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Soil formations in Southern Indian mountains

W. BECKMANN

Institute of Geography, University of Hamburg, G.F.R.

INTRODUCTION

Southern Indian soil formations have often been described. The preceding works have been concerned with questions of soil nutrients and with agricultural usefulness of the soils. Schokalskaya [7] wrote a summarizing paper about soil formations of the Indian subcontinent. A more recent survey was prepared by Raychaudhuri *et al.* [6]. They referred to the Nilgiri and other highsituated regions of Kerala several "major soil groups" using the term " red soils" for the whole Nilgiri and "forest soils" for the eastern Kerala regions. The "red soils" were described as flat, loamy, and poor in minerals, as well as in organic matters. The "forest soils" have a thin layer of partially decomposed organic material immediately under which the soil is dark in colour, being gray-brown to gray-red and rich in nutrients. In these descriptions, the differences in regional conditions and the possibility of varying developmental conditions of the soils were not taken into consideration.

Such problems of the judgments of the soils were treated in works by Dupuis [1], Gaussen, Legris and Viart [2, 3], and Gaussen *et al.* [4]. In the explanations to the sheet "Cape Comorin" of the "Carte Internationale du Tapis Vegetal" Gaussen *et al.* [2] considered the soils of the Nilgiri in relation to relief, altitude and "bioklima": In regions above 1,500 m forest and pasture soils are existing in which the uppermost horizons are black in colour and posses a high content of humus. "This humus is very slowly degraded due to the low temperature at this altitude. This type of soil very rich in organic matter is named "humic ferralitic mountain soil" [2].

The following paper gives a description of several soil formations of the southern Indian West-Ghats. The main problem of investigation is that of the development of the soils. The soil profiles described in this paper are located in the Central-Nilgiri. Soils from other parts of the West-Ghats will be mentioned too.

RESULTS OF OBSERVATIONS

On Dodabetta the Nilgiri reach an altitude of 2,633 m. Large regions within its circumstances and in the southwest and northwest of the Nilgiri have an altitude of more than 2,400 m. These regions are climatically excepcional in the Southern West-Ghats, comparable only to the highest regions of the Palni-Hills, which, in Anaimudi, reach a height of 2,695 m.

Fig. 1. Secondary scrub near Dodabetta (2,600 m), mainly *Rhododendron arboreum* (foto 1.5.1968).

Table shows a survey of the excepcional climatic position of these mountain regions. Large areas are covered with secondary bush or secondary forests (Fig. 1). Pasture is also found in large regions.

The soils found under forest, thick bush, and pasture have a conspicious deep black humus layer, often created in situ but mostly from the accumulation of much material. The humus layer can be deeper than 70 cm (Fig. 2).

In these high altitudes the properties of humus composition are clearly dependent upon local conditions and upon the vegetation. Due to

Fig. 2. Soil formation near Dodabetta (2,600 m), secondary scrub, ancient trough or small valley full with humus material; beneath that relict rotlehm-material *in situ* (foto 1.5.1968).

Table. Climate data

Station	Altitude in m	Precipitation		Temperature		Dry season
		mean annual in mm	dry season in mm	mean annual in °C	driest month	
Calicut	8	3,085	57	27	29	December/March
Ootakamund	2,245	1,394	13	14	13	February
Coimbatore	409	590	112	26	29	December/April
			152		27	June/August
Cochin	3	2,929	135	27	29	December/March
Kodaikanal	2,328	1,668	—	14	—	—
Madurai	133	872	108	28	30	January/April
			89		31	June/July

the extremely high precipitation or due to very foggy western slopes humus formation gradually assume an anmoor-like character (Fig. 3). In the Monsoon-season this material is wet, slimy, and black in colour; whereas during times poor in rain is thoroughly moist but not wet. Partially decomposed residues of fresh organic matter is well worked through by resident soil fauna. Their excrements create large fields of aggregates which take a considerable part of solid material (Fig. 4). The content of these fields of aggregates is extremely high after long periods of only medium moisture of the soils, then the humus-formation is "mull-like".

