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On mineralogical soil investigations, with special reference to the Netherlands Indies

(Über mineralogische Bodenuntersuchungen mit besonderer Berücksichtigung von Niederländisch-Indien.
Recherches minéralogiques sur le Sol spécialement des Indes Néerlandaises.)

by

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I. The aim of mineralogical investigation

The aim of mineralogical soil investigation (c. f. Edelman 1935) may be formulated as follows:

1. To acquire knowledge of the mother material of the soils according to composition and form;
2. to obtain insight into the manner and the stage of weathering;
3. to estimate the mineral reserve of the soils.

These three points may be elucidated as follows:

1. When the soils in a certain area must be classified and when it must be examined which soil-forming factors prevail, it will appear in a number of cases that the mother-material takes up an important position. The rocks that occur in the Netherlands Indies as soilformers, vary to a high degree. To mention only some extreme examples, by the side of basic and intermediary volcanic products there occur liparitic tuffs rich in quartz, limestones, marls, quartzsandstones, etc. On different rocks under similar circumstances the lateritic weathering leads to entirely different soil profiles, so that it is not possible to class the lateritic soils in a reasonable way without taking into account the differences in mother rocks. So the classifying principle used at present in the Netherlands Indies, which is entirely based on the characteristics of the soil profiles, also refers to the properties of the mother-material in the classification and the naming of the soil types.

The composition of the mother material is not yet sufficient, the form should also be taken into account. Volcanic ashes of andesitic composition may produce a soil profile quite different from that on a solid andesitic rock. This difference is caused mainly by the possibility of an entirely different waterhousehold in both substrata; in the same way a coarsegrained volcanic ash can lead to a soil profile different from that on a finegrained ash of the same composition.

An important problem relating to loose volcanic products is the differentiation of the "efflata" (an expression used by Mohr [1908b] for the loose volcanic products) by air or water. The specifically heaviest elements show the tendency to settle sooner than the specifically lighter ones, so that the fresh ash in general does not show the composition of the mother-magma (White 1921). The result is, that a basaltic eruption can yield ashes of andesitic, even of trachitic composition. The pale fine tuffs which can arise as most acid efflating product of the volcanoes lead in the monsoon-climate of East-Java sooner to greyearths, heavy black clays of the regur-type, under conditions while more normal volcanic products would still yield lateritic soils (Mohr 1933—1938).

Connected with the question of the mother material is that of the rejuvenation of the soils. In the Netherlands Indies the most interesting form of rejuvenation of the soils is that caused by volcanic ashes. During the last 40 years every point of Java has at least once undergone a vol. canic ash fall, many places twice or more. The intensity of these rain-of ashes is locally different, but in principlē in the topsoil fresh minerals can always be found, independent of the pedological age of the soils A map of Java with the distribution of some of the principal rains of ashes is found in a paper of White (1926). Besides having a great practical importance this phenomenon has influence on theoretical reflections on so-called autochtonous residual soils. It is a naive view, expressed however by many authors, that merely by chemical analysis of the different horizons of the soil section of residual soils a correct idea can be formed of the nature of the processes that have led to the soil section. In soil science too little attention has been paid to the processes leading to the supply of material from above or from aside. In our present discussion the remark may suffice that owing to the ash falls on Java strictly speaking no genuine autochtonous residual soils are to be found.

An especially large part is played by the ash-cover in South-Sumatra (Idenburg 1937).

The rejuvenation by means of volcanic ashes is not the only factor, which causes the mineralogical composition of a soil to deviate from what the pattern-theory prescribes. Along most of the slopes the soil creeps slowly downwards, so that at a certain point elements can appear which originally formed part of rocks occurring higher on the slope. In cultivated areas, especially in the tropics, this phenomenon can be strengthened through soil-erosion.

Mineralogical analysis is primarily suitable for checking the autochtony of soil sections. A general checking of the autochtony of soil sections to be analysed for the sake of theoretical or other examinations would lead to a purification of our theories of soil formation[1]).

It is desirable to denote soils of which the properties are influenced by allochtonous elements as mixed soils, as is usual in the Netherlands Indies.

