MINERALOGICAL APPROACH TO SOIL STUDIES WITH SPECIAL REFERENCE TO COCONUT SOILS IN CEYLON*

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Summary

Hitherto in tropical and sub-tropical countries, particularly of the British Commonwealth, soil and manurial studies have been made on the basis of a chemical (" Soil Analysis ") or chemical and field experimentational approach.

Historically this is due to the Rothamsted tradition on which British soil workers have been trained, following the footsteps of Lawes and Gilbert and latterly influenced by R. A. Fisher.

While there has been recently a chemical and/or biological approach based on Leaf Analysis such as those of Constable on rubber ; Prevot and Ollagnier and Ferrand ; and Chapman and Gray on groundnuts and oil palms, and of nut water analysis (coconuts) by Salgado, a plea is made for a follow-up of soil investigations based on mineralogical analysis, as carried out by the Dutch workers, Van Baren, Hardon, Druif, Edelman, Van Marel and Vageler in Indonesia with conspicuous success.

An elaboration of the work of Druif on the soils of the Island of Deli forming the Indonesian Archipelago is discussed in detail as an example of the use of mineralogical analysis of reserve minerals, separated by the use of heavy liquids of different specific gravity.

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In a critical examination of the development of methods and techniques to soil investigations in the tropics, three main lines of approach have been evident : (*i*) The purely chemical method, followed by British workers in India, Africa, Ceylon, British West Indies and other parts of the British Commonwealth, influenced mainly by the traditions and methods of approach chiefly following the early Rothamsted tradition, supported of course by late developments in field experimentation on statistical lines as the only unequivocal valid basis for making manurial recommendations ; (*ii*) The more recent biological methods based on plant analysis *e.g.*, Constable (on rubber) ; Chapman and Gray (leaf analysis of oil palms) and Salgado (nut water analyses of coconuts) (28, 30).

These methods of approach, and in particular the reliance on statistical field experiments taking precedence over purely chemical methods (so-called " Soil Analyses ") have been evident in the work of Eden on tea, and of Salgado on coconuts (27), as also the more recent work in East African Territories covering the investigations of the East African Forestry and Agriculture Research Organisation at Tanganyika.

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The German tradition too which was largely based on chemical analysis of soils, no doubt following the successors of Liebig, Wagner and others of the predominantly dominant continental. " Chemical " school have influenced the workers of Holland in Indonesia.

However, in the Netherlands East Indies (now Indonesia) the pioneer work of the Dutch workers, while influenced no doubt by the use of chemical methods, were based on the Continental Schools of Soil Chemistry, have in later years been very largely dominated by the purely *mineralogical* approach to soil studies, both for (*a*) purely pedological studies ; and (*b*) the more practical and applied aspects of soil fertility.

By soil fertility is understood the economic and scientific aspects of the manuring of plantation crops such as tea, rubber, sugar cane and tobacco and also of rice.

The early Dutch workers [*e.g.*, Mohr (21) and Van Baren (1)] were largely Geologists and Mineralogists, and not *Pedologists* or Soil Chemists — so that mineralogy and not chemistry (biological chemistry) dominated their methods of approach to such problems, both of academic and practical importance.

As Nagelschmidt remarks (24) " The study of the soil is a field in which both geologists and agriculturists meet. Geologists are chiefly interested in weathering and decomposition of rocks and minerals which may have been formed under conditions of higher temperature and pressure and are now exposed at the surface of the earth to the combined action of the climatic and the plant and animal association at any given place. Agriculturists are chiefly interested in soil as the medium in which crops grow, but as Soil Scientists they have come to recognise the importance of the rocks as the parent materials of soils, and they study the mineralogical changes associated with the development of a soil profile, the formation of concretions and other phenomena."

Vageler (35) was one of the first to stress the importance of mineralogical analysis as an aid to chemical analysis (which as a German of the Liebig School he valued most). His well known book, translated to English, devotes as many as sixty-four pages to this subject and even has an elementary exposition on the techniques of mineralogical analysis of soils and their interpretation.

As is well known Vageler was the advocate (or even propagandist) for the *chemical mineralogical* school of soil fertility assessment and he had little faith in the use of field experimentation, particularly for tropical plantation crops where the result of such statistical experiments, was a case of post-hoc-propter-hoc, or as Vageler felt putting the cart before the horse. Indeed he speaks rather cynically of the value of field experimentation as a practical basis of assessing manurial needs.

