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Profile Characteristics of Certain Nilgiri Soils *

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Synopsis: Twenty soil profiles in the Nilgiris representing various elevations and rainfall intensities were studied and profile characteristics observed. Most of the soils were formed from charnockite. There were indications of truncation and superimposition of transported material, with the sequence of superficial horizons reversed. Vesicular laterite horizon was not found anywhere in the area. The marked variation in the soils studied within a small area was probably due to changes in composition of parent rock. The urgent need for agreeing upon morphological and chemical criteria for identifying laterites and related soils is recognised.

Introduction: Detailed information regarding the profile characteristics of soils at various elevations in the Nilgiri hills and the influence, if any, of altitude and climate on such characteristics is, at present, not available. Due to lack of agreement between soil workers on the criteria that are employed for recognizing laterite soils and their related types, it has not been possible to define the Nilgiri soil types with any degree of certainty. The present paper describes in detail the profile characteristics of a number of profiles representative of various altitudes on the Nilgiri hills in the context of level and climatic variations and attempts to assign a place to the soils among the recognised soil groups, with particular reference to various concepts regarding laterite and lateritic soils. The profile studies were made during May, 1960, 1961 and 1962 in connection with study tours arranged for M. Sc. (Ag.) students of Soil Science Faculty, Regional Post-Graduate Training Centre, Coimbatore.

Literature Review: *Geology:* Wadia (1939), describing the rock formations of the South Indian peninsula, mentioned charnockite, or Nilgiri gneiss, of wide occurrence in the Madras State and constituting its chief hill masses, such as the Nilgiris, Palnis and Shevaroys. Krishnan (1949) stated that the charnockites, originally called mountain or Nilgiri gneiss, comprised a whole series of rocks, varying from acid to ultra-basic ones, the intermediate syeno-diorite type being most common. The acid type was named charnockite, since this, in common with granitoid igneous and metamorphic rocks, produced rounded hills and gently sloping valleys.

Indian Laterite Soils: Raychaudhuri (1941), from a study of typical red soil profiles from all over India, stated that, laterite soils were associated with the presence of a definite layer of vesicular rock below. Fox (1936), whom Raychaudhuri refers to, made a detailed study of laterite, traversing the same area as was covered by Buchanan more than a century ago, and suggested that, while the term 'laterite' could be used in a comprehensive sense, only the more

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finished product should be precisely termed 'laterite', while the red soils of the Malabar coast, which Buchanan originally designated as laterite, should be mainly regarded as lithomargic laterite, indicating a comparatively unfinished product.

Foreign Laterite Soils: Joachim (1935), studying the general characteristics of Ceylon soils, held the view that the laterisation process was complete in the laterite soils, while it was only partial in the lateritic soils.

Harrison, quoted by Hardy and Follett-Smith (1931), studied the katamorphism of igneous rocks under tropical and temperate climates and remarked that, on badly-drained low-lying areas, primary laterite gave rise, through resilicification of the gibbsite component to argillaceous earth of the type of crystalline kaolin, through the agency of ascending ground water containing silica or silicates in solution.

Chemical Properties of Laterites: Scrivenor (1929) pointed out the wrong assumption made by some workers to the effect that all laterites should contain a high amount of aluminium hydrate and advocated the restricted use of the word 'laterite', taking into account only the original description given by Buchanan, who originated the term. Martin and Doyne (1927) suggested that the chemical composition of clay, which is recognised to be the most important fraction of any soil, was a better basis for differentiation between laterites and related soils and tentatively concluded that soils with a clay silica-alumina ratio of 0 to 1·33 should be considered as laterite soils, those with ratios between 1·33 and 2·0 as lateritic soils, and those with ratios higher than 2·0 as not being related to either of the above types of soil. Hardy (1933) attempted a classification of red soils based on their degree of hydrolytic weathering. According to him a laterite soil was one which was directly derived from laterite and which might be regarded as a residuary rock produced by the weathering of basic and intermediate rocks in hot, humid climates.

