STUDIES ON

MACRO MESO AND MICROMORPHOLOGY AND CLAY MINERALOGY OF THE ACID SULPHATE SOILS OF KERALA

BY

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THESIS

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Affectionately Dedicated to the Memory of

Late Professor (Dr) V.GOPALASWAMY

DECLARATION

I hereby declare that this thesis entitled "Studies on macro, meso and micromorphology and clay mineralogy of the acid sulphate soils of Kerala" 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 of any degree, diploma, associateship, fellowship or similar title of any other University or Society.

Vellayani
29th April, 1989.

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CERTIFICATE

Certified that this thesis entitled "Studies on macro, meso and micromorphology and clay mineralogy of the acid sulphate soils of Kerala" is a record of research work done independently by Sri. M. Subramonia Iyer, 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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M.Subramonia Iyer

CONTENTS

LIST OF TABLES

LIST OF FIGURES AND ILLUSTRATIONS

LIST OF MAPS

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Among the low lying coastal areas of the Tropics are millions of hectares of land with either extreme or potential acidity limiting rice production. (Bloomfield and Coulter, 1973., Van Breemen and Pons, 1978). Pyrite has accumulated in these soils. This gets oxidised on aeration liberating free sulphuric acid which lowers the soil pH to 3.5 and below. This has led to the definition of these soils as acid sulphate soils.

Iron and aluminium toxicities due to high acidity, high phosphorus fixing capacity and consequent phosphate deficiency, deficiency of micronutrient such as molybdenum, boron and at times manganese, copper and zinc contribute towards limiting crop production in these soils. Techniques of water management to maintain the pyrite laden subsoil layers well below the water table are important strategies in the management of these soils. Significant efforts are now being made to develop and test high yielding and pest resistant varieties with tolerance to acidity (Ikehashi and Ponnamperuma, 1978).

The acid sulphate soils are not very extensive on the global scale. However they are found in Vietnam, Thailand, Indonesia, India and some of the West African countries. Together they cover around 9.2 million ha (Moorman and Van Breemen, 1978, IRRI, 1977; Dent, 1986). In India, the acid sulphate soils are located along the West coast in the Kerala region and the Sunderbans region of West Bengal. It is also possibly present in the marshy bog situations, sporadically in some of the forests of the Western Ghats, and the mangrove forests of Andaman and Nicobar Islands. However, the West coast of Kerala contain the more extensively studied and near typical acid sulphate soils of India.

In Kerala the estimated area of acid sulphate soil is about 0.2 mha along the West coast (Subramoney, 1951). These soils along the West coast due to local variations have been named differently as kari, karapadam, kayal, pokkali, kole and kaipad, based on specific features of the location, soil problems presented, colour of the soils or systems of cultivation adopted. Studies on some of these soils namely kari soils were initiated by Narayana Iyer, as early as 1926 of the erstwhile Department of Agriculture of the Government of Travancore. Since then, several works on the kari and the allied soils have been carried out by groups of scientists of the State Department of Agriculture, the Soil Chemistry section of the Central laboratory of the erstwhile University of Travancore and the Soil Science Department of the College of Agriculture of the State Department of Agriculture as also the present College of Agriculture of the Kerala Agricultural University, the legitimate legacy holder of the forerunners.

Most of these studies were on the methods of reclamation of acid sulphate soils for agricultural and other purposes (Subramoney, 1951) the management of the soils for growing of rice, enhancing the productivity of these soils, (Kurup, 1967; Alice Abraham, 1984; Nair et al 1981) methods of amelioration of the acidity with liming materials, (Marykutty, 1986) comparative evaluation of different types of liming materials, etc. However, no systematic study on the genesis, mineralogy both macro and micro primary and secondary minerals, physical and physico-chemical properties relevant to their classification, pedogenic processes etc., had been attempted earlier. Further an apprisal of these acid sulphate soils in relation to other similar soils elsewhere in the world became essential, not only to classify them but to explore the adoption of some of the tree cropping systems practiced elsehwere such as Malaysia (Brinkman, 1976) and successful technologies such as aquaculture adopted in the Philippines (Brinkman and Pons, 1973). The question whether the acid sulphate soils of Kerala would be amenable to such strategies warranted such fundamental studies on the genesis especially about the nature and extent of pyrites and the ripeness of the soils. In order to fulfill this major overriding objecive the current work has been undertaken with the following investigations as the main themes:

i. Stage by stage morphological studies (macro, meso, micro and submicro) of the different horizons of the soil profiles.

ii. Coarse sand, fine sand and silt mineralogy for primary minerals and X-ray, thermogravimetric and chemical methods for secondary minerals.

iii. Physical and physico-chemical studies of the profile samples and evaluation of the ripeness of the acid sulphate soils.

iv. Placement of these soils in the various systems of classification.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Acid sulphate soils suffer extreme acidity as a result of oxidation of pyrite. Often they are unripe, and some times saline as well. Some occur naturally but most have developed as a result of drainage of previously water logged coastal alluvium and peat.

Investigations already conducted on different aspects of the acid sulphate and related acid soils are classified and reviewed in this chapter:-

1. Acid sulphate soils-Definition and significance
2. Geographical distribution
3. Land forms
4. Acid sulphate environments
5. Vegetation
6. Macromorphology
7. Meso and micromorphology
8. Submicroscopy of soils clays
9. Physical properties

9.1 Granulometric composition

9.2 Aggregate analysis

9.3 Moisture retention characteristics

10. Chemical properties

10.1 Soil acidity

10.1.1 Dynamics of tidal environments and the formation of potential acidity

10.2 Soil Eh-Redox potential

10.3 Iron content

1. Acid sulphate soils - definition and significance

Van Breemen and Pons (1978) and Bloomfield and Coulter (1973) considered acid sulphate soils to have the following attributes. These soils are poorly productive. They contain accumulated pyrites. Such soils are usually found in tidal swamps. When these areas are drained the pyrite gets oxidised generating sulphurc acid causing pH values as low as 3.5 to 4.0. They also considered these soils to have a pH below 3.5 (Entisols) or 4.0 (Inceptisols) within a depth of 50cm.

In Soil Taxonomy (USDA, 1975) potential acid sulphate soils have been recognised by the presence of sulfidic materials - "Water-logged mineral or organic soil materials that contain 0.75 per cent or more sulphur (dry weight) mostly in the form of sulphides and that have less than three times as much carbonate ($CaCO_3$) as sulphur".

Dent (1986) required that acid sulphate soils are recognised more by the presence of a sulphuric horizon which he defined as mineral or organic material that has both pH less than 3.5 (1:1 water) and jarosite mottles (hue 2.5 Y or yellower and chroma of 6 or more). Essentially, Dent's definition is only an elaboration of the USDA (1975) definition of sulphuric horizon. This evidently indicates the recognition of organic matter and iron sulphides such as FeS_2 (Pyrites) in these soils to be the source for oxidation to free sulphuric acid and jarosite.

Segalen (1979) distinguished acid sulphate soils within the class of saline soils in the ORSTOM classification. Two sub classes are distinguished:- Thiols - soils with a reduced 'Thion' within 60 cm depth from the surface. A thion has more than 0.75 per cent oxidisable sulphur and becomes acid upon oxidation. Sulfosols - soils with oxidised sulfon within 60 cm of the surface. A sulfon has jarosite mottles, free sulphuric acid, more than 0.75 per cent sulphur and pH less than 3.5.

The FAO/UNESCO Soil Map of the World Legend (FAO/UNESCO, 1974) groups both potential acid sulphate soils and actual acid sulphate soils together as: Thionic Fluvisols -- acid sulphate soils

Ong Jin et al (1985) reported that a soil may be termed as potential acid sulphate soil if on oxidation by treatment with H_2O_2 soil pH is considerably reduced to 3.5 within 100 cm depth from the surface.

Brinkman and Pons (1973) suggested a tentative limit of dangerous acid sulphate soils of pH 2.5 after hydrogen peroxide treatment of the soil.

2. Geographical distribution

Money and Sukumaran (1973) reported that kayal soils are found in the reclaimed lake bed in Kottayam and Alleppey districts and they occupy an area of 0.08 million hectares. The land is situated 2-3 m below the sea level. Karapadom soils occur along the inland waterways and rivers and spread over a large part of the upper Kuttanad covering an area of 0.41 million hectares. The fields lie at about 1-2 m below the sea level. Kari soils are peat soils found in large isolated patches in the Alleppey and Kottayam Districts covering an area of about 0.2 million hectares.

Van Breemen and Pons (1978) reported that on a global basis there are 2 million hectares of acid sulphate soils in Indonesia, 1 million hectares in Vietnam, 0.7 million hectares in Bengladesh, 0.67 million hectares in Thailand and 0.39 million hectares in India, 0.2 million in Khemer (Kampuchea) 0.18 million hectares in Burma and about 0.15 million hectares in Malaysia.

Moorman and Van Breemen (1978) reported that large areas of acid sulphate soils are found in Vietnam, Thailand, Indonesia, India and in several West African countries. Throughout the world an estimated 15 million hectares of acid sulphate soils are found (IRRI/1975). It is a total of about 9.8 million heactares in the problem areas of south and south east Asia (Brady, 1982).

Van Breemen (1976) reported that there are about 5 million hectares of acid sulphate soils in south and south east Asia, about

3.7 million hectares in Africa and about 2 million hectares in South America. The variations in the reported hectarages of acid sulphate soils synchronise with the conceptual change in the definition of acid sulphate soils.

Bhargava and Bhattacharjee (1982) reported that in India saline and acid sulphate soils occur along the Malabar coast of Kerala occupying marshy depressions (lagoons). These have developed on the alluvium derived from laterites under humid tropical climate. These soils undergo fresh water submergence from May to December and sea water innundation under tidal cycles during subsequent lean months.

Bhargava and Abrol (1984) had reported that the acid sulphate soils confined to Malabar coast in the South western part of India have developed under humid tropical climate on the alluvium derived mainly from laterite and lateritic soils and occupy lagoons and similar low lying geomorphic situations.

Bhandyopadhyay and Sarkar (1987) reported that about 5 million ha of coastal area of South western Bengal to be saline and acid. They observed a field to have a pH 3.0 throughout the year. They explained the low pH as due to high content of iron and sulphur.

Pons (1988) reported that in the estuaries of Guinea and Bissau and Mekong delta sulphidic deposits occur. In the coastal plain of

Surinam and Guyana sulphidic materials have been located. The Dutch coastal plains also include areas of older sulfidic materials, whereas younger deposits are poor in sulphide. In all these cases sub-recent sediments are not potentially acid.

3. **Landforms**

Diemont and Van Wijngaarden (1974) working in West Malaysia reported that in the reduced horizon of the strait coast, field pH values varied between 8 and 8.4 and pyrite sulphur contents were less than 0.5 per cent. In contrast in the estuarine swamps pH values of reduced horizons were between 6.2 to 6.8. Organic matter content were higher and pyrite sulphur content were between 1 and 2.5 per cent. Concentrations of dissolved sulphide were similar in the two environments, except during spring tides when they were decreased to undetectable levels in the estuarine soils.

Pons and Van Breemen (1982) attributed the apparent removal of dissoved sulphide and bicarbonate, and the increased accumulation of pyrite, to more effective tidal flushing. Flushing will be enhanced by a net work of tidal creeks and by greater soil permeability associated with the higher content of organic matter. Tidal flushing sould promote pyrite formation, by removing the bicarbonate ion (HCO_3^-), supplying the limited amount of dissolved oxygen necessary to form pyrite from the reduced sulphide and by accelerating rate limiting processes that are otherwise dependent on diffusion.

Dent (1986) reported that sulphide soils develop most extensively where clayey sediment accretes slowly in saline water and simultaneously copious organic matter is supplied by swamp vegetation. Sedimentation hydrology or water chemistry can result in the burial of sulphidic material by non sulphidic alluvium or peat. So that potential acid sulphate soils may be found in fresh water or dry land environments or pyrite may accumulate in peat or alluvium orginally laid down in fresh water. He also reports that within any region of acid sulphate soils there are significant local patterns that are related to the vertical and horizontal distribution of pyrite and calcium carbonate, soil texture and the depth and length of time over which deep drainage has operated. He also reports that soil ripening of acid sulphate soils is arrested by severe acidity, so that acid sulphate soils may remain for many years unripe and therefore poorly structured and poorly drained. The highest, ripest soils are most effectively leached. Low lying, unripe, severely acid soils are most likely to remain saline even after reclamation.

4. **Acid sulphate environments**

Pons and Van Breemen (1982) report the combination of factors required for the accumulation of sulphides that occur in three distinct environment.

Marshy inland valleys and basins flushed by sulphate rich waters draining from older sulphidic sediments. He reports that these are not extensive, but he has examples including sulphidic peats in Uganda (Chenery, 1954) and Leningrad (Krym, 1982) and sulphidic sands in The Netherlands (Poelman, 1973).

Bottoms of saline and brackish seas and lakes

Organic rich sediments deposited in saline or brackish water may accumulate significant concentrations of reduced sulphur, both as Fe(II), monosulphide and pyrite. The littorine bottom sediments of the Baltic contain upto 2 per cent reduced sulphur. Isostatic recovery of the land, following glaciation, has brought some sediments above sea level, leading to the development of acid sulphate in coastal areas of Sweden and Finland (Wieklander, et al 1950: Kivinen, 1950).

Saline and brackish water tidal swamp and marsh

It includes tidal flats, salt marsh and mangrove swamp. This is the potential acid sulphate environment.

5. **Vegetation**

Money and Sukumaran (1973) reported that the pokkali or Kaipad lands of Ernakulam and Cannanore Districts are over grown with mangrove and other salt loving vegetations. Chapmen (1976) reported that individual species or plant associations exert no specific effect on pyrite accumulation. However, species do occupy particular niches related to climate, exposure, depth of flooding, drainage and salinity.

Dent (1986) reported that vegetation fuels the process of pyrite formation by supplying readily decomposed organic matter, mainly through the decomposition of the root systems since most debris is carried away by the tide.

Very high pyrite contents have been reported in peat soils that have been subject to long periods of flooding with brackish water.

Ramachandran et al (1986) reported that in Kerala about a century ago its backwaters were fringed with rich mangrove vegetation. At that time there were about 7 million hectares of mangroves in Kerala which is now reduced as isolated patches and discrete stands of a few species covering only a few hundred hectares.

6. **Macromorphology**

Hsü (1964) reported that one plough layer will be formed in every 60-70 years and weak eluviation of iron and manganese due to low permeability.

Kawaguchi and Kyuma (1969) suggested that the plough sole should not be regarded as an independent genetic horizon of rice soils.

Money and Sukumaran (1973) reported that karapadam soils of Kerala are river-borne alluvial soils. Kari soils are deep black in colour characterised by heavy texture, poor aeration and bad drainage. Large amounts of woody matter at various stages of decomposition occur embeded in these soils. Limeshell deposits of lacustrine origin are commonly observed in the surface and sub surface layers of kayal soils. Yellowish brown spots, mottlings, streaks, incrustation are found in almost all the layers of kari and karapadom soils. Clayey texture of kari and karapadom soils accounts for their poor drainage while the silty clay loam texture of kayal soils affords good drainage. Clay content variations with depth is irregular in all those soils.

Van Breeman (1973) has used a chronosequence to demonstrate profile development in acid sulphate soils. In the young soils the pyrite distribution reflects the situation in original mud. Shallow drainage results in acidification of surface soils. In the next stage as the soils becomes older and better drained, the horizons of jarosite and pyrite occur at progressively greater depth. The change from a horizon containing a little pyrite to one with a large content is abrupt, so the oxidation is apparently confined to a narrow zone.

Rickard (1973) reported that in the mangrove soil, the huge amount of organic material added by the mangrove root system, is broken down under reducing conditions of the profile by sulphate reducing bacteria. Fibrous roots and spongy tissues disappear rapidly laying behind blackened corky and vascular tissues. A strong smell of hydrogen sulphide, inky black mud accumulation in surface depressions and oozes from pores in the face of the soil profile.

Money and Sukumaran (1973) have indicated that acid sulphate soils of Kerala are clays and clayloams. They are very rich in unhumified organic matter. The lower layers contain calcium carbonate. They are nearly neutral in reaction but becomes extremely acidic on drying. From the surface to the lower layer a decrease in acidity is observed.

Dent (1980) proposed models for predicting the probable development of acid sulphate soils based on the extent of drainage.

Dent (1986) reported that the Gr horizon is the main horizon of pyrite accumulation. However, total sulphur content varies widely. He also reported that intense mottling(red) is associated with the liberation of large amounts of soluble iron from pyrite during a period of extreme acidity and intense weathering. This process will as well bequeath a high proportion of exchangeable aluminium.

Bhargava and Abrol (1984) reported that the soil matrix colours in the hue of 2.5 Y, 5Y and 5GY indicate distinctly wet to gleyed and reduced nature of these saline soils. They have reported on the basis of mechanical analysis of the soil that only fine sediments are being deposited in recent times to give rise to the acid sulphate soils in Kerala.

Schoute (1988) reported that between peat layer and adjacent clastic deposits there are indications of a more aerated stage at the time of transgressive sequence caused by channel development in the peat under the influence of the encroaching sea.

7. **Meso and Micromorphology**

Kubiena (1938) introduced microscopic and stereoscopic investigations of undisturbed samples of soils. This lead to the new era in Soil Science known as micromorphology. Micromorphologic technique was formalised by Brewer (1964).

Schmidt-Lorenz (1964) and Gopalaswamy and Nair (1972) were the pioneers in the micromorphological studies of the soils of Kerala.

They studied the laterite soils of the State. Similalr studies on rice soils of Kerala were conducted by Gopalaswamy (1982) and Subramonia Iyer (1985) and on laterite soils by Subramonia Iyer (1985) and Sankarankutty Nair (1986).

Moorman (1963) reported that the accumulation of pyrites is quite common in marine and estuarine deposits all over the world.

Miedema et al (1974) studied the micromorphology of pyrite and its oxidation in four alluvial soils in Newzealand. In a non-calcareous environment the oxidation products of pyrite are amorphous ferric hydroxide and jarosite. Gypsum and goethite were found in the same situation in small quantities.

Pons (1964) and Easwaran (1967) by micromorphological investigations showed that pyrite is commonly associated with root channel, and organic debris in the acid sulphate soils and marine sediments.

Brammer (1971) reported that the clay coatings which are referred to as ferriargillans in the field, normally result from natural clay illuviation process. They can also be the result of irrigation, localised alteration of clay minerals, weathering and neoformation insitu under certain management practices.

Turisina et al (1980) in their macro, meso and micromorpholigical and mineralogical study of saline soils established that concentration of salt alters significantly the make up and structure of soil profile as well as the microstructure of the entire soil mass; the individual mineralogical nature of salt affects the development of a specific structure.

Sehgal and Stoops (1976) reported that the salt affected soils of semiarid environments have a spongy, vesicular, platy salt crust with a well developed lamellar structure and many spherical pores. They have moderate to densely packed soil fabric with dominance of planar voids, the plasma and skeleton predominates over voids. The related distribution is dense, intertextic tending to porphyric. The plasmic fabric is asep ic and inseptic in the surface horizon; with depth, weakly developed sepic (locally crystic) fabric is noticed. In the lime enriched horizon plasmic fabric is masked by the presence of calcite microlites.

Brewer (1964) reported that the preferred orientation observed within the plasma of the S-matrix of soil materials is due to the effect of pressure produced by wetting and drying. He reports that flocculation during transport and sedimentation of alluvial material is the most probable cause of asepic plasmic fabric.

Kampf (1983) reported the occurrence of young iron oxide accumulations in hydromorphic soil and water courses in various parts of Brazil. They contain ferrihydrite and lepidocrocite of widely varying crystallinity. The Fe-oxides are mostly formed by more or less rapid oxidation of Fe (II) containing waters and indicate rejuvenation under hydromorphic conditions of more stable Fe-oxides.

Sehgal et al (1985) reported that the frequent presence of orthoagrotubules in the surface and subsurface horizon of the soil is indicative of high biological activity. Channels and compound packed voids are also suggestive of high biological activity. They report that absence of ferruginous concretions is further supportive of poor mobility of iron.

Stoops and Easwaran (1985) reported that the best micromorphological indicator of hydromorphism is the presence of typic sesqui-oxidic features, manganese segregations (mainly coatings and hypocoatings) and lower chromas in the peds. They also reported that in the strongly hydromorphic soils low chromas dominate and Fe-hypocoating and quasicoatings may occur around larger voids.

Magaldi (1987) reported that the degree of orientation of plasma is reduced in proportion as the age and evolution of soil increases, while unaltered sediments and younger soils exhibit most strongly oriented plasma.

8. Sub Microscopy of Soils and Clays

The large depth of focus, the high degree of resolution and the possibility of obtaining stereo pictures, makes scanning electron microscopy a highly suitable technique for soil fabric studies. (Bisdom, 1980)

Blask (1969), Gillot (1969), Bohr and Hughes (1971) presented scanning electron micrographs and emphasised the possibility of the SEM technique to bring direct information on soil fabric by continuously varying the examined specimen area from the optical microscope range of magnification upto a few square um.

Tovey (1971) in his work on clay minerals emphasised the oriented character of a clay structure and presented an optical technique for quantifying the topographic information obtained from scanning electron micrographs.

Wells and Norrish (1968), Von Reichenbach (1976), correleted particle size and shape to diffusion path of exchangeable cations and structural imperfections were attributed to an increase in inter layer penetration of the exchangeable cations.

Lohnes and Demirel (1978) made thorough review of the research on clay and clay soil fabric using SEM and pointed out a good correlation between the structure and tests that characterised their mechanical behaviour.

Von Reichenbach (1976), presented SEM evidence that potassium dissolve in mica minerals at the exchange fronts penetrating into them. These evaluations were limited by the resolution of the petrographic microscope. Higher magnifications are needed to study the arrangement pattern of clay platelets to form domains.

Stoops et al (1977) reported that highly soluble and practically insoluble authegenic sulphate minerals may be present in soils under different climatological and geomorpholigical conditions. Their crystallisation is a reflection of specific micro and macro environmental conditions. The normal environment of the soluble sulphate mineral is where evapotranspiration exceeds precipitation during most of the year as in an aridic soil moisture regime (SCS, 1975).

Micrographs of soluble sulphate minerals were published by Driessen (1970) and Driessen and Schoorl (1973) (thenardite, bloedite), Chevery et al (1972) (Gypsum and Jarosite) and Easwaran and Barzanji (1974) (Gypsum).

Stoops et al (1977) reported SE micrographs of the thenardite efflorescence on ped faces in the C-horizon of a saline alluvial soil. Crystals have clearly a prismatic habit some times with a tendency to lath shaped - individuals. Different habits of gypsum have been recognised in other soils eg. short prismatic in acid sulphate soils (Miedema et al, 1974) rosette like aggregates of gypsum prisms in a catclay from Nigeria (Moorman and Easwaran, 1977).

Arora et al (1978) reported that scanning electron micrographs of pyrite separated from lignite coal showed the occurrence of several morphological forms of simple and compound particles. Porous and non porous pyrite occur as irregular grains. Individual pyrite crystals are sometimes scattered on the surface of the grains. Framboids of individual pyrite crystal are porous and weakly aggregated into spheroids that are commonly 20 to 50 um in diameter. Polyframboids are made up of framboids cemented together into irregular aggregates. Pyrite microcrystals are 0.25 to 1.5 um across and they have a large exposed surface area. These findings suggest that sulfide oxidation and acidity formation will proceed at a relatively rapid rate when mine spoil is exposed to weathering proces.

9. **Physical Properties.**

9.1 Granulometric Composition

Soil survey staff (1978) reported that kayal soils of Kerala are clay loam throughout the profile while karapadom soils are with clay loam texture for surface soils and silty loam for lower layers. In the case of kari soils they are silty clay with sub-surface soil with clay texture.

Sreedevi et al (1975) reported that clay is the dominating particle size fraction in kari, kole and kayal soils, silt and clay are the dominating fractions in karapadom soils. Kole soils have highest percentage of clay.

9.2 Aggregate analysis

Tabatabai and Hanway (1968) studying the chemical and physical properties of different size natural aggregate of Iowa soils found that organic carbon increased as the aggregate size decreased.

Kolarkar et al (1974) found that there was highly significant positive correlation between soil aggregation on the one hand and clay + silt content, clay content, silt content on the other hand in the decreasing order. They also obtained a significant correlation and negative correlation between soil aggregation and clay ratio. High fraction ranging from 60 to 75 percent had an adverse effect on aggregate formation.

Subramonia Iyer and Yagin Thomas(1983) based on the sensitivity analysis of the structural indices made an attempt to find out the most effective index which describe structural indices of soils. The structural indices in the order of their rank with respect to their sensitive measure are: percentage aggregate less than 0.25mm, (9.47), aggregation index, (6.30), stability index (5.55) and MWD of aggregate (4.40).

9.3 Moisture retention characteristics

Ali (1965) reported the influence of organic carbon on the moisture retention in soils. He observed a beneficial effect of soil organic carbon in improving the soil moisture retention characteristics of soils irrespective of their texture and mineralogical composition of the soil clays. The correlation between organic carbon and available moisture was found to be +0.683.

Ali et al (1966) made studies on the moisture retention relationships of some Indian soils. Surface (0-15cm) and subsurface (15-30 cm) samples from alluvial and saline soils exhibited similar retention curves but differed only slightly. The general trend of curves is that moisture content changed in all soil groups rapidly in lower than higher tension range. Curves of alluvial soils which were clayey texture indicated release of moisture even at very high tention.