In this connection without dilating on this controversy it may be pertinent to refer briefly the comments of both, Vageler and Eden, as these two complementary methods of approach — which should not under any circumstances, according to the writer be competitive, but complementary. Edelman, Hardon and Druif, and more recently Van Marel, were the more prominent Dutch workers all of whom originally worked in Indonesia when she remained a part of the Dutch Colonial Empire. They have subsequently within more recent years continued these lines of work at Wageningen and elsewhere in Holland (11, 15, 16, 7 & 8).

As this paper is not restricted merely to tropical conditions, it may be pertinent to mention that the American school led by Marshall at Missouri (22), and very recently the Australian school led by Brewer at Canberra, have applied mineralogical techniques to soil problems — both in pedological

and soil fertility investigations. In this connection a more recent paper by Graham of Missouri on "Soil mineralogy as an index to the trace element status of some Australian soils," based on his work at the Waite Research Institute, Adelaide, Australia, is of particular interest (14).

The third method of approach and that too mineralogical, though highly specialised in technique, compared to purely *petrological* studies of heavy minerals of the coarse fractions of the soil, is the more recent spectacular development of the study of *clay minerals of soils* a subject which is too vast to be dealt with under the topics of discussion today. This method of approach, using the latest tools of the *X-ray diffraction, optical, dehydration* and *electron microscope techniques*, though beyond the resources of our Crop Research Institutes should form the subject of a major supporting study of unique fundamental and practical importance, which the University, as the spear-head of academic research should undertake. It is unnecessary to dilate on these developments, however important, as there are excellent reviews such as those of Gieseking (13), Nagelschmidt (24), Marshall (22, 18) and Fry and Hendricks (19) and Mac Ewen (20).

The unique importance of these mineralogical methods of approach is evidenced by the fact that in the copy of the recent number of Journal of Soil Science (1956 July, Vol. 7, No. 2) just received there are no less than six papers on mineralogical studies, and of these particular reference may be made to the paper entitled " Petrographic study of two soils in relation to their origin and classification " by Brewer, based on the specialised technique of Kubiena (2a) where the use of thin sections of the soil embedded in a plastic (Plastrone 47) and microscopic techniques are used as a potential aid in determining processes of soil formation and assessing the importance of them in soil classification — a technique the writer had the privilege of studying in Brewer's Laboratory at Canberra last year.

While PEDOLOGICAL interpretation of the nature of mineral colloids (the clay fraction) has shifted from the older concept of silica/sesqui oxide ratios to the percentage occurrence of clay minerals (such as Montmorollinite, Kaoilinite and Illite) the basis of fertility responses (and more particularly lack of responses) to mineral nutrient deficiencies, in particular potash, calcium, and magnesium and even trace elements under tropical conditions can be interpreted more correctly and fundamentally on the basis of *reserve minerals* such as biotites, micas, feldspars and ferro magnesian minerals, than on pure " chemical analysis " (be they based on availability studies using citric acid, dilute acetic acid, dilute sulphuric acid, microbiological techniques such as the Aspergillus method, or pot cultures such as Mitscherlich techniques or Neubauer methods, or foliar diagnosis, or nut water sampling as in the case of coconuts).

Edelman and Van Beers summarise mineralogical soil investigations as aimed at:—

(*i*) To acquire knowledge of the parent material of the soils according to composition and form.

(*ii*) To obtain insight into the manner and the stage of weathering.

(*iii*) To estimate the mineral reserves in the soil.

The techniques are comparatively simple and with a set of sieves used in mechanical analyses, elutriator, a separating funnel and liquids of high specific gravity such as bromoform, nitrobenzene, etc., aided by a centrifuge, and a fairly good petrological microscope, with an elementary knowledge of the essential soil-forming minerals, a routine Assistant of the H.S.C. standard can in a few months be trained in the techniques of separation, identification and counting for the purpose of more quantitative estimation.