Joachim and Kandiah (1941) analysed nine samples of laterite from three representative locations in Ceylon, and in view of the marked variation in composition, felt that the classification of soils into laterite, lateritic and non-lateritic types on the basis of chemical criteria alone, such as silica-alumina ratios of the clay fraction was likely to be misleading. Sen *et al* (1941), marshalling available data stated that the simultaneous occurrence of free sesquioxides and clay minerals of ratio greater than 2·0 in the clay fraction, the presence of appreciable quantities of free sesquioxides in the coarse fractions, as concretions, presence of finely divided quartz and the resilification of sesquioxides through silicic acid present in ascending ground water were four possible explanations for high silica-alumina ratios in clays which revealed distinct signs of laterite formation, as indicated by the presence of free sesquioxides. They were of the opinion that any attempt to evolve a precise definition of laterite soils from silica-alumina or sesquioxide ratios of clay fractions was not likely to meet with success.

Pendleton and Sharasuvana (1946) analysed numerous laterite samples from ancient ruins, natural outcrops and other occurrences in Siam for silica, iron and alumina. The silica-sesquioxide ratios ranged from 0·33 to 3·2. These workers recognised the word 'laterite' strictly in the sense in which it was used by its originator, Buchanan, and applied it only to an illuvial soil horizon largely consisting of iron oxides, with a slag-like cellular or pisolitic structure and of such a degree of hardness that it might be quarried and used for building construction.

Details of Investigation: The profiles examined in the present study were mostly road and clearance cuttings. Colour, texture, arrangement of horizons, details of demarcation between horizons and special features, if any, were noted. Detailed descriptions of some of the representative soil profiles out of twenty profiles studied are presented in Appendix. One profile each from Kodaikanal and Yercaud has also been described for purposes of comparison.

Discussion: *Superficial Horizons:* The characteristics of the superficial horizons in all cases studied bore a maked degree of similarity. There was a dark brown or brownish black organic horizon to start with, characterised by a low bulk density and deep colour. The depth ranged from one to two feet. Below this was a light brown or reddish brown horizon, which was usually deeper, with depth ranging from two to three feet.

In a number of instances the sequence of these horizons was reversed, probably because of the colluvial origin of the horizons. This apparently was brought about by the pattern of variation in topography. In such instances the profile itself was a composite one, consisting of the material formed by the *in situ* disintegration of the gneissic rock below, over which was superimposed the organic and mineral horizons transported by colluvial action. In these cases further indication of the colluvial action was given by the clear line of demarcation between the organic and mineral horizons. In the case of *in situ* weathering, as seen in the profile studied at Pomological Station, Coonoor, such a clear line of demarcation was not observed, but only a diffuse transition zone.

Gravel Layer: The presence of a layer of gravel appeared to be a feature of some of the profiles studied. Similar gravel layers have been found in red soil profiles at Coimbatore, Ambasamudram and Courtallam. It is significant that the gravel layer is associated with horizons of colluvial origin. Moreover, there is a clear demarcation line between the gravel layer and the soil layers above and below and the size of the gravel bits making up the layer is almost uniform. These facts appeared to indicate that the gravel layer was colluvial in origin, but did not explain why the gravel bits were usually of the size range, half to one cm.

Parent rock: The underlying parent rock was seen in profiles studied at Kothagiri, Ootacamund and Nanjanad. In all these instances the rock was gneissic and bluish-grey in colour. Banding was not very pronounced, but could be made out fairly easily. The rocks evidently belong to the kind of gneiss long recognised to be charnockite containing the pyroxene hypersthene or enstatite and appreciable amounts of the dark ferro-magnesian minerals contributing to the dark colour. (Wadia, 1939).

A notable feature of the disintegration of this gneiss was that, while the rock itself exhibited only gneissic characteristics, without any tendency to cleave along one plane, the upper few inches of the original rock exhibited a very well-defined schistose charactor.

