CLAY MINERAL CHARACTERISATION OF THE MAJOR SOIL SERIES OF TRIVANDRUM DISTRICT

By

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DECLARATION

I hereby declare that this thesis entitled "Clay mineral characterisation of the major soil series of Trivandrum District" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Clay mineral characterisation of the major soil series of Trivandrum District" is a record of research work done independently by Shri. Asharaf. M. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Soil clay is the most active and reactive portion of the soil. Layer aluminosilicate clays constitute the main portion of the clay fraction of most soils. In ferruginous soils significant amounts of hydrous oxides and gibbsite are also present in the clay fractions. A clay mineral is a naturally occuring inorganic materials found in soils and other earthy deposits. Structure and composition of these clay minerals are described in detail by Grim (1968) and Giesking (1974). Some of the important inferences from clay mineral data include - physical qualities as shrink-swell potential, plasticity, moisture retention, permeability, cation exchange characteristics, nutrient reserve and release rates, fixation potential and weathering stage. Because of these many effects of clay minerals on soil properties, clay mineral content is used as a classification criterion (USDA, 1975, 1987). Most intensive use of Clay mineral data in the Soil Taxonomy is as one of a set of soil family differenciating characteristics.

Soils of the humid tropics are characterized by intense laterisation and exhibit specific morphology and chemical composition. Climate is the most deciding factor of soil formation. Annual rainfall is considerably higher and temperature is high in the humid tropics. The summers are usually dry with definite dry spell. Under these conditions of intense weathering environment, weathering result in the physical and chemical disintegration and hydrolysis of soil materials. Silicates are completely hydrolysed and even quartz is finally disintegrated and dissolved. Consequently the main ions Si^{4+}, Al^{3+}, Fe^{2+}, Mg^{++}, Ca^{++}, K^{+} and Na^{+} which make up the silicate structure are released. These are to a greater extent removed by water percolating through the profile. Iron,Aluminium and Silicon are partly retained in the soil profile, crystallize to hydrous iron oxides (Goethite/haematite), hydrous aluminium oxides (gibbsite/boehmite) and aluminosilicates (kaolonite/halloysite).

In Kerala, these soils are distributed in the mid-high land and mid land and mid coastal land regions. These soils are red coloured either with iron indurated horizon and/or of a kaolin layer in the profile are termed "red soils". In the laterites, the profile will have a characteristic indurated laterite horizon 'plinthite' and /or a kaolin layer - "kandic horizon".

Gopalaswamy (1969) reported higher content of alumina and iron in the clay fraction of the laterite and lateritic soils of the state. Sathyanarayana and Thomas (1962), Gowailkar (1972), Das and Datta (1974), Schmidt-Lorenz (1978), Venugopal and Koshy (1982) have reported that kaolonite is the dominant clay mineral in the laterite soils of Kerala. Van-der-Merwe and Heystek (1952) identified kaolonite mineral by XRD in the colloidal fractions of grey ferruginous lateritic soils of South Africa derived from granite and sand stone.

Rangasamy et al. (1978) reported that iron bearing kaolinite are dominant in the clay fractions of some ferruginous soils of Eastern Mysore Plateau.

In the present investigation, it is aimed to study the qualitative and quantitative distribution of clay mineral present in established soil series namely, Trivandrum, Nedumangad and Palode series of Trivandrum District. It is also aimed to evaluate the properties of clay fractions in these soil series. A more accurate and complete information on the nature and distribution of clay minerals present in these major soil series will lead to reform the present Soil Taxonomic classification and better understanding of these soils in relation to crop production.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Laterite soil are widely distributed through out the tropical regions of Africa, Australia, Asia and South America. The term 'Laterite', 'ferruginous' and 'ferrallitic' are used to refer to the soils of humid tropics. The term laterite is used to refer those soils having a definite laterite or indurated layer. 'Ferruginous' is used for soils with kaolinite associated with other minerals and iron oxides without free alumina. The term 'ferrallitic' is preferred by the French pedologists to indicate simultaneous release of iron and aluminium during weathering. In the Soil Taxonomy (USDA, 1975, 1987), these soils belong to the soil orders Oxisols, Ultisols and Alfisols.

The laterite layer coined by Francis Hamilton Buchanon, 1807 at Angadipuram, Kerala state) when exposed and allowed to dry become very hard and will not soften when rewetted. It will be irreversibly hardened.

Genesis of Laterite

D' Hoore (1955) showed that the Laterite can be the consequence of either or both of following processes.

1. Concentration of sesquioxides by removal of silica and bases.
2. Concentration of sesquioxide by accumulation from an outside source.

Sathyanarayana and Thomas (1962) while studying some of the profiles of laterite and associated soils in Kerala and South

Kanara District of Mysore found both gneissic and basaltic rocks beneath laterite.

Sivarajasingham et al. (1962) revealed that laterite could be formed over a variety of rocks ranging from basic rocks like basalt and diorite on one side to acid rocks like granite and gneiss on the other side.

Maignien (1966) reported that most of the contemporary laterite soils have developed at a mean annual temperature around 25°C and upto an altitude of 200 metres. Laterite soils were mostly seen in the tropical environment where annual precipitation was at least 1200 mm.

Soil survey (1969) reported that laterites are formed in areas having humid tropical climate with fairly heavy rainfall, uniform temperature and tropical type of vegetation.

The studies by soil survey (1970) has shown that laterite are developed from gneissic parent material.

The soil survey staff (1970) reported that the soil clays in the Trivandrum, Nedumangad and Palode series majorly contain Kaolinite.

Morphology

Gopalaswamy (1969) while presenting the morphological descriptions of five laterite profiles in Kerala found no distinct variation in the colour even upto a depth of 250 cm.

A representative soil profiles of lateritic weathering (Millot, 1970) consists of :-

An upper horizon-lateritic or ferrallitic, humic and rich in iron concretions.

An alluvial horizon with crust in the process of encrustation.

An horizon of mottled clay or lithomarge

An horizon of initial decomposition

Parent rock

Sing et al (1990) revealed that some soils of North West Himalayas was characterized by heavier texture in to horizon. Field observation showed the occurance of clay argillans indicating the traslocation of clay in the profile as evidenced by thin continuous and distinct clay coating on ped faces thus attesting the presence of argillic horizon.

Physical Properties

According to Manickom (1977) and Subramonia Iyer (1979) the intense weathering laterite soils have a very low silt content. Gopalaswamy (1969), Gowaikar and Datta (1971) reported a decrease in the content of sand fractions with depth in most of the lateritic soils.

The bulk density and particle density are uniform in different horizons at laterite soil profiles in Kerala indicating more or less uniform weathering (Gopalaswamy and Nair, 1972).

Chemical Properties

Bauer (1898) was the first to recognize the chemical characterisation of laterite by pointing out the higher content of iron and alumina and low content of silica. Sathyanarayana and Thomas (1962) revealed that the laterite profile from Angadipuram and Kasargode were acidic (4-5) pH and with extremely low CEC (2, 5-7.0 cmol kg^{-1} of soil). Silica content decreases with depth while a reverse pattern is exhibited by alumina content. These soils are low in bases.

Gopalaswamy (1969) observed higher content of alumina and iron and lower content of silica in the laterite profile from Kerala.

Some soils of North West Himalayas are moderately contain high in organic matter which shows a regular decrease with depth. Exchange capacity values are usually higher in horizons containing high clay or high organic matter. It was reported by Sing et al (1990).

Mineralogy

Fine sand mineralogy

Agarwal et al. (1957) working in the soils of Upper Vindhyan Plateau found that the percentage of light minerals to be more or less uniform in all the horizons whereas the variation in the content of heavy minerals was not regular. The common light minerals observed were quartz, feldspar and mica. Slight variation in shape, size and weathering were exhibited by grains. In an another study at the same soil, by Singh and Agarwal (1971) concluded that these soils are of a residual nature. Quartz constituted the major portion of the fine sand fraction of these soils.

Sarkar and Raj (1973) carried out the mineralogical studies of fine sand fractions of some soils of South India and observed that the minerals present were in conformity with the parent rock. Iron bearing minerals were appreciably high in laterites with limonite being characteristic of low level laterite. Micaceous minerals were also present in appreciable amounts. The red soils had low ferro magnesian minerals and traces of micas. Zircon was present invariably in all clay fractions.

Lespsch and Buol (1974) working on Oxisol and Ultisol toposequences showed that quartz was the dominant mineral in the sand fractions varying from 62-97%. Heavy opaques were the second most common minerals. The content of opaque decreased from top to bottom.

Saratchandran Nair (1977) examined the sand fractions of the rice soils of Wyanad and found predominance of quartz in most profiles. In one sample, opaque was dominant, the feldspar being totally absent.

Murali et al (1978) have reported that light fractions was dominant by quartz and some feldspar in the soils of Southern India. The heavy minerals consists mainly biotite and magnetite. Rangaswamy et al (1978) found that the sand fractions of the ferruginous layers of the laterite soils had considerable amounts of haematite. Mica and quartz were dominant in the silt fractions.

Subramonia Iyer (1979) found that the quartz as the most abundant light minerals in the laterite red soil associations in Kerala. Ilemenite constitute about 20-25%. Ferromagnesian minerals were 5-15%. Mica present in traces. Zircon was the other mineral identified.

Lietzke and Whiteside (1980) revealed that the dominant mineral of sand fraction of Belize soils is slilica in the form of quartz and quartzite.

The fine sand mineralogy of some soils of Uttar Pradesh in the north east extension of the Indo-Gangetic alluvial plains was studied by Raina and Banerjee (1989). The dominant mineral in all the soil is quartz. Muscovite is the second most abundant mineral and there is very little feldspar. Chlorite is the dominant heavy minerals; these minerals are also scarce and there are only traces of tourmaline, zircon or iron-ores.

Spiers et al (1989) carried out the mineralogical studies of fine sand fraction of north east Alberta. The fine sand suite was dominated by quartz. With lesser amounts of Na^+, K^+ and Ca^{++} feldspar and minor amounts of individual heavy mineral species.

Bhattacharya and Ghosh (1990) studied the fine sand minerals of Alfisol derived from Granite Gneiss and reported that quartz is the dominant mineral followed by feldspar and kavlinite.

Diaspore appear as a major mineral in C_2 horizon whereas in other layers its content is relatively low.

Laterite show successions of horizons of different induration and sequence of minerals in different hydration status (Tardy et al, 1990). He discussed the distribution and thermodynamic stability of Al-haematite and Al-geothite and showed that the chemical composition of geothite, haematite and kaolinite is controlled by equilibrium with other phases, silica activity, temperature and by the activity of water.

Mayalagu and Paramasivan (1990) studied the sand grain mineralogy of padula series in lateritic soil tracts of Sivagangai taluk in Tamil Nadu. The sand fractions formed from plinthite over granitic gneiss were found to contain light minerals because of their relative resistance to weathering. Quartz was the dominant light mineral and there was very little feldspar. Among the heavy minerals, plinthite fragments predominated. The only variation with depth was a slight decrease in the light mineral content.

Minerology of fine sand fractions in all pedons of soils of Northern plateau zone of Orissa indicates the dominance of quartz and orthoclase feldspar (Sahu, Patnaik and Das, 1990).

Totey and Bhawmik (1990) worked in mineralogy of fine sand fractions in Madhya Pradesh. They found that all pedons were rich in weatherable minerals like plagioclase, chlorite, horn blende and their inherent fertility status was rated high.

Clay Mineralogy

Bagchi (1951) using X-ray diffraction technique showed that red and laterite soil contain mainly kaolinite. The laterite soil from Belgaum contain both kaolinite and goethite.

Nye (1955) reported that in the laterite soils over granite in Nigeria, clay minerals were predominantly kaolinite with subsidiary quartz, geothite and mica in the free draining parts of the profile, while in the reduced zone, there was montmorillonite probably formed by silication of kaolin.

Agarwal et al (1957) observed that an increase in silica sesquioxide ratio down the slope. The ratio of more than 2.0 is suggestive of the siallitic nature of soils and clays. The CEC supported by X-ray studies showed that the dominant clay fractions of some of the soils were montmorillonite while in others it was illite.

McKeague (1965) found that the mineralogical property of the podzol soil studied were closely related to the soil redox conditions. McKeague et al (1973) found kaolinite in all horizons, and chlorite and lattice expansible mineral in surface horizons. The general weathering trend suggested to the alteration of mica to a lattice mineral and further alteration of montmorillonite.

Jepson and Rowse (1975) directly observed individual kaolinite particles under electron microscope. They report that the decrease in particle size and having less typical hexagonal phase of kaolinite appears to be correlated with the evolution of their specific surface area.

De Alwis and Pluth (1976) reported amorphous minerals to be in the range of 2.0-8.1% in the clay fraction of red and latosol profiles of Sri Lanka. They found higher content of amorphous material at A horizon and translocated clay rich B horizon than the lower layers. The SiO_2 / Al_2O_3 ratio ranged from 2-2.8, suggesting that amorphous content dissolved was present as subcrystalline clay like materials than free oxide or hydrous oxides. The estimation of amorphous materials was done by using the formula.

$$\frac{\%\ SiO_2 + \%\ Al_2O_3}{0.9}$$

Rangasamy et al (1978) in their study of ferruginous soils of Karnataka found that clay had considerable amounts of amorphous ferri-alumino silicates (AFAS). Kaolinite was the dominant mineral of the clay. Iron was the structural component of kaolinite. Smectite content was considerable only in the clays of the profile with impeded drainage.

Murali et al (1978) while investigating the clay fraction of ferruginous soils in South India reported the major constituent to be kaolinite followed by amorphous ferri-aluminosilicate.

Hugh (1978), Paramanathan (1977), Easwaran and Wongchow Bin (1978) reported the existence of fibrous type of kaolinite minerals along with mica and vermiculate in some soils of Nigeria.

Herbillion and Rodrique (1979) reported that kaolinite exhibiting small particle size be qualified as more oxidic than larger kaolinites.

Milo et al studied the mineralogy of clay and found that kaolinite and metahalloysite were the predominant minerals and geothite and gibbsite were frequent. Small amounts of talc, smectite, mica and interstratified minerals were also present.

The mineralogy of clay fractions of four soil profiles developed under different parent materials, climate and vegetation was studied by X-ray diffraction analysis, (Guptha and Awasthi, 1982). The result indicated the presence of illite in all the profiles, chlorite, smectite, vermiculite and kaolinite were the other important clay minerals depending on the weathering condition in one or other of the soil horizons. Interstratified minerals in the form of chlorite vermiculite and chlorite-smectite were also found in some of the profiles.

Rao and Krishnamurthy (1982) when studied the clay mineralogy of lateritic soils of Goa found that minerals in the sand, slit and clay fraction developed from gneissic granite, quartz, mica and kaolinite were the main constituent of silt fractions. The kaolinite had appreciable amount of iron substitution in the octahedral layers.

Saxena and Singh (1983) studied the clay mineralogy of semi arid region soils of Rajasthan and showed that illite was predominant

Um (1990) studied characteristic of clay mineral derived from residual soils on granite using chemical, X-ray diffraction analysis and Infrared spectroscopic analysis. The coarse clay contained more K_2O and less Al_2O_3 than the fine clay. Kaolins, hydroxy interalyered vermiculite and illite were the dominant minerals in the two size fractions.

Sahu and Dash (1991) reported the clay mineralogy of some coastal salt affected soils of Orissa and found to certain kaolinite is the major type of mineral.

Free Iron Oxides

Iron oxides of both crystalline and amorphous form occur in appreciable quantities in the soils of humid tropics. Geothite and haematite are the common crystalline forms of iron oxides in these soils.

Cook (1973) found that the free iron oxides content in the clay, fraction of some Typical Hapludulls vary from 6-15 per cent.

Beckman et al (1974) in their study on the genesis of red and black soils of Australia indicated the unusual association of haematite with montmorillonite in one of the profiles. The clay fraction contained higher amounts of montmorillonite and higher amounts of haematite than the red soils of the region.

Eswaran and Wang Chow Bin (1978) in Malaysia observed that crystallinity of iron oxides decreases down the profile. Free iron oxides amorphous to X-rays found in the lower horizons. But in recent alluvium and grey brown soils, while the clays from non -calcic brown and brown soils were predominantly with in montmorillionite type minerals.

Ramanathan and Krishnamurti (1985) studied the soil clays using DTA technique. The clays were found to contain kaolinite and illite in the red soils, while in the laterite soils, kaolinite was the dominant mineral, similar observation is also reported by Subramoniam Iyer and Gopalaswamy (1985) in a lateritic alluvium of Trivandrum District.

Xie (1987) studied the clay mineralogy in relation to weathering of a catena of dark brown forest soil on granite. Acid eluviation appeared in the AB and B horizons where feldspar break down and vermiculite formation were extensive. Biotite and interstratified smectite-kaolinite remained in the C horizon.

Nikolaeva and Sokolova (1989) examined the clay mineral of zabaikalie region of Moscow and found to contain mostly illite, smectite, kaolinite, chlorite and mixed layered silicates.

X-ray diffraction of soil clays from five pedons selected in the South Kheri forests demonstrated that kaolinite was the dominant silicate minerals, both at the surface and subsurface. In addition, small amounts of geothite, gibbsite and integrated micaceous minerals were identified (Banerjee et al, 1989).

Clay mineralogical studies of three lateritic profile from Goa have matured to the extent of producting gibbsitic clay. (Maurya and Karkore, 1990).

in the surface, there were increase in the amount of geothite and haematite.

Anand and Gilkes (1987) reported that haematite and geothite contents differ with the parent material. They found that laterite soils of Western Australia developed from dolerite contained large amounts of geothite and haematite than those from granite.

Clay Mineral Genesis

Jackson (1965) used the term intermediate desilication (kaolinization) and intense desilication (laterisation) for the mineral alteration in the humid tropical climate. He proposed intermediate desilication as the process of clay transformation in Ultisol as intense desilication in laterite soils. These two process are characterized by the intense and protracted weathering of parent rocks and soils under wet and dry seasons resulting in the enrichment of sesquioxide components giving free iron oxides, kaolinites and halloysite. An alteration of kaolinite layers with chlorite or illitic layers was observed in soils derived from gneiss (Stahr and Gudmundsson, 1981).

Moller and Klamt (1982) observed on genesis of clay minerals in an Oxisol and suggests that chlorotized vermiculite is formed from the alteration of mica and weathers directly to kaolinite or through the formation of gibbsite.

Kaolinite

Structural alterations as the mechanism of kaolinite synthesis has been proposed by some workers. Humbert (1948) suggested that if silica is present in abundance as in the case of moderately basic rocks, kaolinite crystallises directly. However he proposed authigenic crystallization of kaolinite is when the rock is acidic.

Maignien (1966) suggested three pathways of kaolinite genesis namely, (1) kaolinite is formed directly from primary silicate minerals (2) It is formed through the medium of collasols or amorphous gels and (3) It is formed directly from ionic solutions.

Millot (1970) reported that mineral transformation and neoformation from the product of hydrolysis are the principal process for the genesis of clay minerals.

Ojanuga (1973) proposed kaolinite synthesis by rapid dissolution, re-precipitation and recombination processes in some soils of Nigeria based on electron micrography of kaolinites. Such a sequence was supported by the fact that kaolinite of the clay and silt fractions contained FeIII in their structure, a legacy from a parent gel. Amounts of iron in kaolinite and AFAS were significantly correlated ($r = 0.71$) and each was correlated to free iron oxides. ($r = +0.56$ and 0.71 respectively) indicating an equilibrium between iron in solution in AFAS and in Kaolinite.

Chatterjee and Rathore (1976) found kaolinite as one of the alteration product where basalt has weathered under a leaching regime.

Rangasamy et al (1978) working on the mineralogy of some ferruginous soils of Eastern Mysore plateau proposed total hydrolysis of the primary rock mineral, and recombination of hydrolytic products as bases are leached, leading to the formation of amorphous ferri aluminosilicate (AFAS) and crystallization of kaolinite, from AFAS on further leaching. It appears that both mineral transformation and neosynthesis are operating in kaolinite formation in different soil situations.

Ojanuga (1979) proposed three factors directly leading to kaolinite synthesis viz.,

1) Lowering of pH in the weathering environment by the high temperature induced dissociation of soil water in humid tropical climate.
2) Marked leaching by rainfall and
3) Mineralogical composition of soil or parent material

Kaolinite in clays of laterite, lateritic and red soils is usually an indicator of a highly leached environment with good drainage leading to acid soils. Some believe that kaolinite is stable during the lateritic weathering while others are of the opinion that it decomposes to yield aluminium hydroxide. Kaarathanasis and Hajek (1983) presumed that smectite to kaolinite transformation is a combination of dissolution, precipitation and structural re organization processes.

