2				V.V.		Loenen, F. C. van
	Omgeving Manokwari	8				V.V.		Loenen, F. C. van
	Genjem	3	25					Soelen, W. J. van
	Tor-Biër	4			60.000		1:200.000	Soelen, W. J. van
	Oransbari	9			2.400		1: 63.360	Soelen, W. J. van
1952	Omgeving Merauke	18				V.V.		Loenen, F. C. van
	Sago-moeras Kota Radja	2				V.V.		Loenen, F. C. van
	Sentani-Hollandia Strip	2	415				1: 20.000	Soelen, W. J. van
	Kota Radja	2	300				1: 20.000	Soelen, W. J. van
	Kota Nica	2	450				1: 20.000	Razoux Schultz, F. H. N.
	Biër-Wiroe	4			95.000		1:250.000	Soelen, W. J. van
	Omgeving Merauke	18		8.000			1: 25.000	Razoux Schultz, F. H. N.
1953	Dojo Lama	2	1.215				1: 20.000	Soelen, W. J. van
	Grimé-Sekoli	3			17.500		1:100.000	Soelen, W. J. van
	Koembe	18				V.V.		Reynders, J. J.
	Biak-Korim	5				V.V.		Mouthaan, W.P.J.L.
	Tagemeer	16				V.V.		Mouthaan, W.P.J.L.

	Toran-Koembe-Maro	18			32.000		1:100.000	Soelen, W. J. van
1954	Ransiki	9	3.500				1: 20.000	Reynders, J. J.
	Noemfoor	7			30.000		1: 63.360	Razoux Schultz, F. H. N.
	Moejoe	19			60.000		1:250.000	Razoux Schultz, F. H. N.
	Bian-Toran	18			27.000		1:100.000	Razoux Schult, F. H. N.
	Koerik	18	600				1: 20.000	Reynders, J. J.
1955	Randawaja	6		2.000			1: 50.000	Razoux Schultz, F. H. N.
	Noordkust Japen	6	850				1: 20.000	Soelen, W. J. van
	Rheinauwen	2	150				1: 10.000	Reynders, J. J.
	Sidai	10		2.200			1: 50.000	Soelen, W. J. van
	Sentani	2	100				1: 5.000	Andriesse, P. J.
1956	Kota Nica	2	70				1: 2.000	Andriesse, P. J.
	Soemberbaba	6		200			1: 50.000	Reynders, J. J.
	Seroei-Korenbobi	6		175			1: 50.000	Reynders, J. J.
	Mokmer	5			230		1:100.000	Reynders, J. J.
	Kepi	17	150				1: 10.000	Soelen, W. J. van
	Mappi	17			58.000		1:100.000	Soelen, W. J. van
	Maro-Koembe	18		26.300			1: 50.000	Reynders, J. J.
	Rijstbedrijf Koembe	18	400				1: 5.000	Reynders, J. J.
	Mappi	17				V.V.		Loenen, F. C. van
	Mopa-vlakte	18	1.250				1: 10.000	Soelen, W. J. van
	Zd.kust Japen-Koeroedoe	6			4.800		1:100.000	Razoux Schultz, F. H. N.
1957	Orai-Woské-Tor	4	3.250				1: 20.000	Soelen, W. J. van
	Ajamaroe	14			220.000		1:100.000	Reynders, J. J.
	Wisselmeren, Kamoe	16			120.000		1:100.000	Reynders, J. J.
	Amban-Andai	8	1.900				1: 20.000	Soelen, W. J. van
	Manokwari	8			2.000	V.V.		Reynders, J. J.
	Mopa-vlakte	18	750				1: 10.000	Soelen, W. J. van
1958	Kebar	12		37.000			1: 50.000	Reynders, J. J.
	Grimevlakte	3		5.000			1: 50.000	Razoux Schultz, F. H. N.
	Sibil	20				V.V.		Reynders, J. J.
	Hollandia	2	4.000				1: 20.000	Razoux Schultz, F. H. N.
	Grimevlakte	3		5.000			1: 50.000	Razoux Schultz, F. H. N.
	Baliem	21				V.V.		Schroo, H.
	Paal Poetih	18	1.500				1: 10.000	Schlette, B.
	Betaf-Armopa	4		25.000			1: 50.000	Reynders, J. J.

SOME PEDOLOGICAL DATA CONCERNING SOILS IN THE BALIEM VALLEY, NETHERLANDS NEW GUINEA

by

Ir. H. Schroo[1])

1. *Introductory*

The upper river basin of the Baliem river is situated in the central mountains of Netherlands New Guinea. The West Baliem river rises at an altitude of approximately 4000 metres in the eastern part of the Nassau mountains near the Carstensz peaks and flows in an easterly direction. There, the river is fed by a tributary flowing from east to west, called the East Baliem river, which rises near the snow-capped Wilhelmina peak. The accompanying survey map (fig. 1) shows how the river finally bends round in a south-easterly direction. It is in this section of the Baliem that a wide valley has been formed, the "*Great Baliem Valley*", which will be discussed below. In the southeast the river leaves the mountains via numerous rapids, finally joining the Vriendschap river in the lower plains to form the wide Eilanden river which falls into the Alfoera sea.

Very little is known about the district discussed below. The first infor-

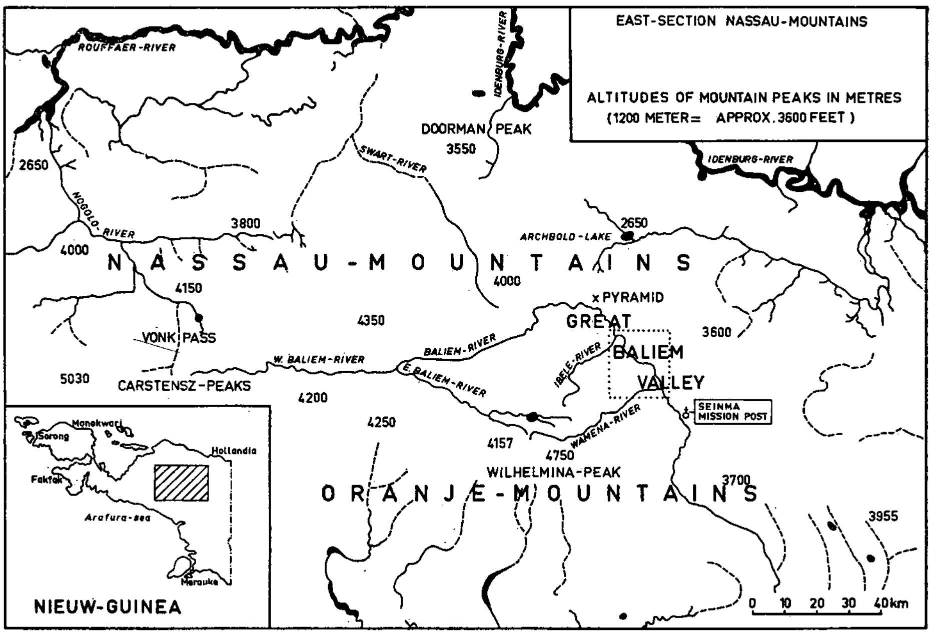


Fig. 1.
Locality map of the Baliem Valley.
Situatiekaart van de Baliemvallei.

[1]) Director of the Bureau of Soils, Department of Agriculture and Fisheries, HOLLANDIA (Netherlands New Guinea).

mation is provided by the results of the Archbold expedition (1938/39) which made a cross-trip to this area. It is only in recent years that more has become known about the Baliem valley and its people as a result of the pioneer work carried out by Australian and American Missionary Societies. Missionary posts, equipped with airplanes and air-strips, were established at some ten locations in this wild, unadministered district for mutual communication between the posts is possible only by means of small air craft.

In 1956 the first Dutch Administration Post (fig. 2) was established at the confluence of the Baliem and Wamena rivers. This post can be reached from the capital Hollandia by air.

Owing to the fact that good airphotos of the district are still lacking and the area cannot be entered properly, owing to the state of war existing between the wild native tribes, very little is known at present about the geology and pedology of the Great Baliem Valley. Consequently, the following soil reconnaissance survey in the neighbourhood of the Wamena Administrative Post and the Tulem Missionary Post is to be regarded as an initial contribution towards a better pedological knowledge of this undeveloped section of highland.

2. *General observations on the Great Baliem Valley*

The great Baliem valley is about 45 kilometres in length, measured from Pyramidemountain in the north-west to the Seinma Missionary post in the south-east (fig. 3). The valley is hemmed in between steeply rising limestone formations which constitute the major part of the Central Mountains (fig. 4). As a result the valley varies in width by an average of about 15 kilometres.

Seen from the air this part of the valley appears as an extensive marshy plain in which the Baliem river meanders with innumerable bends. The two important western tributaries are the Ibélé and the Wamena.

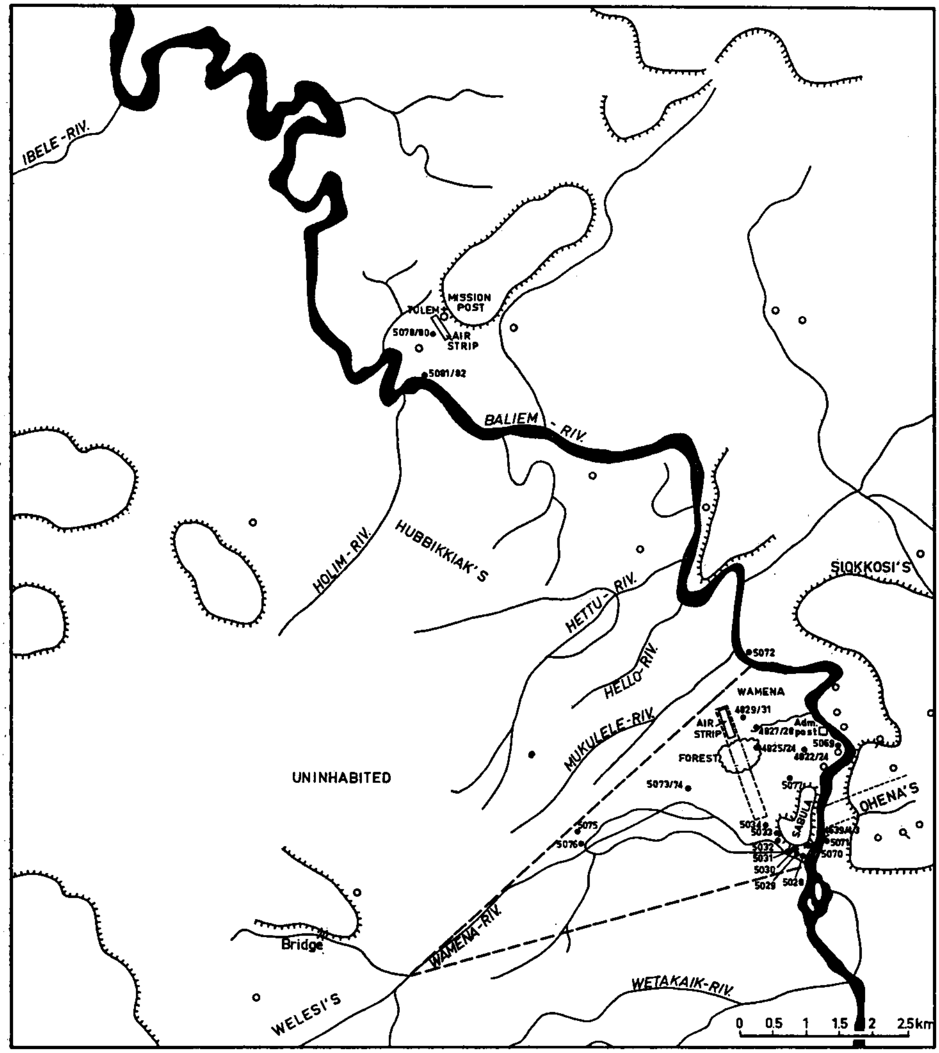
It is obvious that the Baliem river has altered its course several times in the past, so that partially or entirely silted-up river bends (oxbows) and pools can be observed (fig. 5). River bed soils, levee soils, basin and swamp soils, etc. will therefore alternate in this area and hence the texture of the various deposits will change accordingly. On both sides of the valley elongated salients of the adjoining limestone formations can be seen which, with occasional interruptions, continue up to the river (fig. 6).

It seems very likely that at certain sites these limestone ridges used to form single continuous barriers across the plain, causing parts of the valley to be transformed into temporary swamps or lakes. The dammed-up water then rose until a spill-way was found in this barrier where it could overflow and carve a new outlet through the limestone ridge (present rapids, fig. 7).

However it will not be possible to obtain confirmation of this theory until complete airphoto runs have been studied.

Nevertheless, it is certain that the plain is built up of material brought down by the Baliem from the hinterland and by material brought down by the numerous smaller tributaries from the mountains on either side of the plain.

So far as is known, the surrounding mountains chiefly consist of limestone rock with quartz sandstone layers. The limestone weathers readily, the dissolving lime being drained away in surface and underground watercourses. Recent silt from the Baliem and also from the Wamena contains several



native settlements / inheemse nederzettingen

sites of sampling / plaats van bemonstering

hill contours / heuvels

section of alluvial fan / segment van puinkegel

Fig. 3.
Detailed map of a part of the Baliem Valley.
Detailkaart van een gedeelte van de Baliemvallei.

percentages of calcium carbonate (see sample analyses 5082, 5072 and 5070 and 5076). What remains as the final product of this limestone weathering is the original mineral contamination of the limestone which seems to consist chiefly of quartz. Here and there, at the base of eroded limestone hills, blinding white deposits of pure quartz sand can be spotted from the air.

The quartz sandstones also weather readily as the calcareous cement

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 2.
View on the Wamena Administration Post. In the back-ground Casuarina vegetation on the levee of the Baliem river and more in the back limestone hills of the opposite river bank.
Overzicht van de Bestuurspost Wamena; op de achtergrond de Casuarinabegroeiing op de Baliem-oeverwal en daarachter weer de kalksteenheuvels aan de overkant van de rivier.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 4.
View on the plain near Tulem between the Baliem river and the eastern mountains. In the back-ground a salient of the limestone mountains (to the right) crossing the plain as far as the Baliem river.
Uitzicht op de vlakte bij Tulem tussen Baliem en oostelijk bergland. Op de achtergrond een lange uitloper van het kalkgebergte (rechts) hetwelk dwars door de vlakte tot aan de Baliem reikt.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 5.

View on the Poegima plain and eastern mountains. The plain is composed of fluviatile deposits in which ancient river courses are still recognizable from the air.
Uitzicht op de Poegima-vlakte tussen Baliem en oostelijk bergland. De vlakte bestaat uit fluviatiele afzettingen, waarin de oude rivierlopen vanuit de lucht nog te herkennen zijn.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 6.

The Baliem river a little south of the Administration Post. At the left (east bank) limestone hills. At the foot of these hills sampling place nr. 5071.
De Baliemrivier even ten zuiden van de Bestuurspost. Links kalksteenheuvels op oostelijke oever, aan de voet waarvan de monsterplaats nr. 5071 gelegen is.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 7.

The fast flowing Wamena river has cut a new bed in her own cobblestone deposits simultaneously forming bank terraces. To the left: middle terrace with cobblestone profile. More to the left follows the high terrace.

De snelstromende Wamena heeft zich een nieuwe bedding in haar eigen rolsteenpakketten ingesneden, zulks onder vorming van oeverterrassen. Links: midden terras met rolsteenprofiel. Op dit terras volgt meer naar links het hoogterras.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

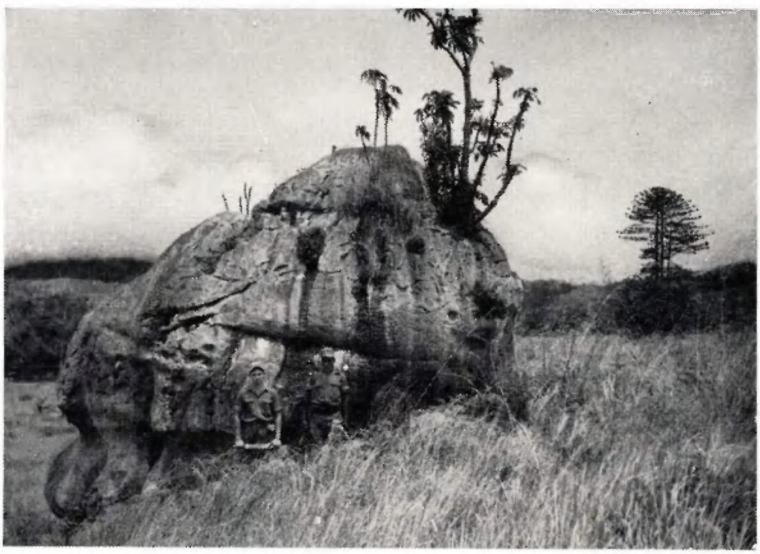
Fig. 8.

Near the Administration Post the slowly flowing Baliem river is navigable for motorboats. At the left levee with Casuarina montana vegetation.

De langzaam stromende Baliem, nabij de Bestuurspost, is voor motorboten bevaarbaar. Links oeverwal met Casuarina montana begroeiïng.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 9.
The Baliem river a little south of the Administration Post. Both levees with Casuarina montana vegetation.
De Baliemrivier, even ten zuiden van de Bestuurspost. Links en rechts oeverwallen begroeid met Casuarina montana.



Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 10.
Boulder on the boundary of middle and high terrace. Originally this block stood in the middle of the Wamena river as is shown by the abrasion zone at the base of the block. To the utmost left the present-day river bed and lower terrace. To the right Araucaria tree.
Rotsblok op de grens van midden- en hoogterras. Dit blok lag vroeger midden in de rivier, gezien de abrasiezone aan de basis van het rotsblok. Geheel links de huidige bedding op laagterras. Rechts Auro-caria-boom.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 11.

Landscape of the upper course of the Wamena river where the talus cone (fan) is not yet covered by sand and loam as is the case more down-stream. Here lies the topmost segment of the alluvial fan.

Landschap bij bovenloop van de Wamena, alwaar de puinkegel nog niet is afgedekt met zand en leem, zoals meer stroomafwaarts. Hier ligt dus het top-segment van de alluviale waaier.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 12.

Extensive grass plain to the west of the Administration Post in no man's land, looking in easterly direction. This plain is the high terrace of the Wamena river. In the fore-ground and right centre the Wamena middle terrace. Height difference between the terraces $\pm$ 5 m.

Grote grasvlakte west van de Bestuurspost in niemandsland, genomen in oostelijke richting. Deze vlakte is het hoogterras van de Wamena. Voorgrond en rechts het middenterras van de Wamena. Het hoogteverschil tussen beide terrassen is $\pm$ 5 m.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 13.
Limestone landscape with dolinas, east bank of the Baliem river. The soil on the slopes is a shallow and stony, brown calcic loam; in the depressions and valleys the soil is deeper by colluviation.
Het dolinen vormend kalksteenlandschap op oostelijke Baliemoever. Op de hellingen ligt een ondiepe en stenige, bruine kalkleem; in de kommen en dalen is deze laag door aanspoeling van de hellingen dikker.

Kantoor voor Voorlichting en Radio Omroep Nederlands Nieuw Guinea

Fig. 14.
Aerial photo of one of the limestone salients in the plain (fig. 11). In places the thin soil layer has slumped down. Native crops are cultivated in beds laid out in the direction of the inclination thus promoting erosion.
Luchtfoto van één der kalksteenuitlopers in de vallei. De dunne grondlaag is hier en daar in plakkaten weggespoeld. De bevolkingsbedden liggen in de hellingsrichting, waardoor de erosie wordt bevorderd.

dissolves, whereby they again disintegrate into the original quartz grains and traces of accessory minerals. These weathering products are washed away by surface water from the steep slopes and are taken up by watercourses and streams which deposit the material in the Baliem plain.

It must be assumed that not all minerals found in addition to the quartz in the river deposits are derived from the limestone contaminations and the quartz sandstones. It is probable that other types of rocks such as slate and ancient volcanic rock intrusions were also cut into here and there in the upper course of the West Baliem, East Baliem and other tributaries. After disintegration these rocks add other mineral combinations to the river sediments. Thus, a mineralogical comparison between Baliem and Wamena sands reveals for instance, that in the former orthoclase and other potash-producing minerals are present which are virtually absent from the Wamena sands (see tables 1 and 3).

Therefore, we may expect to encounter in the plain: very old, completely weathered and decalcified Baliem sediments, recent Baliem sediments running close to the river and the sediments of the tributaries. The larger, rapidly flowing tributaries have formed alluvial fans in the plain; one of these, the Wamena fan, will be discussed further.

In conclusion, reference should be made to the brown limestone soils found on the steep slopes of the mountain massifs and on the limestone ridges in the plain. These soils are also found as a colluvium at the foot of those slopes.

3. The Baliem soils (see tables 1 and 2)

Along the stretch between Tulem and the Administrative Post, the Baliem is a slow-flowing and very winding river which is bordered on both sides by well developed, raised levees (fig. 8).

The river probably deepened its bed between the levees during a later period when its erosion base was lowered. So far as is known, there is no further flooding of the levees presently.

Undoubtedly, there will be places along the Baliem where the river water is still capable of flooding the adjoining land at high water levels. The best soils are found in these strips and on the levees themselves which thus represent the recent Baliem deposits. Although they have no great potential fertility owing to the lack of a good mineral reserve, the actual fertility of the topsoil is good as long as the soil remains forest covered.

The *Casuarina* vegetation appears to produce a particularly rich litter that makes plant nutrients accumulate in the topsoil (fig. 9).

A good example is formed by the high phosphate and potash contents of the topsoil (0–15 cm, no. 4639) under *Casuarina* forest and the much lower figures for phosphate and potash in the corresponding subsoil (30–50 cm, no. 4641). The organic matter content of sample no. 4639 is accordingly 5.92% C, as compared to a content of 1.48% C in sample no. 4641.

The mineralogical composition of the sand fractions however is equally poor in valuable minerals in both cases.

The same applies to a comparison between sample no. 5081 taken near Tulem in a *Casuarina* forest on the top of the levee and sample no. 5082 of recent Baliem silt taken at river level lower down the levee. Although the last sample is much richer in lime, the sample taken from the levee is rich in phosphate and potash due to its very high organic matter content.

Tabel 1. Mineralogische analyses der recente en oude Baliem-afzettingen.
Table 1. Mineralogical analyses of recent and old Baliem deposits.

Voedingselementen leverende mineralen / *Plant nutrient providing minerals*	Monsternummers Bodemkundig Bureau / *Numbers of samples of the Bureau of Soils*									
	4639	4641	5081	5082	5072	5070	5078	5079	5080	5071
Kalium / *Potassium*										
Orthoklaas / *Orthoclase*	7	7	9	3	8	6	sp	1	2	1
Biotiet / *Biotite*	sp	sp	–	–	sp	sp				
Muscoviet / *Muscovite*	2	1	sp	1	sp	sp				
Glauconiet / *Glauconite*	2	1	1	1	1	sp	–	–	–	sp
Sericiet / *Sericite*	1	sp	–							
Fosfaat / *Phosphate*										
Apatiet / *Apatite*	–		sp	sp	sp	–				
Natrium/Calcium / *Sodium/Calcium*										
Albiet / *Albite*										
Oligoklaas / *Oligoclase*										
Int. Plagioklaas / *Int. Plagioclase*										
Bas. Plagioklaas / *Bas. Plagioclase*										
Epidoot / *Epidote*	sp	sp	–							
Magnesium/Calcium										
Hypersteen / *Hypersthene*										
Augiet / *Augite*	–		sp	sp	sp	sp				
Amfibool / *Amphibole*	sp	sp	sp	sp	sp	sp				
Chloriet / *Chlorite*										
Serpentijn / *Serpentine*										
Calciet / *Calcite*	sp	sp	sp	1	sp	sp				
Schelpfragmenten / *Shellfragments*	6	5	sp	18	24	11				
Ca-concreties / Ca-concretions										
Diversen / *Miscellaneous*	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp
Gesteente fragmenten / *Rockfragments*										
Inert materiaal / *Inert material*										
Kwarts / *Quartz*	83	86	86	57	55	78	96	94	95	96
Org. SiO_2 / *Organic Silica*	–	–	sp	sp	sp	sp	4	4	2	sp
IJzerconcreties / *Fe-concretions*	1	1	4	19	12	5	sp	1	1	3
Percentage zandfractie / *Sand fraction in %*	–	–	4	–	23	14	8	11	10	15

Opmerkingen: 1. Bovenstaande cijfers hebben betrekking op honderdkorreltellingen verricht aan de, met ammonia voorbewerkte zandfracties (2000–50 mu).
Remarks: Figures refer to 100 grain countings carried out on the sand-fractions (2000–50 mu) after treatment with NH_3OH.

2. Diversen: de zware mineralen zirkoon, toermalijn, rutiel.
Miscellaneous: the heavy minerals zircon, turmaline, rutile.

sp = traces.

Another direct comparison may be drawn between this sample no. 5082 from Tulem and samples nos. 5072 and 5070 taken from the levee at river level upstream and downstream respectively of the Administrative Post.

All three samples, consisting of recent Baliem silt, are very rich in lime (i.e. free calcium carbonate) and contain a small percentage of potash-releasing minerals (chiefly orthoclase), traces of the phosphate-releasing mineral apatite and traces of the pyroxene-amphibole group.

A striking contrast, from a mineralogical and chemical point of view, to these recent Baliem soils is formed by the old Baliem soils of which the samples nos. 5078, 5079 and 5080 are representive. They are taken from the three upper horizons of a soil profile near the Tulem airstrip, where a heavy, bleached, clay loam was found. About 99% of the sand fraction, the latter amounting to 10%, consisted of quartz grains. The soils are highly acid and the content of available calcium is extremely low; the same applies to the content of available magnesium, potassium and phosphate. The peaty topsoil is slightly better but still very poor. The soil was covered with thin grasses and weeds. According to the experience of the local missionary no plant could be grown on this soil without the use of fertilizers.

Although little is to be expected from the fertility of the old Baliem soils in generally, it is not unlikely that the above mentioned soil at Tulem represents an extremely poor soil phase of this group. The phase may be representative for the lower areas in the valley where the soil has been thoroughly leached through a process of prolonged subhydric weathering, followed by the podzolizing effect of the acid peat. Nothing but the quartz is left from the original mineral skeleton of this soil.

4. *The Wamena soils* (see tables 3 and 4)

The entire plain south-west of the Administrative Post is actually an alluvial fan system of the Wamena river. In the course of time this river has carried down enormous masses of boulders, gravel, sand and silt (figs. 10, 11).

From the point at which the Wamena appears from the steep foothills of the mountains, its sedimentation area, showing itself as a wide grass plain, slopes down into the direction of the Baliem at a gentle gradient (see section of alluvial fan on the detail map fig. 3).

This plain, the subsoil of which contains a cobblestone layer of more than 5 metres thick in places, contains in its topsoil a surface layer of sandy loam which is 15 to 50 cm thick.

The cobblestone layer chiefly consists of nummulite limestone, dark grey limestone, calcareous quartz sandstone and quartzitic pebbles which are also found in the present river bed. The extensive grass plain now forms the upper Wamena terrace (fig. 12).

Owing to the lowering of its erosion base, the river has cut into its own deposits for a depth of several feet and now roars over its previous bed of cobblestones as a braided river to the confluence with the Baliem, south of the Administrative Post.

The lowering of its erosion base is to be associated with the piercing and wearing of the southern limestone barrier which formerly obstructed the drainage of the Baliem valley. The Wamena now has a narrow terrace and an undeveloped lower terrace.

The great grass plain was formerly occupied and the inhabitants took the trouble to work up this shallow sandy loam into beds and to remove the stones.

It is not known how long it was possible to raise tuberous crops on these beds and what fallow period was required.

TABEL 2. Recente en oude Baliem-afzettingen
Table 2. Recent and old Baliem deposits

Nummer *Number*	Monster/*Sample* Laag *Layer*	Monster/*Sample* Plaats *Location*	Texture class	pH H_2O	pH KCl	$CaCO_3$ %	Organic matter C% (W.Black
4639	0–15	Recente Baliem-afzetting – Baliem oeverwal zuid van Bestuurspost onder Casuarinabos. *Recent Baliem deposit – Levee of Baliem river south of Administration Post under Casuarina forest*	Sandy loam	7.1	6.4	2.9	5.92
4641	30–50	Idem/*Ditto*	Sandy loam	7.4	6.3	4.5	1.48
5081	0–15	Op Baliem-oeverwal bij Tulem; onder bos. *Levee of Baliem river near Tulem under forest.*	Silty clay loam	6.4	5.8	0	6.84
5082	–	Slibbank Baliem bij Tulem. *Silt bar of the Baliem river near Tulem.*	Silty loam	7.9	–	7.8	0.52
5072	–	Oeverwal Baliem op waterlijn boven Bestuurspost. *Levee of Baliem river at water level up-stream of Administration Post.*	Silty loam	7.9	7.0	6.8	1.22
5070	–	Oeverwal Baliem op waterlijn beneden Bestuurspost. *Levee of Baliem river at water level down-stream of Administration Post.*	Silty loam	7.9	6.9	4.4	2.00
		Zeer oude Baliem-afzetting. *Very old Baliem deposit.*					
5078	0–25	Vlakte bij airstrip Tulem. *Plain near airstrip of Tulem.*	Silty clay loam	4.1	3.9	0	4.17
5079	25–45	Idem/*Ditto*	Silty clay loam	4.2	3.9	0	2.32
5080	45–75	Idem/*Ditto*	Silty clay loam	4.5	3.8	0	0.59
		Colluvium/*Colluvium*					
5071	0–25	Bruine kalkleem voet kalkheuvels zuid van Bestuurspost. *Brown limestone soil at the foot of limestone hills south of Administration Post.*	Silty clay loam	5.4	4.2	0	0.87

Opmerkingen/*Remarks:* – = niet bepaald/*not determined.*
[1]) = dpm = mgr/kg grond/*dpm = mg/kg soil.*
[2]) = samenvatting van tabel 1/*summarization of table 1.*

Beschikbare basen in 3% azijnzuur extract *Available bases in 3% acetic acid*			Beschikbaar *Available* P_2O_5 (Truog) dpm[1])	Mineralogische samenstelling van de zandfractie[2]) *Mineral composition of sand-fraction*		
CaO dpm[1])	MgO dpm[1])	K_2O dpm[1])		Inert. mat %	Ca. mat %	K. min. %
–	–	280	43	84	6	10
–	–	95	13	86	5	9
7.360	555	150	260	90	sp	10
41.930	1860	55	3	76	19	5
38.950	1200	100	4	67	24	9
26.350	1225	145	3	83	11	6
400	65	100	8	100	0	sp
180	< 10	45	3	99	0	1
260	< 10	35	3	98	0	2
2150	< 10	57	3	99	0	1

TABEL 3. Mineralogische analysestaat der Wamena-afzettingen
Table 3. Mineralogical analysis of Wamena deposits

Voedingselementen leverende mineralen *Plant nutrient providing minerals*	Monsternummers Bodemkundig Bureau					
	5076	5075	5073	5074	4829	4827
Kalium/*Potassium*						
Orthoklaas/*Orthoclase*	sp	sp	sp	sp	sp	1
Biotiet/*Biotite*						
Muscoviet/*Muscovite*						
Glauconiet/*Glauconite*						
Sericiet/*Sericite*						
Fosfaat/*Phosphate*						
Apatiet/*Apatite*						
Natrium/Calcium / *Sodium/Calcium*						
Albiet/*Albite*						
Oligoklaas/*Oligoclase*						
Int. Plagioklaas/*Int. Plagioclase*						
Bas. Plagioklaas/*Bas. Plagioclase*						
Epidoot/*Epidote*						
Magnesium/Calcium						
Hypersteen/*Hypersthene*						
Augiet/*Augite*						
Amfibool/*Amphibole*						
Chloriet/*Chlorite*						
Serpentijn/*Serpentine*						
Calciet/*Calcite*	4					
Schelpfragmenten/*Shell fragments*	15					
Ca-concreties/*Ca-concretions*						
Diversen/*Miscellaneous*	sp	sp	sp	sp	sp	sp
Gesteente fragmenten/*Rock fragments*						
Inert materiaal/*Inert material*						
Kwarts/*Quartz*	75	98	96	94	99	98
Org. SiO_2/*Organic silica*	sp	sp	sp	sp	sp	sp
IJzerconcreties/*Fe-concretions*	6	2	4	6	1	1
Percentage zandfractie *Sand fraction in %*	73%	69%	46%	47%	25%	49%

Opmerkingen: 1. Bovenstaande cijfers hebben betrekking op honderdkorreltellingen verricht aan de, met ammonia voorbewerkte zandfracties (2000–50 mu).
Remarks: Figures refer to 100 grain countings carried out on the sand-fractions (2000–50 mu) after treatment with NH_3OH.