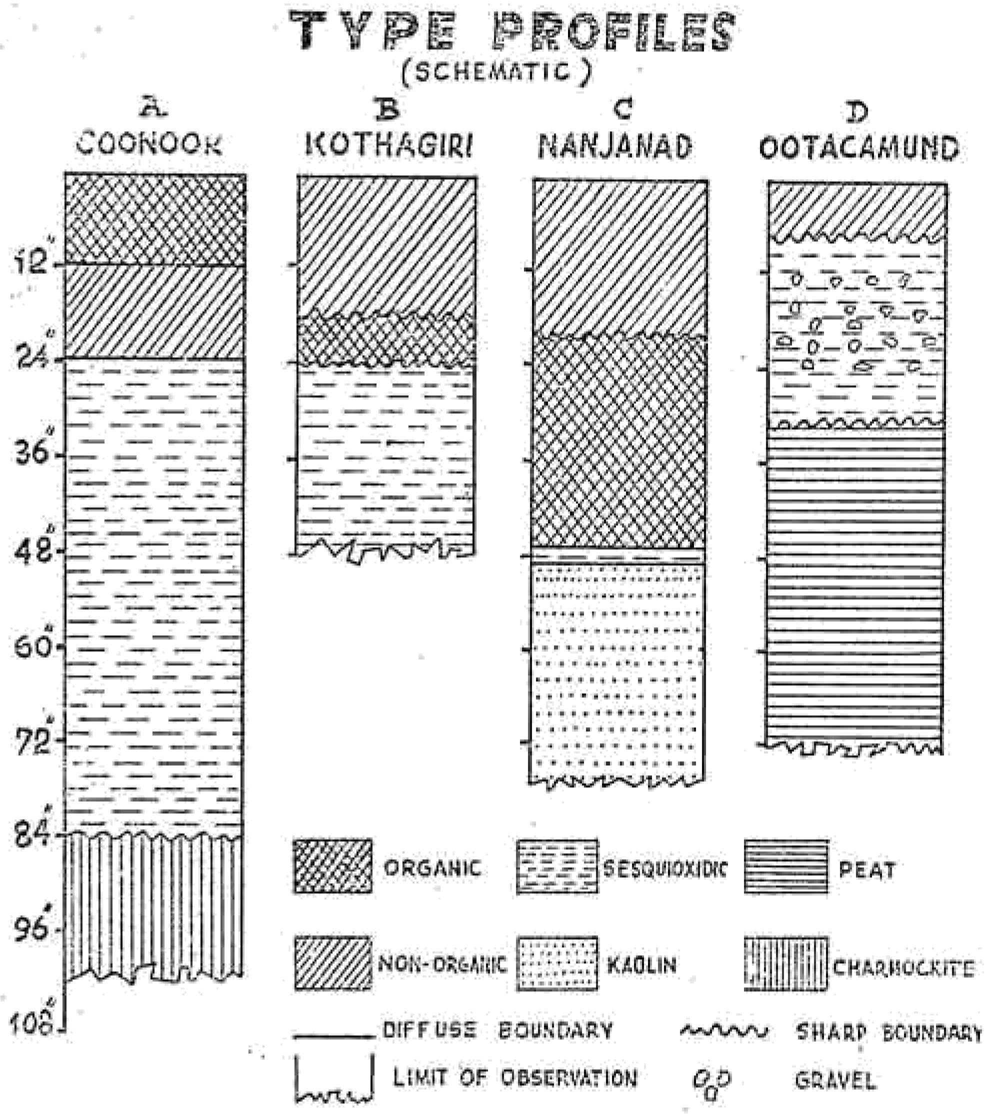
A remarkable observation was that the vesicular, pisolitic laterite rock, which is a common feature of the low.level laterities of the Malabar and Coromandel coasts, was not to be seen anywhere, although a number of profiles, situated at various representative localities on the Nilgiris were carefully examined for the presence of laterite rock. Even in Gudalur, which has an appreciably higher rainfall, (90'') laterite rock was not seen.

Kaolin: Distinct localised accumulations of kaolin were observed in Coonoor, Ootacamund and Nanjanad. Light yellow or red material (limonitic and hematitic form of iron oxide) was found to be present at the same depth very near the profile containing kaolin, although there was no variation in topography to account for the presence of different material like kaolin and hydrated iron oxides at same locality.