Rao and Krishnamurthi (1985) studied on the nature of soil kaolinite of Southern India. It is shown that iron was a structural constituent of the kaolinite and that the extent of substitution of iron for aluminium depend on parent material and profile drainage.

Baker and Scrivner (1985) based on simulation study in a Typic Hapludolls suggested that desilication resulted in transformation of smectite to kaolinite in the upper horizons while in the lower horizons, the smectite was preserved due to high silicon content in the soil, supported by higher silicon content in the soil at lower depth. They have observed an uniform distribution of Al_3^+ throughout the profile (this model take into account possible recycling of Si and Al by plants).

Some kaolinitic soils derived from basaltic material contain 2:1 minerals as a discrete phase and /or interstratified with kaolin as determined by XRD and chemical analysis of popular CDB of treated clays, while others show little or no evidence of 2:1 minerals. The profile contain kaolin with high normal CEC and permanent negative charges which cannot be accounted for by the presence of 2:1 clay mineral alone and which are attributed to a degree of isomorphous substitution. This substitution and / or mineral impurities may have limited kaolin crystal growth during neoformation.

Iron Oxides

Tylor and Grayky (1967) reported that in an ion free environment of (other than Hian) the more acid conditions favoured the formation of haematite rather than goethite. They have shown that haematite can be formed in the presence of large quantities of water. Haematite formation is favoured by conditions that favour aggregate formation (Fischer and Sehwertmann, 1975). The principal mechanism of formation is by internal dehydration of the aggregated amorphous iron oxides.

Iron oxides in the Ap and B_{22} horizons of a representative profiles of dark red latosol were analysed by Pombo et al (1982). The presence of haematite and goethite in the Ap and B_{22} horizons was verified by X-ray diffractometry, haematite was prevalent. Maghaematite was present in coarse clay fractions of both horizons and in the fine clay fractions of the Ap horizon.

Fontes and Weed (1990) studied the ironoxides is selected Brazilian Oxisols and found to certain haematile and / or goethite. Citrate Diothionite treatment of clays showed haematite preferentially dissolved compared with goethite.

The mineralogical composition of the clay fractions of two paleudults from Indonesia have been investigated by Bender, Bentzon and Larson (1992). Ironoxide have an important role in the weathering of the layer silicate by repeated redox cycles. Most of the iron oxide is present as goethite, but minor amounts of lepidocrocite is also found in one of the profiles.

Interaction of Iron Oxide with Kaolinite

Association of iron oxide with kaolinite has been reported by many workers.

Follett (1965) reported that 'Ferric hydroxides' sorption by kaolinite was intermediate, and crystallographically by basal plane surfaces. This was unaffected by the presence of excess of NH_4^+ or Ca^{++} or Al_3^{+++} ions.

Greenland and Oades (1968) reported that association of iron hydroxides with kaolinite clay surfaces was dependent on the surface characteristic of the iron compound and of the clay and the properties of the medium in which they are dispersed. More ready sorption of iron oxide occurs when the pH of the surrounding medium is low.

Blackmore (1973) showed that hydroxy ferric ions positively charged, adhere strongly to kaolinite clay surfaces replacing cations on the surfaces.

De-Alwis and Pluth (1976), Jones et al (1982) and Schwertmann and Kampf (1985) by electron microscopy showed that close association between iron oxides and kaolinite does not exists.

Methods of clay mineralogical analysis

The X-ray diffraction analysis is very useful for the identification of minerals in soil clays. The diffraction characteristics of each minerals-chemical structure arises from the uniqueness of the atomic arrangement in it. This arrangement results in an unique array of diffraction peaks for each mineral called a diffraction pattern which is used as a finger print to identify each mineral. The intensity of each diffraction peak is proportional to the number of diffraction planes or more simply the concentration of each kind of minerals in a mixture. Diffraction analysis of soil clay consists of mounting of specimens followed by X-ray irradiation and qualitative and semi-quantitative interpretation of the pattern.

A chemical method of quantitative determination of vermiculite in soils have been developed by Alexiades and Jackson (1966). The CEC of the sample is first determined with $CaCl_2$ and replacement of Ca with $MgCl_2$. An another similar sample is washed with KCl, heated to 110°C overnight. The K remaining exchangeable is determined by NH_4Cl washings. The differences between the two gives the interlayer charge due to vermiculite. The vermiculite content is calculated based on the average value of interlayer charge of 154 meq/100 g of vermiculite.

The method used for determination of amorphous materials and kaolinite was that proposed by Hashimoto and Jackson (1960). A clay sample containing amorphous material was boiled in 0.5 <u>N</u> NaOH for exactly 2.5 minutes at clay : Solution ratio of 1 : 1000 to dissolve the components of the element (Si, Al and Fe) that constitute the component determined calorimetrically and allocated to the mineral. In the determination of kaolinite clay samples free of amorphous materials were heated to 500°C for 4 hours to distruct the structure of kaolinites. The residue was subjected to 0.5N NaOH boiling for 2.5 minutes at clay : NaOH ratio of 1 : 1000 and the dissolved elements of kaolinite determined calorimetrically. The elements were allocated to the mineral by following unit cell formula of the kaolinite in the clay fraction as given by Kiely (1955).

Mica, feldspar and quartz in the clay fraction is determined by the method proposed Kiely and Jackson (1965). The clay is first fused with $Na_2S_2O_7$. The melt is cooled, extracted with HCl, subsequently dissolved in hot 0.5 N NaOH. The residue as well as the clay sample without these treatment are analysed for K_2O and Na_2O by the HF-$HClO_4$ method (Jackson, 1958). The K_2O and Na_2O values can then be used to calculate mica, feldspar and quartz contents.

The characteristics of iron oxides in the clay fraction can be done using the clay fraction obtained after ultrasonic dispersion (Edwards and Bremner, 1967). To remove kaolinite, Kampf and Schwertmann (1982) tested this method and found very useful in identification and characterization of goethite and haematite.

MATERIALS AND METHODS

MATERIALS AND METHODS

In order to study the qualitative and quantitative distribution of the clay mineral present in the established major soil series, namely Trivandrum, Nedumangad and Palode series of the Trivandrum district, soil profile were described in the type locations.

One profile per each location was dug and described as per the prescribed procedures upto a depth of about 1.5 metres.

The profile features and in-situ observations were recorded as per the FAO guide lines (1978). After demarcating each horizon, undisturbed samples were taken using core samplers. Bulk samples were also collected from different horizons. The colour of the soil was recorded using Munsell Soil Colour Chart (1963).

Laboratory Studies

All the bulk samples were air dried in shade and big clods were broken with wooden mallot. The samples were then sieved through a 2 mm sieve. The gravel content and soil material was thus separated and quantified.

Physical Properties

1. Moisture percentage

10 g of air dried samples were taken in a previously weighed china dish and oven dried at 105 ^{o}C for 24 hours, cooled and weighed. This process was repeated till constant weights were obtained and moisture percentage of the soil were calculated.

2. Soil colour

The soil colour was determined by using the Munsell Soil Colour Chart (1963), both at field moist conditions and in air dried samples.

3. Mechanical analysis

The mechanical composition of soil samples was determined by the International pipette method after oxidation of organic matter with hydrogen peroxide and removing the cementing agent by treating with hydrochloric acid. Sodium hydroxide was used for dispersion of the sample (Piper, 1967).

4. Bulk density

The bulk density was determined as described by Dakshinamurthy and Gupta (1968) using core samples.

Chemical Properties

1. Soil Reaction

The soil pH was determined using 1:1 soil water suspension with 'systronic' digital pH meter.

2. Electrical coductivity

Electrical conductivity of the samples in 1:5 ratio of soil water extract were determined using 'systronic' digital direct reading soil conductivity bridge and expressed in ds/m^2.

3. Organic carbon

Organic carbon of the soil samples were determined by Walkley and Black's method (Jackson, 1973).

4. Total chemical analysis of soil

HCl extract of the soil in constant boiling HCl was prepared and total iron, and aluminium were determined.

5. Cation exchange capacity of the sample

The cation exchange capacity was determined using neutral N ammonium acetate as described by Jackson (1973).

Mineralogical Analysis of Fine Sand Fractions

The fine sand fractions separated by mechanical analysis were treated for the removal of organic matter and iron and separated following the procedure of Carver (1971). Fine sand slides were prepared and examined under the petrological microscope based on the procedures of Brewer (1964, 1976).

Separation and Analysis of Clay Fraction

The clay fraction was separated by the method of Puri (1950). Total SiO_2, Al_2O_3, Fe_2O_3, TiO_2, K_2O and sesquioxides were estimated in the sodium carbonate fusion extract adopting the procedures (Jackson, 1973). The cation exchange capacity of the clay was determined by method of Jackson (1972). The samples were first saturated with calcium using N $CaCl_2$. The calcium adsorbed in an aliquot were determined by the Atomic absorption spectrophotometer.

Mineralogical Analysis of Clay Fraction

1. X-ray Diffraction Analysis

For complete X-ray diffraction analysis of clay, two different cation saturation were required, Mg and K clay with Mg-clay with glycols in addition. K saturated samples were further X-rayed after heat treatment. An aliquot of clay suspension (about 50 mg) was boiled in 50 ml Na acetate buffer (pH 5.0) for five minutes. The suspension was centrifuged clear. 40 ml of N Mg acetate of pH 7.0 was added to the residue mixed and centrifuged. This treatment was repeated twice and the residue was washed twice with N $MgCl_2$ with pH 7.0. The excess salt was washed off with 99% ethanol.

Another aliquot of clay suspension (50 mg) was similarly treated with N Na-acetate buffer (pH 5.) and washed three times with N KCl, twice with N K-acetate (pH 7.0) and once more with N KCl. Excess salt was washed off with 99% ethanol. The clay was suspended in water and poured on a slide, air dried and X-rayed.

Glycol solvation

The purpose of glycol solvation is to differenciating the smectite group of minerals from other 2:1 layer silicates. Smectite group of minerals expand to 18 A^o in glycol and thus can be differentiated from the other $14A^o$ spacing minerals. The amount of glycol needed for solvation is mixed with ethanol to get 10% by volume of glycol. The ethanol solution thus prepared was added to the clay using pipette, this suspension is poured to a slide and air dried. The requirement of glycol will vary with size and nature of the mineral content. By trial and error method used only sufficient quantities of glycol. If more glycol is used, the treated samples will give wet appearance of the dried specimen and if less glycol is used, the specimen give dry appearance instead of moist.

Heat treatments

The samples after K-saturation and dried on slides are then placed on smooth asbestos sheet and placed in an electric furnace near the Pyrometer and largely out of the contact with bottom portion of the furnace. The heating to the stated temperatures - 300 ^{o} C and 550^{o}C is continued for two hours. The specimen is then cooled in a desicator and X-rayed. The X-ray diffraction for all treatments were carried out in a Philips-PW 1011 X-ray diffractrometer using Cu K a radiation.

The diagnostic spacings after different treatments used for various minerals were

1) Kaolinite - 7 A^{o} in all the treatments except K-550^{o}C
2) Mica - 10 A^{o}, in all the treatments
3) Chlorite - 14 A^{o} in all the treatments
4) Quartz - 4.3 A^{o} in all the treatments
5) Feldspar - 3.2 A^{o} in all the treatments

6) Smectite – 14-16 A^{o} with Mg saturation

17 A^{o} with Mg glycol solvation

14 A^{o} in K-550 ^{o}C

7) Vermiculite – 12-14 A^{o} on Mg saturation

14 A^{o} with Mg glycol solvation

10 A^{o} in K-300 ^{o} and K 550 ^{o}C

Thermo Gravimetric Analysis (TGA)

The clay sample for TGA was prepared by the method of Meckenzie (1955). The Mg solvated clay was used for analysis.
The TGA was carried out using a Standton Thermo balance model TR 01. The weight of the clay required was 50 mg. The heating rate was 5 ^{o}C in an atmosphere of static air.

Quantitative Determination of Clay Minerals

Silicate minerals in the clay fraction were quantitatively determined based on physico chemical properties. The clay fraction were first freed of amorphous materials as given by Rangasamy et al (1975). A known quantity of clay suspension was boiled for exactly 2.5 minutes in 0.5 M NaOH maintaining a clay-solution ratio of 1:1000. The residue was washed free of NaOH and stored in M Nacl solution making up to known volume. The concentration of clay of suspension was determined after ammonium carbonate washings.

Determination of kaolinite by selective dissolution (Alexiads and Jackson, 1966)

A known quantity of clay suspension was NH_4^+ saturated and oven dried at 110^{0}C for 16 hours. Exactly 0.2 g of NH_4-clay was taken in a silica crucible and heated at 550^{0}C for 4 hours. The heated clay after cooling was boiled for exactly at 2.5 minutes in 0.5 N NaOH in a stainless steel beaker, maintaining a clay solution ratio of 1:500, immediately cooled and centrifuged. The supernatent and distilled water washing were acidified weighed to a known volume and preserved in polythene bottle for analysis. The extract was analysed for Si and Al by the molybdo silicate yellow colour method (Jackson, 1958) aluminon method (Krishnamurthy et al, 1974) respectively. The clay residue was treated with citrate-bicarbonate-dithionate (Mehra and Jackson, 1960). To the extract, the Fe is released by NaOH treatment and was analysed by orthophenanthroline (Krishnamurthy, 1970) and content of kaolinite was estimated using the formula,

% of kaolinite = (% of SiO_2 + Al_2O_3 after dehydration − % of SiO_2 + Al_2O_3 before dehydration) x 1.14

The factor 1.14 word is taken in account of structural water content.

Determination of smectite group and vermiculite minerals (Alexiads and Jackson, 1965)

A known aliquot of clay suspension containing 0.2 g of clays was washed five times with 0.5 N $CaCl_2$, followed by once with distilled water and five times with 99% methanol acetone mixture

(1:1). The Ca was then replaced by Mg by washings five times with 0.5 N $MgCl_2$ and once with distilled water. The extract was made up to a known volume with distilled water and Ca was determined by flame emission. The determined Ca was expressed as milliequivalent, per 100 g of oven dry samples and was designated as CEC (Ca/Mg).

K-saturation of the same sample was done by washing five times with 0.5 N KCN solution, once with distilled water and five times with methanol-acetone mixture (1:1). The K-saturated sample was dried overnight in a hot air oven at 110°C. The unfixed K was replaced by ammonium by washing five times with 0.5 N NH_4Cl. The extract was made up to a known volume with NH_4Cl and K was measured by flame emission at 7740°A. The K was expressed as milliequivalents/100 g oven dry sample and was designated as CEC (K/NH_4).

Vermiculite and smectite in the samples were calculated by using the following formulae.

$$\text{Vermiculite (\%)} = \frac{\text{CEC (Ca/Mg)} - \text{CEC } (K/NH_4) \times 100}{154}$$

$$\text{Montmorillonite (\%)} = \frac{\text{CEC } (K/NH_4) - 5 \times 100}{105}$$

Where 5 meq/100 g is assigned to the edge CEC of clay. Quartz, Feldspar and Mica determination by Sodium Pyro Sulphate fusion (Kiely and Jackson, 1968)

An aliquot of clay suspension containing 0.2 g of clay was NH_4^+ saturated and oven dried. The clay was mixed with 12 to 15 g of

$Na_2S_2O_7$ powder in a silica crucible. The mixture was fused under a fume hood till a $Na_2S_2O_7$ crust started to form on the surface of the melt. The melt after cooling was slaked by gentle boiling in 60 ml 3 N HCl. The resulting suspension was centrifuged and the residue washed twice with 3 N HCl.

The residue was transferred to a stainless steel beaker with 0.5 N NaOH and more 0.5 N NaOH added to bring the volume to 150 ml. The suspension was boiled for exactly 2.5 minutes, cooled and centrifuged, washed three times with 3 N HCl. The residue was oven dried at 110° C and weighed.

The original clay sample (AFAS-free) and the residue from the above treatment were both analysed for K_2O and Na_2O by the HF-$HClO_4$ method (Jackson, 1958). The calculation of mica, feldspar and quartz contents as given by Kiely and Jackson (1965) is as follows.

1. Percentage feldspar K_2O = $\frac{\text{per cent } K_2O \text{ in residue} \times \text{percent residue}}{100}$ x 1.73 (conversion factor for residue K_2O to feldspar K_2O)

2. Mica K_2O = Total initial K_2O - Feldspar K_2O

3. Per cent mica = per cent mica K_2O x 10

4. Per cent K feldspar = Per cent K_2O in residue x (per cent residue)/100 x 13.2 (conversion factor for residue K_2O to microline in clay size)

5. Per cent Na feldspar = Per cent Na_2O in residue x (per cent residue)/100 x 13.7 (conversion factor for residue Na_2 to albite in clay size) - per cent K feldspar

6. Per cent quartz, by difference

Scanning Electron Microscope Analysis of clay fraction

Selected clay sample suspension in glycerine poured on slides, air dried and examined. The dried clay were fitted in the circular recepticle of the GFC fine coat-ion sputter and under vacuum and 8MA and 8KV. Gold was coated (Bluish white Fluorescense) for four minutes. Removed and placed in SEM and scanned, observations were recorded. SEM photograph were taken and interpreted (Bisdom, 1980).

Surface Area of Clay Fraction

Total, external and internal specific surface area of clay samples were determined by ethylene-glycol retention method (Hendricks and Dyal, 1956).

Soil Classification

Interpretation of analytical data in the clay and soil fraction were done and finally fitted in the USDA Soil Taxonomy systems appropriately upto soil family levels with specific references to clay mineral composition (USDA, 1974, 1987).

RESULTS

RESULT

A study was undertaken to gather information on the detailed qualitative and quantitative clay mineralogy of the established major soil series namely, Trivandrum, Nedumangad and Palode series of Trivandrum District. One representative profile from each series were dug and described, samples collected and analysed for physcio chemical and mineralogical properties.

Physiography

All the three profiles studied were located in a slopy topography. The profiles from Trivandrum series were located towards the toe slope while that from Nedumangad and Palode are in the mid slope of hillocks. The slope of the profile sites varies from 5-15 per cent. With respect of the topography of the sites, there was similarities through profiles were situated in the mid land and mid upland situations.

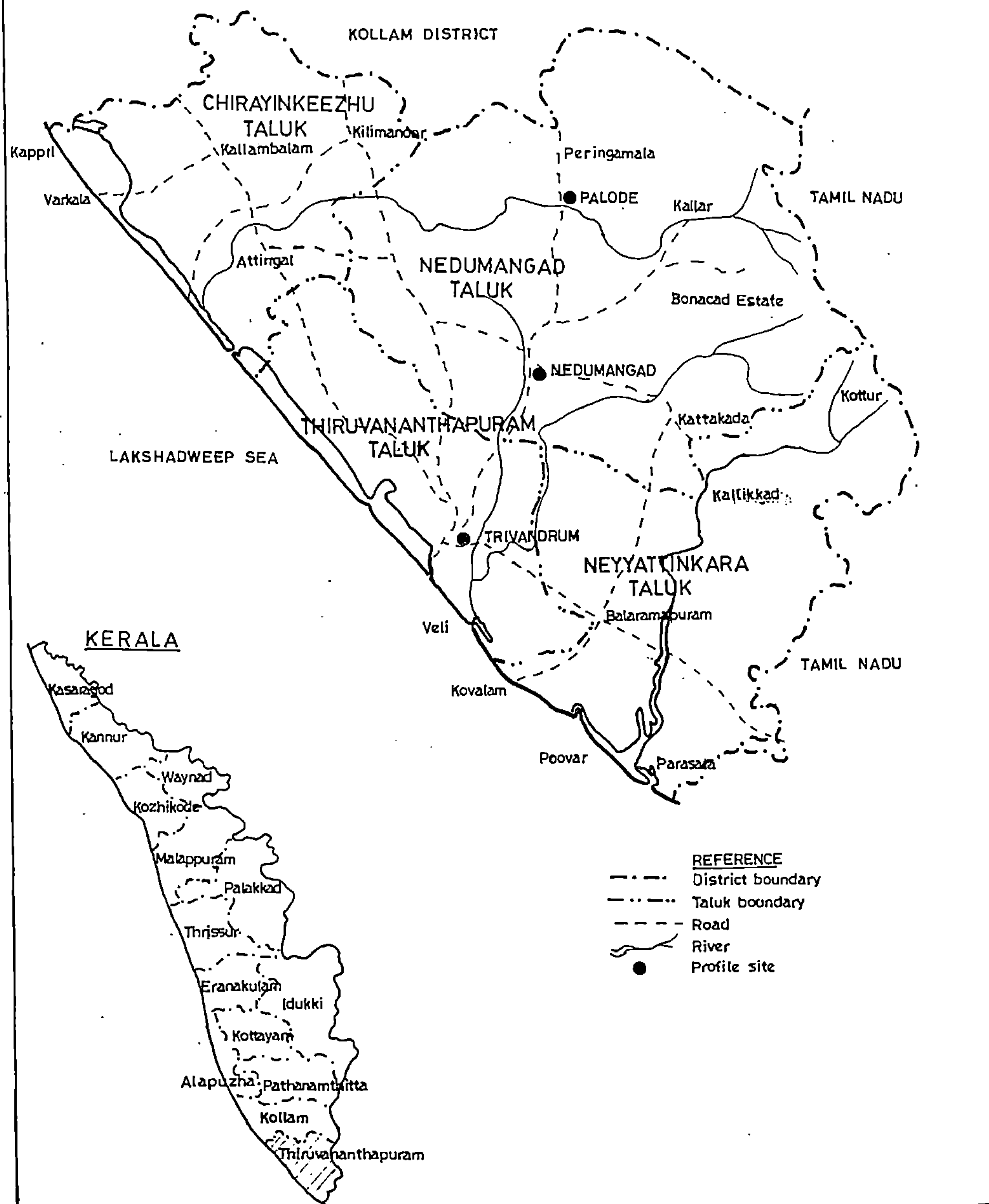
Climate

All the three sites received more than 2000 mm of rainfall. A dry spell was noticed in all the three locations during the months of January and Ferbruary when the number of rainy day was less. The mean maximum, mean minimum and mean annual temperature of the sites were more than 22 °C.