2. Diversen: de zware mineralen zirkoon, toermalijn, rutiel, brookiet.
Miscellaneous: the heavy minerals zircon, turmaline, rutile, brookite.

sp = traces.

Numbers of samples of the Bureau of Soils

4825	4822	5077	5069	5028	5029	5030	5031	5032	5033	5034
1	1	sp	1	sp	sp	sp	sp	sp	sp	sp
			sp	sp	1	sp				
sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp
98	97	93	96	97	95	94	98	97	98	96
sp	sp	sp	sp	sp	sp	sp	sp	sp	sp	sp
1	2	7	3	3	4	5	2	3	2	3
39 %	58 %	33 %	52 %	43 %	45 %	47 %	51 %	37 %	45 %	44 %

TABEL 4. Wamenagronden
Table 4. Wamena Soils

Nummer *Number*	Monster/*Sample* Laag *Layer*	Monster/*Sample* Plaats *Location*	Texture class	pH H_2O	pH KCl	$CaCO_3$ %	Organic matter C% (W.Black)
5076	–	Zandmonster uit rivierbedding dicht bij monsterplaats 5075. *Sand sample from river bottom near sampling place 5075.*	Loamy sand	7.7	7.0	17.3	0.48
5075	0–15	Zandige deklaag op rolstenenpakket; grasvlakte 6 km west van Bestuurspost. *Sandy surface layer over cobblestone deposit; grass plain 6 km west of Administration Post.*	Sandy loam	5.0	4.0	0	1.34
5073	0–20	Zwarte, venige bovengrond; grasvlakte 3 km west van	Sandy clay loam	5.7	4.8	0	3.06
5074	20–30	Bestuurspost *Black peaty topsoil; grass plain 3 km west of Administration Post.*	Sandy clay loam	6.1	5.1	0	2.68
4829	0–30	Monsterkuil/*Sample pit* 4829/31 bij vliegveld/*near airstrip.*	Silty loam	5.8	–	0	2.36
4827	0–45	Idem/*Ditto* 4827/28	Loam	6.5	–	0	1.78
4825	0–55	Idem/*Ditto* 4825/26	Loam	5.5	–	0	1.82
4822	0–40	Idem/*Ditto* 4822/24 zuid van Bestuurspost/*South of Administration Post.*	Sandy loam	5.6	–	0	0.88
5077	0–20	Nieuwe weg zuid van Bestuurspost. *New road south of Administration Post.*	Loam	5.9	4.6	0	1.21
5069	0–25	Op oeverwal bij Bestuurspost; groentebed onder Casuarina-begroeiing. *Levee near Administration Post; vegetable bed under Casuarina vegetation.*	Sandy loam	7.3	6.5	0.1	3.64

Opmerkingen/*Remarks:* – = niet bepaald/*not determined.*
[1]) = dpm = mgr/kg grond / *mg/kg soil.*
[2]) = samenvatting van tabel 3/*summarization of table 3.*

Beschikbare basen in 3% azijnzuur extract *Available bases in 3% acetic acid*			Beschikbaar *Available* P_2O_5 (Truog) dpm[1])	Mineralogische samenstelling van de zandfractie[2]) *Mineral composition of sand-fraction*		
CaO dpm[1])	MgO dpm[1])	K_2O dpm[1])		Inert. mat %	*Ca. mat* %	*K. min.* %
70400	1990	45	–	81	19	sp
1350	160	115	3	100	0	sp
3640	32	60	3	100	0	sp
3750	< 10	35	3	100	0	sp
2600	–	45	8	100	0	sp
4800	–	40	11	99	0	1
2500	–	50	11	99	0	1
2100	–	50	3	99	0	1
2940	< 10	45	3	100	sp	sp
5660	365	240	78	99	sp	1

Sample no. 5075 (see map fig. 3) is representative of this topsoil; it has a pronounced acid reaction, is low in available calcium, potassium and phosphate and the organic matter content is also low.

Nearly 100% of the sand fraction, amounting to 69% of the total, consists of inert material with only traces of orthoclase and heavy minerals. It is interesting to note that the mineralogical analysis of sand sample no. 5076 taken from the present river bed itself, shows the same mineralogical composition after the lime fragments have been removed.

Sample no. 5073/74 is more representative of the lower and marshy part of the grass plain. The sand fraction which in these samples, after removal of the organic matter, amounts to about 25%, consists for about 99% of inert material such as quartz and ferruginous concretions. This toplayer of 30 cm depth is very poor in potassium and phosphate and has an extremely low magnesium content. Its lime status (and consequently the acidity) is somewhat better owing to calcareous groundwater rising from the underlying, water-bearing rubble layer.

Peat formation in this area is caused by the combination of marshy conditions and low temperature. There is no peat formation on the sandier, more elevated soils near the apex of the alluvial fan because here, soils are rather subject to desiccation and organic matter is decomposed more rapidly.

The topsoil samples nos. 4829, 4827, 4825 and 4822, taken from the area between the air-strip and the Administrative Post, show exactly the same mineralogical and chemical pattern as the above samples which are typical for the alluvial fan.

The specimen may vary somewhat in texture as is to be expected in fluviatile deposits.

Sample no. 5069 was taken on the outerside of the Baliem-levee from a vegetable bed with an excellent growing crop. The spot was still stocked with Casuarina trees.

Although the site of sampling might lead us to assume that we are dealing with a Baliem deposit, the mineralogical analysis proves however that this sample may be included in the Wamena deposits. The sample has a marked sandy composition and a short distance north of the site of sampling a great deal of cobblestones of typical Wamena origin was encountered in the other beds. It is obvious that this site was a former outlet of a branch of the Wamena.

The chemical analysis of sample no. 5069 differs from that of the other Wamena samples on account of its actual high fertility, despite the fact that the potential fertility is low according to the mineralogical analysis. The soil still contains a trace of lime, (calcium carbonate) so that the figures for available calcium are still high. The very good phosphate-, potassium- and magnesium-figures are chiefly to be attributed to the high humus content (C% = 3.64) of this recently developed land and to the fact that wood-ash was worked into the beds during reclamation. Hence, the fertility of this piece of land is of a temporary character.

In conclusion we would draw attention to the mineralogical figures of samples 5028–5034 which again show typical Wamena features. These samples were taken from the area lying in the corner between the Baliem, Wamena and the Sabula-hill (see map).

5. The brown limestone soils

The brown limestone soils were formed by weathering and solution of limestone rock and are composed of the least weatherable minerals originally contained as contaminations by the limestone.

It is obvious that a very large amount of limestone has to be dissolved before a thin layer of soil is formed. Consequently, these soils are generally very shallow, particularly as they are exposed to erosion on the steep deforested slopes. It is only in basins and at the foot of the hills that the soil is deeper, owing to the fact that eroded soil has accumulated in such places (fig. 13).

The admixture of iron gives these soils their brown colour. Where the soil is subject to great heat on account of maximum exposure and where optimum drainage conditions prevail, the soils assume more reddish-brown hues as a result of dehydration of the iron compounds. Where such conditions are not predominant the soil tends to make on a more yellowish-brown hue.

The hill side soils are extremely susceptible to drought, owing to the fact that the rainwater runs off along the surface and also sinks through the porous shallow soil into the limestone rock underneath. This factor, combined with their natural poverty and the absence of any soil cover, mark them as some of the poorest agricultural soils.

The weaker native clans who are chased away by the stronger from the better soils, take refuge into the hills and are forced by necessity to cultivate these hillside slopes. They take a great deal of trouble to clear the ground of stones which are piled-up along the contour lines and at right-angles thereto in the form of low walls (fig. 14).

Sample no. 5071 was taken from a sweet potato bed at the foot of a limestone hill. About 99% of the sand fraction, which here amounts to 15% of the total consists of quartz grains (see tables 1 and 2). The soil is very acid (pH = 5.4) and contains very little organic matter. There is still a sufficiently of available calcium, but available magnesium-, potassium- and phosphate-figures are extremely low.

These soils are probably only capable of bearing one crop of sweet potato after which they must remain fallow for a considerable time.

6. Mineralogical characteristics of the soil types

The mineralogical composition of the sand fraction is an important aid in distinguishing the origin of the various soil types encountered in a field survey.

The recent Baliem sediments and the recent Wamena deposits both contain calcareous material, viz. calcite and shell fragments. The former, however, also contain about 10% of potash-releasing minerals and traces of apatite as a specific characteristic.

If, on the other hand, we compare the old Baliem soils, the old Wamena soils and the limestone soils, mineralogically speaking no significant difference can be discovered between them. It is, however, possible to perform the mineralogical analysis in another way, viz. by separating the heavy minerals from the light ones by using – Bromoform (s.g. 2,90). The qualitative and quantitative composition of the "heavy mineral fraction" thus obtained, provides a means of making a further distinction. Representatives of the heavy minerals are to be found as traces in the "Miscellaneous" group and in the form of ferruginous concretions in the "Inert material" group in all Wamena soils, the old Baliem soils and the limestone soils.

The heavy minerals in the recent Baliem soils are the amphiboles, pyroxenes and biotite which occur as traces only. After concentration of these minute quantities of heavy minerals, however, the heavy fraction analysis reveals the following detailed pattern:

TABLE 5.

	Baliem soil (recent) no. 5082	Wamena soil (recent) no. 5076	Wamena soil (old) no. 5075	Limestone soil – no. 5071
Opaque (ore)	83%	74%	85%	83%
Remainder	17%	26%	15%	17%
Remainder				
Zirconium	8	63	62	57
Tourmaline	31	13	12	11
Rutile	3	22	19	22
Brookite	–	–	–	2
Alterite	3	1	4	2
Anatase	–	1	3	4
Hypersthene	2	–	–	–
Augite	41	–	–	2
Amphibole	36	–	–	–
Biotite	4	–	–	–

The table 5 clearly shows the difference between the heavy fractions of the Baliem soil with its dominant pyribole-association and the Wamena soil with its dominant zirconium-rutile-association. From this its follows that the Baliem cuts upstreams into other rocks than those which already occurred in the river basin of the Wamena. At the same time it can be seen that the recent and old Wamena soils are entirely identical in their heavy mineral fraction. Consequently the only essential difference between the two is the characteristic abundance of calcareous fragments in the recent Wamena soils.

It is interesting to note that the dominant zirconium-rutile-association in the Wamena soils can be attributed to a predominant limestone origin of this material, as the brown limestone soil is characterized by the same association.

In the Baliem silt this association is quantitatively outweighed by the pyribole-association and the limestone influence on its composition is masked accordingly.

Unfortunately the old Baliem soil at Tulem (nos. 5078/5080) did not yield sufficient heavy minerals on separation to allow for a heavy fraction analysis.

7. *Summary, conclusions and recommendations*

a. Although it is not yet possible to make a firm statement on the soil fertility of the Baliem valley as a whole, on the basis of the few soil samples available, it would be an obvious assumption that the older fluviatile soils of which this valley must largely consist have a low potential fertility. This assumption is based on the fact that the valley is filled-in by erosion material brought down by the rivers from the adjoining mountains. Since these adjoining mountains largely consist of limestone and quartz sandstone and even the composition of freshly deposited Baliem silt may be called "poor" from the mineralogical point of view, the potential fertility of most Baliem soils cannot be high.

A considerable part of these deposits must also have been in a marshy condition for a very long period, thus causing further decalcification and leaching of the soil, so that in these districts also the actual soil-fertility is extremely low.

The brown, loamy limestone soils, found on the slopes and at the foot of the limestone hills, the latter rising out of the plain in the form of ridges, were formed by weathering and solution of the limestone rock which is poor in nutritive minerals.

The recent Baliem deposits, comprising the vegetation-covered levees of this river, are comparatively richer in plant nutrients, as are also strips where Baliem silt is still deposited at high water.

b. The native population attempts to prevent as far as possible a further decline in fertility by the use of a "bed-system" for cultivating its sweet potato crops. Not only are the beds continuously molded up with plant waste and other dirt, but also a closed draining system around ten beds is used by which losses of dissolved nutrient salts are substantially reduced. From aerial observation it could be ascertained that the natives also allow the beds to remain fallow over a considerable period. This obviously requires a great deal of land for each "clan", depending on the number of its members and the duration of the fallow period on which the rotation system is based.

The natives also try to maintain a bed-system on the slopes of the limestone hills, making the ground fairly free from stones which are piled-up into low walls along the contour lines and at right-angles thereto.

c. There is no doubt that land hunger must already exist in various areas of the Baliem valley. This evil is probably thrown by the stronger tribes on the weaker ones by force of arms. The fact that the shallow, dry and deforested hillside soils are still being tilled and planted can hardly imply anything else than a substantiation of this theory.

The aims of the Administration to intervene in the endless state of war between the clans and to call a halt to the fearful incidence of yaws and other tropical diseases by medical action will lead to a rapid decline in the mortality figure in the near future. As a result, the biological balance between density of population and land space which has been established for countless ages by means of famine, war and disease, will be radically shifted towards a situation of acute land shortage.

The usual measures for eliminating the problem of land shortage are intensification of agricultural methods, resettlement-schemes and transmigration of groups of the population.

The planning of these measures requires in the first place a soil survey of the Baliem valley as a whole.

d. The first step in making this soil inventory is to compile good airphotos (1 : 20.000) of the Baliem valley as soon as possible. From these photos an analysis can be made of the character and distribution of the various soil types, the hydrological condition of the land, the vegetation, the extent of natural forests, the land occupation, particularly the bed acreage and the rotation schemes employed.

The air-photo analysis should be followed by terrestrial surveys, in which connection very profitable use could be made of a helicopter-service.

e. As regards the development aspects of the present Administrative Post, it may be observed that the post and all uninhabited land to the west thereof as far as the mountains, is situated on an alluvial fan of the Wamena. This means, that the subsoil largely consists of banks of stone covered by a shallow layer of sandy loam. The potential and actual fertility of this soil is particularly low. The higher soils are drought-susceptible and the lower parts are moist and marshy. The natural vegetation consists of grasses, ferns and poor weeds. The tree species natural to this area is *Casuarina montana.*

The grass plain affords natural possibilities for cattle raising, whereas reafforestation of certain parts would help to lessen the acute timber shortage which is experienced in various places. Horticulture might be a possibility on a small scale, mainly on the Baliem levees and any narrow adjoining strips. The intensive use of these soils for any length of time will require the application of artificial fertilizers.

(Submitted, January 1959).

8. *Samenvatting, conclusies en aanbevelingen*

De Grote Baliemvallei, gelegen in het Centrale Bergland van Nederlands Nieuw Guinea, met een lengte van ± 45 km en een wisselende breedte van gemiddeld ± 15 km, ligt ingeklemd tussen steil oprijzende kalksteenformaties. Uit de lucht gezien doet deze vallei zich voor als een grote drassige vlakte, waarin de Baliem meandert. De belangrijkste zijrivieren zijn de Ibele en de Wamena. De Baliem heeft vele malen zijn loop veranderd, waardoor een landschap van oeverwallen, stroomruggronden en komgronden is ontstaan met plaatselijk poelen en moerassen. Het omringende gebergte bestaat uit gemakkelijk verweerbaar kalkgesteente en kwartszandlagen. Doordat de Baliem en enkele zijrivieren in hun bovenloop ook andere gesteentesoorten aansnijden, zoals leisteen en oud-vulkanische gesteente-intrusies, heeft men in de vlakte te maken met het naast elkaar voorkomen van zeer oude, doorverweerde en ontkalkte sedimenten en verschillende jonge kalkrijke sedimenten. Op de hellingen van de kalksteenheuvels en als colluvia vindt men bruine kalkgronden.

a. Alhoewel thans op basis van de weinige beschikbare grondmonsters nog geen uitspraak gedaan mag worden over de vruchtbaarheid van de Baliemvallei in haar geheel, zo ligt toch de veronderstelling voor de hand, dat de oudere fluviatiele gronden, waaruit deze vallei grotendeels moet bestaan, een geringe potentiële vruchtbaarheid bezitten.

Deze veronderstelling is gebaseerd op het feit, dat de vallei is opgebouwd uit erosie-materiaal, dat door de rivieren uit het belendende bergland naar beneden werd gevoerd. Aangezien dit belendende bergland voor het grootste deel uit kalksteen en kwartszandsteen bestaat en ook de huidige samenstelling van vers gedeponeerd Baliemslib mineralogisch „arm" te noemen is, kan dus ook de potentiële vruchtbaarheid der Baliemgronden niet hoog zijn.

Een belangrijk deel dezer afzettingen moet bovendien gedurende een zeer lange periode in moerassige toestand verkeerd hebben, waardoor de grond verder ontkalkt en uitgespoeld is, zodat in die arealen ook de actuele vruchtbaarheid zeer gering is.

Ook de bruine kalklemen, welke aangetroffen worden op de hellingen en aan de voet van de kalkheuvels, welke laatste als graten in de vlakte opduiken, zijn arm aan plantenvoedingsstoffen. Zij zijn ontstaan door verwering en oplossing van het mineraalarme kalkgesteente.

Relatief rijker aan plantenvoedingsstoffen zijn de recente Baliemafzettingen, welke de begroeide oeverwallen omvatten en plaatselijke stroken waar, bij hoogwater, nog Baliemslib wordt afgezet.

b. Door toepassing van een bedden-systeem bij de verbouw van haar knolgewassen, tracht de bevolking een verdere teruggang van de actuele bodemvruchtbaarheid zoveel mogelijk tegen te gaan.

Niet alleen worden de bedden doorlopend opgehoogd met plantenafval en ander vuil, doch ook is het goten-systeem gesloten, waardoor verlies aan opgeloste voedingszouten in belangrijke mate wordt verminderd.

Het is wel zeker, dat de bevolking hierbij tevens de gebruikte beddengronden telkenmale voor langere tijd braak laat liggen. Dit vereist uiteraard veel land per „clan", zulks afhankelijk van de duur der braak welke aan het rotatie-schema ten grondslag ligt.

Op de hellingen der kalkheuvels tracht de bevolking zich eveneens met een bedden-systeem te handhaven, waarbij de grond vrij van stenen gemaakt wordt en de stenen tot muurtjes gestapeld worden langs de tranches en loodrecht daarop.

c. Het lijdt geen twijfel dat plaatselijk reeds landhonger in de Baliemvallei aanwezig geacht moet worden. Dit euvel wordt vermoedelijk gewapenderhand door de sterkere stammen afgewenteld op de zwakkere stammen. Het nog steeds bewerken en beplanten van de schrale, droge en ontboste kalkheuvels kan haast niet anders dan een bewijs voor deze stelling inhouden.

De noodzaak om bestuurlijk te gaan ingrijpen in de eindeloze oorlogstoestand tussen de „clans" en om door medisch ingrijpen paal en perk te stellen aan de ontstellende omvang van framboesia e.a. tropische ziekten, maakt dat het sterftecijfer in de naaste toekomst snel zal dalen. Hierdoor wordt het biologisch evenwicht, dat zich sedert talloze eeuwen instelde tussen bevolkingsdichtheid en grondruimte, drastisch verschoven naar de toestand van acute landhonger.

De gebruikelijke maatregelen welke dienen om het probleem van landhonger op te heffen zijn intensivering van de landbouwmethodes, resettlement en transmigratie van bevolkingsgroepen.

De planologie van deze maatregelen vereist allereerst een bodemkundige inventarisatie van de Baliemvallei in zijn geheel.

d. Een eerste benadering van deze bodemkundige inventarisatie is het doen vervaardigen, op korte termijn, van goede luchtfoto's (1 : 20.000) van de Baliemvallei.

Uit deze foto's kan een analyse gemaakt worden omtrent: het karakter en de verspreiding der verschillende bodemtypen, de hydrologische toestand van het terrein, de begroeiing, de landoccupatie inz. het beddenareaal en de toegepaste vruchtwisseling. Bovendien blijkt uit deze foto's ook de bebossingsgraad en bevolkingsdichtheid.

De luchtfoto-analyse dient opgevolgd te worden door terrestrische waarnemingen, waarbij met zeer veel voordeel gebruikt gemaakt zou kunnen worden van een helikopter.

e. Voor wat betreft de ontwikkelingsaspecten van de tegenwoordige Bestuurspost Wamena, kan worden opgemerkt, dat de post en al het onbewoonde land ten westen daarvan tot aan het bergland, gelegen is op een alluviale waaier van de Wamena. Dit impliceert dat de ondergrond grotendeels uit steenbanken bestaat, welke afgedekt zijn door een ondiepe laag van zandige leem. De potentiële en actuele vruchtbaarheid van deze grond is bijzonder laag. De hogere gronden zijn droogtegevoelig, de lagere delen zijn vochtig en venig. De natuurlijke vegetatie bestaat uit grassen, varens en schrale onkruiden. De boomsoort welke daar van nature groeide is *Casuarina-montana*.

De grasvlakte biedt mogelijkheden voor veeteelt, terwijl een herbebossing der vlakte ook mogelijkheden voor de plaatselijke houtvoorziening biedt. Op de Baliem-oeverwal en eventuele smalle aangrenzende stroken zou tuinbouw op kleine schaal mogelijkheden bieden. Een enigszins intensief gebruik van die grond op langere termijn impliceert echter noodzakelijkerwijs het gebruik van kunstmest.

Zusammenfassung, Folgerungen und Empfehlungen

Die Grosze Baliemebene, im Zentral Gebirgsland Niederländisch Neu Guineas, mit einer Länge von ± 45 Km und einer wechselender Breite von ± 15 Km, liegt eingeklemmt zwischen steil aufsteigenden Kalksteinformationen. Von der Luft aus gesehen breitet das Tal sich als eine grosze, sumpfige Ebene aus in welcher der Baliemflusz mäandert. Die wichtigsten Nebenflüsze sind die Ibele und die Wamena. Die Baliem hat ihren Lauf oft geändert wodurch eine Landschaft von Uferwällen, leichte und schwere Auetonböden mit vielerorts Sümpfen und Pfuhlen entstanden ist. Das Gestein des umringenden Gebirges ist hauptsächlich leicht verwitterendes Kalkgestein mit Quarzsandschichten. Weil die Baliem und einige ihrer Nebenflüsze im Oberlauf auch andere Gesteinsarten, wie Schiefer und alt-vulkanische Gesteinsintrusionen anschneiden, findet man in der Ebene nebeneinander sehr alten, stark verwitterten, entkalkten Sedimente und jüngeren, kalkreichen Sedimente. Auf den Abhängen der Kalksteinhügeln und Kolluvia findet man braune Kalkböden.

Obgleich heute auf Grund des zur Verfügung stehenden Analysematerials kein Urteil ab zu geben ist hinsichtlich der Fruchtbarkeit der Baliemebene als Ganzes, so liegt doch die Vermutung auf der Hand, dasz die fluviatilen älteren Ablagerungen aus den die Ebene grösztenteils aufgebaut sein soll, eine geringe potentielle Fruchtbarkeit aufweisen. Diese Vermutung gründet sich auf der Tatsache, dasz die Böden der Ebene aus Erosionsmaterial der Berge hervorgegangen sind. Weil das anstoszende Gebirge grösztenteils aus Kalkgestein und Quarzsandstein besteht und auch die Zusammensetzung des frisch abgelagerten Schluffs des Baliemfluszes als mineralogisch arm zu bezeichnen ist, kann auch die potentielle Fruchtbarkeit nicht hoch sein. Auszerdem soll ein beträchtlicher Teil dieser Ablagerungen sich während längerer Zeit in sumpfiger Lage befunden haben was eine weitergehende Entkalkung und Auslaugung zufolge hatte. Diese Gebiete weisen auch eine geringe aktuelle Fruchtbarkeit auf.

Auch die braunen Kalklehmböden, welche man findet auf den Hängen und am Fusze der Kalksteinhügel welche als Grate in der Ebene liegen, haben einen niedrigen Nährstoffgehalt. Einen relativ höheren Nährstoffgehalt haben die rezente Baliemablagerungen aus den die Uferwälle aufgebaut sind und örtlich einige streifförmigen Niederungen wo beim Hochwasser noch Baliemschluff zur Ablagerung gelangt.

Die Eingeborenen versuchen beim Knollengewächsbau mittels Anlage von Beeten einen weiter fortschreitenden Zurückgang der aktuellen Fruchtbarkeit weitmöglichst ein zu halten. Nicht nur werden die Beete fortwährend erhöht mit Pflanzenabfälle und Müll, sondern auch das Furchensystem ist geschloszen damit den Verlust gelöster Nährsalze weitgehend verringert wird. Auch eine mehr oder wenig längere Dauer der Brache trägt dazu bei. Selbstverständlich braucht dadurch jede „Clan" oder Sippe, viel Land abhängig von der Dauer der dem Fruchtwechsel zugrunde liegenden Brache.

Auch auf den Hängen der Kalkhügeln, versuchen die Eingeborenen ihre Ackerwirtschaft mittels eines Beetensystems bei zu behalten wozu Steine vom Boden entfernt und zu Mäuerchen aufgeschichtet werden entlang oder waagerecht der Höhenlinien.

Zweifellos besteht schon in der Baliemebene örtlich Landhunger. Dieses Übel wird wahrscheinlich durch die stärkeren Sippen mit den Waffen in der Hand abgewälzt auf die schwächeren Sippen.

Als Beweis zu dieser Behauptung gilt die immer erneute Bearbeitung und Kultivierung trockner und kahler Kalkhügeln.

Das notwendige Eingreifen durch die niederländischen Zentralbehörde zur Beendung des anhaltenden Kriegszustands zwischen den Sippen und die ebenso notwendige Bekämpfung der Framboesiaplage und anderen tropischer Krankheiten, wird in nächster Zukunft ein rasches Herabsinken der Sterbeziffer zu Folge haben. Dadurch wird das uralte biologische Gleichgewicht zwischen Bevölkerungsdichte und Bodenraum eine drastische Verschiebung in der Richtung akuter Landhunger erleiden.

Die üblichen Methoden zur Abhelfung dieses Problems sind Intensivierung der Agrarwirtschaft, Neuansiedlung und Transmigration. Als Grundlage für die Planung dieser Maszregeln ist an erster Stelle eine völlige bodenkündliche Inventur der Baliemebene unerläszlich. Als erste Annäherung dieser Inventur gilt die Anfertigung von Luftbildern 1 : 20.000 auf kurzer Frist. Diese Bilder dienen als Grundlage einer Analyse hinsichtlich Art, Verbreitung und Ausdehnung der verschiedenen Bodentypen, des Entwässerungszustandes des Geländes, der Vegetation, der Bodenbenutzung insbesondere die Fläche der Beetenanlagen und des üblichen Fruchtwechsels. Auszerdem ersieht man aus den Luftbildern auch die Bewaldung und Bevölkerungsdichte.

Die Luftbildanalyse soll von einer terrestrischen Aufnahme befolgt werden wozu Anwendung eines Helikopters sehr nützlich sein wird. Hinsichtlich der Aspekte der Fortentwicklung der heutigen Verwaltungsstation sei bemerkt, dasz die Station und das westlich davon nicht-bewohnte Gelände bis zum Gebirge auf einen alluvialen Schutthalde des Wamenafluszes liegt. Dies impliziert, dasz der Untergrund grösztenteils aus Steinbänke besteht von einer dünnen sandigen Lehmschicht überdeckt. Die potentielle und aktuelle Fruchtbarkeit dieses Bodens ist auszerordentlich niedrig. Die höheren Böden sind trockenempfindlich, die niederen Teile sind feucht und anmoorig.

Die natürliche Vegetation setzt sich zusammen aus Gräser, Farne und ärmliche Unkräuter. *Casuarina montana* findet dort ihren natürlichen Standort.

Die Grasebene bietet Aussichte für Viehzucht während teilweise Aufforstung für die lokale Holzversorgung wichtig erscheint.

In kleinerem Umfang wird Anbau von Gemüsen auf den Uferwählen des Baliemfluszes und eventuell auf schmalen anstoszenden Streifen möglich sein. Intensiver langfristiger Gebrauch dieser Böden macht aber Anwendung von Kunstdünger unbedingt notwendig.

THE LANDSCAPE IN THE MARO AND KOEMBE RIVER DISTRICT

(Merauke, Southern Netherlands New Guinea)

by

Ir. J. J. Reynders[1])

1. Introductory

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

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

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

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

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

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

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

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

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

[1]) Formerly Soil Scientist Bureau of Soils, Netherlands New Guinea. At present: Mineralogical and Geological Institute of the University of Utrecht.

[2]) International Training Centre for Aerial Survey.

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

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

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

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

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

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

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

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

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

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

2. *Geology*

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

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

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

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

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

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

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

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

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

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

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

3. Division into soil landscapes

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

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

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

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

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

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

[1]) tide-gauge Merauke.

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

The sand ridges

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

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

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

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

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

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

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

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

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

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

The soil landscapes

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

Young soil landscape. J 1.

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

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

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

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

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

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

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

Profile description (1)[1]

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

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

Medium young soil landscape. J 2.

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

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

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

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

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

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

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

Profile description (2)

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

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

100–120 cm moist, grey, loamy clay with scattered iron concretions and yellow mottles; merging into:

>120 cm moist, grey loamy clay with many yellowish brown iron concretions.

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

Profile description (3)

0– 20 cm moist to wet, black humic clayey silt to silty clay, with tongues grading into:

20– 70 cm wet, grey, clayey silt with many yellow mottles in places soft iron concretions scattered at a depth of about 40 cm; merging into:

70– 90 cm wet, grey loam with sand lenses and shell remnants; yellow mottles also occur in places.

90–110 cm ditto but with scattered iron concretions.

>110 cm wet, grey, fine sandy loam with sand and loam lenses.

Medium old soil landscape. O.1.

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

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

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

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

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

Profile description (4)

0– 10 cm moist to wet crumbly to friable dark brown (10YR 2/2) humic clayey silt; merging into:

10– 30 cm wet, dark brown, friable, clayey silt with rust stains; merging with tongues into:

30– 50 cm wet, light grey (10YR 6/1) yellow and red mottled clay; gradually into:

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

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

Profile description (5)

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

The old landscape. O.2.

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

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

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

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

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

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

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

The following profile occurs in the higher parts:

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

The following profile occurs in the lower parts:

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

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

Decalcification

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

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

TABLE 1.

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

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

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

TABLE 2.

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

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

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

TABLE 3.

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

Fig. 2

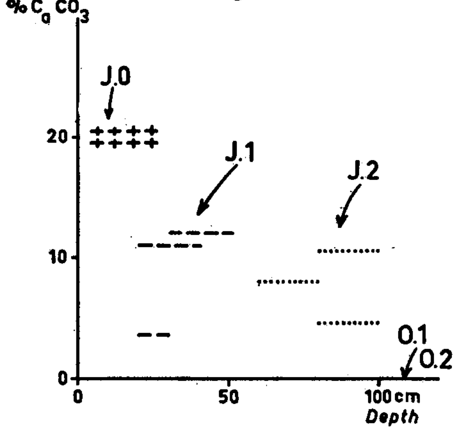
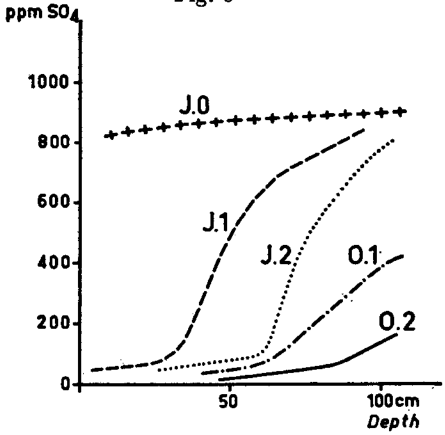


Fig. 3



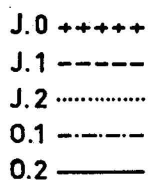


Fig. 2.
Approximate percentage free $CaCO_3$ in the topmost horizon of profiles in the landscapes as recognized.

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

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

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

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

Sulphate formation

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

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

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

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

The various reactions are either elemental or combined.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Determination of the age of the area

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

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

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

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

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

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

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

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

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

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

(Submitted December 1958.)

SUMMARY

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

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

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

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

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

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

SAMENVATTING

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

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

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

Het optreden van sulfaatvorming in deze mariene en moerassige gronden evenals de profielbeschrijvingen, toont een grote overeenkomst met katteklei-gronden. Bij het uitdrogen van de bovengrond wordt bij aanwezigheid van vrije kalk gips gevormd boven het grondwater. Bij het ouder worden der gronden blijkt het sulfaatgehalte in de bovengrond zowel als naar beneden in het profiel af te nemen. In een tussenperiode komt in het medium-jonge landschap J.2 op een diepte van 1 meter gipsvorming voor.