10. Chemical Properties

10.1. Soil acidity

Schachtschabel (1971) studied the causes and nature of soil acidity and indicated that soil pH less than 5 was governed by the release of protons (mainly hydrated ions of exchangeable aluminium) in soil solution whereas high pH value were associated with biological reduction of carbondioxide.

Ponnamperuma et al (1973) reported that the main disorder on the acid sulphate soils is considered to be soil acidity.

Kuruvilla and Patnaik (1973) in their study of the acid sulphate soils of Kerala indicated that both aluminium toxicity and ferrous iron toxicity could limit rice growth, ferrous iron being developed in the presence of excess of organic matter contained in these soils.

Aiyer et al (1971) have reported that the problem due to continuous submergence such as ferrous iron accumulation and H_2S production in Kuttanad soils could be reduced by establishing blue green algae in the rice fields.

Alice Abraham (1984) studied the release of soluble aluminium in the rice soils of Kerala under submerged conditions and reported that exchangeable aluminium was the main constituent of soil acidity.

Grinsven (1986) reported that initial proton consumption of the surface soil on submergence is greater than the subsoil, due to higher CEC and base saturation values. With progressive proton consumption and increasing reaction times, the proton consumption of the subsoil becomes wider due to higher rates of mineral dissolution in the sub soil. Lower dissolution rates in the surface soil was due to lower content of easily weatherable minerals, and also due to excessive leaching.

Ananthanarayana et al (1988) reported that the soil pH decrease or increase depend upon the relative magnitude of negative and positive charges and exchangeable hydrogen.

Curtin et al (1987) reported that titratable acidity was found to be present in substantial quantities in non colloidal (2-5 and 5-20 μm) as well as in colloidal (< 0.2 μm) fractions. Titrable acidity, CEC and effective CEC was significantly correlated with their contents of organic carbon and Al and Fe extracted by NH_4OAC (pH 4.8), pyrophosphate and citrate dithionite-bicarbonate. The results also indicate that the non-colloidal fractions may be more important in iron retention and related aspects of soil chemistry.

Raju (1988) reported that texturally Kuttanad soils were predominently clay to clay loam. Sandy pockets were much more in kari soil. Bulk and particle densities were significantly lower in kari soils due to their higher organic matter content.

Raveendran Nair (1988) reported that pH of low land wet soils varied from 3.6 t 6.5, drying resulted in lowering of pH. According to him this increase of acidity is due to oxidation of ferrous iron to ferric iron and loss of ammoniacal form of nitrogen by drying.

Swarup (1988) reported that high concentrations of CO_2 and reduced redox potential (Eh) influence the soil pH.

Verma and Hu Neu (1988) reported that the higher initial soil pH decreases the redox potential, EC, and concentration of Fe^{2+}, Mn^{2+}, Zn^{2+}, K^+, Mg^{2+}, Na^+ and NH_4^+ in the soil solutions regardless of duration of submergence. There was a constant decrease in redox potential and increase in solution pH with an increase in period of submergence. The EC increased during the first few weeks of submergence, after which they showed constant decrease.

10.1.1 Dynamics of tidal environments and the formation of potential acidity.

The time required for the formation of potential acidity in appreciable quantity (ie. formation of pyrite) is probably in order of decades to centuries so the tidal marsh vegetation has to persist at a given location for at least such a period of time in order to build up sufficient quantities of pyrite. This implies that sedimentation must be slow (Moorman and Pons, 1974). During the spring tides the concentration of dissolved sulphide in estuarine sediments droped to undetectable levels; whereas they remained almost constant along the accreting coast. These observations can be explained by much more effective tidal flushing in tidal marshes with well developed creek system. Tidal flushing would favour temporary limited aeration, necessary for complete pyritization of ferric iron and leaching of interestitial water and concentration of HCO_3^- so that a relative low pH (6.5 - 7.0) is maintained (Dent 1986).

Acceleration of $CaCO_3$ dissolution is also the result of tidal flushing, oxidation of some pyrite during low tides would also remove $CaCO_3$ (Kooistra, 1978).

Van Breeman (1976) argues that in acid (pH less than 4.4) oxidised environments (Eh greater than +400mv) jarosite is more stable than amorphous ferric oxide; and field observation confirm that the more severe the acidity, the more dominant is the jarosite deposition, over ironoxide deposition. In terms of acid production per mole of pyrite is equivalent to 3 moles of H^+. Jarosite is ultimately hyrolysed to goethite releasing a further mole of H^+, this reaction goes to completion over many years rather than months under field conditions. He also reported that once atmospheric oxygen has penetrated into pyrite substratum, oxidation of pyrite is not stopped instantaneously on subsequent flooding and restoring reduced conditions, because oxidative capacity is stored in the ferric iron. It maintains the further oxidation of pyrite .

Ponnamperuma (1972), Yamane (1978) and Ponnamperuma (1978) reported that peat soils and some of the acid sulphate soils have pH values of 5 even in the flooded state.

Ponnamperuma (1965) reported that increase in pH of most acid soils are largely due to the reduction of Fe (III) to Fe (II). Although increase in pH of acid soil is brought about by reduction, the fairly stable pH attained after few weeks of flooding is regulated by partial pressures of carbondioxide (pCO_2).

Money and Sukumaran (1973) reported that the kari and karapadom soils of Kerala record pH below 5.0. They also reported that there are instances where some samples of these two soils have recorded pH as low as 3.0. The pH of these soils are found to decrease on air drying.

10.2 Soil Eh - Redox potential

Patrick and Mahapatra (1968) reported that redox potential (Eh) of aerated (well drained) soils range between + 700 and + 500 mV. It ranges between + 100 and - 100 mV in reduced soils while in highly reduced soils it ranges between -100 and -300 mV.

Ponnamperuma (1972) reported that the lowering of Eh increases the availability of N, P, Si, Fe, Mn and Mo and reduces the availability of S, Cu and Zn.

Ponnamperuma (1981) reported that soils low in active iron and manganese and high in organic matter showed the quickest Eh decrease. Eh falls sharply upon flooding and reaches a minimum within few days, rises rapidly to a maximum and then decrease asymptotically with time. Presence of organic matter and low content of nitrate and mangnese dioxide and temperature of 35°C favour the decrease in Eh and values as low as -0.25 V may be attained within two weeks of flooding. He also reported that the specific conductance of the solution of most of the soils decrease after submergence attains a maximum and decline to a fairly stable value which varies with soils.

More et al (1988) reported that EC of soil ranged from 0.8 to 19.0 dS m^{-1}. Soluble cations CEC and EC were higher in the surface and decrease down the profiles.

10.3 Iron content

Ponnamperuma et al (1973) reported that values upto 90 mole m^{-3} within two weeks of flooding.

Dent (1986) reported that values between 9 and 18 mole m^{-3} of iron are more common. Soils may yield very little soluble iron either because of small total iron content or small amounts of iron in an easily reducible form. Old acid sulphate soils in which most iron is in the form of well defined crystaline goethite and haematite because of small amounts of easily reducible iron. Young acid sulphate soils with abundant colloidal iron are likely to yield higher dissolved iron concentrations following flooding.

Brinkman (1970) reported that displacement and loss of bases by Fe^{2+} may cause acidification or ferrolysis.

Ponnamperuma (1972) and Parfit (1978) reported that sulphate is dissolved by both crystalline and amorphous iron oxides. The increase in concentration of water soluble iron when acid soils are flooded is due to desorption of SO_4^{-2} following reduction of oxides.

Money and Sukumaran (1973) reported that water soluble iron upto 140 and 100 ppm is found in the kari and karapadom soils respectively. Maximum value of soluble iron observed in kayal soil was only about 40 ppm .

Pisharody (1968) studied forms and distribution of iron and manganese in six soil profiles of Kerala. He noted that variation in the water soluble, exchangeable, reducible and active forms of Fe were from 9.0 to 45.1, 6.2 to 58.6, 5.0 to 100.8 and from 26.9 to 202.4 ppm respectively. These results indicate that the soils were adequately supplied with available form of Fe.

Aiyer et al (1975) reported that on a comparative basis kayal soils have a significantly lower amount of available iron compared to the kari and karapadom soils. They also reported that iron toxicity is likely to be more serious in kari and karapadom soils than kayal soils.

10.4 Aluminium content

Nikolsky (1963) reported that the toxicity limit of aluminium and iron for fish is 0.2 mg/l and 0.5 mg/l respectively. Such concentrations develop in the overlying water of acid sulphate soils.

Van Breemen (1973) has shown that Al^{3+} activity is inversely related to pH, increasing roughly ten fold per unit pH decrease. He also reported that aluminium concentrations of ground water from acid sulphate soils in Thailand will range from 0.4 ppm at pH 5.5 to 54 ppm at pH 2.8.

10.5. Sulphur content

Moorman (1963) reported that the accumulation of sulphides and in particular pyrite is quite common in marine and estuarine deposits all over the world.

Sukumara Pillai and Money (1967) have reported that sulphate sulphur per cent of kari soils of Kerala ranges between 1.2 and 4.3. In these soils free sulphuric acid is formed by the oxidation of sulphur compounds present in the wood fossils found under the soil.

Money and Sukumaran (1973) reported that the amount of sulphate in kayal soil is much lower than those of kari and karapadom soils. Total content of sulphur is high, it varies with layers in the profile. Sulphide is found in the lower layers and sulphate in the exposed upper layers.

Karwasara et al (1986) reported that inorganic sulphur was more than organic sulphur due to rapid oxidation by high soil temperature. Total inorganic and organic S were positively correlated with organic carbon texture, clay, clay + silt, and CEC. Heat soluble S has significant correlation with organic carbon only. Generally in heavy textured soils more organic carbon and sulphur are present. Available forms of S namely Morgan's Reagent, water and heat soluble were not correlated with texture and CEC. pH was found to have no effect on any of the forms of S.

10.6 Organic carbon, organic matter

Money and Sukumaran (1973) reported that the kari and karapadam soils of Kerala contain fair amounts organic matter. Kayal soil have low status of organic matter. Kari and karapadam soils have organic carbon of about 15 percent, while kayal have values below 4.0 percent.

10.7 Soil Cation Exchange Capacity(CEC)

Money and Sukumaran (1973) reported that the kari, karapadam and kayal soils recorded values of cation exchange capacity in the range of 15.4 to 40.7, 16.4 to 37.8, and 12.8 to17 milli equivalents per hundred grams of soils respectively.

Venugopal and Koshy (1978) observed that CEC of the clay fraction of the laterite and red soil indicated the preponderance of kaolinite type minerals in them.

11. **Sand mineralogy**

Siddiquie (1966) and Viswanathan (1965) reported that the heavy minerals of beach sand and coastal soils are ilmenite, zircon, rutile, monazite, sillimanite and others such as garnet, staurolite and tourmaline. They are products of the action of rivers which carried them to the coast. The heavy minerals are thought to be derived from crystalline basement rocks chiefly granitic - gneissic-charnokite - norite types.

Sharma et al (1984) reported that light mineral fraction accounted for 94 to 97.2 percent of fine sand mainly quartz followed by feldspars and mica. Among the light minerals the quantity of quartz ranged from 53.0 to 75.8 percent. They also reported that the formation of secondary quartz requires alternate wetting and drying cycles in the soils, and that the silica redissolved on wetting is not completely removed by leaching. Chlorite was present due to alkaline reaction and reducing conditions. Heavy minerals constituted 2.8 to 5.5 percent of the fine sand fraction. Among these the opaque minerals magnetite, and ilmenite were 50 to 70 percent of heavy minerals. Presence of euhedral crystals of zircon to the tune of 2.5 to 14 percent in the heavy mineral isolated and tourmaline between 3 and 5 percent was also detected.

Villar Celoria et al (1985) reported that the reducing conditions prevalent in the hydromorphic soils curb the weathering of their component materials as is shown by higher proportion of weatherable minerals (feldspars and ferromagnesions) in their sand fraction, and their low levels of free iron, aluminium oxides. The low level of free iron oxide is favoured by the solubility, and leaching of reduced ferrous iron.

12. **Clay mineralogy**

Gopalaswamy (1961) reported that the clays of Moncompu profile showed an appreciable amount of alumina. Calcium oxide existed in traces in the clay fraction of most soils. The percentages of MgO and K_2O were appreciable. Clays of most of these soils had high content of non-exhangeable potassium indicating the presence of illitic as well as montmorillonitic minerals.

Kawaguchi and Kyuma (1969) reported that three types of clay mineral composition in the world rice soils. Of the three types 7 -dominant type (kaolinite type) be regarded as the most weathered and 14 dominant type (2:1 minarals) as the least weathered. The 14-7 and 7-14 combination occur most frequently among the soils developed on recent alluvial as well as deltaic sediments.

Hattori (1978) reported that acid sulphate soils derived from brackish alluvial sediments contain a considerable amount of Al-interlayered minerals (Thailand and Cambodia). He has reported that soils derived from riverine alluvial sediments contain 2:1 type of minerals of vermiculitic nature, 10 Å minerals and minerals without the dominance of species (Western Japan, Central Plain of Thailand, Burma, Bangladesh, India and Sri Lanka).

Kawaguchi and Kyuma (1969) measured the amount of exchangeable Al and silica released in the course of drying of Fe_2^{+} - montmorillonite. Depending on the partial pressure of oxygen during the drying process the extent of clay destruction varied ie. higher the oxygen partial pressure, the higher the amount of aluminium and silica released. The intensity of the charactaristic peak of clay in the X-ray diffractogram showed a corresponding difference; the most drastically oxidised clay showed the lowest peak height. Brinkman (1970) gave attention to the same phenomenon and named the process "ferrolysis". This is in effect chloratisation under a reduced environment.

Yoshida and Itoh (1974) postulated the possibility of Al - interlayering of expanding 2:1 type clays, leading to lowering of cation exchange capacity.

Van Breemen (1976) identified haematite in the red mottles occurring in certain acid sulphate soils of Thailand. He ascribed its occurrence partly to the dehydrating terrain conditions and partly to the strong acidity.

Ghosh et al (1976) in his studies on the acid sulphate soils of Kerala revealed the occurrence of Kaolinite and halloysite (18-32 per cent), in association with smectite (18-32 per cent), illite (6-12 per cent), chlorite (4-11 per cent). In addition gibbsite (upto 4 per cent) and traces of amphibole together with quartz and feldspars were detected.

Douglas (1981) reported that the formation of smectites is highly dependent on both the type of parent material and on a soil environment that discourages formation of aluminium polymers ie. a low pH or the presence of organic Al complexing compounds.

Pombo et al (1982) reported the presence of Maghaematite in the coarse clay fraction of both Ap and B_{22} horizons of the latosols.

Wakatsuki et al (1984) had reported that prolonged paddy cultivation brought about modification in the clay minerology of Ap horizons. Characteristic changes consisted of the formation of 18 - 25 Å minerals, composed of interlamellar humus-smectite complexes and interstratified minerals.

Huang et al (1987) reported the clay mineralogy and elemental composition of 7 clayey low land soils in the tropical an sub tropical regions of China. The predominant clay minerals varied from kaolinite to illite and montmorillonite, depending on parent material. A tendency to desilication was observed. Totaliron decreased with depth while Al increased. Factor analysis showed that the major elemental compositions were Si-Al, Si-Al-K-Mg, Si-Al- Fe-Mg or Si-Al-Mg-Fe.

Shamshuddin et al (1986) reported that the acid sulphate soils of peninsular Malaysia have yellowish mottles of jarosite and/or natrojarosite. The other minerals present are kaolinite, mica, mica-smectite and smectite. The soils were highly buffered at pH 3 - 5, which was due to the presence of high levels of aluminium.

13. **Chemical and physical process in Acid Sulphate Soils**

Dent (1986) reported that the main chemical process in the development the acid sulphate soils is the gradual formation of pyrite in a waterlogged environment. Subsequently this pyrite gets oxidised by aeration due to natural or artificial drainage. He also reported that the essential conditions for pyrite formation are an anaerobic environment, a source of dissolved sulphate, organic matter, a source of iron, and time. He reported that waterlogged sediments rich in organic matter create reducing conditions, reduces sulphates.

Pons et al (1982) reported that from elemental sulphur poly sulphides are generated in the acid sulphate soils due to intermittent or localised oxidation.

Chenery (1954), Thomson (1972) and Poelman (1973) reported that the source of dissolved sulphates for pyrite formation in the acid sulphate soils may be from sea water, brackish water or sulphate rich ground water.

Harmsen (1954) and Berner (1970) reported that the amount of sulphide produced in acid sulphate soils are related to the amount of organic matter metabolised.

Van Beers (1962) and Rickard (1973) reported that the supply of organic matter is the common limiting factor for the amount of pyrite produced in acid sulphate soils.

Goldhaber and Kaplan (1974), Howarth (1979) reported that pyrite is formed within ten days by direct precipitation from dissolved Fe^{2+} and polysulphide under favourable conditions in the acid sulphate soils.

Arkesteyn (1980) reported that at low pH <u>Thiobacillus ferroxidans</u> oxidises reduced sulphur species and iron II thereby returning iron III to the system in the acid sulphate soils.

Singer and Stumm (1970) reported that at pH value lower than 3.5 chemical oxidation of pyrite is a slow process, with a half time of the order of 1000 days in the acid sulphate soils.

Dent (1986) reported that whenever there is waterlogged soil or sediment with a pyrite sulphur content greater than 0.5 per cent, the amount and distribution of carbonates determines whether or not an acid sulphate soil can develop.

Kooistra (1978) suggested that sulphide oxidation at low tide may also generate acidity. Under this condition carbonates are dissolved. Dent (1986) reported that in tropical estuarine sediments the conditions for insitu carbonate and high pyrite accumulation is found to be mutually exclusive. Dent (1986) further reported that goethite is the most commonly identified iron oxide in the acid sulphate soils. Some times it will be slowly transformed to haematite. Characteristic pale yellow deposits of jarosite precipitate as pore fillings and coating on ped faces under strongly oxidising severe acid conditions, has been noticed.

Dent (1986) reported that reaction of pyrite with oxygen is slow, whereas that with ferric ion is fast and is catalysed by the bacterium - Thiobacillus ferroxidans. In this and similar situations it is the view of Arkesteyn (1980), that autotrophic organisms like this, which also appear to be ubiquitous in acid sulphate soils help to overcome the kinetic barriers that exist in purely chemical sytems. The usual way to control this oxidation is to add large amounts of lime which maintain a pH at a level where ferric ions are insoluble, and Thiobaccilus ferroxidans is rendered inactive. At high levels of pyrite the rate determining step is oxidation to ferrous ion, at low levels it is the oxidation of pyrite by ferric ion. They have also reported that they have achieved to deter this process in the laboratory using either a bactericide to kill Thiobacillus thioxidan s or 1:10 orthophenanthroline, which is specific chelating agent for ferrous ions.

14. **Soil genesis and weathering**

Zhang Xiao - mian (1981) reported that in the process of gleysation of rice soil a large part of free iron oxides in the clay fraction is reduced and leached, with a resulting formation of greyish blue or grey gley horizon.

Brammer (1971) reported that the clay coatings which are referred to as argillans in the field, normally result from the natural clay illuviation process but they can also be the result of irrigation, localised alteration of clay minerals.

Nettleton et al (1987) reported that the climatic shifts and continued intense weathering apparently are responsible for the formation of Ca-clays and the Fe and Mn-oxide concentrations causing poor dispersion.

Carsow and Dixon (1985) had reported that SEM indicated jarosite occurred as cubes and octahedra. These isometric form suggest jarosite formation from pyrite present in the parent material. Smectite and kaolinite are the major clay constituents and they are both poorly crystalline in the major A and B horizons.

Slager et al (1987) reported that during the geogenesis stratified sediments are formed, above which are the sedements with slightly disturbed stratification with or without a matrix of faecal pellets. Pedogenesis during the sedimentation phase included development of channels in the sediment, formation of channel neo ferrans, biological homogenisation, pyrite accumulation and partial oxidation and precipitation of iron as ferric hydroxide. During brackish water phase pyrite accumulates in various amounts, mass eluviation may occur, part of the pyrite may be oxidised and precipitation of iron, as ferric hydroxide occurs, ferric hydroxide crystallises into goethite. Pyrite becomes oxidised resulting in the formation of jarosite, gypsum, silica and ferric hydroxide.

15. Soil Classification

Dent (1986) reported that the broad concept of acid sulphate soils encompasses unripe saline soils that will become acid if drained, unripe severely acid soils, and ripe aluminium saturated soils that are severely acid or potentially acid in the deep sub soil.

Central to the classification of actual and potential acid sulphate soil in Soil Taxonomy (USDA, 1975) are the occurrence of a sulphuric horizon or sulphidic material. A sulphuric horizon is composed of mineral or organic soil material with a pH less than 3.5 and yellow jarosite mottles. Sulphidic materials are waterlogged mineral or organic soil materials 0.75 percent sulphur and less than 3 times as much cabonate ($CaCO_3$ equivalent) as sulphide sulphur.

Potential acid sulphate soils are either Sulfaquents (Aquents with sulphidic material within 50cm of the mineral soil surface), Sulfic Fluvaquent (Fluvaquents with sulphidic material between 50 and 100cm depth).

In most cases mineral acid sulphate soils cropped to rice can be classified as Sulfaquepts (Aquepts with a sulphuric horizon that has its upper boundary within 50 cm of the soil surface), Sulfic Tropaquepts (Tropaquepts with jarosite mottles and a pH 3.5 - 4 somewhere within the 50 cm depth or with jarosite mottles and a pH less than 4 in some part between 50 - 150 cm depth), or Sulphic Haplaquepts (comparable to Sulfic Tropaquept but under a more temperate climate). But the clay content in these horizons does not show sharp change as compared with horizons just above or beneath it. The smectite peaks increased steadily with depth hence no evidence for clay translocation or destruction can be drawn.

Gorbunov (1963) reported that the sodic condition bring about degradation of clay minerals leading to accumulation of amorphous oxides of slica, alumina and iron associated with repeated synthesis of clay mineral).

The FAO - UNESCO Soil Map of the World, scale 1:5,000,000 (FAO/ UNESCO, 1974) distinguishes Thionic Fluvisols with a sulphuric horizon of sulphidic material or both, within the 125 cm depth. So Thionic Fluvisols include potential and actual acid sulphate soils.

Kawaguchi and Kyuma (1969), Tanaka and Yoshida (1970), Van Breemen (1976) and Van Breemen and Pons (1978) have reported that within the limits of the diagnostic criteria, acid sulphate soils vary widely in their physical and chemical properties.

Van Breemen and Pons (1978) reported that in acid sulphate soils eventhough the content of clay and organic matter is high the unbuffered CEC is normally low (10-25 meq/100g) due to low pH and chloratisation of swelling clay minerals. They also reported that the pH of surface soil is normally 3.5-6.5 in sulfaquents, 3-4 sulfaquepts and 4-5 in sulphidic Tropaquepts; a pH below 3 is exceptional.

In Soil Taxonomy (USDA, 1975) it has been reported that the pH of potentally acid soils drops below 3.5. Simple air drying of the soils in the shade give inconclusive results because microbially induced pyrite oxidation is hampered once the soil is dry.

Paramanathan and Gopinathan (1982) reported that a 'cat clay' or acid sulphate layer is one with a pH of about 3.3 or less on the air drying soil and a soluble sulphate content in the air dried soil exceeding 0.1 per cent. They reported that in acid sulphate soils the main diagnostic horizon for the inceptisols have been over ruled by the sulphidic subsoil where its upper limit occurs within 50 cm. The sulphidic material derives its importance from its chemical acidifying potential, to which the genetic significance of the cambic horizon has been sacrificed. The presence of sulphidic material between 50 cm and 100 cm in Inceptisols without a clear sulphuric horizon, could be given due recognition. With this criteria such soils are classified as Typic Tropaquepts. They proposed that a sulphidic subgroup be established to indicate soils having a cambic horizon overlying sulphidic material within one meter. The above mentioned situation in Malaysia would thus be classified as sulphidic Tropaquept. Soils with sulphidic material within 50 cm but overlain by a well developed cambic and/or sulphuric horizon would then fall into sulphidic Tropaquepts and Typic Sulfaquepts respectively.

Segalen (1979) distinguished acid sulphate soils as per ORSTOM classification within the class of saline soils. Two sub classes are distinquished, Thiosols - soil with a reduced 'thion' within 60 cm of the surface. A Thion has more than 0.75 per cent oxidisable sulphur and becomes acid upon oxidation. Sulphosols - soil with an oxidised 'sulfon' wihin 60 cm of the surface. A sulfon has jarosite mottles, free sulphuric acid, more than 0.75 per cent sulphur and a pH less than 3.5. These correspond to potential acid sulphate soils and actual acid sulphate soils. The definitions are based on Soil Taxonomy and suffer the same difficulties.

Dent (1986) reported that in the ILRI nomenclature for acid sulphate soils a distinction was made between peat and non peat. Distinction of sandy and clayey groups within the mineral soils distinction of raw acid sulphate soils, ripe acid sulphate soils and acid aluminium soils according to reserves of pyrite and sulphate acidity has also been made in the ILRI classification. Separation accordng to climate has been tackled by adopting different diagnostic depth limits according to the potential soil water deficit.