Laterite number (Kerner - Marilun) whose value above 50 indicates that climatic limits are favourable for laterite formation. The laterite number (L) is calculated by faling into consideration

MAP OF THIRUVANANTHAPURAM DISTRICT SHOWING PROFILE SAMPLE SITE

SCALE - 1 : 400000



the values of annual rainfall in millimeter (R), semi annual rainfall in millimeter of wet season (S) and of dry season (D) and mean minimum temperature in degree celsius (tm). Thus $L = R^{1/4} (S-D)\ tm\ 100^{-1}$. From the derived data, it is observed that the 'L' values of 35.5, 32.8 and 22.9 were recorded respectively in the Trivandrum, Nedumangad and Palode series and are below 50.

Macromorphology

The macro morphological profile properties namely colour, texture, structure, consistancy, horizon boundary, presence of roots, permeability, mottling, drainage, depth of ground water, erosion were compared.

Colour

The profiles of Trivandrum and Nedumangad series recorded similar observations. The profile at Palode has a black surface soils and greyish to dark brown sub sruface horizon (Plate No. 2,3,6,7,10 and 11).

Gravel content

The gravel content of Trivandrum series ranges between 67.0 and 71.3 per cent. At Nedumangad it ranges between 58.5 and 70.3 per cent. at Palode, the gravel content ranges between 46.5 and 75.0 per cent. Concerationary Gravels are comparatively more present in Nedumangad series. At Palode and Trivandrum series, non concretionary gravels are more throughout the profile. On comparison, the grain size increases with depth.

Texture

In all the profiles the surface and profile throughout are gravelly clay loam in texture. The gravel present at palode are grey to black coloured and non concretionary in nature. The gravels of Trivandrum and Nedumangad serial are non concretionary and mixure of concretionary and non concretionary in nature. They are dark brown to reddish brown coloured.

Structure

The depth wise variation in soil studied at Palode series was from weak medium fine crumb to coarse subangular blocky. At Nedumangad, it is from weak medium subangular blocky to coarse angular blocky, while at Trivandrum the dominant structure is coarse angular blocky in nature throughout the profile, through it is weak and medium in the surface.

Consistancy

All the profiles behaved in a little manner with respect to the consistancy. The surface soils remained friable non sticky and non plastic while the sub surface soils were firm, sticky and plastic with increase in depth.

Boundaries

The soil boundaries were gradual smooth at top and gradual wavy at bottom in all the three sites.

Present roots

The activity of coarse and medium roots is more abundant in the surface and sub surface soils at Palode and Nedumangad while it is maximum only at surface horizons at Trivandrum with few medium roots in the subsurface horizons.

Permeability

In all the profites permeability was rapid or moderatively rapid in the upper horizons and slowly permeable in the lower horizons. There was marked difference in the permeability of the soil layers and the hard laterite layers.

Mottling

Mottling coare rarely observed in the surface horizons in all the sites. While it is yellow (10 YR 8/8), brown (5 YR 4/8), reddish brown (2.5 YR 4/4), Violet (10 YR 4/4) and red (10 YR 8/6) the lowest horizon at Trivandrum and subsurface horizon at Nedumangad profile. At Palode pale brown (10 YR 6/6), weak red (2.5 YR 4/2), Yellow (7.5 YR 6/8) and grey (2.5 YR 3/4). Mottlings are seen in sub surface horizons. At Trivandrum up to a depth of 150 cms, mottlings observed were very few to nil.

Land use

At Trivandrum and Nedumangad, the soils under cultivation with coconut, jack, mango, banana and tapico while that of Palode is under decidous forest.

Drainage

All the profile sites were studied in well drained locations with more stagnant water even after heavy rains. That is there is similarily in the drainage profile pattern in the three sites.

Depth of ground water

Depth of ground water varied from 9 to 15 meters.

Evidence of Erosion

Irrespective of the sites, the surface soils are in the advanced stages of rill erosion. The erosion is maximum at Nedumangad sites leading to gully erosion.

Laterite horizon

It is soft and friable at Palode and hard at Nedumangad. It become firm and still harder at Trivandrum. The colour mottling observed in the laterite layer is unique in each series (Plate 3,6,9). At Trivandrum the laterite layer is below 60 cm and has a width of 110 cm. At Nedumangad, the laterite layer is from 30 cm and has a width of 120 cm. At Palode there is no conspicous hard layer. It is in the initial stages of formation and consolidation (Plate No. 9).

Epipedon

The diagnostic epipedon observed at Trivandrum and Nedumangad series are ochric in nature. While a mollic epipedam is observed in Palode series.

Diagnostic subsurface horizon

At both Trivandrum and Palode, a typical kandic horizon is observed. While at Palode series, the argillic horizon is in the initial stage of formation.

In the Trivandrum and Nedumangad series about two times clay increase is observed in the B_2t horizons. While at Palode series it is less in on 1.5 times.

Physiolography, Geology and Soil climate

The Trivandrum and Nedumangad series are situated in the gently slopy to steep slopy of the mid land region of the state.

The Trivandrum series developed from gneissic rocks while the Nedumangad is designed from Khondolite rocks. The Palode series is situated in the mid up land situations on low hills developed from Khondolites.

The annual mean rainfall is less during summer months. In these sites during the months of January and Febuary. During this period, part of the moisture control section of the Trivandrum series and consecutive days while at Palode series it will be comparatively less than sixty days.

The mean annual air temperature of the three sites is 27.2^{o} C and the decrease between the mean summer and winter temperature is 1.8^{o} C.

PROFILE DESCRIPTIONS

<u>Information of the sites</u>	:	Laterite profile, Trivandrum series
a. Profile No.	:	I
b. Soil Name	:	Laterote soil, Trivandrum series
c. Higher category	:	Inceptisol – Ultisol
d. Date of examination	:	4-6-1990
e. Author	:	Asharaf M.
f. Location	:	Half a kilometre from Vellayambalam junction towards right of Vellayambalam Sasthamangalam road Trivandrum, Trivandrum District.
g. Elevation	:	10 m MSL
h. <u>Land form</u>		
1. Physiographic position Building cut	:	Building cut
2. Surrounding land form	:	Slopy
3. Microtopography	:	Slopy
4. Slope on which profits is situated	:	toe slop of a hillock, slopy
(i) <u>Climate</u>	:	Humid tropical climate. Mean annual rainfall is 2001.6 mm which is distributed throuthout the year with a dry spell of about two months during, January and February.

II. <u>General Information of the soil</u>

a. <u>Parent material</u>	:	Laterite derived from the granite
b. <u>Drainage</u>	:	Moderately well drained with moderately slope internal permeability.

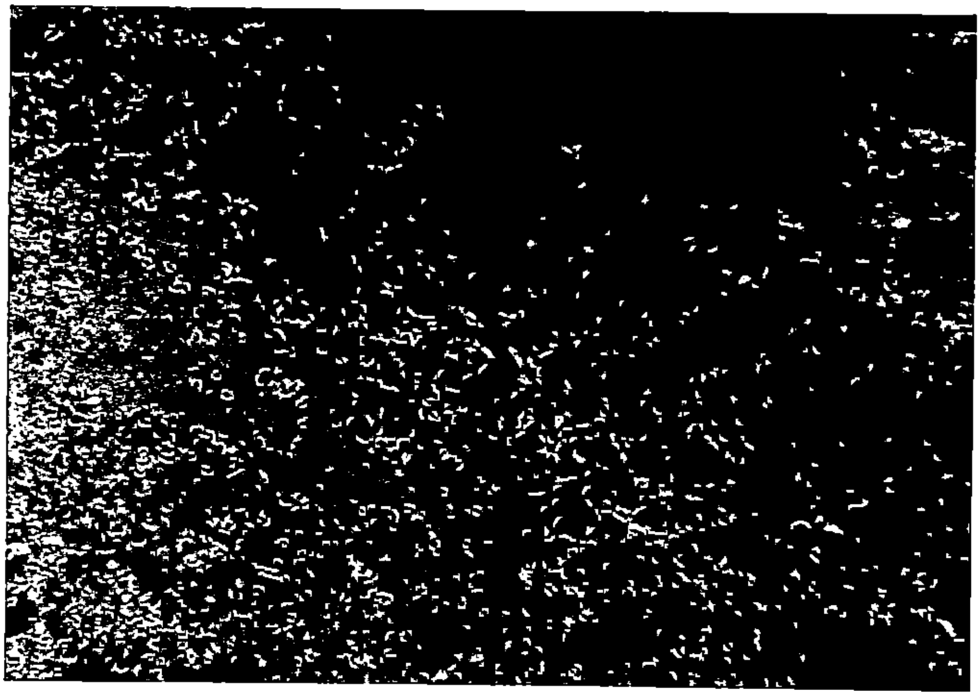


Plate 1. Profile site of Trivandrum series

c. Moisture condition in the profile : Moist throughout

d. Depth of ground water table : 10 meters

e. Presence of surface stone : Nil

f. Evidence of erosion : Severe rilly eroded

g. Presence of salt or alkali : Nil

h. Human influence : Cultivated - Building cut.

III. Brief description of the profile

Soil survey (1969) reports that Trivandrum series consists of Laterites formed as a result of humid tropical climate with fairly heavy rainfall and uniform temperature and tropical type of vegetation. Generally iron and laterite gravels are found on the surface of these soils. They become strikingly visible on eroded areas. The presence of red and yellow mottlings, so characteristic of laterite soil is another distinguishing feature. The depth of quarrible type of laterite varies considerably. Generally with depth the kaolintic clay content increases. A layer of kaolinitic clay content increases. A layer of koalinitic clay can be seen in very deep profiles. The horizon is hard and compact. Related soils are the vizhinjam and Pangapara series. In Vizhinjam series just below the A1 horizon a strong A3 horizon can be observed while in Trivandrum series there is no A_3 horizon, in stead a yellow brown B1 horizon can be observed. In general Trivandrum soils are more reddish in colour.

Brief description of the profile (present)

Dark reddish brown to yellowish red gravelly clay loam to gravelly clay. Surface soils are characterised by the presence of nodular non-conaretionary iron rich gravels. Telture of the B1 horizon and B2 horizon varies from gravelly clay loam to gravelly clay. The soil is having a AB profile and are deep with well developed B horizon. The plinthile is within one meter and characterised by a compact vesicular structrue and are non quarriable in nature.

IV. Profile desoriotion

Horizon	Depth (cm)	Description
Ap	0-14	Dark reddish brown (5 YR 3/4) moist, Reddish brown (5 YR)dry; gravelly clay loam, coarse granular; slightly sticky slightly plastic; dry loose friable; very few very coarse and medium coarse; Gravells smooth boundary moderately; were drained. Nodular iron rich coarse gravels present.
A2	14-26	Dark reddish brown (5 YR 3/4) moist yellowish red (5 YR 4/8) dry; gravelly clay loam dry friable, moist weak subangular blocky structure slightly sticky slightly plastic medium to fine many roots; moderately well drained granular smooth boundary; coarse to fine non correctiony and concretionary gravel present.
B1	26-66	Yellowish red (5 YR 4/6) moist and dry; gravelly clay loam; subangular blocky structure dry firm, moist slightly sticky slightly plastic; fine to very fine roots, moderately well drained; gradual smooth boundry non yellowish red concretionary gravel present.

Plate 2. Trivandrum soil series profile

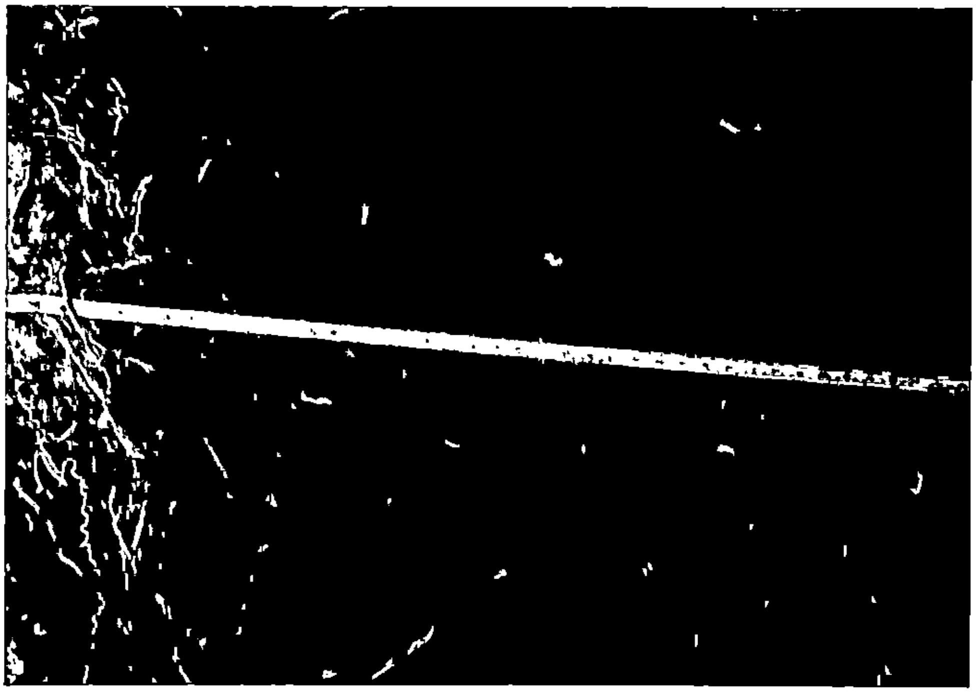


Plate 3. Plinthite layer of Trivandrum series

g. Elevation : 15 meters M.S.L.

B2t	66-175	Red (2.5 YR 416) moist and dry; gravely clay; sub angular blocky structure, slightly massive; dry firm moist sticky and plastic; very coarse to very fine roots, common; moderately slowly permeable gradual wavy boundary vesicular character is observed. Gravels are non concretionary and slightly hard.
B2T	175-200+	Red (2.5 YR 4/6) moist and dry; gravelly clay; hard massive and block structre dry firm moist sticky and plastic; roots nil moderately, slowly permable medium few distinct mottlings present-yellowish red (5 YR 4/6) reddish brown (5 YR 4/4/).

Information to sites	:	Laterite soil - Nedumangad series
a. Profils No.	:	II
b. Soil name	:	Laterite soil-Nedumangad series
c. Higher category	:	Ultisol - Inceptisol
d. Date of examination	:	11-6-1990
e. Author	:	Asharaf M.
f. Location	:	Puravankonam,Karakulam, Nedumangad - Trivandrum, Trivandrum District 20 meters from Trivandrum - Nedumangad road - Building cut.
g. Elevation	:	15 meters M.S.L.
h. Land form		
1. Physiographic position	:	Side slope of a hillock
2. Surrounding land form	:	Gently slopy to slopy
3. Microtopography	:	Gently sloping
4. Slope on which profile is located.	:	Mid slope of a hillock, sloping

i. <u>Climate</u> : Humid tropical climate; mean annual rainfall is 2061.7 mm which is distributed throughout the year with dry spell of about two months during January and Feburay. The mean temperature ranges from 22.3 to 32.5^{0} C.

II. <u>General introduction of the soil</u>

a. <u>Parent material</u> : Derived from biotite gneisses and charnoekites.The riverine alluvium is seen associated in the banks of rivers and low lying areas.

b. <u>Drainage</u> : Moderately well drained with moderately slow internal permeability.

c. <u>Moisture condition in the profile</u> : Moisture throughout

d. <u>Depth of ground water table</u> : 10 meters

e. Presence of surface stones : Nil

f. Evidence of erosion : Moderate to severly erroded with medium to rapid run off.

g. Permeable of salt or alkali Nil

h. Human influence : Cultivated, Building cut

III. <u>Brief description of the profile</u>

Soil survey (1970) reports that the Nedumangad series is represented by soils associated with laterite, developed from gneissic parent material and are located in areas having undulating to rolling type of topography. They are dark brown to dark greyish brown on surface and comes under the textural gade of gravelly clay loam to gravelly clay, gravelly clay loam being the predominant texture. The surface soil is mixed with varying amounts of organic matter. The soils are deep to very deep. The subsoil texture varies from gravelly loam to gravelly clay. Accumulation of grey coloured kaolinitic clay is observed in veins or pockets resulting from leaching or weathering and complete transformation of feldspar. Laterite stones of irregular size and shape having red colour which runs to pink on exposure are met with from the second layer downwards. The hardness of these stones is related to the hydration and dehydration process. Quarriable type of laterite is not generally met with. The gneissic parent rock is usually located below 5 meters. These soils are developed under conditions of warm humid tropical climate with fairly high rainfall. Geographically associated soils are the Palode series.

Soil description (present)

Soil is deep and yellowish red coloured with gravelly clay loam to gravelly clay texture. Surface soil is characterized by fine to medium in an concretionary gravel. Plinthite is with in a depth of one meter with characteristic vesicular structure. The veins of the plithite contain accumulation of kaolnitic clay and is grey to greyish blue coloured. The plinthite is not quarriable. The soil is with biotite mica throughout the profile indicating the biotite gneissic parent material. The sub surface horizon are with fine faint to medium distinct mottlings of light reddish brown (5 YR 6/4) reddish yellow (5 YR 6/6), yellow (10 YR 7/8) violet (10 YR 4/4) and white (10 YR 8/1).