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

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

ZUSAMMENFASSUNG

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

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

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

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

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

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

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

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

LITERATURE

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

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

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

AERIAL SURVEY IN THE VICINITY OF POTCHEFSTROOM, TRANSVAAL

by

Dr. G. C. Maarleveld[1] and Prof. J. S. van der Merwe[2]

1. INTRODUCTORY

In the course of years various authors have divided Southern Africa into a number of physico-geographical units. One of the most recent divisions is the one drafted by Wellington (1955).

In his excellent handbook on Southern Africa this investigator distinguishes 12 regions which are again subdivided. This division is undoubtedly of great scientific value. However for purposes of soil conservation, soil science, botanical survey and advisory work on spatial arrangement this division is less valuable. It appears that for these purposes the regions of Wellington's division provide almost no or very few data or in other words: the given division is insufficiently detailed. Therefore it appeared usefull to investigate to what extent geographical interpretation of aerial photos can contribute to the framing of a more detailed division.

In the first place we will contemplate the geological and morphological characteristics of the landscapes distinguished by aerial survey. In the second place the vegetation of the landscapes will be dealt with and finally the soil scientific value of a detailed survey will be reviewed.

2. AERIAL SURVEY

The survey was carried out based on stereoscopic interpretation of aerial photos of the vicinity of Potchefstroom.

Potchefstroom is situated ca. 120 km southwest of Johannesburg at an altitude of about 1350 m on the vast South-African plateau called the Highveld.

Wellington (1955) divides the Highveld into four areas (fig. 1). In this article only the Highveld with pre-Karroo surface will be dealt with.

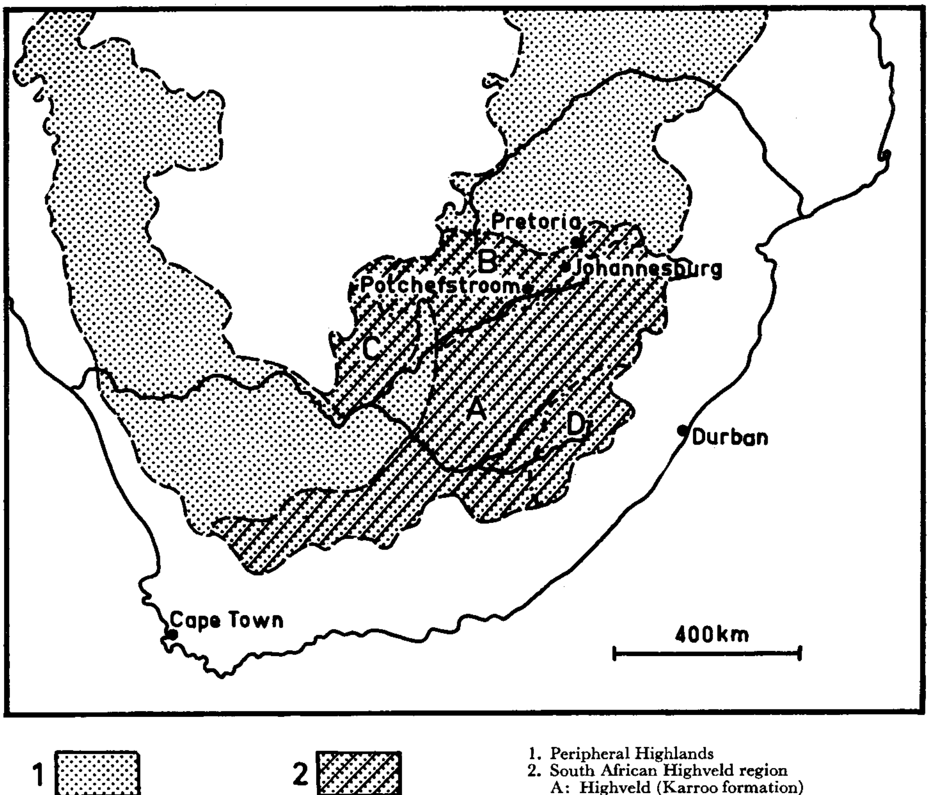
Apart from the high situation the landscape is characterized by the outcrop of rocks of pre-Karroo age. The presence of ridges consisting of hard rock is related to differences in resistence against weathering of the various deposits: the ridges are the remaining harder rocks.

The firm rocks of importance in this article are of pre-Cambrian age and belong for the greater part to the Transvaal System. This System is subdivided into three series: the Black Reef Series, the Dolomite Series and the Pretoria Series. The Black Reef Series is the oldest and is seldom found in the investigated area. The *Dolomite Series* is very important and consists of dolomitic limestones or Olifantsklip alternating with cherty bands and occasionally thin shales. Sparse vegetation and little differences in relief are typical for areas where dolomite crops out. Here the rises of the ground have

[1]) Geologist of the Netherlands Soil Survey Institute, during 1957 lecturer at the University of Potchefstroom, Department of Geography.

[2]) Professor of Geography, University of Potchefstroom.

The authors are indebted to Prof. P. B. Ackerman and Mr. A. A. Bisschoff for advice. Mr. J. Forster made borings for us.



1. Peripheral Highlands
2. South African Highveld region
   A: Highveld (Karroo formation)
   B: Highveld (pre-Karroo surface)
   C: Kaap Plateau
   D: Basuto Highlands.

Fig. 1. Peripheral Highlands and Highveld in South-Africa according to Wellington (1955)

as a rule softly inclining slopes consisting of chert. Numerous quartz veins easily recognizable on the aerial photos occur in the dolomite. These quartz veins have a special hydrological significance as they can prevent water circulation (Nel, Truter and Willemse, 1939). Besides many sinkholes (depressions of varying size) occur. Furthermore dolomitic rock is known for the occurrence of subterranean water flow. In other places water comes to the surface as "eyes". These springs give rise to permanently water carrying rivers as the Mooirivier near Potchefstroom. It is obvious that the area in which dolomite crops out, has to be considered a special landscape. The dolomite landscape is easily recognizable on aerial photos especially by its typical relief, by the frequent outcrops of hard rock and by a tree-less vegetation.

The youngest Series of the Transvaal System is the Pretoria Series called after its typical development in the vicinity of the city of Pretoria. Here quartzites typical for this Series crop out: the Timeball Hill, the Daspoort and the Magaliesberg quartzites with intercalated shales and lavas. In the neighbourhood of Potchefstroom these rocks are also found. Caused by complicated tectonic movements recurrence of the same sequence of rocks is found in various places. Hills and ridges consisting of quartzite are easily recognizable on aerial photos. Here the hard rock crops out nearly always and the ridges sometimes run parallel. We have named the area in which these ridges and hills occur the *ridge-and-valley landscape*. In this landscape also more level parts occur consisting of fairly deeply weathered shales as field investigations have shown. The ridge-and-valley landscape is easily recognizable on the aerial photo also by its special vegetation which will be discussed lateron. The ridge-and-valley landscape is bordered by the *pediment landscape* which slopes to the river valleys. The pediments have been developed in diabase and amygdaloidal andesite. Field research has shown that fine material lies at the surface in most cases with occasionally coarse and angular material at some depth which material, according to its composition, originates from higher grounds. In this case the reason for distinguishing a special landscape was its typical relief. The vegetation of this landscape will be discussed elsewhere in this article.

In the area near Potchefstroom two locally important rivers occur: the Mooirivier and the Loopspruit. Throughout the year the Mooirivier carries water supplied by the springs in the dolomite landscape. The Loopspruit carries varying amounts of water dependent on the precipitation. The Loopspruit has a wide alluvial plain especially at the place where this river falls into the Mooirivier. On aerial photos the moist soils along the rivers are easily recognizable by their darker hues but also by a different vegetation. As the alluvial soils along the Mooirivier and Loopspruit occupy a much greater area than along the brooks (spruiten), a special river landscape has been distinguished. Field investigations have shown that these soils are heavy with black to grey coloured topsoils, however the occurrence of gravel and stones is not uncommon. Concretions of lime are generally found at slight depths. The heavy fluviatile deposit overlies a layer of very coarse, more or less rounded material especially near the river or brook. This layer can be traced going upwards along the slopes the material becoming more angularly shaped, untill further upwards at a fairly steep slope the coarse angular material crops out. Also the heavy grey to black layer can be continued like the layer of the coarse material. In this direction the colour changes and the layer becomes lighter textured.

3. VEGETATION

The vegetation of the various landscapes has already been mentioned before. Of the vegetation in the vicinity of Potchefstroom Louw (1951) has made a thorough study of which a thankful use is made here. This investigator distinguishes: the vegetation of vleis and pools, those of hills and ridges, the grassveld and the thornveld. In this article we will only trace how far the distinguished landscapes are characterized by a certain vegetation.

In the first place we will dwell on the heavy soils along the rivers and brooks i.e. on the association with the largest distribution in the river landscape. As the soils here are heavy and not aerated this is the cause that only shallow rooting trees occur. Only two exotic species are found viz: *Salix babylonica* and *Populus canescens*.

The *pediment landscape* with its faint slopes is characterized by grasses and the Thorn Veld. This grassland is called Themeda Veld[1]) or Sweet Veld and is well reputed with the farmers. It is included among the best grasslands of

[1]) Consequently of the dominating of *Themeda triandra*.

Southern Africa. The accompanying Thorn Veld is characterized by the dominance of *Acacia karroo*.

To-day the Thorn Veld is expanding which is ascribed to deterioration of the grassland, mainly due to overgrazing.

On the higher parts of the *ridge-and-valley* landscape trees, shrubs and herbs rooted in quartzite crevices are found. The lower slopes are generally occupied by mountain grass and *Acacia caffra*, while on the lowest parts often *Acacia karroo* grows. For the *dolomite landscape* "sour" grasses are typical. Very characteristic are *Triraphis andropogonoides*, *Pogonarthria squarrosa* and *Eragrostis gummiflora*. In the Veld this type of grassland is known to be bad, being at its best in spring and early summer.

From the above mentioned appears that by dividing into natural landscapes based on aerial photos, regions can be defined characterized by a specific morphology, geological (petrological) conditions and a specific vegetation. Therefore it is not surprising that the number of farms strongly fluctuates with the type of landscape.

4. SOIL SURVEY

Remains the question of the soil scientific value of the aerial photo map. To be informed on this subject a small part was surveyed in detail and a great number of borings to ca. 1.40 m below surface were made. The surveyed area is indicated on appendix 1. When comparing the soil map (appendix 2) with the aerial photo map (appendix 1) the close similarity is striking. The valley soils in the centre of the map are also indicated on the soil map. According to the soil map parent rock crops out in the ridges occurring in the eastern part of the area. The soil map reveals that the ridge in the centre of the aerial photo map consists of a number of narrow quartzite ridges also with outcroppings of hard rock. Between the ridges rock debris is found. The fairly level soils lying between the ridges (see aerial photo map) consists of grey loam of varying thickness overlying a cemented layer called "ferricrete" (the grey ferruginous lateritic soil of Van der Merwe, 1941). In places the loam layer is thin mostly caused by soil erosion.

The eastern part of the surveyed area consists of chert and belongs to the Dolomite Series. On the aerial photo map this part is indicated as belonging to the higher part of the dolomite landscape. In many places chert crops out while downward on the slopes chert debris comes to the surface. Further downward red loam of varying thickness is found (the brown to reddish-brown ferruginous lateritic soil of Van der Merwe, 1941). The chert debris partly overlies shales, thus a downward movement of the debris must have taken place.

Taking all together it may be inferred that the aerial photo map provides very valuable data for the soil surveyor. At least aerial photo interpretation facilitates to a great extent the work of the soil surveyor.

(Submitted December 1958.)

SAMENVATTING

Aan de hand van stereoscopisch uitgewerkte luchtfoto's werd een bodemkundige opname verricht van een deel van het Highveld in de omgeving van Potchefstroom (Unie van Zuid-Afrika). Ter toetsing van de bodemkundige waarde van de, door luchtfoto-interpretatie verkregen, geomorfologische kaart

(bijlage 1) werd deze vergeleken met een detailbodemopname (bijlage 2) van een deel van hetzelfde gebied. Hierbij bleek, dat eerstgenoemde kaart zeer waardevolle gegevens voor de bodemopname leverde.

De streek rond Potchefstroom werd verdeeld in vier gebieden nl.: het reliëfrijke landschap, het pedimentlandschap, het dolomietlandschap en het rivierlandschap (bijlage 1). Het reliëfrijke landschap is vrij sterk heuvelachtig met tussen de heuvels vlakkere delen bestaande uit diep-verweerde schalies. Dit landschap is op de luchtfoto gemakkelijk aan zijn vegetatie te herkennen, nl. op de hoogste delen alleen begroeiing van bomen en struiken in spleten van het kwartsietgesteente, gebergtegras en *Acacia caffra* op de lagere hellingen en vaak *Acacia karroo* op de laagste delen van de hellingen. Het pedimentlandschap ligt tussen het reliëfrijke- en het rivierlandschap. De pedimenten zijn ontwikkeld in diabaas en amygdaloidale andesiet. De vegetatie bestaat in hoofdzaak uit grassen en het zg. Thorn Veld. Het grasland, genaamd Themeda Veld of Sweet Veld, behoort tot het beste van Zuid Afrika. In het Thorn Veld domineert *Acacia karroo.* Het dolomietlandschap bestaat uit dolomitische kalksteen, ook wel Olifantsklip genoemd, afgewisseld met hoornsteenhoudende lagen en soms dunne schalies.

Talrijke kwartsgangen, op de luchtfoto's gemakkelijk te herkennen, komen in de dolomiet voor. Deze kwartsgangen zijn hydrologisch van betekenis doordat zij de watercirculatie kunnen verhinderen. Evenals elders in dolomietgesteente vindt men hier dolinen, bronnen („eyes") en ondergrondse waterafvoer. Het dolomietlandschap is op de luchtfoto te herkennen aan zijn typisch reliëf, het veelvuldig voorkomen van vast gesteente aan het oppervlak en de boomloze grasvegetatie. Het grasland wordt getypeerd door „zure" grassen en staat als slecht bekend.

Het rivierlandschap omvat de alluviale gronden langs de Mooirivier en de Loopspruit. Het is op de luchtfoto's te herkennen aan de donkere tinten en aan de afwijkende vegetatie waaronder slechts twee, vlakwortelende, boomsoorten, beide exoten nl. *Salix babylonica* en *Populus canescens.* De landschappelijke verschillen komen ook tot uiting in het aantal boerderijen dat per landschap sterk wisselt.

ZUSAMMENFASSUNG

Auf Grund stereoskopisch ausgearbeiteter Luftbilder wurde eine Bodenkartierung vorgenommen von einem Teil des „Highveld" in der Umgebung Potchefstrooms (Süd-Afrikanischer Union). Zur Überprüfung des bodenkündlichen Wertes dieser, durch Luftbildinterpretation erhaltenen geomorphologischen Karte (Tafel 1), wurde diese verglichen mit einer detaillierten Bodenteilaufnahme (Tafel 2) desselben Gebietes. Daraus erwies sich die geomorphologische Karte für die Bodenaufnahme als sehr wertvol.

Die Umgebung Potchefstrooms wird in 4 Teilgebiete verteilt d.h.: reliefreiche Landschaft, Pedimentlandschaft, Dolomietlandschaft und Fluszlandschaft (Tafel 1). Die reliefreiche Landschaft hat ein ziemlich stark hügeliges Gelände mit zwischen den Hügeln, aus tief-verwitterten Schiefer bestehenden flächeren Teilen. Im Luftbilde ist diese Landschaft durch die Vegetation leicht erkenntlich, im höheren Gelände Baum- und Sträucherwuchs nur in Spalten des Quarzitgesteins, Gebirgsgras und Acacia caffra auf den niederen Abhängen und oft Acacia karroo auf den niedersten Abhängen. Die Pedimentlandschaft nimmt eine Zwischenlage ein zwischen der reliefreichen- und

der Fluszlandschaft. Die Pedimente sind entwickelt im Diabas und amygdaloidalen Andesit. Die Vegetation wird hauptsächlich von Gräsern und dem sog. Thorn Veld gebildet. Das Grasland, Themeda Veld oder Sweetveld genannt, gehört zum Besten Süd-Afrikas. Im Thorn Veld dominiert Acacia karroo. Das Hauptgestein der Dolomitlandschaft ist dolomitischer Kalkstein oder Olifantsklip, in Abwechselung mit Hornstein führenden Schichten und zuweilen mit dünnem Schiefer.

Zahlreiche Quarzgänge, im Luftbild leicht erkenntlich, werden im Dolomit gefunden. Diese Quarzgänge sind von hydrologischer Bedeutung weil sie der Wasserzirkulation verhinderen können. Wie anderswo gibt es im Dolomitgestein Dolinen, Brunnen („eyes") und unterirdischer Abfuhr. Im Luftbild ist die Dolomitlandschaft erkenntlich an ihrer typischen Relief, dem häufigen Vorkommen von Gesteinsaufschlüsze und an der baumlosen Vegetation. Das Grasland wird durch das Vorkommen saurer Gräser charakterisiert und wird nicht sehr geschätzt.

Die Fluszlandschaft umfaszt die alluvialen Böden entlang der Mooirivier und Loopspruit. Sie ist im Luftbild erkenntlich an den dunklen Abtönungen und an einer abweichenden Vegetation unter der nur zwei, flachwurzelende, Baumarten vorkommen, die Exoten Salix babylonica und Populus canescens. Die landschaftlichen Differenzen gelangen auch zum Ausdruck in der landschaftlich stark wechselenden Zahl der Bauernbetriebe.

LITERATURE

Louw, W. J., 1951: An ecological account of the vegetation of the Potchefstroom Area. Botanical Survey of South Africa, Memoir nr. 24.

Merwe, C. R. van der, 1941: Soil Groups and Sub-Groups of South Africa. Dep. Agric. For. Chem. Series. nr. 165. Sci. Bull. nr. 231.

Nel, L. T., F. C. Truter and J. Willemse, 1939: The Geology of the country around Potchefstroom and Klerksdorp. Geol. Survey Sheet nr. 61.

Wellington, J. H., 1955: Southern Africa. Cambridge.

SOILS AND GILGAI MICRORELIEF IN A CENTRAL AFRICAN RIVER PLAIN IN THE LIGHT OF THE QUATERNARY CLIMATIC CHANGES

by

Ir. M. F. van Oosten [1])

1. INTRODUCTION

The Lufira River, in the Province of Katanga (S. E. Belgian Congo), is one of the tributaries of the River Lualaba, which forms with other streams the mighty Congo River. About 150 km north of the "coppertown" Jadotville the Lufira leaves the high plains of Katanga, where its source lies near the North Rhodesian border and enters a deep tectonic depression in which it takes its course through a broad, rather flat plain, known as the Lufira Valley. This depression is one of the smaller ones, called "Rift Valleys" which accompany the big Central African Rift Valley, extending from the Red Sea (itself forming the northern prolongation) to Mozambique. The great Central African lakes are the deepest parts of this rift valley. The deepest part of the Lufira Valley is filled-in with different fluviatile and lacustrine sediments, great parts of which are covered by marshes. Situated on a somewhat lower level than the rest of the valley and strongly differing by its soils and vegetation, we will call this part the Lufira Plain. The Lufira river flows through these deposits and marshes (see fig. 1).

Nearly all lacustrine sediments contain considerable amounts of lime and gypsum and the surface has a typical micro-relief, known in some other parts of the world and especially in Australia, from where the name originates, as "gilgai micro-relief".

The problem of the formation of the different sediments and of the origin of the gilgai micro-relief arose during the preparation of soil maps of two parts of the Lufira Plain, each of about 25 $\times$ 25 km, from October 1953 till October 1954. The simplified soil map of the northernmost of these two parts is shown here (see appendix).

As it was not possible during the field work to devote any special time to the study of the subjects treated with in this article, it is fairly certain that a number of facts, which would perhaps have changed to some extent the explanations presented here, have certainly been overlooked. Nevertheless, our ideas deduced from field observations, may contribute to the solution of the interesting problem of climatic changes in the Quaternary in Africa and to the still scarce literature on gilgai soils.

2. GEOLOGY

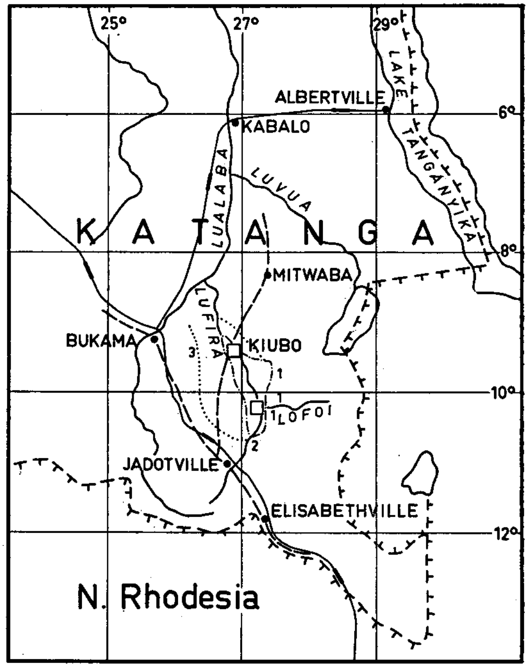
Between the Cambrium and the Lower Carboniferous, the so-called Kundelungu sediments were deposited. These sedimental rocks, mainly shales and lime shales, are now bordering the Lufira Valley to the east and the south and are forming its bottom.

[1]) This study was made when writer was soil scientist of the I.N.E.A.C. (National Institute for Agricultural Study in Belgian Congo); part of the field work was done in collaboration with Mr. A. v. Wambeke of mentioned institute. For the permission to publish the results and part of the soil map, writer expresses his gratitude to the Board of Directors of the I.N.E.A.C.

Fig. 1. Location map of the Lufira Plain, Belgian Congo

1. Kundulungu Plateau
2. Monts Koni
3. Kibara Mountains.

Railroad
Road
Lufira Plain
Lufira Valley
Mapped blocks



After the deposition of the Kundelungu sediments, intensive folding of their southern part took place resulting in the formation of what are called the „Monts Koni", now forming the southern limit of the Lufira Rift Valley.

From the Cretaceous till the Miocene the deposition of rather thin layers on top of the Kundelungu sediments took place. Towards the end of the Tertiary a general peneplanation marked the end of the geological phenomena in the regions now surrounding the Lufira Valley.

The Quaternary in Africa was characterized by a number of climatic changes, the pluvial and dry periods of which correspond with resp. the North-European glacial and interglacial periods. This conformity is for North-Africa fairly apparent to-day. From the studies in the Lake Albert and Lake Edward region resulted the following division of the Quaternary for this continent. (Leaky, 1931, 1935, 1949).

Recent	tendency to drier
	NAKURAN; humid phase
Late Pleistocene	dry phase
	MAKALIAN; humid phase
Upper Pleistocene	dry phase
	GAMBLIAN; pluvial period
Middle Pleistocene	dry phase
	KAMASIAN; pluvial period
Lower Pleistocene	dry phase
	KISEGIAN; pluvial period

The Kisegian, Kamasian and Gamblian correspond with the Mindel-, Riss- and Würm glaciations of Northern Europe. When Leaky made his investigations in Africa, the history of the Late Pleistocene or the Late Glacial as it is mostly called, was still rather obscure. So he did not try to correlate his periods after the Gamblian with any period of Northern Europe. But his number of dry and humid phases correspond exactly with those known from investigations in the Middle East as described recently by Butzer (1957). One dry phase after the last great pluvial, synchronizes with the North European Alleröd time of the Late Glacial. A following wet phase corresponds with the last advance of the ice after the Alleröd, whereas a prolonged very dry period represents the time between Preboreal and Atlantic, the latter synchronizes again with a last wet period. As the Central African wet and dry periods may be assumed to be contemporary with those in the Near- and Middle East, the Makalian represents in this case the last cold phase after the Alleröd time (Younger Dryas) and the Nakuran the Atlantic.

3. GEOMORPHOLOGY

According to Lepersonne, Cahen and Mortelmans, the tectonic movements which caused the formation of the Lufira Rift Valley, took place during the dry phase between Kamasian and Gamblian (Eemian interglacial). Besides the downward movement of the Rift Valley bottom, an uplift of a part of the Kundelungu system, now bordering the Valley to the east, took place. As a result the difference in altitude between the Valley bottom and the Kundelungu Plateau, the latter with its horizontal skyline still remarkably reflecting the end-tertiary peneplain, amounts today up to 400 m. The Kundelungu escarpment rises very steep from the Lufira Valley, situated on 900 m elevation; a considerable part of this escarpment is a completely vertical wall.

To the west the Lufira Valley is separated from the Upemba Rift Valley, where the Lufira joins the river Lualaba, by the Kibara Mountains consisting of older sediments which have never been covered by those of the Kundelungu system.

The Lufira river enters the Rift Valley from the already described Monts Koni in the south via a number of falls (Chutes Cornet) and leaves it, after a course of about 150 km at the village of Kiubo situated at the road Jadotville-Mitwaba. Here, the falls of Kiubo (45 m high) mark the entrance to the deeply cut canyon in the Kibara Mountains, through which the river continues its course to the Upemba Valley.

About 20 km to the southeast of the Kiubo falls the Dikuluwe river coming from the southwest joins the Lufira, more upstream preceded by the Lufwa, which comes from the northeast. About 100 km upstream near the village of Mokebo, the Lofoi joins the Lufira, coming down the Kundelungu escarpment with the highest fall in Africa and the second highest in the world (380 m in one jump).

A great part of the Rift Valley is a flat or slightly undulating plain, covered with a low dry forest. The transition to the Lufira plain situated 10–20 m lower, is in general very gradual, but in some places of the western border a rather steep, 5–10 m high escarpment exists.

The Lufira Plain, extending over most of the length of the Valley from some distance north of the Chutes Cornet till the Kiubo Falls, has a width of 15 to about 22 km and becomes gradually wider to the north. Its central part is covered by impenetrable marshes through which the Lufira streams, its waters in open connection with the marshes. North and south of these marshes are large flat grass plains in some places extending from horizon to horizon. The only marked relief consists of river levees 1–2 m in height. A great number of old river beds and ox-bows, sometimes with low eroded levees prove that these rivers repeatedly changed their courses.

The whole Rift Valley, part of it a game reserve area, has abundant wild life; different species of antilopes including the giant Eland Antilope, buffaloes, elephants, hyenas, hippopotamus and leopards are found here. Lions, abundant on the Kundelungu plateau, have sometimes been observed.

4. VEGETATION

The dry forest outside the Lufira Plain consists of *Combretum*, *Terminalia* and *Pterocarpus* as dominating species. It is a rather open, low forest with abundant growth of grasses during the rain season. The grass vegetation of this plain is rather poor in species. The dominating grasses are *Themeda triandra*, *Hyparrhenia* sp., *Setaria* sp. and *Panicum* sp. The *Leguminosae Sesbania* sp. and *Crotolaria* sp. are often mixed with the grasses.

The river levees, only 100 to 300 m wide, are often characterized by a fair stand of *Acacia (Faidherbia) alba*. In the southern part of the plain *Borassus* sp. can be found scattered on the river levees.

5. SOILS

5.1. General

The soils of the Lufira Valley outside the Lufira Plain belong to the red latosols. Their colour is 5 YR (Munsell Color Chart) when shales and 2.5 YR when lime-shales form the underlying rock. The profile development is restricted to a surface layer of 15–20 cm with 1–2% humus and a structural B-horizon. Some deep soils may occur, but often the underlying rock is reached within a depth of 1 and 2 meter. Some dm above the rock a thin gravel layer of rounded latosolic concretions and quartz gravel is often found. Some rounded gravel and cobblestones may be present together with the latosolic gravel in the overlying soil or at the surface, but in some places heavy concentrations are found at the surface of somewhat lower situated elongated strips, or covered with only a thin soil layer.

Large areas of the Valley have a hard laterite surface crust or are only covered with 10–30 cm of grey or grey-brown soil. Nevertheless, vegetation is not lacking, the roots of which penetrate the many cracks of the laterite crust.

The Lufira Plain consists mainly of very heavy, grey or grey-brown clays with gilgai micro-relief. They will be discussed in detail in § 6. A part of these gilgai soils is inundated during the rain season. The depth of inundation varies from some cm to one m or even more and flooding lasts from 1 to 5 months. Situated between the gilgai soils and the marshes are half bog soils (near the marshes). They often have a deep black, humose surface layer, with 10% organic matter or more. They are covered with undecomposed plant remains and inundation lasts 8 to 10, in some wet years even up to 12 months. There is no structural profile development as they are always wet. The black colour changes gradually into grey reduction colours with heavy brown mottling when lying above the groundwater. At a greater distance of the marshes, where the period of inundation is shorter, the black layer becomes gradually thinner. These soils belong to what were formerly called "humic gley" and "low humic gley" soils. In certain types a layer with lime concretions at a depth of about 1.50 m may be found, but gypsum is generally absent. Soils really transitional to the gilgai soils have a very slight microrelief and a gypsum layer at 195 cm below surface; deeper down to 240 cm a layer with lime concretions is found.

The transitional belt between the gilgai soils and the described red latosols, forms at the same time the transition between the Lufira Plain and the other part of the Valley. Its soils generally resemble the gilgai soils, but latosol concretions may be abundant at the surface and than a layer of these concretions is generally found at a certain depth. Sometimes this layer overlies the shales directly. In other cases a layer, comparable with the material of the gilgai soils and containing lime concretions and some gypsum, may be found under the layer with latosolic concretions. A remarkable feature of these transitional soils is the great number of rounded pebbles and cobblestones found at the surface, mixed with numerous prehistoric tools made out of these cobble-stones.

Along the Lufira and its tributaries and along a part of their old courses, levees occur with soils markedly lighter textured than the gilgai soils. They are characterized by a considerable silt fraction (45–55%) and a small percentage of fine sand. Contrary to the adjoining gilgai soils the adsorption complex is mainly Ca-saturated. Their structure is fine blocky above 30 cm and medium angular blocky between 30 and $\pm$ 130 cm.

Partly situated between the meanders of the rivers, partly forming low lying elongated strips along the rivers, basin soils are found. They are light to heavy clay soils with sometimes a rather varying texture. Sometimes sand is found in the subsoil. They are badly drained and often inundated for long periods, the duration of inundation depending on the altitude. Due to the drainage conditions the topsoil is often strongly humose and sometimes even a surface muck layer has been formed. Mottling is abundant throughout the profile and sometimes reduction colours occur already high in the profile. Contrary to the gilgai soils lime concretions are never found; some dispersed small gypsum crystals have sometimes been observed. Among the differences with the gilgai soils and the transitional soils are the 10–20 times lower values of Na in the adsorption complex. As a result Ca and Mg occupy about 95% of the adsorption complex, the Mg-content being generally somewhat higher than the Ca-content.

In the northern part of the Lufira Plain along the Lufira a soil occurs the topographical situation of which suggests an older river levee system. Its texture is about the same as that of the recent river levee soils, even there may be slightly more sand (3–8%). In some places two superimposed profiles are found; after gradually becoming heavier to a depth of 1–1,50 m a sudden change in texture occurs. The fine sand fraction increases up to 30–45% and the colour changes from yellow-brown to grey-brown. Where these soils are situated along the border of the Lufira Plain they cover the described transitional soils with the rounded pebbles and cobble-stones.

We will also describe a formation found near Kiubo (see soil map) and in some other places more to the south which is no soil properly speaking. It is a hard, throughout caverneous lime crust of 25 to 100 cm. It lies at the surface or is covered by a generally rather thin soil layer. At a depth of some dm to 1 m under the lime crust reddish lime-shales are found. Between lime crust and shales reddish soil is found with a downward increasing number of shale fragments. The soil is the product of the weathering of the shales as is proved by some intercalated rock material different from the shales and still present as a thin horizontal layer in the soil.

Similar lime crusts, known as desert crusts, are known from North Africa and the United States. They are supposed to have been formed in a very dry climate.

In one place a thick layer of whitish calcareous material underlies the lime crust, mixed with a great number of rounded pebbles and cobble-stones of the same type as described above. This material must have been deposited before formation of the lime crust.

5.2. Geogenesis of the soils

When trying to reveal the formation of the described landscape, there are some facts, which may serve as a starting-point.

Already the numerous artifacts found between the rounded cobble-stones at the surface of the gilgai-red latosol transitional area were mentioned. Their age has been determined by Mr. Cabou, Director of the Archeological Museum at Elisabethville, as being Late Pleistocene, i.e. the Makalian and a part of the following dry phase. As these artifacts and cobble-stones are concentrated along the borders of the gilgai micro-relief of the transitional soils, they have been involved in the formation process of the micro-relief during the period following the Makalian.