Other humus-formations are recognized on lee — side places in the

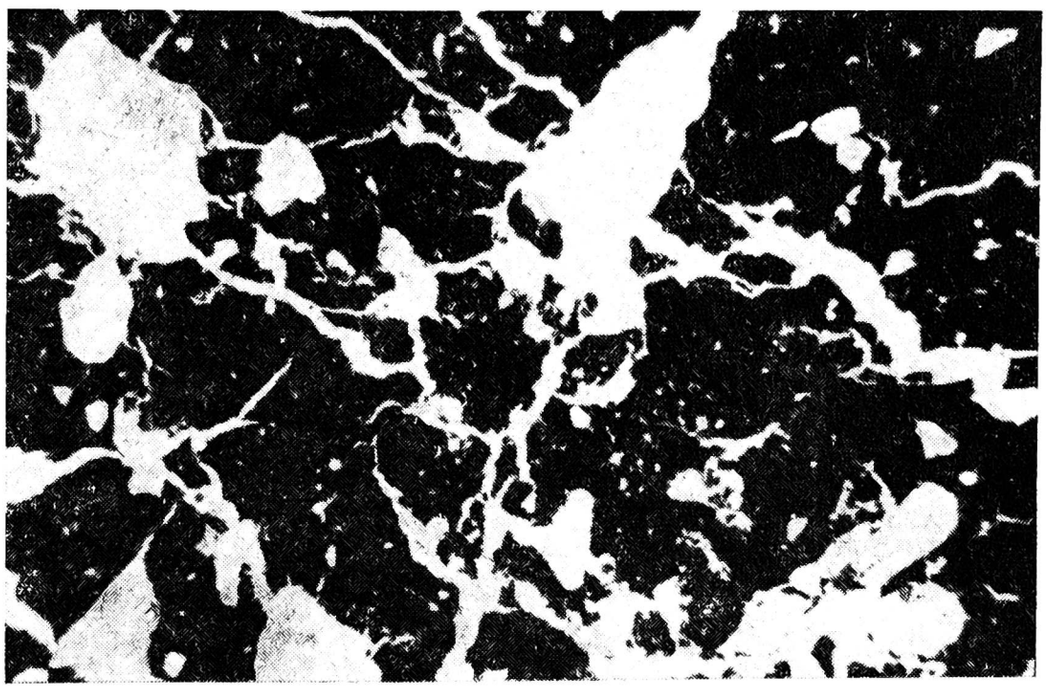

Fig. 3. Thin section (about 60×), A horizon from the soil in Fig. 2. Humus — formation = anmoorlike; dense humic material, as cavities only fissures which will disappear when the material becomes wet, then the material is totally dense.

high Nilgiri. There the A-horizon is much flatter, its colour is brown, even during the monsoon there is no "anmoor-like" character. The upper 10-15 cm are looser and better worked through by resident soil fauna; but there is more half- or not decomposed organic material (Fig. 5). This humus-formation is like "feinmoder".