As the variation in material described above cannot be accounted for by variation in topography, altitute, rainfall or temperature the indication is that such variations have been brought about by changes in the mineralogical composition of the parent rock, charnockite. It has been recognised by Wadia (1939) that due to variation in the proportion of the constituent minerals of the charnockite-type rock, several varieties, with composition ranging from that of an acid or intermediate hypersthene granite (typical charnockite), through several gradations of increasing basicity, to that of ultra-basic pyroxenites, were possible.

Relationship between climatic factors, elevation and profile characteristics: The general profile characteristics observed during the present study did not appear to be markedly dependent upon elevation. Thus the characteristics observed at Adderley (2400') and Ootacamund (7600') were similar. The annual rainfall for the places examined varied within narrow limits and except for Ootacamund (51''), Gudalur (90''), Nanjanad (55'') and Naduvattam (100'') was between 57'' and 66'' for most of the places. Hence the effect of rainfall on profile characteristics could not be made out clearly. Occurrence of kaolin was observed at Coonoor (5800') and Nanjanad (7400'). Thus the occurrence did not appear to be influenced by elevation, these places differing considerably in their elevation. Moreover, kaolin was not found at Kothagiri, which was comparable to Coonoor with reference to elevation. The occurrence of peat at Ootacamund and Nanjanad was not associated with high rainfall, the annual rainfall for Ootacamund and Nanjanad being the least of the rainfall figures for the places studied. These observations probably indicate that the profile characteristics were predetermined by differences in the chemical composition of the parent rock acting in conjunction with variation in the degree of leaching, introduced by differences in climatic factors operative ages ago.

The profiles studied at Gudalur were distinctive in that the dark coloured organic matter horizon found in the case of soils occurring at higher elevations in the Nilgiris was not present. This is presumably due to the lower elevation and the concomitant higher temperatures, which would be unfavourable for the accumulation of organic matter in appreciable proportions. Gudalur soils, moreover, contained typical ferruginous gravel not met with in the present study anywhere else in the Nilgiri area. The perceptibly higher rainfall probably accounts for the formation of this gravel which is a characteristic formation associated with highly leached conditions as those found along the Malabar coast.



Type profiles: Two definite types of profiles were observed at the sites examined (Figure: A & B). The first type (A) represented dominantly *in situ* formation of the soil. The profile at the Pomological Station, Coonoor, is an example. This consisted of a foot of dark brown, organic matter containing material, which might have been transported, followed by a foot of brown soil and then by five feet of a compact red and yellow material, consisting of rock in various stages of disintegration. Below this, was to be found the gneiss rock, which had weathered into the compact material occupying the greater part of the profile. The second type (B) represented a truncated profile over which transported material had accumulated, giving rise to an apparent inversion of the sequence of superficial horizons. Kothagiri C profile is an illustration. The clear lines of demarcation appeared to corroborate the idea of a transported origin. Most of the profiles examined in the Nilgiri hills and at Kodaikanal and Yercaud were observed to conform to one or the other of the two type profiles mentioned above.

Two other profile types of a localised nature deserve mention, (Figure: C & D). These are the kaolin profile (C) and the peat profile (D). The kaolin profile at Coonoor was simple, with only a foot of highly organic material, occurring over more than seven feet of kaolin. At Nanjanad the sesquioxidic and organic horizons of transported origin occurred, with their original sequence reversed, over the kaolin horizon. The peat horizon at Charing Cross, Ootacamund was characterised by sesquioxide enriched soil in the first three feet, followed by peat, a clear line of demarcation separating the two horizons.

It was interesting to observe that the profiles studied at Kodaikanal and Yercaud had essentially the same characteristics as those of the Nilgiri soils. The parent rock at Yercaud also was the same ash-blue gneiss. Wadia's (1939) reference to the uniformity of rock in the case of Nilgiris, Palnis and Sheveroys appears to explain the observed similarities in profile features.

Gudalur profiles exhibited more of the characteristics of low-level laterites. Ferruginous gravel, not found anywhere else in the present study, were frequently seen in these profiles. Another striking feature was the absence of the dark coloured organic horizons invariably associated with soils situated at higher elevations in the Nilgiris.