The discussed lime crust near Kiubo must have been formed in a very dry period, following the deposition of the mentioned underlying white calcareous material with the rounded stones. This places the origine of the lime crust also after the Makalian.

The rounded pebbles and cobble-stones themselves can only have been deposited during a wet period preceding the Makalian and in which displacement of large masses of water has taken place. The same argument can be used in the case of the latosolic gravel layer found in the transitional soils. They must originate from a wether or not cemented and afterwards destructed part of a laterite formation described below.

When trying to correlate these facts with the different Quaternary periods, we may arrive at the following scheme. After formation of the Rift Valley in the dry period following the Kamasian, a lake occupied the place of what is now the Lufira Plain during the Gamblian. The Lufira and other rivers brought water from the surrounding mountains and from the Katanga Plateau into this lake, filling it gradually during the long Gamblian period. As a drainage system in the direction and in place of the later formed Rift Valley and also the passage through the Kibara Mountains were already formed after a first uprising of the Kundelungu Plateau in the Miocene (Lepersonne, Cahen and Mortelmans), the course of the waterflow in the Rift Valley after its formation was already more or less fixed. As the clay sediments with the gilgai micro-relief are about 6 or 7 m thick, there must have been a considerable difference in level between the original lake bottom and the surface of that part of the Valley now covered by the red latosols. It is not clear wether the lower part represents a river valley, cut in the shales by the Lufira before or during the forming of the Rift Valley, or is only the deepest sunken central part of the latter, but the difference must have existed before the formation of the lake. At Kiubo, upstream of the Kiubo Falls, there is in the river a high threshhold on which the bridge in the Jadotville-Mitwaba road is constructed. During the dry season the river can be crossed here by foot. During the Gamblian this threshhold was perhaps even higher than today. A deeper sunk central part of the Valley may explain the former existence of a lake, the water of which was on a level with the treshhold.

Deposition of the latosolic gravel on top of the shales in the red latosol region and of the same material in the already mentioned transitional soils of the Plain, can only have taken place during a wet period with abundant water as this gravel is the disruption product of an older laterite crust. Therefore the author dates the formation of this laterite crust also back to the Gamblian pluvial. The formation of such a crust can still be studied in some places where shales are under the influence of the groundwater of the Plain. Here the crust dates back to a younger period (probably to the Nakuran) and the various stages of its formation are still visible. On top of a layer of nearly unaltered, platy shale fragments lies a layer of irregular rounded, yellow-brown concretions. Higher in the profile concretions are increasingly cemented thus giving rise to a real hard crust of still recognizable concretions near the surface. When breaking the concretions or even the crust, the original shale structure is still recognizable. After disruption these crusts furnish the material for the rounded, shining, reddish-brown latosolic concretions which, though strongly impregnated with iron, still reveal their origin from the shales.

After a short and not very severe dry period, deposition of the parent material of the red latosols and of the rounded pebbles and cobble-stones took place during the following humid Makalian. The red latosols are situated on the same level as the now existing parts of the laterite crust. We consider these parts to be remnants of the disrupted crust from the Gamblian period, which explains its very irregular occurrence between the red latosols.

The parent material of the red latosol can only have been deposited after disruption of the laterite crust in these places; this is also proved by the occurrence of a layer of concretions on top of the unaltered shales in these places. Thus this layer and the layer of concretions in the transitional soils of the Plain were deposited during the disruption of the laterite crust. In the next phase, the rounded pebbles and cobble-stones were transported via still recognizable lower lying places with heavy concentrations of stones in the red latosol region. Sometimes these stones are still mixed with latosolic gravel.

In some places they are found in the latosolic gravel layer between the red latosol and the shales and also in the gravel layer of the transitional soils where these soils are underlain by lime shales. These soils don't show the gilgai micro-relief and the position of stones and gravel has not been disturbed as in the transitional soils with micro-relief.

During the last sedimentation phase the transported soil increased and the parent material of the red latosol and the soil on top of the gravel layer of the transitional soils were deposited, both still partly mixed with pebbles and stones.

During the end of the Makalian or the beginning of the following dry period, the people that used the rounded stones for tool-making must have lived along the border of the Lufira Plain.

The long and very dry period following the Makalian must have been the time of formation of the described lime crust.

During the last humid phase (the Nakuran) the Lufira and other rivers formed levees and basins. As already mentioned some older alluvial deposits along the Lufira can be found. Butzer (1957) thought it possible to distinguish some minor climatic changes in Northern Africa and the Middle East correlating with the North-European Subboreal-Subatlantic. A connection with the mentioned older and younger deposits of the Lufira may exist, but our observations don't allow any further conclusion.

6. THE GILGAI MICRO-RELIEF

6.1. Profile Description

The first impression one gets in the Lufira Plain of a typical, well developed gilgai soil during the dry season when all grass vegetation has been burnt down, is of a wide plain, covered with a regular pattern of dark coloured, round or slightly polygonal depressions, all of about the same size and separated by much lighter coloured, grey-brown, yellowish-brown or olive-brown, higher parts. The size of the depressions, from border to border is 10–15 m; the depth varies between 20 and 50 cm, but size as well as depth are mostly rather uniform in the same type of gilgai soil. The horizontal stretches of the higher parts and of the depressions are rather small; as a result the slopes of the depressions occupy most of the surface.

Apart from the colour of the soil the higher parts are still more contrasting with the depressions as they often are covered with numerous whitish lime concretions, sometimes of considerable size. In type 2 (see below) concretions of 15 cm in diametre are no exception. Especially these bigger concretions are of a very irregular shape, with a brownish weathered surface and mostly hollow inside; the inside surface covered with fine $CaCO_3$ crystals. Where latosolic concretions and cobble-stones occur at the surface, as described for the transitional soils, they are found exclusively at the surface of the borders. During the rain season the vegetation often reflects perfectly the micro-relief, but in the reverse way. Due to more favourable moisture conditions the grasses are better developed and taller species are growing in the depressions. These correspond with places having higher or denser vegetation or differently coloured vegetation when different species occur.

The gilgai soils of the Lufira Plain can be divided into a number of types different in colour, quantity of lime and gypsum, occurrence of these constituents in more or less concentrated layers, quantity and depth of mottling and dimensions of the micro-relief. Four main types can be distinguished, besides some other occupying only small areas in the southern part of the Plain.

As the profiles of the depressions have many features in common and sometimes are resembling each other strongly, a classification has been made of the profiles of the higher parts.

Type 1. Brown; with less gypsum than in the other types and never forming a hard, very concentrated layer; lime concretions at the surface not abundant; very few mottling; medium micro-relief (25–45 cm); in general not inundated during the rainy season. The surface is covered with many big termite hills (1.5–3/ha) of 1–2 m high.

Type 2. Light grey-brown, but as a result of abundant and strong mottling giving a yellowish-brown impression; abundant gypsum in a strongly concentrated, hard layer; lime concretions occur at a certain depth under the gypsum layer, also as a layer of intensive concentration; very big and abundant lime concretions at the surface; strong micro-relief ($\pm$ 50 cm); inundated during the rainy season, in some places to 1.50 m.

Type 3. Dark grey; gypsum and lime as in type 2; contrary to the other types effervescence with HCl occurs already above the gypsum layer; strong micro-relief; no or perhaps slight inundation during the rainy season.

Type 4. Light grey; gypsum and lime as type 2; abundant lime concretions (only small-sized) at the surface; directly from the surface downward many fine lime concretions occur throughout the soil; the whole profile effervesces with HCl; weak micro-relief (10–25 cm) but the depressions are irregularly shaped and sized.

As an example the description is given here of the profile of a depression and of a higher part of type 1.

Depression

0– 15 cm	Dry; clay; small angular blocky, hard; distinct mottling abundant around roots; many roots; 10 YR 3/1.
15– 40 cm	Dry; clay; medium angular blocky, hard; few mottling around roots; many roots; 10 YR 4/1.
40– 60 cm	Dry; clay; coarse prismatic, breaking into coarse and medium angular cubic blocks; very hard; very few mottling around roots; many roots and hair roots; 10YR 4/1.
60– 90 cm	Dry; clay; very coarse angular prismatic, with flat, shiny faces, breaking into coarse and medium angular cubic blocks, also with flat, shining faces; some indistinct mottling; hair roots medium abundant; 10YR 4/1.
90–140 cm	Dry; clay; coarse prisms as above, breaking in medium blocks; very hard; few mottling; hair roots medium abundant; 10YR 4/1.
140–180 cm	Slightly moist; clay; coarse, angular cubic blocks with flat, shining faces; medium abundant, not very distinct mottling; some scattered gypsum; few hair roots; 10YR 5/2.
180–210 cm	Slightly moist; clay; texture as above; compact; distinct, medium abundant mottling (7.5YR 6/8); abundant gypsum in big, well developed crystals; some hair roots; slight reaction with HCl; 2.5Y 6/2.
210–240 cm	Moist; clay; medium angular blocky, with flat, shining faces; very pronounced, medium abundant mottling (10YR 6/6); many gypsum crystals; still some hair roots; fair reaction with HCl; 10YR 6/1.
240–260 cm	Moist; clay; more or less structureless, but breaking into weakly developed blocks; much distinct mottling (10YR 6/8) occasionally hardened into soft concretions; medium abundant gypsum crystals; good reaction with HCl; 10YR 7/1.
260–280 cm	Very moist; clay; structure as above; friable; abundant very pronounced mottling (7.5YR 6/8), occasionally hardened into soft concretions; some small gypsum crystals in small conglomerations; strong reaction with HCl; 10YR 7/1.
280–300 cm	Very moist; mottled clay with abundant lime concretions; strong reaction with HCl.

Foto Ir. van Oosten Stiboka nr. 10905

Fig. 2.
Lufira river with levee. In the background the Kundulungu peneplain.
La rivière Lufira avec levée naturelle. En arrière-plan la pénéplaine de Kundulungu.

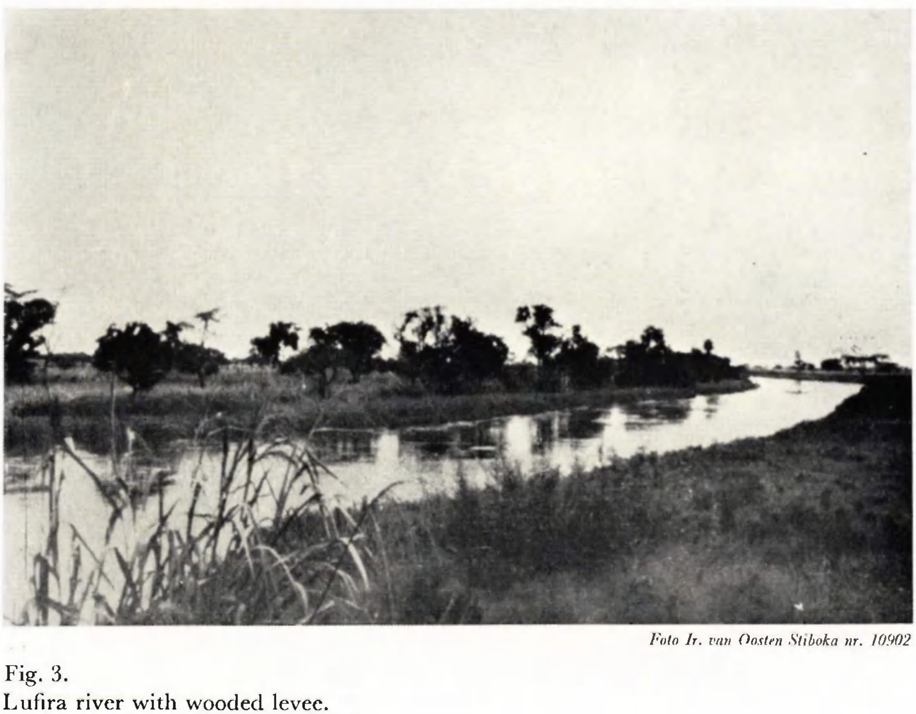


Foto Ir. van Oosten Stiboka nr. 10902

Fig. 3.
Lufira river with wooded levee.
La rivière Lufira avec levée naturelle boisée.

Foto Ir. van Oosten Stiboka nr. 10904

Fig. 4.

Gilgai plain in summer; dark coloured depressions and borders lighter coloured by lime concretions at the surface.

Plaine à microrelief Gilgai en été; des dépressions à couleur foncée et des rebords clairs par des concretions de chaux superficielles.

Foto Ir. van Oosten Stiboka nr. 10901

Fig. 5.

Gilgai plain in rainy season.

Plaine à microrelief Gilgai en saison des pluies.

Foto Ir. van Oosten Stiboka nr. 10903

Fig. 6.
Profile pit; ridge in the foreground, basin (dark coloured) in the back.
Coupe de profile; au premier plan levée naturelle, une dépression (à couleur foncée) en arrière-plan.

Higher part

0– 14 cm	Dry; clay; small and medium angular blocky, hard; much distinct mottling around roots; many roots; 7.5YR 6/2.
14– 38 cm	Dry; clay; medium and coarse angular or somewhat subangular blocky; hard; little mottling around roots; some small lime concretions; medium abundant roots; 7.5YR 5/4.
38– 65 cm	Dry; clay; coarse angular blocky; hard; some little mottling around roots; some small lime concretions; medium abundant roots; 10YR 4/4.
65–125 cm	Dry; clay; coarse angular blocky; hard; no or some scattered mottling; bigger lime concretions; few roots; slight reaction with HCl; 10YR 4/4.
125–140 cm	As above, but smaller lime concretions and fair reaction with HCl; 10YR 4/3.

Two common features, found in all types, but not yet mentioned above, are the wide cracks at the surface, especially on the higher parts during the dry season and furthermore the penetration of dark surface material along the cracks to the deeper layers in the depressions. The cracks can be several cm wide and sometimes penetrate the soil to a depth of 1.50 –2 m. The dark surface material occurs as dark humus coatings on the surfaces of prisms and blocks of the deeper layers.

In some types the surface of the depressions is self-mulching. On drying or under very slight pressure the soil is breaking into fine structure elements, but it becomes a structureless, sticky mass when wet.

The most remarkable profile characteristic is the change of colour from blackish to brown or grey-brown over a distance of some meters only. This is beautifully demonstrated when digging a trench cross-sectioning a higher part and a depression. A second characteristic is the typical structure of coarse prisms and blocks with flat, shining surfaces, which also occur in all types. On the slopes between higher parts and depressions the flat upper faces of the peds are often inclined parallel to the surface of the slope.

As is shown in table 1a, the clay content of the gilgai soils is very high and the clay fraction + fraction 2–20 micron together nearly always amount to more than 80%. In a certain type, occurring in the southern part of the plain, even a clay content of 80% and a content of clay + 2–20 micron fraction of 95% was found. As also can be taken from the tables 1a and 1b, the clay content in the depressions is always less than in the higher parts, at least in the toplayers. The whole soil is a very sticky, impermeable clay when wet and cracks strongly on drying, then forming the described very hard prismatic and blocky structures.

The pH of the toplayers is generally lower than would be expected after a first impression. In most of the types there is no reaction with HCl in the layers overlying the gypsum-concentration layer, though lime concretions may be present. In general a pH > 7 is found at the depth at which reaction with HCl starts; often this depth is the same as where gypsum appears in the profile, but sometimes it is higher or lower. Generally gypsum in profiles of type 1 occurs at a depth of $\pm$ 60 cm in the higher parts i.e. $\pm$ 1 m higher than in the depressions. In other types the depth of occurrence below surface is often less; in type 2 gypsum sometimes occurs even at the surface of the higher parts. The layer with lime concretions also may occur much higher as

TABEL 1a. Analyses: Depression

Horizon	Depth (cm)	Texture (mu)								C	pH	Exchangeable bases		Soluble salts	$CaCO_3$	$CaCO_4$ 2 aq.
		0–2	2–20	20–50	50–100	100–250	250–500	500–1000	1000–2000			K	Na			
H_1	15	61,3	18,5	15,4	3,1	1,0	0,2	0,3	0,2	1,68	5,2	0,27	0,70	43	–	–
H_2	40	63,5	18,4	14,3	2,0	1,2	0,2	0,1	0,3	1,47	5,4	0,29	0,84	35	–	–
H_3	60	61,3	15,4	17,3	3,7	1,7	0,2	0,2	0,2	1,10	5,6	0,29	0,90	35	–	–
H_4	90	60,9	17,4	16,7	2,7	1,2	0,3	0,1	0,7	0,80	6,3	0,23	1,56	38	–	–
H_5	140	64,1	14,5	16,5	3,3	1,1	0,2	0,2	0,1	0,57	6,8	0,25	2,35	77	–	–
H_6	180	67,8	14,6	12,8	2,8	1,3	0,3	0,2	0,2	0,28	7,4	0,30	4,70	590	1	1
H_7	210	64,8	12,0	12,4	2,9	1,6	0,6	2,7	3,0	0,20	7,4	0,54	5,32	1.643	1	11
H_8	240	68,1	12,2	13,3	4,1	0,3	0,3	0,7	1,0	0,20	8,0	0,40	6,70	1.131	7	2
H_9	260	67,3	12,1	14,0	2,8	1,5	0,3	0,7	1,3	0,15	7,9	0,40	6,90	1.500	3	3
H_{10}	280	69,5	12,1	12,7	2,8	0,8	0,3	0,8	1,0	0,15	8,0	0,41	7,80	1.438	6	3
H_{11}		69,7	12,3	13,0	2,1	1,1	0,3	0,5	1,0	0,13	8,0	0,43	8,00	1.408	5	2

TABEL 1b. Analyses: Higher part

Horizon	Depth (cm)	Texture (mu)								C	pH	Exchangeable bases		Base exchange capacity	Soluble salts
		0–2	2–20	20–50	50–100	100–250	250–500	500–1000	1000–2000			K	Na		
H_1	14	77,0	11,9	6,3	2,0	1,7	0,3	0,4	0,4	0,90	6,4	0,47	0,55	19,6	96
H_2	38	76,9	12,1	6,7	1,7	2,0	0,2	0,2	0,2	0,58	6,5	0,43	0,92	19,1	91
H_3	65	75,9	12,1	7,5	2,4	1,7	0,1	0,2	0,1	0,37	7,5	1,29	3,35	22,9	144
H_4	125	77,3	10,0	7,6	2,2	2,2	0,2	0,2	0,3	0,36	7,7	0,52	4,00	23,1	418
H_5	140	75,3	14,4	7,0	1,2	1,2	0,1	0,1	0,1	0,23	8,0	0,63	4,50	21,8	1.189

in the example of type 1; it may be found immediately below the gypsum layer or even partly mixed with it, but also a distance of 1 meter may exist between gypsum and lime layer.

An important feature is the high percentage of Mg in the adsorbing complex, being often 2–3 times as high as Ca.

TABEL 2. Analyses

Horizon	Depth (cm)	Exchangeable bases				Soluble Salts	$CaCO_3$
		Ca	Mg	K	Na		
H_1	30	3,1	9,1	0,57	0,94	57	0,3
H_2	55	2,0	12,7	0,64	2,31	411	–
H_3	100	4,8	16,8	0,64	5,10	944	5,1
H_4	160	4,5	18,2	0,56	7,00	1,270	6,1
H_5		4,8	12,8	0,37	2,90	317	2,6
H_6		3,7	8,6	0,31	1,17	94	1,4
H_7		3,6	8,6	0,29	0,87	56	0,5

As the complete analysis of the exchangeable bases was not available for the example[1]) given here, table 2 shows the figures for a type of a gilgai soil in the southern part of the Plain. In this soil a lime concretion layer occurred from 100–160 cm below surface; gypsum was absent. The figures are from a profile in a depression. As analyses of the red latosols also show Mg figures as high as or higher than the Ca figures, the chemical composition of the Kundelungu shales must be held responsible for the high Mg content of these soils.

The Na-content in the adsorbing-complex often was as high as the Ca-content but was sometimes markedly higher in certain layers. Soluble Na-salts however did not occur; soluble salts, measured with a conductivity bridge, never reached a conductivity of 4000 micro-ohms, the figure generally taken as a limit between saline and non-saline soils. A considerable part of the soluble salts consisted of $MgSO_4$; it appeared at the bottom of the profile pits some days after digging as a thick, very loose, flaky layer with long white crystal needles.

6.2. Discussion of profile data

When considering the given profile descriptions and the chemical data, it is impossible to resist the impression, that the described gilgai soils have a good deal of their characteristics in common with Solonetz soils.

Though the given Na-figures does not always reach the 15–30% of the total of exchangeable bases, given by different writers as typical for a well developed Solonetz, we may point to the high Mg-figures. Mg-Solonetzes with 40–60% Mg in the adsorbing-complex are known from different parts of the world. In these cases it is assumed that a high Mg-percentage in the adsorbing-complex has the same effect as Na. Not all scientists agree to this viewpoint, but it appears to have an additional effect as to the formation of solonetzic features in the soil, when occurring together with Na in the complex. Although the columnar structure with rounded tops characteristic of a

[1]) As the Soil Laboratory had great difficulties in analysing these lime- and gypsum-rich soils, at that time unknown in Belgian Congo, only a small part of the analyses of importance for this article were carried out, when a fire destroyed all soil samples. So chemical data are rather scarse and often inadequate for our purpose.

Solonetz soil does not occur, Solonetz soils with a prismatic structure as in our case have often been described. If ever a real saline soil existed from which the present profile has been developed by leaching of the soluble salts, is difficult to decide, but is highly probable. Anyhow even now a fair amount of $MgSO_4$ is found in the deeper layers, as is already mentioned.

Also the low pH of the toplayers does not point to a Solonetz, but in the now prevailing climate, causing a large accumulation of organic matter which was even larger in the humid Nakuran climate, a certain degree of solodization may be expected. Little is known about Mg-Solonetzes. Their characteristics and differences in profile development after leaching, compared with real Na-Solonetzes have hardly been studied. We suppose, that during the Solonetz stage the pH in such soils never rises to real alkalinity as in Na-Solonetzes as no formation of strongly hydrolized $NaCO_3$ takes place. Author's recent observations in the Middle East seem to confirm this. Heavy clay soils with coarse prismatic structure, strongly resembling the gilgai soils in profile development, showed Mg-percentages up to 90% in the adsorbing-complex while the pH was only 8.8–8.9, figures quite common in other soils of the region. In these soils, situated in a sub-arid climate with "Brown Soils" as the normal zonal soil development climax, a significant accumulation of organic matter was lacking and leaching was rather insignificant, so the absence of any sign of solodization seems very logic. In tropical climates however when special conditions prevent a rapid decomposition of the organic matter produced by an abundant vegetation, or in temperate climates where a fair amount of organic matter goes with considerable leaching, a certain degree of solodization may be expected. Actually an old marine deposit occurs in the Netherlands, known as "Knipklei", having a high percentage of Mg in the adsorbing-complex and besides a layer with bad columnar structure, a low (weakly acid) pH but no bleached horizon, typical for well-developed Solodi. This however can also be explained by the fact that the pH of these Mg-soils is never high enough to cause an important dispersion of the clay, which appears to be one of the main reasons for the formation of the bleached horizon.

A case of solodization in the tropics as mentioned above, is represented by the Lufira soils, where the low pH also indicates a certain solodization also without bleached horizon, for the reason as mentioned above. The existence of weakly acid A-horizons with a pH increasing with depth up to 8.2 in soils without bleached horizons, but with other characteristics of leached Solonetzes, have also been observed in the U.S. and Russia.

In the case of the Lufira soils and of the mentioned soils in the Middle East, the influence of the parent material on the typical Solodi profile development is yet unknown.

Often reference is made to the "sandy, bleached layer" of the Solodi, so a fair amount of sand must have been present in the parent material. But in our case we have generally to do with very heavy soils, almost without sand (the Middle East soil consisted also mostly of clay and silt fractions). This heavy texture may add considerably to the prevention of strong leaching.

6.3. Origin of the micro-relief

According to various Australian soil scientists a relation exists between the micro-relief, the bad structure and the impermeability of the soil. Australian gilgai soils possess a high percentage of clay (mostly montmorillonite) and an adsorbing-complex partly saturated with Na. The strong shrinking and swelling of montmorillonite clays on resp. drying and wetting is known. Presence of Na in the adsorbing-complex seems to stimulate this property. As already discussed in chapter 6.2 Mg may entirely of partly, substitute Na. The already mentioned soils in the Middle East, with only 50% clay fraction and large amounts of $CaCO_3$ (about 35%), but with 90% Mg and only some percents of Na in the adsorbing-complex crack nevertheless strongly during the dry season.

During the long dry season in Australia, soil from the surface falls into the cracks. After the first rains, which disappear quickly into the cracks, especially in the depressions, the clay of the subsoil becomes wet and swells whereas higher in the profile and inside the structure elements the soil still remains dry. Thus stresses set up especially in places where lack of space occurs caused by the fallen down topsoil. In places with less stress the pressure finally will force a quantity of soil upward to give way for the expanding clay. When once a slight difference in micro-relief exists, the phenomenon becomes more and more pronounced as the water of further rains runs into the depressions causing a very rapid moistening. There will be also an increasing tendency to wash soil particles from the higher parts into the depressions and thus into the cracks.

As a result of the described movement, taking place every year, the entire soil to a certain depth is slowly moving from the top of the higher parts into the depressions and partly into the cracks, here pushed away sideward and finally forced up again in the higher parts. This phenomenon is known as self-swallowing or self-mulching.

In the Lufira Plain the gilgai soils are also very heavy, however the composition of the clay differs from those in the Australian gilgai soils as they consist mostly of illite, mixed with some montmorillonite. The Mg-content in the adsorbing-complex of the Australian soils has not been discussed, but from the figures it appears to be 2–4 times as high as the Na-content and often as high as the Ca-content. The Na-content is not very high, often 3–6% and seldom more than 15%. Nevertheless these rather small quantities of Na are held to have been instrumental to the formation of the micro-relief by its influence on structure and on cracking of the soil. As we assume that Mg may act as, or in any case may support the action of Na, Mg must also be regarded a micro-relief forming factor. As the Lufira soils contain 10–20% Na in the adsorbing-complex, the resemblance with the Australian soils is rather strong, but this Na-content hampers a definitive solution as to the influence of Mg.

The illite clays, as present is the Lufira soils, shrink and swell much less than montmorillonite clays.

Regarding the Lufira soils and the mentioned soils of the Middle East, the author however is inclined to consider the influence of the composition of the adsorbing-complex on the formation of the micro-relief of much more importance than the nature of the clay. Therefore we can accept the Australian theory on the origin of the micro-relief but considering the actual profile conditions of the Lufira gilgai soils, it is hardly possible that the mechanism of the self-swallowing movement characteristic for a "living" gilgai soil, is still active today. The yearly filling-in of the cracks in the depressions with dark topsoil and lateral expansion in the direction of the higher parts must inevitably result in a gradual deplacement of this dark soil towards the higher parts; finally depressions and higher parts must require a fairly uniform profile. As can be taken from the given description, not only no sign of such a development exists but besides two other facts make the existence of a self-swallowing movement very improbable.

The first is the occurrence of numerous big termite hills on the gilgai soil of type 1 (see description). Besides numerous small termite hills of another type some dm in height, together with shrubs and scattered low trees, occur on the transitional soils with gilgai micro-relief and on some types of gilgai soil in the southern part of the Plain. A self-swallowing movement of some importance would continuously destruct the termite hills and stop the growth of shrubs and trees. The absence of termite hills and vegetation on other types of gilgai soils is due to yearly inundations. This is proved by the occurrence of small termite hills, shrubs and trees on the higher parts in places where only slight inundations occur which partly fill the depressions for a shorter or longer time.

A third, very remarkable feature, found in all types of our gilgai soils is the lighter texture of the soil in the depressions. The sand fraction in these gilgai soils being rather unimportant, it is the silt content which is much higher in the depressions. As this textural difference is connected with the gilgai micro-relief, it can only be explained by a transport of lighter textured soil from the higher parts to the depressions. Such transport by rainwater running into the depressions, explains also the accumulation of lime concretions at the surface of the higher parts as a result of erosion.

So the soil, transported to the depressions, accumulates at the surface, a part will fall into the cracks and finally arrive in the subsoil of the higher parts, due to the self-swallowing movement. Thus we may expect the texture of the depressions becoming gradually heavier downward, as is the case, and the texture of the higher parts showing lighter textured layers in the subsoil or in any case a more or less homogeneous texture of the whole profile. Indeed our figures slightly indicate a more or less homogeneous texture of the higher parts, but they are too few and lacking exactness to arrive at a conclusion. Anyway the presence of textural differences between depressions and higher parts contradicts a self-swallowing movement of the soil.

As discussed above, the black profile of the depressions can only have been developed after the self-swallowing movements of the soil, which caused the micro-relief together with the textural differences and the accumulation of lime concretions on the surface of the higher parts, came to an end. The formation of the gilgai micro-relief itself must in this case have taken place during an earlier dry period. As the already discussed artifacts are found on the surface of the higher parts, mixed with lime concretions, this dry period can only have been the one between Makalian and Nakurian.

The origin of the lime concretions, now lying on the surface, can be explained by a leaching of the topsoil of the original lake deposits and accumulation at a certain level or by an accumulation due to precipitation out of supersaturated groundwater. In any case, accumulation took place before formation of the micro-relief started and the soil must have been rich in lime; even today the deeper layers contain considerable quantities of lime. As the gypsum sometimes is accumulated in the decalcified toplayers, it must have been formed, after leaching of lime and other salts, by an upward movement of the groundwater during a period in which the climate favored such a movement. Moreover as accumulation of lime concretions on the surface is a result of the formation of the micro-relief, the leaching of lime must have taken place in a wet period, preceding the dry one in which formation of the micro-relief took place.

Based on these considerations we now can try to date the different phenomena.

During the dry period between Gamblian and Makalian, after drying-up of the lake described in chapter 5.2, salinization of the soil took place. As this dry period was not a very severe one, the groundwater table may have been rather high, strongly favoring salinization by the upward movement of soil water, leaving behind the salts after evaporation. The lime concretions may have been accumulated in the same manner during this time.

During the Makalian leaching changed the soil into a Solonetz, with perhaps concentration of the difficultly soluble $CaCO_3$ as concretions at a certain depth, if they were not formed in the above described way.

In the following dry period the micro-relief came into existance, caused by the phenomena, described by Australian scientists.

Renewed leaching took place during the Nakuran, but due to the then existing micro-relief much more pronounced in the depressions than on the higher parts. Solodization occurred to a certain degree. The rich vegetation in the depressions furnished also the organic matter which penetrated the profile deeply.

When the climate became gradually arid again renewed upward movement of soil water (even today at a depth of 3 m only at the end of the dry season) caused formation of gypsum and underlying lime deposits. Deposition may perhaps already have started when leaching of the toplayers was still going on. Contrary, also today some leaching still occurs down to a certain depth, as is proved by humus coatings on structure elements of deeper layers. The relief of the gypsum layer is often more pronounced than the surface relief; it occurs at greater depths in the depressions than in the higher parts. The depressions receive more rain water during the rain season and remain wet much longer than the higher parts. In the latter upward movement of soil water goes much higher resulting in deposition of gypsum on a higher level. In soils without micro-relief and without cracking, deposition of gypsum much higher in the profile than in the gilgai soils can be expected. Such places, but still under the influence of the groundwater of the Plain are rare, but in the transitional soils on limeshales small amounts of gypsum are indeed finely dispersed through the whole soil, even to the surface. The absence of micro-relief will be caused by Ca (80–90%) in the adsorbing complex, which stresses again the important role of the composition of the adsorbing complex in gilgai micro-relief formation.

It is difficult to ascertain if the origin of the lime concretion layer underlying the main gypsum concentration, is partly or totally recent. The distance between the gypsum layer and lime concretion layer is very variable (between 0 and about 1 m) and the position of the groundwater table and its movement during the seasons in the different types of gilgai soils is hardly known. Partly the material may contain remains of former deposits (dry phase between Gamblian and Makalian!). This will moreover also be the case with the gypsum.

We mentioned already that judging from profile studies the self-swallowing movement and thus the whole process causing the micro-relief has stopped in the present, climatic conditions being the main reason. Leaky (1949) defines the prevailing climate, after the wet Nakuran, as "tendency to drier", so differences cannot be very great. As the rainfall today is about 900 mm a year and the number of months without any rainfall is hardly five, the climate may be still too wet for a sufficient working of the mechanism causing the micro-relief. Nevertheless the slight deformation of the gypsum layer observed in some places may be an indication, that some soil movements (perhaps indicating the first signs of a returning of self-swallowing with the gradually increasing aridity of the climate) take place. With the heavy cracking of the soil, this may well be the case. In the mentioned places, the gypsum layer does not rise gradually from depression to higher part, but somewhere in the slope profile it occurs suddenly on a one to some dm higher level, showing distinct signs of an upward movement, as an uplift of a soil mass of the higher part along the natural cleavage lines.