Beneath pasture — in relation to other additional conditions — the

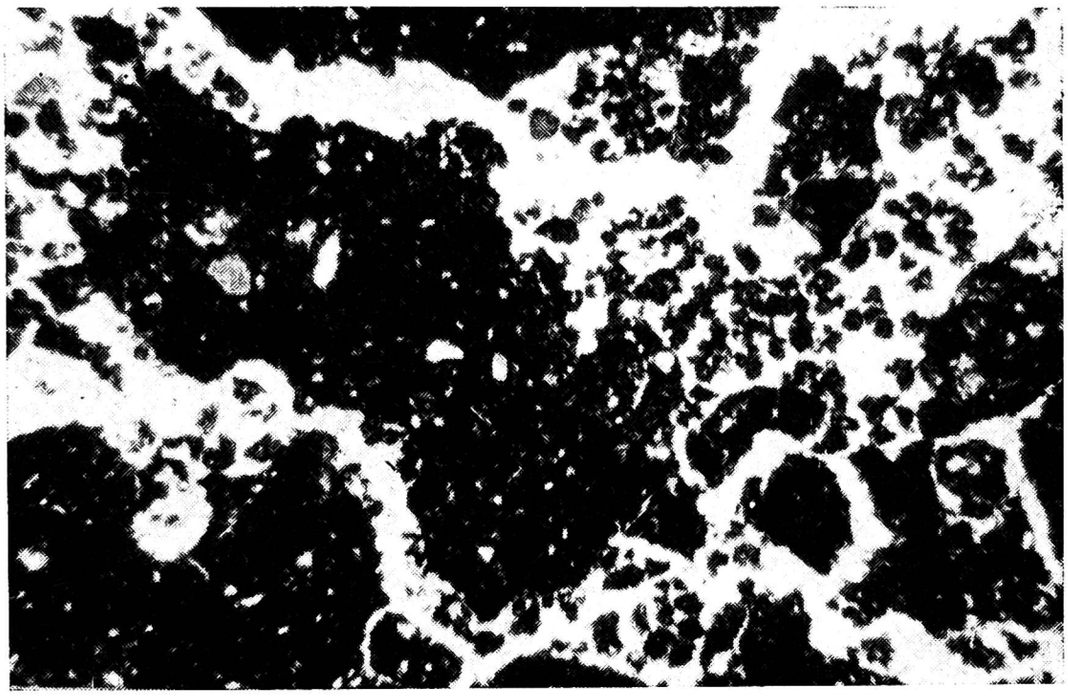

Fig. 4. Thin section (about 60×), the same horizon as in Fig. 3. Aspect of micromorphology at the end of wet season: the dense and very humic material has been worked through by resident soil fauna; there are large fields of excrements, this material is now very stabil against wetness.

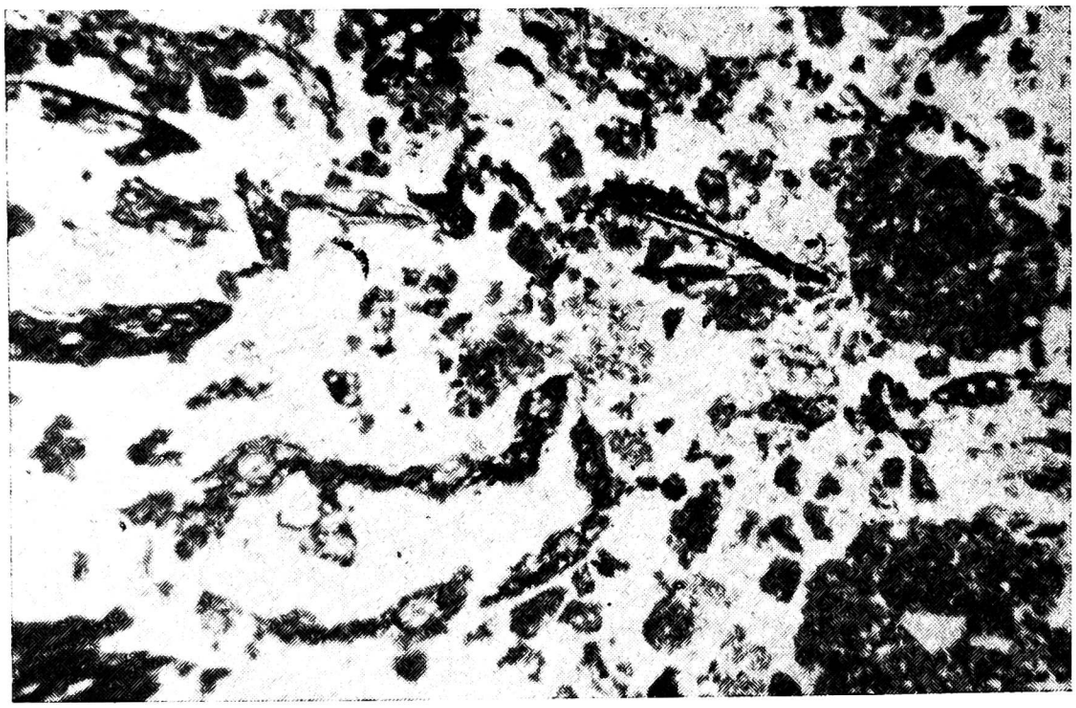

Fig. 5. Thin section of a soil near Dodabetta (2,500 m), steep slope to east, very much dryer than that in Fig. 2. This humus-horizon is not anmoor-like; many half-decomposed rests and fragments of organic material, excrements of the soil fauna are found.