In alluvial soils, as well as in regions that have been strongly liable to erosion, mineralogical analysis is often the only method to determine the origin of the material, which knowledge is often of importance as a basis for mapping.

Many residual and very many alluvial soils in the Netherlands Indies are irrigated and are consequently gradually covered by and mixed with irrigation silt. In the Netherlands Indies since 1906 (Mohr 1908a) the composition of irrigation silt has often been investigated, especially in connection with the many works carried out for the improvement of irrigation. It has viz. appeared that the eventual success of the irrigation is to a high degree connected with the quality of the irrigation silt. In general, in judging the quality of irrigation silt the same standards have been applied as for valuing soil. Part of the examination of silt is done with mineralogical methods.

In general the irrigation leads to the rise of mixed soils, which is in itself a phenomenon never to be overlooked in soilwork, and that again may best be studied with mineralogical methods.

Finally, it may be remarked that the occurrence of the rare elements in the soil is closely connected with the mineralogy of the soil, which has not yet sufficiently been recognized in soil science. A general discussion of this subject is found in Edelman (1935 and 1937).

2. The hydrolysis of the principal rock-forming minerals is different under different circumstances (Mohr 1911, Miss Neeb 1934, 1935).

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[1]) In Europe things are slightly different from the Netherlands Indies, because volcanic pollutions over large areas do not occur. The loess, however, occurs in many places in Western Europe as pollution of soils. The periglacial climates of the youngest ice-age, which lasted up to about 8000 B. C. have moved much material along often faint slopes (solifluction) and many of our present soils have had to develop on these already replaced materials. Consequently, autochtony of residual soils is rare also in Western Europe (see C. H. Edelman, Sedimentpetrologische Onderzoekingen, III. Über allochtone Bestandteile einiger sogenannten Verwitterungsprofile Mittel-Deutschlands. Mededeelingen van de Landbouwhoogeschool, Wageningen, 40, 1, 1936 and G. Deines, Die Forstliche Standortslehre, Hannover 1938.). In the Mediterranean area both volcanic ashes and desert-dust occur as pollutions of soil sections. This may be seen especially from the *terra rossa*, which very often contains fresh minerals that do not occur in the limestones on which the soil is found.

Thus ore (often ilmenite) weathers very slowly under subaeric circumstances (lateritic weathering) and comparatively quickly under amphibic and subhydric circumstances. Conversely, in comparison with the dark minerals the feldspars weather in amphibic surroundings more slowly than in lateritic weathering. These phenomena are naturally of very great importance for forming a correct idea of the rise of the different soil types, while at the same time they may be useful for identifying soils whose soil type under the influence of special factors is changing and further for studying the history of the material constituting the alluvial soils and often „pre-weathered" in other places.

The weathering-stage (recent—juvenile—virile—senile) forms an extremely important subject, first of all for soil-systematics, further in connection with the estimation of the mineral reserve of the soils, to be mentioned in 3. The pedological difference between a recent andesitic ash soil, a young andesitetuff-lateritic soil and an old andesitetuff-lateritic soil is so great, that it has no sense to practise soil science, if such distinction cannot be carried out. The soil profile, it is true, is in the three above mentioned cases also entirely different, but it is clear, that there are numerous transition-cases which can easily be distinguished microscopically.

The already discussed rejuvenation of the soils might as well have been discussed in connection with the weathering-stage of the soil.

3. The mineral reserve of the soils is a subject about which much has been written in soil literature in a general sense, but that has only seldom been properly studied in determining the value of the soils. This lack in soil investigation has been the cause of many expensive and irreparable mistakes in selecting the soil. The virginal soils in the tropics exert an irresistible attraction on prospectors, especially when the soils bear a luxuriant primeval forest. Such a forest gives some information as regards the waterhousehold of the soil, but need not at all involve a rich soil. In the surface soil all sorts of plant-feeding elements have been accumulated by the age-old vegetation, which may give rise to not unsatisfactory chemical analyses. When the forest has been chopped and when in the first years of cultivation the saved up fertility has been consumed (often also washed away), an enormous decline in productivity of the soil can often be established and the plantation has from promising become indigent. Now, it is true, an experienced soil-surveyor might have predicted this unfortunate development by means of thorough profile-study, but the mineralogical investigation always proves the sum. In the above-discussed case it might have been established straightaway that the soil is entirely weathered out and

that after the consumption of the jungle-fertility nothing is to be expected from the soil, simply because there is nothing left in it. In other cases the soil turns out to be rich in components which might weather in future; the soil is still virile or even juvenile and the collapse indicated will not at all occur.