Plate 4. Profile site of Nedumangad series

Plate 5. Nedumangad soil series profile

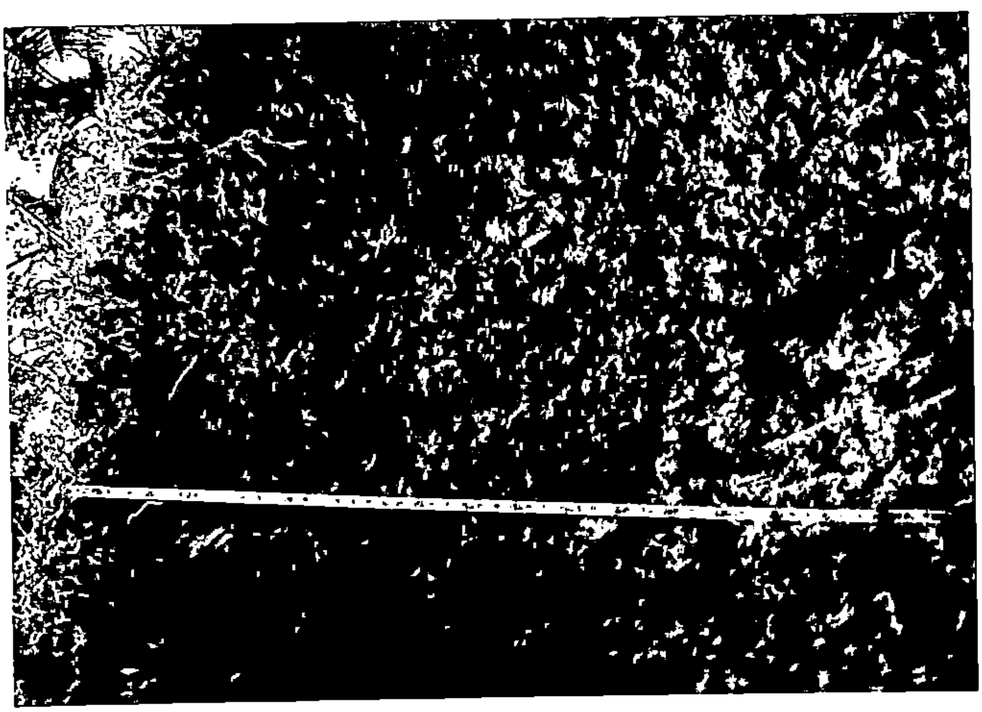


Plate 6. Plinthite layer of Nedumangad series

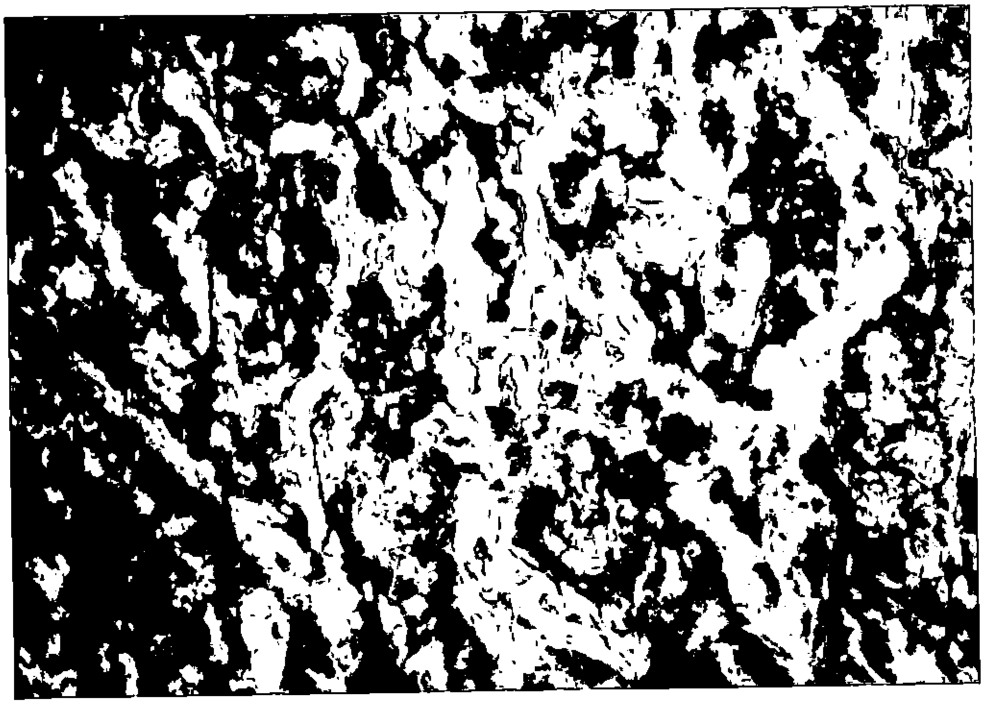


Plate 7. Profile site of Palode series

Plate 8. Palode soil series profile

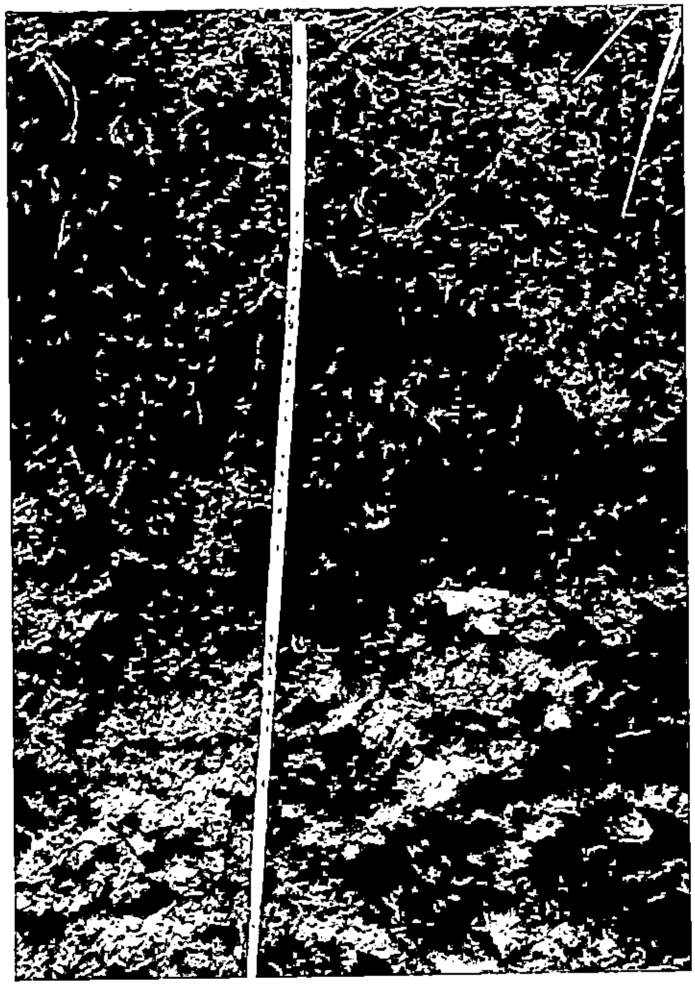
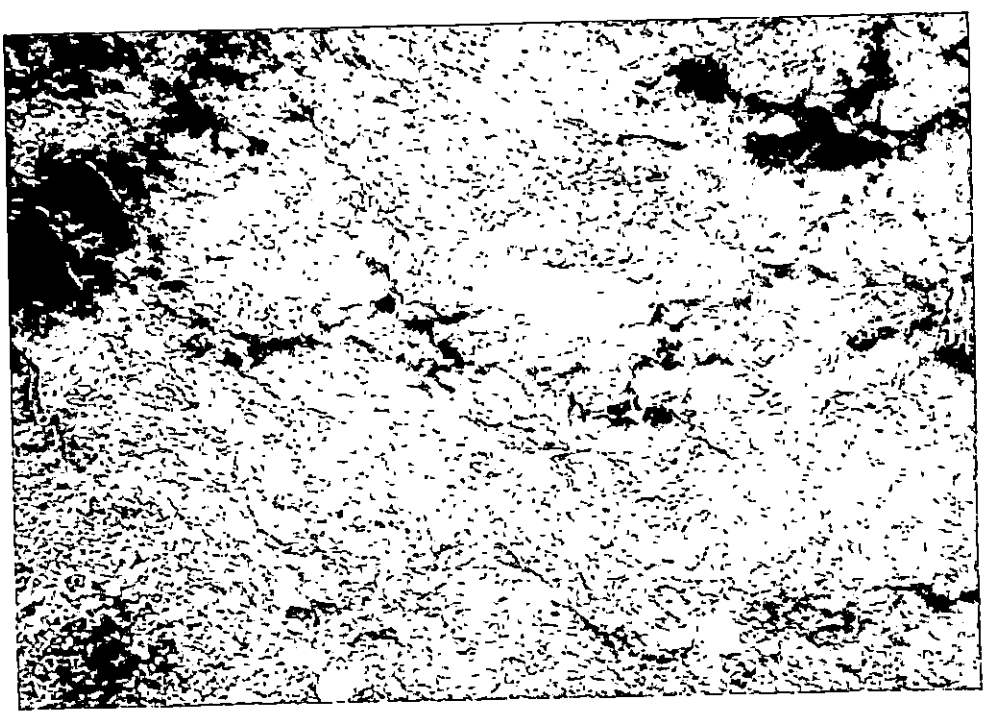


Plate 9. B_2 layer of Palode series profile showing weathered gneissic boulders.



IV. Profile Description

Horizon	Depth (cm)	Description
Ap	0-14	Yellowish red (5 TR 4/6) moist Yellowish red (5 YR 6/5) dry; gravelly sandy clay loam texture. coarse crumby to weak subangular blocky sturcture, dry friable, moist slightly sticky and slightly plastic; many coarse and medium roots; Moderatly permeable; distinct brokened boundary in an concretionary medium to fine gravels.
A_3	14-30	Yellowish red (5 YR 4/8) moist, reddish yellow (5 YR 6/6) dry; gravelly clay loam, subangular blocky ; dry slightly hard moist slightly sticky and slightly plastic; many coarse and medium roots, moderately, slowly permeable, gradual wavy boundary non-concretionary, fine and coarse gravels many present. Few faint mottlings of light reddish brown (5 YR 6/4), reddish yellow (5 YR 6/6), Yellow (10 YR 7/8), Violet (10 YR 4/4) and White (10 YR 8/1) present. Distinct many clay films and clay skins.
B_1	30-96	Yellowish red (5 YR 5/8) moist, light redish brown (5 YR 6/4) dry; gravelly clay loam; subangular blocky ; dry firm moist sticky and plastic few coars roots; permeability moderately slow, diffused wavy boundary. Many coarse distinct violet (10 YR 4/4), Yellow (10 YR 8/6), are the mottlings present. Gravels are concretionary. Plithite with few distinct veins filled with kaolinite present.
B_2t	96- 150+	Yellowish red (5YR 4/8) moist and dry; gravelly clay; sub angular blocky; roots absent. A dry firm and massive but not quarriable, moist sticky and plastic. Plinithite layer with district vesicular character, veins filled with keolinite. Many coarse distinct mottlings of violet (10YR 4/4) and yellow (10YR 8/6) present.

Information of the site : Forest soil –'Hill soil' – Palode series

a) Profile No : III

b) Soil Name : Forest soil – Hill soil – Palode series

c) Higher category : Mollisol – Inceptisol

d) Date of examination : 26-6-1990

e) Author : Asharaf M.

f) Location : Jawaharlal Nehru Tropical botanical Garden campus, Palode within one kilometer from the office of the Director retained – forest land.

g) Elevation : 25m. M.S.L.

h) Land form

1) Physiographic position : very steep slope- undulating terrain

2) Surrounding land form : Terraced

3) Microtopography : steep slope

4) Slope on which profile is located : Towards the mid slope of a hill with steep slope

I. Climate

Humid tropical climate ; mean annual rainfall is 2061.7 mm which is distributed throughout the year with a dry spell of about two months during January and February. The mean temperature ranges from 22.3 to 32.5 °C.

II. General information of the soil

a) Parent material	:	Derived from biotite gneissic rock
b) Drainage	:	moderatly well drained with moderatly slow internal permeability
c) Moisture conditions in the profile	:	moist throughout
d) Depth of ground water table	:	20-25 meters
e) Profile of surface stones	:	weathered gneissic boulders of 8-10 cm. Few present
f) Evidence of erosion	:	Moderate to severly erroded. gully erroded
g) Presence of salt or alkali	:	Nil
h) Human influence	:	Undisturbed retained forest land

III. Brief description of the profile

Soil survey (1970) reports that Palode series represents the finely weathered greyish brown to black hill soils that are found occuring on the eastern parts of Nedumangad taluk. The depth of these soils vary considerably from shallow to deep with gravelly loam to clay textured surface soils having greyish brown to black colour. The sub soil texture also varies from gravelly loam to clay which gradually merges with an admixture of soil and weathered gneissic material. The clay content increases with depth. Laterite gravels are seen impregnated in the 'B' horizon just below the surface horizon. In eroded areas the laterite can be seen exposed. The hardness and type of laterite varies with relief. Quarriable type of laterite is of limited occurance in this series. Only mid land region of the taluk quarriable type of laterite is located. These soils are observed in areas having undulating type of topography. The weatherd feldspathic gneiss which forms the parent material is soft on top and become hard as depth increases and finally merges with the hard gneissic rock below. These soils are developed under to warm humid tropical climate with high rainfall. Associated soils are the Nedumangad series.

Soil description (present)

The soil is medium to shallow with black to very dark greyish brown colour. The soil profile is gravelly throughout with medium sized many non concretionary gravels. Black in colour in the surface and strong brown in the subsurface layers. The organic mineral horizon extends up to about 60 cms.

IV. Profile description.

Horizon	depth	description
A_1	0 - 13	Black (10YR 2/1) moist and dry, gravelly sandy loam; weak fine crumb structure; dry friable, moist non sticky and non plastic many medium and coarse roots. No directly well drained , many black medium non conectionary gravels, organisms and ferri organans are observed.
A_2	13 - 55	Black (10YR 2/1) moist, very darkbrown (10 YR 2/2) dry; gravelly clay loam, moderate medium subangular blocky structure; dry slightly hard moist slightly sticky

		and plastic. few fine roots, gradual wavy boundary, moderately well drained, many medium to fine distinct and faint dark brown (10YR 2/2), brownism yellow, p (104R 6/8), pale brown mottles; (104 R 6/6) weak red (2.5YR 4/2) many medium to large nonconcretionary gravels present.
B_1	55 - 138	Very dark greyish brown (10YR 3/2) moist, dark brown (10YR 3/3) dry; gravelly clay; subangular to angular blocky; dry firm moist sticky and plastic, gradual smooth boundary, moderately slow permeability; coarse angular non concretionary gravels many present. Weak red (2.5 YR 4/2) and red (2.5 YR 4/8) few faint mottles presents.
B_{12}	138 - 150+	Strong brown (7.5 YR 5/8) moist and dry; clayey massive ; dry sticky and plastic; slowly permeable medium laterite non concretionary stones and big boulders present. Few to many faint and distinct grey (2.54 R 3/4), yellow (7.54R 6/8), very pale brown (104 R 8/4), dark reddish brown (104 R 8/4) and white (2.54 R 4/8) mottles present.

Table 1. General Information of the Profile sites

Sl. No.	Soil Series	Physiography	Geology	Rainfall (mm) (Mean annual)	Mean annual air temp.	Area (hecters)	Mean air temperature	
							Summer	Winter
1.	Trivandrum	Mid land slopy	Gneissic	2001.6	26.8	23678.96	31.9	28.5
2.	Nedumangad	Mid upland slopy to steep slopy	Khondolite	2001.6	26.8	43279.84	31.9	28.5
3.	Palode	Mid upland slopy	Khondolite	2199.3	25.2	9328.75	30.5	27.6

Source : 1. Reconnaissance soil survey report of Trivandrum District, (1980-81) state soil survey organisation, State Department of Agriculture, Kerala.

2. Soils of Kerala, soil survey organization, Department of Agriculture (soil conservation unit) Kerala.

Soil physical properties

The mechanical composition of the soil profile are presented in table 1. and figure 2.0 to 5.0.

The gravel content of Trivandrum series ranges between 67 and 71.3 per cent. At Nedumangad, it ranges between 67 and 71.3 per cent. At Nedumangad, it ranges between 58.52 and 70.3 percent. At Palode, the gravel content ranges between 46.5 and 75 per cent. In all the sites the surface and profile are gravelly throughout. The size of the gravel increases with depth while the hardness decreases with depth in all the sites. Gravels of surface soils and the sub surface layers are non-concretionary in nature. In all the profiles the gravel content is more than 46 percent and to a maximum of about 75 per cent.

Coarse sand.

In Trivandrum series, it ranges between 29.2 in the lowest layers and 43.25 in the surfaces. It decreases with depth. In the Nedumangad series, it ranges between 20.4 in the lowest layers and 34.2 at the third layer. It increases with depth up to the third layer and abruptly decreases at fourth layer. In the Palode profiles it ranges between 46.2 to 51.20 per cent. It is maximum in the subsurface horizon and then decrease with downwards (Table). Maximum coarse sand is observed at Palode and comparatively least at Nedumangad and intermediates at Trivandrum series.

Fine sand

Among the series, the maximum fine sand were observed at Palode series followed by Trivandrum and Nedumangad. The horizon wise variation in the fine sand content is almost same at Trivandrum and Nedumangad when compared to Palode. The fine sand content ranges between 7.9 to 12.8 per cent, 6.27 to 12.45 and 10.33 to 15 at Trivandrum, Nedumangad and Palode series respectively. Fine sand content were maximum in the surface soils of Palode followed by Nedumangad and Trivandrum.

Silt

The maximum silt content was observed in Trivandrum series followed by Nedumangad and Palode. The profile variation is less at Trivandrum and Nedumangad and comparitively wide at Palode. The silt content ranges between 14.75 and 18.5, 13.0 and 21.61 and 10.94 and 15.15 at Trivandrum, Nedumangad and Palode series respectively.

Clay

The clay content of the Palode profile ranges between 19.0 and 23.41 per cent. While at Trivandrum, it ranges between 23.5 and 36.19 per cent and at Nedumangad it ranges between 18.41 and 36.60 per cent. The maximum clay content was noticed in the Trivandrum profile and the minimum of Palode. Nedumangad remains with medium clay status. Profile variation in clay content is narrower at Trivandrum and Nedumangad series and comparitively slightly wider at Palode series. More than one and half time

Sl. No.	Series Name	Horizon Symbol	Depth cm	Gravel %	Coarse sand %	Fine sand %	Silt %	Clay %	Textural ratios			Bulk density g/cc
									Fine sand/ Coarse sand	Silt/ Clay	Sand + Silt/ Clay	
1.	Trivandrum	Ap	0 - 14	67.00	43.25	12.20	16.50	23.50	0.28	0.70	3.06	1.11
		A_2	14 - 26	67.30	44.35	12.80	14.75	24.00	0.29	0.62	2.99	1.09
		B_1	26 - 66	71.00	36.60	7.90	15.60	29.00	0.22	0.15	2.072	1.15
		B_2t	66 - 175	70.44	29.20	9.10	18.50	32.00	0.32	0.58	1.775	1.10
		B_2T	175 - 200$^+$	71.30	16.15	9.50	14.83	36.19	0.59	0.41	1.118	1.03
2.	Nedumangad	Ap	0 - 14	58.50	29.25	12.45	16.30	18.41	0.43	0.89	3.154	1.15
		A_3	14 - 30	70.30	30.25	11.81	13.00	27.64	0.39	0.47	1.99	1.17
		B_1	30 - 96	68.85	34.16	9.74	21.61	31.60	0.295	0.68	2.073	1.09
		B_2t	96 - 150$^+$	64.50	20.14	6.27	14.83	36.60	0.311	0.41	1.13	1.06
3.	Palode	A_1	0 - 13	46.5	47.81	15.00	15.15	19.00	0.31	0.80	4.10	1.25
		A_2	13 - 55	55.7	51.20	13.41	11.69	21.00	0.27	0.567	3.66	1.22
		B_1	55 - 138	60.00	48.20	10.33	12.56	23.41	0.21	0.54	3.00	1.10
		B_{12}	138 - 150$^+$	76.00	46.20	12.87	10.94	22.50	0.29	0.41	5.56	1.07

clay increase was noticed in the Second and third profile of Trivandrum, Nedumangad and Palode series respectively.

Textural ratio

The textured ratio of various horizons of the three soil series are given in the table 1. and fig.5.

Fine sand/coarse sand

Fine sand/coarse sand ratio of Trivandrum series soil profiles ranges between 0.29 and 0.43. This ratio ranges between 0.21 and 0.31 at Palode soil series profile. Except first and second layer, it increases with depth in Trivandrum series. It decreases with depth at Nedumangad series upto third layer and then shows a gradual increase. The similar observation is also observed at Palode profile.

Silt/clay

It ranges between 0.41 to 0.70, 0/41 to 0.89 and 0.41 to 0.80 at Trivandrum, Nedumangad and Palode series respectively. It decreases with depth at Nedumangad and Palode series while up to third layer it exhibit a decrease with depth and then an alternate increase and decreases.

Clay ratio (sand + silt/clay)

It ranges between 1.11 and 3.06, 1.13 to 3.15 and from 3.04 to 5.56 at Trivandrum, Nedumangad, Palode series respectively. It decrease with depth in the Trivandrum soil series profile and in Palode, series profile except the last layer where a increase in trend is observed. At Nedumangad it exhibited an alternate decrease and increase with depth.

On comparison of the texturd ratios, leaching and lessivage were found to be more active at Nedumangad profile followed by Palode and Trivandrum.

Bulk density

The bulk density of the soil series are presented in table 2 and it ranges between 1.07 to 1.25 at Palode, 1.06 to 1.17 at Nedumangad and from 1.03 to 1.11 at Trivandrum series. It is seen that the bulk density is maximum at Palode series and least at Trivandrum series with Nedumangad series intermediate position. It increases with depth in all the profiles.

Chemical properties

The chemical properties of the three such series presented in table 3 and figure 6.0 to 8.0.

pH

The pH of a soil showed an acidic reaction. The values ranges from 4.85 to 5.44. In Trivandrum series it ranges between 4.85 and 5.10. At Nedumangad it is between 4.86 and 5.1 and at Palode it range below 5.09 and 5.44. Between profiles Trivandrum and Nedumangad series exhibit lesser variation. On comparison the Palode series exhibited a higher pH value, with little difference between the horizon except the surface layer.