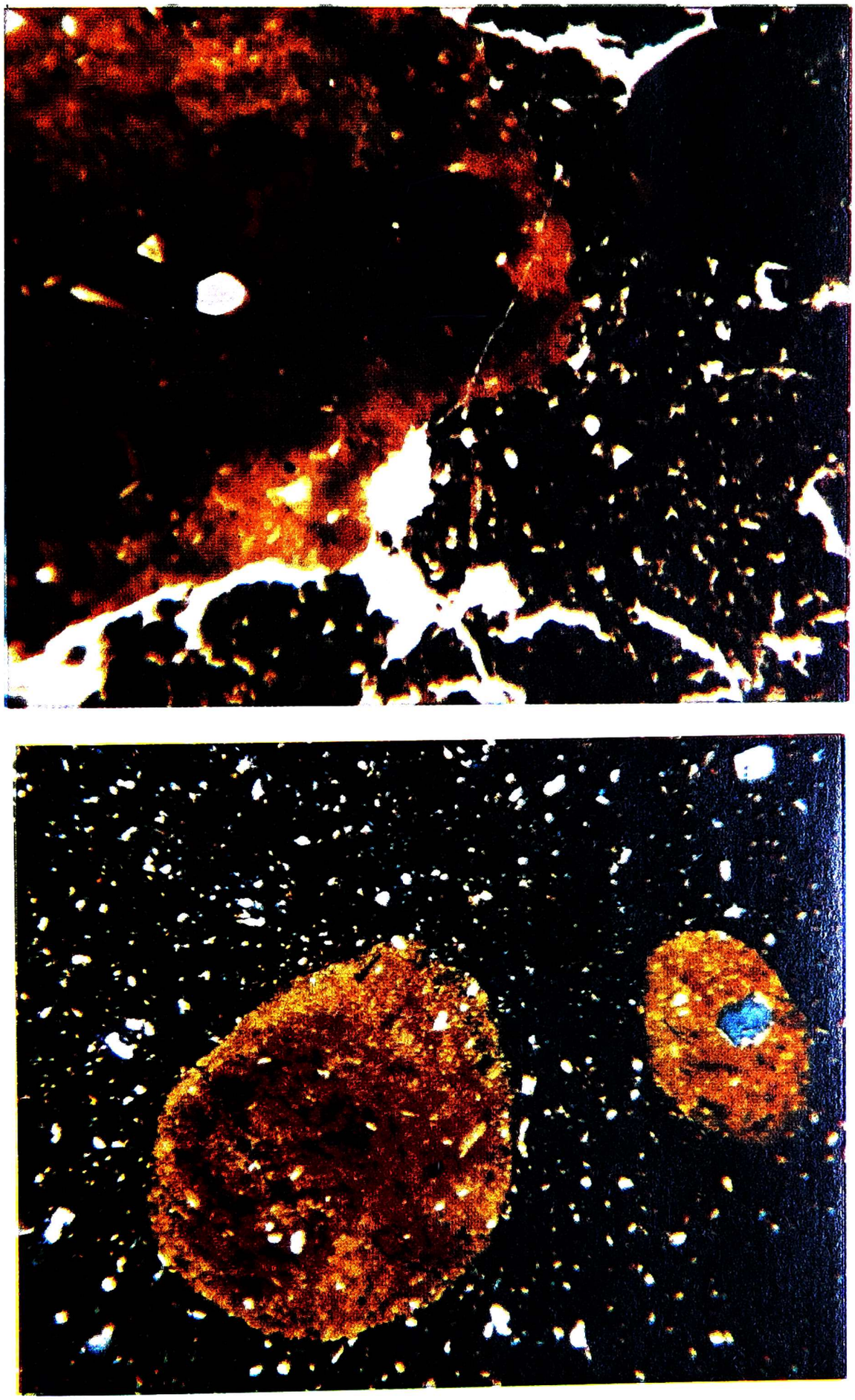

Fig. 6. Thin section of the soil near Dodabetta (see Figs. 2, 3 and 4). A horizon; very humic material — recently developed — with fragment of relict rotlehm-material.

Fig. 7. Thin section of the soil near Dodabetta (see Figs. 2-6), crossed Nicols. Fragments of relict rotlehm-material in very humic material of the recent A horizon.

humus-formation is comparable to those mentioned. The humus layer is merely flatter owing less organic matter being provided by the vegetation.