Bharghava and Abrol (1984) classified soil as tropaquents because the mean summer (March, April, May), and winter (Nov.-Dec.) temperatures at 50 cm depth differ by less than $5^{o}C$. Soils at Arikulam, Calicut are sulfohemist since sulphuric horizon has its upper boundary within 50 cm of the surface, at Elakunnapuzha, Ernakulam, is hemistic aquents, ie, aquent with hemic material underneath, and Ambalapuzha Alleppey soils are sulfaquents; aquent with sulphidic material that has its upper boundary within 50 cm.

Osborne (1984) in the acid sulphate soils reported that the mean pH of the jarositic horizons was 3.64 + 0.20 within 40- 60 cm depth. This suggests that definition of sulphuric horizon requires an amendment. Pyrite, may according to him, reform during the flooding period.

MATERIALS AND METHODS

MATERIALS AND METHODS

In order to study the stage by stage morphology (macro, meso, micro and submicro), sand and clay mineralogy as well as physical and chemical properties of the acid sulphate soils of Kerala two profiles each from kari (Karumadi) karapadam (Moncompu), kayal (Mathikayal) pokkali (Vytilla) kole (Kattukambal) and kaipad (Kattampally) areas were collected. These locations selected represent the different acid sulphate soil environments of Kerala. The soils profiles of all the sites are located 1-2 metres below mean sea level, waterlogged during the major part of the year and are under rice and fish culture.

Kari, karapadom, kayal, and pokkali areas receive moderate rain fall and kole and kaipad receive moderate to heavy rainfall.

1. Kari land is situated in marshy inland basins.
2. Karapadom is situated in reclaimed marshy basins.
3. Kayal lands are situated in marshy inland basins flushed with sulphate rich waters.
4. Pokkali and kaipad areas are situated in saline and brackish water tidal swamp and
5. Kole lands are situated at marshy inland valleys flushed by sulphate rich waters.

At kari, karapadom, kayal, pokkali, and kole areas two crops of rice are raised while only one crop is raised at kaipad areas of Kattampally.

Two profiles were dug at each location 100 meters apart as per prescribed procedures. The profiles were dug to a depth of one meter.

Field description-Macromorphology

The profile features and insitu observations were recorded as per FAO guide lines for soil description (1978).

After demarcating each horizon, undisturbed soil samples were taken using 'Kubiena box'. Core samples were collected to determine bulk density, aggregate analysis and moisture retention characteristics. The bulk samples were also collected from each horizon for other physical and chemical analyses. Composite samples were also collected from 0-50 cm depth from each profile, for mineralogical analysis. The colour of the soil was recorded using Munsell Soil Colour Chart. The colour on field moist and air dried soils were recorded.

Laboratory Studies

All bulk samples were air dried in shade. Clods were broken with a wooden mallet. Then the samples were sieved through a 2mm sieve.

1. Physical properties.

1.1. Soil Colour

The Soil colour was determined using the Munsell Soil Colour Chart (1958).

1.2. Granulometric analysis

The granulometric analysis of the soil samples from each horizon and 0-50 cm depth samples from each soil profiles were determined by the Robinson's International Pipette method after oxidation of organic matter with 30 percent v/v hydrogen peroxide. Cementing agents were removed by treating with hydrochloric acid and sodium hexametaphosphate was used for soil dispersion (Black, 1965).

1.3. Bulk density

Bulk density was determined by core method as described by Gupta and Dakshinamurti (1980).

1.4. Aggregate analysis

Aggregate analysis was done by wet sieving using Yoder's apparatus as described by Gupta and Dakshinamurti (1980).

1.5. Moisture retention characteristics

Moisture retained by the soil at 1/3 and 15 bars were determined by pressure plate apparatus as described by Black (1965).

2. Chemical properties

2.1. Soil reaction (pH)

The soil pH was determined using 1:1 soil water suspension with Perkin Elmer pH meter.

2.1.1 Soil pH was determined in soil (Dent, 1986)

2.1.2 Soil pH was determined in air dried soil (Dent, 1986)

2.1.3 Soil pH was determined in air dried, 30 percent v/v hydrogen peroxide treated soils (Dent, 1986).

2.2 Redox potential (Eh)

Redox potential of the soil samples was determined using 1:1 soil water suspension using platinum electrode with Perkin Elmer pH meter.

2.3 Electrical conductivity (EC)

Electrical conductivity was determined in 1:1 soil water suspension using direct reading conductivity meter 'Systronics' model 303 by the method described in Agriculture Handbook No. 18 (1951).

2.4 Organic carbon

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

2.5 Total Iron and Total Aluminium

Total iron and total aluminium content was determined in a diacid (Nitric acid and perchloric acid) extract of the soil using Atomic Absorption Spectro Photometer as per the procedure sugested by Black (1965).

2.6	Water soluble iron	: Jackson (1973)
2.6.1	Exchangeable iron	: Jackson (1973)
2.6.2	Active iron	: Asami and Kumuda (1959)
2.7	Exchangeable aluminium	: Jackson (1973)

2.8 Sulphur content

2.8.1 Organic sulphur was extracted by the method of Evans and Rost (1945)

2.8.2 Sulphate sulphur

Sulphate sulphur was extracted with 0.15 per cent $CaCl_2$ solution. (Hesse, 1971)

2.8.3 Heat soluble sulphur

Heat soluble sulphur was extracted by the method of (Hesse, 1971)

2.8.4 Water soluble sulphur

Water soluble sulphur was extracted by the method of Freney (1958)

Sulphur in soil extracts was determined by colorimetric method (Jackson, 1973).

3.0 Cation exchange capacity

Cation exchange capacity was determined using neutral normal N ammonium acetate at pH 7.0, (Black, 1965).

4.0 Mineralogical analysis of fine sand fraction of soils

The fine sand was separated from 0-50 cm depth from each of the profiles and examined under Leitz ortholaux petrological microscope. Separation was based on Stoke's law (Carver, 1971). Preparation of fine sand was done by combined methods of Kilmer and Alexander (1949), Jackson (1956), Mehra and Jackson (1964).

Slides of the fine sand was prepared (Carver, 1971) for microscopic examination. Microscopic analysis of the sand mineral slides were done following the procedure described in USDA Soil Survey Investigation Report SCS, (1975), (Black, 1965)

5.0 Meso morphology

From undisturbed samples collected in the Kubiena box after impregnation with Canada balsam (Refractive Index 1.54) and curing, a small chip was sawn off, one side was ground flat and polished and fixed on a flat microscopic slide with Lakeside Cement - 70. The upper surface of the chip on the slide was ground and polished using different grades of carborandum powder and alloxite powder respectively. These polished blocks were then examined under reflected light and under magnification of 100x. Photomicrographs were taken and interpreted (Fitzpatrick, 1980).

6.0 Micromorphology

The polished blocks prepared for mesomorphological observations are then thinned by grinding with carborandum 60, 120, 400 and 600 grade powders. Final polishing was done with alloxite powders of 800 and 1000 grade till the chip attained a thickness of 20 µ. A cover glass was then fixed on the thinned section using molten Canada balsam, avoiding air bubbles. Excess Canada balsam was removed by careful cleaning and washing with xylene. The slides were then put under Leitz ortholaux Petrological Microscope and observations were recorded under plane polarised light and crossed nicols (Brewer, 1976). Photomicrographs were taken and interpretations were made as per the procedures outlined by Brewer (1976), Stoops and Jongerius (1975), Easwaran and Banos (1975) and Fitzpatrick (1980).

7.0 Quantitative determination of Pyrite

Quantitative determination of Pyrite of the soils by microscopical method as described by Pons (1964) was done.

100 mg dry soil was weighed and mixed in a beaker with 10 ml of water. Homogeneous suspension was made by stirring with a policeman. Pipetted out a drop and placed on a microscopic slide. Nearly all the moisture was removed by evaporation and a small drop of glycerine was added. Covered with a cover glass of known surface area. Pyrite bodies were measured with an ocular micrometer at a magnification of 200X. They were counted in four size groups. Average weights of pyrite bodies within these pyrite size classes, calculated and then the per cent of pyrite was computed.

8.0 Mineralogical analysis of Clay fraction

8.1 X-ray diffraction Analysis (XRDA)

The clay for X-ray analysis was separated by the method of Jackson (1973). The clay samples was thoroughly washed with distilled water and then with methanol. The X-ray diffraction was carried out in a Philips 1140 X-ray diffractometer using copper $K\alpha$ radiation. An iron filter with a scanning speed of 5^{o} per minute was used. Estimation of clay mineral composition by determination of the relative areas of the diffraction peaks were made (Black, 1965).

8.2 Thermogravimetric Analysis (TGA)

The Thermogravimetric analysis were performed using Digital Thermogravimetric Analyser fabricated by Regional Research Laboratory, Trivandrum. Loss of weight for every 5^{o} temp rise were recorded up to 1000^{o}c.

9.0 Scanning Electron Microscopic Analysis of soils and soil fractions (SEM)

Soil chips of $5mm^{3}$ size, silt and clay sample suspension in glycerine were examined. Soil chips were fixed on the brass studs with Dotts Electro Conductor adhesive, clay suspensions were evaporated in these studs by air. These studs were fitted in the circular receptacles of the JFC fine coat ion sputter and under vacuum and 8 ma and 8 KV gold was coated (Blueish Violet fluorescence) for 4 minutes. Removed and placed in SEM and scanned. Observation of the samples was made under different magnification and SEM photographs were taken by ORWO Panchromatic NP 27/120 27 Din 400 ASA Films and interpreted (Easwaran, 1971; Stoops, 1974; Chen et al, 1976 and Bisdom, 1980).

10.0 Particle size distribution of soil fraction($<$0.005 mm)

The Sedigraph 5000 D particle size analyser was used to measure the particle size distribution ranging from 45 to 0.1 µm (350 mesh).

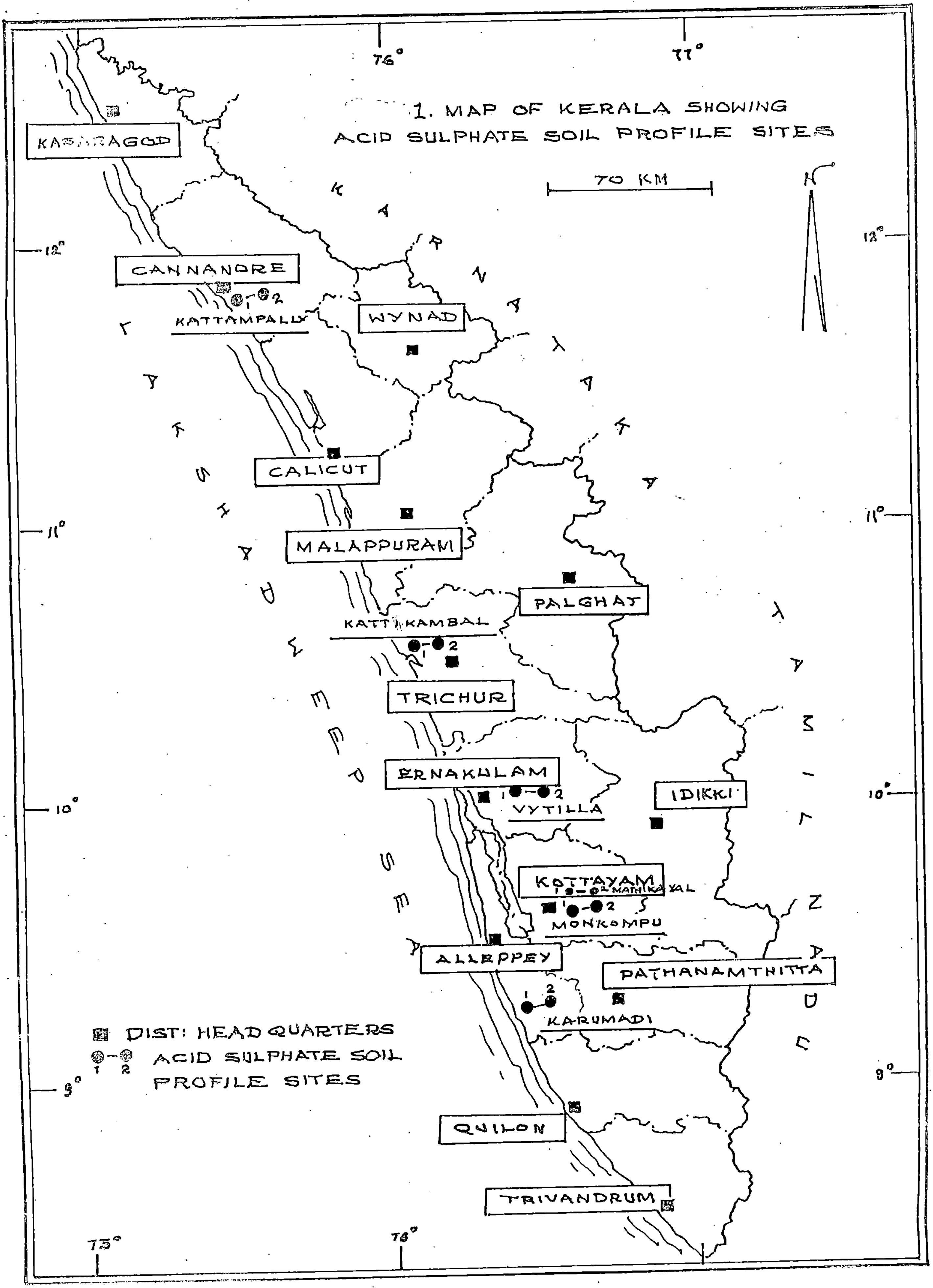
RESULTS

RESULTS

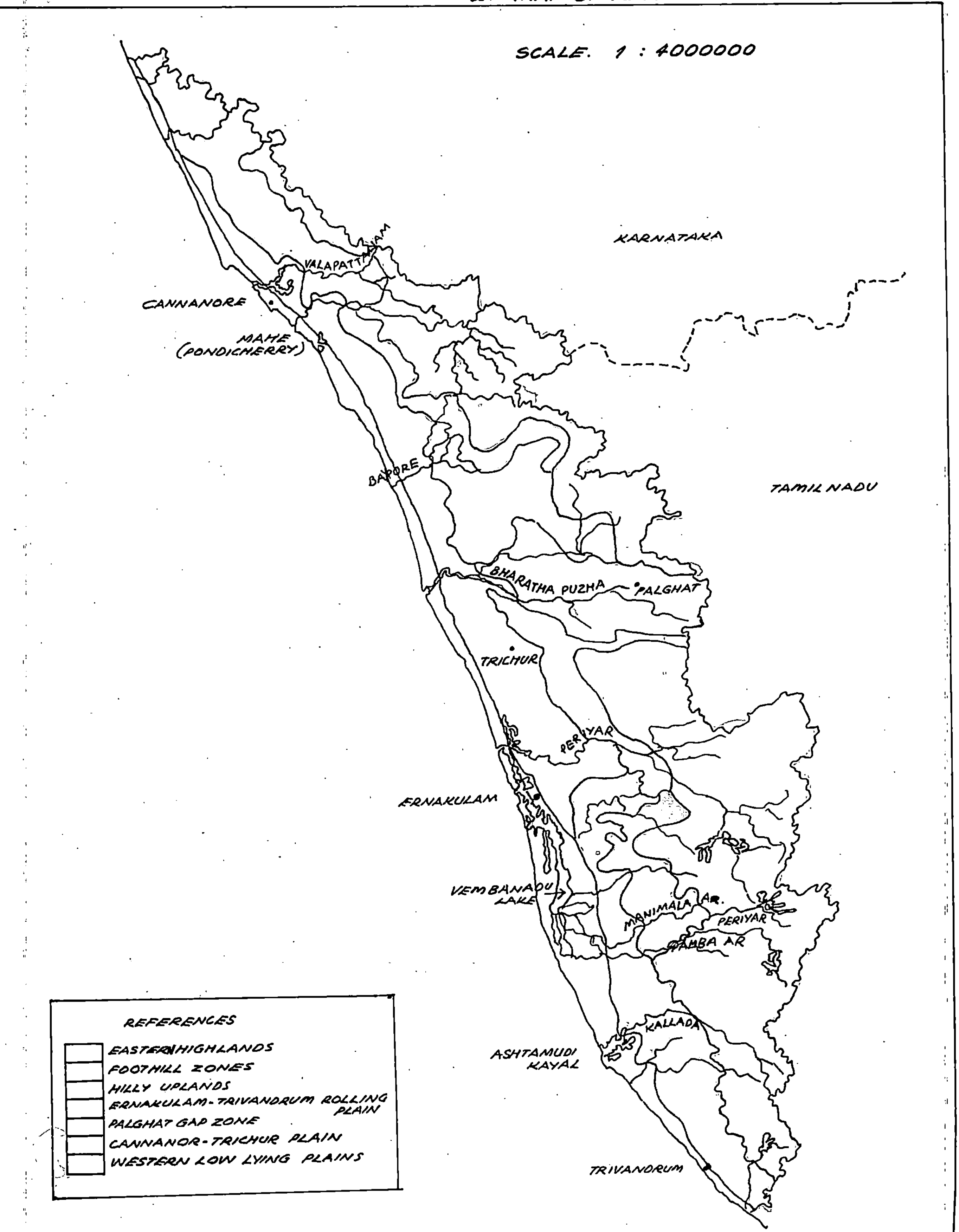
Acid sulphate soils cover an estimated area of 0.2 million hectares in Kerala State as discontinuous pockets within a narrow belt on the West coast. Locally these are known as kari (Karumadi), karapadom (Moncompu), kayal (Mathikayal) pokkali (Vytilla) kole (Kattukambal) and kaipad (Kattampally) soils. A study was undertaken to characterise macro, meso and micromorphology and clay mineralogy of these soils taking two representative soil profiles in each of these soil types.

1. Geology and Geomorphology

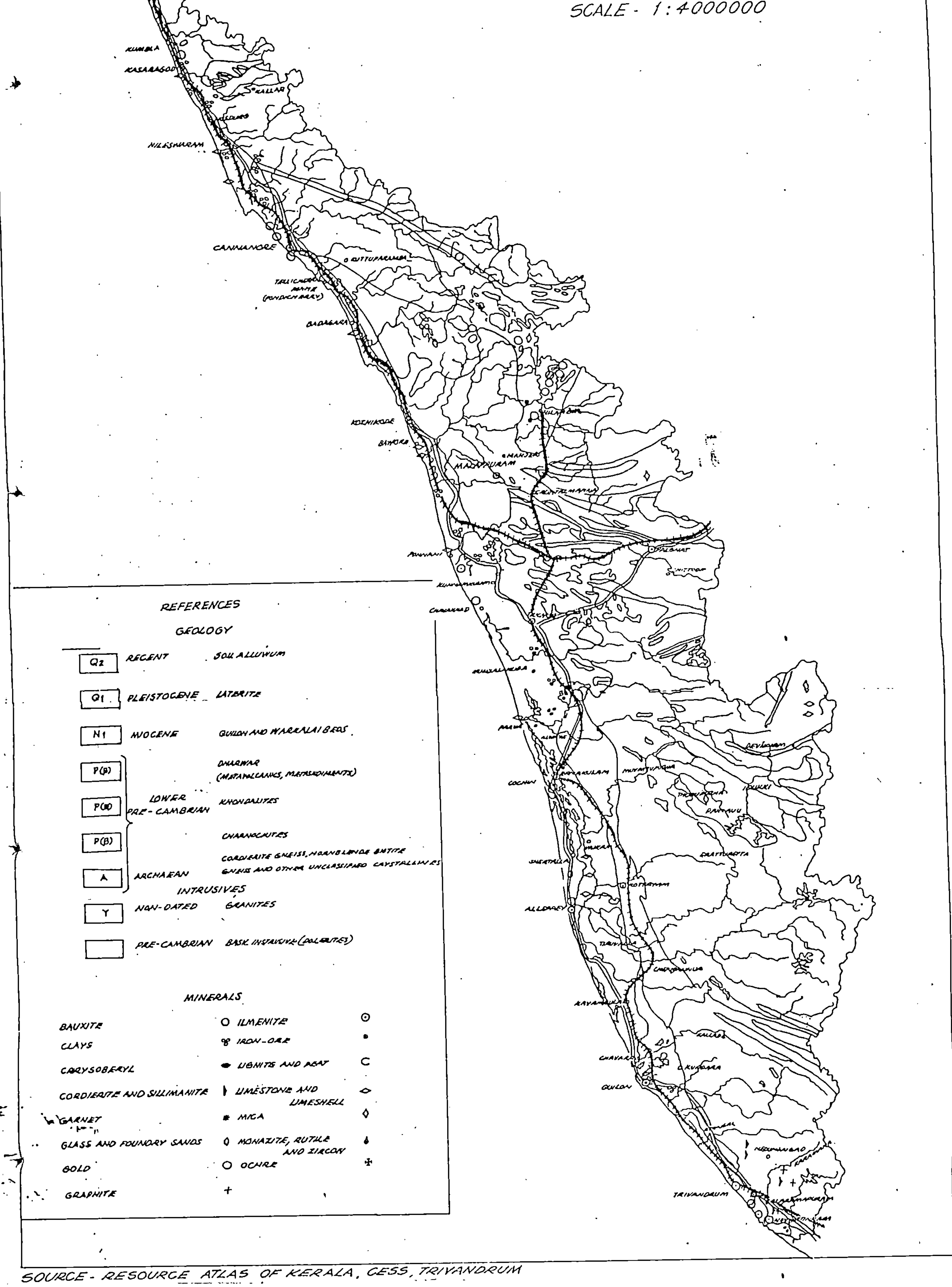
The Western Ghats on the Eastern boundary of the State are archean and are steep intially, followed by flat topped hills, terraced hills etc. many of them are laterite and lateritic formations. These formations constitute the midland region of the State. The coastal laterites are rem nants of these oldest features. Small outcrops of upper tertiary strata are found at places beneath the superficial cover of laterites. Along the coastal belt where acid sulphate soils are confined, other significant geologic formations are bright coloured sand and clay enclosing bands of lignite with lumps of fossil resin and pyritous clay - Warkalli formation (Wadia 1966). Occasionally these lie over limestone strata which are full of fossil molluscs, corals and forminiferers (Kayal lands and Kaipad lands of the present study). The most abundant being gastropods, mainly of middle miocene period.