7. CONCLUSION

From the preceding the author arrives at the conclusion that the gilgai soils of the Lufira Plain represent a more or less solodized Solonetz. For the formation of the gilgai micro-relief the composition of the adsorbing-complex seems to be one of the most important factors. As the most favourable composition is also typical for Solonetzes, it would be interesting to know if the occurrence of gilgai micro-relief in other parts of the world is also related to Solonetz, or solodized Solonetz soils.

It is tried to explain the totality of the combined processes of soil formation and micro-relief in the light of climatic changes during the Pleistocene. As our data are rather scarce, further research revealing new facts may necessitate a partial revision of some of the datings.

(Submitted January 1959.)

SAMENVATTING

Getracht is een bijdrage te leveren tot de studie van de fluviatiele en meersedimenten met een z.g. „gilgai" microreliëf, voorkomende in een tectonische depressie (Rift-valley of slenk) bekend als de Lufiravallei in het zuiden van Haut-Katanga, Belgisch Kongo. De vallei ontleent haar naam aan de Lufirarivier, die het gebied in de lengterichting doorstroomt.

Er bestaat een verband tussen sedimentatie en bodemvorming enerzijds en anderzijds de klimaatveranderingen, welke in Afrika in het Kwartair hebben plaatsgevonden, nl. de afwisseling van vochtige en droge perioden, overeenkomend met resp. koudere en warmere perioden tijdens het Kwartair in Europa. Na het ontstaan van de slenk kunnen worden onderscheiden één natte en twee vochtige perioden resp. Gamblian, Makalian en Nakuran met drogere of zelfs ariede interstadialen. Het ontstaan van de slenk zelf wordt toegeschreven aan tectonische werking gedurende de droge pre-Gamblian-periode, waardoor een deel van een schiervlakte, daterend uit het eind Tertiair, een daling onderging.

Heden doet het grootste deel van de vallei zich voor als een zwak golvende vlakte bedekt met open moessonbos. In het midden vindt men op $\pm$ 10–20 m beneden het algemene niveau van de vallei een vlakte met oude meerafzettingen. Dit deel, door schrijver de Lufiravlakte genoemd, vormt een uitgestrekt, vlak savannegebied, waarin de 1–2 m hoge oeverwallen van de Lufira en haar zijrivieren de enige terreinverhogingen zijn.

Buiten de Lufiravlakte vindt men rode latosolen ter dikte van 1–2 m op

klei- of kalkschalies, afgewisseld met grote oppervlakten met een laterietpantser. De Lufiravlakte zelf wordt grotendeels ingenomen door zeer zware, grijze tot grijsbruine kleien met een zg. gilgaimicroreliëf. Deze gronden bevatten gips- en kalkconcreties; de laatste liggen in groten getale aan de oppervlakte. Een gedeelte van deze gronden wordt in de regentijd diep geïnundeerd.

Tussen deze gronden en de uitgestrekte moerassen in het centrale deel van de Lufiravlakte vindt men kleigronden zonder gilgaimicroreliëf met een sterk humeuze bovengrond van wisselende dikte. Het zijn langdurig geïnundeerde, slecht ontwaterde gronden.

De gronden op de overgang van de Lufiravlakte naar de rode latosolen gelijken in het algemeen op de gilgai-kleigronden. Tussen de aan de oppervlakte liggende kalkconcreties vindt men echter vaak talrijke rolstenen en prehistorische werktuigen uit deze stenen vervaardigd. Ook treft men aan de oppervlakte soms laterietconcreties aan; in dit geval bevindt zich een laag van deze concreties op een bepaalde diepte in het profiel.

Aangenomen wordt, dat in het Gamblian-pluviaal zich een meer bevond ter plaatse van de tegenwoordige Lufiravlakte. Schrijver meent het ontstaan van een laterietpantser in het niet overstroomde gedeelte van de vallei ook in deze tijd te moeten plaatsen; de huidige oppervlakten van deze vorming zijn resten van het pantser uit het Gamblian.

Na een geleidelijke opvulling van het meer door de rivieren tijdens het Gamblian vond uitdroging plaats in de daarop volgende droge periode.

Het Makalian ving aan met afbraak van het laterietpantser. De afbraakprodukten werden verspoeld en in de vorm van laterietconcreties op de blootgekomen schalies en langs de rand van de vlakte op de kleilagen gedeponeerd. In een later stadium werden, door naar de vlakte stromende riviertjes, de kleilagen, die nu de rode latosolen vormen, afgezet. Vooral in het begin van dit stadium werden door de riviertjes grote aantallen vuistgrote rolkeien getransporteerd, die in en nabij de beddingen en langs de rand van de vlakte werden gedeponeerd, waar ze gedeeltelijk met de laterietconcreties werden vermengd.

Tegen het eind van het Makalian of in het begin van de daarop volgende droge periode bewoonden mensen, die uit de rolstenen hun werktuigen vervaardigden, de rand van de vlakte.

Gedurende de laatste humiede periode (Nakuran) vormden de Lufira en haar zijrivieren oeverwallen en kommen in een smalle strook in de oudere meerafzettingen.

De Gilgaikleien

Het gilgaimicroreliëf doet zich voor als min of meer ronde of zwak veelhoekige depressies, gescheiden door smalle, hogere randen. Er konden enkele typen gilgaigronden onderscheiden worden op grond van kleur, gips- en kalkgehalte, ontwatering en sterkte van het microreliëf.

De depressies variëren van 10–15 m in diameter en 20–50 cm in diepte, maar zijn in éénzelfde type zeer uniform. De grond van de depressies is tot op grote diepte zeer donkergekleurd, terwijl de randen bruin, grijsbruin of grijs zijn, al naar het type. Uitsluitend op de randen vindt men talrijke kalkconcreties. De gerolde keien, artefacten en laterietconcreties van de overgangsgronden worden ook uitsluitend op de randen gevonden. In de gilgaigronden treft men meest aanzienlijke hoeveelheden gips en koolzure kalkconcreties aan, die vaak vrij harde banken vormen; de gips bevindt zich dan boven de kalkconcretielaag.

Het kleigehalte is zeer hoog, tot 90%, maar de depressies zijn altijd iets lichter dan de randen. De gronden zijn zeer plastisch, ondoorlatend in natte toestand en scheuren sterk bij uitdroging, vooral de randen.

De prismastructuur of een grove blokstructuur met een tendens naar prismastructuur is kenmerkend voor alle gilgaigronden.

In het adsorptiecomplex overweegt Mg, dat vaak 2 tot 3 maal zo hoog is als Ca; Na neemt 10–20% in en is gelijk aan of iets hoger dan Ca. Morfologisch en chemisch doen deze bodems sterk aan een solonetz denken en gezien de vrij lage pH en de diepgaande humusinfiltratie aan een zekere graad van solodisatie. Weliswaar is het Na aandeel van het adsorptiecomplex vaak lager dan bij een typische solonetz, maar naar ook elders is gebleken, kan Mg blijkbaar de rol van Na, althans gedeeltelijk overnemen. Het ontbreken van een bleke uitlogingshorizont, typisch voor een echte solodi, kan verklaard worden door het relatief lage Na-gehalte. Hierdoor wordt slechts weinig $NaCO_3$ gevormd, waardoor de pH zelden hoog genoeg stijgt om kleidispersie te veroorzaken, hetgeen een van de voorwaarden schijnt te zijn voor het ontstaan van de bleke horizont.

Het microreliëf ontstaat door het afwisselend zwellen en krimpen na resp. bevochtiging en uitdroging, waarbij de structuur en de samenstelling van het adsorptiecomplex, dat op zijn beurt de structuur ook weer beïnvloedt, een belangrijke rol spelen. Gedurende het droge seizoen rollen gronddeeltjes in de scheuren. Het water van de eerste buien verzamelt zich daar eveneens, waardoor de klei in de diepte uitzet en spanningen veroorzaakt, waardoor de grond zijdelings wordt omhooggedrukt. Anderzijds wordt grond van de hogere randen door de regen naar de depressies verspoeld, waar het weer in de scheuren terechtkomt. Deze als het ware rondgaande verplaatsing van de grondmassa, „self-swallowing" genaamd, is de oorzaak van de accumulatie van omhoog gekomen en blootgespoelde kalkconcreties, rolstenen en laterietconcreties op de randen.

Drie verschijnselen wijzen er volgens schrijver op, dat de „self-swallowing" beweging momenteel niet meer plaatsvindt. De grote profielverschillen tussen depressies en randen zijn niet in overeenstemming met een nog voortdurende beweging, die een homogenisatie van beide delen zou moeten veroorzaken. Ook de termietenheuveltjes en de struiken, die op de randen van bepaalde gilgaitypen voorkomen, zouden door een dergelijke beweging vernield worden.

Gezien het voorkomen van artefacten, daterend uit het Makalian, op de randen van het microreliëf moet dit laatste uit een droge periode na het Makalian dateren. Gedurende het Makalian was reeds een Mg-solonetz ontstaan als gevolg van de uitspoeling van oplosbare zouten, opgehoopt gedurende de voorafgaande ariede periode (Gamblian-Makalian interpluviaal) bij de uitdroging van het Gamblian-meer. De kalkconcretielaag werd gevormd in deze tijd door afzetting uit opstijgend bodemvocht òf in het Makalian door uitloging van de bovenliggende lagen. Tijdens het Nakuran veroorzaakte een hernieuwde uitspoeling, die nu uiteraard het sterkst in de depressies was, een gedeeltelijke solodisatie, vooral van de depressies waar de donkere humus diep in de bodem drong. Toen na het hoogtepunt van het Nakuran, bij het geleidelijk weer droger worden van het klimaat, de opstijgende waterbeweging vanuit het hoogstaande grondwater (dat zelfs momenteel op vele plaatsen op het eind van het droge seizoen niet dieper dan 3 m staat) weer een aanvang nam, werden geleidelijk de gipslagen afgezet, een proces dat nog steeds voortduurt. De sterkere uitloging van de bovendien langer vochtig blijvende depressies in de natte tijd, verklaart de diepere ligging van het gips in de depressies dan in de randen.

RÉSUMÉ

L'article presenté ici veut donner une contribution à l'étude des sédiments fluviatiles et lacustres d'un microrelief typique, nommé „gilgai" qui se trouvent dans une dépression tectonique (Rift Valley), nommé „Vallée de la Lufira" dans la partie sud du Haut-Katanga (Congo Belge). La rivière Lufira avec quelques confluents traverse cette vallée dans sa longueur.

Les phénomènes de sédimentation et pédologiques sont liées aux changements de climat en Afrique pendant l'époque quaternaire. Il s'agit d'une alternance des périodes humides et arides, qui correspondent avec le changement de climat pendant cette époque en Europe. Après la formation du „Rift Valley" on distingue une période pluviale et deux periodes humides, resp. le Gamblien, le Makalien et le Nakurien avec leur interstadiales sèches ou même arides. L'origine de la Vallée de la Lufira est attribuée à l'effondrement tectonique d'une partie d'une ancienne pénéplaine pendant la phase sèche précédant le Gamblien.

Aujourd'hui la plupart de la Vallée se presente comme une plaine faiblement ondulée et couverte par un forêt clair. Au milieu se trouve une partie avec des sédiments lacustres, située à un niveau de 10–20 m. au-dessous du niveau général de la Vallée. Cette partie, que nous appelons „Plaine de la Lufira", forme une vaste plaine, couverte d'une savane. Les levées naturelles de la Lufira et ses confluents, haute de 1–2 m., forment les seules élevations dans ce terrain plat.

En dehors la Plaine de la Lufira on trouve des latosols rouges, reposant à 1 ou 2 mètres sur schistes ou schistes calcaires alternant avec des vastes surfaces à cuirasse latéritique. La plupart de la Plaine de la Lufira est occupée par des argiles très lourdes de couleur grise ou brun-grisâtre à microrelief „gilgai". Le sol renferme du gypse et des concrétions de $CaCO_3$. Des nombreuses concrétions de carbonate sont accumulées à la surface. Une partie de ces sols est fortement inondée pendant la saison des pluies.

Entre ces sols et les marécages étendues, occupant la partie centrale de la Plaine, se trouvent des argiles sans microrelief avec une couche humifère plus ou mois épaise à la surface. Il s'agit des sols fortement inondés et mal drainés.

Les sols de transition au bord de la Plaine entre le sol gilgai et les latosols rouges ressemblent en général le sol gilgai, mais souvent on trouve mélangées avec les concrétions de $CaCO_3$ des nombreuses pierres roulées et des outils préhistoriques fabriqués de cettes pierres. Également on peut trouver des concrétions latosoliques à la surface; dans ce cas une couche de cettes concrétions se trouve à un certain profondeur dans le sol.

On suppose l'existence d'un lac pendant le Gamblien pluvial à la place ou se trouve maintenant la Plaine. Pendant la même période nous datons la formation d'une cuirasse latéritique. Nous considérons les surfaces de cette cuirasse, qu'on trouve maintenant encore dans la Vallée comme vestiges de cette ancienne cuirasse gamblienne.

Après un remplissement graduel du lac par les rivières pendant le Gamblien, il y avait un déchessement pendant la période sèche suivante.

Le Makalien commençait avec la destruction de la cuirasse latéritique, dont les produits de destruction comme concrétions latéritiques furent déposées sur les schistes dénudés et le long du bord de la Plaine. Plus tard sur la couche de concrétions se produisait la déposition des pierres roulées ensemble avec, et graduellement remplacées par, une déposition d'argile.

Vers le fin du Makalien ou le commencement de la période aride suivante les indigènes, qui utilisaient les pierres roulées pour fabriquer leurs outils, habitaient au bord de la Plaine.

Pendant la dernière phase humide (le Nakurien), la Lufira et les autres rivières formaient des levées naturelles et des cuvettes.

Les sols à microrelief gilgai

Le microrelief se manifeste comme des dépressions, entourées des rebords élevés, plus ou moins circulaires ou faiblement polygonales. Nous avons pu distinguer quelques types de sol gilgai, se distinguant par la couleur, la quantité de gypse et carbonate de chaux, le drainage et les dimensions du microrelief. Les dimensions des cuvettes varient entre 10 et 15 m de diamètre et 20–50 cm de profondeur, quoiqu'ils sont très uniformes dans la même type. Les dépressions sont d'une couleur très foncée, tandis que les rebords sont bruns, brungrisâtres ou gris selon la type. A la surface des rebords on trouve de nombreuses concrétions de carbonate de chaux. Les pierres roulées, les outils préhistoriques et les concrétions latéritiques du sol de transition au bord de la Plaine se trouvent également exclusivement à la surface des rebords. Des quantités considérables de gypse et de carbonate de chaux se trouvent généralement dans le sol gilgai, souvent concentrées en couches assez dures. Les carbonates se trouvent en général au-dessous du gypse.

Les sols ont un pourcentage d'argile très élevé, mais toujours plus bas dans es dépressions que dans les rebords. Ils sont très plastiques et imperméables pendant la saison de pluies; pendant la saison sèche il y existe des grandes crévasses à la surface, spécialement dans les rebords.

La structure prismatique ou de blocs très grossiers à tendence prismatique est une caractère spéciale de toutes les types du sol à gilgai.

Le complexe adsorbant est surtout saturé de Mg, le Mg étant souvant 2–3 fois plus élevé que le Ca; le Na, variant entre 10 et 20%, égale le Ca ou il y a de plus.

Considérant les donnés morphologiques et chimiques, le sol ressemble fortement un Solonetz et bien, vue le pH assez bas et l'infiltration profonde d'humus, avec une certaine degrée de solodisation. Na dans le complexe adsorbant ne monte pas toujours jusqu'au pourcentage typique d'un Solonetz; nous croyons que le Mg peut remplacer, en tous cas partiellement, le Na dans les Solonetz. L'absence d'un horizon clair lessivé, typique pour le Solodi, est expliquée par le pourcentage bas de Na dans le complexe adsorbant. En manque d'une formation suffisante de $NaCO_3$ le pH montait jamais jusqu'au valeur favorable à la dispersion de l'argile, ce qui semble un des facteurs le plus important à la formation d'un horizon clair.

Le microrelief est causé par la dilatation et retraction alternante de l'argile après resp. la humidification et le desèchement. Pendant la saison sèche des particules de la surface des dépressions comblent les crevasses de rétraction en bas. L'eau des premières pluies se ressemble ici et la dilatation de l'argile cause des tensions qui soulèvent enfin à côte une partie de sol. A son tour la surface des rebords subit une érosion de sol vers les dépressions. Ce mouvement du sol, appelé „self-swallowing", a causé la concentration des concrétions de carbonate de chaux, des pierres roulées et des concrétions latéritiques à la surface des rebords, ainsi que la différence en texture entre rebords et dépressions.

Trois phénomènes indique que le mouvement „self-swallowing" n'est plus active. La grande différence en profile entre dépressions et rebords en couleur et en texture n'est pas en raccord avec une homogénisation continuelle D'ailleurs les termitières et les arbustes qui se trouvent sur les rebords de certaines types de sol à gilgai, spécialement sur ceux des sols de transition au bord de la Plaine, auraient été détruites par le mouvement. Aussi la formation du microrelief doit dater d'une période sèche après le Makalien, en rapport avec les outils préhistoriques, datant de cette période et mélangés avec les pierres roulées à la surface des rebords. Plutôt, pendant le Makalien, le lessivage des couches superficielles des sels solubles, accumulés pendant la phase sèche précédante, causait la formation du Solonetz. Les concrétions de carbonate de chaux maintenant à la surface, sont accumulées dans le sol avec le procès de salinisation ou pendant le Makalien par le lessivage mentionné ci-dessus. Pendant le Nakurien, donc après la formation du microrelief, un nouveau lessivage, naturellement plus prononcé dans les dépressions, causait une solodisation partielle et la formation du profil foncé des dépressions. Après le maximum du Nakurien, la reprise du mouvement ascendant de l'eau de la nappe phréatique élevée (maintenant encore par place à 3 m de profondeur seulement à la fin de la saison sèche) a déposée du gypse, un procès maintenant actif encore. Le lessivage, qui est plus prononcé dans les dépressions, qui sont en outre toujours plus humides, cause une ascension beaucoup plus prononcée dans les rebords. Ceci donne une explication de la position du gypse, qui ne suive pas le microrelief, mais qui se trouve beaucoup plus éloigné de la surface dans les dépressions que dans les rebords.

LITERATURE

Arkley, R. J. and H. C. Brown, 1954: The origin of mima mound (hogwallow) micro-relief in the far western states. Soil Sci. Soc. Am. Proc. *18*, 195–199.

Bentley, C. F. and C. O. Rost, 1947: A study of some solonetzic soil complexes in Saskatchewan. Sci. Agr. *27*, 293–313.

Butzer, K. W., 1957: Late glacial and postglacial climatic variation in the Near East. Erkunde *11*, 21–35.

Cahen, L. et G. Mortelmans, 1939: Etudes géologiques de la région des feuilles Molabe-Kasari et Sampwe. Bull. Soc. Belge Géol., Paléont. et Hydrol. *49*, 1–2, 131–181.

Cahen, L. et G. Mortelmans, 1940: Contribution à la carte géologique du Katanga.
1941: La géologie des degrés carrés Mokabe et Sampwe. Bull. Soc. belge Géol., Paléont. et Hydrol.

Costin, A. B., 1955: A note on gilgaies and frost soils. Journ. Soil Sci. *6*, 32–34.

Ellis, J. H. and O. G. Caldwell, 1935: Magnesium clay solonetz. Trans. 3rd Int. Congr. Soil Sci. *1*, 348–350.

Hallsworth, R. G., G. K. Robertson and F. R. Gibbons, 1955: Studies in pedogenesis in New South Wales. VII. The gilgai soils. Journ. Soil. Sci. *8*, 1–31.

Joffe, J. S., 1949: Pedology, 2nd. ed. New Brunswick, N.I.

Joffe, J. S. and H. C. McLean, 1924: Alkali soil investigations. II Origin of alkali soils. Soil Sci. *18*, 13–30, 133–149.

Joffe, J. S. and M. Zimmerman, 1945: Sodium, calcium and magnesium ratios in the exchange complex. Proc. Soil Sci. Soc. Am. *9*, 51–55.

Leaky, L. S. B., 1931: The stone age cultures of Kenya Colony. Cambridge.

Leaky, L. S. B., 1935: The stone age races of Kenya. Oxford.

Leaky, L. S. B., 1949: Tentative study of the pleistocene climatic changes and stone age culture sequence in N.E. Angola Lisboa, Comp. Diam. Angola; Musée do Dunde; Serv. Cultur; Publ. Cult. 4.

MacGregor, J. M. and F. A. Wyatt, 1945: Studies on solonetz soils of Alberta. Soil Sci. 59, 419–435.
Mitchell, J. and F. F. Riecken, 1937: The chemical nature of some typical soil profiles of Saskatchewan, Canada. Sci. Agr. *18*, 109–119.
Moreau, R. E., 1933: Pleistocene climatic changes and the distribution of life in E. Africa. Journ. of Ecol. *21*, 415–435.
Nikiforoff, C. C., 1930: Solonetz and Solonchak soils of the Red river. Am. Soil Surv. Assoc. Bull. *11*, 141–150.
Nikiforoff, C. C., 1937: The Solonetz-like soils in Southern California. Journ. Am. Soc. Agron. *29*, 781–796.
Nikiforoff, C. C., 1941: Hardpan and micro-relief in certain soil complexes of California. U.S.D.A. Techn. Bull. 745.
Oosten, M. F. van, 1958: Soil and Land classification of the Shahabad Valley, Iran. Khuzistan Development Service – Food and Agriculture Organization of the United Nations.
Robert, M., 1939: Contribution à la géomorphologie du Katanga. Mém. Inst. Roy. Co. Belge. Coll. in 8°, 9, fasc. 5.
Stephen, I., L. Bellis and A. Muir. 1956: Gilgai phenomena in tropical black clays of Kenya. Journ. Soil Sci. *7*, 1–9.
Veenenbos, J. S. en J. van Schuylenborgh, 1951: Het knip- of knikverschijnsel van kleigronden. Boor en Spade *4*, 24–39.
Wambeke, A. van, et M. F. van Oosten, 1956: Carte des sols et de la végétation du Congo-Belge et du Ruanda-Urundi. *8* Vallée de la Lufira (Haut-Katanga) A et C; Notice explicative de la carte des sols. I.N.E.A.C. Bruxelles.
Williams, O. B., 1955: Studies in the ecology of the Riverine Plain. I. The gilgai micro-relief and associated flora. Austr. J. Bot. *3*, 99–112.

PROPERTIES OF ROCKS IN CIVIL AND RURAL ENGINEERING

by

Dr. Ir. H. W. van der Marel

INTRODUCTION

Civil and rural engineers exploring in foreign countries often have to know in a short time the quality and durability of rocks and gravels with which they are not familiar as regards their suitability for certain purposes. Moreover, the choice of the material to be used is mostly large when the object is the construction of railway embankments or dams in countries where various geological formations occur. By mechanical testing the quality of a rock in wet or dry condition against mechanical forces perpendicular or parallel to the bedding plane, can be characterized by the following properties: compressive (crushing) strength, modulus of rupture (transverse strength), tensile strength, Young's modulus (elasticity in flexure), modulus of rigidity (elasticity in shear), Poisson's ratio $\left(\frac{\text{Young's modulus}}{2 \times \text{modulus of rigidity}} - 1\right)$ impact toughness (hardness), scleroscope (bonding) hardness, abrasive hardness, cementing value, grindability, etc.

However, the mechanical results may be largely influenced by moisture condition and the direction into which the sample is analysed. Moreover, they do not give information about the durability of a rock against weathering conditions, e.g. a high resistance of a rock against abrasion may coincide with a low as well as with a high resistance to weathering conditions. The following are examples of chemical, X-ray and differential thermal analyses of various kinds of rocks and gravels and their use in civil and rural engineering constructions under various weathering and other conditions[1]).

ROCKS AND GRAVELS USED IN CONSTRUCTIONS

a. Magmatic rocks

Intrusive (plutonic) magmatic rocks (see table 1) which are commonly used for constructional works, e.g. granite, syenite, leucite, nepheline, diorite, gabbro, peridotite (the order being that of increasing basicity)[2]) are formed by slow cooling of the molten magma. Therefore, they consist of a compact mass mostly composed of close interlocking, well-developed crystals uniform in size with a granular (granitoid) texture. Extrusive (volcanic) magmatic rocks (see table 1) which are also generally used for constructional works, e.g. rhyolite, phonolite, trachyte, dacite, andesite, basalt, diabase, pikrite (the order being that of increasing basicity), have resulted from more rapid cooling. Thus they contain larger crystals embedded in a fine-grained ground mass (felsitic structure).

[1]) The author is indebted to Professor Ir. E. C. W. A. Geuze, Director of the Laboratory of Soil Mechanics, Delft, for critical remarks.

[2]) Light coloured acidic rocks are chiefly composed of quartz, orthoclase and white mica (muscovite) = ca $> 65\%$ SiO_2. Basic magma have less silica = ca $< 50\%$ SiO_2 and more iron, lime and magnesium minerals (hornblende, augite, hypersthene, magnetite), which give rise to dark coloured types.

Table 1. Rocks and their components

A. Magmatic Rocks

I. Without texture: pitchstone, perlite, obsidian, pumice stone.

II. With texture.

Calcium-alkali group

<table>
<tr><td>extrusive (volcanic)</td><td>rhyolite</td><td>trachyte</td><td>dacite</td><td>andesite</td><td>diabase, basalt</td><td>pikrite</td><td></td></tr>
<tr><td>ganganous (intermediate)</td><td>granite porphyry (aplite, pegmatite)</td><td>syenite porphyry (minette, vogesite)</td><td>quartz diorite porphyry</td><td>diorite porphyry</td><td>gabbro porphyry (odinite)</td><td></td><td></td></tr>
<tr><td>intrusive (plutonic)</td><td>granite</td><td>syenite</td><td>quartz diorite</td><td>diorite</td><td>gabbro, norite</td><td>peridotite, pyroxenite</td><td>anorthosite</td></tr>
<tr><td rowspan="4">main components</td><td>quartz</td><td>without quartz</td><td>quartz</td><td colspan="4">without quartz</td></tr>
<tr><td>K-feldspar
Na-feldspar</td><td colspan="4">Na/Ca feldspar with increasing Ca/Na ratio but in decreasing amounts ⟶</td><td>without feldspar</td><td>Ca-feldspar</td></tr>
<tr><td colspan="3">micas, pyroxenes, amphiboles</td><td colspan="4">biotite, pyroxenes, amphiboles</td></tr>
<tr><td colspan="3">without olivine</td><td colspan="4">with and without olivine</td></tr>
</table>

Alkali group

<table>
<tr><td>extrusive (volcanic)</td><td>quartz keratophyre</td><td>alkali trachyte</td><td>leucite- and nepheline-phonolite</td><td colspan="2">tephrite</td><td>leucite
nepheline
melilite } basalt</td><td>augitite limburgite</td><td>trachy dolerite</td></tr>
<tr><td>ganganous (intermediate)</td><td>alkali granite porphyry</td><td>alkali syenite porphyry</td><td>nepheline porphyry</td><td colspan="5"></td></tr>
<tr><td>intrusive (plutonic)</td><td>alkali granite</td><td>alkali syenite (laurvikite,) monzonite</td><td>nepheline and leucite-syenite</td><td>shonkinite</td><td>theralite</td><td>missourite fergusite</td><td></td><td>essexite</td></tr>
<tr><td rowspan="5">main components</td><td>quartz</td><td colspan="7">without quartz</td></tr>
<tr><td colspan="2" rowspan="2">orthoclase</td><td rowspan="2">orthoclase, leucite, nepheline</td><td colspan="2">leucite/nepheline</td><td rowspan="2">leucite, nepheline melilite</td><td rowspan="2"></td><td rowspan="4">all minerals with the exception of quartz</td></tr>
<tr><td>orthoclase</td><td>plagioclase</td></tr>
<tr><td colspan="5">mica, Ca- and alkali pyroxenes + ditto amphiboles</td><td>biotite, pyroxenes</td><td>pyroxenes</td></tr>
<tr><td colspan="3">without olivine</td><td colspan="3">with and without olivine</td><td>with olivine</td></tr>
</table>

B. SEDIMENTARY ROCKS

a) *Mechanical action:*

coarse grained: conglomerate (round particles), breccie (angular particles), graywacke (rounded and angular particles) — siliceous, ferruginous, carbonaceous, kerogenous

medium grained: sandstone, (siliceous, ferruginous, micaceous, argillaceous, calcareous, glauconitic, feldspathic (arkose), kerogenous)

fine grained: mudstone, shale (carbonaceous, argillaceous, ferruginous, bituminous, kerogenous).

b) *Chemical action:*

travertine, calcareous tuff, gypsum, anhydrite, carnalite, sylvinite, halite, kieserite, polyhalite, iron banks (concretions), manganese banks (concretions), bauxite, limonite (iron ore), phosphate, flint, chert.

c) *Organogenic action:*

limestone (coral, foraminiferous, crinoidous, molluscous, öolitic, glauconitic, argillaceous, dolomitic, chalk, marl, diatomaceous, carbonaceous).

C. METAMORPHIC ROCKS

a) *Foliated* (banded):

light coloured and coarsely laminated: gneiss (sericite, biotite, hornblende, garnetiferous, etc.)

dark coloured and finely laminated: schist (chlorite, actinolite, hornblende, garnetiferous, amphibolitic, sillimanite, graphite, tourmaline, talc).

b) *Non foliated:* slate (carbonaceous), phyllite (micaceous), quartzite, marble (white, pink, gray, etc.), dolomitic marble, dolomite, serpentine, hornfels (baked shale formed by volcanic action), soapstone.

[1]) Classification essentially after H. Rosenbusch (Elemente der Gesteinslehre, 4th Ed., 1923 edited by A. Osann, E. Schweizerbartsche Verlagsbuchhandlung, Stuttgart pp. 779) and compiled by B. G. Escher (Algemene Geologie, 6th Ed. 1945, N.V. Wereldbibliotheek, Amsterdam pp. 525. Rosenbusch classified the magmatic rocks on texture and geological association in addition to mineralogical composition. Other classifications are for example of P. Niggli (Die Magmentypen, Schweizerische Mineral. und Petrogr. Mitt., 1936, *16*, 335–399) which is based on chemical composition modified by other considerations and of S. J. Shand (Eruptive rocks, 3th Ed. 1947, Thomas Murby, London pp. 488) which is based on relative excess or deficiency of silica, alumina, sodium potash, lime and the texture of the rocks.

When the molten mass is suddenly chilled by very rapid cooling, a glassy brittle mass (e.g. obsidian) is formed. When the rate of cooling has been intermediate between that in extrusive and that in intrusive rocks, a porphyritic structure results, i.e. many large crystals (phenocrysts) embedded amongst finer crystals. These kinds of rocks (see table 1), e.g. aplite, pegmatite, alkali granite porphyry, syenite porphyry, quartz diorite porphyry, diorite porphyry, gabbro porphyry (the order being that of increasing basicity), which are most generally used in constructional works, are found in gangs or dikes. Molten lava has flown here from the inner magmatic chamber to the outside of the earth's crust.

Magmatic rocks may therefore show from the outer to the centre successively, a glassy, a porphyritic, a felsitic and a granitoid structure, the difference being caused by the different rates of cooling.

Magmatic rocks are very suitable for construction works as they have favourable mechanical properties (see table 2). The coarser plutonic ones are somewhat less tough and less resistant to abrasion (traffic) than the finer-grained volcanic ones, which agrees with the coarser structure of the first and the fine-grained and closely interlocking structure of the latter. However, when these magmatic rocks contain bubbles or are even spongy (due to gases expanding from the molten mass) their strength and abrasive resistance is considerably decreased.

TABLE 2. Mechanical properties of several kinds of rocks as used in civil and rural engineering constructions.

Description	Kind of rocks		
	magmatic	sedimentary[1])	metamorphic[1])
Compressive (crushing) strength ($lb.inch^{-2} \times 10^3$)	35–50	5–30	20–40
Modulus of rupture (transverse strength) ($lb.inch^{-2} \times 10^3$)	3–6	0.7–3	3–6
Tensile strength ($lb.inch^{-2} \times 10^3$)	1–2	0.1–1.5	0.8–3
Young's modulus (elasticity in flexure) ($lb.inch^{-2} \times 10^{-6}$)	9–12	0.8–9	4–10
Modulus of rigidity (elasticity in shear) ($lb.inch^{-2} \times 10^{-6}$)	2–6	0.3–4	2–6
Impact toughness (cm)	15–30	3–15	10–20
Scleroscope hardness (scleroscope units)	80–110	20–60	50–80
Abrasive hardness (H_D) (revol. $\times$ $inch^2 \times 10^{-3}.lb^{-1}$)	25–35	2–15	6–20

See for details e.g. Lord (1916), Jackson (1916), Kessler (1927), Kessler and Sligh (1927, 1932), Kessler et al. (1940), Woolf (1930), Obert et al. (1946), Windes (1949, 1950), Evison (1956).