Common to the described humus formations is the extraordinarily small content of larger unweathered minerals or rock fragments. Only quartz usually persists. Next to this a striking number of other fragments are observable in the humus horizons. They consist of the remainders of soil material from deeper horizons of the soils. This material is entirely

Fig. 8. Soil formation near Dodabetta (2,200 m); steep slope to south-west; soil similar to that in Fig. 2. Humus-horizon until 70 cm; humus formation is anmoor-like; beneath that the "whitened horizon" (about 30 cm); beneath that the relict rotlehm-material.

different from those originating today in the high Nilgiri. These remnants are irregularly mixed in with the humus matter (Fig. 6). Characteristics of brown and red loam (braunlehm and rotlehm), and also occasionally remnants of lateritic horizons are recognizable. However, the properties of the braunlehm and the rotlehm have already largely disappeared. These remnants appear strongly "gealtert" (Fig. 7).

A humus layer is always absent in the soil if its surface is continually open and unprotected against direct sunlight and rain due to specific land

uses. This is especially true for soils continually under agricultural cultivation.

Beneath the A-horizon there is often a horizon observable which — in the field — one could refer to as "whitened" (Fig. 8). It shows a few special features in the thin sections: the soil material is entirely colourless, the humus content is small, diffus patches of concentration of iron are present (they are often already recognizable in the field). By contrast, the remaining solid soil material is very poor in iron, transport of silt and loam inside of the soil structure of this horizon is clearly indicated by x-Nicols observation. These characteristics conclude "pseudovergleyung".

Always observable in this horizon are the previously-mentioned material remnants of other soil horizons and formations.

Beneath this horizon material of extremely variable nature and origin is found. It is often intensively red in colour and is usually dense. Roots of the present vegetation are scarcely apparent. This presents a very similar picture to (B)-horizons of tropical rotlehm (Fig. 9). Conspicuously missing in the upper layer of this material is the often described highly movable "Gefügeplasma" of tropical rotlehme. Quartz is usually the only mineral remaining. The "rotlehm-basic-material" is dense and penetrated only by narrow fissures.

In other locations an often brown to gray-brown-yellow material is found instead of the red. Many stones and blocks of the parent rocks are still present. This material is similar to that of "weathering horizons" of tropical soils. This material is either present in the soil's originating profile or the material has been transported. In the second case it is principally mixed in with the previously-mentioned (B)-horizon. The texture of the remaining stones and blocks is usually completely destroyed. Between the A-horizon (and the occasionally present "whitened" layer) and the subsoil a horizon is observable which still clearly possesses the features of the subsoil, but which has already been considerably changed from above. In most cases, it is now dark brown in colour, is not so dense, and possesses more pore spaces than the unaltered material at greater depth. Signs of clay transport or iron concentrations are not recognizable. The material appears "verbraunt" and "vererdet".

DISCUSSION

In the presentation of the observation results a naming of the examined soil types and soil horizons has been renounced. It is problematic because contradictions are already present in the literature and because the development of this typical mountain soils was not continuous.

In the following, the soil formations under dense bush or forest and under closed pasture will stand in the foreground of examinations. Only these soils show a still somewhat complete profile. The soils under very