It may be useful to elaborate some of these points at this stage, and in this connection I can do no better than by quoting J. H. Druif (5) describing the problems in Deli, Indonesia as a model of mineralogical approach in the study of scientific problem with unique practical implications :—

" The tropical climate with its abundant rainfall has caused an intense weathering, everywhere resulting in almost, but not quite, identical upper layers. Plant growth is luxuriant and as the maximum elevation of the part of the country under survey reaches not more than about 350m., differences in climate (rainfall, temperature) may be neglected. From a soil-investigator's point of view a monotonous country might be expected and, when visiting the country for the first time, observing everywhere the same reddish brown soil, one would be inclined to think one's expectations fully justified.

" But if in this country one thing is more certain than another, it is the fact that this very homogeneous looking province of Sumatra's East Coast is camouflaging many differences existing between its soils. Long years of experience and more or less heavy financial losses have taught that it is, and always has been, impossible for Estate A to raise the same crop as Estate B on a soil that looks like the other as two peas in a pod. A statement that requires some explanation.

"For many years the only division made was in the three classes, *viz.*, the greyish white soils of the coastal plain, the red soils of the country surpassing the 25m. tranche, and some black soils occurring seemingly without any regularity in both parts, and it seemed that that was all there was to be said of the soils of Deli.

" When experiments went wrong, it was put down to the rain (or the sunshine) that had favoured one locality more than another and when the long-term average price of an estate crop proved to be twice as high as that of its neighbour, it was supposed that the managers must have been more competent or must have had better luck ; that the true reason could have been the soil, nobody would have believed ten years ago.

"On the other hand, to distinguish one brown red loamy sand with free quartz particles from another, also containing free quartz, the individuals however being slightly bigger and the sand being perhaps a shade darker, is neither easy nor very convincing. And it must be granted too, that in the field the difference between an older volcanic mudstream (in the Dutch Colonies called 'lahar'), now presenting itself as a more or less brown-red loamy sand containing many boulders and pebbles, and an older river high level terrace, built up of thousands of other boulders and pebbles embedded in a red-brown sandy loam, is not so very striking, however important it may prove to be after all.

" When our station took up the investigation of the soils, work started as usual ; mechanical analyses were made by hundreds, chemical analyses at least ten times as many. Then followed the period, when it was thought that every problem concerning the soil could be solved by the pH-determination and that the physical properties as fixed by ATTERBERG c.s., just provided what the soil investigators needed for the finishing touch.

" Although in practice these investigations did not prove to be a complete failure they came so near to it as to make no difference. The mysterious problem of the distribution of good and poor lands for crop raising and the question as to where and how their boundaries could be traced, remained unsolved.

" The chemical analyses ought to have been helpful, but as they were made by chemists and especially with regard to the problems of fertilizing and amelioration, nobody realised that the differences found were of a pure *petrographical*, not to say *geological*, nature and therefore needed geological interpretation, which was at that time however not forthcoming.

" When, in 1929, the present writer took over the investigations, these were started by him along new lines, because in his opinion our Dutch agro-geologist, the late Prof. VAN BAREN, was absolutely right when laying down the principle of all soil-investigations by saying : ' *In the beginning was the rock and the rock is the mother of the soil.*' Surely, when all is said and done, in 99 out of 100 cases a soil is nothing else but an altered rock, which alteration is the result of weathering under the influence of a definite climate and with the assistance of certain organisms, the exception to the rule being the case of a pure organic soil.

" When we consider the soil however as nothing else but a changed rock, it enters the province of geology and from that point of view we may say, as a rock is an established geological fact, the extension and importance of which can be measured by ordinary geological methods, so it must be for the soil itself. We may safely assume that, wherever the same rock (*viz.*, the same facies of the same geological formation) weathers under identical conditions of climate and plant-growth, the same soil will be formed, whereas where a different rock or geological formation (*viz.*, division or sub-division) is met with, another soil may be expected.

" Now, as far as the tobacco growing part of Deli is concerned we may neglect all differences in climate, but with the geology and the petrography it proves to be quite another story. Already a rough geological survey makes it clear that from the point of view of a geologist, and especially of a geologist who occupies himself with the study of the Quaternary of the country, Deli, instead of being monotonous, is highly complicated.

" So the present writer started by taking a great many samples from all over the country, first of the rocks (most of them of volcanic origin, so-called ' tuffs ') and later on of the different soils developed upon them. All were subjected to a thorough petrographical, *viz.*, mineralogical examination, while their extension was fixed by ordinary geological field work, giving due rights to tectonical, geomorphological and stratigraphical features.