The tracing and identifying of the "misleading soils[1])" is one of the principle tasks of soil science in those areas where land is still available and it must be considered as the principal contribution of the mineralogical soil-work on land that is still to be cleared.

It must be remarked that cases may occur that soils can agriculturally speaking be very well useful with or without a comparatively small mineral reserve, viz. when they show a favourable profile and water-household and their economic situation is very favourable.

The plant-nutrition must then be provided for entirely or chiefly by means of manuring. A favourable composition of irrigation water and irrigation silt can be sufficient to decide to clearing of poor, but irrigatable soils. There are also habitats, e. g. reclamed eutrophic swamps, in which the cause of the soil fertility lies not at all in the mineralogical composition, but in the eutrophic situation. Yet it is desirable in the special and deviating cases mentioned to know what can be expected from the inorganic material of the soil itself.

Conversely, there are soils of a mineralogically favourable composition with such great faults in the profile, that reclamation is not recommendable, which can only be established by means of profile-study.

Summing up, it may be remarked:

a) The mineralogical investigation contributes to the classification of the soil types and their correct mapping, also it promotes a rapid survey owing to the insight acquired into the structure of a certain area.

b) With the aid of mineralogical analyses the autochtony and the rejuvenation of the soils can easily be checked.

c) Mineralogical investigation is of great use for the study of the value of irrigation and its influence on the soil.

d) Mineralogical investigation is necessary to obtain insight into the geochemistry of the rare elements in the soil.

e) Mineralogical investigation is of great importance for the fundamental knowledge of the genesis of the principal soil types.

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[1]) Baeyens indicated these soils in his book: Les sols de l'Afrique Centrale, spécial ment du Congo Belge, Tome I. Le Bas-Congo (Gembloux 1938), with the pithy phrase "terrains trompeurs".

f) Mineralogical investigation simplifies the investigation of the weathering stage of the soils.

g) Mineralogical investigation means the simplest and most effective way to the valuation of the mineral reserve of the soils which in countries where selection of land is still possible, means one of the most important questions in soil science.

II. Survey of the contributions to soil-mineralogy in the Netherlands Indies

It is a remarkable fact, that among the soil-scientists in the Netherlands Indies unanimity of opinion exists as regards the points of view discussed, while in other tropical countries so little attention has been paid to the subject.

The preference of soil-workers in the Indies for applying mineralogical methods in soil science is probably a consequence of the work of Prof. Dr. E. C. J. Mohr, the founder of soil science in the Indies, who has had a clear insight into the matters under treatment and developed them and who in this regard has led to a tradition, which the younger generation of investigators has followed with pleasure. Mohr's views on the rise of the principal soil types occurring in the tropics (Mohr 1922, 1930, 1933—1938) cannot be discussed here and it may suffice to remark here, that without neglecting other soil-forming factors, he has done full justice to the minerals in the soil. Mohr's publications are written for the greater part in Netherlandish and therefore they have not had that influence on the development of soil science, which would agree with the importance of his works and his ideas. One of his books has been translated into English by Pendleton (Mohr 1930). We may mention Mohr 1908, 1909, 1910a and b, 1911, 1915a and b.

In the "Jaarverslag van het Laboratorium voor Agrogeologie en grondonderzoek van 1910" (Annual Report of the Laboratory of Agrogeology and Soil Investigation of 1910) some cases were already discussed in which on the strength of an unfavourable mineralogical composition an advice against reclamation was given.

Mohr has been working in the General Experimental Station for Agriculture at Buitenzorg, a governmental institution intended especially for developing native agriculture. Indirectly, however, his work has exerted great influence on the soil-scientific investigations of the private experimental stations, which give advice to the European concerns in the Indies and of which the accomplishments in the field of mineralogy will be discussed presently.