Table 3. Chemical Properties of Soil

Sl. No.	Series	Horizon Symbol	Depth cm	pHw (1:1)	Ec ds/m (1:5)	Organic Carbon %	CEC Cmol/kg	Fe %	Al %
1.	Trivandrum	Ap	0 - 14	4.95	0.20	0.84	4.8	4.78	9.53
		A_2	14 - 26	4.85	0.20	0.69	5.8	4.50	10.50
		B_1	26 - 66	5.10	0.22	0.69	5.0	4.32	11.35
		B_2t	66 - 175	5.06	0.21	0.43	7.7	5.20	11.50
		B_22T	175 - 200^+	5.07	0.20	0.23	8.0	5.35	11.85
2.	Nedumangad	Ap	0 - 14	4.86	0.20	0.36	7.90	1.18	7.45
		A_3	14 - 30	4.99	0.21	0.66	7.25	3.95	9.50
		B_1	30 - 96	5.03	0.21	0.47	7.25	2.60	10.66
		B_2t	96 - 150^+	5.10	0.20	0.26	5.45	4.07	10.87
3.	Palode	A_1	0 - 13	5.09	0.19	0.41	15.2	0.64	5.05
		A_2	13 - 55	5.33	0.21	0.90	10.3	1.44	7.55
		B_1	55 - 138	5.44	0.22	0.45	11.5	1.15	8.14
		B_{12}	138 - 150^+	5.35	0.20	0.15	12.0	1.50	8.14

Electrical conductivity

There was not much difference in the electrical conductivity between and within the series. All are below 0.2 ds/m^2.

Organic carbon

The maximum organic carbon content was observed in Trivandrum soil series. But a still higher content of organic carbon was obtained in the second horizon of Palode series. Among them the least content of organic carbon exhibited by Nedumangad series. But Palode and Nedumangad within profile variation less while the same at Trivandrum is more. It ranges between 0.23 to 0.84 at Trivandrum series, while at Nedumangad it is between 0.26 and 0.66 per cent and 0.15 to 0.90 percent at Palode.

In general all the profiles had a decrease in depth variation in soil organic carbon content. The observation of difference noticed is lower organic carbon value for surface and higher at subsurface in Trivandrum and Nedumangad series as a different pattern from Palode series profiles.

Cation exchange capacity

The cation exchange capacity of the profile samples of Trivandrum, Nedumangad and Palode series are presented in table No 3 and figure 7.0. It ranges between 4.8 and 8.0 cmol kg^{-1}, 5.45 and 7.25 cmol Kg^{-1} and 9.5 and 15.2 cmol kg^{-1} at Trivandrum, Nedumangad and Palode series respectively. In all the series it decrease with depth. Comparatively in the Palode series exhibited maximum CEC in the surface and less in the sub surface horizons. But Trivandrum and Nedumangad series within the profile variation of CEC is less.

Total chemical composition

Distribution iron and aluminium in soils

Table No.3 presents the distribution of total iron and aluminium content of the soil series. The total iron percentage varied from 0.64 to 1.50 in the Palode series. At Nedumangad series, it ranges between 2.28 and 4.07. At Trivandrum it ranges between 4.78 to 5.35. In general total iron content increases with depth in all the three series. There is marked difference between and within profile distribution of total iron content. Total aluminium also exhibited a similar pattern. It ranged between 4.85 to 8.14 at Palode, 7.45 to 10.87 at Nedumangad and from 9.53 to 11.85 at Trivandrum series.

Mineralogy of fine sand fraction

Table 4 present the results of the mineralogical studies of fine sand fractions of soil series. The light mineral fraction consisted predominantly of quartz in all the three soil series. The percentage of quartz varies from 86.75 to 97.34 per cent in Trivandrum, 89.16 to 93.55 percent in Nedumangad and 91.58 to 94.38 per cent in Palode series. On comparison an increase in trend down the profile was noticed in three series which is maximum and conspicuous at Palode series followed by Nedumangad and Trivandrum series.

Table 4. Fine sand mineralogy of the profile

Sl. No.	Series	Depht cm	Black opaques ilemanite %	Leucoxene %	Heavy minerals			Sillimanite %	Kyanite %	Light minerals quartz %
					Red opaques Haematite %	Zircon %	Rutile %			
1.	Trivandrum	0 - 14	1.75	2.02	3.60	0.08	-	5.80	-	86.75
		14 - 26	0.65	0.30	0.60	0.05	0.01	1.05	-	97.34
		26 - 66	1.25	0.90	3.00	0.25	0.01	2.80	-	91.79
		66 - 175	0.95	0.70	2.07	0.24	-	2.36	-	93.68
		175 - 200+	0.70	1.10	5.90	0.22	-	1.20	-	91.88
2.	Nedumangad	0 - 14	2.05	0.90	3.35	0.04	-	4.50	-	89.16
		14 - 30	0.75	0.25	2.05	0.19	0.01	3.20	-	93.55
		30 - 96	1.10	0.19	4.50	0.08	-	2.85	-	91.28
		96 - 150+	0.83	0.10	5.55	0.08	-	1.15	-	92.29
3.	Palode	0 - 13	2.50	-	-	0.02	-	5.00	0.90	91.58
		30 - 55	1.80	-	1.2	0.02	-	3.58	1.30	93.40
		55 - 138	1.50	-	1.15	0.05	-	2.20	1.25	93.80
		138 - 150+	1.60	-	1.00	0.05	-	2.22	0.75	94.38

Plate 10-11 Fine sand mineralogy of Trivandrum soil series profile

Plate 12-13 Fine sand mineralogy of Trivandrum soil series profile

Plate 14 Fine sand mineralogy of Trivandrum soil series profile

Plate 15 Fine sand mineralogy of Nedumangad soil series profile

Plate 16-17 Fine sand minerqlogy of Nedumangad soil series profile

Plate 18 Fine sand minerqlogy of Nedumangad soil series profile

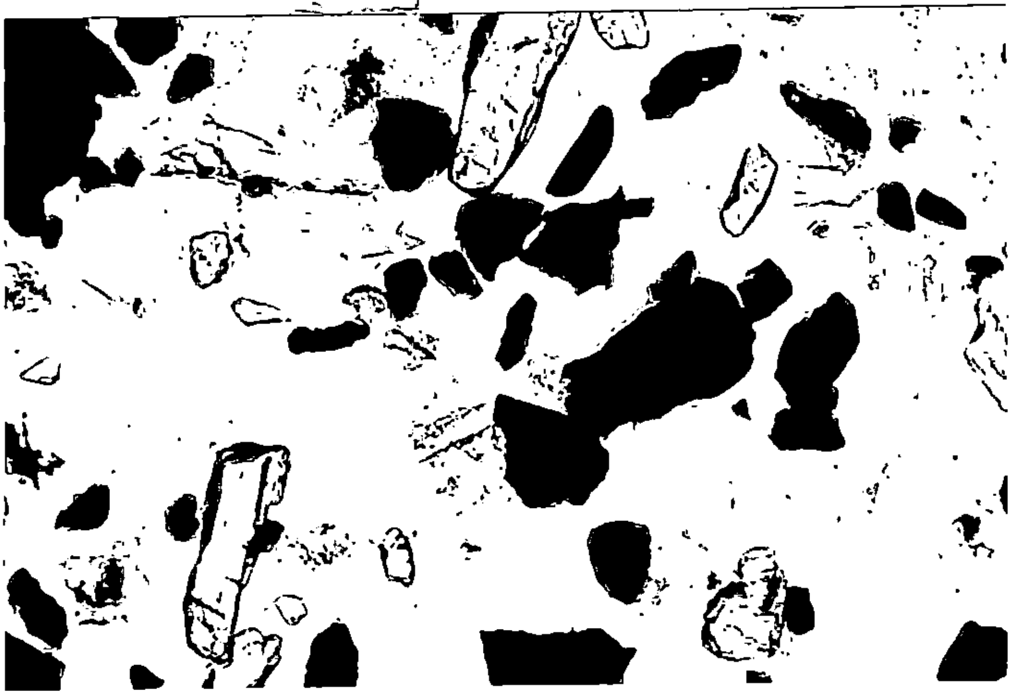


Plate 19. Fine sand minerqlogy of Palode soil series profile

Plate 20-21 Fine sand mineralogy of Palode soil series profile

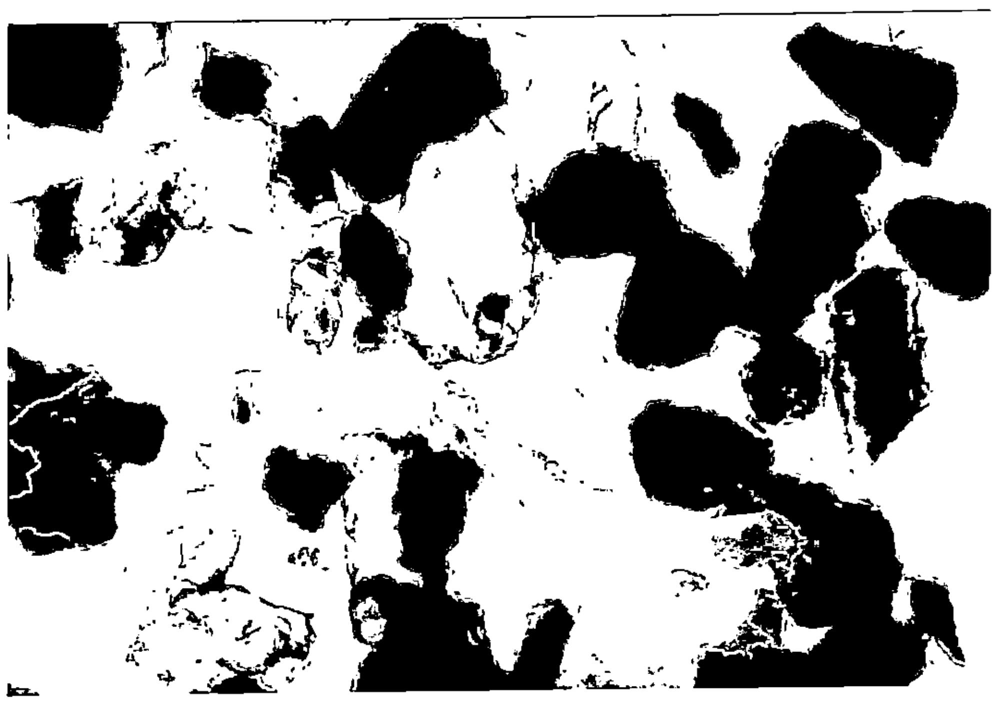
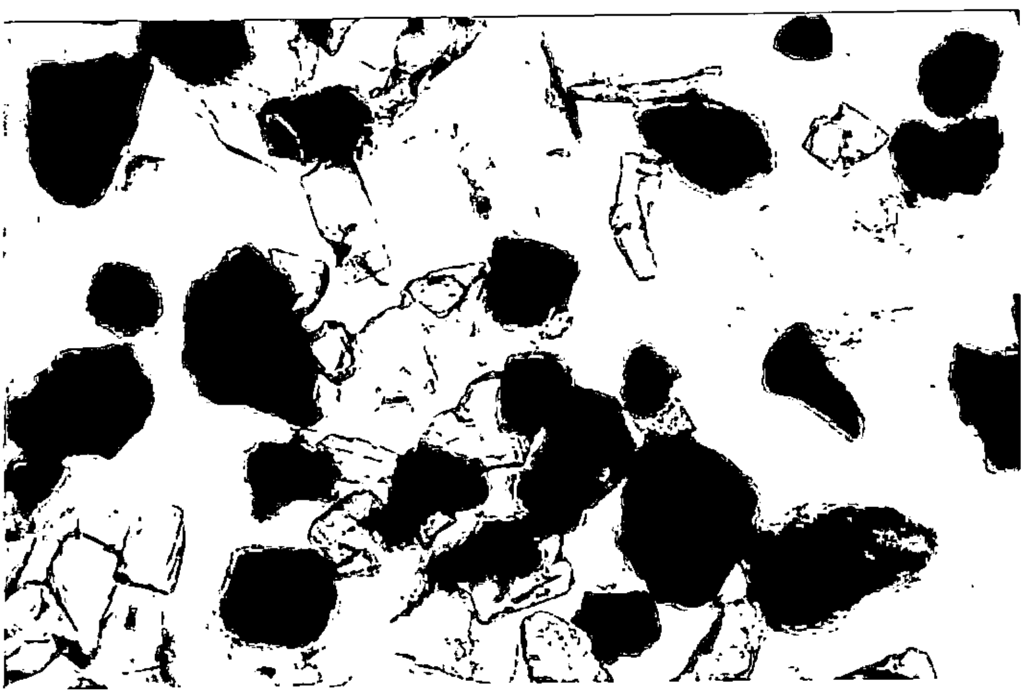


Plate 22 Fine sand minerology of Palode soil series profile



The heavy mineral suite consisted of ilemenite, leucoxene, haematite, zircon, rutile and sillimanite in the Trivandrum series. In the Nedumangad series, all the six mineral mentioned above are present with very small quantities of rutile and observation of importance is the presence of mica (Biotite). In the case of Palode series, all the minerals except rutile and leucoxene were present in the black mica content were comparatively higher. The occurance of different minerals in the series was in the order of Rutile < Zircon < leucoxene < ilemenite < sillimanite < Hematite the Trivandrum series, rutile < Zircon < leucoxene < ilemenite < sillimanite < hematite in the Nedumangad series and zircon < kyanite < haematite < ilemenite < sillmanite < in the Palode series.

The distribution of quartz in the profile doesnot show any regular pattern.

The sillimanite content was found to increase markedly in the Trivandrum soil series. At Nedumangad and Palode a decrease with depth was observed.

Rutile was only of limited occurance in these profiles.

Zircon is only one of the most resist accessary mineral of soils to both chemical attack and abrasion. In the samples studied there were Euhedral, rounded and broken crystalls of Zircon. The distribution of zircon showed an increase in trend in the case of Trivandrum and Nedumangad series.

No

The Kyanite was identified only in Palode series. It show a characteristic pale blue colour. Tne distribution in the profile show an increase in the depth.

The ilemenite comes under the broad group of black opaques and show brown to black metallic lusture. Ilmenite was the most abundly occuring mineral in Palode soil series while it was in the order of lower comparitive abundance at Nedumangad and Trivandrum series.

The mineral leucoxene are seen as rounded grains, sometimes with relict shape of ilmenite. Pitted surface has been observed in some grains. Most of the grains are highly altered ilmenite. Leucoxene was completely absent in the Palode series. They decrease with depth, decrease being maximum in Trivandrum series.

Haematite predominates in the Trivandrum and Nedumangad series comparitively. On comparison it shows that within the profiles and between the locations, the difference were more.

Analysis of clay fractions.

1. Surface area measurement of clay fractions.

The total external and internal surface area measurement of the clay fraction from B_2t horizon of Trivaqndrum and Nedumangad series and B_{12} horizon of Palode series are presented in table 5.

Total surface area

It ranges between 32.0 and 118 m^2 /9-1 in the Trivandrum series and between 33.0 and 91 m^2/9-1 and 35.0 and 126 m^2 9^{-1} in

Nedumangad and Palode series respectively. It increases with depth in the three soil series.

Chemical composition of clay

The results of the chemical analysis of clay and molar ratios are presented in Tables.

1. Silica

Silica formed the major constituent of clay and it varied from 1.73 to 5.55 percent in Trivandrum, 1.5 to 10.2 per cent in Nedumangad and 0.99 to 3.64 percent in Palode series. The distribution among the series show increase with depth. Between the profiles this trend is comparatively in the decreasing order of Palode > Nedumangad > Trivandrum series.

Aluminium

The content of alumina (Al_2O_3) was highest in the Trivandrum series. The ranges observed in three series observed were 4.8 to 9.76 in Trivandrum, 5.85 to 8.0 in Nedumangad and 0.85 to 10.24 percent in Palode series. It decrease with depth and this trend were maximum in the Trivandrum series followed by Nedumangad and Palode series. Between Trivandrum and Nedumangad profile within the profile variation is comparatively less.

Iron

It ranges between 7.3 and 11.35 percent in Trivandrum 4.65 and 8.63 in Nedumangad and 2.25 and 5.8 percent Palode series. The Fe_2O_3 content show a definite decrease with depth in the three

Table 5. Chemical Composition of Soil Clay

Sl. No.	Series	Horizon Symbol	Depth cm	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	SiO_2 / Al_2O_3	Surface Area M^2/g	CEC Cmol/kg	SiO_2 / Fe_2O_3
1.	Trivandrum	Ap	0 - 14	5.55	6.85	9.30	0.81	118	12.6	0.596
		A_2	14 - 26	4.50	9.76	7.95	0.461	81	14.3	0.556
		B_1	26 - 66	4.30	7.90	7.30	0.544	84	9.5	0.589
		B_2t	66 - 175	2.65	4.85	10.50	0.546	65	8.1	0.252
		B_2T	175 - 200+	1.73	7.65	11.35	0.226	32	7.5	0.152
2.	Nedumangad	Ap	0 - 14	4.35	5.85	4.65	0.743	33	14.5	0.935
		A_3	14 - 30	3.33	7.93	8.63	0.419	91	13.0	0.385
		B_1	30 - 96	1.50	8.00	6.75	0.187	59	15.8	0.22
		B_2t	96 - 150+	10.20	6.85	5.83	1.48	34	12.2	1.749
3.	Palode	A_1	0 - 13	3.64	0.85	3.33	4.28	72	21.8	1.093
		A_2	13 - 55	1.50	9.95	2.25	0.15	126	18.5	0.666
		B_1	55 - 138	0.99	8.63	4.55	0.1147	63	26.1	0.217
		B_{12}	138 - 150+	1.11	10.24	5.80	0.108	35	17.6	0.19

series and this trend was maximum in Trivandrum followed by Nedumangad and Palode series.

Molar ratios

Silica - Alumina ratio, It ranges between 0.226 and 0.81 in Trivandrum, 0.187 and 1.48 in Nedumangad and 0.108 and 4.28 in Palode series. The silica alumina ratio showed a tendency to increase with depth in all the locations. The maximum variations was observed at Palode such followed by Nedumangad and Trivandrum series.

Silica Iron ratio

It ranges between 0.152 and 0.596 per cent in Trivandrum, 0.22 and 1.749 per cent in Nedumangad and 0.19 and 1.093 per cent in Palode series. The ratio also show a tendency to increase down the profile. Maximum increase was observed in Trivandrum followed by Nedumangad and Palode.

Claymineralogy

AFAS content (Amorphous ferri aluminium silicate)

AFAS content of clay fractions of the three soil such as presented in table 5. It ranges between 21.4 to 25.9 per cent in Trivandrum series, between 18.6 and 24.3 at Nedumangad and 10.8 to 13.9 at Palode series. The Palode series contained lower AFAS than Nedumangad and Trivandrum series. It increase with depth in all the series.

Table 6. Mineralogical composition of soil clays

Sl. No.	Series	Horizon Symbol	Depth cm	Kaolinite %	Vermiculite %	Smectite %	Mica %	Feldspar %	Quartz %	AFAS %
1.	Trivandrum	Ap	0 - 14	46.5	0.2	4.2	1.9	traces	9.7	21.4
		A_2	14 - 26	50.3	0.7	3.8	1.5	0.1	10.9	26.3
		B_1	26 - 66	55.9	1.2	4.0	0.8	0.1	12.2	24.5
		B_2t	66 - 175	63.9	0.8	3.0	0.1	traces	14.5	25.3
		B_2T	175 - 200$^+$	64.8	1.3	2.5	traces	traces	15.5	25.9
2.	Nedumangad	Ap	0 - 14	62.0	6.5	7.1	10.9	0.9	11.5	18.6
		A_3	14 - 30	50.4	0.2	6.1	8.4	0.7	9.8	23.7
		B_1	30 - 96	44.2	0.2	7.0	9.6	0.3	5.3	24.1
		B_2t	96 - 150$^+$	57.5	0.11	6.9	6.7	0.1	6.6	24.3
3.	Palode	A_1	0 - 13	30.5	5.5	12.5	21.4	2.8	1.9	10.8
		A_2	13 - 55	25.7	1.5	7.1	18.5	2.2	1.7	11.0
		B_1	55 - 138	29.9	0.8	9.5	16.6	2.2	5.3	12.5
		B_{12}	138 - 150$^+$	25.5	1.5	9.9	20.3	1.5	6.8	13.9

Both the Smectite and vermiculite content does not exhibit a definite profile pattern in these three soil series.

Mica, Feldspar and Quartz

Mica , feldspar and quartz content of the AFAS- free clay from the soil series are presented in table 8. In the Trivandrum soil series, mica content ranges between traces and 1.9 per cent. At Nedumangad, it ranges between 6.7 and 10.9 per cent. On the Palode series, it ranges between 15.5 and 21.4 per cent.