" In this way it could be proved for instance, that not three, but at least five totally different volcanic deposits have contributed to the building up of Deli, *viz.*, a liparitic tuff, belonging to the Lower Quaternary, two dacitic tuffs, an older and a younger one, the last mentioned partly developed as a lahar or mudstream, a deciteliparitic tuff, only occurring in the western part of the country and an andesite-dacitic tuff, which gives birth to the so-called ' black dust soil.' The two dacitic tuffs probably belong to the Middle Quaternary, the dacite-liparitic is of an age as yet unknown and the andesite-dacitic must be considered as of Upper Quaternary age.

" It was found moreover that several red loamy sands, in earlier times without more ado incorporated with the general class of ' red soils ' (most of the latter being of young volcanic origin), were actually weathered to layers of Tertiary marine deposits and the microscopical examination made it clear that, with the exception of a part of the Middle Tertiary (the Keutapang and the Grensklei), the Tertiary of Deli must have been free from any volcanic activity.

" With regard to the coastal plain the only division that had so far been practised was the simple one in sand, loam and clay these three being present on every estate. Nevertheless the estates in this part of our country also showed marked differences in their long-term average-price, which, in view of the disposable soil-facts was more or less incomprehensible.

" Now it could be proved that such was due to the fact, that some of those sands, loams and clays were derived directly from liparitic tuff, some from dacitic or from andesitic-dacitic, and that others represented a mixture of volcanic and older Tertiary material.

" Only those estates, raising their crops from an identical petrographical unit showed long-term averages running into the same figures.

" In all these examinations the '*heavy mineral method*' played a very important part, more than a thousand analyses being carried out to reach these conclusions. By the same method many instances of the appearance of different patches of tuff in the region of others and of unexpected outcrops of Tertiary deposits were cleared up. In the same way the solution of an old problem was found, *viz.*, why in many instances the eastern and western zones of an estate yielded higher valued crops than the middle part, the answer being, that those zones were formed by old high level river terraces, not before recognized as such because their borders against the original land surface were wholly or nearly obliterated by denudation. (Almost all rivers in Deli are running due N–S).

" Once the mineralogical composition of a Deli soil becomes known, it is possible now to conclude forthwith as to its origin, and that enables the investigator immediately to form his conclusions as to its possible continuation and extension. The same holds good if something out of the ordinary is met with, because in nearly all cases it will be possible to deduce which kind of geological influence must be held responsible, and that in its turn, makes it possible to draw conclusions as to the probable extension and boundaries of the discovered ' abnormality.'

" So geology together with petrography and mineralogy, and in combination with geomorphology, tectonics and stratigraphy has proved to be a very sound base for all investigations concerning the Deli soils and today we may assume that the very tangled mass of soil evidence is sorted out and that we know accurately how many principal kinds of soil Deli possesses, where they are to be found and how much of the surface is covered by each.

" The present writer expresses his firm belief that in this very complicated country, where much primary jungle is still left and where big areas are covered by dense secondary jungle, where neither the eyes nor a fine feeling in the fingertips are of much help no methods, other than these mentioned, could have solved the very intricate but highly important problem of identification, classification and tracing of boundaries in the time thus far spent on it."

The following interesting points of the value of mineralogical analysis (*i.e.*, analysis of heavy minerals) may be noted :—

(*i*) In alluvial soils, as well as 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 soil mapping. This is particularly true of the coconut soils of Ceylon, where the alluvial types form an elaborate array of soil types depending on the degree of erosion and the age of alluvia and also as to whence the alluvia came.

(*ii*) The occurrence of trace and minor elements in the soil is closely associated with the mineralogy of the soil which thanks to the work of Van Marel (36) and of Graham (14) is gradually being recognised by Soil Scientists as of great practical importance.

(*iii*) The preponderance of a particular mineral or combination of minerals is of great value in studying soil formation, their changes in recent times or through the effluxion of long years *e.g.*, in the quantitative study of the Grundy Soil Profile, derived from Loess, Haseman and Marshall (18) observed that the mineral *zircon* was used for the first time as in immobile indicator of gains or losses.