1. MAP OF KERALA SHOWING ACID SULPHATE SOIL PROFILE SITES
70 KM
N
76°
77°
75°
12°
11°
10°
9°
KASARAGOD
CANNANORE
KATTAMPALLY
WYNAD
CALICUT
MALAPPURAM
PALGHAT
KATTUKAMBAL
TRICHUR
ERNAKULAM
VYTILLA
IDIKKI
KOTTAYAM
MANKAYAL
MONKOMPU
ALLEPPEY
PATHANAMTHITTA
KARUMADI
QUILON
TRIVANDRUM
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
DIST: HEAD QUARTERS
ACID SULPHATE SOIL PROFILE SITES

2. MAP OF KERALA - NATURAL REGIONS

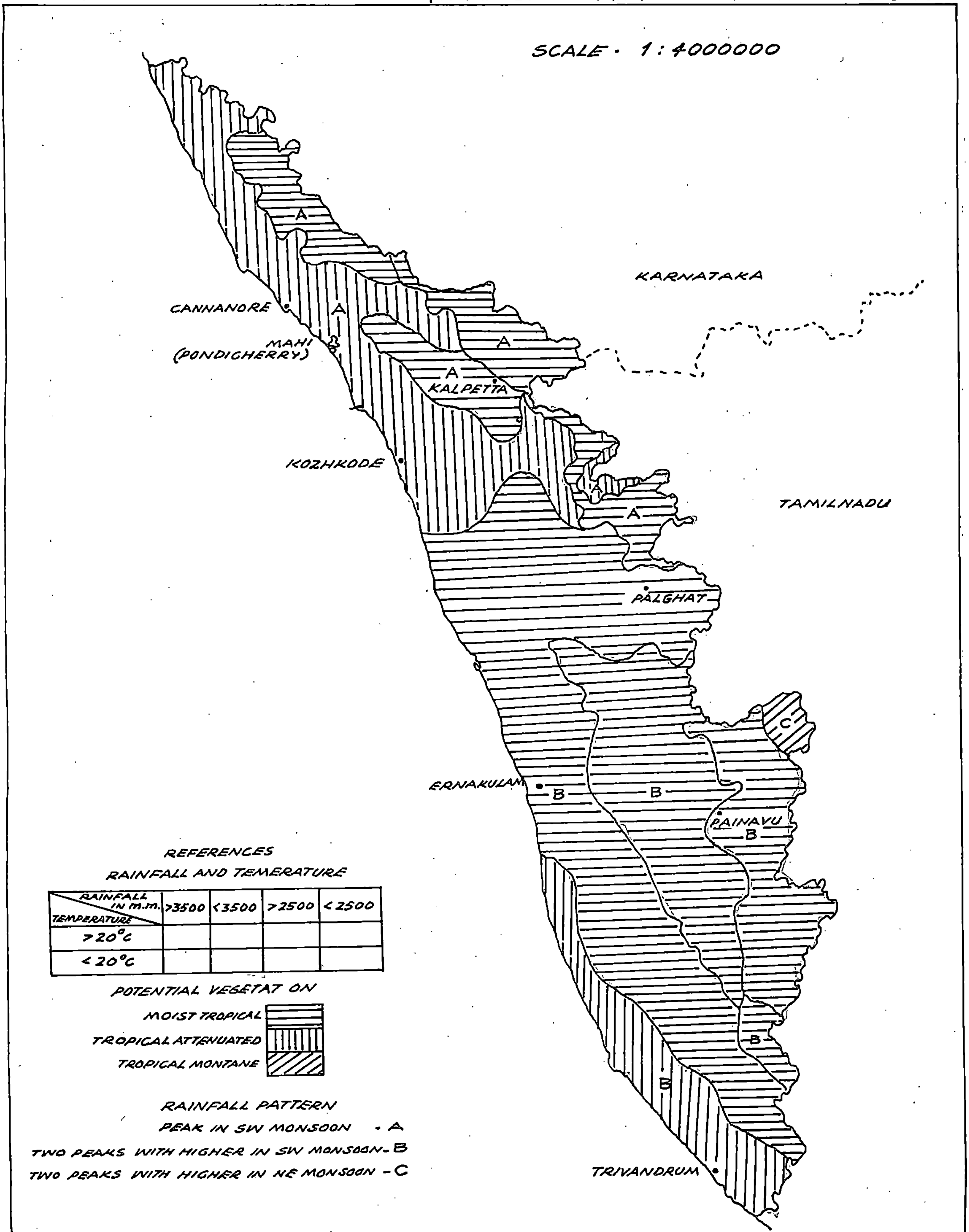


SOURCE: RESOURCE ATLAS OF KERALA, CESS, TRIVANDRUM



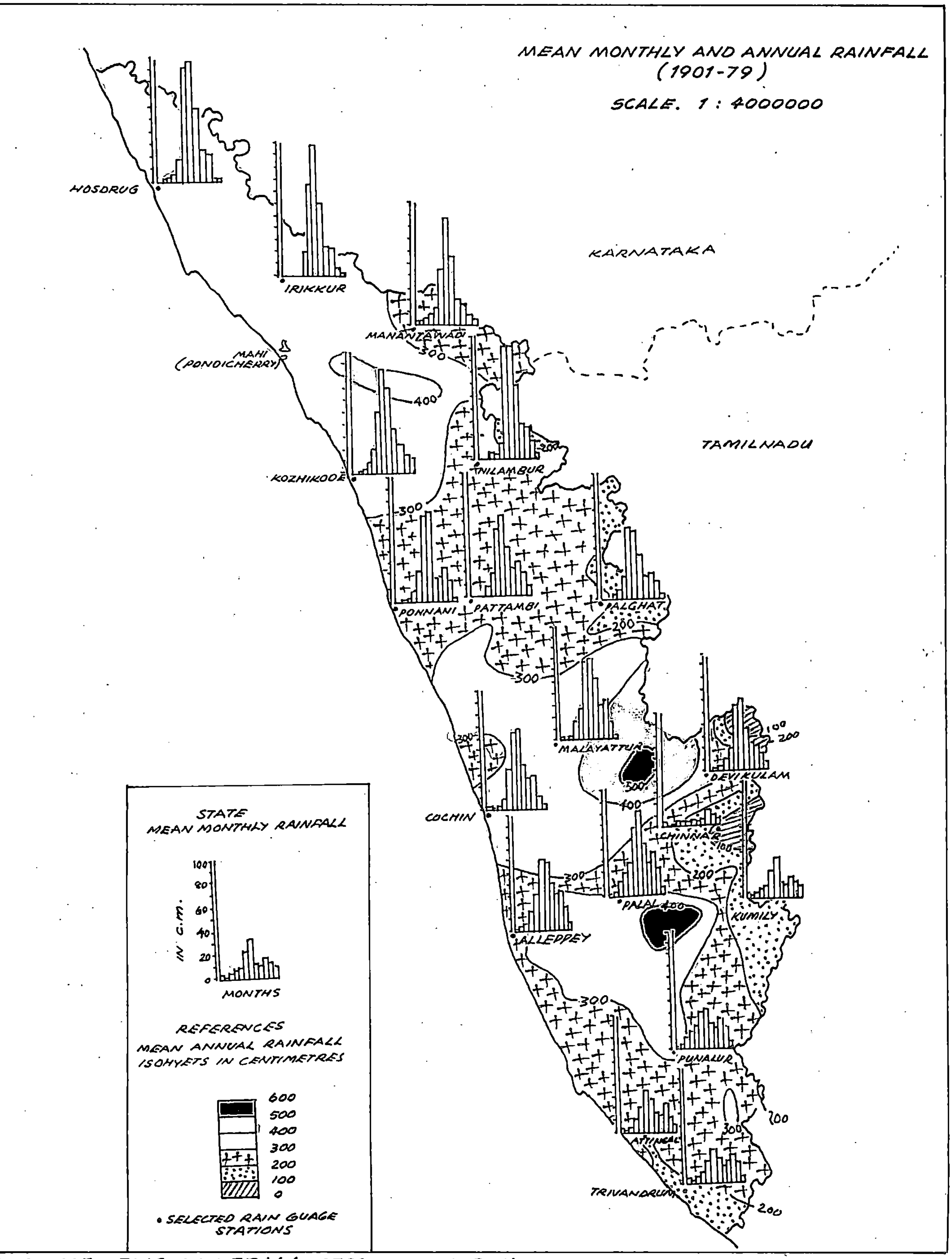
SOURCE - RESOURCE ATLAS OF KERALA, CESS, TRIVANDRUM

4. MAP OF KERALA - BIOCLIMATIC REGIONS



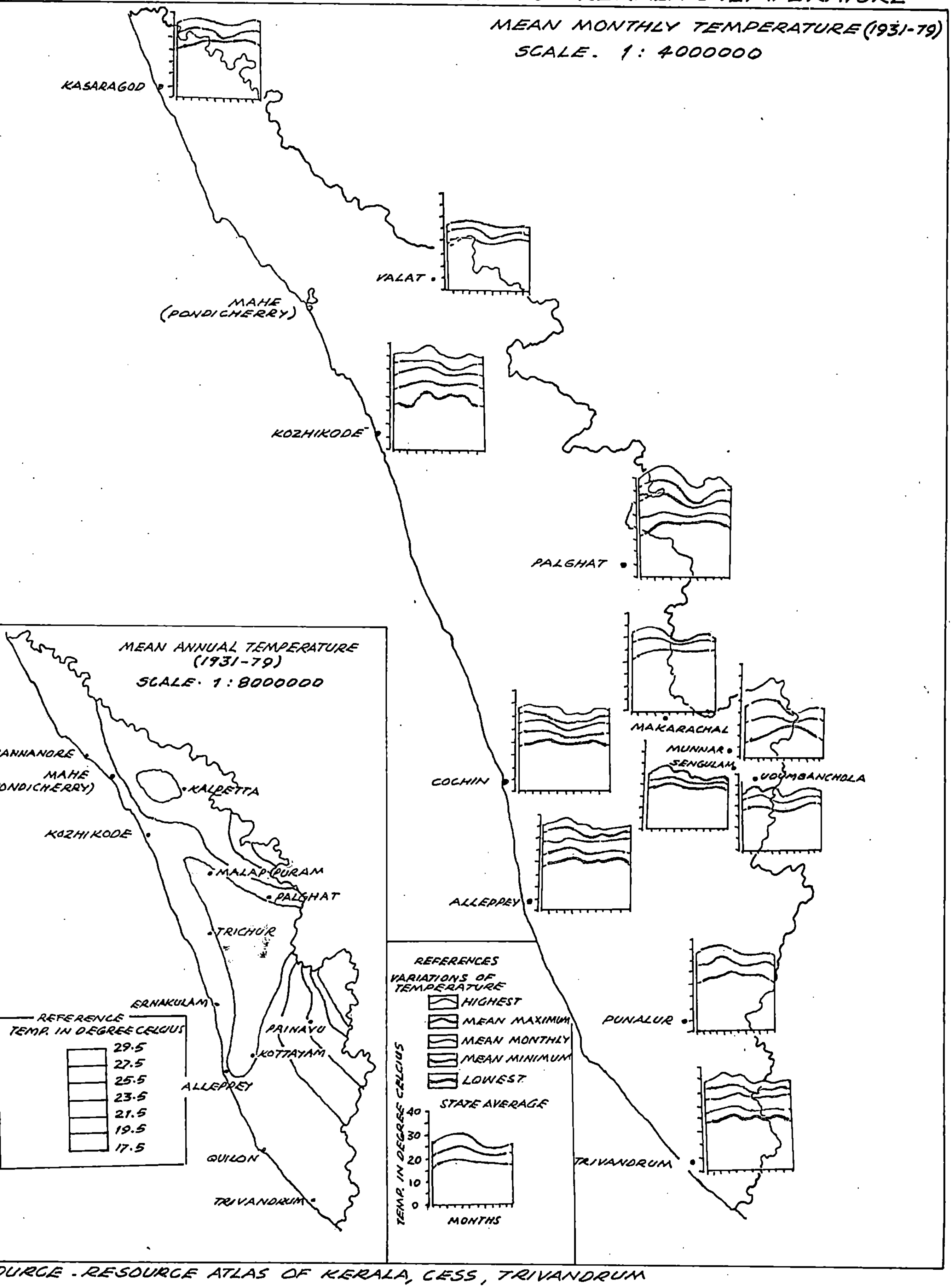
SOURCE - RESOURCE ATLAS OF KERALA, CESS, TRIVANDRUM

5. MAP OF KERALA - RAINFALL



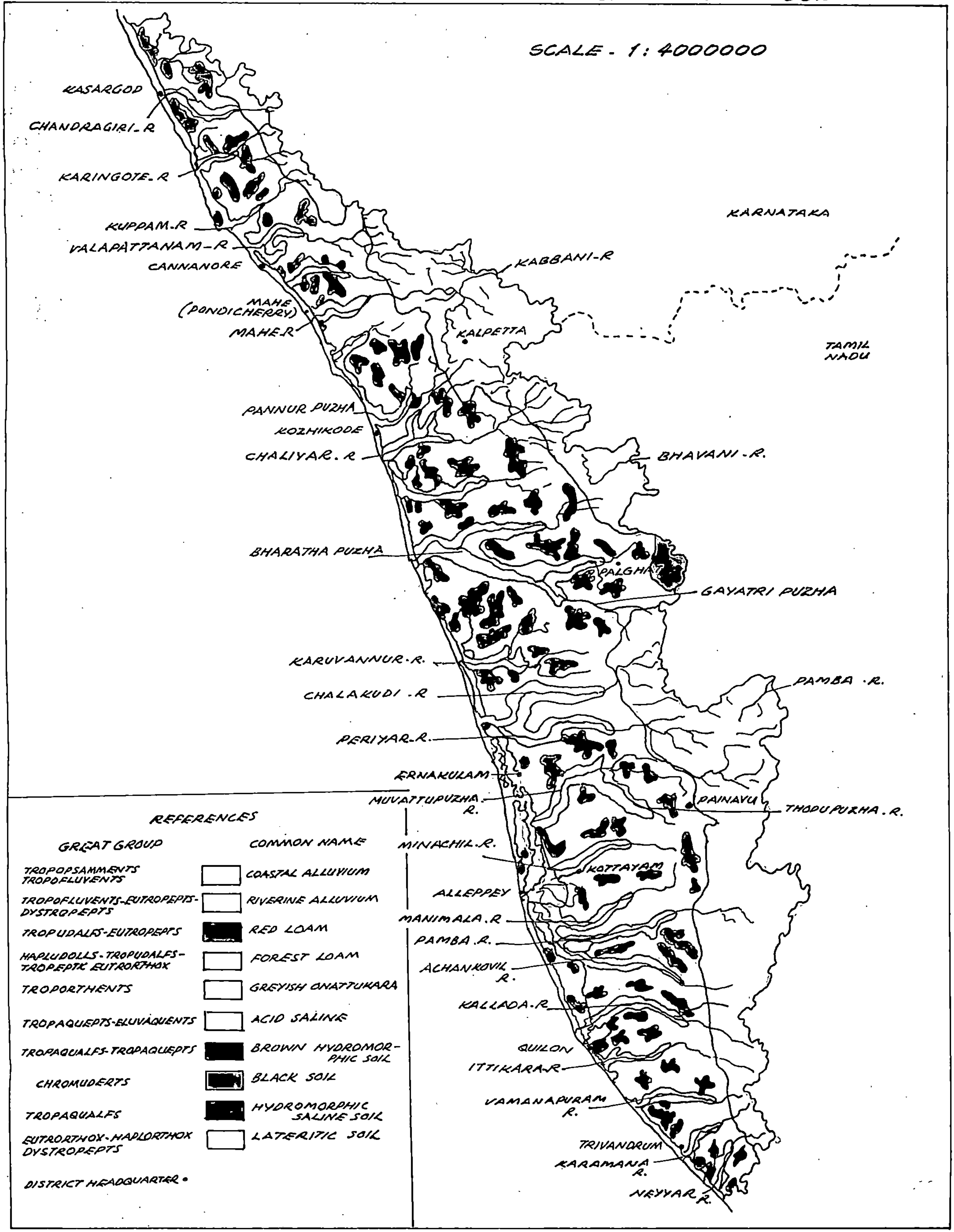
RESOURCE ATLAS OF KERALA CESS, TRIVANDRUM

6. MAP OF KERALA - TEMPERATURE



SOURCE - RESOURCE ATLAS OF KERALA, CESS, TRIVANDRUM

7. MAP OF KERALA - SOIL



SOURCE - RESOURCE ATLAS OF KERALA, CESS, TRIVANDRUM.

The laterite cap varies from pliocene to post tertiary (pleistocene) in age. The West coast of Kerala has a highly irregular inner shore of submergent aspect which encompasses several lagoons and lakes locally known as "kayals" with numerous islands within them. The lagoons or backwaters coincide with the lower reaches of the streams. Vembanad lake (75 Km in length) is parallel to the shoreline and elongated. Some of the lagoons are transverse like Kattukambal lake and Kattampally swamp. The formation of lagoons probably began with the submergence of the irregular terrain in the remote geologic past. Subsequent to this submergence as the major geographic event, the straightening of the outershoreline has been effected by the growth of offshore bars, spits bay mouth bars etc. The lagoons are continuously being silted up by the sediments brought by the streams and tidal flow. The profile sites are within 9^{0}-11^{0} **N** and 75^{0}-76^{0} **E** and their physiographic position is coastal lowland and elevation to mean sea level is 1.0 to 2.0 m. parent material of the profile soils are lateritic alluvium (lateritic falls and recent outwash).

2. **Climate**

The climate of the region is humid tropical. The mean annual rainfall ranges between 2342.7 mm at Karumadi and 2981.1 mm at Vytilla, Ernakulam District. The bulk of the rainfall is received from May to October. The lean period is from December to March. Due to excessive rainfall and substantial runoff received, these soils occupying lowlands remain submerged and wet from May to December with some/occasional rains from March to May. The annual

Pan ëvapotranspiration (PET) of these regions is around 1500 mm. and deficit conditions prevail from December to March. Humidity is very high and it is 77.5 per cent at Kattukambal, Trichur District and 79.0 per cent at Karumadi in Alleppey District. The mean maximum temperature is 30.0^{o}C at Moncompu, Kottayam District and 31.8^{o}C at Karumadi in Alleppey District. Mean minimum temperature is 22.3^{o}C at Moncompu, Kottayam District and 24.9 at Vytilla, Ernakulam District. The mean annual temperature of this region is 26.2^{o}C at Mathikayal, Kottayam District and 28.0^{o}C at Vytilla, Ernakulam District.

3. **Vegetation**

A variety of vegetation exist near the backwaters in the coastal region. Mangrove varieties in swamp followed by inland, saltswamps and salt pan veg etation.

Mangrove formations of this region are wholly arborescent though the trees become shrubby at the northern and southern geographical limits. The characteristic feature of mangroves are the tangled proproots where Rhizophora species predominate, of short aerial pneumatophores with Avicinnia and Sonneratia and knee roots associated with Bruguira. In the transition to brackish condition Acrostichum, Acanthus etc. are the principal undergrowths of mangroves.

The nearby dominant mangrove vegetation of these soil profile sites are Rhizophora apiculata and Bruguira gymnorrhiza at Karumadi, Moncompu, Kattukambal, while mangrove vegetation of Vytilla consists of Rhizophora mucuronata R. apiculata, Bruguira gymnorrhiza and B. parviflora and at Kattampally it consists of Avicinnia officinalis

A. marine, Exoccaria agallolcha, Kandelia cadela, Bruiguira gymnorrhiza and B. parviflora.

Mangrove fauna of this region is primarily composed of arthropods and molluscs with a variety of fish in the creeks and rivers. There are a variety of avian fauna such as Terns, Ardeoloa and Teals in this region.

Mangrove transition via brackish water swamp to fresh water of this region is characterised by reed communities. Phragmite , Typa and Scirpus are all taxa observed in this region. Mangrove areas of this region comes under the category known as "Tidal forests'.

4. **Agriculture**

Rice is a natural crop of choice for the vast stretches of these wetlands in the West coast of Kerala State. Floods, saline water intrusion, soil acidity and iron and aluminium toxicity are some of the major hazards to agriculture in this region.

Thanneermukkom barrage and Thottapally spillway at Kuttanad and Kattampally spillway at Kattampally have been constructed to protect flood and salinity intrusion endangering rice cultivation.

5. **Drainage**

The lagoons of this region are flooded with fresh rain water received from the uplands (May to November). The drainage problems of this region are further compounded by the ingress of sea water with alternate cycles of high and ebb tides. In view of this the drainage of the région is poor. The entire flood water of the Kutanad are through the Thottappally spillway kept open during the monsson seasons.

6. Soil Macromorphology

The comparative macromorphological features of the soils are presented table 1 & fig 1-1.5. The soils occupy depositional surfaces which continue to receive alluvium mainly from the surrounding laterite and lateritic hills. A great deal of heterogenity is revealed by the morphological characteristics.

6.1 Soil colour

The soil matrix colours in the epipedon are black (2.5 Y 2/0), very dark grey (2.5 Y 4/0), very dark greyish brown (2.5 Y 3/2), dark yellowish brown (10 YR 3/1), dark brown (10 YR 4/3) and dark yellowish brown (10YR 3/4).

6.2 Colour mottles

Variety of colour mottles are observed in different pedons. At Karumadi the prominent mottles observed are dark greyish brown (10 YR 4/4), pale yellow (2.5 Y 7/4), and light olive brown (2.5 Y 5/4) in epipedon and olive yellow (2.5 Y 6/8) in the subsurface layers. At Moncompu the epipedon is with olive yellow (2.5 Y 6/8), olive brown (2.5 Y 4/4), red (10 YR 4/6) and (10 YR 4/8) yellowish brown (10 YR 5/8) mottles and at lower layers yellowish brown (10 YR 5/8), brownish yellow (10 YR 6/6), dark brown (7.5 YR 4/4) to olive yellow (2.5 YR 6/8) mottles are observed. Similarly at Mathikayal the mottles present at epipedons and in the lower layers are yellowish brown (10 YR 5/8) to dark brown (7.5 YR 5/8). At Vytilla the colour mottles are light olive brown (2.5 Y 5/1) to dark yellowish brown (10 YR 4/4) through yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/8). In the epipedons and at lower layers

Table 1.0 Macromorphology of the acid sulphate soil profiles

Local name of the soil	KARI SOIL		KARUMADI	
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	1 and 2			
b) Soil name	Kari soil			
c) Higher category classification	Entisol			
d) Date of examination	17-8-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Karumadi, Ambalapuzha, Alleppey District			
g) Elevation	1 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Rice cultivation,drainage experimental field of Kerala Agri.University			
k) Climate	Humid tropical climate; Mean annual rain fall: 2342.7 mm; Mean maximum temperature: 31.8°C; Mean minimum temperature 23.9°C; Mean annual R.H: 79.0%			
II. General Information on the Soil				
a) Parent material	Lateritic alluvium			
b) Drainage	Moderate to slowly drained			
c) Moisture conditions	Moist throughout the profile			
d) Depth of ground water table	76 Cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet erosion to rill erosion			
g) Presence of salt or alkali	Class 1. Sulphate, chloride present. Class 2. Moderately affected by salinity			
h) Human influence	Rice cultivated, drainage experimental field of KAU			
III. Brief General Description of the Profile	Black and grey coloured, silty clay soil with partially decomposed wood under different stages of decomposition. Pale yellow jarosite mottles present within 50 cm. Other mottlings present are dark yellowish brown to olive yellow in collour. Decayed iron oxide coated mangrove plant parts are present throughout the profile.The soil is moist throughout the profile with ground water below 76 cm.			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth	0-9, 0-12 cm.	9-35, 12-38 cm	35-58, 38-60 cm	$58-100^+$, $60-100^+$ cm
c) Colour	Dark grey(2.5Y 4/0) Very dark grey (5Y 3/1)	Black(2.5Y 3/0) Black(5Y 2/2)	Black(2.5Y 2/0) Black (2.5Y 2/0)	Black(2.5Y 2/0) Black (2.5 2/0)
d) Colour mottling	Olive Yellow (2.5Y 6/8) Yellowish brown(10YR 5/2)	Olive yellow (2.5Y 6/6) Pale Yellow(2.5Y8/4)	Yellowish brown (10YR 4/4) Pale Yellow(2.5Y 7/6)	Olive brown (2.5Y 4/4) Pale Yellow(2.5Y 7/4)
e) Texture	Silty clay,SiC	Silty clay,SiC	Silty clay,SiC	Silty clay,SiC
f) Strurcture	Coarse prismatic	Coarse prismatic	Subangular blocky	Subangular blocky
g) Consistence	Very sticky and plastic when wet and moist , hard when dry			
h) Cutans	Broken and continuous thick clay sesquioxides and organan on the ped faces			
i) Cementation	Cementation is by organan,ferran and ferriargillan			
j) Pores	Few fine and medium discontinuous horizontal and oblic inped and exped vesicular ope and closed pores			
k) Content of rock and mineral fragments	Nil			
l) Content of mineral nodules	Both concretions and nodules (sesquioxidic) present as nodules and hypocoatings			
m) Pans	Thin disrupted plough pan and plough layer present			
n) Content of carbonate, soluble salts	Chloride, sulphate and carbonate present			
o) Artefacts	Nil			
p) Features of biological origin	Partially decomposed wood fossils,relics of lime shell present			
q) Content of roots	Many fine to median roots of rice and weeds,fossil pneumatophorse of mangroves			
r) Nature of boundary	Gradual smooth	Gradual wavy	Gradual wavy	—
s) pH	5.5	5.5	5.5	6.0
V. Special observations				
a) Depth of jarosite mottle laden layer, colour	Jarosite mottle rich layer is within 50 cm, shallower with 40-50 cm thickness It is pale yellow coloured (2.5Y 7/4) and olive yellow coloured(2.5Y 6/6)			
b) Presence of lime shell/ molluscan shell	Both lime shells and molluscan shell are absent but fine lime shell microlites are present in the subsurface layers			
c) Dominant surrounding mangroove and other vegitations	_Rhizophora apiculata_, _Brugirea gymnorrhiza_			
VI. Soil Classification	ILRI system : Unripe, saline, sulphidic clay, potential acid sulphate Soil Taxonomy : Sulfaquents ORSTOM : Thiosols FAO/UNESCO : Thionic Fluvisols			
VII a) Plate number	1.0			
b) Figure number	1.0			

Table 1.1 Macromorphology of the acid sulphate soil profiles

Local name of the soil	KARAPADOM SOIL MONCOMPU			
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	3 and 4			
b) Soil name	Karapadam soil			
c) Higher catogory classification	Entisol			
d) Date of examination	18-8-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Rice Research Station, Moncompu, Kuttanadu, Kottayam District			
g) Elevation	- 1 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Bulk rice croped field, RRS, Moncompu			
k) Climate	Humid tropical climate; Mean annual rain fall: 2510 mm; Mean maximum temperature 30^{0}C; Mean minimum temperature: 26.2^{0}C; Mean annual temperature ; Mean relative humidity: 78%			
II. General Information on the Soil				
a) Parent material	Lateritic alluvium from the granitic rock			
b) Drainage	Class 1 poorly drained			
c) Moisture conditions	Profile moist throughout			
d) Depth of ground water table	50 cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet erosion to rill erosion			
g) Presence of salt or alkali	Class 1, salinity class 1, 4-8 mS cm^{-1} slightly affected			
h) Human influence	Rice cultivated for about 40-50 years			
III. Brief General Description of the Profile	Deep, poorly drained, dark grey to very dark grey with clay loam surface and silty clay loam subsurface horizons. Subsurface horizons show thick iron ochre on profile face and ped faces, gleying, streaks and abundant mottles of olive brown, dark brown and few red colour, sesquioxidic concretions and nodules, sand pockets. Organic matter at different stages of decomposition are present which decreases with depth. Pale yellow jarosite mottles and pyrite present			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth in cm	0-14, 0-10	14-34, 10-35	34-65, 35-60	65-100$^+$, 60-100$^+$
c) Colour moist	Very dark brown (2.5Y 2/2) Very dark greish brown (2.5Y 3/2)	Very dark brown (10YR 2/2) Very dark greish brown (2.5Y 3/2)	Very dark greish brown (10YR 3/2) Very dark grey (2.5Y 3/0)	Very dark grey (10YR 3/1) Very dark grey (2.5Y 3/0)
d) Colour mottling	Olive brown (10YR 4/4) Dark brown (7.5YR 4/4)	Olive brown (10YR 4/4) Red (10R 4/8)	Yellowish brown (10YR 5/8) Light olive brown (2.5Y 5/6)	Dark greish brown (10YR 3/1) Olive brown (2.5Y 4/4)
e) Texture	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay, Silty clay loam
f) Strurcture	Coarse prismatic	Coarse prismatic to sub angular blocky	Subangular blocky	Subangular blocky
g) Consistence	Very sticky and plastic when wet and hard when dry			
h) Cutans	Broken and continuous thick ferran, clay sesquioxides and organan on ped faces			

i) Cementation	Cementation is by ferran, ferriorganan, organan and ferriargillan
j) Pores	Few fine and medium discontinuous horizontal and oblic, inped and exped vesicular open and closed pores
k) Content of rock and mineral fragments	Rock nil but few lateritic gravels present
l) Content of mineral nodules	Both concretions and nodules are present. They are lateritic and ferritic They are present as free concretions and nodules and as hypocoatings.
m) Pans	Thin disrupted plough pan and plough layers present
n) Content of carbonate, soluble salts	Carbonate, chloride and sulphate present
o) Artefacts	Nil
p) Features of biological origin	Worm-casts of burrowing fauna and relics of lime shells present
q) Content of roots	Fine to medium rice and weed roots, pnematophores of earlier mangrove vegetation were present in abundent quantities within 0 to 70 cm.
r) Nature of boundary	Gradual wavy Gradual smooth Gradual smooth —
s) pH	5.5
V. Special observations	
a) Depth of jarosite mottle laden layer, thickness and colour	Jarosite mottle laden layer is present within 0-50 cm. It is shallower with 20-25 cm thickness and light olive brown (2.5Y 5/6) to Olive brown (2.5Y 4/4)
b) Presence of lime shell/ molluscan shell	Lime shell pieces are present in the subsurface horizons
c) Dominant surrounding mangrove and other vegetations	<u>Rhizophora apiculata</u>, <u>Bruguirea gymnorrhiza</u>
VI. Soil classification	ILRI system : Unripe, saline, sulphidic clay, potential acid sulphate Soil Taxonomy : Sulfaquents ORSTOM : Thiosols FAO/UNESCO : Thionic Fluvisols
VII a) Plate number	2.0
b) Figure number	1.0