[1]) Data only of compact types.

Magmatic rocks are furthermore very resistant to weathering; the basic ones, e.g. basalt decomposes faster and also has more binding (cementing) power than the acidic ones, e.g. granite. This characteristic is reflected by their behaviour, against 25% HCl for 1 hour at ca 100 °C (see table 3). Thus 2 to 6% is dissolved in acid rocks against ca 12 to 40% from basic rocks.

TABLE 3. Elements dissolved (in %) from several kinds of magmatic rocks by extraction with 25% HCl for 1 hour on a boiling water bath

	K_2O	CaO	MgO	Na_2O	Mn_3O_4	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	SiO_2	Total
I. *Without structure*											
27 Obsidian	tr	tr	0.02	tr	tr	0.46	tr	tr	tr	0.08	0.56
II. *With structure*											
Calcium-alkali group, extrusive											
3 Granite, Georgia	0.04	0.09	0.02	tr	tr	0.20	0.20	0.02	0.07	0.26	0.90
5 Diorite, Massachusetts	0.13	1.07	0.44	0.03	tr	3.72	0.63	0.02	0.47	2.00	8.51
1 Gabbro, Massachusetts	0.18	1.24	0.42	0.02	tr	4.60	0.48	0.05	0.70	2.05	9.74
6 Dacite, San Luis Obispo County	0.22	0.11	0.50	0.03	0.01	2.58	0.54	0.17	0.07	1.84	6.07
4 Diabase, Massachusetts	0.01	1.17	0.08	0.13	tr	4.93	1.84	0.16	0.11	4.25	12.68
2 Basalt, Somerset County	0.02	1.05	1.47	0.16	tr	4.65	2.85	0.08	0.06	8.60	18.94
Alkali group, extrusive											
282 Leucite basalt, Wyoming	6.16	1.68	0.80	0.10	tr	2.13	6.90	0.22	0.68	20.68	39.35

TABLE 4. Elements dissolved (in %) from diabase gravel from a quarry in Curacao by extraction with 25% HCl for 1 hour on a boiling water bath. Furthermore from silicified diabase tuff gravel from another quarry in Curacao

		K_2O	CaO	MgO	Na_2O	Mn_3O_4	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	SiO_2	Total
11	compact >1 mm.	0.01	2.28	5.40	0.07	0.02	5.40	5.50	0.12	0.05	12.75	31.60
12	soft >1 mm.	0.02	2.10	6.75	0.06	0.02	7.79	6.85	0.31	0.04	20.58	44.52
1332	soft <1 mm.	0.02	3.58	6.98	0.05	0.04	7.90	7.32	0.06	0.03	23.30	49.28
7721/31	silicified diabase tuff	0.01	0.82	1.70	0.07	0.02	4.05	2.65	0.14	0.11	8.80	18.37

Furthermore, their differential thermal analyses (d.t.a.) curves[1]) show straight lines to 1000 °C (see figure 1) on account of lack of secondary minerals with O H groups. The latter are formed by decomposition of primary magmatic minerals.

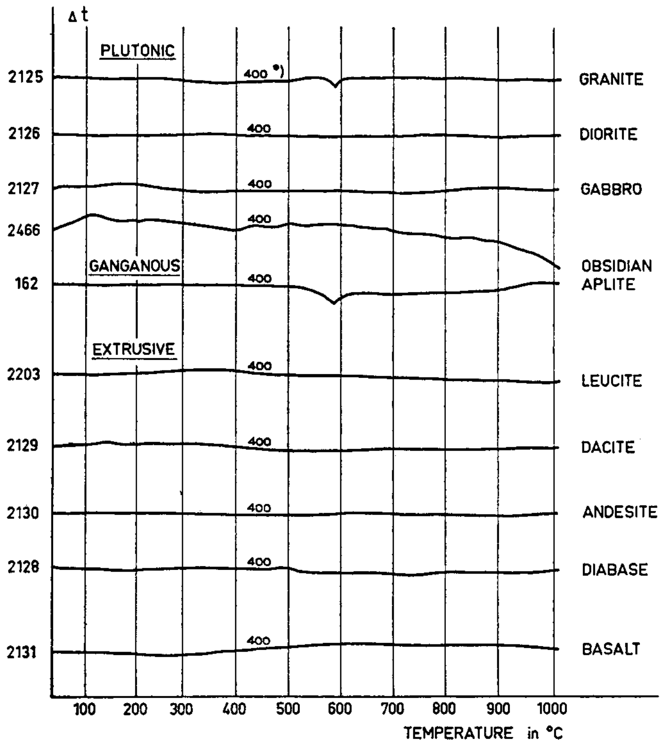


Fig. 1.
D.t.a. of some magmatic rocks

*) Weight of dried (1 hour at 105 °C) sample in mg

An exception are rocks which contain large amounts of quartz (25–35%) e.g. granite, rhyolite, pegmatite, aplite, quartz-porphyry, etc., which have a sharp but small thermal effect at 573° (see figure 1). This results from the reversible inversion of α-quartz (low quartz with trigonal symmetry) to β-quartz (high quartz with hexagonal symmetry).

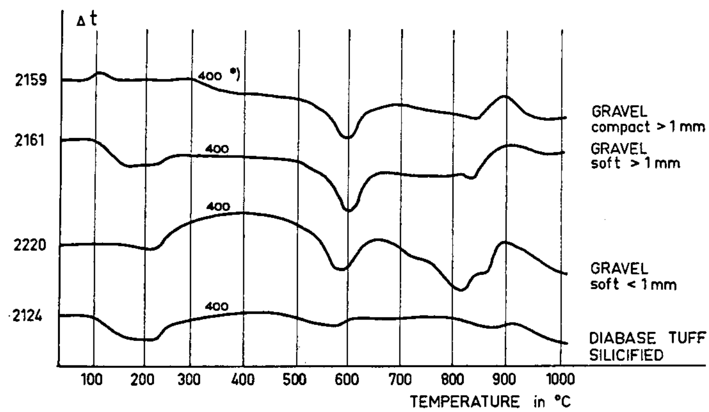
This sharp inversion reaction is used by several authors, e.g. Faust (1948) and Barshad (1952), to obtain a calibration point for the temperature scale in the d.t.a. Thus according to Tuttle (1949), quartz of various origin showed only a variation of 0.60 °C above and 1.30 °C below the standard inversion temperature of 573.3 ± 0.1 °C.

Plate I, figure 2 and table 4 show the X-ray, d.t.a. and chemical analyses, respectively of coarse diabase gravel which was previously cleaned by washing with water and fine < 1 mm diabase particles with adhering weathering products both sampled from the same quarry of diabase rock which was explored near Willemstad (Curaçao) for the platform of an airfield. They show that the diabase gravel has been largely weathered – see the greater

[1]) All the d.t.a. tests described in this article have been performed with the equipment constructed and described by De Bruyn (1954).

amounts for total substance dissolved by 25% HCl at ca 100°C and the greater thermal effects at the d.t.a. as compared with that of unweathered diabase rock (see table 3 and figure 1). Consequently, the gravel which is sampled in this quarry should first be washed and sieved and only the coarser ones (> 1.5 inch) should be used for constructive purposes, i.e. where great resistance to mechanical and weathering forces are needed for years without interruption for repairs.

The silicified diabase tuff, which can easily be distinguished by X-ray and differential thermal analysis from the foregoing samples (see plate I and fig. 2) is very resistant (see table 4) and therefore the most suitable.



*) Weight of dried (1 hour at 105°C) sample in mg

Fig. 2.
D.t.a. of some samples of diabase gravel from a quarry at Curacao and of silicified diabase tuff from another quarry at Curacao

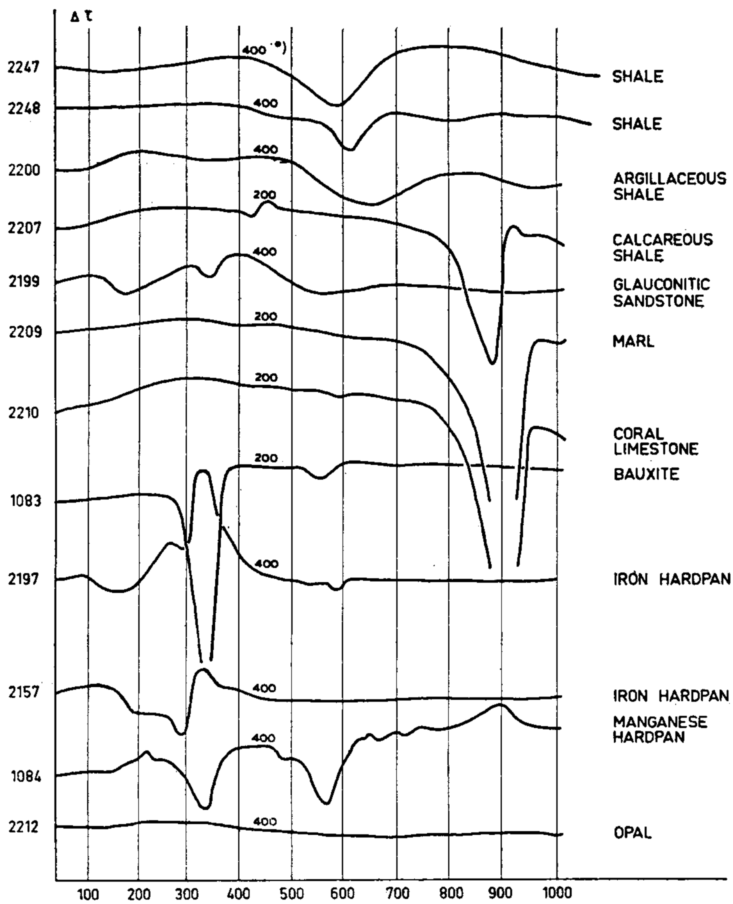
b. Sedimentary rocks

Rocks belonging to this group (see table 1) which can be employed for constructional purposes (e.g. conglomerate, breccie, sandstone, tuff, marl, chalk, limestone, shale), are derived from debris of other rocks on account of wind, water, gravity, chemical and organogenic action.

By sedimentation the heavier and coarser fragments are sorted from the lighter and finer ones and stratified rocks result. They have all gradations of fineness, i.e. ranging from soft and friable to compact and hard. The coherence is due to the amount of clay which is included or to the kind and amount of cement (siliceous, calcareous, ferruginous, manganous, aluminous), by which the separate particles are held together. Hardpans in soils which may cover large areas result from percolating water carrying colloidal weathering products to a lower level. There these colloids are flocculated by electrolytic action and soil particles are included. A coherent mass (ferruginous, manganous, aluminous, calcareous) results which, when dry, may be very hard and resistant e.g. crystallites of iron and manganous oxides formed from amorphous hydroxides, cement the particles together. Hardpans may also result in hot dry seasons from the escape of CO_2 from capillary water containing dissolved iron or manganese-hydrocarbonates or from evaporation of capillary water with dissolved weathering products. Also in this case a compact mass is formed at a certain depth beneath the soil surface. Finally hardpans may be formed through the action of iron and manganese bacteria, e.g. Leptothrix ochracea, Bacillus circulans, Bacillus polymyxa – see Leeper and Swaby (1940), Roberts (1947), Baars (1950), Bromfield (1954) – when sufficient easily decomposable nutritive organic matter (humus) occurs.

Mechanical strength of sedimentary rocks varies considerably. From nearly zero to amounts as mentioned in table 2 may be found for the more compact types.

Figure 3 shows the d.t.a. diagrams, table 5 the chemical and plate II the X-ray analyses of several sedimentary rocks. They show that with the exception of sandstone, shale and opal all have strong endo- (and exo-) thermal reactions and that, with a further exception of bauxite, large amounts of material are dissolved when the samples are treated with 25% HCl for 1 hour on a boiling waterbath. Chalk and limestone even effervesce at room temperature when treated with diluted acid, e.g. 1% HCl.



*) Weight of dried (1 hour at 105 °C) sample in mg

Fig. 3.
D.t.a. of some sedimentary rocks

Table 5. Elements dissolved (in %) from several kinds of sedimentary rocks with 25% HCl for 1 hour on a boiling water bath

		K_2O	CaO	MgO	Na_2O	Mn_3O_4	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	SiO_2	Total
13	argillaceous shale, U.S.A.	0.28	1.08	1.05	0.02	0.01	1.97	1.71	0.02	0.15	2.50	8.79
W–2	argillaceous shale, The Netherlands	0.04	1.19	0.96	0.05	0.03	8.15	1.25	0.02	0.05	6.26	18.00
984	iron hardpan, ditto	tr	0.35	0.22	tr	0.04	25.70	0.41	0.06	1.43	2.48	30.69
676	iron hardpan, ditto	tr	tr	0.08	tr	0.09	51.54	3.35	0.18	0.05	1.35	56.64
M	manganese iron hardpan, Sumatra	tr	0.3	tr	tr	17.1	13.6	9,8		tr	6.8	47.6
171	bauxite (red), Surinam	tr	tr	tr	tr	tr	7.20	6.93	0.08	0.02	0.04	14.27
985	bauxite (white), ditto	tr	0.03	0.02	tr	tr	0.17	8.36	0.02	tr	tr	8.60
170	bauxite (red), Bintan Island (Indonesia)	0.01	0.01	tr	tr	tr	6.88	4.29	0.08	tr	0.04	11.31

Table 6. Elements dissolved (in %) from several kinds of metamorphic rocks by extraction with 25% HCl for 1 hour on a boiling water bath

		K_2O	CaO	MgO	Na_2O	Mn_3O_4	Fe_2O_3	Al_2O_3	TiO_2	SiO_2	P_2O_5	Total
273	black slate, The Netherlands	0.10	0.28	0.63	0.09	0.04	2.89	1.56	0.01	1.55	0.06	7.21
H–5	gray pyritic slate, ditto	0.03	0.96	2.48	0.04	0.02	24.30	3.55	0.04	0.68	0.01	32.11
215	gray slate, Belgium	0.01	0.02	0.66	tr	tr	4.96	2.04	0.02	2.08	0.04	9.83
1001	phyllite, Luxemburg	0.02	0.07	0.26	tr	tr	2.91	1.09	0.03	1.05	0.08	5.51
26	sericite schist, Silesia	0.03	1.21	0.13	tr	tr	0.35	1.19	tr	0.09	tr	3.00
25	paragonite schist, Vermont	0.12	0.30	0.27	0.02	tr	2.03	0.89	0.05	0.80	0.10	4.58
22	actinolite schist, California	tr	0.47	1.14	tr	tr	1.43	1.27	0.08	1.86	0.14	6.39
21	biotite gneiss, Massachusetts	0.90	0.29	0.62	tr	tr	3.91	1.72	0.26	3.98	0.15	11.83
24	soapstone, Virginia	tr	3.20	5.05	tr	0.02	3.70	1.83	0.09	2.78	0.03	16.70
966	serpentine, Celebes	tr	tr	9.68	tr	0.03	5.05	0.49	0.03	17.50	tr	32.78
967	serpentine, Moravia	tr	0.01	8.35	tr	0.04	4.83	0.86	0.03	20.82	tr	34.94

Table 7. Elements dissolved (in %) from weathered serpentine rock from a quarry near Havana by extraction with 25% HCl for 1 hour on a boiling water bath. Furthermore of antigorite and chrysotile

		K_2O	CaO	MgO	Na_2O	Mn_3O_4	Fe_2O_3	Al_2O_3	TiO_2	SiO_2	P_2O_5	Total
	Weathered serpentine, Havana	tr	0.43	22.85	tr	0.03	6.71	0.70	0.03	30.66	tr	61.41
	Weathered serpentine, Havana	tr	1.99	21.10	0.01	0.02	8.25	1.46	0.04	31.85	tr	64.72
756	antigorite, Pennsylvania	tr	0.03	8.35	tr	tr	2.01	0.29	0.02	10.30	tr	21.00
918	chrysotile, Saxony	tr	0.07	28.05	tr	0.06	2.86	1.59	0.04	27.60	tr	60.27

Also, under natural conditions iron and manganese hardpans are not very resistant to weathering. Thus, when used for road constructions in the tropics with heavy rainfalls they will last only for some 5 years. Bauxite, which mostly consists of hydrargillite $Al\ (OH)_3$, is more resistant to weathering than the iron and manganese hydroxide and oxide concretions.

Yet, the application of all this material, i.e. hardened tuffs, (loose, ejected volcanic material cemented by silicic acid) may still be economical in regions where resistant rocks are lacking or where they can only be obtained from other regions at high cost.

Sandstone and shales (mud stones) are formed from material that has already resist weathering processes and therefore they only contain very resistant minerals like quartz, illite + kaolinite, respectively. The cementing value of both these rocks e.g. in macadam roads is of course practically nil, as they do not provide appreciable amounts of binding cement (sesquihydroxides and silicic acid) when weathering.

c. Metamorphic rocks

The rocks and gravels belonging to this group (see table 1) which are of importance for constructional works, e.g. gneiss, schist, amphibolite, slate, quartzite, marble, have resulted from the metamorphism of magmatic or sedimentary rocks, on account of hydrothermal action, high pressure, high temperature, gases and fluid action.

Metamorphism may be slight or it may be so radical that the original rock cannot be accurately identified. Metamorphic rocks derived from clays which have withstood high pressures, are mostly very hard but have a slaty cleavage. It is due to the parallel alignment of minute mica flakes rectangular to the pressure direction, which gives the surface a dull silvery appearance.

When the metamorphosis has been more vigorous, many new (secondary) minerals (sericite, chlorite, tourmaline, garnet, epidot) are formed in parallel layers, which results in a banded (foliated) structure (gneiss, schist). All these rocks, even those very resistant to weathering (e.g. some types of slates) are less suitable for civil and rural engineering purposes as they are apt to split. Some types of slates with extreme hardness and perfect cleavage (phyllites), however, are used for roofing.

Mechanical properties of these kinds of rocks naturally vary considerably in the direction perpendicular and parallel to the plane of stratification.

Metamorphism of shales and slates caused by contact with molten lava gives rise to baked, very resistant rocks = horn rock (horn fels). However, they are mostly folded through volcanic action and therefore less suited to constructional purposes as they contain many fissures.

The mechanical properties of metamorphic rocks with a compact, not folded or foliated structure, such as some types of slates, marble, dolomite, quartzite and serpentine are mentioned in table 2.

Figure 4, table 6 and plate III show the d.t.a., chemical and X-ray analyses of several kinds of metamorphic rocks. They show that slates, schists and gneiss, which are very resistant to HCl, have only a small thermal reaction. On the other hand, serpentine which looses to 50% of its constituents when treated with 25% HCl and marble and dolomite which are even wholly dissolved, have a large thermal reaction. Also in nature marble, dolomite and serpentine rocks have, under the same conditions of weathering deeper profiles overlying the bedrock than slate – and quartzite rocks. The

Plate I.

X-ray photographs of diabase samples from a quarry at Curaçao and of unweathered diabase rock from Massachusetts. Furthermore of silicified diabase tuff from another quarry at Curaçao.

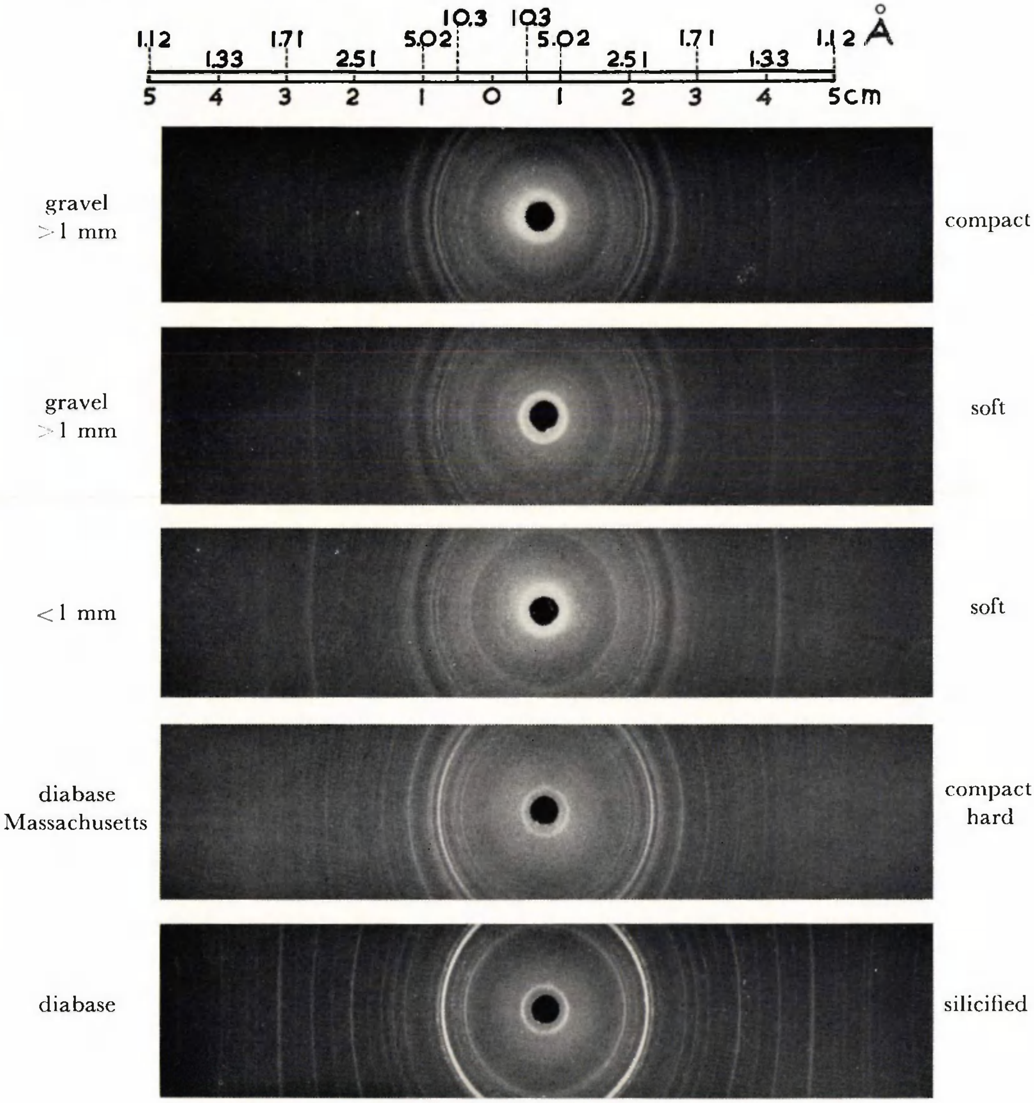


Plate II. X-ray photographs of magmatic and sedimentary rocks.

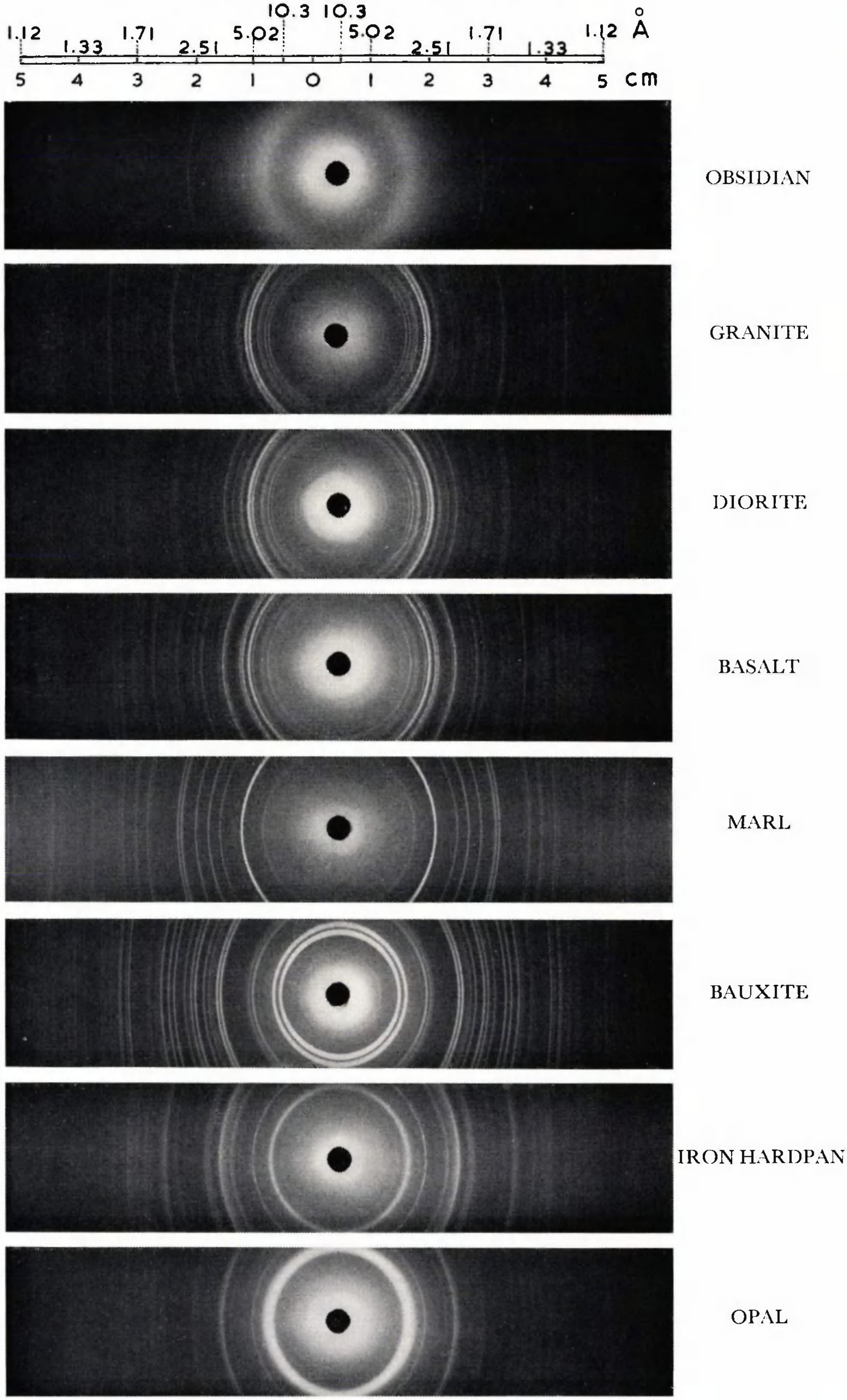
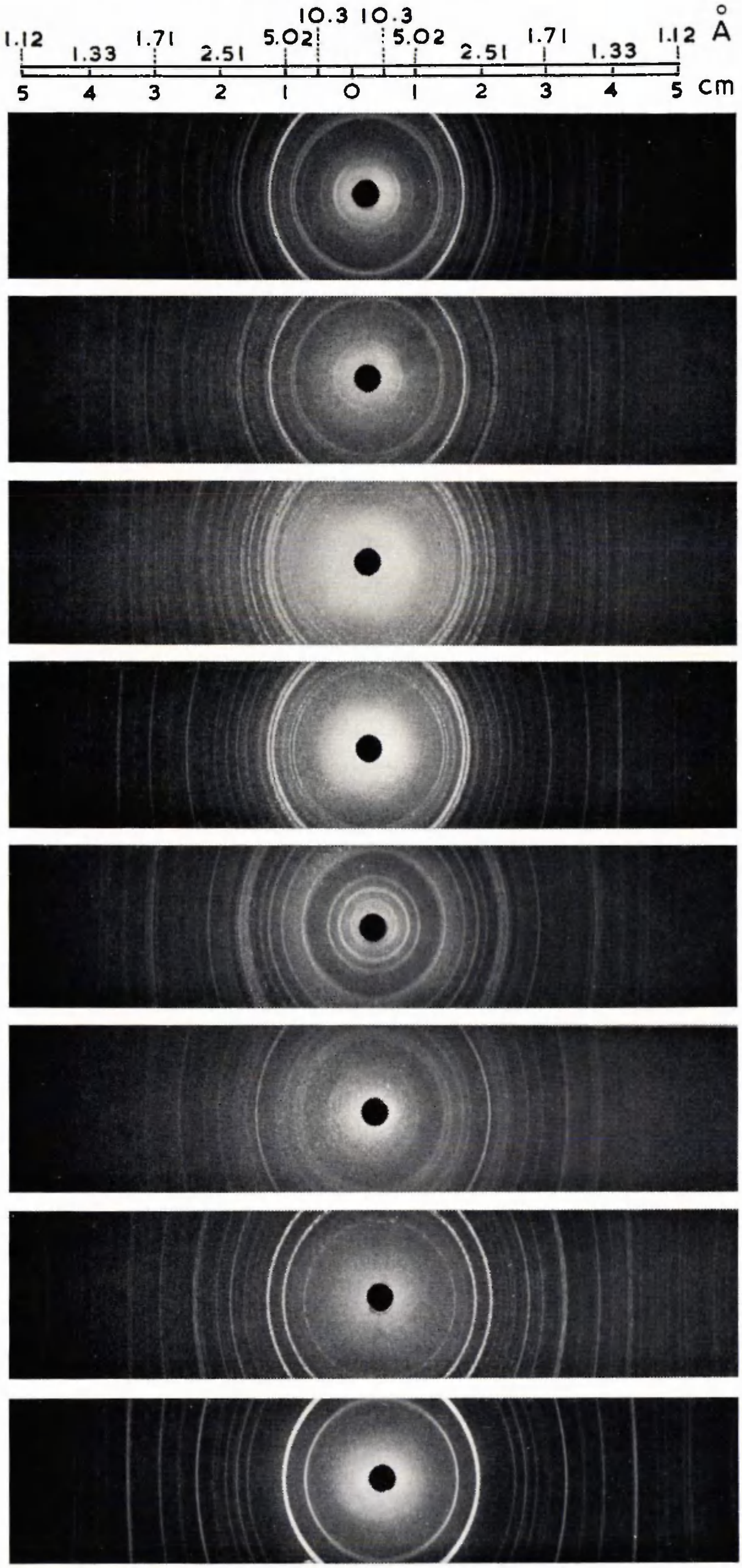


Plate III. X-ray photographs of metamorphic rocks.



SLATE

PARAGONITE SCHIST

CHLORITE SCHIST

BIOTITE GNEISS

SOAPSTONE

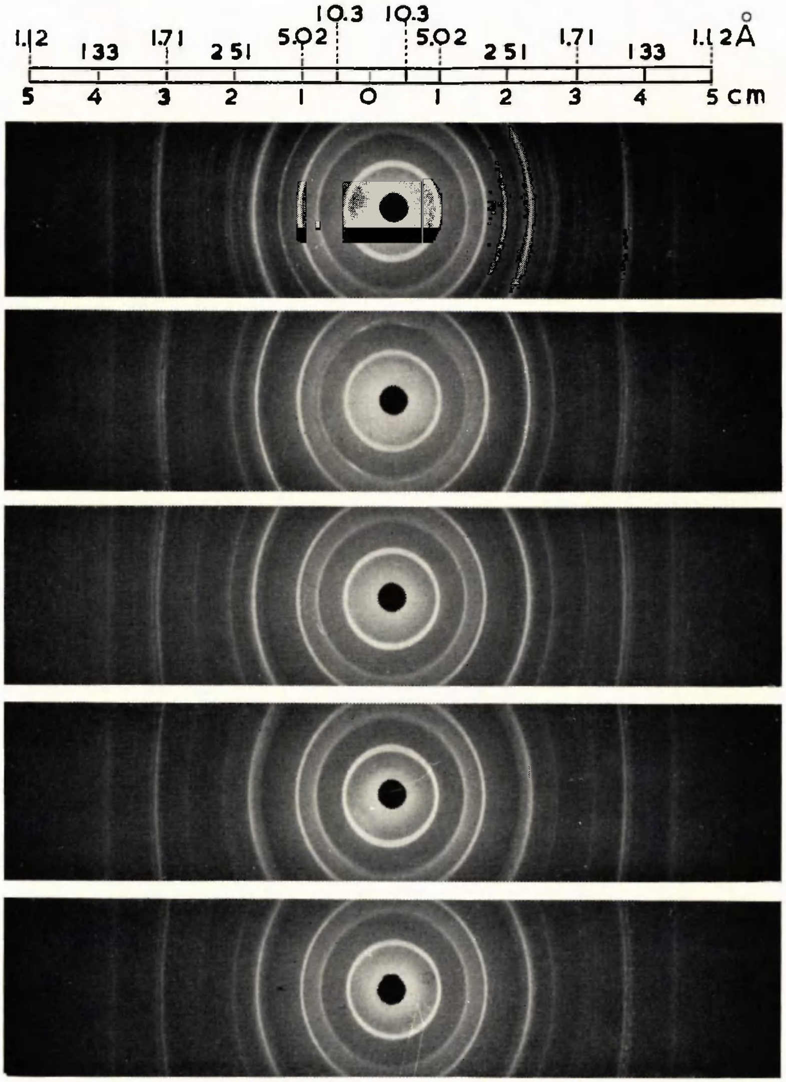
GLAUCONITIC SANDSTONE

DOLOMITIC LIMESTONE

QUARTZITE

Plate IV.