The Laterite Question: It will be useful to make an attempt to classify the soils examined in the present investigation as 'laterite soils' or 'lateritic soils', based on the profile characteristics, which have been studied in detail. The definitions of the terms 'laterite' and 'lateritic' and the distinction between the two have not been made precisely so far. The basis of classification of Martin and Doyne (1927) which depends upon silica - alumina ratios of the clay fractions was found to be unsatisfactory by Sen *et al* (1941), who pointed out that even in a true laterite soil the ratio might be comparatively high, due to causes like the presence of finely divided quartz in the clay fraction and the presence of part of the free sesquioxides as concretions in the coarse fraction. Joachim and Kandiah (1941) and Pendleton and Sharasuvana (1946) obtained for typical laterite soils examined by them values of silica - sesquioxide ratio higher than those suggested by Martin and Doyne. In the case of Nilgiri laterites silica - alumina ratios of less than 1·33 have been observed by Raychaudhuri and Mukherjee (1941) although the vesicular or nodular laterite rock, characteristic of typical laterite soils, was not found in any profile in the study.

According to the Seventh Approximation for Soil Classification proposed by the United States Department of Agriculture (1960) the soils previously considered laterite soils or lateritic soils fall under the order 'Oxisol'. But it is found difficult to fit in the Nilgiri soils into any of the sub-orders and lower divisions described therein. It is also stated in the Approximation that additional work has to be done for the further classification of tropical soils.

Assuming that only profile characteristics should be depended upon for the study of laterites and related soils, in view of the complete absence of the vesicular or pisolitic laterite horizon in the soil profiles examined the possibility that the soils are laterite will be ruled out. The next step would be to see if the soils could be called lateritic soils. According to Joachim (1935) the laterisation process is only partial in lateritic soils. According to Pendleton and Sharasuvana (1946) a laterite soil was one in which there was only an incipient or immaturely developed laterite horizon, and in which, it was believed, a true laterite horizon would develop if the prevailing conditions persisted long enough.

The Nilgiri soils are known to have a low pH (about 5) and low availability of applied soluble phosphatic fertilisers. These are indicative of highly leached conditions and the presence of free sesquioxides. In profiles at Coonoor, Ootacamund and Nanjanad accumulation of considerable sesquioxides and kaolin is noticed. If, according to Pendleton, lateritic soils are those which would develop a true laterite horizon if prevailing conditions persist long enough, the Nilgiri soils examined cannot be considered lateritic soils, because the annual rainfall does not exceed about 60" for the places studied, while a number of places in the plains in South India have this rainfall, without developing lateritic soils.

It is therefore suggested that it will be useful if workers on tropical soils agree upon the profile morphological features and physical and chemical properties that are to be considered conjointly for classifiying soils as laterite soils, lateritic soils, or red soils.

Summary and Conclusions: Twenty soil profiles studied at Kallar, Adderley, Kothagiri, Coonoor, Ootacamund, Nanjanad, Naduvattam and Gudalur in the Nilgiris indicated that most of the soils were formed from charnockite, otherwise called Nilgiris gneiss. In most of the localities there were indications of trunction of the original profile and the superimposition of transported material, with the sequence of superficial horizons reversed. Kaolin occurred locally in Coonor, Ootacamund and Nanjanad, in the lower horizons. Peat occurred similarly at Ootacamund and Nanjanad.

The vesicular and pisolitic laterite horizon characteristic of the low level laterite soils of Malabar was not met with in any of the profiles examined, nor was there any other horizon similar to the true laterite horizon. Ferruginous gravel or

laterite pebbles, which are usually associated with laterite soils, were not found in any amount. In their place, only gravel consisting of quartz crystals held together by sesquioxidic cementing material were found. Typical ferruginous gravel was however seen in Gudalur profiles.

The soils were observed to vary markedly even within a small area. The occurrence of kaolin and sesquioxide deposits was highly localised. This appeared to suggest that variations in the parent rock composition account for the soil variation, as the other pedogenic factors like clim ate and vegetation do not change within such small areas. This view is in consonance with the known properties of charnockite, the parent rock of most Nilgiri soils, which is known to varv considerably from acid to ultrabasic conditions.