Table 1.2 Macromorphology of the acid sulphate soil profiles

Local name of the soil	KAYAL SOIL		MATHIKAYAL	
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	5 and 6			
b) Soil name	Kayal soil			
c) Higher catogory classification	Entisol			
d) Date of examination	19-8-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Mathikayal,Kuttanad,Kottayam District			
g) Elevation	- 1.5 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Rice cultivated,cultivators field			
k) Climate	Humid tropical climate; Mean annual rain fall: 2510 mm; Mean maximum temperature 30^{0}C; Mean minimum temperature: 22.3^{0}C; Mean annual temperature : 26.2^{0}C; Mean annual relative humidity: 78%			
II. General Information on the Soil				
a) Parent material	Lateritic alluvium from granitic rocks			
b) Drainage	Class 1 poorly drained			
c) Moisture conditions	Profile moist throughout			
d) Depth of ground water table	40 cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet erosion to rill erosion			
g) Presence of salt or alkali	Class 1, salinatic class 1, 4-8 mS cm^{-1} slightly affected			
h) Human influence	Rice cultivated for about 40-50 years			
III. Brief General Description of the Profile	Very deep,poorly drained, dark greish brown to very dark greish brown, silt loam to silty clay loam profile with subsoil lime shells, lime shell layer, yellowish brown, strong brown, yellowish red and brownish yellow mottles and streaks. Organic matter comparatively less which remain almost same throughout the profiles. Jaroste and pyrite mottles present even in the surface horizons.biotite mica is present in high quantity in the profile face.			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth in cm	0-10,0-9	10-22,9-26	22-46,26-45	46-100^{+},45-100^{+}
c) Colour moist	Very dark grey (10YR 3/1) Very dark brown (2.5Y 2/2)	Very dark brown (10YR 2/2) Very dark greish brown (2.5Y 3/2)	Very dark grey (10YR 3/1) Very dark brown (10YR 3/2)	Very dark grey (10YR 3/1) Very dark brown (10YR 3/2)
d) Colour mottling	Olive brown (10YR 3/1) Strong brown (10YR 5/8)	Olive brown (10YR 4/4) Dark brown (7.5YR 4/4)	Yellowish brown (10YR 5/8) Yellowish red (10YR 4/8)	Yellowish brown (10YR 5/8) Yellowish brown (10YR 5/8)
e) Texture	Clay loam throughout the profile			
f) Strurcture	Coarse prismatic to subangular blocky	Coarse prismatic to subangular blocky	Subangular blocky	Subangular blocky
g) Consistence	Slightly sticky and slightly plastic when wet and hard when dry			
h) Cutans	Broken and discontinuous sesquan, ferriargillan, ferran			

i) Cementation	Weakly cemented by ferriorganan, ferran and organan			
j) Pores	Few, fine to medium continuous and discontinuous vertical and oblic inped and exped vesicular open pores			
k) Content of rock and mineral fragments	Rock nil but many lateritic gravels present			
l) Content of mineral nodules	Both concretions and nodules are present as free and as hypocoatings. They are lateritic and ferritic			
m) Pans	Very thin disrupted plough pan and thin plough layers present			
n) Content of carbonate, soluble salts	Carbonate chloride and sulphate present			
o) Artefacts	Nil			
p) Features of biological origin	Faunal faecal materials and relics of lime shell pieces			
q) Content of roots	Fine to medium rice and weed roots, very few pnemotophores of earlier mangrove vegetation are present in abundant quantities within 0-60 cm			
r) Nature of boundary	Gradual wavy	Gradual smooth	Gradual smooth	—
s) pH	6.0	5.5	5.5	5.5
V. Special observations				
a) Depth of jarosite mottle laden layer, thickness and colour	Jarosite mottle laden layer is within 0-50 cm, it is with 25-35 cm thickness and olive brown (10YR 4/4) to yellowish brown (10YR 5/8) coloured.			
b) Presence of lime shell/ molluscan shell	Lime shell layer present below 65 cm			
c) Dominant surrounding mangrove and other vegetations	*Rhizophora apiculata*, *Bruguierea gymorrhiza*			
VI. Soil classification	ILRI system : Saline, sulphidic sand, potential acid sulphate soil Soil Taxonomy : Sulfofluvaquents ORSTOM : Thiosols FAO/UNESCO : Thionic Fluvsols			
VII a) Plate number	3.0			
b) Figure number	1.0			
	—			

Table 1.3 Macromorphology of the acid sulphate soil profiles

Local name of the soil	POKKALI SOIL VYTILLA			
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	7 and 8			
b) Soil name	Pokkali soil			
c) Higher catogory classification	Entisol			
d) Date of examination	8-9-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Bulk rice cultivated field of RRS, Vytilla, Ernakulam District			
g) Elevation	- 1.5 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Bulk rice cropped field of RRS, Vytilla			
k) Climate	Humid tropical climate; Mean annual rain fall: 2981.1 mm; Mean maximum temperature: 31.1^{0}C; Mean minimum temperature: 24.9^{0}C; Mean annual temperature: 28^{0}C; Mean annual relative humidity: 79%			
II. General Information on the Soil				
a) Parent material	Lateritic alluvium from the granitic rocks			
b) Drainage	Class 1 poorly drained			
c) Moisture conditions	Profile moist throughout			
d) Depth of ground water table	61 cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet erosion to rill erosion			
g) Presence of salt or alkali	Class 1, salinity class 2, 8-15 mS cm^{-1}			
h) Human influence	Rice cultivated for about 35 to 40 years			
III. Brief General Description of the Profile	Deep, poorly drained, highly saline, soft, very dark grey to very drak greish brown coloured soil with silty loom texture throughout the profile. Fair amounts of decaying organic matter present. Throughout the profile is soft plastic,sticky with shining ped faces. Very few yellowish brown, olive brown and brownish yellow mottles are present in the subsurface horizons. Jarosites mottles are not clearly observable due to high soluble salt masking.			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth in cm	0-16,0-10	16-33,10-30	33-60,30-57	60-100^{+},57-100^{+}
c) Colour moist	Very dark grey (10YR 3/1) Very dark brown (10YR 2/2)	Very dark grey (7.5YR 3/0) Very dark grey (10YR 3/1)	Very dark grey (10YR 3/1) Very dark grey (10YR 3/1)	Very dark greish brown (10YR 3/2) Very dark grey (10YR 3/1)
d) Colour mottling	Pale yellow (2.5Y 7/4) Dark yellowish brown (10YR 4/4)	Light yellowish brown (2.5Y 6/4) Yellowish brown (10YR 5/6)	Yellowish brown (10YR 5/8) Yellowish brown (10YR 8/6)	Absent Olive brown (2.5Y 4/4)
e) Texture	Silty clay throughout the profile			
f) Strurcture	Coarse prismatic	Coarse prismatic to subangular blocky	Coarse prismatic to subangular blocky	Subangular blocky
g) Consistence	Very sticky and plastic when wet and very hard when dry			
h) Cutans	Broken and continuous thick organan,ferriargillan and sodium sulphate on ped faces.			

i) Cementation	Cementation is by sodium sulphate organan and ferriargillan
j) Pores	Many fine to medium discontnuous and continuous vertical and horizontal inped and exped vesicular, tubular open and dentritic pores
k) Content of rock and mineral fragments	Lateritic concretions and few nodules present but rock fragments nil
l) Content of mineral nodules	Lateritic concretions and nodules are present as free and as hypocoatings they are few in distribution
m) Pans	Thin disrupted plough pan and plough layers present
n) Content of carbonate, soluble salts	Less carbonate and more sulphate and chloride present
o) Artefacts	Nil
p) Features of biological origin	Faunal faecal materials and relics of lime shell pieces present
q) Content of roots	Fine to medium rice and weed roots and very few fosil pnematophores present within 30 cm depth

r) Nature of boundary	Gradual wavy	Gradual smooth	Gradual smooth	—
s) pH	6.0	5.5	5.5	5.5

V. Special observations	
a) Depth of jarosite mottle laden layer, thickness and colour	Jarosite mottle laden layer is present below 50 cm, deeper and thinner (6-10 cm) and pale yellow (2.5Y 7/4) to light yellowish brown (2.5Y 6/4)
b) Presence of lime shell/ molluscan shell	Pieces of relic lime shells and microlites present in the subsurface horizons
c) Dominant surrounding mangrove and other vegetations	_Rhizophora mucronata_, _R. apiculata_, _Bruguierea gymnorrhiza_ and _B. Parviflora_
VI. Soil classification	ILRI system : Saline sulphidic sand, potential acid sulphate soil Soil Taxonomy : Sulfofluvaquents ORSTOM : Thiosols FAO/UNESCO : Thionic Fluvisols
VII a) Plate number	4.0
b) Figure number	1.0

Table 1.4 Macromorphology of the acid sulphate soil profiles

Local name of the soil	KOLE SOIL KATTUKAMBAL			
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	9 and 10			
b) Soil name	Kole soil			
c) Higher catogory classification	Inceptisol			
d) Date of examination	7-11-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Kattukambal, via Kunnankulam, Trichur District			
g) Elevation	- 1.5 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Rice cultivation,cultivators field			
k) Climate	Humid tropical climate; Mean annual rain fall: 2647.8 mm; Mean maximum temperature: 31.6^{0}C; Mean minimum temperature: 23.2^{0}C; Mean annual temperature: 27.2^{0}C; Mean annual relative humdity: 77.5%			
II. General Information on the Soil				
a) Parent material	Lateritic aluvium from granitic rocks			
b) Drainage	Class 1 poorly drained			
c) Moisture conditions	Profile moist throughout			
d) Depth of ground water table	35 cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet to rill erosion			
g) Presence of salt or alkali	Class 0, salinity class 0, 0-4 mS cm^{-1}			
h) Human influence	Rice cultivated for 40-50 years			
III. Brief General Description of the Profile	Shallow, poorly drained,yellowish brown to dark grey with abrupt textural difference between horizons. The lateritic aluvial soil with partially decomposed organic matter is present on the gravelly hard red to dark brown subangular blocky laterite layer. Gravels are also present in the surface layers. The subsurface horizons indicate the presence of high degree of gleying with streeks and traped fossil organic matter and yellowish brown, yellow mottles.			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth in cm	0-16,0-15	16-29,15-25	29-66,25-60	66-100^{+},60-100^{+}
c) Colour moist	Dark yellowish brown (10YR 4/4) Dark yellowish brown (10YR 4/4)	Dark brown (7.5YR 4/4) Dark grey (10YR 4/1)	Dark brown (10YR 3/3) Dark brown (10YR 3/3)	Dark yellowish brown (10YR 4/3) Dark red (2.5YR 3/6)
d) Colour mottling	Brownish yellow (10YR 6/8) Light red (2.5YR 6/6)	Yellowish brown (10YR 5/6) Brownish yellow (10YR 6/6)	Strong brown (7.5YR 5/8) Dark yellowish brown (5YR 3/2)	Dark reddish brown (5YR 3/2) Yellowish brown (10YR 5/6)
e) Texture	Gravelly silty clay	Silty clay	Silty clay	Gravelly silty clay
f) Strurcture	Coarse to subangular blocky	Coarse prismatic to subangular blocky	Subangular blocky	Subangular blocky
g) Consistence	Slightly sticky and slightly plastic when moist and hard when dry			
h) Cutans	Thick continuous ferran, ferriargillan and ferriorganan			

i) Cementation	Cementation is by ferran, ferriargillan and by ferriorganan
j) Pores	Few fine and medium discontinuous oblic and random; inped and exped vesicular open and closed pores
k) Content of rock and mineral fragments	Rock nil but many weathered angular lateritic gravels present
l) Content of mineral nodules	Many lateritic and faritic angular weathered concretions and nodules as free and as hypocoatings
m) Pans	Thin disrupted plough pan and plough layers present
n) Content of carbonate, soluble salts	Less chloride and sulphate present
o) Artefacts	Nil
p) Features of biological origin	Very few faunal fecal materials and worm casts present
q) Content of roots	Fine to medium roots of rice and weeds present upto 30-40 cm
r) Nature of boundary	Gradual wavy — Gradual wavy — Abrupt wavy — —
s) pH	5.5
V. Special observations	
a) Depth of jarosite mottle laden layer, thickness and colour	Very few scatered jarosite mottlings observed in the subsruface layer but few pyrite present
b) Presence of lime shell/ molluscan shell	Absent
c) Dominant surrounding mangrove and other vegetations	_Rhizophora apiculata_, _Bruguiera gymnorrhiza_
VI. Soil classification	ILRI system : Ripe clay with acid sulphate subsoil. Soil Taxonomy : Sulfic Tropaquepts ORSTOM : Thisols FAO/UNESCO : Thionic Fluvisols
VII a) Plate number	5.0
b) Figure number	1.0

Table 1. 5 Macromorphology of the acid sulphate soil profiles

Local name of the soil	KAIPAD SOIL	KATTAMPALLY		
	h1	h2	h3	h4
I. Information on the site				
a) Profile number	11 and 12			
b) Soil name	Kaipad soil			
c) Higher catogory classification	Entisol			
d) Date of examination	8-11-1982			
e) Author of description	M.Subramonia Iyer			
f) Location	Near to the Kattampally spillway on the banks of the Kattampally river, Canannore			
g) Elevation	1.5 to 2.0 meter			
h) Land-form	Low land			
i) Slope on which profile is sited	Class 2 Gently sloping 2-6%			
j) Vegetation or land-use	Bulk rice cultivated, cultivators field			
k) Climate	Humid tropical climate; Mean annual rain fall: 2864.9 mm; Mean maximum temperature: 31.2^{0}C; Mean minimum temperature: 23.8^{0}C; Mean annual temeprature: 27.5^{0}C; Mean annual relative humidity: 78%			
II. General Information on the Soil				
a) Parent material	Lateritic alluvium from granitic rocks			
b) Drainage	Class 2 imperfectly drained			
c) Moisture conditions	Profile moist throughout			
d) Depth of ground water table	65-70 cm			
e) Presence of surface stones or rock outcrops	Nil			
f) Evidence of erosion	Sheet erosion to rill erosion			
g) Presence of salt or alkali	Class 1, salinity class 1, 4-8 mS cm^{-1}, slightly affected			
h) Human influence	Rice cultivation for about 20-30 years			
III. Brief General Description of the Profile	Deep, moderately drained, dark grey to dark greish brown with abrupt and widely different soil texture with abundant partially decomposed fibrous fossil woody matter at mixed with silt and clay. Iron pipes, limeshells, moluscan valves small iron enriched concretions and nodules present. Iron mottles are more in the lime shell layer, gravels are present in the surface horizons but not in the subsurface layers. In the subsurface horizons sandy pockets present.			
IV. Description of Individual Soil Horizons				
a) Horizon symbol	h1	h2	h3	h4
b) Depth in cm	0-9,0-9	9-22,9-25	22-36,25-41	36-100$^+$,41-100$^+$
c) Colour moist	Dark greish brown (2.5Y 4/2) Dark greish brown (2.5Y 3/2)	Greish brown (2.5Y 5/2) Dark greish brown (2.5Y 4/2)	Dark grey (2.5Y 4/0) Very dark greish brown (2.5Y 3/2)	Dark grey (2.5Y 4/0) Very dark grey (2.5Y 3/0)
d) Colour mottling	Not clearly observable in the field but very few dark greish brown (2.5Y 3/2) mottles present in the subsurface layers			
e) Texture	Silty clay loam Clay	Clay loam Clay loam	Silty clay loam Silty clay	Clay Silty clay
f) Strurcture	Coarse granular	Coarse prismatic	Coarse prismatic to Subangular blocky	Subangular blocky
g) Consistence	Slightly sticky and slightly plastic when wet and slightly hard when dry			
h) Cutans	Broken and continuous thick and thin ferran, sesquioxides and ferriorganan.			

i) Cementation — Cementation is by ferran ferriorganan and organan

j) Pores — Few medium discontinuous horizontal and oblic inped and exped vesicular and tubular open and dentritic pores

k) Content of rock and mineral fragments — Rock nil but many lateritic gravels present in the sufrace layers

l) Content of mineral nodules — Lateritic concretios and nodules few present in the surface layers

m) Pans — Plough pan absent but very thin disrupted plogh layer present

n) Content of carbonate, soluble salts — Carbonate chloride and sulphate present

o) Artefacts — Nil

p) Features of biological origin — Fossil limshells, molluscan valves, faunal faecal materials

q) Content of roots — Medium to coarse grass roots up to 30 to 40 cm. Below this whole roots, pneumatophores of 'Kandamaram', fossil mangroves present

r) Nature of boundary	Gradual wavy	Gradual wavy	Gradual wavy to abrupt wavy	Abrupt wavy
s) pH	6.0	6.0	6.5	6.5

V. Special observations

a) Depth of jarosite mottle laden layer, thickness and colour — Jarosite layer absent but jarosite mottles present, shllower very thin less than 10 cm and pale yellow coloured (2.5Y 7/6)

b) Presence of lime shell/ molluscan shell — Both lime shells and molluscan shells present as a layer below 61 cm

c) Dominant surrounding mangrove and other vegetations — Avicinnia officinalis, A. marine, Exocaria agallolcha, Kandelia candela Bruguiera gymnorrhiza and B. parviflora

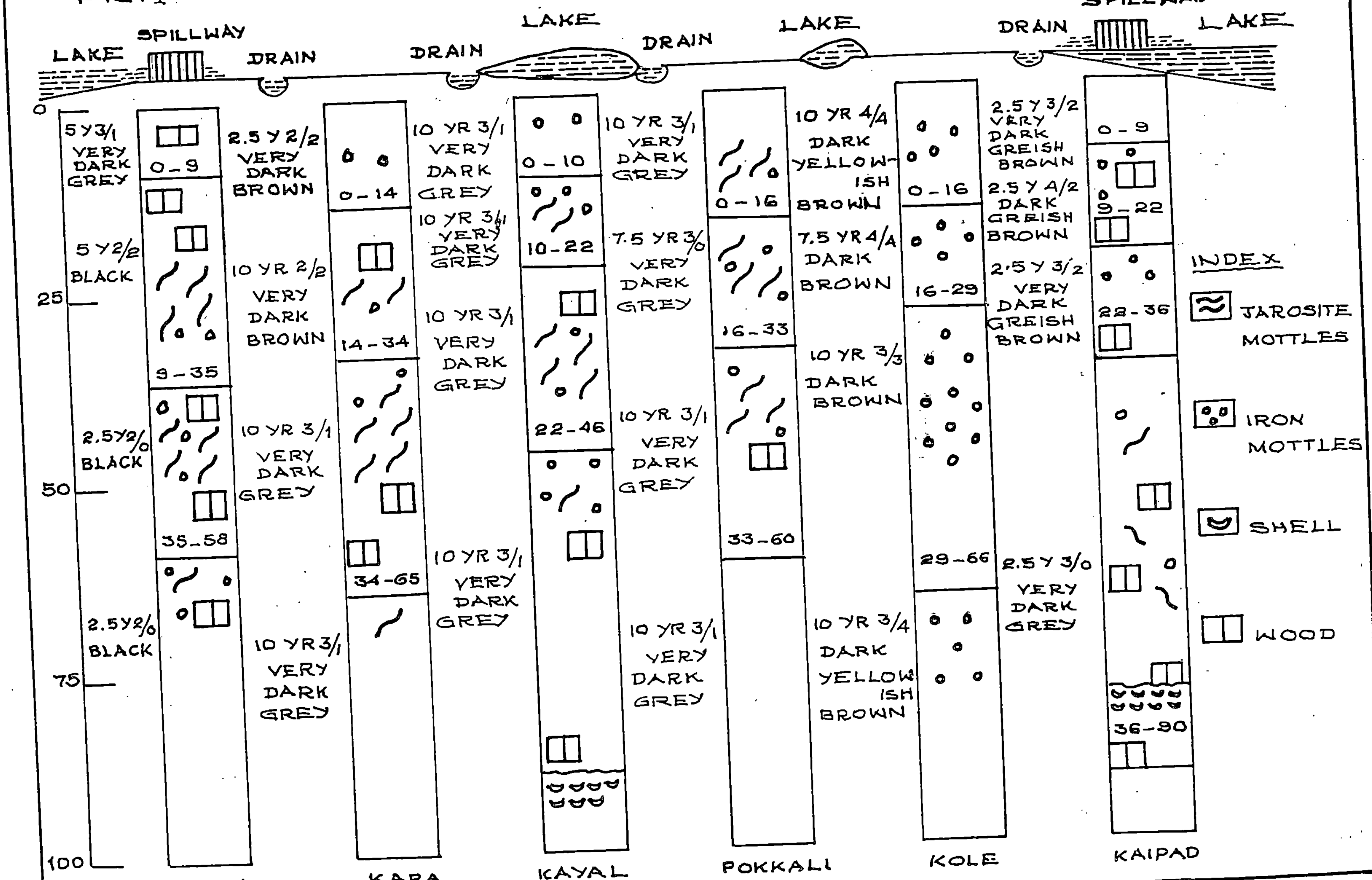
VI. Soil classification

ILRI System : Unripe, saline, sulphidic play, potential acid sulphate
Soil Taxonomy : Sulfaquents
ORSTOM : Thisols
FAO/UNESCO : Thionic Fluvisols

VII a) Plate number — 6.0

b) Figure number — 1.0

FIG. 1 ACID SULPHATE SOILS OF KERALA – MACROMORPHOLOGY



it is brownish yellow (10 YR 6/8 or absent. At Kattukambal, in the epipedons it is yellowish brown (10 YR 5/6) to light red (2.5 YR 6/6) through brownish yellow (10 YR 6/6) to strong brown (7.5 YR 5/8) while at lower layers, it is dark reddish brown (5 YR 4/2) to reddish brown (2.5 YR 5/4) and dark brown (10 YR 4/4) to dark reddish brown (5 YR 3/2). At Kattampally prominent colour mottles are absent both in the epipedons and lower layers.

6.3 Texture

At Karumadi, Vytilla and Kattukambal the pedons are silty clay throughout the profile while at Moncompu it is silty clay loam througout the profile.The soil texture of the last layer at Kattukambal I and Kattampally I is clay and the second and third horizons of both the profiles are clay loam and silty clay, respectively.

6.4 Structure

Except the surface horizon at Mathikayal and subsurface horizons at Kattampally, all other soils are with coarse prismatic to subangular blocky structure.

6.5 Stickiness and plasticity

At Karumadi, Moncompu and Vytilla the soils are very sticky and plastic and turns very hard on drying. At Mathikayal the soils are slightly sticky and slightly plastic at subsurface horizons when wet, and moderately friable on drying. At Kattukambal and Kattampally the soils are slightly sticky and slighly plastic when wet,and slightly hard when dry.

6.6 Boundary

At Karumadi, the boundary is gradual smooth in the epipedons, and gradual wavy in lower layers, while at Moncompu, Mathikayal, and Vytilla a reverse pattern in the epipedons and lower horizons are observed. At Kattukambal and Kattampally gradual wavy boundary in the epipedons and abrupt wavy boundary in the lower layers are observed.

6.7. Presence of roots

Irrespective of the locations, the root activity of the current vegetation is observed, upto a depth of 30-40 cm from the surface; while root channels of pneumatophores of earlier mangrove vegetations and other epiphytes are even beyond the depth of observation made in all the locations. Wood fossils noticed at Kattampally are partially decomposed barks and roots of earlier mangrove vegetations locally named as "Kandamaram".