Mohr's work was continued under the direction of his successor Dr. J. Th. White (1919, 1920, 1921, 1922, 1925, a and b, 1926), who managed to develop greatly that section of the General Experimental Station for Agriculture that was founded by Mohr and devoted to soil science, the present Institute for Soil Science. Dr. E. Scheibener has been working for years in this Institute. Scheibener examined many soils mineralogically and his work has been of great use for many reports and advices of the Institute of Soil Science, but only little has been published (Scheibener 1925). From the Annual Reports of the General Experimental Station for Agriculture the progress of the work appears.

Dr. Scheibener was succeeded by Dr. F. A. van Baren, under whose direction very extensive mineralogical investigations are at present being made in connection with the many soil-surveys that have been started of late years. As has been said in the first section this mineralogical investigation bears reference to the identification of the soil types and is therefore a part of the actual soil-mapping. By the side of this the mineral reserve must be determined, especially in the cases of soil investigations in connection with projects for colonisation of Javanese in other parts of the Archipelago, for which the mineral reserve of the soils to be reclaimed must be known in order to learn the eventual fertility of the soils and thus to judge the rentability of the colonisation. Of the numerous reports containing these mineralogical data little is published.

In the former Experimental Station for Tea at Buitenzorg, one of the private experimental stations, at present incorporated into the Experimental Station West Java at Buitenzorg, Vageler (1927) also took up mineralogical investigation, entirely according to the lines developed by Mohr.

The Experimental Station for Vorstenlanden Tobacco at Klaten (Java) on the other hand has had less need of mineralogical investigation, because the soils used for the tobacco in Middle-Java lie almost entirely on the "efflata" of the recent Volcano Mt. Merapi and so vary only little in original composition (De Vries 1911). The soils do vary very much in weathering stage, while from the work of Tollenaar (1932) it appears, that the composition of the soils is more complicated than was originally supposed. The areal of this crop, however, does not allow of extensive application of mineralogical methods.

Of great fundamental importance is the work of Miss Neeb (1934, 1935) in the Experimental Station for the Java sugar cane industry at Pasoeroean. The attempts of this private experimental station to come to a regional survey of the sugar-cane soils will be left indiscussed here. The mineralogical investigation of Miss Neeb, which formed part of the work in connection with the soil mapping, aimed at simplifying the distinction of the soil-types and at the same time examining the genesis of the soils. With the last-mentioned subject Miss Neeb scored remarkable successes indicated already in Part I. An older publication from the same experimental station is from Löb (1906).

Mineralogical investigation found an extensive application in the soil survey of the Deli Experimental Station at Medan (Sumatra wrapper tobacco Experimental Station at Medan). It was Dr. Druif who succeeded in revealing the regional soil science of this province with the aid of the mineralogy of the soils. Deli consists practically entirely of comparatively young, loose volcanic and fluviovolcanic deposits of different nature, which have led partly to residual, partly to alluvial soils, of which the mutual situation is complicated. Owing to the fact that the different volcanic products vary in mineralogical composition, the different units were successfully separated regionally and thus mapped. It is self-evident that in the detailed mapping also other criteria were used which need not be discussed here. An agrogeological survey map 1 : 100.000 was published by Druif in 1938.

The fundamental principles of the investigations of Druif were laid down in three larger publications (Druif 1932, 1934, 1937a), while a fourth part is still to be published. A summary in English appeared in 1935. Special attention may be called to the third part (Druif 1937a), in which Druif gives elaborate descriptions of the influence of weathering on the different minerals constituting the soil of Deli, one of the few contributions to the subject known in literature. In another publication Druif (1937b) examined which rare elements occur in the different minerals of the soils of Deli and which significance they would have for the culture of Sumatra tobacco.

In our country a publication by Jochems and Ten Cate (1932) became well known, in which the results of a systematic investigation of the market-prices of Sumatra tobacco classed according to Druif's outline of the Deli soils are mentioned. It appears that each of the soil-units distinguished by Druif produces its own type of tobacco with a priceclass of its own. This fact has given many people confidence in Druif's work and with it in mineralogical investigation. Dr. Druif's work at Medan is now finished; he is at present working in the Institute for Soil Science at Buitenzorg, already often mentioned.