Similarly among the minerals resistant to weathering *Tourmaline* and *Apatite* may be useful as an index of study of soil genesis and soil development, though these are not so stable to weathering, according to Druif under the chemical and biological weathering conditions in the Tropics.

In fact Druif suggests that the minor nutrient elements, such as *boron* and *zinc*, are probably furnished to many soils from the weathering of such very resistant minerals as *tourmaline* and *green spinel*. If this does occur, then the importance of the mineral reserve in the soil is even greater than has been generally thought possible.

Among heavy mineral studies on soils Dorotly Carrol (3) from mineralogical study of the soils of Western Australia, concluded that ; (*i*) The character of the heavy residue of a soil often gives a clear indication of the nature of the parent rock ; (*ii*) The diagnostic value is enhanced by the total amount of heavy minerals, by distinctive features of a mineral species, and by the amount of magnetic material ; (*iii*) The study of heavy minerals can be very useful in geological mapping and Soil Genesis in pedological studies.

The process of soil development under lateritic conditions have been studied by several workers. Hardy and Rodrigues (17) have studied lateritic soils from the British West Indies and from the Southern States of America. The chief conclusion of their studies is evidence that laterization is a primary process, occurring within the inch or two of weathered crust of the parent rock.

The succeeding process of soil development is apparently a podsolic process even under tropical conditions, as is indicated by an increase in quartzy surface.

Harrison has written an extensive treatise on the chemical, microscopical, petrological aspects of the katamorphism of the igneous rocks — under the humid tropical conditions of British Guiana.

Mineral Reserve of the Soil

The mineral reserve of the soil is a subject about which much has been written in soil literature in a general sense, but has only been seldom studied in determining the value of the soils from the standpoint of fertility.

We owe a debt of gratitude to the Dutch workers in Indonesia, Hardon (15, 16) Edelman (9, 11) Druif (7, 8) and Van Baren (1) and more particularly to Van Marel (36) who in his recent work, now being followed up at Wageningen since the loss of Holland's Colonial Empire, has continued this line of work, pregnant with the unique economic and practical consequences to the subject of manurial responses, more particularly of deep rooted plantation and horticultural crops.

Here again I may be pardoned for quoting *in extenso*, the words of Edelman and Beers (10).

" 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 whaterhousehold 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), and 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 " 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 irrigable 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 eutrophis 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."

The further observations of Edelman made in 1939 are prophetic and pregnant as warning signs to countries like Ceylon now planning a cyclonic tempo of land development — in particular of the opening of Highland Crown Jungles under coconuts on an extensive scale.

To quote his own words, " It is remarkable that among Soil Scientists in the Netherlands Indies unanimity of opinion exists as regards the points of view discussed which *in other tropical countries so little attention has been paid to the subject.*"

The reason is not far to seek : In other parts of the tropics and even in Ceylon to date, (except at the Coconut Research Institute) Soil Scientists, have been mere Chemists and/or Statisticians with so little Geological or Mineralogical background, which naturally limits their outlook. It has been until recently the same even in India, where fortunately within the recent few years there have issued a series of coordinated soil mineralogical studies under the leadership of Raychaudhuri and others — work which the Indian Society of Soil Science in their recent Symposium have fostered and published.

It is unfortunate that their tendency has been for pure Chemists with a University Degree in Chemistry to blossom forth as Soil Chemists without even having studied the elements of mineralogy or even looked through a petrological microscope.

As Edelman states, " *Unfortunately many investigators in Soil Science are not familiar with the fundamental principles of Mineralogy.*"

The purpose of this paper is to make a plea that Soil Chemists in Ceylon break away from the purely Chemical traditions and blaze a new trail — in particular in relation to Soil Surveys of new land for development before the actual blaze of the virgin jungles commences, and that we Soil Chemists

help our country in sparing everybody involved — the administrators, the revenue and land officers, the poor colonists, the S.S.C. educated youths, the land grabbers and land exploiters, the middle class and capitalists to whom the Government of this country hopes to alienate land on the basis of their new land policy and the Departments of Land Development and the Ministry of Lands and Land Development and our indefatigable Minister himself — from any possible mistakes and those expensive ones, which Ceylon with its underdeveloped economy and an ambitious policy of expanding its stagnant economy, cannot afford to risk ; and that in all soil work — and soil surveys in particular we look at the untapped reserves of the soil wherever we look for good land or even for so called marginal land.