6.8 Permeability

Except the surface horizons at Mathikayal and Kattampally the internal soil permeability is slow to very slow throughout the profiles. At the surface horizons of Mathikayal and Kattampally the observed permeability are moderately slow.

6.9 Concretions/nodules

Irrespective of the locations in all the soil profiles typical sesquioxidic features are observed, except at Kattampally, where scattered occurrence of manganese concretions are observed in the epipedons. They are present as coatings and hypocoatings. Sesqui oxidic features observed in these soils, except at Kattampally are "diffused nodules" and hypocoatings. The sesquioxidic diffused nodules are dominant feature in the epipedons and lower layers at Kattukambal profiles.

6.10 <u>Jarostie horizon-depth of occurrence, thickness and colour</u>

Irrespective of the locations jarosite mottles rich horizons are found (pale yellow 2.5 Y 6/6, 2.5 Y 6/7) within the depth of 50 to 90 cm. Its thickness ranges from 40-50 cm at Karumadi, 20-25cm at Moncompu, 20-35 cm at Mathikayal and 6-10 cm at Vytilla. Though such mottles are present at Kattampally and Kattukambal "jarosite" rich horizons are absent. Jarosite mottled horizons are shallower at Karumadi, Moncompu, Mathikayal, Kattukambal and Kattampally, while comparatively deeper (below 50 cm) and thinner (6-10 cm) at Vytilla. Irrespective of the locations jarosite mottles are observed within a depth of 50 cm from the surface.

6.11 <u>Drainage</u>

Surface horizons are moderately drained and subsurface horizons are illdrained. In the profile as a whole, at Karumadi, Moncompu, Mathikayal, Kattampally and Kattukambal the soil drainage is comparatively moderately slow, while that at Vytilla, is very slow.

6.12 <u>Evidences of erosion</u>

Irrespective of the locations in all these sites, the soils have experienced moderate sheet erosion with indications of advanced sheet and rill erosions in pockets.

7. Granulometric composition

The granulometric composition of soils at different locations are presented in tables 2 to 2.3. The profile distribution pattern is illustrated in figures 1.1 to 4.

Table 2.0 Granulometric composition of acid sulphate soil profiles (percent by weight)

Location	Kari soil Karumadi I				Karapadom soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	65-100+	0-10	10-22	22-46	46-100+
Coarse sand	1.5	1.7	1.5	2.0	16.0	18.3	3.2	2.0	1.0	1.5	1.2	0.30
Fine sand	6.0	4.9	7.5	12.8	25.0	24.5	3.0	2.1	50.1	52.4	55.3	57.6
Silt	26.3	24.7	26.1	29.5	17.0	16.6	28.2	27.8	19.3	18.0	12.3	12.0
Clay	51.0	49.8	46.0	43.1	28.0	31.0	58.0	63.0	28.0	26.5	30.0	28.5
Partially decomposed Wood	15.2	18.9	18.9	13.6	14.0	9.6	7.6	5.1	1.6	1.6	1.2	1.6
Texture	SiC	SiC	SiC	SiC	SiCl	SiCl	SiC	Cl	Cl	CL	Cl	Cl

Table 2.1 Granulometric composition of acid sulphate soil profiles (Percent by weight)

Location	Kari soil Karumadi II				Karapadom soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-12	12-38	38-60	60-100+	0-10	10-35	35-60	60-100+	0-9	9-26	26-45	45-10
Coarse sand	1.6	1.7	1.7	1.7	17.0	19.0	4.5	1.5	1.3	1.5	1.0	0.75
Fine sand	7.8	5.5	6.8	10.8	24.0	23.5	4.0	3.8	51.3	53.9	54.4	53.8
Silt	28.0	26.8	27.3	26.9	18.0	16.0	26.8	27.5	18.6	17.4	15.6	12.8
Clay	52.6	56.0	49.2	44.5	28.7	33.0	55.0	61.3	27.3	26.1	28.3	28.9
Partially decomposed wood	10.0	10.0	15.0	16.1	12.3	8.5	9.7	5.9	1.5	1.1	0.75	1.1
Texture	SiC	SiC	SiC	SiC	SiCl	SiCl	SiCl	SiCl	Cl	Cl	Cl	C

Table 2.2 Granulometric composition of acid sulphate soil profiles (percent by weight)

cation	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
rizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
pth in cm	0-16	16-33	33-60	60-100+	0-16	16-29	29-66	66-100+	0-9	9-22	22-36	36-100+
arse sand	13.5	9.6	2.8	1.5	13.0	9.0	8.0	15.0	14.5	16.2	6.5	12.0
ne sand	16.5	13.0	10.1	15.0	12.5	11.0	12.0	13.5	28.8	29.0	18.8	16.5
lt	20.5	22.3	21.8	20.8	23.0	22.2	27.0	20.0	25.1	18.2	20.0	20.5
ay	45.0	54.2	56.3	59.0	51.0	51.3	52.0	50.2	30.0	35.0	45.5	48.2
rtially ecomposed ood	4.5	0.6	9.0	4.0	0.5	0.7	1.0	0.3	1.6	1.6	9.2	3.8
exture	SiC	SiC	SiC	SiC	SiC	SiC	SiC	C	SiCl	C	SiC	C

Table 2.3 Granulometric composition of acid sulphate soil profiles (percent by weitht)

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-10	10-30	30-57	57-100+	0-15	15-25	25-60	60-100+	0-9	9-25	25-41	41-100+
Coarse sand	11.6	6.2	2.2	1.8	11.0	8.5	7.8	10.0	13.2	15.5	7.6	12.8
Fine sand	15.8	13.7	12.1	14.9	12.9	11.6	11.5	12.0	29.8	30.2	11.5	12.8
Silt	21.8	23.8	22.3	21.0	26.3	28.0	30.8	27.5	22.5	16.3	15.8	21.0
Clay	43.0	56.0	57.3	60.0	48.5	50.5	49.6	50.0	33.0	34.5	51.6	50.4
Partially decomposed wood	9.1	1.3	6.1	2.3	1.3	1.4	0.3	0.5	1.5	3.5	13.5	3.0
Texture	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	Cl	Cl	SiC	SiC

FIG. 1.1
COMPARATIVE COARSE SAND DISTRIBUTION IN THE ACID SULPHATE SOILS OF KERALA

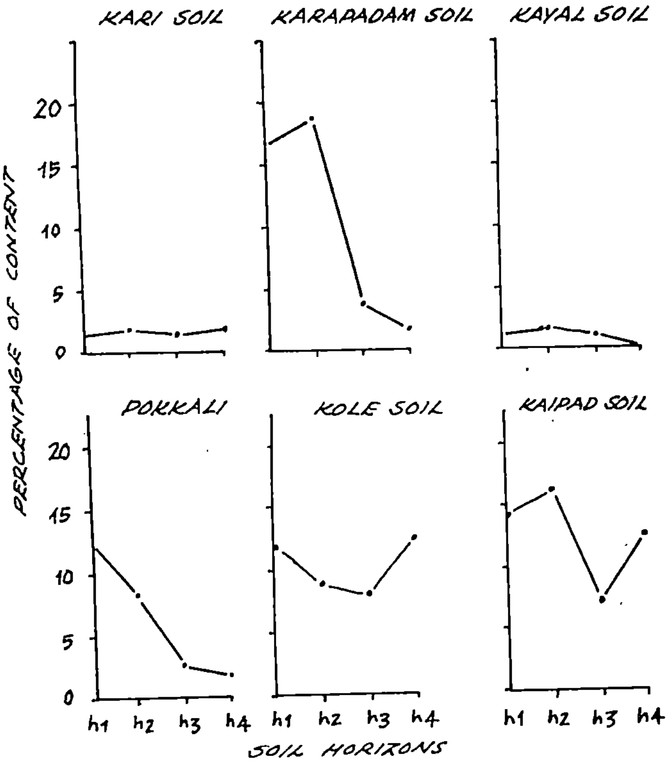


FIG. 2
COMPARATIVE FINE SAND DISTRIBUTION OF ACID SULPHATE SOILS OF KERALA

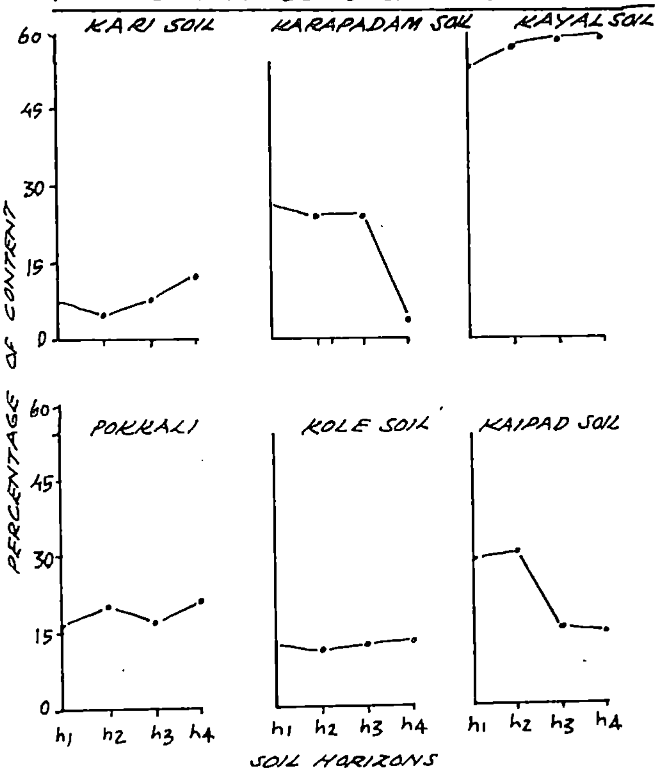


FIG. 3
COPARATIVE SILT DISTRIBUTION OF ACID SULPHATE SOILS OF KERALA

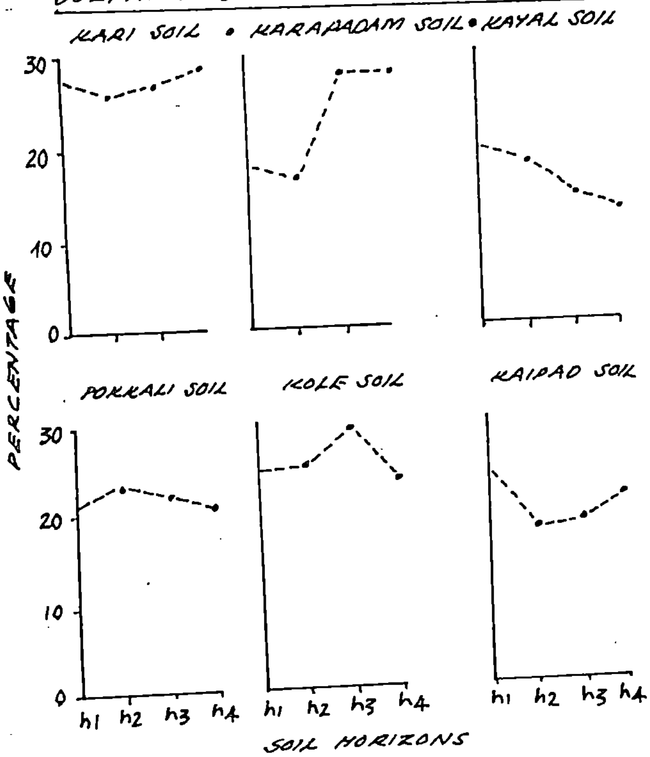


FIG. 4
COMPARATIVE CLAY DISTRIBUTION OF ACID SULPHATE SOILS OF KERALA

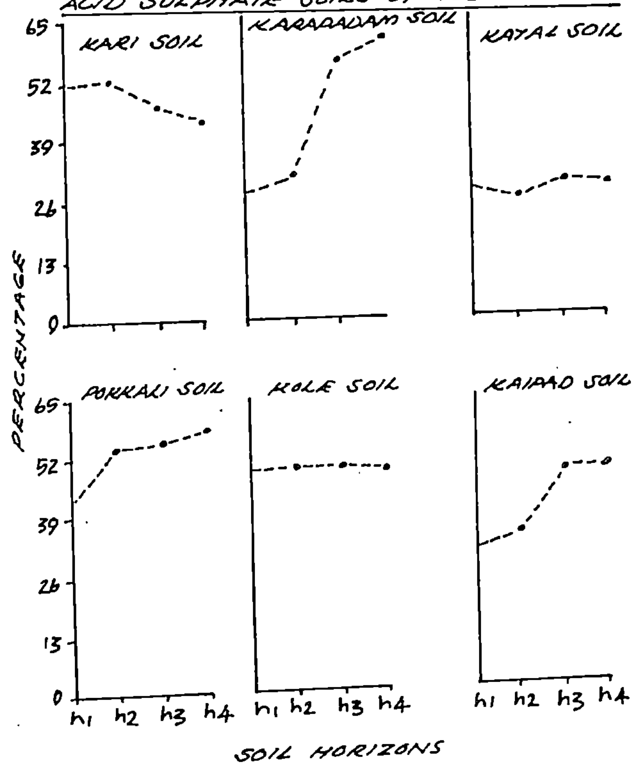
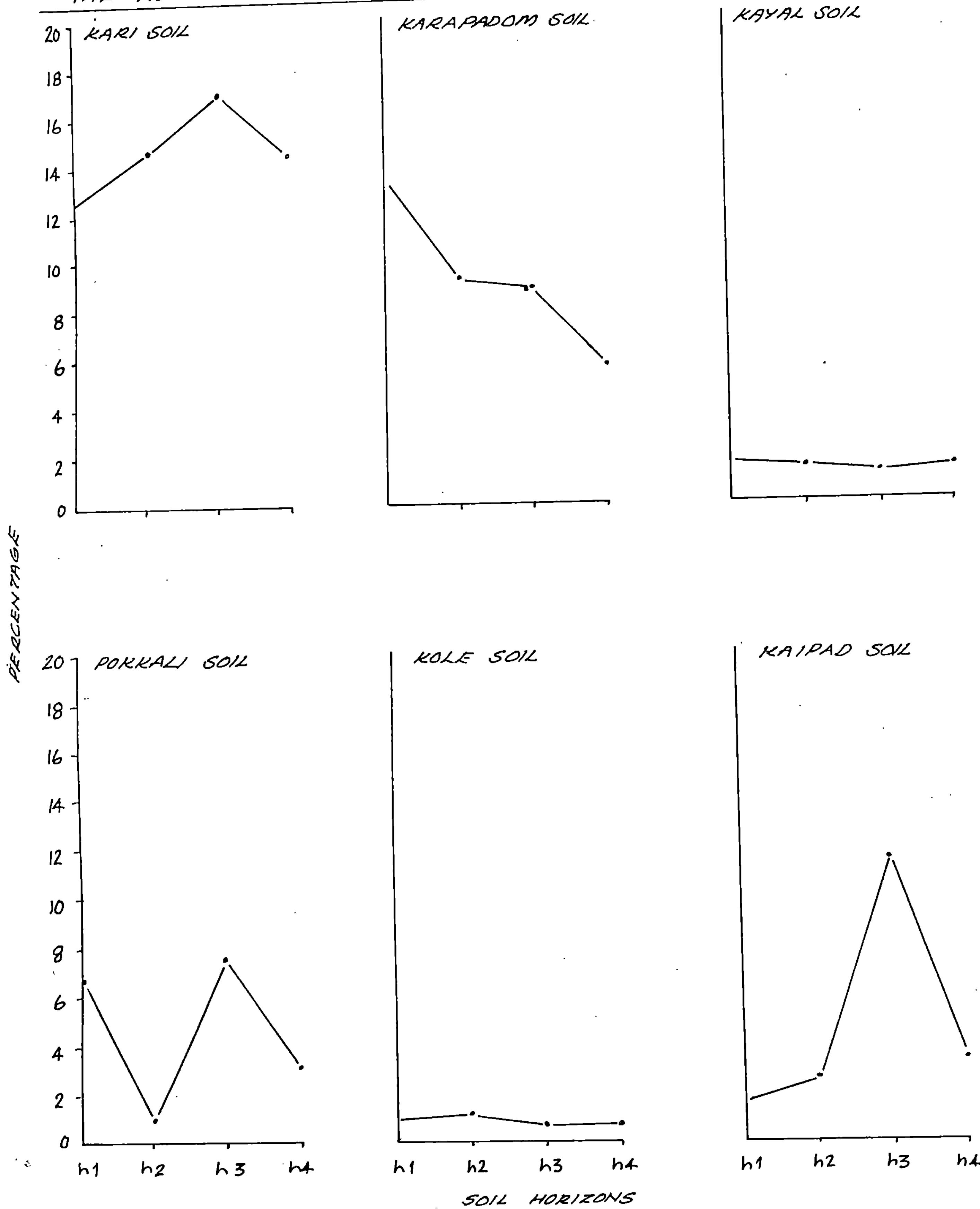


FIG. 4.1
COMPARATIVE DISTRIBUTION OF PARTIALLY DECOMPOSED WOOD IN THE ACID SULPHATE SOILS OF KERALA



7.1 Coarse sand

Mean coarse sand content ranges between 1.5 and 18.5 percent in these soils. Their content are in the increasing order at Mathikayal< Karumadi < Vytilla < Moncompu < Kattampally < Kattakambal.

There is significant difference between the coarse sand content at different locations. Irrespective of the locations, except at Karumadi and Mathikayal, there is a significant difference in the content of coarse sand between horizons. Higher coarse sand content is present at Moncompu profiles and lower at Mathikayal profiles.

7.2 Fine sand

Mean fine sand content ranges between 3.5 and 55.7 percent in these soils. Their content are in the increasing order at Karumadi< Kattukambal< Vytilla < Kattampally< Moncompu < Mathikayal.

In the case of the fine sand content there is significant difference between locations. Irrespective of the locations within the profiles there is significant difference between the content of fine sand except at Kattukambal. Higher fine sand content is found at Mathikayal and lower at Karumadi.

7.3 Silt

Mean silt content ranges between 12.4 and 28.9 percent. With regard to the silt content there is significant difference between locations. Except at Karumadi, Vytilla and Kattukambal, there is significant difference between soil horizons. The silt content of these soils are in the increasing order at Mathikayal < Kattampally< Moncompu < Vytilla < Karumadi < Kattukambal. Higher silt content is found at Kattukambal and lower at Mathikayal.

7.4 Clay

Mean clay content ranges between 26.3 and 62.2 percent in these soils. The clay content of these soils are in the decreasing order at Karumadi > Kattukambal > Vytilla > Kattampally > Moncompu > Mathikayal.

In the case of clay content significant difference between soil horizons has been observed.

7.5 Partially decomposed wood

Mean content ranges between 0.40 and 19.65 percent. They are in the decreasing order at Karumadi > Moncompu > Vytilla > Kattampally > Mathikayal and > Kattukambal. At Karumadi. Mathikayal and Kattukambal there is no significant difference between soil horizons with respect to their partially decomposed wood content.

8. **Textural ratios**

The textural ratios of the soils are presented in tables 3 to 3.3 and in figures 5,6 and 7.

8.1 Fine sand/Coarse sand (FS/CS)

Mean FS/CS ratio ranges between 0.91 and 131.85. FS/CS ratios are in the decreasing order at Mathikayal > Vytilla > Karumadi > Kattampally > Kattukambal > Moncompu.

Significant differences in the FS/CS ratios are observed between locations, while between horizons significant differences are observed at Mathikayal. Wider ratios are observed only at Mathikayal and narrower at Moncompu.

8.2 Silt/Clay

Mean Silt/Clay ratio ranges between 0.35 and 0.76. Silt/Clay

Table 3.0 Textural ratios of the acid sulphate soil profiles

Location	Kari soil Karumadi I				Karapadom soil Moncompu I				Kayal soils Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	65-100+	0-10	10-22	22-46	46-100+
Fine sand / Coarse sand	4.0	2.9	5.0	6.4	1.6	1.3	0.94	1.1	50.1	34.9	46.1	192.0
Silt / Clay	0.52	0.49	0.57	0.68	0.61	0.54	0.49	0.44	0.69	0.68	0.41	0.42
Sand+Silt / Clay	0.66	0.63	0.76	1.03	2.1	1.9	0.59	0.51	2.5	2.7	2.3	2.5

e 3.1

Location	Kari Soil Karumadi II				Karapadom soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-12	12-38	38-60	60-100+	0-10	10-35	35-60	60-100+	0-9	9-26	26-45	45-100+
Fine Sand / Coarse sand	4.9	3.8	4.0	6.4	1.4	1.2	0.89	2.5	39.2	35.9	54.4	71.7
Silt / Clay	0.53	0.48	0.55	0.60	0.63	0.48	0.49	0.45	0.68	0.67	0.55	0.44
Sand + Silt	0.71	0.61	01.73	0.89	2.1	1.8	0.64	0.54	2.6	2.8	2.5	2.3

Table 3.2 Textural ratios of the acid sulphate soil profiles

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-16	16-33	33-60	60-100+	0-16	16-29	29-66	66-100+	0-9	9-22	22-36	36-100+
Fine sand / Coarse sand	1.2	1.4	3.6	10.0	0.96	1.2	1.5	0.90	1.9	1.8	2.9	1.4
Silt / Clay	0.46	0.41	0.39	0.35	0.45	0.43	0.52	0.39	0.84	0.52	0.43	0.43
Sand + Silt / Clay	1.1	0.83	0.62	0.63	0.95	0.82	0.90	0.97	2.3	1.8	0.99	1.02

e 3.3

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-10	10-30	30-57	57-100+	0-15	15-25	25-60	60-100+	0-9	9-25	25-41	41-100+
Fine sand / Coarse sand	1.4	2.1	5.5	8.3	1.2	1.4	1.5	1.2	2.3	1.9	1.5	1.0
Silt / Clay	0.50	0.43	0.39	0.35	0.54	0.55	0.62	0.55	0.68	0.47	0.31	0.42
Sand + silt / clay	1.14	0.78	0.64	0.63	1.04	0.95	1.01	0.99	1.98	1.79	0.68	0.92

FIG. 5

COMPARATIVE TEXTURAL RATIOS OF THE ACID SULPHATE SOILS
FINE SAND / COARSE SAND

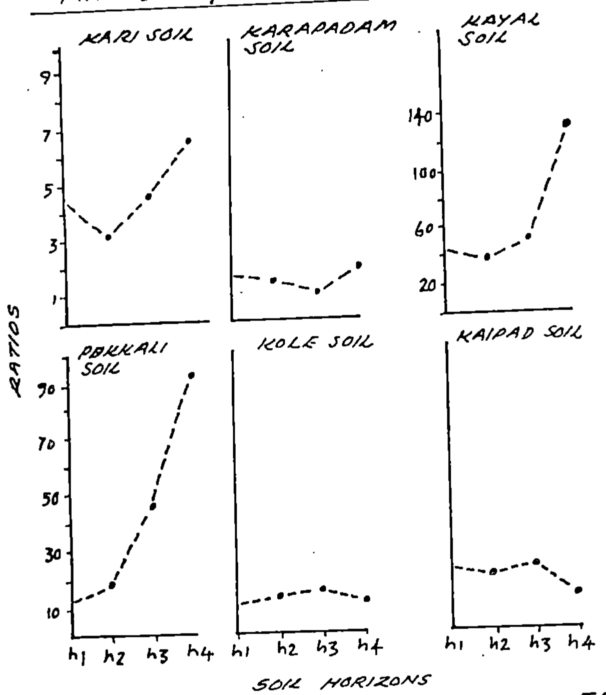


FIG. 6

COMPARATIVE SILT/CLAY RATIOS OF ACID SULPHATE SOILS

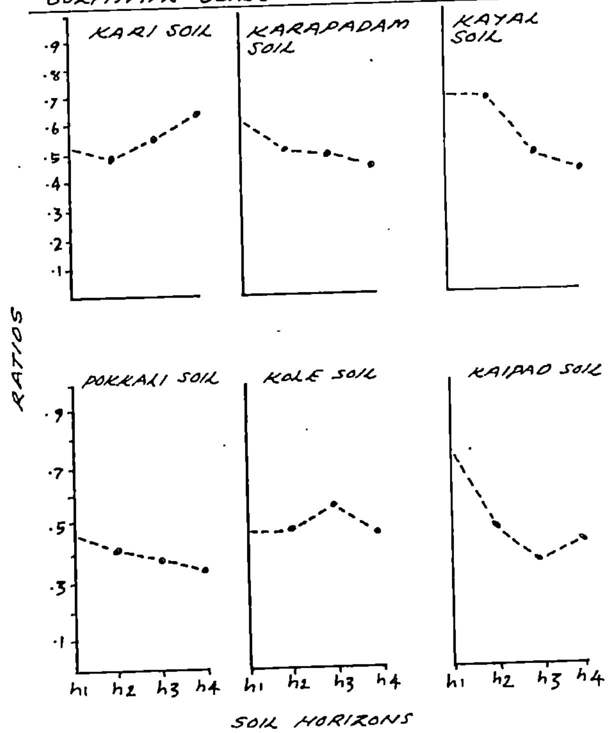
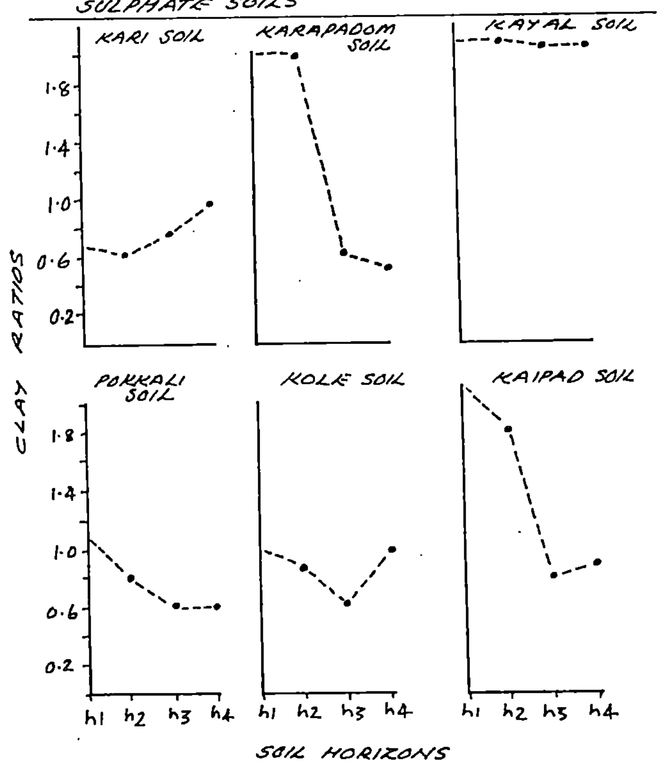


FIG. 7

CAMPARATATIVE CLAY RATIOS OF ACID SULPHATE SOILS



ratio of these soils are in the increasing order at Kattampally < Mathikayal< Moncompu< Karumadi < Kattukambal < Vytilla.