Feldspar

it ranges between traces to 0.1 percent in the Trivandrum series. In the Nedumangad series it ranges between 0.1 and 0.9 per cent. In the palode series it ranges between 1.5 and 2.8 per cent.

Quartz

It ranges between 9.7 and 15.5 per cent in Trivandrum series between 6.6 and 11.5 per cent, and between 1.9 and 6.8 per cent in Nedumangad and Palode series respectively.

The distribution of mica, K-feldspar, Na-feldspar and quartz in the inner soil series does not exhibited any definite profile pattern.

X-ray diffraction analysis of the clay fractions.

The X-ray diffractogram of clay fractions separated from the soil series after treatment are given in figure 10. The results indicate the predominant of kaolinite in all the surface samples

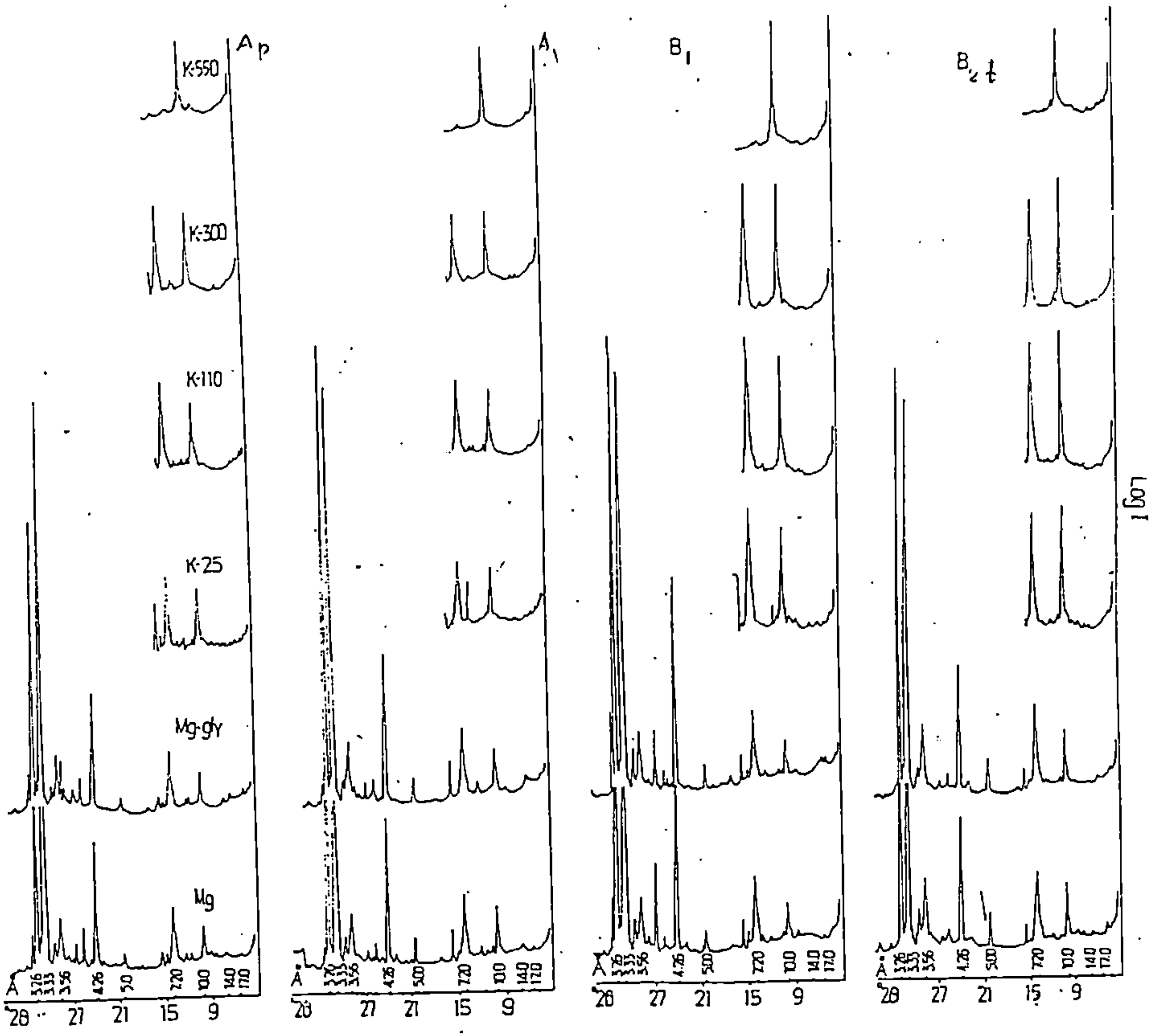


Fig. : X-ray diffractograms of AFAS-free clay (< 2 μ) fractions pedon; Co. Kα radiation

Trivandrum Series

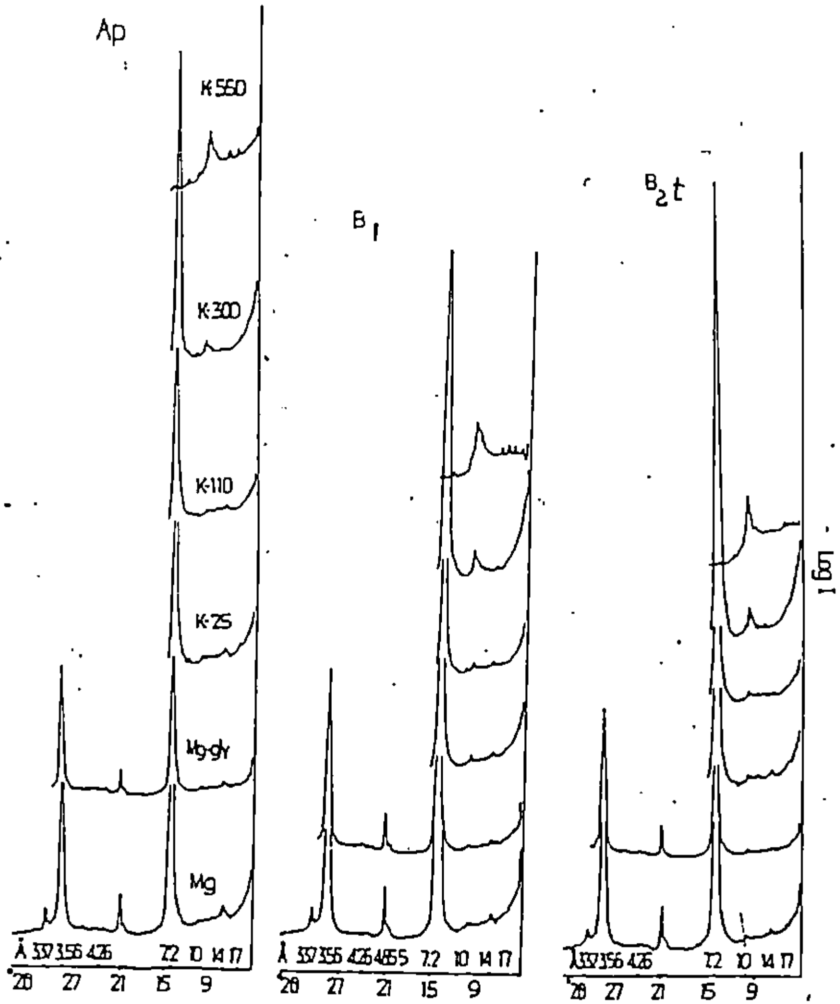


Fig. : X-ray diffractograms of AFAS-free clay (< 2 μ) fractions

Nedumangad Series Co Kα radiation

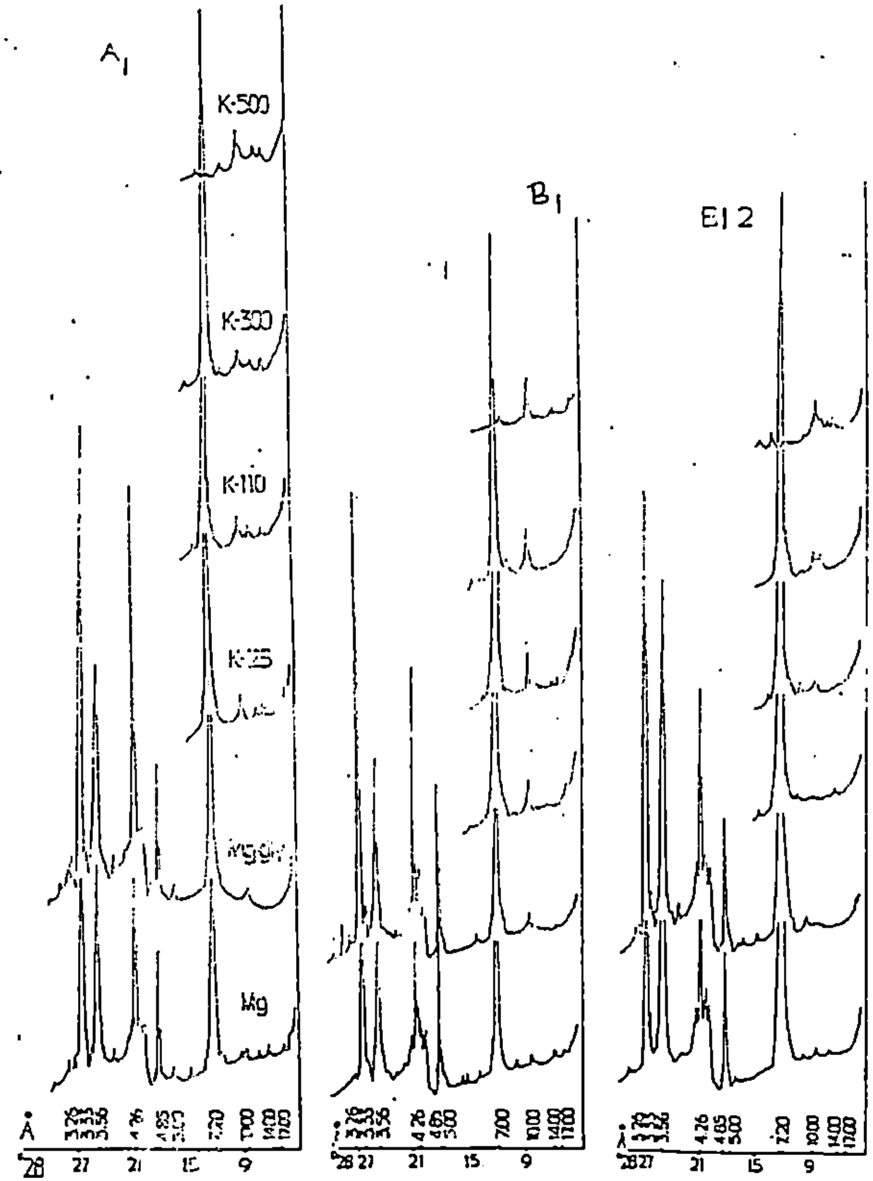


Fig. : X-ray diffractograms of AFAS-free clay (<2 μ) fractions

Palode Series Cu Kα radiation

studied ranging from 26 and 65 per cent. The chlorite and 2:1 type of minerals were in the decreasing order Palode > Nedumangad > Trivandrum. Similarly chlorite crystallinity was also indicated by sharp peaks between 12.5 A^{o} and 14 A^{o} on K saturation and 550 ^{o}C heating of the clay. Quartz was almost absent to traces in the surfaces layers, while feldspar was present. The quartz content increases with depth, while feldspar content decreases with depth. Serieswise the content of quartz is in the decreasing order from Palode series > Nedumangad > Trivandrum. While the feldspar exhibited a reverse pattern. Mica was the another mineral of importance identified in these soil series. They were in the increasing order Trivandrum < Nedumangad < Palode series. It decreases with depth in all the series. Micc was formed quite crystalline as identified by the 10 A^{o}, 5A^{o} and 3.3 A^{o} peales. The 3.3 a^{o} peaks of mica included in quartz peak (3.3 A^{o}). The second order peak of mica is not one half of the first order peak, the peak indicating dominance of biotite mica. The first order peak of the mica show shoulders on the low angle side in the increasing order from Palode sum < Nedumangad < Trivandrum indicating that the mineral was undergoing weathering in the increasing order. The feldspar was identified by 3.2 A^{o} peak and the quartz by 4.3 A^{o} peak.

The laterite layer – B_2t horizon contains Kaolinite in large amounts with very low quantities of mica. Vermiculite and ailment were identified more in this horizon. Persistence of chloritization was also indicated by the persistent peaks between 12.5 A^{o} and 14A^{o} on heating to 55 ^{o}C. The 17 A^{o} peak with Mg

Fig. Differential Thermal Analysis Curve of Clays - Trivandrum Series

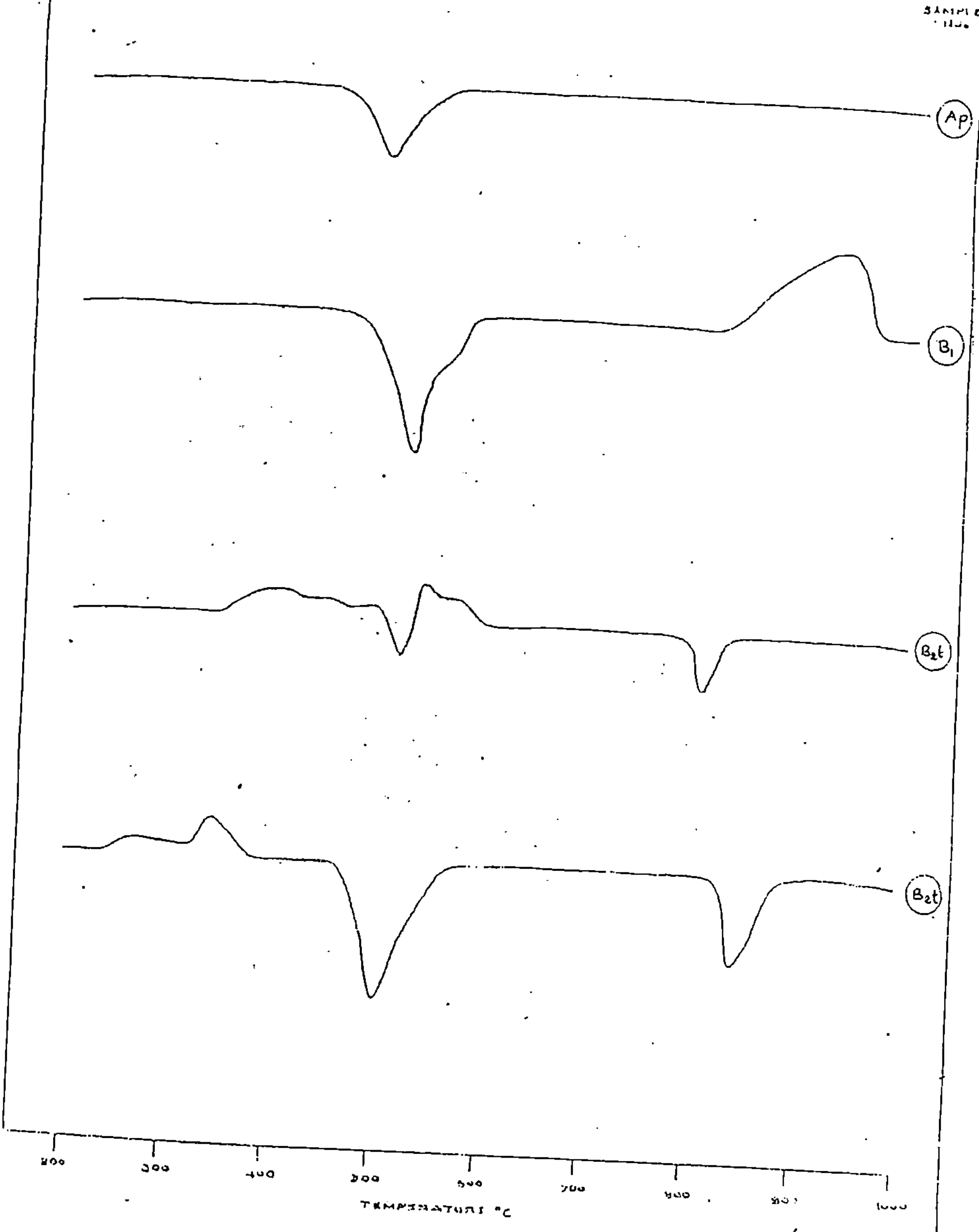


Fig. Differential Thermal Analysis Curve of

Clays - Nedumangad series

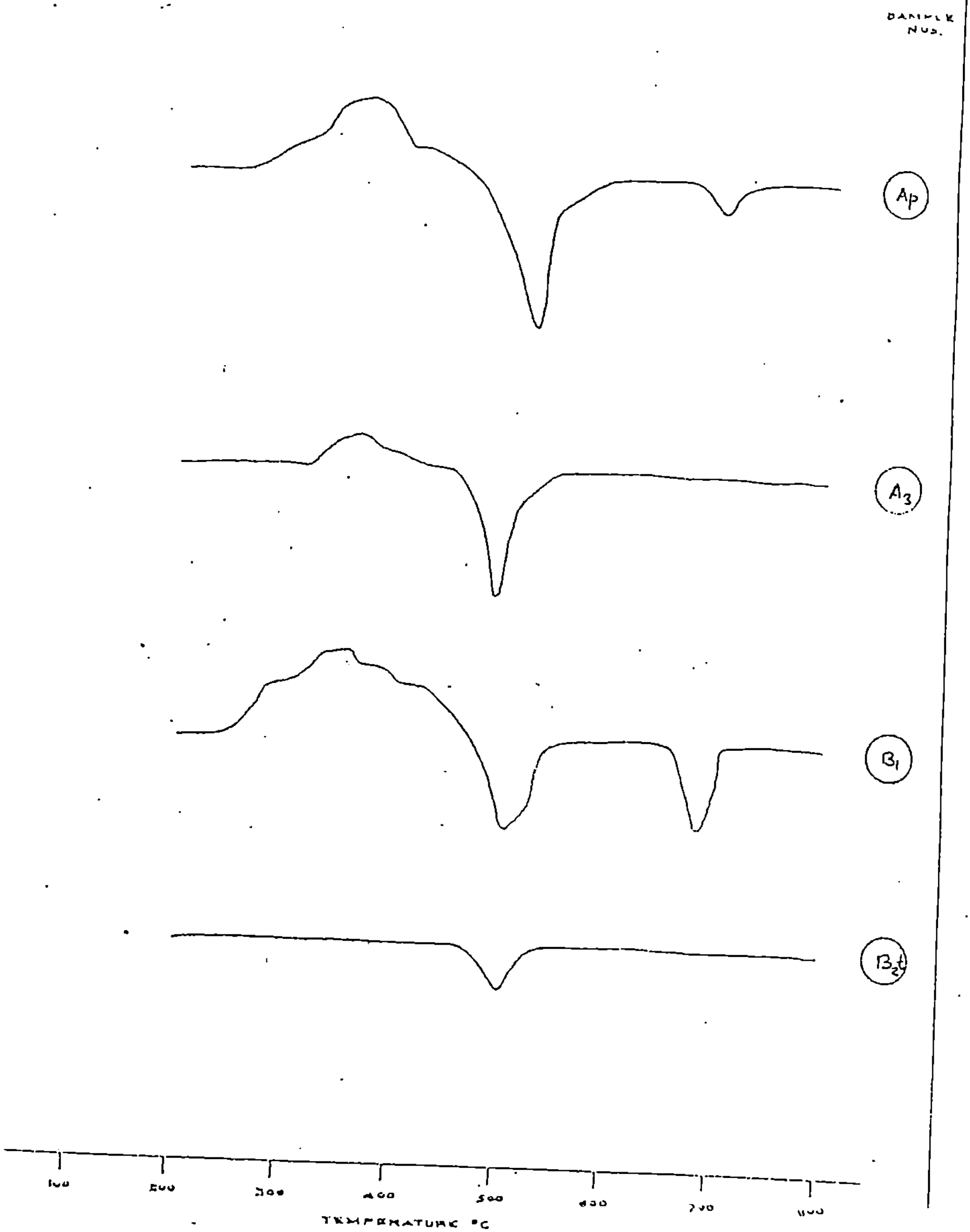
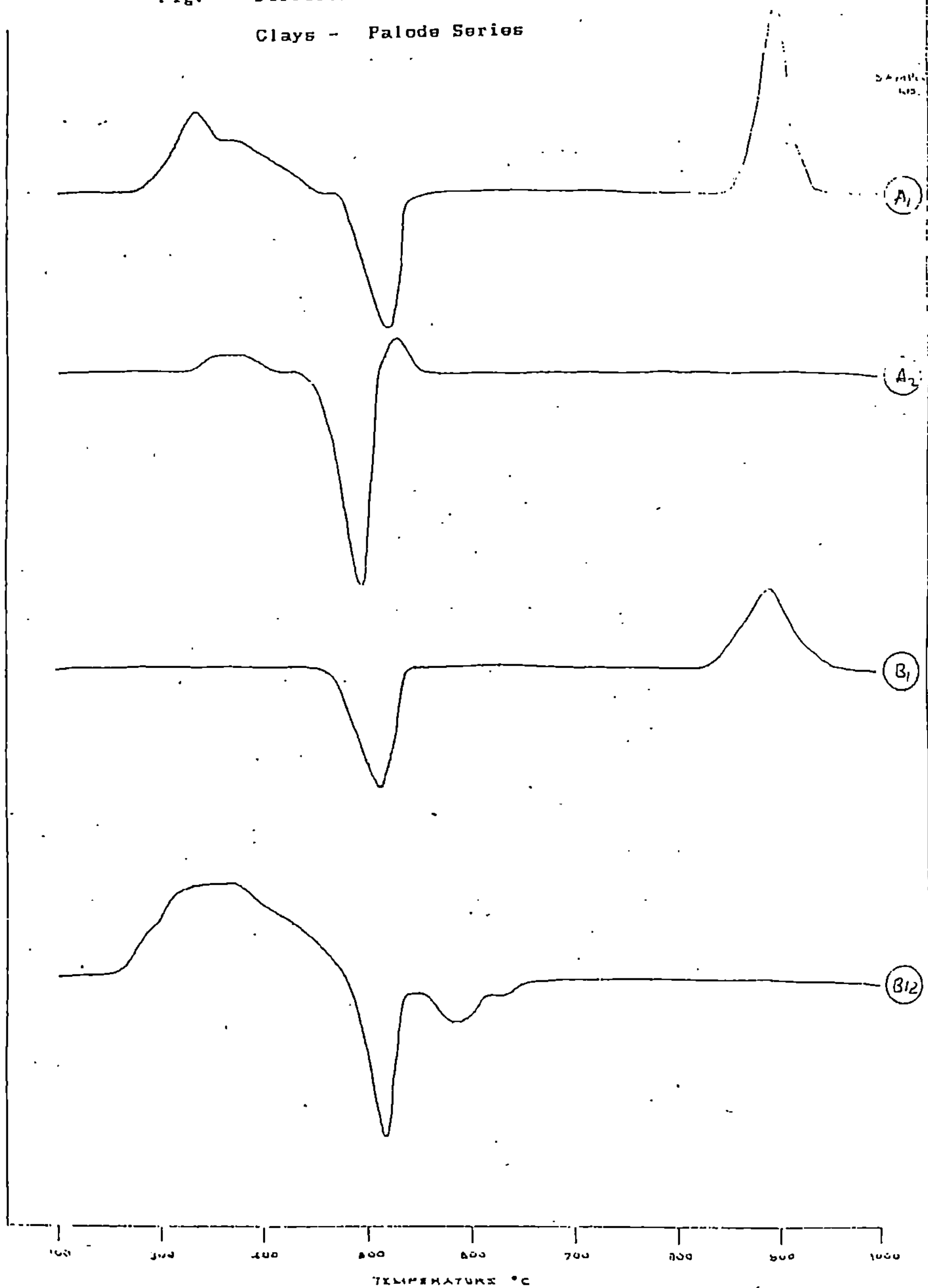