In view of the absence of definite criteria for deciding as to what soil group the Nilgiri soils belonged, it was difficult to decide this point. If, according to certain workers, the presence of laterite rock is essential as a criterion of laterite soils the Nilgiri soils are not laterite soils. But peculiarly enough, the clay silica-alumina values of Nilgiri soils at above 5,000 feet have been found by previous workers to be below 1·33, the value suggested as the upper limit for laterite soils, by Martin and Doyne. If, according to certain other workers, the presence of sesquioxidic accumulation and kaolinite might be taken to indicate incipient laterisation, the soils may be called lateritic soils. In any case it is recognised that there is an urgent need for agreement among soil workers in defining morphological, physical and chemical criteria for distinguishing between laterite soils, lateritic soils and non-laterite soils.

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APPENDIX

Detailed description of Soil Profiles

(Figures following place name are height above M. S. L. and mean annual rainfall respectively)

1. **Adderley** : 2400 feet. 60".

Behind Railway Station.

0 - 18": Brown sandy loam, blocky. Contains gravel of about 1-2 cm. diameter, mostly of partially disintegrated rock.

19 - 46": Bright brownish red loam, blocky. Contains more gravel than first horizon, but of about the same size.

47 - 62":* Brown loam, no gravel. Contains sparsely distributed pockets of powdery kaolin.

2. **Kothagiri** : 6000 feet. 64".

(a) *On Coonoor - Kothagiri Road, between 10 and 10 miles 1 furlong.*

0 -8": Brown loam, light due to presence of organic matter. Clear line of demarcation between this and the succeeding horizon.

19 – 24″: Darker brown loamy soil. Distinct array of pebbles of single crystals of quartz, angular in shape (1 cm.) Pebbles formed from clusters of small quartz grains held together by sesquioxides absent.

25 – 48″:* Reddish brown rock material in different stages of disintegration.

General: Appears to be a superimposition of colluvial material on a truncated profile, with its superficial horizons missing.

(b) *Behind Farm Tea Estates Syndicate Factory.*

0 – 12″: Yellowish brown soil.

13 – 30″: Brown soil, blocky structure. Clear line of demarcation between this and the succeeding horizon.

31 – 33″: Regular array of quartz pebbles of fairly uniform size.

34 – 324″: Orange, compact material, consisting of rock in different stages of disintegration.

325 – 360″:* Disintegrating gneissic rock, with the upper portion exhibiting schistose structure.

General: The superficial horizons of this profile resemble those of the preceding one.

3. **Coonoor** : 5800 feet. 60″.

(a) *Pomological Station: (Low level)*

0 – 12″: Dark brown, made up principally of organic matter and plant residues. Apparent density low. Contains fine gravel.

13 – 24″: Light brown loam with more gravel.

25 – 84″: Compact material, mottled red and yellow, slightly vesicular, consisting of rock in various stages of disintegration. Contains fine quartz grains loosely cemented together by iron oxides.

85 – 102″:* Gneiss rock, bluish grey coloured. Distinct line of demarcation between original and disintegrating portions of the rock.

General: Original rock has only a gneissose form, while the disintegrating rock lying immediately above it has a pronounced schistose form. Soil at this spot appears to have been formed *in situ* and there is not much colluvial action as in a number of other profiles examined.

(b) *Sim's Park: Kaolin profile:*

0 – 12″: Dark brownish black humus. Low apparent density. Original form of plant residues recognisable.

13 – 96″:* Almost pure kaolin, cream coloured, with vertical cleavages dividing the whole mass into a number of vertical prisms. Quartz crystals of irregular and angular shape and average diameter ½ cm. dispersed in fair abundance throughout this horizon.

(c) *Opposite Kerala Timber Depot.*

0 – 32″: Light brown sandy loam. Appreciable proportions of angular grit particles present. Tendency towards crumb structure.

33 – 62″: Dark brown clayey loam. Low grit content.

63 – 83″: Gravel horizon. Fairly uniform sized gravel, of about ½ cm. average diameter, rounded. Gravel consists of angular quartz particles held together by ferruginous material.

84 – 120″:* Very hard and compact. Orange to light brown colour. Clayey loam.

. **Ootacamund** : 7600 feet. 51″.