X-ray photographs of weathered serpentine rock and its white weathering product from a quarry at Havana. Furthermore of serpentine, antigorite and chrysotile.



Havana — weathered serpentine rock

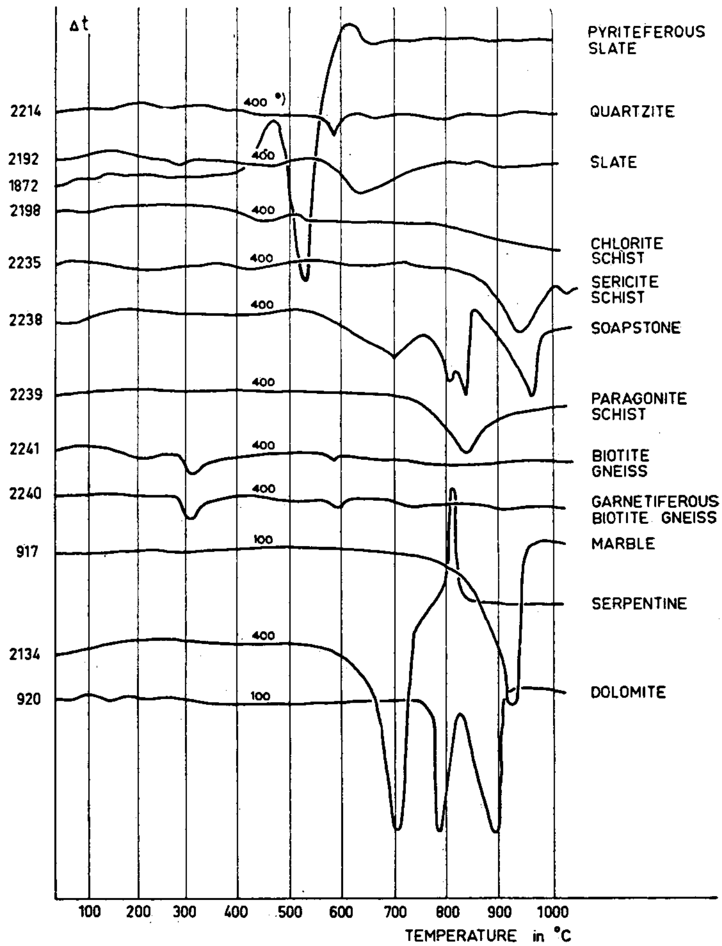
Havana — white weathering product

Celebes — serpentine

Macedonia — antigorite

Arizona — chrysotile

Fig. 4.
D.t.a. of some metamorphic rocks



•) Weight of dried (1 hour at 105 °C) sample in mg

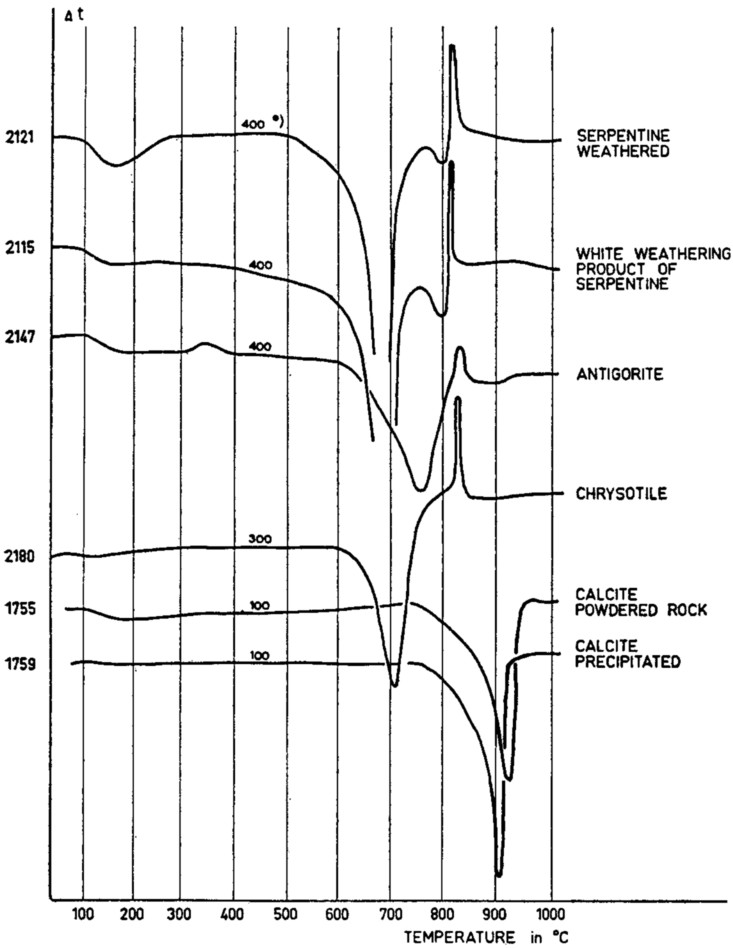
latter rock resulted from a filling up of the pores of sandstones by silicic acid gel, which afterwards hardened (crystallized) under pressure. The cement can even in this case be so firm, that the rock breaks across the original sand particles rather than around them. The extreme hardness of quartzites may in spite of their extremely great resistance to mechanical forces prevent them from being used for constructions.

Of all the above named compact rocks, serpentine rocks are still the most suitable for outwork constructions. They result from metamorphism of ultra-basic rocks (peridotite) and they contain antigorite and chrysotile. Both minerals are a high graded Mg-silicate mineral (ca 30 to 40% MgO), the former being the earthy and the latter the fibrous variety.

However, strongly weathered serpentine rock, e.g. as found in a quarry in the vicinity of Havana (Cuba) has only a compressive strength varying from 400 to 830 kg cm^{-1},[1]) which is caused by the presence of cracks filled with a

[1]) Analysed by: Instituut voor Bodemmaterialen en Bouwconstructies, Delft, Netherlands.

black coated (high Mn-graded) mass. This strongly weathered rock has large endo- and exothermal effects in its d.t.a. diagrams (see figure 5) which are caused by chrysotile and some antigorite (see also plate IV). The thermal effects are smaller for the compact serpentine rock than for the soft desintegrated serpentine (see figures 4 and 5). It is caused by the increased pressure of the H_2O vapour escaping from the more compact unweathered particles, thus increasing the temperature and consequently the entropy of the H_2O molecules and by which the thermal effect of the reaction is decreased. For the same reason the thermal effect of very fine precipitated calcite is also larger than that of coarse calcite (see figure 5).[1])



•) Weight of dried (1 hour at 105 °C) sample in mg

Fig. 5.
D.t.a. of weathered serpentine from a quarry at Havana.
Furthermore of antigorite, chrysotile and of coarse and fine calcite.

[1]) A decrease in particle size, however, not always coincides with a larger thermal effect at a d.t.a. For example, the heat of formation ($\triangle H^0$) of carbon dioxide from diamond is larger than that from fine graphite = –94.507 and –94.052 kcal mole^{-1}, respectively and therefore the exothermal effect in the d.t.a. is also larger for the first reaction. Another example is that very fine quartz and kaolinite particles with a pronounced disordered layer (Beilby layer) on their surface (and therefore with less active mass per unit weight) have a smaller thermal effect than the coarser ones.

By heating with 25% HCl for 1 hour at 100 °C, 33% and 64% were dissolved from the unweathered compact serpentine rock and the soft thoroughly weathered serpentine, respectively (see tables 6 and 7). Consequently the weathered serpentine is far less resistant to weathering action under equal conditions than the unweathered serpentine.

Marble is very suitable for monuments which require a rock which, although somewhat less resistant than serpentine or basic igneous rocks does not stain during the weathering process.

WEATHERING OF ROCKS AND GRAVELS

Water is one of the most predominant weathering agents. Thus when rocks are immersed in water or when water is condensed on rocks cooler than the surrounding air, they will hydrolyse and the pH of the water will increase (e.g. marble) or decrease (e.g. gypsum). The reaction will proceed until an equilibrium is attained. Weathering leads to a decrease in the free energy of formation = $\triangle F°$ ($\triangle F° = \triangle H° - T \triangle S°$ in which T = temperature in °Kelvin and S = entropy).

According to Keller (1954) there exists a close direct relation between the rate of weathering of minerals and their heats of formation ($\triangle H°$). The latter can be used instead of $\triangle F°$ because in this case differences between the entropy of the various compounds are only small. Thus olivine is more susceptible to weathering than pyroxene.

Furthermore magnesite ($MgCO_3$) rock, with $\triangle H° = -266$ kcal. mole^{-1} and with a solubility product (K) = 2×10^{-4} at 298°K (25 °C), will under equal conditions dissolve better than limestone or marble ($CaCO_3$) rock with $\triangle H° = -288$ kcal. mole^{-1} and with a solubility product = 1.2×10^{-8} at the same temperature. However, dolomite ($CaMg(CO_3)_2$) rock with $\triangle H° = -556$ kcal. mole^{-1} will be far more insoluble than $CaCO_3$ or $MgCO_3$ rock.

The relation between the activity product (K′) of a slightly soluble salt and the free energy of its equilibrium reaction ($\triangle F°$) is as follows:

$$K' = \frac{f^{+}\ \text{c-cation} \times f^{-}\ \text{c-anion}}{\text{c salt}} = f^{+} f^{-} K$$

$$\triangle F° = -RT \ln K' = -RT \ln f^{+} f^{-} K$$

in which: f^{+} and f^{-} are activity constants

K = c-cation.c-anion = solubility product (c salt is a constant)

R = the gas constant = 1.986 g cal deg.$^{-1}$ mole^{-1}

T = absolute temperature (°Kelvin)

The activity coefficient of an ion in a solution depends on its nature, and its valency; furthermore on the activity of the other ions in the liquid and on the dielectric constant (ε) of the solution.

The rate at which reaction products of the rocks are removed (e.g. by flowing water) or are dissolved by other agents in the water (e.g. sesquihydroxides by acids and silicic acid by alkalis) is another factor by which the weathering of rocks by hydrolysis is influenced.

Reaction rate increases with temperature ca 10 to 20% for each rise of

1 °C. It is caused only to some extent by increased collisions and largely by the increase of activated ions.

The relation between reaction rate and temperature can be represented by the Van 't Hoff – Arrhenius equation:

$$\frac{d \ln k}{dT} = \frac{E^+}{RT^2}, \text{ which becomes in its integrated form: } k = k_o e^{-\frac{E^+}{RT}}$$

k = reaction rate caused by effective collisions;
k_o = a constant = the reaction rate if all collisions are effective;
E^+ = activated (excess) energy above the average energy properly located in the ions.

The velocity constant of heterogeneous reactions is also increased by speed of stirring (motion); Hixson (1944) found the relation: $k = \alpha(N)^\beta$ in which k is the reaction rate at a certain temperature, N = the rate of stirring and α and β are constants.

Reaction rate also largely depends on the extent of the surface which is in contact with the weathering agents. Thus porous rocks or fine gravel will weather at a faster rate than compact rocks or coarse gravel. Consequently compact heavy limestone (bulk density of limestone and basalt = ca 2.8 to 3.0 and ca 2.6 to 2.8 respectively), although it will be slightly dissolved by diluted HCl, may be used in constructions where acid water or acid vapours are absent, e.g. for the outer cover of sea walls. It should, however, not be used in acid peats, where an acid resistant rock, although somewhat porous, is to be preferred.

Another dominant agent in the weathering process is oxygen. Oxidation of rocks is caused by the free energy of the several elements of the rocks being lower in the oxidized state than in the original one. The process which predominates, is the one in which the greatest loss is obtained.

The rate of an oxidation process primarily depends on the amount of oxygen present in the system. The atmosphere contains 15 to 20 × as much oxygen as water at the same temperature. When temperature or the amount of electrolytes in the water increases, the amount of oxygen decreases considerably.[1])

Another factor is the rate in which the free energy of the system can be lowered. Thus, aluminium is much faster oxidized ($\triangle F^\circ$ Al_2O_3 = −376.77 kcal. mole.$^{-1}$) than iron ($\triangle F^\circ$ Fe_2O_3 = −177.1 kcal. mole.$^{-1}$).

Weathering of rocks is also increased by acids, e.g. sulphuric acid is formed to even a normality of 1 N by oxidation of iron sulphide in soils by bacterial action (genus Thiobacillus). The process is accelerated by flowing water which carries oxygen to the bacteria.

Humic acids are formed in peats under anaerobic conditions and they corrode (bleach) the underlying bed rock considerably. Podzols, which are well-known for their deficiency in plant nutrients are the result of this action. But also very weak acids, e.g. carbon dioxide acid, are destructive at high

[1]) Fresh water of 0 °C, in contact with oxygen of the air, contains 14.62 ppm oxygen as against 7.67 ppm oxygen at 30 °C. Sea water with a chlorinity (total amount of Cl, Br and J in ppm, assuming that the Br and the J have been replaced by Cl) of 20% contains only 11.00 ppm oxygen at 0 °C and merely 5.37 ppm oxygen at 30 °C (see for further details Fox, 1907).

temperatures in the long run because the H^+ions have a high ionic potential $\left(\frac{\text{charge}}{\text{size}}\right)$ and thus they can diffuse easily through the solution or penetrate into the crystals.[1]) In this way under tropical conditions carbon dioxide in rain water to an amount of only ca 5–10 ppm can break down resistant magmatic rocks to 25 m deep layers of thoroughly weathered material which consist mainly of bauxite $\{(Al\ (OH)_3$ and $AlOOH)\}$ mixed with iron hydroxide (FeOOH) and iron oxide (Fe_2O_3) = goethite (limonite) and hematite respectively.

By bacterial action ca 5 to 8 m^3 CO_2 per ha is formed in one year in common soils of temperate climates. In forest and garden soils 5 times as much may be produced.

Water flowing in regions with carbonaceous rocks gives rise to caverns in which the well-known stalactites and stalagmites are found. The reactions involved may be represented as follows:

$$H_2O + CO_2 \leftrightarrows H_2CO_3$$

$$\text{or } K_1' = \frac{fH_2CO_3cH_2CO_3}{fH_2OcH_2OfCO_2cCO_2} \text{ or } \frac{fH_2CO_3cH_2CO_3}{PCO_2} =$$

$$= K_1'fH_2OcH_2O\ CfCO_2 = K_1.$$

$$H_2CO_3 \leftrightarrows H^+ + HCO_3^+ \quad \text{or } K_2 = \frac{fH\ cH.fHCO_3c\ HCO_3}{fH_2CO_3c\ H_2CO_3}$$

$$HCO_3 \leftrightarrows H^+ + CO_3^{--} \quad \text{or } K_3 = \frac{fH\ cH.fCO_3c\ CO_3}{fHCO_3c\ HCO_3}$$

$$\underset{\text{(solid)}}{CaCO_3} \leftrightarrows \underset{\text{(dissolved)}}{CaCO_3} \leftrightarrows \underset{\text{(solution)}}{Ca^{++} + CO_3^{--}}$$

$$\text{or } K_4' = \frac{f\,Ca\ c\ Ca\ f\,CO_3\ c\ CO_3}{f\,CaCO_3\ c\ CaCO_3} \quad \text{or } f\,Ca\ c\ Ca\ f\,CO_3\ c\ CO_3 =$$

$$= K_4'\ f\,CaCO_3\ c\ CaCO_3 = K_4$$

From the above results:

$$\frac{K_4}{K_1\,K_2\,K_3} = \frac{f\,Ca\ c\ Ca\ \ P\,CO_2}{(fH\ cH)^2}$$

$$\text{or } \frac{f\,Ca\ c\ Ca\ \ P\,CO_2}{(fH\ cH)^2} = \frac{K_4}{K_1K_2K_3} = K.$$

($f\,CO_2 = f\,H_2O = 1$; $c\ H_2O$, $c\ CaCO_3$ are constants; $c\ CO_2 = CPCO_2$ where C = Henry's law constant and PCO_2 = partial pressure in atm.)

Consequently, the reactions which give rise to solution and precipitation of $CaCO_3$ when in contact with water depend on three variables:

[1]) Ion velocity at infinite dilution at 18 °C in cm $\text{Volt}^{-1}\text{sec.}^{-1} \times 10^{-4}$:
$OH^- = 18.0$; $Cl^- = 6.8$; $\frac{1}{2}\,SO_4^{--} = 7.0$; $\frac{1}{2}\,CO_3^{--} = 6.2$
$H^+ = 32.7$; $K^+ = 6.6$; $\frac{1}{2}\,Ca^{++} = 5.3$; $\frac{1}{2}\,Mg^{++} = 4.6$

a. the activity and concentration of the Ca-ions in the liquid, which depends on temperature, amount and nature (valency) of other ions in the same liquid;
b. the partial pressure of free CO_2 in the liquid which depends on temperature and other gases in the same liquid;
c. the activity and the concentration of the H-ions in the liquid which depends on temperature, amount and nature (valency) of other ions in the same liquid.

Thus, if the concentration (pressure) of CO_2 increases and therefore also that of the H ions, the concentration of Ca in the solution will increase. (After the last equation K can only remain constant if the concentration of Ca increases as the concentration of the H ions stands in the denominator; even in its second power.)

Conversely, if the concentration of the H ions decreases, and therefore that of the CO_2 concentration (pressure) also, K can only remain constant if the concentration of calcium ions in the liquid decreases; calcium therefore must precipitate as $CaCO_3$.

After the observations of Wattenberg and Timmermann (1938) the solubility (ionic)product of $CaCO_3$ in water at 20 °C, being 5×10^{-9}, increases to 2660×10^{-9} in sea water at the same temperature, i.e. the latter is about 500 times larger. This phenomenon is caused by the reduced activity of the Ca and CO_3 ions in sea water on account of its larger content of other ions and the product of the active Ca and CO_3 ions (not of the dissolved Ca and CO_3 ions) in the sea water, being a constant value. Consequently, carbonaceous rocks will be more easily attacked by sea water than by fresh water, which contains only a small amount of electrolytes.

Furthermore, in colder climates more $CaCO_3$ rock will be dissolved than in warmer climates, as in the former case more CO_2 can be dissolved in the water than in the latter, e.g. solubility of CO_2 in water at 0 °C = 17.15 ml/l and at 24 °C = 7.82 ml/l (see Buck et al., 1932).

In hot arid regions temperature divergencies to about 40 °C between day and night cause mechanical desintegration of the rocks. The coarser and darker coloured rocks are more affected than the corresponding finer and lighter coloured ones. A primitive manipulation to break large rocks is to heat them first and then to cool them suddenly by water.

Through frost action water in the capillaries of porous rocks (porosity of limestone and sandstones = to 20–30%) expands to 9% of its volume, thereby exerting a pressure of about 2000 lbs. inch^{-2}.[1]) Its heat of crystallization at atmospheric pressure is ca 80 cal/gram, which is equivalent to ca 34 kg mtr/gram. The effectiveness of frost action is best illustrated by Cleopatra's Needle. The inscription of this obelisk which had for centuries withstood the weathering action in the hot climate of Egypt, when removed

[1]) If n = the porosity and t_s = the tensile stress in a rock in the equilibrium state when all the water in the pores of the rock has become ice, the following relation exists (see Kessler and Sligh, 1927):

$$2000 = \frac{(1-n)\, t_s}{n} \text{ or } t_s = \frac{2000\, n}{1-n}$$

In this way a rather porous sandstone of ca 25% porosity may be subjected to a disrupting force of 667 lbs. inch^{-2}. High elasticity and high permeability of the rock, however, will decrease the internal stress considerably.

to London was soon damaged and had to be protected by paraffin-waxes, i.e. water detergent aliphatic molecules. (see Schaffer, 1932).

The effectiveness of these detergents has been increased by the introduction of a positive charge which is opposite to that of the mostly negative charge on the surface of clay and rock particles. Consequently, positively activated paraffin-waxes, e.g. Estarfin (Stockhausen & Co, Krefeld), Perlit (Bayer, Leverkusen), Resistol (Scholten, Foxhol) are tenaciously bound by the material which is to be protected.

Silicones, although more expensive, may also be used, e.g. B 50 (Bayer, Leverkusen), MS 10 (Wocker Chemie, München), Rhodorsil 50K (Rhone-Pouleng, Paris), Drisil (Midland Silicones, London) for protection – see for details e.g. Essen-Kray et al. (1954).

Furthermore large organic compounds with strong hydrophobic groups (alkyl or phenyl) and of a cationic nature, e.g. D.D.A.C. (Armour, Welmington) and $(C_2H_5)_2NH_2^+ Cl^-$, respectively.

In recent years the high cost of labour, transport and materials has largely stimulated the use of all these additives to protect buildings and roads against the destructive action of water and frost.

Mechanical desintegration is also caused by chemical action. In this way SO_4^{--} ions formed by oxidation of pyrite and marcasite, which minerals are commonly found in slates, may react with minute particles of calcite, a mineral which may also occur in the slate. As a result, when the material has dried up, $CaSO_4 . 2H_2O$ (gypsum) is formed which has a volume twice as large as that of the original slate. The expansion causes "scaling" of the slate which is a very destructive process, especially for slates which are used for roofing (see Kessler and Sligh, 1932). Therefore, slates which are to be used for roofing in towns where the air is defiled with SO_2 fumes from chemical industries or from the combustion of coal in furnaces and stoves, should first be analysed for $CaCO_3$.

Scaling of granite of monuments has the same cause. The Ca^{++} ions result from the mortar or from the decay of calcareous minerals which are originally present in the granite and the SO_4^{--} ions from the atmosphere (see Kessler et al., 1940).

Efflorescenses – mainly consisting of $CaCO_3$ – also cause mechanical desintegration by chemical action as the crystals which develop in the pores of the rock exert a wedging action.

Finally, galvanic corrosion of rocks may be very destructive under certain conditions. Thus a network of small short-circuited electric currents caused by differences in the amount of diffused oxygen from the air into several successive water layers (differential aeration current) may be present on the surface of rocks particles. At the anode, i.e. the part with the smallest amount of oxygen, the rock material is dissolved and at the cathode oxygen is reduced to OH^- ($2H_2O + O_2 + 4\,e^- \rightarrow 4\,OH^-$). Or, if the current is very intensive, hydrogen gas is formed at the cathode ($2H^+ + 2\,e^- \rightarrow H_2$). An excess of OH^- may lead to precipitation of insoluble $Ca\,(OH)_2$, $Mg(OH)_2$, or sesqui- and manganous hydroxides as a porous film on the anode. By films of insoluble precipitates or a film of hydrogen gas the resistance of the circuit is increased and consequently the destructive corrosion reaction is hindered. Flowing acidic waters rich in oxygen will thus be most destructive.

Galvanic corrosion is greatly increased by electrolytes as they decrease the resistance of the system considerably, because the electromotoric force of a circuit depends on the current and the resistance. Galvanic corrosion is furthermore increased by temperature as an increase of temperature leads to a decrease of the resistance. Thus, the specific conductance (χ) of water of 25 °C in contact with carbon dioxide of the atmosphere is about 1.4×10^{-1} ohm^{-1} cm^{-1}. However, brackish water has at 5 °C ca 5000×10^{-6} ohm^{-6} cm^{-1} and at 25 °C = ca 8000×10^{-6} ohm^{-1} cm^{-1}. Ocean water has ca 33000×10^{-6} ohm^{-1} cm^{-1} and 53000 ohm^{-1} cm^{-1}, respectively. As the electrolyte concentration increases, the corrosive rate goes through a maximum = ca 0.5 N solution (approximately equivalent to that present in ocean water) and then decreases. The decrease is caused by a decrease in oxygen solubility at the higher concentrations (see for details Thomas et al., 1934).

Corrosion rate goes also through a maximum when the temperature is increased as solubility decreases when temperature increases.

A high conductivity of the solution furthermore permits cathode and anode areas to be active at a farther distance from each other.

For every coulomb of galvanic current which flows a definite weight of anode (rock) material dissolves: Thus,

$$W = \frac{Mit}{z\ 96500}, \text{ in which}$$

W = weight of the dissolved anode material in grams;
M = atomic weight of the dissolved anode material;
i = galvanic current in Ampères;
t = time of flow of current in seconds;
z = valence of the cations formed at the anode.

Chemicals, which form insoluble protective films or which decrease the corrosion rate of the metal to be protected called inhibitors, e.g. phosphates, silicates, carbonates, and magnesium-, zinc-, nickel- salts respectively are applied to decrease galvanic corrosion. Another procedure to decrease galvanic corrosion is cathodic protection. In this case the negative side of a direct low voltage current (30 to 50 Volt) of high density (100–200 amp.) produced by a rectifier is connected with the material to be protected. From there the current travels to scrap steel anode pipes placed in the soil at some distance from the material. Cathodic protection is commonly used (see e.g. Uhlig, 1955) – to prevent galvanic corrosion of oil pipes and oil tanks in soils with a high salinity (desert soils with seasonal rains). It however cannot be applied to prevent corrosion of rocks and gravels because the latter have a too high specific resistance = ca 10^6 to 10^8 ohm cm^{-1} against ca 10^{-5} ohm cm^{-1} for iron.

DISCUSSION

From the above it may be concluded that the suitability of a rock or gravel for civil and rural engineering practices depends on many factors. Besides mechanical and economical factors (foundations, roof spans in mines, cost of transport), there are architectural and decorative considerations (pillars, colour of monuments) and the rock must moreover be resistant to weathering action. The value of a rock for road construction depends largely upon the extent to which it will resist the destructive influences of traffic. Moreover, when used in macadam roads, it depends on the cementing properties (kind of weathering products) of the rock. Thus, a rock which is unsuitable for one purpose may be the right material for another.

By a petrographic analysis, which is a quick inexpensive method *(microscope, polishing machine)* if used by an experienced investigator, the nature of a rock can be identified with great accuracy.

However it does not give information about mechanical strength and resistance to weathering agents of the rock in situ, which properties are in fact, the most important for the civil and rural engineer. He is less interested in the exact identification of a rock.

The mechanical method does not give information about the durability of a rock against weathering conditions. Moreover, mechanical analyses may be largely influenced by moisture condition and the direction in which the sample is analysed.

By chemical analysis valuable information can be obtained about the durability of the rock against weathering conditions. However, chemical analyses are not only laborious and expensive, but various instruments and much room are also needed.

The d.t.a. method is very quick and thereby the instrument is not complicated and needs small space only. Although this procedure is not quantitative (Van der Marel, 1955) – it gives preliminary valuable information about the nature of a rock and its state of weathering.

From the above it follows that each method has its own merits. Only by using them all, definite information can be obtained about the properties of the rock to be used in the prospective construction and about its future behaviour against the weathering agents in situ. Yet, unequal distribution of the stress on the surface of the rock particles, caused by bad filling of the joints with mortar, unequal settlement of the construction, swaying of tall buildings due to storms, fatigue effects of the rocks caused by strong torsion, flexure or tension and large differences in thermal expansion between the rock and its frame construction,[1]) may upset all predictions based on analyses and theoretical calculations. Therefore, to avoid catastrophes in the future, an adequate security factor should always be taken in the calculations of rock constructions.

(Submitted 1959)

SAMENVATTING

Verschillende gesteentesoorten en hun verschillende eigenschappen worden besproken, speciaal met het oog op het gebruik ervan voor civiel- en cultuurtechnische werken.

Bij mechanisch gesteente-onderzoek zijn de resultaten zeer afhankelijk van het vochtgehalte en de richting waarin het gesteentemonster wordt onderzocht. De verkregen cijfers geven derhalve alleen informatie over de kwaliteit van het monster op een bepaald ogenblik tijdens de test, zodat men daaruit niets kan voorspellen met betrekking tot toekomstige gedragingen in situ. Deze hangen ook af van de verdeling van de op het gesteente werkende krachten over het gesteente-oppervlak en van de plaatselijk zeer wisselende omstandigheden ten aanzien van de verwering.

Verwering van gesteente is afhankelijk van de hoeveelheid vocht, zuurstof,

[1]) Thermal expansion coefficient of iron and steel = 10 to 11 $\times$ 10^{-6}, marble = 4 to 16 $\times$ 10^{-6}, granite = 6 to 9 $\times$ 10^{-6}, slate = 9 $\times$ 10^{-6}.

electrolyten en zuurgraad evenals van de grootte van het oppervlak en de snelheid waarmede verweringsprodukten worden afgevoerd en ten gevolge waarvan het verweringsproces kan voortgaan.

Vooral bij de waterlijn van zeewater met een hoog zout- en zuurstofgehalte werken sterk destructieve krachten. Bijzonderheden hiervan worden vermeld.

Eveneens worden voorbeelden gegeven van de toepassing van de differentiaal thermaal-, röntgen- en chemische analyse bij de waardering van gesteenten voor civiel- en cultuurtechnische doeleinden.

ZUSAMMENFASZUNG

Verschiedene Gesteinsarten und deren Eigenschaften in zivil- und kulturtechnischer Hinsicht werden einer Besprechung unterzogen. Mechanische Untersuchungen werden erheblich beeinfluszt durch Feuchtigkeitverhältnisse und die Richtung in welcher die Gesteinsprobe analysiert wird.

Ein mechanischer Test erteilt daher nur Auskünfte über die Qualität eines Gesteins während eines bestimmten Moments in der Testapparatur und es ist nicht möglich daraus auf das künftige Verhalten eines Gesteins zu schlieszen. Letzteres wird bedingt durch die Verteilung der Angriffspunkte der Kräfte über die Gesteinsoberfläche und auch durch die örtlichen Verwitterungsverhältnisse welche erhebliche Differenzen aufweisen können.

Die Gesteinsverwitterung wird bedingt durch den Gehalt an Wasser, Sauerstoff, Elektrolyte und den Säuregrad. Auch die exponierte Flächengrösze und die Geschwindigkeit des Abtransports der Verwitterungsprodukte nachdem ein Fortschreiten der Verwitterung wieder möglich ist, sind wichtige Bedingungen.

Besonders nahe der Wasserlinie des hoch-salzigem und auszerdem sauerstoffreichem Meerwassers sind die auf das Gestein einwirkende destruktiven Kräfte besonders stark. Einzelheiten davon werden erwähnt.

Auch Beispiele werden gegeben von der Anwendung der Differential thermal-, Röntgen- und chemische Analysen bei der Bewertung von Gesteinsarten für zivil- und kulturtechnische Zwecke.

LITERATURE

Baars, J. K., 1950: Manganese deposits in rice fields. Trans. 4th International Cong. Soil Sci. Amsterdam Vol. I, 193–195.

Barshad, I., 1952: Temperature and heat of reaction calibration of the differential thermal analysis apparatus. Amer. Mineral. 37, 667–694.

Bromfield, S. M., 1954: The reduction of iron oxide by bacteria. The Journ. of Soil Sci. *5*, 128–139.

Bruyn, C. M. A. de, and H. W. van der Marel, 1954: Mineralogical analysis of soil clays. Geologie en Mijnbouw *16* (nw. serie) 69–83 and 407–428.

Buck, K., H. W. Harvey, H. Wattenberg and S. Gripenberg, 1932: Ueber das Kohlensäuresystem im Meerwasser. Cons. Perm. Internatl. p. l'Expl. de la Mer *79*, pp 70.

Essen-Kray, Pels Leusden and Bergmann, 1954: Ueber die Verwendungsmöglichkeit von Siliconen in der Ziegelindustrie. Ziegelind. *7*, 403–406.

Evison, F. F., 1956: The seismic determination of Young's modulus and Poisson's ratio for rocks in situ. Géotechnique *6*, 118–123.

Faust, G. T., 1948: Thermal analysis of quartz and its use in calibration in thermal analysis studies. Amer. Mineral. *33*, 337–345.

Fox, G. J. J., 1907: Conseil permanent international pour l'exploration de la mer. Copenhagen. Publication de Circonstance *41*.

Hixson, A. W., 1944: Nature and measure of agitation. Ind. and Engr. Chem. *36*, 488–496.