Fig. Differential Thermal Analysis Curve of

Clays - Palode Series



saturation and ethylene glycol solvation indicated the presence of Smectite and 14 A° peak in Mg saturation and ethylene glycol solvation indicated the presence of the vermiculite mineral.

The identification of expanding mineral was further supported by the collapse of the 14 A° or 17 A° peaks on K-saturation and heating to 300°C.

The interstratification was noticed in all the series comparatively more in the Palode series by the persistence 20 A° peak in K- saturated 550 °C heat treatment.

Differential thermal analysis of clay samples

The DTA curves of clays samples of the three soil series are presented in figure 11, 13, 15. It can be seen that the samples from Palode and Nedumangad series show exothermic peaks vary both in size and shape at 300 - 400 °C. Since the organic matter in the clays had not been destroyed before differential thermal analyses. These exopeaks have been identified due to organic matter. The size and peak height were in the increasing order Trivandrum < Nedumangad < Palode. All the samples show the characteristic endopeak between 500 ° and 600 °C typical of Kaolinite. characteristic exopeaks of kaolinats at about 900°C was also exhibited in its Nedumangad and Trivandrum soil series samples. Small endothermic peaks between 680 - 700 °C exhibited in the increasing order in the Trivandrum, Nedumangad and Palode series are indicative of chloritic type of minerals.

Plate 23. Scanning electron micrograph of B_2t horizon of Trivandrum soil series profile

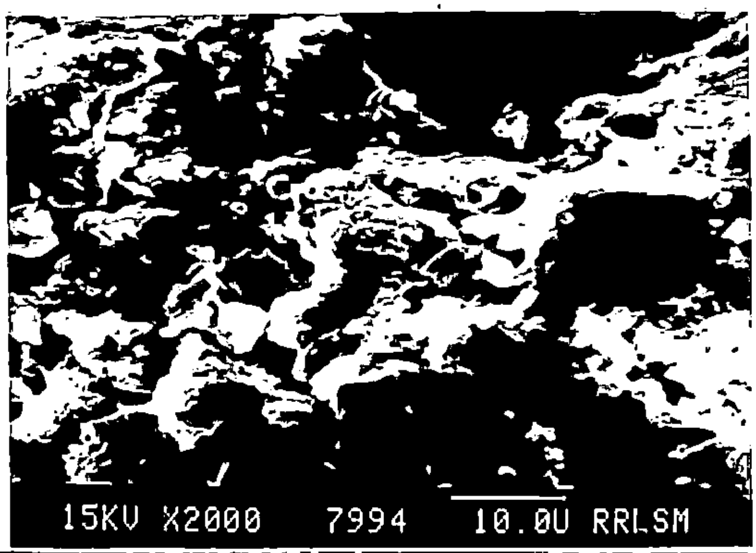


Plate 24. Scanning electron micrograph of clay from B_2t horizon of Trivandrum soil series profile

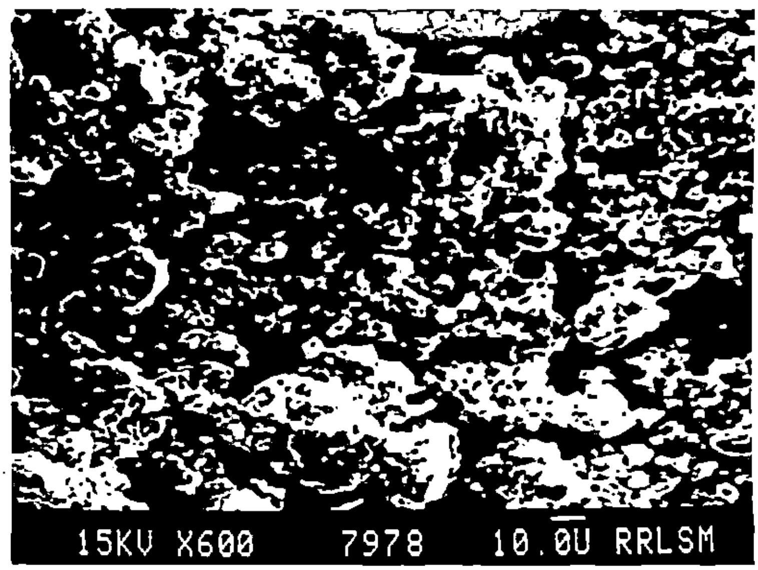


Plate 25. Scanning electron micrograph of B_2t horizon of Nedumangad soil series profile

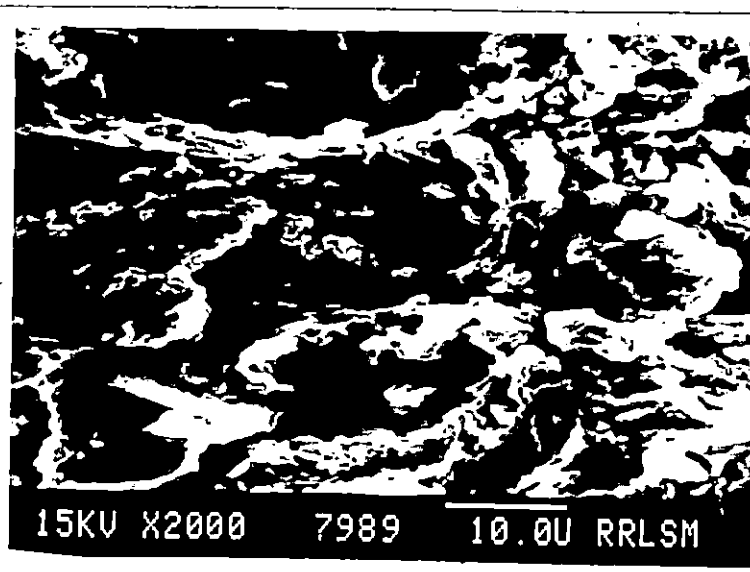


Plate 26. Scanning electron micrograph of clay from B_2t horizon of Nedumangad soil series profile

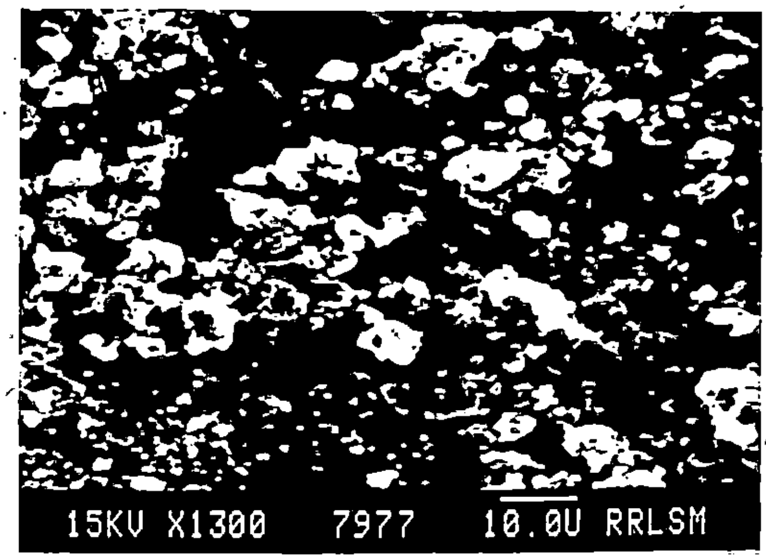


Plate 27. Scanning electron micrograph of $B_{12}t$ horizon of Palode soil series profile

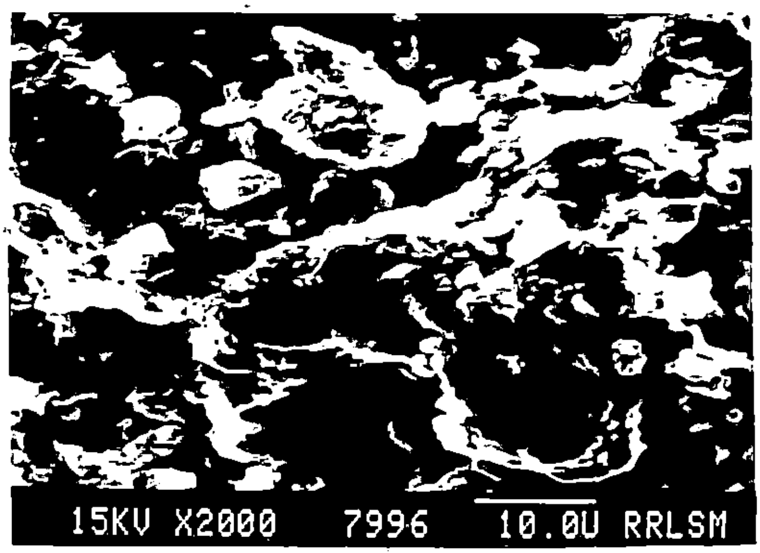
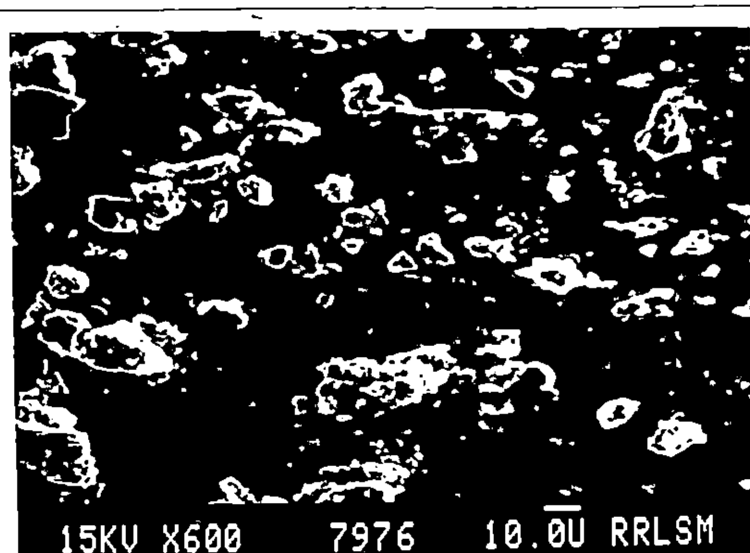


Plate 28. Scanning electron micrograph of clay from $B_{12}t$ horizon of Palode soil series profile



SEM analysis of soil and clay fractions.

The SEM analysis of undisturbed soil samples and separated clay fractions from B_2t horizon at Trivandrum and Nedumangad series were done. (plate No) The observations revealed that the B_2t horizon is a highly iron impregnated translocated clay rich horizon. The scanning electron micrograph of the clay fraction reveal the dominance of kaolinite aggregates with iron impregnation.

Specific surface area measurement of clay fractions

Data on specific surface area of the samples are presented in table 5. The value range, between 32.0 to 126 $m^2 g/-1$. The highest value was given by the A_1 horizon of the Palode series. and the lowest by the B_2t horizon of Trivandrum series. The contribution of organic matter to the specific surface area were indicated by the comparative higher values in the surface and a profile pattern of decrease with depth in all the three series.

Classification

The required information for the soil classification as per soil Taxonomy (USDA., 1975, 1987) gathered from the present investigation and are proposed classification presented in table.

Trivandrum series - fine skeletal kaolinitic isohyperthermic family of kandiustelts.

Nedumangad series - Fine skeletal kaolinitic isohyperthermic family of kanhaplic Haplustalfs.

Palode series - Coarse skeletal mixer isohyperthermic family of Hapludolls.

Table 7. Soil classification as per soil Tatonomy (VSDA, 1975, 1987)

Sl. No.	Series	Soil texture	Clay mineralogy	Temperature regione	Diognostic subsurface horizon	Moisture region	Epipedon	Classification Propose Upto family Level
1.	Trivandrum	Fine skelital	Kaolinitic	Iso hyper thermic	Kandic horizon	Ustic	Ochira	Fine skelital kaolinitic iso hyper-thermic family of kandiustults.
2.	Nedumangad	Fine skelital	Kaolinitic	Iso hyper thermic	Kandic horizon	Ustic	Ochira	Fine skeletal kaolinitic iso hyper-thermic family of kanhaplic Haplustalfs
3.	Palode	Coarse skelital	Mixed	Iso hyper thermic	Developing argillic horizon	Udic	Mollic	Coarse skelital mixed iso hyper-thermic family of Typic Hapludolls

DISCUSSION

DISCUSSIONS

Genesis and classification.

The three major soil series studied namely, Trivandrum, Nedumangad and Palode fall in the class of soils earlier very broadly termed Laterite and lateritic soils. Such soils have long been considered to be the products of weather and soil formation under tropical climate with a well defined rainy season and warm dry summer. Among the series, the Palode series are deep dark brown to black soils with gravely loam surface gradient to gravely clay loam be grail clay sub soil are also products of 'lateritic' weathering except that the faculties process of undersign or encrustation (Millot, 1970) has not taken place.

The Trivandrum and Nedumangad series occur in the mid land regions of the Trivandrum District of Kerala state at an altitude of 20-100m above M.S.L while the Palode series in mid upland region occur at an altitude at 125 - 150 m above M.S.L. They are situated about 15, 20 and 50 kilometers in land.

The three soil series comes under the humid climate (annual rainfall 250 mm). Of the three pedons the Trivandrum and Nedumangad experience a dry period of two months. While at Palode the existing forest canopy and higher elevation reduces the dry spell experiences by the site when compared to the above two pedons by creating a cooler micro climate. The mean annual temperature is more than 22°C in all the three sites. It was reported that the denudations of laterite cover and formation of laterite gravel during pleistocene climatic fluctuations (Brunner 1970).

The role on which the soil is formed is the pre-cambrian peninsular gneiss of the Archaen system (Wadiar, 1961) - the biotite constant is in measuring towards the inland. The gneiss is granitic in composition and is fairly coarse grained. The high temperature prevalent in these sites hastens the hydrolytic efficiency of water. The long dry spell prevent the accumulation of organicmatter. Under these conditions, the primary minerals constituting the role are weathered rapidly and silica, aluminum, iron and bases are released to the solutions, silica is lost in preference to the aluminium as the solubility of silicon is independent of pH <9.0 while solubility of aluminium is pH dependent. (Millot, 1970). During saprolitisation iron is released and reprecipitates closer to its source (Folster, et al., 1971). As a result of the differential movement of ions, there will be accumulation of iron and aluminium in these soil profiles. The effect of organic matter and cooler microclimate in a forested environment lessens the rate of laterisation as observed in the Palode soil series profile.

The soils are classified based on the criteria, diagnostic surface and subsurface horizons and soil moisture and soil temperature regime, applied in a defined sequence.

The diagnostic epipedon of the Trivandrum and Nedumangad soils are Ochric epipedon while the Palode series is mollic epipedon, having eliminated embark anthropic, plaggen and histic epipedons.

The diagnostic subsurface horizons is obviously the zone where enrichment of clay has taleen place falling in the B_2t horizon in the Trivandrum and Nedumangad soils and in he B_{12} horizon of palode series.

In Trivandrum and Nedumangad soil series, the thickness of horizon of clay enrichment, increase in clay the certain exchange coast of clay by 1 M NH_4O AC (ratio of CEC to clay) are used to identify the horizon as a candic horizon. (soil survay staff, 1987). The clay rich horizon - B_{12} at Palode series is identified as an developing argillic horizon. There are no other diagnostic horizons observed in these three series. proceeding along the directions given in keys to Soil Taxonomy (soil survey staff, 1987), the following classification is arrived.

1. Trivandrum series - Kandiustults
2. Nedumangad series - Kanhaplic Haplustalfs
3. Palode series - Typic Hapludolls.

Physical Properties of Soils

1. The soil profile study are with gravelly sandy loam to gravely clay loan surface and are with gravely clay loan to gravely clay sub surface layers. Coarser fractions are more in the surface and decrease with depth. While a reverse pattern is exhibited by the finer fractions. This observation is reflected in the textural ratio variations clearly indicating the progressive weathering and soil development processes in this profiles. The more coarser and less finer fractions in the Palode series than Nedumangad and Trivandrum such is indicative of the relative rate of weathering and soil profile development.

The observed increase in gravel contained in the decreasing order from Trivandrum > Nedumangad > Palode is indicative of the relative rate of physical process in the soil development in there series. Comparatively the more the profile development, the more the gravel content. It is also indicative of the relative rate of agent of lessivage namely water received and percolated through the profile. The content of gravels from 46.0 to 75.0 percent is indicative of heavy and contains rainfall received and drained through these soils. These fractions form significant portion at the solum - soil. Hence there are not to be ignore in soil samples for assigning fertility and productivity. (Subramonia Iyer (1979) The observed lower bulk density is indicative of more clay content and more closer packing of soil particles. There is not much difference between the profiles except the lowest layers indicating equivalent clay translocation and accumulation process in these series.

Chemical Properties

The soil are acidic with very low soluble salt concentration. The relative difference in the exposure of these profiles to rainfall, in solution and cultivation is indicative in the relative distribution of organic carbon content between the profile and within the profile. Their increase content and at palode series is due to the thick ever green forest canopy retained in the sites.

The cation in exchange capacity of the soil is less than 10 C $molkg^{-1}$ Trivandrum and Nedumangad series while at Palode series it is above 10 C $molkg^{-1}$. This is because of the pre ponderance of the kaolinitic type of clays in Trivandrum and Nedumangad series. They are low activity clay (LAC) soils. The observed increases in CEC at Palode is due to a mixed clay mineral composition. Here again the values are not high, indicating that the presence of appreciable quantity of kaolinitic type of clay minerals. The high cation exchange capacity on the upper layers (mollic epipedan) of Palode series is due to the contribution by high organic matter present.