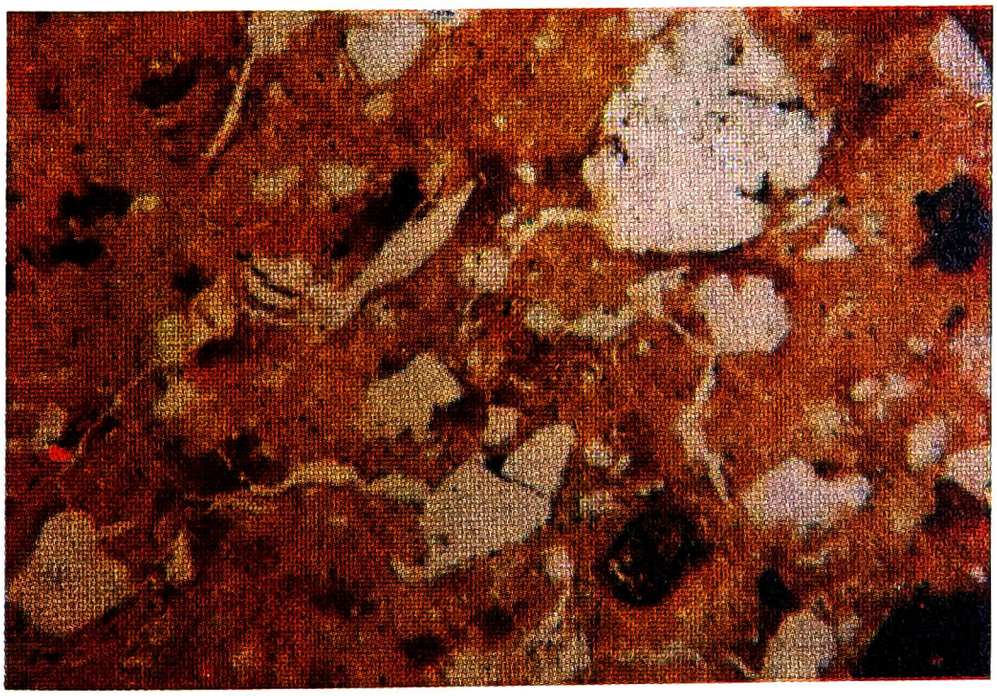

Fig. 9. Thin section (about 100×), soil as in Fig. 2, sample of the subsoil (150 cm). The relict rotlehm-material; only quartz is remaining; concentrations of iron and large parts of material less in iron are observable.

irregular vegetation or under permanent aggricultural cultivation are always degraded and mostly present an incomplete profile.

The results of the own observations cover essentially those of Gaussen, Legris and Viart [2]. The "humic ferralitic mountain soil" described by them is the prevailing soil formation of the high Nilgiri. It is found under bush, forest, and pasture, usually at an altitude of more than 1,500 m. On the dry eastern slopes of the Nilgiri they are seldom under 2,000 m. In the very moist western parts of the Nilgiri they are often encountered under 1,500 m. These soils are found nowhere under open vegetation cover or agricultural crops. Similar soils are also observable near Kodaikanal and other high locations of the Palni-Hills. In the southern and western Ghats, for example, east of Trivandrum they are encountered at altitudes between 1,200 and 1,500 m.

The humus layer of these soils is regularly very deep. However, the content of only partially or not — decomposed organic material is very small. This humus, therefore, does not show an accumulation of undestroyed material, it is not "rohhumus-like". The character of this humus-formations partially resembles that of "mull", of "feinmoder", or even that of "anmoor". These different humus formations arise in dependency upon various local conditions. In specific locations there also appears to be an evident seasonal change in the properties of the humus. "Mull" and "anmoor" have been observed one after the other at the same place. Such a clear seasonal change during the year has been especially observed in locations of high moisture, scarcely in those of moderate moisture, and never in very dry places.

The "whitened" horizon is observable only in a few profiles. Its micromorphological features indicate "pseudovergleyung"; it is noticeable only in this horizon. Frequently it is found in soils in which the humus formations show the seasonal differences. It is still not to decide, how far a tendency towards podzolisation is present, the climatic conditions of the Nilgiri or the Palni-Hills do not exclude it.

The lower parts of the soil profile consist of different weathered materials, they are changing in composition and origin within very small distances in the field. In its micromorphological features are recognizable materials of rotlehm, lateritic horizons, and of "weathering horizons". Such material is well known from regions of tropical climates. The Malabar-coast-region and its low-situated hinterland possess such climatic conditions. Here rotlehm and laterites are the prevailing soil formations.

The climate of the high situated regions of the western Ghats, especially at altitudes above 1,500 m, shows features under which one cannot expect the development of such soils. Hence, the assumption seems to be valid that the previously described soils in these mountains which show such characteristics did not originate under the present local and climatic conditions. On the contrary, older material seems to be developed under

other climatic conditions. Therefore, the development of these soils was not continuous, they exhibit multiphase development. The topsoil is usually recently developed (disregarding the remnants of older material which is mixed in), beneath it follows a layer in which the older soil material was changed corresponding to today's local conditions. Beneath that follows the more or less unaltered relict material.

A characterization of such soils formations is difficult. To speak only of "red soils" is certainly inexact. The term "forest soils" only signifies that it deals with soils under forests. The term "humicferralitic mountain soils" as used by Gaussen, Legris and Viart [2] characterizes until now the best these soils under forest and pasture in the Nilgiri. It considers the concentration of organic matter in the topsoil and states that beneath that topsoil ferralitic soil material or weathered rock material is present.

Not taken into consideration is the question of whether this ferralitic material arose under present-day-local conditions or if it is older and developed when other climatic conditions prevailed. The latter is probably correct.

The presence of multiphase soil development should be regarded when a term for such soils is sought, because the recognition of a soils developmental history is of the greatest interest to its judgment.

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