Besides the official and private experimental stations, also private investigators have occupied themselves with the mineralogy of Indian soils. J. van Baren (1928, 1930) gave many data in his publications.

Loos (1925) described a small number of soils very elaborately from a mineralogical point of view. Senstius (1930), in his investigation of the mountain soils of Java (and the Phillippines), gave attention to the rejuvenation of the soils by the volcanic activity and he was able to establish that the volcano slopes of Java yield strictly speaking no autochtonous profiles. Miss Carroll (1933/34) has paid special attention to the mineral reserve of some Indian soils.

Among the great European agricultural concerns in the Netherlands Indies there is one that has his projects for reclamation mineralogically examined. Of such activities, however, nothing is ever published.

III. On the technique of the mineralogical investigation

The technique of mineralogical soil investigation agrees closely with that of sedimentary petrology, for which we may refer e. g. to C. H. Edelman, Ergebnisse der sedimentpetrologischen Forschung in den Niederlanden und den angrenzenden Gebieten 1932—1937 (Geologische Rundschau, 29, 1938, 223—271). In the Indies the investigations have largely been made on grain fractions 1—5 ($> 50\ \mu$) according to the mechanical analyses of Mohr (1910), which is applied by most of the experimental stations. Miss Neeb examined, besides, the sixth (silt) fraction according to the Mohr method (50—20 μ). Druif has been obliged to have his own preparations made, because during the period of his work at Medan few mechanical analysis were made. His simple method is described in the publication of 1934. In general it may be said, that the work of the soil mineralogist is very much simplified if it can be combined with methods of mechanical analysis which yield not only figures, but also fractions. Institutions, which preserved the fractions of former mechanical analysis, will be able to use these also for mineralogical analysis.

Often, however, samples specially will have to be prepared for the sake of mineralogical investigation. As regards the preliminary treatment of these, it is necessary to peptize as intensely as possible, especially in connection with the frequent aggregates in the sandfractions. A fixed prescription for this peptisation cannot be given. It should correspond with the methods that proved most efficient for soils of a certain area. The soil is then brushed lightly by a sieve of 50 μ. With sufficient peptisation this should not cause any difficulties and can take place in 5 to 10 minutes. Especially in case of the presence of "pseudo-sand" much can be attained by boiling.

A slight preliminary investigation settles which specific weight separations come in for examination, also whether separation by means of the magnet is recommendable, which is later checked microscopically.

In these methods the fact should be taken into consideration that in the tropics the native labourers are abundant and cheap, in contrast to Europe.

In most cases the separations with Sp. W. 2.90 and Sp. W. 2.6 come in for treatment. The latter separates among others the weathering products. From the results of these separations the soil can, if one takes into consideration the nature of the mother material, often already be characterized, especially in connection with the mineral reserve. Yet a further quantitative method is very advisable, in order to place the valuation of the mineral reserve on a basis suitable for comparison and for the distinction of the soil-types.

The microscopical examination naturally requires knowledge of the chief minerals. Unfortunately many investigators in soil science are not familiar with the fundamental principles of mineralogy, and they will therefore first of all have to get thoroughly acquainted with this subject-matter, before they will be able to carry out the investigations with any chance of success. The laboratory of the first mentioned of the present writers is always open to initiate those interested into soil-mineralogy.

IV. Final remarks

In the above only the rockforming minerals came up for discussion, and not the secundary products. Yet such secundary products occur in the sand fractions of the soils, e. g. laterite concretions and occasionaly clay minerals. In general the investigation of these requires the technique of the methods for characterizing clays and clayfractions and as such falls outside the scope of the present subject.

Three investigators found in the Netherlands Indies aluminium-sulphate in often well-crystallised forms in materia lanalysed by them (Marr 1908, Loos 1925, Middelburg 1936). This material which belongs to pickeringite, may arise under the influence of groundwater corresponding with solfatares, but also through oxydation of clays rich in FeS_2 (chiefly in shore deposits). In both cases the soils are to such an extent acid, that they cannot be used for normal crops.

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