The higher iron content and aluminium content in this soils are indicative of the rate of laterisation process in these soils. The more silica and bases are leached enriching. Iron and aluminium in these profiles based on the selective rates at laterisation processes. The observed low content of iron and aluminium at Palode series is due to less laterisation processes favoured by lessened impact of rainfall, insolation and hence more organic matter, wetter and cooler atmosphere in the site. These factors are anitlaterisation factors. Precisely organing matter, moisture and low temperature decrease the rate of laterisation (Maignien (1966), Patnaik, (1971)).

Subramonia Iyer (1979), Sankarankutty Nair (1984) have reported that the higher clay content with kaulinitic type clay minerals results in the low cat ion exchange capacity of the clay rich sub surface horizons in the horizons in the lateritic soil of the Trivandrum District. The present study is an agreement with these earlier conclusions reported.

Fine sand mineralogy.

In all the three series studied, the light fraction of the mineral is dominated by quartz. The predominance of quartz in the light fraction at the expense of feldspar and ferromegnisium mineral observed in these series is indicative of the highly weathered nature of the soils, through the observation it Palode series is comparatively less. A very little quantity (traces) of feldspar is present in these soils. In the decreasing order Palode > Nedumangad > Trivandrum. Quartz and other transparent mineral grains were found to be invariably coated with iron oxide. The angularity of grains retained in these series in the decreasing order from Palode > Nedumangad > Trivandrum in indicative of the relative rates of abrasion and mutual attresion of grains carried by moving water through the profiles.

Saratchandran Nair (1977), Subramonia Iyer (1979), Venugopal (1980), Sankarankutty Nair (1982) and Sivadasan (1989) in their studies on the laterite and associated soils of Kerala had observed the predominance of quartz in light fractions. It is obvious that the dominance of quartz in these soil series is due to selective accumulation on account of it, resistance to weathering. The heavy mineral (Black and red opaques) formed a very low fraction of Trivandrum soil series. But their content is comparatively, more in the Nedumangad and Palode series.

The relative higher content of ilemenite and haematite is clearly indicated the higher iron content of the respective horizons and profiles. The mineral assemblages at Nedumangad and Palode series are more or less the same, suggesting the original parent material similarities of these series namely Khondolites - the gnessic rock. (Sivadasan, 1989) The fine sand, ilemenite distribution Trivandrum series behaves similarly to that of varkala series (reported by Sankarankutty Nair, 1984). Another mineral of importance observed in these three series is leucoxene. They are in the decreasing rate at Trivandrum > Nedumangad > Palode. This is due to the relative weathering intensitive of the three sites. The leucoxene is an altered form of ilemanite. According to Tylor and Mardsen (1938) ilemenite undergoes weathering and form leucoxene an amorphom hydroxide titanium. The sillimanite content is in the increasing order from Trivandrum < Nedumangad < Palode series. This is clearly

reflected in the relative aluminium content between and within profiles.

Another important observation is the higher percentage of haematite. In the sand fractions of Trivandrum and Nedumangad series and sub surface layers of Palode series. This is reflected in the colour of these series (red). This feature is common to all these three series. High haematite content and intensity of redness of soil have been reported in Afrcian soils. (Rainlenk Report, 1952). The Zircon content showed variations between the series through the variation is less between the Palode and Nedumangad series. Within profile variation at all the series did not show much Within the profile. This points to relative difference in the weathering between the series.

In general the comparison of mineral assemblages in all the three series indicate that no stratification of parent material has taken place and soils are developed from an uniform parent material - gneissic rocks.

Absence of feldspar and predominance of quartz also show a higher degree of weathering. The opaques accumulation were in the increasing order than Palode < Nedumangad < Trivandrum suggest, the relative degree pf weathering. This trend is found to be regular within Palode series which is indicative of its autochthonous formation. A striking contrastic observation is the presence of more black opaques in the Palode series. This is due to the removal of other constituent by weathering. This is in conformity with the observation made by Turton et al (1962) working in the Laterite soils of Australia.

Clay Minerology

The clay fractions of all the three profiles investigated contain kaolinite in relatively higher proportions than other minerals. Kaolinite content of Trivandrum and Nedumangad series is relatively higher than Palode series. Where appreciable amounts of 2:1 type of minerals also present. Kaolinite content decrease down the profile in Trivandrum and Nedumangad series while there is no definite distribution pattern at Palode series. Mica was present in varying proportions in all the three profiles. Mica was in laeger proportion in Palode and Nedumangad series than Trivandrum. 12-23 percent mica content was reported in the clay fraction of red latosol of Srilanka (De- Alwis and Pluth, 1976) The mica content decreases with depth with in profile. Feldspar was not detected by XRD in the clays of Trivandrum and Nedumangad series though it is present in Palode series. The chemical analysis indicated small amounts of feldspar even Trivandrum and Nedumangad series. Quartz content was relatively higher in the clay fractions of Trivandrum and Nedumangad series than Palode series. Though all the three series contained expanding mineral they were present in larger quantities at Palode and Nedumangad series comparatively. Both the clay fraction of Nedumangad and Palode series appreciable quantities of vermiculite and smectite present. The chemical data also indicated that smectite present in the clay fractions of Palode and Nedumangad series in apprciable amounts and this content very less in Trivandrum series.

The primary mineral content of clay fructions are lesser than corresponding sand fractions from the three series. This observation is very much same with the common understanding into the sand fraction are relatively less weathered than the clay fractions. Among the three profiles investigated, Trivandrum series with most weathered profile with Nedumangad and Palode profile following it.

The relative gibbsite content in the clay fraction of the three profiles, higher kaolinites and AFAS content with lesser feldspar and mica in Trivandrum and Nedumangad series indicating its weathering status. Further the climatic conditions even today are conduccive for lateritic weathering in the regions of all the three sums in the decreasing order Trivandrum > Nedumangad > Palode series. A forest micro climatic condition is absent in the Trivandrum and Nedumangad series. The presence of biotite mica (trioctahedral) and quartz content in the clay fractions is an unusual observations in the clay fractions from all the three series. It is established and well known that the biotite will weather faster than muscovite. Similarly the quartz is a mineral resistant to weathering. The possible explanation for such an occurance iss that silt sized biotite and quartz might have undergone physical weathering resulting these clay sized minerals.

Amorphous ferri alumino silicates

The molar SiO_2/ Al_2O_3 ratio of the clays extracted by boiling in 0.5 N. NaOH followed by CBD was in the range of 1.21 to 2.15. The molar ratios of the clay varied greatly in the clays of all the three series. De Alwis and Pluth (1976) indicated the molar SiO_2/Al_2O_3 ratio of the amorphous materials in the clays of Latosol of Srilanka to be 2.0 to 3.2. Krishna Murthi et al (1976) found molar SiO_2/Al_2O_3 ratio of AFAS to be in the range of 2.00 to 3.55 in the clays of subtropical ferruginous soils. The Fe^{++} content in the clays is a low to account for the amorphous mineral. Therefore, Fe in AFAS here to be consider to be Fe^{3+} form.

The FeOOH component thus calculated was in the range of 38.5 to 50.0 and 27.0 to 41.0 per cent in the Trivandrum and Nedumangad series respectively. The lower FeOOH component observed in Palode series.

Kaolinite

Considerable Fe was extracted by CBD after boiling the clays with 0.5 M NaOH. Fe thus extracted was consider to be part of the structure of kaolinite. The Fe_2O_5/Al_2O molar ratio was > 2 and SiO_2/R_2O_3 ratio close to 2, but higher (Rangasamy et al. 1975) believed that kaolinite in these soil was the product of pedogenesis precipitated from the unstable AFAS minerals. The substitution of iron for aluminium expected in these soils was found in all the three such in the decreasing order Trivandrum < Nedumangad < Palode. Iron content in the kaolinite was related to the climate and parent material (Rao et al 1985). It was indicative that as the humidity decreases in the tropics, the degree of iron substitution for aluminium increases. The results in the present investigation favours the result of Rao. et al

1985) This confirms the fact that humidity is also one of the factors of laterite weathering. The comparatively higher aluminium was recovered in the kaolinite of Nedumangad and Palode series has come from the ginnsite (identified by XRD)

Lepidocrocite, haematite and goethite were the three dominant iron oxide minerals present in the three soil series. Lepidocrocite was the dominant iron oxide mineral in all the three pedons. Lepidocrocite is known to occur very commonly in the hydromorphic soils. Subramania Iyer (1989) has reported the preponderance of lepidocrocite in the acid sulfate soils of Kerala by micro morphological observations. The presence of this minerals in these soils which are well drained is an unusual observations thopugh Darsi and protz (1978) Fabrics et al (1985) have reported their preponderance in the ferruginous soils and oxisol, respectively.

Biotite in these soils continously supply Fe^{++} ions which would transform directly to lepidocrocite. The acidic well drained soil situations is favourable for the persistance of such Fe^{++} ions released during biotite weathering. X-ray diffractogram also indicated the presence of lepidocrocite, haematite and goethite in these soils. In the Trivandrum series, the hamatite content is more than the geothite content. In Nedumangad and Palode series a reverse pattern isa in operation. Haematite imparts a red colour to the soil even in minute quantities. The dark reddish brown colour observed in the field in the Trivandrum and Nedumangad profile supports the higher haematite content in these profiles. Association of hamatite and goethite, together is a common feature of highly weathered acidic tropical soils.

Scanning Electron Microscopic Analysis

The sample of soil and clay subjected for soil analysis are untreated. Hence the thick iron coating and presence of amorphous iron and aluminium oxide mask the specific crystallinity of individual mineral. But the samples from Trivandrum and Nedumangad series indicate collection of kaolinitic mineral, with thick iron coating. The such clusters of kaolinitic materials with thick iron impregnation had been identified as kaolinite by X-ray diffraction analysis. Schmidt - Lorenz (1974) pointed out that during laterization, silicon was removed from the profile whereby kaolinites and adsorbed ferrichydroxide were transformed into hematites, goethite and gibbsits. Hematite is usually dominent in laterite represented by form of micro aggreates of clay and silt sizes in which little kaolinits may also be present. The present study confirms this report.

Specific Surface Area Measurement of Clay Fractions

The speric surface are measurement of the clay samples were higher in the increasing order from the Trivandrum < Nedumangad < Palode series. Depth wise decrease profile pattern is exhibited by all the three series. These observations are indicative of the role of organic matter to the specific surface area. Rajendran (1992) in a study on the elctro chemical properties of oxisols and ultisols of Kerala also got similar observations. The depth wise increase in the clay content in all the three soil series situated was not reflected in the specific surface area because of the dependance of specific surface area property with organic matter. Thomson et al 91988) also reported similar observations. One masking of specific surface area with increase in clay content is due to the AFAS coating of clay in these soils confirmed by chemical analysis and SEM analysis in the present investigation.

Classification

Based on the available information on soil texture, clay minerology temperature regime, diamorphic horisons, and moisture regime, the three soil series are classified as ;

1. Trivandrum series - Fine slidital kaolinitic isohyperthermic family of kandiustults
2. Nedumangad series - Fine skelital kaolinitic isoheperthermic family of kanhaplic Haplastalts.
3. Palode series - Coarse skelital mixed isohyperthermic family of Haplydolls.

As per sequentially proceeding the directions given in the keys to Soil Taxonomy (USDA, 1987).

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

With regard to the climate, geomorphology and geology of the Trivandrum, Nedumangad and Palode, the major sites of Trivandrum District, Kerala state fall within the status condusive for laterization. The denydation of forest has hartened the process of laterigation in these regions. From Palode to Trivandrum series it can be seen that deforestation and subsequent hardening has' taken place in these soil series which is an important constraint to agricultural development in these ferruginous soils, the most reactive portion, namely, the clay fraction and most coarser fractions namely, gravel decide the properity and utility of the soil. The physio chemical properties, nutriant availability of these soils are governed both qualitatively and quantitively by the nature and distribution of clay and clay minerals. Because of these many effects of clay mineral on soil properties, the nature and content of clay mineral, is used as a classification criteria in the family level in the soil Taxonomy (USDA, 1987).

In the present investigation, a study was under taken together information on detain qualitative and quantitative clay mineralogy of the major soil series namely, Trivandrum, Nedumangad and Palode, Trivandrum.

1. The three major soil series studied earlier known as laterite and lateritic soils are products of weathering under humid tropical climate with well defined rainy seasons and warm temperature

2. The Trivandrum series is situated in the mid land region of the state comparatively closer to sea while the Nedumangad and Palode series are situated in the mid up land regions and far away from the sea. The parent material of the three series are gneissic rock.

3. The Palode series comes under forested and denuded regions, Nedumangad series comes under denudaded and laterites, the Trivandrum series highly laterised and hardened in the laterite zone of the Trivandrum District.

4. The annual rainfall of the three pedon site is more than 250 mm - Humid climate with a clear warm and dry period of two months. Though the effect of dry spell and rainfall on soil is lesser in the forested environment at Palode series.

5. The mean annual air temperature of the three sites are more than 22° C and the difference in mean air temperature during winter summer is < 5° C.

6. The prevalent pattern of rainfall and temperature experienced in the site indicate ustic moisture regime in Trivandrum and Nedumangad series and udic moisture regime at Palode series. Similarly the temperature regime of all the three sites is isohyperthermic.

7. The higher organic matter and cooler microclimate in the forested environmental Palode series in the mid up land position away form the coast seasons the rate of laterization.

8. The diagnostic epipedon of the Trivandrum and Nedumangad soil series are ochric while that of the Palode series is mollic.

9. The diagnostic subsurface horizon in the Trivandrum and Nedumangad series is kandic while that of Palode series is a developing argillic horizon.

10. Based on the available information from the field the three soil series were classified as:-

Trivandrum series	:	Kandiustults
Nedumangad series	:	Kanthaplic Haplustalfs
Palode series	:	Typic Hapludolls

11. The Trivandrum and Nedumangad series are red to reddish brown colour with gravelly clay loam to gravelly clay while the Palode series is black to dark greyish brown with gravelly clay loam to gravelly clay. The gravels and clay are significant soils fractions governing to properties and utility of these soils. In all the series, both the fractions are 46 to 75 per cent and 18.41 and 36.6 percent.

12. The soil structure is weak fine granular to subangular blocky at Trivandrum series, medium weak crumby to subangular blocky at Nedumangad and at Palode series it is medium crumby to subangular blocky. The soil is slightly sticky and slightly plastic to sticky and plastic at Trivandrum and Nedumangad at moist.

13. Significant amount of varying mottlings observed only at Trivandrum and Nedumangad series.

14. The plinthite layer of more than 50 cm thickness is observed both at Trivandrum and Nedumangad series with 1-1.2 meter depth, with characteristic vesicular and vermiform sturcture and veins filled with greyish white to greyish blue kaolinite. These plinthite are not quarriable.

15. At Palode series the argillic horizon is in the developing stage with angular blocky sturcture.

16. The soils of all the three series are acidic, non saline and iron rich.

17. The cation exchange capacity is $<$ 10 cmol Kg^{-1} in Trivandrum and Nedumangad series and at Palode it is $>$ 10 cmol Kg^{-1} indicating the kaolintic and mixed clay mineralogy of the series respectively.

18. The organic carbon content is local at Trivandrum and Nedumangad series and medium at Palode series. It decreases with depth in all the three series.

19. The light fractions of fine sand minerals were doninantly quartz. The content is in the increasing order Palode $<$ Nedumangad $<$ Trivandrum series.

20. In all the series the heavy fructions of fine sand is black and red opaques. The black opaques or in the increasing order Palode $<$ Nedumangad $<$ Trivandrum series while a

reverse pattern in the red opeque content observed in these three series.

21. The leucoxene content, the altered ilemanite is more in the increasing order Palode < Nedumangad < Trivandrum series, while the sillimant exhibit a reverse pattern in this series.

22. Observation of importance is the increased content of biotite mica in the fine sands and clays of their soil series. But the feldspar is less to traces.

23. High harmatite and zircon content is another specific observation of the fine sand mineralogy of these soil series.

24. Appreciable amount kaolite is present in all the three soil series in the increasing order Palode < Nedumangad < Trivandrum series. The uniform parent material from which the soil series are developed. In the Nedumangad and Palode series, in addition vermiculite and smestite are present in the increasing order. The clay mineralogy of Trivandrum and Nedumangad series is kaolinite, while that of Palode series is mixed.

25. The iron minerals present are harmth, goenite and unusual presence of lepido arocite.

26. The unusual presence of appreciable amount of mica in the clay fractions is in the increasing order Trivandrum < Nedumangad < Palode series suggests the formation of lepidocrocite from biotite.

27. The amorphous ferrialuminium silicate present in the clay fractions is in the increasing order Palode < Nedumangad < Trivandrum series. The humid Aorpical, past and present climate are favourable for continued substitution of aluminium in kaolinite by iron in all the three soil series.

Based on the available information on soil fixture, clay mineralogy, moisture temperature regime, diagnostic horizons the three soil series are classified as per soil Taxonomy (USDA, 1975, 1987).

1. Trivandrum series : Fine skeletal kaolinitic isohyperthermic family of Kandiustults
2. Nedumangad series : Fine skeletal kaolintic isohyperthermic family of Kanhaplic Haplustalfs.
3. Palode series : Coarse skeletal mixed isohyperthermic family of Hapludolls.

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By

ASHARAF M. B.Sc. (Ag.)

ABSTRACT OF A THESIS

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ABSTRACT

The Trivandrum, Nedumangad Palode soil series are the major soil series established in the The Trivandrum District. A study was undertaken to gather detailed qualitative and quantitative clay mineralogy of these soil series taking one representative the soil profile from each of the series. From the information on the field morphology, temperature and moisture regimes and mineralogy, it has been attempted to classify these soil series as per soil Taxonomy (USDA, 1975, 1987) upto the family level.

The Trivandrum soil series situated in the mid land laterite zone of the Trivandrum District 20-25 meters above M.S.L. and 15-20 km away from the sea. While the Nedumangad and Palode series is situated in the mid upland laterite zone, 25-50 meters above M.S.L. and 30-60 km away from the sea. The Trivandrum and Nedumangad series are comes under denudaded and cultivated laterite tract while the palode series comes under the retained semievergreen lateritic tract. All the three series are developed from the gneissic rocks rich in ilemanite and biotitemica. The laterisation is in the increasing order from Palode < Nedumangad < Trivandrum series with developing lateritic argillic horizon (B_{12}) and laterized kaolinitic (B_2t) horizons respectively . The Trivandrum and Nedumangad series are red to reddish brown coloured while the Palode séries dark greyish brown to black coloured with gravelly sandy clay to gravelly clay texture. In all the three soil series the gravels are clay form the principal major components more than 45 per cent and more

than 30 per cent respectively. The clay increase down the profiles is about two times in Trivandrum and Nedumangad series and it is about 1.5 times increase in Palode series. The Trivandrum and Nedumangad series are with Ochric epipedons and Kandic diagnostic subsurface horizon, while the Palode series is with mollic epipedon and developing lateritic argillic subsurface diagnostic horizons. All the soils are acidic, non saline and with low CEC. In the Trivandrum and Nedumangad series, the CEC is < 10 cmol kg^{-1} and in Palode series it is > 10 cmol kg^{-1}. Hence the Trivandrum and Nedumangad series become Kaolinitic and low activity clay (LAC) soils and the Palode series is mixed and comparatively active clay soils. The sand mineralogy contains quartz, and leucoxene, heamatite, biotite, sillimanite in all the three soils series indicating the uniformity of parent materials. The chemical analysis and X-ray diffraction analysis reveal appreciable amounts of kaolinite (60-80 per cent), in the Trivandrum and Nedumangad series and 30-40 per cent in the Palode series. The AFAS also forms significant amount in the increasing order Trivandrum <Nedumangad <Palode comparatively appreciable amounts of vermiculite, smectite and mica are present in the Palode series (10-20 per cent) imparting a mixed mineralogy to clay. From the available information from the feild observation and gathered information on moisture, temperature regimes, the Trivandrum, Nedumangad and Palode series are temtatively classified initially as Kandiustelts, Kan haplic Haplustalfs and Typic Hapuldolls respectively. Finally with the gathered information in the mixture, mineralogy, these soils were finally classified upto family level as follows.

Trivandrum series	:	Fine skeletal kaolinitic isohyperthermic family of kandiustults.
Nedumangad series	:	Fine skeletal kaoliniticisohyperthermic family of kanhaplic Haplustalfs.
Palode series	:	Coarse skeletal mixed isohyperthermic family of Typic Hapludolls.