(a) *Tourist Rest House foundation, near main road. Kaolin profile.*

0 – 24″: Brown clay loam with negligible amounts of grit. Weakly developed prismatic structure.

25 – 30″: Gravel layer with similar sized rounded gravel of average diameter ½ – 1 cm.

31 – 54″: Pink with white mottling. Mainly clayey. Weakly developed prismatic structure.

55 – 84″: Kaolin mainly white in colour. Initially compact, but crumbles to a fine powder. Contains brownish red mottles, which are indistinguishable from the kaolin matrix through properties other than colour.

85 – 132″:* Numerous striations of yellow and brownish red on matrix of white. Compared with the kaolin profile at Sim's Park, Coonoor, the above one is prominently devoid of quartz.

(b) *Peat profile, foundation for building, between foregoing profile and road:*

0 – 4″: Brown soil, with ill-defined columnar structure.

5 – 7″: Black peaty material mixed with soil.

8 – 11″: Orange-brown clayey loam.

12 – 24″: Gravel layer, with bits of one cm. average diameter.

25 – 27″: Vein-like formation of orange material.

28 – 31″: Similar to first horizon, but lighter brown.

32 – 72″:* Deep black peaty material, well-defined prismatic structure, with cracks separating the prismatic members.

General: The same peaty nature of the profiles was observed in an area of about 10 cents covered by the foundation trenches.

5. **Nanjanad** : 7400 feet 55″.

About two furlongs from main road to village: Kaolin profile:

0 – 20″: Light brown, clayey soil with good crumb structure. Numerous cracks present. Tendency towards a columnar structure:

21 – 47″: Dark brown soil with good crumb structure.

48 – 50″: Yellowish brown material very soft and pliable, probably limonite.

51 – 77″:* Ashy white kaolin, higly plastic. A number of vertical cracks divide the mass into prisms.

6. **Naduvattam** : 6000 feet. 100″.

0 – 52″: Dark brown, clayey. Prominent absence of grit. Disintegrating parent material in the form of stones 4 cm. across found near surface. Blocky.

53 – 86″: Light brownish red, clayey. Very weakly developed prismatic structure. Grit absent.

87 – 90″: Brownish red, clayey, blocky. Transition horizon.

91 – 121″: Red, clayey, blocky. Fine angular quartz, about 1 – 2 cm. diameter is distributed throughout in fair amounts.

122 – 137″: Reddish brown — brownish yellow mottles. Contains angular quartz, 2 – 3 mm. diameter. Clayey, blocky.

138 – 177″: Similar to previous horizon in other respects. But quartz sparsely distributed.

Below 177″:* Charnockite rock.

7. **Gudalur** : 3800 feet: 90″.

North of town:

0 – 15″: Light brown, clayey loam, blocky. High content of ferruginous grit.

16 – 25″: Brown clayey loam. Considerable amounts of ferruginous gravel of ½ cm. average diameter. Blocky.

26 – 47″: Light reddish brown, highly clayey, prominent absence of coarse particles. Weakly developed prismatic structure.

48 – 57″: Brown clayey loam. Weakly developed prismatic structure

58 – 60″: Reddish brown clayey loam. Contains ferruginous gravel of about ½ cm. average diameter.

61 – 97″:* Light brownish red. Prominent absence of coarse particles. Clayey. Very weakly developed prismatic structure.

8. **Kodaikanal** : 6700 feet. 66″.

Two furlongs from Kodaikanal, on Fernhill road.

0 – 20″: Dark brown loam with gravel.

21 – 50″:* Yellowish brown loam, brown shade increasing with depth. Orange patches occur in a matrix of yellowisn brown.

9. **Yercaud** : 4500 feet. 63″.

Inside Montfort School commpound, southern bank of foot-ball field:

0 – 31″: Dark brown clayey loam, presumably high in organic matter. No stones.

32 – 34″: Clear line of demarcation after foregoing horizion. Band of stones extending about 100 yards (lateral limit of profile exposed).

35 – 53″: Reddish brown loam. Contains considerable amounts of small, and angular, gravel, consisting of quartz crystals cemented together by iron oxides.

54 – 80″:* Bright brownish red clayey loam, with stray bits of stones.

* Limit of observation.

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