Jackson, F. H., 1916: Methods for determination of the physical properties of road-building rock. U.S. Departm. Agricult. Bulletin *347*, pp. 28.
Keller, W. D., 1954: The bonding energies of some silicate minerals. Amer. Mineral *39*, 783–793.
Keller, W. D., 1954: The energy factor in sedimentations. Journ. Sedim. Petrol. *24*, 62–68.
Kessler, D. W., 1927: Building stones. Internatl. Critical Tables. McGraw Hill Book Comp. Inc., New York, Vol. II, pp 47–56.
Kessler, D. W. and W. H. Sligh, 1927: Physical properties of the principal commercial limestones used for building construction in the United States. Technologic Paper Bur. of Stand. No. 349, *21*, 497–590.
Kessler, D. W., and W. H. Sligh, 1932: Physical properties of slate. U.S. Department of Commerce. Bur. of Stand. R. P. 477, 377–411.
Kessler, D. W., H. Insley and W. H. Sligh, 1940: Physical, mineralogical and durability studies on the building and monumental granites of the United States. U.S. Natl. Bur. Stand. *25*, 161–206. Rpt. 1320.
Leeper, G. W., and R. J. Swaby, 1940: The oxidation of manganous compounds by micro organisms in the soil. Soil Sci. *49*, 163–168.
Lord, F. C. F., 1916: Relation of mineral composition and rock structure to the physical properties of road materials. U.S. Departm. Agricult. Bulletin *348*, pp. 26.
Marel, H. W. van der, 1956: Quantitative differential thermal analysis of clay and other minerals. Amer. Mineral. *41*, 222–244.
Obert, L., S. L. Windes and W. I. Duvall, 1946: Standardized tests for determining the physical properties of mine rock. U.S. Bur. of Mines. Rpt. 3891, pp. 67.
Roberts, J. L., 1947: Reduction of ferric hydroxide by strains of Bacillus polymixa. Soil Sci. *63*, 135–140.
Schaffer, R. J., 1932: The weathering of natural building stones. Dept. Scientif. and Ind. Res. Special Rept. *18*, p. 42.
Thomas, S. D., Th. G. Thompson and C. L. Utterback, 1934: The electrical conductivity of sea water. J. du Conseil, *9*, 28–35.
Tuttle, O. F., 1949: The variable inversion temperature of quartz as a possible geologic thermometer. Amer. Mineral *24*, 723–730.
Uhlig, H. H., The corrosion Handbook. John Wiley and Sons Inc., New York, 1955, pp. 1188.
Windes, S. L., 1949: Physical properties of mine rock. Part. I U.S. Bur. of Mines, Rpt. 4459, pp. 79.
Windes, S. L., 1950: Physical properties of mine rock. Part II. U.S. Bur. of Mines. Rpt. 4727, pp. 37.
Wattenberg, H. and E. Timmermann, 1938: Die Löslichkeit von Magnesiumkarbonat und Strontiumkarbonat in Seewasser, Kieler Meeresforschungen *2*, 81–94.
Woolf, D. O., 1930: The results of phycisal tests of road building rock. U.S. Departm. Agric. Miscellaneous Publ. *76*, pp. 148.

SOIL CONDITIONS IN THE KHULNA DISTRICT
(East Pakistan)

by

Dr. Ir. K. van der Meer[1])

1. INTRODUCTION

The Khulna District is a part of the Ganges delta area in East-Pakistan and is subjected to influences of the tides. The difference between low and high tide amounts to ca. 3–3.50 metres. Human occupation is found on the levees of ancient rivers which in places rise above the brackish water clay, or on the levees of tidal channels and tidal rivers (fig. 1).

For the protection of land and dwellings the area has been embanked thus giving rise to the existance of a very great number of small polders. In most cases, however, the dikes are not capable to their task consequent of insufficient height, too steep slopes, lack of maintenance and undermining by a very great type of crab. Therefore dike-bursts are manifold causing flooding of the land with brackish to salt water from the tidal streams and inflicting great damage to the crops. Moreover water control in the small polders is very defective because of leaking sluices by which water streaming forth at low tide, flows back equally rapid at high tide in various places.

Permanent ricegrowing is the prevailing cropping system. Rice is sown at the beginning of the wet monsoon (May-June), planted out afterwards and is harvested, dependant on the kind, from mid-October to the middle of January.

Water supply of the rice crop depends on the beginning, the proceeding and ceasing of the rainy season in which many variations occur, thus causing many risks for the one and only crop on account of drought on the one side and drowning on the other side.

The purpose of the soil survey in the area was to draft plans, in co-operation with agriculturists and rural- and civil engineering specialists, to remove the mentioned difficulties and to create possibilities to obtain two harvests a year instead of one by improvement of dikes, effective control of drainage and drafting an irrigation system.

2. SOIL CONDITIONS

The Khulna District is a part of an extensive declining area situated at the Bengal Gulf. The thickness of the alluvial sediment layers (alternating fluviatile and marine deposits) amounts to some hundreds of metres. Generally the depositing power of the rivers is such, that in most cases a fluviatile subsoil is found.

During the last centuries the transgressive force of the sea appears to have increased through which a topsoil of brackish water sediments, overlying a transitional peat layer, has been formed. Sedimentation took place in the normal way by a system of creeks, levees and basins. This system is characterized by some circumstances which greatly influence soil quality.

a. Conditions during sedimentation were of a nature that the swamp soils have a $CaCO_3$/sulphides ratio to such a degree that cat clay formation

[1]) Nederlandsche Heidemaatschappij.

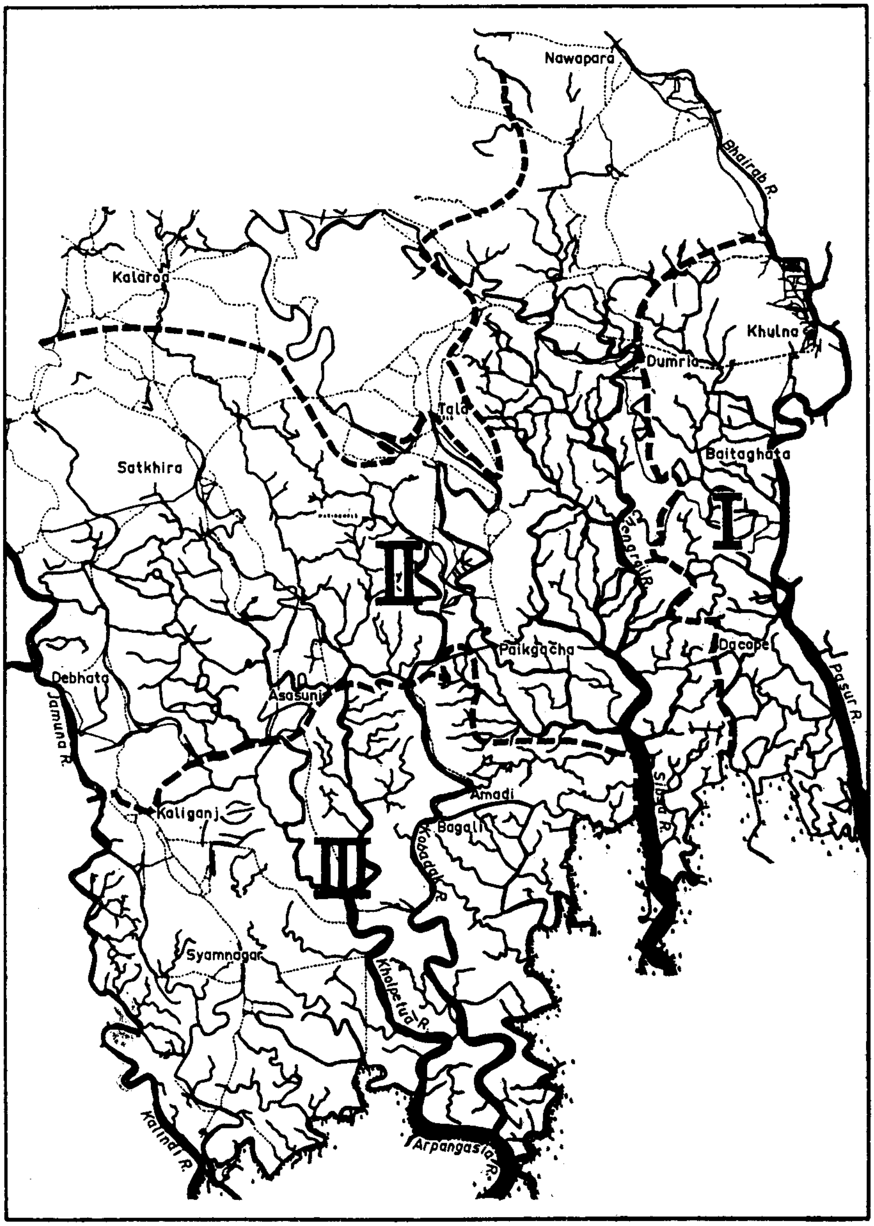


Fig. 1. Map of the Khulna District, East Pakistan.
I Fresh
II Fresh-brackish
III Brackish-saline
(By courtesy of the F.A.O. Agric. Div. Land and Water Use Branche, Rome).

may start easily. In the southern part of the area this has already taken place showing the well-known yellow spots in the profile accompanied by a low pH.

In the north, where drainage conditions are such that the subsoil is not yet aerated, pH values are not yet as low, but from analyses may be taken that this will also be the case after aeration has set in.

b. In the greater part of the surveyed area the topsoil has been subjected during centuries, and still up to the present day, to regularly occurring flooding with brackish to salt water.

As a consequence the soil adsorption complex has a very high degree of saturation with Na and Mg, giving rise to the well-known problems on soil structure and permeability. Naturally flooding is also reflected in a lower or higher salinity of the soil, the degree of which varies greatly in connection with duration, frequency and intensity of flooding and salt content of the flood water. High salinity figures may occur in an area periodically flooded with salt, tidal water as well as in an area with permanent salt water. In the last case, however, the intensity of occurring of high salinity figures is greater than in the first one. In the survey under review, however, not much attention was paid to salinity as its occurrence is not systematically connected with soil differences but is accidental. Furthermore the salinity will disappear after a short period of desalinisation after finishing the improvement works so that no more harm can be done to the crops, such in contrast to the influence of sodium and magnesium. In the course of time every polder has been flooded many times and is in a more or less advanced stage of desalinisation but the influence of sodium and magnesium is still undiminished.

c. At present a part in the east of the surveyed area is still under the influence of fresh water from the rivers Ganges and Brahmaputra. This is the cause that brackish or salt water influences are unknown here in spite of the occurrence of considerable differences in high and low tide. In this area fresh water tidal sediments are found showing a tidal sedimentation pattern without the occurrence of cat clay. Furthermore difficulties with brackish and salt water flooding do not occur and consequently no structure and permeability problems exist. Therefore the soils belong to the best in the district seen from an agricultural point of view.

3. TECHNICAL PROBLEMS

The ultimate purpose of the survey was, in co-operation with experts in other fields, to arrive at a responsible execution of a carefully drafted and well founded plan.

In view of the special soil properties, soil conditions play an important role in the execution of the agricultural and land development plans. In this connection the following problems are to be dealt with:

a. The danger of cat clay formation in case of drainage

Apart from the regularly returning floods part of the district is subjected to imperfect drainage conditions. Partly, however, this is a fortunate circumstance owing to which soils susceptible to cat clay formation have not yet got acid which in future too, is to be prevented. External drainage conditions are to be put under control but internal drainage has to remain unchanged. This implies that this type of soils is only suitable for perpetual rice growing.

Drainage, internal as well as external, will render this type of soils unsuitable for rice as well as for other crops.

b. Subsidence

A part of these soils overlies a fairly thick peat subsoil of a slushy consistency. The whole of it is in equilibrium with the prevailing drainage conditions. Locally no alternations are intended in view of the danger of cat clay formation. However, peat also underlies the fresh water tidal sediments. These sediments having larger agricultural potentialities do need a better drainage and with it the problem of subsidence makes its appearence. According to the available modes of computation subsidence will amount to about 50% of the thickness of the peat layer thus bringing about a lowering of the surface of ca. 0.50 metre which locally may cause damage for irrigated dry cultures, in connection with the realization of an adequate drainage.

c. Water management potentialities

Thanks to great tidal differences and the altitude of the average surface relative to these differences, good external drainage is possible. Internal drainage conditions are varying but are well correlated with the various soil groups. In the fresh water tidal sediments, which are in need of a fairly deep internal drainage in view of the most desired agricultural use, permeability of the topsoil as well as of the subsoil is satisfactory thus giving a favourable picture.

The whole profile of cat clay soils and soils susceptible to cat clay formation is badly permeable which, in view of perpetual rice growing, is to be desired. So in this case only good external drainage must be the aim, then internal drainage is of no importance and has even to be prevented for various agricultural and pedological reasons.

Thus it appears that in special cases a combination of unfavourable soil properties may be profitable.

(Submitted 1959)

SAMENVATTING

In het Khulna district (Gangesdelta, Oost-Pakistan) komt een groot aantal polders voor, die regelmatig door brak tot zout water uit getijderivieren worden overstroomd, hetgeen verzouting veroorzaakt. De bodemgesteldheid is van dien aard, dat de gronden gevoelig zijn voor kattekleivorming en gedeeltelijk reeds katteklei bevatten. De ontworpen drainage- en irrigatiewerken moeten er dus op gericht zijn, om enerzijds verdere kattekleivorming tegen te gaan en anderzijds de zouthuishouding te verbeteren, waarbij het voorkomen van overstromingen ook een belangrijke rol speelt. Deze gronden zijn eigenlijk alleen geschikt voor continue rijstbouw. Slechts een klein gedeelte van het gebied, dat onder invloed staat van zoete getijderivieren, heeft grotere landbouwkundige mogelijkheden.

ZUSAMMENFASZUNG

Im Khulna Distrikt im Ganges Delta, Ost-Pakistan, befinden sich viele Polder, welche regelmäszig von Brack- und Salzwasserüberschwemmungen aus Gezeitenflüsze zu leiden haben wodurch Versalzung der Böden auftritt. Die Bodenbeschaffenheit ist derart, dasz die Böden sehr empfindlich sind für die

Bildung von Pulvererde und zum Teil schon daraus bestehen. Daher sollen die Entwürfe von Entwässerungs- und Irrigationsanlagen derart gestaltet werden, dasz einerseits einer weitergehenden Pulvererdebildung Einhalt wird getan, anderseits aber die Salzhaushalt verbessert wird. Hierbei spielt die Vorbeugung von Überschwemmungen eine sehr wichtige Rolle. Überhaupt eignen sich diese Böden nur zum fortdauernden Anbau von Reis. Nur ein kleiner Teil, unter Einflusz süszem Gezeitenfluszwassers, bietet gröszere landwirtschaftliche Aussichten.

LIST OF PUBLICATIONS

The text of the publications is in Dutch. Extensive summaries in English are added. Price in Dutch guilders.

SERIES I. SOIL SURVEY OF THE NETHERLANDS

Volume I *Pijls, F. W. G.:* A detailed soil survey of the community Didam. 116 pag., col. maps. a.o. annexes. Price f 5.50. 1948.

Volume II *Liere, W. J. van:* Soil conditions in the Westland. Col. printed profiles in text, 152 pag., col. map a.o. annexes. f 6.—. 1948.

Volume III *Koenigs, F. F. R.:* A soil survey of the environs of Azewijn. 46 pag. col. map. Price f 3.25. 1949.

Volume IV *Schelling, J.:* A soil survey of the agricultural area of the municipality of Groesbeek. 55 pag., col. maps a.o. annexes. Price f 3.65. 1949.

Volume V *Veenenbos, J. S.:* Soil conditions of the area between Lemmer and Blokzijl in the border-area of the Noordoostpolder. 161 pag., col. maps a.o. annexes. Price f 6.—. 1950.

Volume VI *Bakker, G. de:* Soil conditions of some Zuidbeveland polders and their adaptations for fruit-growing. 182 pag., col. maps a.o. annexes. Price f 6.—. 1950.

Volume VII *Edelman, C. H. et al:* A soil survey of the Bommelerwaard boven de Meidijk. 137 pag., col. maps. Price f 6.—. 1950.

Volume VIII *Egberts, H.:* Soil conditions in the Betuwe. 88 pag., col. map a.o. annexes. Price f 6.—. 1950.

Volume IX *Buringh, P.:* Soil conditions in the environments of Wageningen. 131 pag., col. map a.o. annexes. Price f 6.—. 1951.

Volume X *Schelling, J.:* A soil survey of northern Limburg (municipalities Ottersum, Gennep and Bergen). 139 pag., col. maps a.o. annexes. Price f 6.—. 1952.

Volume XI *Meer, K. van der:* Soil conditions in the bulbdistrict. 155 pag., col. map a.o. annexes. Price f 7.—. 1952.

Volume XII *Bennema, J. and K. van der Meer:* Soil survey of the island of Walcheren. 169 pag., col. map a.o. annexes. Price f 7.—. 1952.

Volume XIII *Diepen, D. van:* Soil conditions in the Maaskant-region. 213 pag., col. maps a.o. annexes. Price f 7.—. 1952.

Volume XIV *Roo, H. C. de:* Soil conditions in north Kennemerland. 202 pag., col. maps a.o. annexes. Price f. 7.—. 1953.

Volume XV *Haans, J. C. F. M.:* Soil conditions of the Haarlemmermeer. 154 pag., col. maps a.o. annexes. Price f 7.—. 1954.

Volume XVI *Liere, W. J. van and G. G. L. Steur:* A soil survey of the municipality of Epe and a reconnaissance soil survey of a part of the municipality of Heerde. 88 pag., col. maps. Price f 7.—. 1955.

Volume XVII *Burck, P. du:* A soil survey of the horticultural district Geestmerambacht. 159 pag., col. map a.o. annexes. Price f 9.75. 1957.

Volume XVIII *Sonneveld, F.:* Soil survey and attuned agricultural investigations in the Land van Heusden en Altena. 320 pag. col. maps a.o. annexes. Price f 15.75. 1958.

Volume XIX *Kuipers, S. F.:* A contribution to the knowledge of the soils of Schouwen-Duiveland and Tholen according to the conditions prior to 1953. 192 pag., col. maps a.o. annexes. Price f 9.75. 1960.

SERIES II. STUDIES ON SOIL SCIENCE

Nr. 1. *Maarleveld, G. C.:* Gravel bearing middle pleistocene sediments. 105 pag., fig., tab., maps. Price f 17,40. 1956.

Nr. 2. *Jongerius, A.:* Morphological investigations of soil structure. 93 pag., photos, sketches. Price f 6.50. 1957. Out of print.

Nr. 3. *Pons, L. J.:* Geology, soil formation and history of the drainage conditions of the Land van Maas en Waal and a part of the Rijk van Nijmegen. 156 pag., fig., photos, tab. and maps. Price f 9.—. 1957.

Nr. 4. *Zonneveld, I. S.:* A study of soil and vegetation of a fresh water tidal delta. Dutch text (Volume B), 396 pag.; english summary (Volume A) with fig. and tables, 210 pag.; (Volume C) col. maps and tab. Prices Vol. A f 10.—, Vol. B f 7.50, Vol. C f 12.—. 1960.

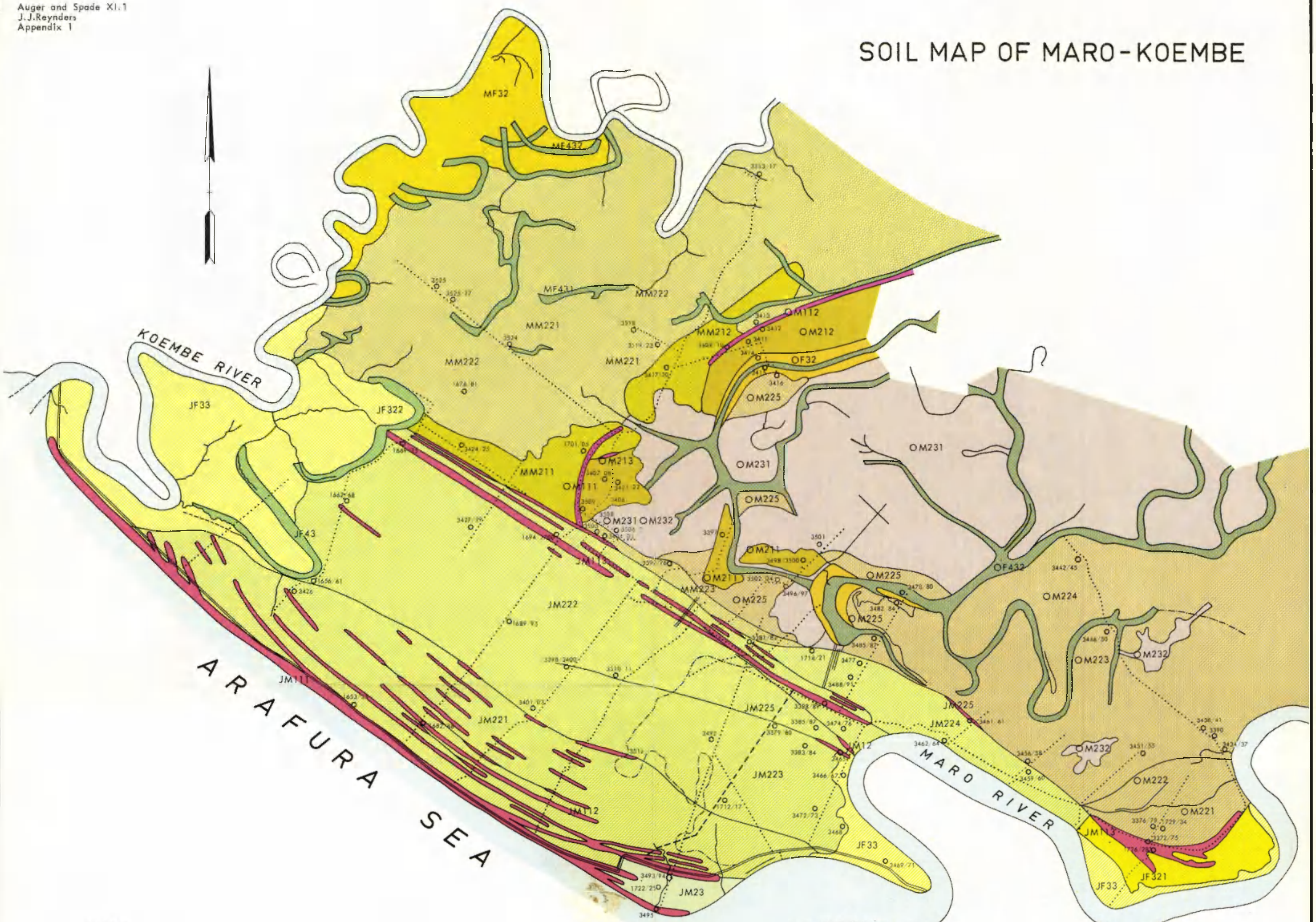
SERIES III. AUGER AND SPADE

(Scattered contributions to the knowledge of the soils of the Netherlands).

Auger and Spade I.	283 pag., 1948, price f 6.90.	
Auger and Spade II.	222 pag., 1948, price f 5.90.	
Auger and Spade III.	316 pag., 1949, price f 6.90.	
Auger and Spade IV.	365 pag., 1951, price f 8.90.	
Auger and Spade V.	268 pag., 1952, price f 6.90.	
Auger and Spade VI.	250 pag., 1953, price f 8.65.	
Auger and Spade VII.	255 pag., 1954, price f 7.65.	
Auger and Spade VIII.	237 pag., 1957, price f 8.30.	
Auger and Spade IX.	172 pag., 1958, price f 8.—.	
Auger and Spade X.	249 pag., 1959, price f 10.40.	
Auger and Spade XI. Auger and Spade XII.	in preparation;	dedicated to activities of Dutch soil scientists outside the Netherlands; both in English.

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

SOIL MAP OF MARO-KOEMBE



LEGEND

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

o location of sampling pits

scale 1:100.000
reduced from 1:50.000

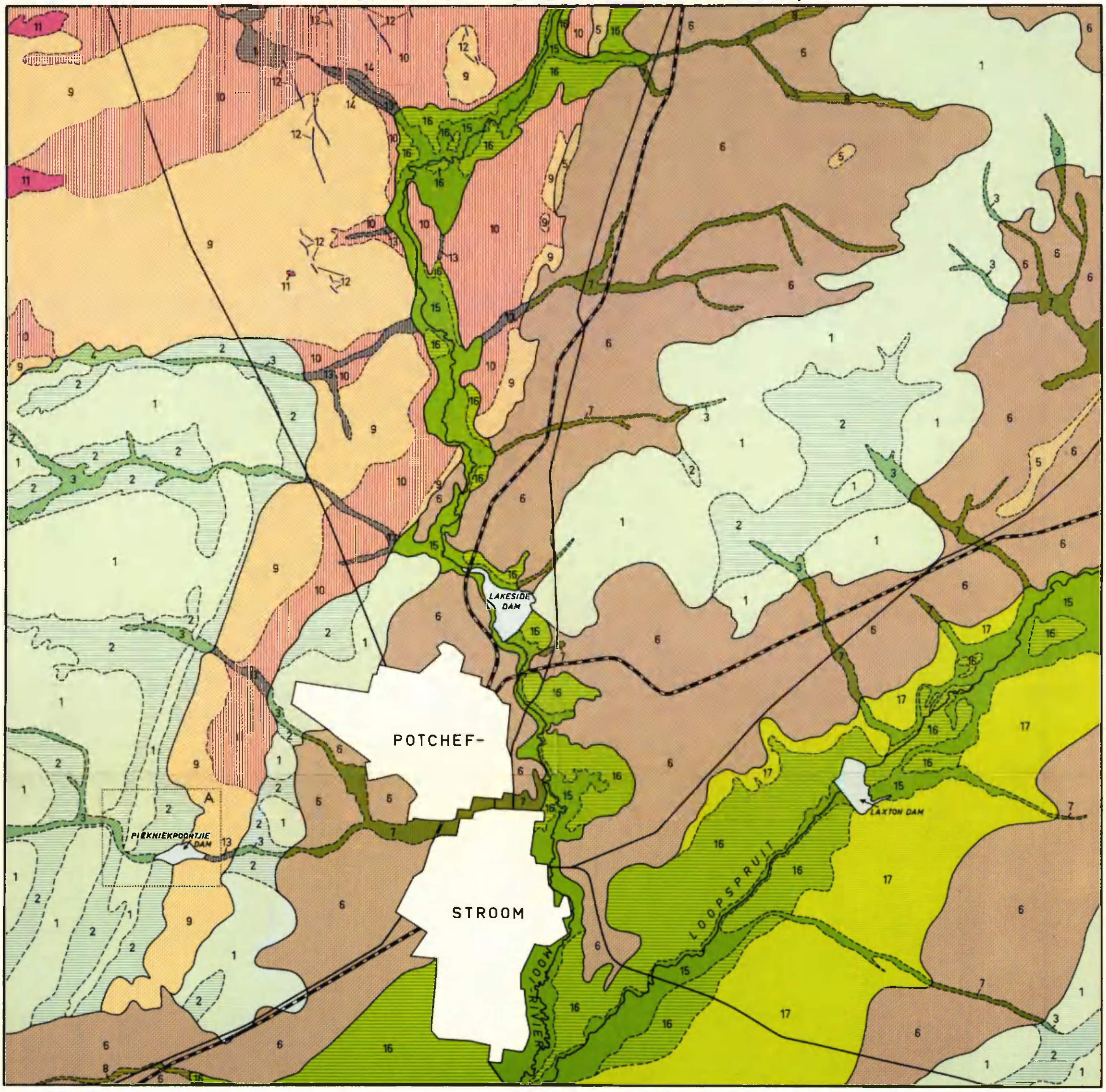
0 1 3 5km

Agricultural Experiment Station
Hollandia Netherlands New-Guinea

Lithography Netherlands Soil Survey Institute

AUGER AND SPADE XI
Maarleveld and van der Merwe
Appendix 1

GENERALIZED AIRPHOTO INTERPRETATION MAP OF THE ENVIRONMENTS OF POTCHEFSTROOM, TRANSVAAL



Scale 1:100.000

0 1 2 3km

LEGEND

RIDGE AND VALLEY LANDSCAPE

1 heights

2 fairly level parts

3 moist valley soils

4 fairly dry valley soils

PEDIMENT LANDSCAPE

5 heights

6 pediment

7 moist valley soils

8 fairly dry valley soils

DOLOMITE LANDSCAPE

9 fairly high parts

10 lower parts

11 sink-hole etc.

12 veins

13 moist valley soils

14 fairly dry valley soils

RIVER LANDSCAPE

15 moist river soils

16 fairly dry river soils

17 non-irrigated alluvial soils

A area near Piekniekpoortjie Dam shown on appendix 2

Lithography Netherlands Soil Survey Institute

GENERALIZED SOIL MAP OF THE ENVIRONMENTS OF PIEKNIEKPOORTJIE DAM NEAR POTCHEFSTROOM

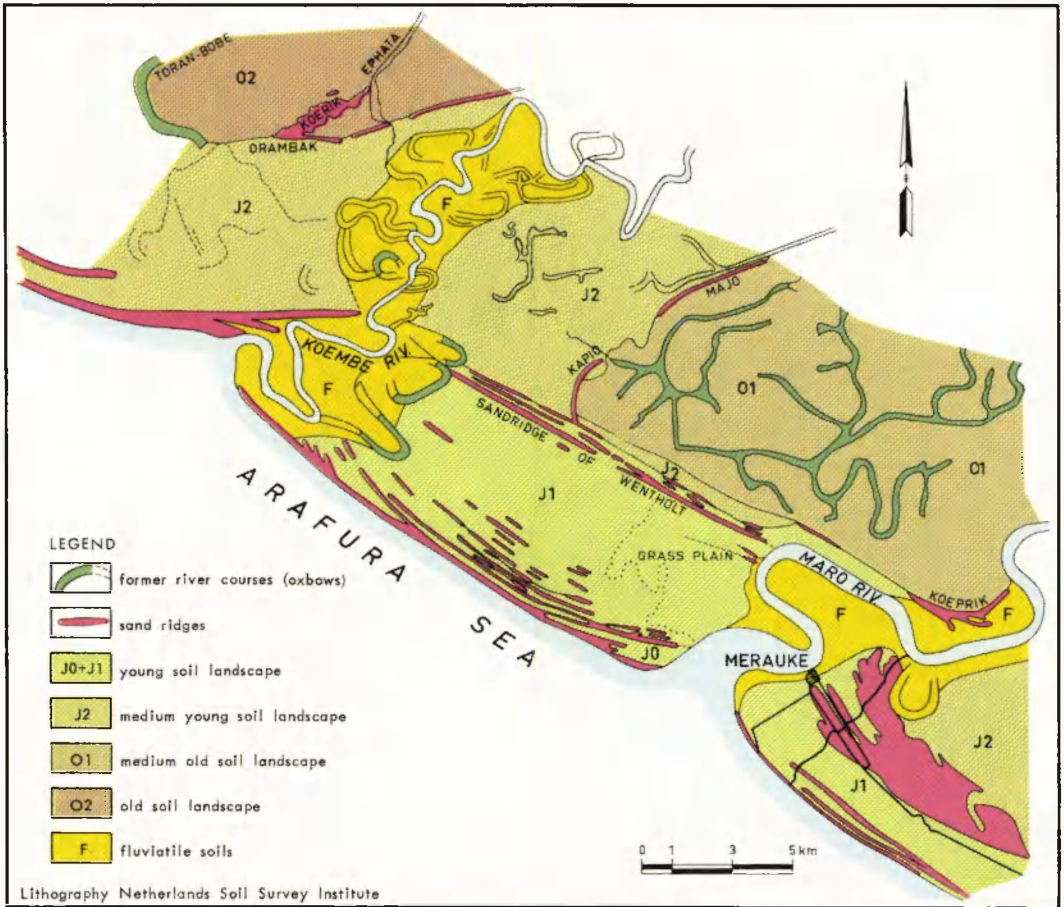
LEGEND

scale 1:12 000

0 120 240 360 m

1	50–120 cm	brook clay	
2	> 120 cm	brook clay	
3	< 50 cm	red loam	
4	50–120 cm	red loam	
5	> 120 cm	red loam	
6	< 50 cm	grey loam	
7	50–120 cm	grey loam	
8	< 50 cm	mixture of red and grey loam	
9		lava	
10		quartzite	
11		quartzite rubble land	
12		crystalline rock rubble land	
13		chert	
14		chert rubble land	
		ferricrete underlying grey loam	

Lithography Netherlands Soil Survey Institute



DRUK M.P.S. DEN HAAG

Fig. 1 Soil landscapes of Maro-Koembe

Scale 1:250.000 reduced from 1:100.000
Agricultural Experiment Station, Hollandia.
Netherlands New-Guinea