The cream of the land has already been exploited. The healthy peneplains and the salubrious patnas with cooling breezes are under tea ; the wet zone highlands are being re-afforested with high yielding rubber ; and wherever highland crown jungles remain, the only alternatives are the doubtful " dry-farming " Schemes, yet interesting and awaiting further study, the Dry Farming Projects the Science and function of which the excellent resources of the Research Station at Maha Illuppalama should one day reveal ; but wherever these cannot be economically grown, coconuts form the last refuge as an economic crop — but even *Cocos Nucifera* to justify itself needs a reasonably good soil among other things — and one whose potential fertility must be tapped for an economic life of 70 years or so — and that from reserve minerals — which only mineralogical studies alone can confirm. To quote Edelman (10), referring to soil surveys must be determined, especially in the case 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.

TABLE I

Soil Mapping in Deli

Mineralogische samensteling der DELI TUFFEN
Mineralogical composition of the Deli tuffs

SOORTEN DER TUF *Name of tuff*	Vulkanisch glass	Kwarts	Sanidien	Albiet	Oligoklaas	Andesien	Magnetiet	Ilmeniet	Biotiet	Groene Amfibool	Roodbruine Amfibool	Hypersthеen	Diopsidische Pyroxeen	Sesquioxydh Pyroxeen	Apatiet	Zirkoon	Spinel	Orthiet	Granaat	Perowskiet
Lipariettuf Liparitic tuff	=	@	=	+	+		×	×	@	+		×	1		×	@	1	+		
Dacito-lipariettuf Dacite-liparitic tuff	=	@	+	×	=	1	=	=	=	=	×	+	1		×	=	1			
Jong daciettuf Younger dacitic tuff	=	=	×		=	+	@	@	+	@	+	@	1		+	+	×		+	1
Oude daciettuf Older dacitic tuff	=	+	+		=	=	=	=	=	@	×	+	×	1	+	+	×		×	1
Andesito-daciettuf Andesite-dacitic tuff	=	×	1		@	@	=	=	=	=	=	@	×	×	×	×	1		×	×

Legenda : @ Overvloeding — abundant = Veel — much + Matig — moderate × Weinig — rare 1 Zeldzaam— trace

Table III – Mineralogische somenstelling der z.g., Overslag grenden

	Vulkanisch glass	Kwarts	Orthoklaas	Plagioklaas	Magnetiet	Ilmeniet	Biotiet	Gr. Amfibool
Araskaboe/bij Station	@	@	=	@	+	+	=	£
Batang Koewis	@	@	=	@	+	+	&	@
Goenoeng Rinteh	@	+	£	£	+	+	£	@
Goenoeng Rinteh	@	+	£	£	+	+	=	£
Goenoeng Rinteh/Bras Boelan	@	+	=	@	+	+	=	£
Goenoeng Rinteh/Bras Boelan	@	+	£	£	+	+	@	@
Goenoeng Rinteh/Bras Boelan	@	+	£	@	+	+	=	@
Patoembah/Dolok Raga	@	+	£	@	+	+	&	£
Patoembah/Dolok Raga	@	+	£	@	+	+	&	£
Goenoeng Rintch	@	+	=	@	+	+	£	£
Soengei Bahasa/Limau Moenkoer	@	+	=	@	+	+	&	£
Soengei Bahasa/Limau Moenkoer	@	+	£	@	+	+	&	£
Soengei Bahasa/Limau Moenkoer	@	+	£	@	+	+	×	@
Soengei Bahasa/Tengkoesan	@	+	=	+	+	+	&	@
Soengei Bahasa/Bekassa	@	+	£	@	+	+	&	£
Soengei Bahasa/Tengkoesan	@	+	£	@	+	+	&	£
Tj. Morawa Kanan, Weg 14	@	+	£	@	+	+	&	£
Tj. Morawa kiri	@	+	@	@	+	+	£	@
Tj. Morawa kiri	@	+	=	£	+	+	&	£
Tj. Morawa kiri	@	+	=	@	+	+	=	£

\+ Overvloedig — abundant, flood @ Zeer Veel — very much & Veel — much £ Normaal — Normal = Matig — Moderate × Weinig — few

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