As in the case of fine sand/coarse sand ratios there is significant difference between the silt/clay ratios of locations. Except at Vytilla and Kattukambal there is significant differences between soil horizons. Wider ratios are obtained at Kattampally and narrower at Vytilla.

8.3 Clay ratio

Mean clay ratio ranges between 0.53 and 2.75. Mean clay ratios of the soil are in the increasing order at Mathikayal < Kattampally < Moncompu < Vytilla < Kattukambal < Karumadi.

As in the case of fine sand/coarse sand and silt/clay ratios, clay ratios are significantly different between locations. Except at Kattukambal there is significant difference between horizons with regard to their clay ratios. Clay ratios are wider at Mathikayal and narrower at Karumadi.

9. Structural indices of soils

The percentage aggregates greater than 0.25 mm diameter and stability index of the soils is presented in table 4 to 4.3 and in figures 8 and 9.

9.1 Percentage aggregate above 0.25 mm diameter

Mean percentage content of soil aggregates above 0.25 mm diameter ranges between 4.65 and 68.0. They are in the increasing order at Vytilla < Mathikayal < Kattukambal < Kattampally < Moncompu < Karumadi.

ble 4.0 Structural indices of the acid sulphate soil profiles

Location	Kari soil Karumadi I				Karapadom soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	65-100+	0-10	10-22	22-46	46-100+
Percentage aggregate above 0.25 mm	50.7	48.1	54.5	51.9	52.3	53.9	55.5	58.1	58.1	58.5	58.6	57.5
Stability Index	7.9	8.8	6.5	7.4	7.3	6.7	6.1	6.2	5.2	5.1	5.1	5.0
Organic matter %	13.9	18.3	7.4	11.7	11.2	8.4	5.7	6.0	1.3	1.1	1.0	0.75
Clay %	51.0	49.8	46.0	43.1	28.0	31.0	58.0	63.0	28.0	26.5	30.0	28.5

able 4.1

Structural indices of the acid sulphate soil profiles

Location	Kari soil Karumadi II				Karapadom soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-12	12-38	38-60	60-100+	0-10	10-35	35-60	60-100+	0-9	9-26	26-45	45-100+
Percentage aggregate above 0.25 mm	53.5	51.2	57.8	53.9	53.2	56.1	50.5	58.3	57.5	60.0	58.9	57.8
Stability Index	8.1	9.0	7.9	11.5	6.8	6.0	6.5	5.5	6.1	6.0	5.5	5.0
Organic matter %	12.9	17.5	6.5	11.9	11.7	9.0	6.5	6.2	1.5	1.5	1.3	0.95
Clay	52.6	56.0	49.2	44.5	28.7	33.0	55.0	61.3	27.3	26.1	28.3	28.9

e 4.2 Structural indices of the acid sulphate soil profiles

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-16	16-33	33-60	60-100	0-16	16-29	29-60	60-100+	0-9	9-22	22-36	36-100+
Percentage Aggregate abve 0.25 mm	57.5	56.6	56.7	58.9	56.7	57.8	58.0	58.3	54.2	55.2	53.6	53.9
Stability Index	5.7	5.7	5.6	5.3	5.3	5.3	5.2	6.1	5.5	6.3	6.9	6.8
Organic matter %	3.9	3.8	3.6	3.2	2.0	1.8	1.5	1.0	2.8	6.3	8.9	8.4
Clay	45.0	54.2	56.3	59.0	51.0	51.3	52.0	50.2	30.0	35.0	45.5	48.2

ble 4.3 Structural indices of the acid sulphate soil profiles

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-10	10-30	30-57	57-100+	0-15	15-25	25-60	60-100+	0-9	9-25	25-41	41-100+
Percentage Aggregate above 0.25mm	62.5	60.3	61.0	58.5	58.7	60.0	60.3	57.7	56.2	55.7	55.6	53.2
Stability Index	6.1	7.7	5.8	5.7	5.8	5.8	6.2	6.0	5.6	6,8	7.0	5.9
Organic Matter %	4.1	3.9	3.8	3.1	2.5	2.0	1.9	1.1	3.0	6.1	8.5	9.0
Clay %	43.0	56.0	57.3	60.0	48.5	50.5	49.6	50.0	33.0	34.5	51.6	50.4

FIG. 8
COMPARATIVE STRUCTURAL INDICES OF THE ACID SULPHATE SOIL

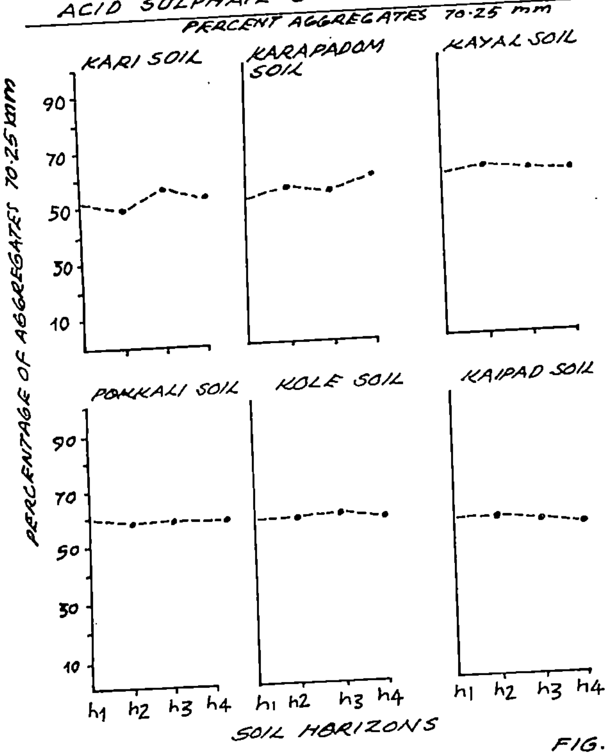


FIG. 9
COMPARATIVE STRUCTURAL INDICES OF ACID SULPHATE SOILS

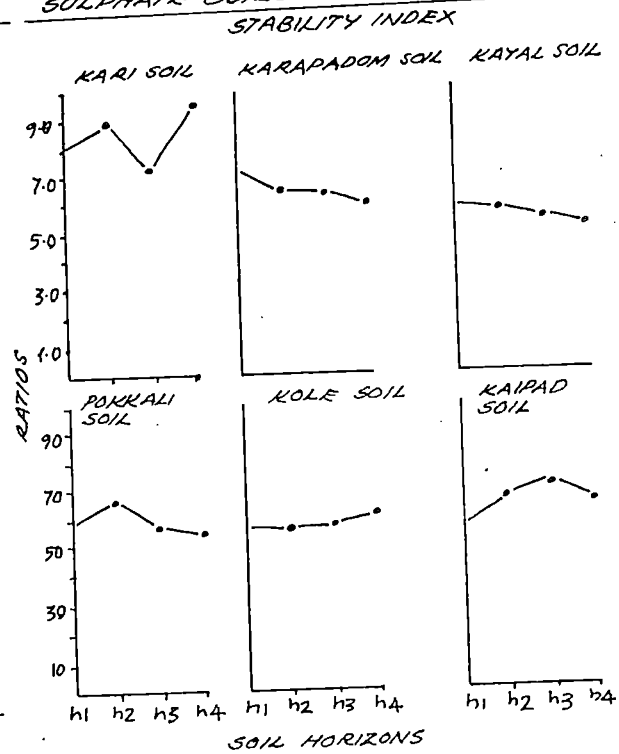
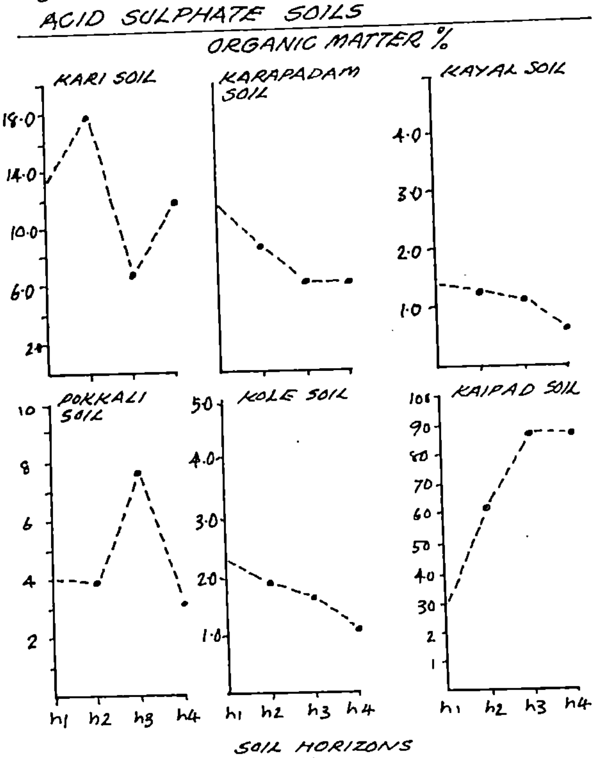


FIG. 10
COMPARATIVE STRUCTURAL INDICES OF ACID SULPHATE SOILS



There is significant differences in the percentage content of soil aggregates above 0.25 mm diameter between locations. Within the profiles significant differences are observed only at Karumadi and Moncompu. Both maximum and minimum soil aggregation are found at Vytilla.

9.2 Stability index

Mean soil stability index of the soils ranges between 5.0 and 9.45.
They are in the increasing order at Karumadi < Moncompu < Vytilla < Kattukambal < Kattampally < Mathikayal.

Though there are significant differences between stability index of soils between different locations, significant differences within the profiles are found only at Karumadi.

10. **Soil moisture content**

Soil moisture characteristics of the soil is presented in tables 5 to 5.3 and figures 11 and 12.

10.1 Soil moisture retained at 0.3 bars

Mean moisture content retained at 0.3 bars of these soils ranges between 5.55 and 30.0 percent. They are in the increasing order at Mathikayal < Kattampally < Kattukambal < Vyttilla < Moncompu < Karumadi.

There is significant difference in the soil moisture content retained at 0.3 bars, between locations. Similarly significant differences within the profile are found except the profiles at Vytilla.

le 5.0 Moisture rentention characteristics of the acid sulphate soil profiles (percent by weight)

Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	65-100+	0-10	10-22	22-46	46-100+
Moisture retained at 0.3 bars %	6.1	5.3	6.1	9.6	15.1	16.4	10.8	11.0	26.7	27.5	28.8	26.4
Moisture retained at 15 bars %	5.3	3.3	5.9	7.7	14.1	16.1	8.2	8.5	23.5	24.3	25.9	25.4
Available water % (by difference)	0.8	2.0	0.2	1.9	1.0	0.30	2.6	2.5	8.2	8.2	4.5	1.0
Orgamic matter %	13.9	18.3	7.4	12.7	12.2	8.4	5.7	6.0	1.3	1.1	1.0	0.75
Clay %	51.0	49.8	46.0	43.1	28.0	31.0	58.0	63.0	28.0	26.5	30.0	28.5

e 5.1 Moisture retention characteristics of the acid sulphate soil profiles (percent by weight)

Location	Kari soil Karumadi II				Karapadam soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-12	12-38	38-60	60-100+	0-10	10-35	35-60	60-100+	0-9	9-26	26-45	45-100+
Moisture retained at 0.3 bars %	5.8	5.8	6.4	9.2	12.1	17.4	11.8	10.5	23.5	24.7	31.2	24.5
Moisture retained at 15 bars %	5.5	3.8	5.2	8.5	11.0	15.5	9.5	8.8	21.8	21.5	27.9	24.1
Available water % (by difference)	0.3	2.0	1.2	0.7	1.1	1.9	2.3	1.7	1.7	3.2	3.3	0.4
Organic matter %	12.9	17.5	6.5	11.9	11.7	9.0	6.5	6.2	1.5	1.5	1.3	0.95
Clay %	52.6	56.0	49.2	44.5	28.7	28.7	55.0	61.3	27.3	26.1	28.3	28.9

Table 5.2 Moisture retention characteristics of the acid sulphate soil profiles (percent by weight)

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-16	16-33	33-60	60-100+	0-16	16-29	29-66	66-100+	0-9	9-22	22-36	36-100+
Moisture retained at 0.3 bars %	17.6	16.4	17.0	15.1	21.6	18.8	19.9	16.0	24.0	24.8	19.1	14.2
Moisture retained at 15 bars %	17.1	14.4	16.5	13.7	15.9	14.2	15.0	13.2	18.8	21.8	15.2	11.8
Avilable water % (by difference)	0.5	2.0	0.5	1.4	5.7	4.6	4.9	2.8	5.2	3.0	3.9	2.4
Organic matter %	3.9	3.8	3.6	3.2	2.0	1.8	1.5	1.0	2.8	6.3	8.9	8.4

e 5.3 Moisture retention characteristics of the acid sulphate soil profiles (percent by weight)

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-10	10-30	30-57	57-100+	0-15	15-25	25-60	60-100+	0-9	9-25	25-41	41-100+
Moisture retained at 0.3 bars %	17.5	17.4	18.5	15.3	23.5	20.1	21.8	15.0	22.5	23.8	20.8	16.3
Moisture retained at 15 bars %	16.0	14.7	17.0	14.1	17.4	16.3	17.8	12.4	16.3	20.5	17.6	13.5
Available water % (by difference)	1.5	2.7	1.5	1.2	6.1	3.8	4.0	2.6	6.2	3.0	3.2	2.8
Organic matter %	4.1	3.9	3.8	3.1	2.5	2.0	1.9	1.1	3.0	6.1	8.5	9.0

FIG. 11

COMPARATIVE MOISTURE RETAINED AT 0.3 BARS(%) IN THE ACID SULPHATE SOILS

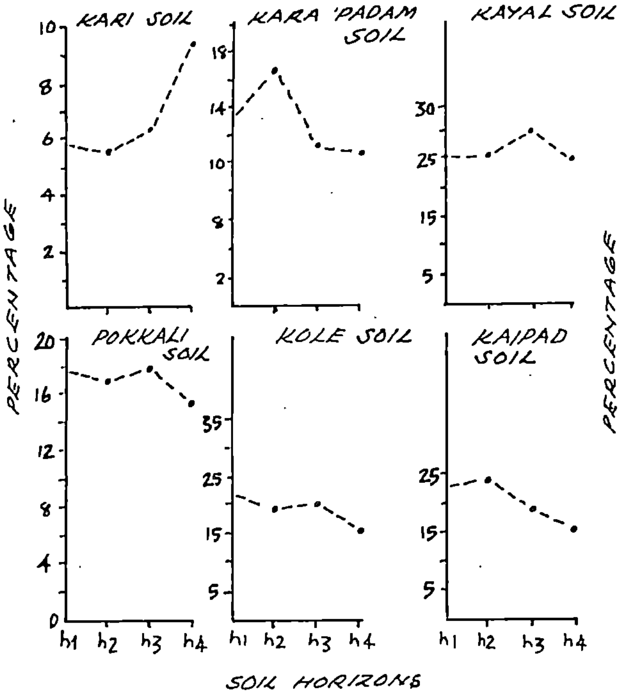


FIG. 12

COMPARATIVE MOISTURE RETAINED AT 15 BARS(%) IN THE ACID SULPHATE SOILS

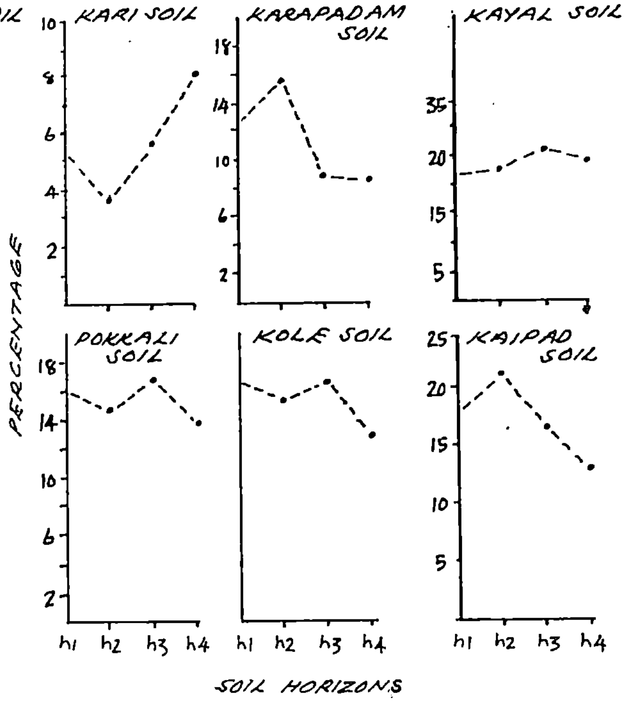
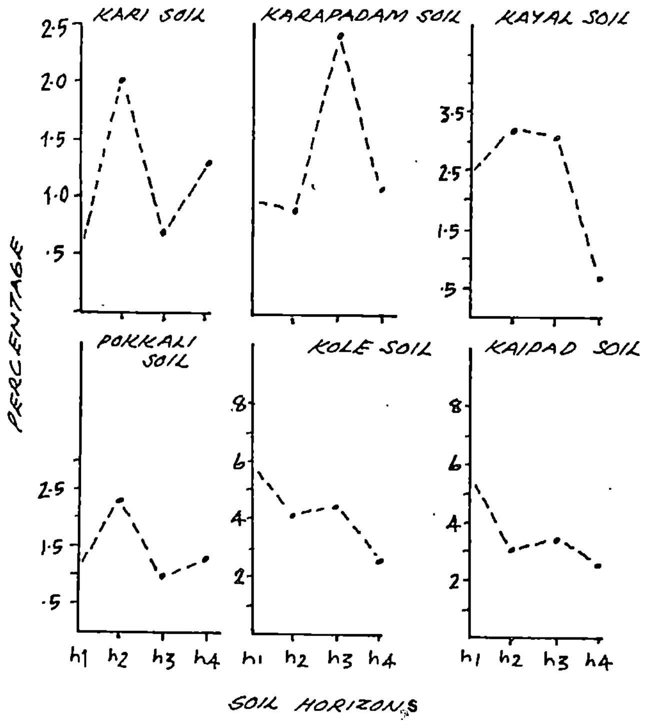


FIG. 13

COMPARATIVE AVAILABLE SOIL MOISTURE %



10.2 Soil moisture retained at 15.0 bars

Mean mositure content retained at 15 bars of these soils ranges between 3.55 and 34.40 percent. They are in the increasing order Mathikayal< Kattampally < Vytilla <Kattukambal< Moncompu < Karumadi.

Though there is significant difference in the moisture retained at 15.0 bar, between locations. Significant differences within the profile are found only at Kattampally.

10.3 Available water

Mean available water content of these soils ranges between 0.5 and 5.90 percent. They are in the decreasing order at Kattukambal > Kattampally > Mathikayal > Vytilla > Karumadi> Moncompu.

There is significant difference between locations with respect to the avilable water content. Significant differences between horizons are found only at Mathikayal, Kattukambal and Kattampally profiles.

11. Organic mater

The content of organic matter are presented in tables 5 to 5.3 and figure 10.

Mean organic matter content of the soils ranges between 0.85 and 17.90 percent. They are in the decreasing order at Karumadi> Moncompu > Kattampally > Vytilla > Kattukambal> Mathikayal. Soil organic matter content of these soils differ significantly between locations, while within profiles they differ significantly at Karumadi, Moncompu and Kattampally only.

12. Measurement of soil acidity and related chemical properties

The results are presented in tables 6 to 6.3 and figures 15 to 33.

ble 6.0 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	35-100+	0-10	10-22	22-46	46-100+
Wet soil pH pH (H_2O) 1:1	3.0	2.5	2.6	2.4	4.1	3.6	3.0	3.0	4.1	3.3	3.1	3.1
Air dried soil pH (H_2O) 1:1	2.5	1.8	2.0	2.2	3.0	2.2	4.0	5.2	3.2	2.6	3.9	3.2
Air dried 30% H_2O_2 treated soil pH (H_2O_2) 1:2	1.8	1.5	1.4	1.4	2.4	2.0	1.6	1.6	2.0	1.8	2.2	1.9
Wet soil electrical condectivity mS cm^{-1} 1:2	5.0	12.3	9.0	10.8	1.60	1.68	8.7	4.7	0.89	2.28	2.60	2.64

ble 6.0 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

	Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
	Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
.	Air dried soil electrical conductivity ECe mS cm^{-1} 1:2	6.2	12.6	10.8	13.8	0.37	2.47	5.9	7.5	0.81	2.67	2.82	4.60
6.	Soil pH in 0.01 M $CaCl_2$ solution 1:2	2.8	2.1	2.5	2.2	2.8	2.0	3.8	2.9	3.8	3.1	2.8	2.9
7.	Redox potential (Eh) (mV) 1:1	+490	+520	+510	+540	+490	+460	+510	+520	+485	+500	+510	+450
8.	Organic carbon %	8.1	10.6	4.3	6.8	6.5	4.9	3.3	3.5	0.73	0.63	0.58	0.44
9.	Total Fe_2O_3 3%	10.3	10.8	11.4	12.1	7.2	7.4	8.1	8.4	6.2	6.6	7.3	6.8

e 6.0 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	35-100+	0-10	10-22	22-46	46-100+
Total Al_2O_3 %	11.6	12.4	12.0	11.9	8.2	9.3	10.1	10.3	8.2	8.3	8.5	9.1
Sesquioxide %	21.9	23.2	23.4	24.0	15.4	16.7	18.2	18.7	14.4	14.8	15.8	15.9
Exchangable Al of soil C mol(p+) kg^{-1}	19.3	18.3	16.5	18.5	4.5	5.8	5.8	6.0	3.5	4.0	4.5	4.2
Exchangeable Fe ppm	36.4	35.4	34.6	34.8	25.5	26.4	39.4	40.9	26.3	25.3	24.6	23.9
Soil CEC C mol(p+) Kg^{-1}	43.6	44.1	45.5	46.3	14.0	13.6	15.0	14.3	10.8	11.3	11.8	12.3
Effective CEC C mol(p+) kg^{-1}	21.8	21.4	22.0	22.2	9.4	9.3	9.5	10.0	8.9	8.1	9.7	9.7

ble 6.0 Measurement of soil acidity and related chemical properties of the acid sulpahte soil profiles

Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
6. Al Saturation of effective CEC %	88.5	85.5	75.0	83.3	47.8	62.4	61.1	60.0	39.3	19.4	46.4	43.3
7. Active Fe ppm	269.9	385.7	339.4	416.6	228.7	187.5	146.3	151.5	80.2	77.6	76.3	72.7
8. Total sulphur %	0.26	0.34	0.15	0.22	0.22	0.17	0.12	0.12	0.04	0.03	0.03	0.02
9. Suphate sulphur ppm	119.3	236.8	203.7	342.3	12.3	50.8	113.8	143.2	20.4	47.4	57.3	90.0
0. Water soluble sulphur ppm	148.6	285.9	247.3	311.6	37.3	68.5	141.1	176.5	32.9	72.8	76.0	114.2
1. Organic sulphur ppm	56.1	63.7	61.6	65.2	49.1	51.6	55.7	57.6	49.6	51.9	52.0	54.2
2. Heat soluble sulphur ppm	259.9	515.1	440.3	562.9	37.4	111.1	247.9	311.7	44.9	119.1	125.1	196.1

able 6.1 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Kari soil Karumadi II				Karapadam soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-12	12-38	38-60	60-100+	0-10	10-35	35-60	60-100+	0-9	9-26	26-45	45-100+
Wet soil pH pH (H_2O) ratio 1:1	2.8	2.6	2.5	2.5	3.9	3.7	3.0	3.8	3.7	3.0	3.0	3.1
Air dried soil pH (H_2O) 1:1	2.3	2.1	1.9	2.0	3.0	2.5	3.8	3.0	3.5	2.6	3.5	3.3
Air dried 30% H_2O_2 treated soil pH 1:2	1.6	1.8	1.4	1.5	2.4	2.1	2.0	1.5	2.2	1.9	2.5	2.0
Wet soil electrical conductivity mS cm-1	8.6	11.6	8.5	9.7	1.5	8.6	3.0	4.3	1.5	2.0	2.4	2.8
Air dried soil electrical conductivity mS cm-1	9.8	12.0	10.0	13.0	0.50	1.68	3.5	6.2	0.92	2.3	2.6	4.5
Soil pH in 0.01 M $CaCl_2$ solution 1:2	2.6	2.4	2.4	2.5	3.2	2.3	3.6	3.4	4.0	1.5	3.0	3.5
Redox potential (Eh) (mV) 1:1	+505	+515	+530	+540	+495	+370	+515	+520	+470	+490	+510	+500

ble 6.1 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Kari soil Karumadi II				Karapadam soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Organic carbon %	7.4	10.1	3.7	6.8	6.7	5.2	3.7	3.5	0.86	0.86	0.75	0.55
Total Fe_2O_3 %	11.2	11.5	12.1	13.0	7.3	7.8	8.1	8.5	6.8	7.2	8.0	8.3
0. Total Al_2O_3 %	12.0	12.5	12.7	11.8	9.3	10.2	11.1	11.4	9.0	9.3	8.9	9.3
1. Sesquioxide %	23.2	24.0	24.2	24.8	16.6	18.0	19.2	19.9	15.8	16.5	16.9	17.6
2. Exchangeble Al C mol (p+) kg^{-1}	16.3	17.2	18.2	18.5	6.0	6.9	7.2	6.8	4.6	5.1	5.5	5.3
3. Exchangeable Fe ppm	36.0	35.0	35.2	34.7	33.2	39.4	41.0	39.7	27.5	26.5	25.4	24.7
4. Active Fe ppm	327.8	362.0	392.6	404.3	189.5	211.1	189.5	195.0	73.5	70.2	68.9	65.5
.5. Soil CEC C mol (p+) kg^{-1}	43.5	45.1	46.5	46.9	15.2	14.8	15.5	14.0	11.5	12.3	12.5	13.0

ble 6.1 Measrement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Kari soil Karumadi II				Karapadam soil Moncompu II				Kayal soil Mathikayal II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
. Soil effective CEC Cmol (p+) kg^{-1} of the soil	22.0	21.5	22.0	22.1	10.2	10.4	10.2	11.0	9.9	9.5	10.1	10.4
7. Al saturation of effective CEC%	74.1	80.0	82.7	83.7	58.8	66.3	70.6	61.8	46.5	53.7	54.5	50.9
8. Total sulphur %	0.30	0.34	0.20	0.25	0.30	0.25	0.23	0.20	0.08	0.07	1.0	0.9
9. Sulphate sulphur ppm	185.4	225.8	189.1	244.1	14.7	36.4	69.8	119.3	22.4	47.8	53.3	58.1
0. Water soluble ppm	225.8	273.0	230.1	294.5	26.2	51.6	90.6	148.6	33.25	64.9	71.3	112.1
1. Organic sulphur ppm	60.4	63.0	60.6	64.2	49.3	50.7	52.9	56.1	49.8	49.9	51.8	54.1
2. Heat soluble sulphur ppm	403.4	491.2	411.4	531.1	32.6	79.6	152.2	259.8	49.3	54.8	116.3	192.1

able 6.2 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-16	16-33	33-60	60-100+	0-16	16-29	29-66	66-100+	0-9	9-22	22-33	33-100+
Wet soil pH pH (H_2O) 1:1	2.9	2.9	3.2	3.3	4.4	4.6	4.4	4.4	3.1	4.6	3.5	6.4
Air dried soil pH (H_2O) 1:1	2.8	2.6	2.4	2.9	3.8	3.9	3.8	3.5	2.4	3.8	2.8	6.1
Air dried 30% H_2O_2 treated soil pH 1:2	1.6	1.4	1.6	1.6	2.2	2.2	2.2	2.2	2.2	2.0	1.8	3.3
Wet soil electrical conductivity mS cm^{-1} 1:2	5.8	6.7	7.2	7.2	0.75	0.28	0.29	0.34	2.76	1.95	2.28	4.0
Air dried soil electrical conductivity mS cm^{-1} 1:2	6.8	8.0	10.5	8.5	0.36	0.49	0.27	0.37	3.3	2.95	3.4	6.4
Soil pH in 0.01 M $CaCl_2$ solution 1:2	2.4	2.3	2.0	2.5	3.4	3.6	3.4	3.0	2.0	3.8	2.8	5.8

6.2 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Redox potential (Eh) mV) 1:1	+470	+490	+480	+470	+450	+450	+440	+520	+480	+485	+480	+450
Organic carbon %	2.3	2.3	2.1	1.9	1.2	1.0	0.87	0.58	1.6	3.7	5.2	4.9
Total Fe_2O_3 %	4.2	4.5	4.3	4.3	3.4	3.6	5.9	5.2	6.3	5.2	6.1	5.0
Total Al_2O_3 %	4.8	5.2	5.5	5.3	4.6	4.5	6.1	4.3	5.3	6.6	6.6	4.0
Sesquioxide %	8.4	9.4	9.8	9.6	8.0	8.1	12.0	9.5	11.6	11.8	12.7	9.0
Exchangeable Al of the soil Cmol (p+) kg^{-1}	5.9	3.5	3.4	4.5	5.7	5.2	8.2	8.5	8.5	5.3	5.0	4.8
Exchangeable Fe ppm	33.0	36.1	39.8	37.2	35.8	36.6	35.5	34.6	28.9	28.3	36.1	32.0
Active Fe ppm	120.6	118.0	115.5	110.3	93.3	87.1	83.8	76.3	102.6	156.6	195.2	187.5
Soil CEC Cmol (p+) kg^{-1} soil	24.9	23.9	22.5	21.6	17.9	18.1	23.5	23.8	23.0	21.5	15.8	13.5
Soil effective CEC Cmol (p+)kg^{-1}	16.8	15.0	14.5	11.8	10.8	10.0	13.2	14.2	13.6	12.1	11.2	10.5

ble 6.2 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
7. All saturation of effective CEC %	35.1	64.7	23.4	38.1	52.8	52.0	62.1	60.7	62.5	43.8	44.6	45.7
8. Total sulphur %	0.08	0.07	0.08	0.07	0.05	0.04	0.04	0.03	0.06	0.13	0.17	0.16
9. Sulphate sulphur ppm	130.3	152.4	198.2	161.5	12.2	14.6	10.5	12.3	66.1	60.1	67.9	123.0
0. Water soluble sulphur ppm	161.4	187.2	240.8	197.9	23.2	26.0	21.3	23.5	86.3	79.2	88.5	152.9
1. Organic sulphur ppm	56.8	58.2	61.2	58.8	49.1	49.3	48.9	49.1	52.6	52.2	52.7	56.3
2. Heat soluble sulphur ppm	283.8	331.7	431.4	351.6	26.9	32.2	23.4	27.4	144.2	131.1	148.2	267.8

6.3 Measurement of soil acidity and related chemical properties of the acid sulphate soil profiles

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-10	10-30	30-57	57-100+	0-15	15-25	25-60	60-100+	0-9	9-25	25-41	41-100+
Wet soil pH pH (H_2O)1:1	2.9	2.1	3.2	3.4	4.5	4.5	4.4	4.6	3.9	4.1	4.6	5.9
Air dried soil pH (H_2O) 1:1	2.7	2.8	2.8	2.8	3.9	3.8	3.5	3.9	3.2	3.3	3.3	5.6
Air dried 13% H_2O_2 treated soil pH 1:2	1.8	2.0	2.0	1.5	2.3	2.2	2.9	2.5	2.0	1.5	2.3	2.7
Wet soil electrical conductivity mS cm^{-1}	6.3	6.5	7.0	6.9	0.52	0.31	0.33	0.40	2.4	2.1	2.4	4.4
Air dried soil electrical conductivity mS cm^{-1}	7.4	8.0	10.3	8.2	0.68	0.51	0.40	0.45	2.91	3.3	3.5	6.5
Soil pH in 0.01 M $CaCl_2$ solution	2.3	2.4	2.3	2.0	3.2	3.5	3.3	2.9	2.2	2.8	3.3	5.5
Redox potential (Eh) (mV) 1:1	+480	+490	+500	+460	+455	+450	+510	+480	+490	+490	+450	

6.3 Measurement of soil acidity and related chemcial properties of the acid sulphate of soil profils

Location	Pokkali soil / Vytilla II				Kole soil / Kattukambal II				Kaipad soil / Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Organic carbon %	2.1	2.0	2.8	1.9	1.0	0.95	0.75	0.83	2.2	3.3	5.5	5.2
									6.5	5.8	6.0	4.8
Total Fe Fe_2O_3 %	4.3	5.0	4.4	4.3	3.5	3.7	6.0	5.5	5.8	6.4	6.6	5.0
Total Al Al_2O_3 %	5.0	5.4	5.4	4.9	4.8	4.7	6.3	4.4	12.3	12.2	12.6	9.8
Sesquioxide %	9.3	10.4	9.8	9.2	8.3	8.4	12.3	9.9				
Exchangeable Al of the soil Cmol(p+)kg^{-1}	4.7	3.3	3.5	4.6	5.5	5.0	7.8	8.2	7.6	4.5	4.1	4.9
Exchangeable Fe ppm	34.5	36.5	40.1	38.0	36.0	36.8	35.7	34.5	29.0	28.5	33.1	31.5
Active Fe ppm	115.5	112.9	107.7	110.3	87.1	85.0	80.7	82.8	118.0	146.3	202.9	190.1
Soil CEC Cmol (p+) kg^{-1}	25.0	24.2	23.8	21.5	18.1	18.3	22.5	22.2	22.0	20.7	18.5	16.3
Soil effective CEC Cmol(p+)Kg^{-1}	15.5	14.8	14.5	12.3	11.2	10.7	9.9	12.5	12.5	13.3	12.0	11.2

ble 6.3 Measurement of soil acidity and related chemical properties of the acid sulphate of soil profils

Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
Horizon No.	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
'. Al saturation of effective CEC%	30.3	22.3	24.1	37.4	49.1	46.7	78.8	65.6	60.8	33.8	34.2	43.7
. Total sulphur %	0.06	0.06	0.08	0.06	0.04	0.04	0.03	0.04	0.08	0.15	0.16	0.15
. Sulphate sulphur ppm	141.4	152.4	194.6	150.5	18.0	14.9	12.9	13.8	53.2	66.1	69.8	124.8
). Water soluble sulphur ppm	174.3	187.2	236.5	191.5	30.1	26.5	24.1	25.2	77.7	86.3	90.6	55.0
. Organic sulphur ppm	57.5	58.2	60.9	58.5	49.5	49.3	49.1	49.2	52.1	52.6	52.9	56.4
2. Heat soluble sulphur ppm	307.7	331.7	423.3	339.6	39.7	32,9	28.6	30.6	122.3	144.2	152.2	271.8

FIG. 15

COMPARATIVE WET SOIL pH OF ACID SULPHATE SOILS

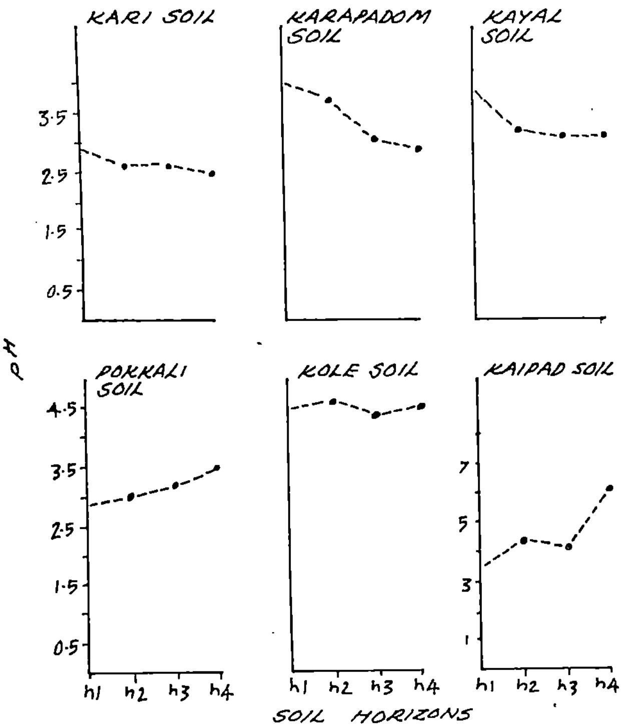


FIG. 16

COMPARATIVE AIR DRIED SOIL pH OF ACID SULPHATE SOILS

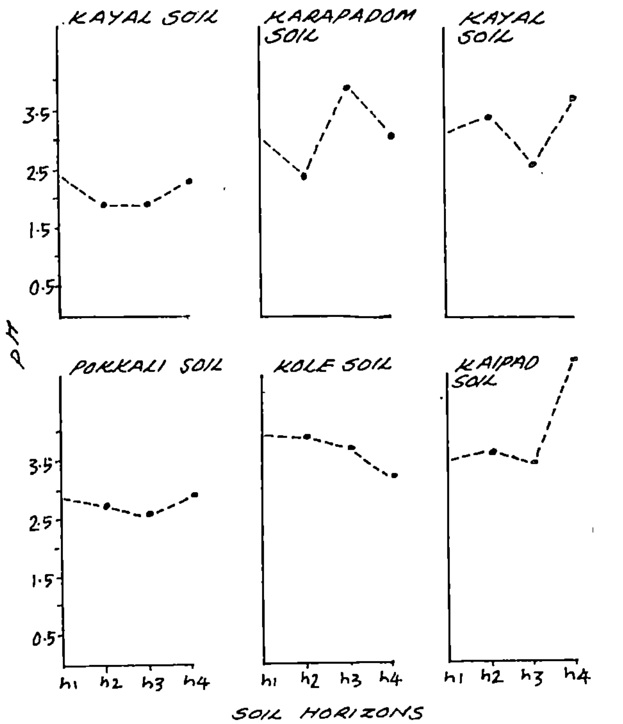


FIG. 17

COMPARATIVE AIR DRIED 30% H_2O_2 TREATED SOIL pH OF ACID SULPHATE SOILS OF KERALA

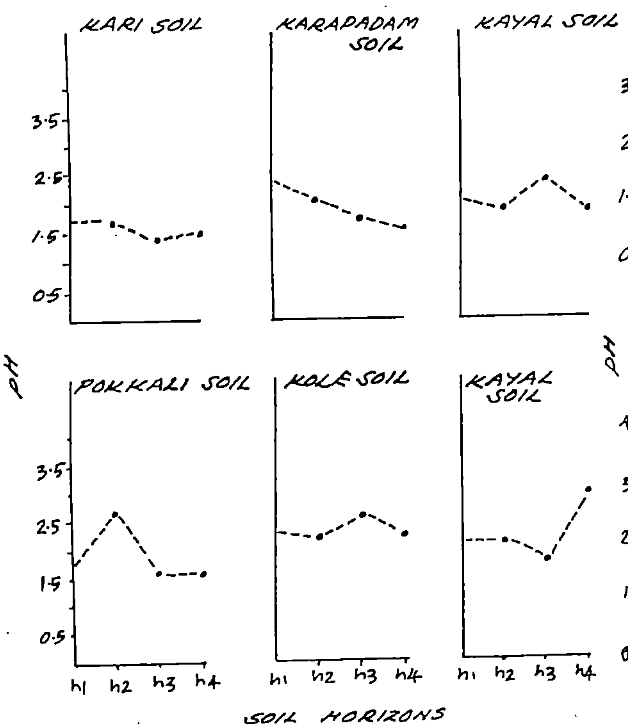


FIG. 18

COMPARATIVE SOIL pH IN 0.01 M $CaCl_2$ SOLUTION OF ACID SULPHATE SOILS OF KERALA

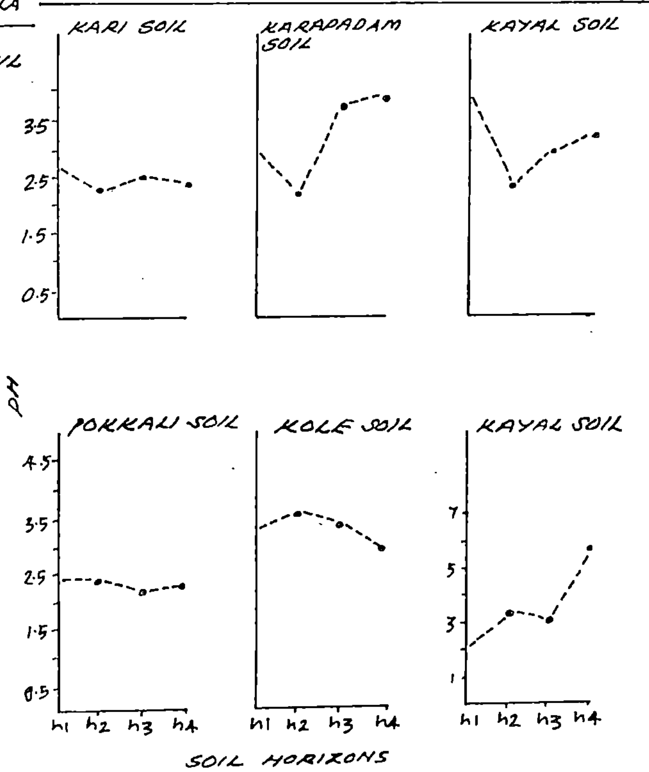


FIG. 19

RELATIONSHIP BETWEEN SOIL HORIZONS TOTAL SULPHUR CONTENT AND AIR DRIED SOIL pH OF SAMPLES FROM ACID SULPHATE SOILS OF KERALA

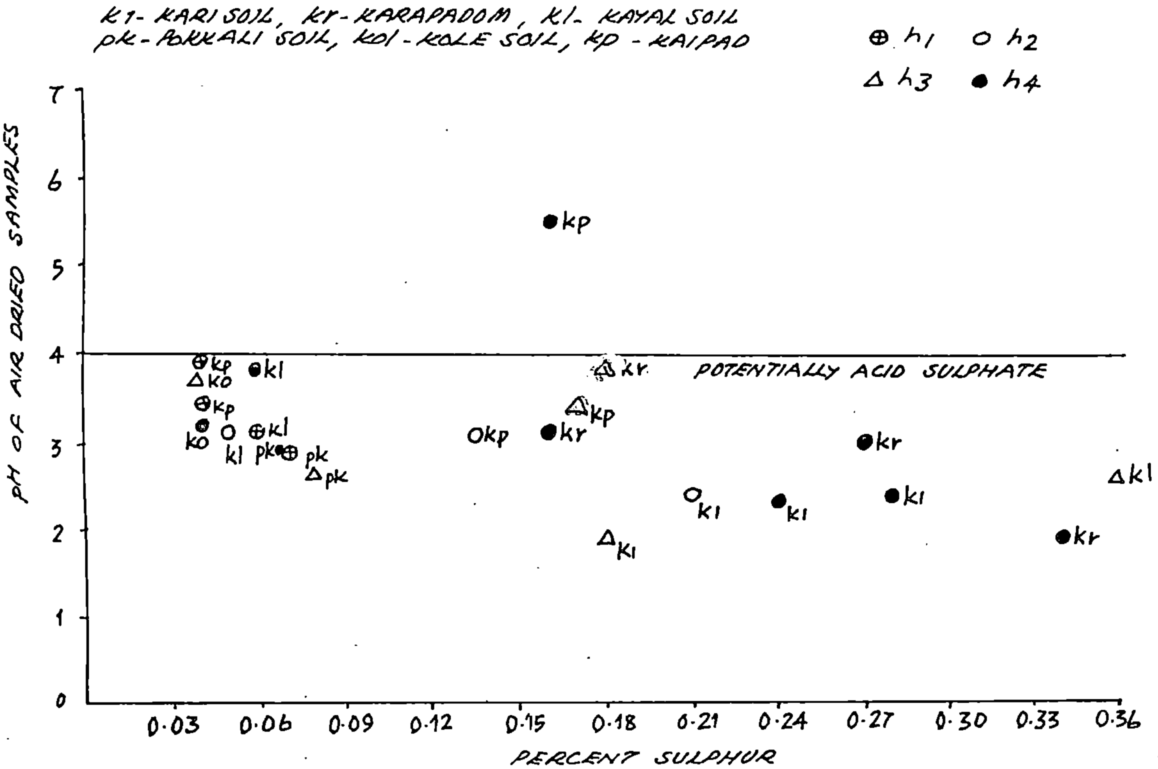
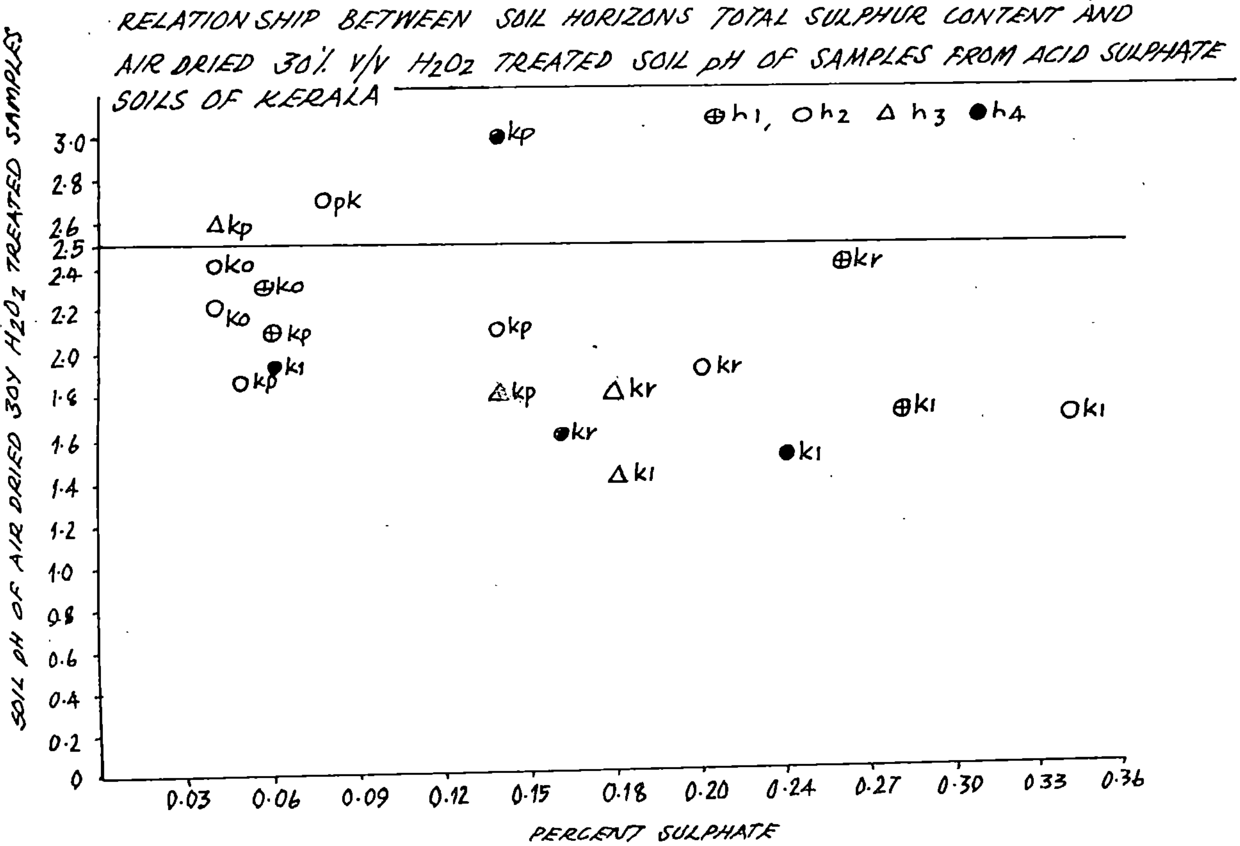


FIG. 20

RELATIONSHIP BETWEEN SOIL HORIZONS TOTAL SULPHUR CONTENT AND AIR DRIED 30% V/V H_2O_2 TREATED SOIL pH OF SAMPLES FROM ACID SULPHATE SOILS OF KERALA



12.1 Wet soil pH [pH(H_2O) 1:1]

Mean wet soil pH of these soils ranges between 2.45 and 6.15. It is in the decreasing order at Kattukambal > Kattampally> Moncompu > Mathikayal > Vytilla > Karumadi.

There is significant difference in the wet soil pH between different locations. Except at Karumadi and Kattukambal there is significant difference in the wet soil pH between horizons.

12.2 Air dried soil pH [pH(H_2O) 1:1]

Wet soil samples collected are air dried and pH determined in 1:1 soil water suspension after 30 minutes equilibrium. Mean air dried soil pH ranges between 1.95 and 3.90. It is in the decreasing order at Kattukambal > Kattampally > Moncompu > Mathikayal> Vytilla > Karumadi. Irrespective of the locations the air dried soil pH differed significantly. Significant differences within the profile are found only at Moncompu, Mathikayal and Kattampally.

12.3 Air dried 30 percent H_2O_2 treated soil pH(1:2)

Mean value of air dried H_2O_2 treated soil pH of these soils ranges between 1.40 and 3.0. They are in the decreasing order at Kattukambal > Kattampally > Mathikayal > Moncompu > Vytilla > Karumadi. Air dried H_2O_2 treated soil pH of these soils differ significantly between locations. Significant difference for the same within the profiles are observed only at Moncompu, and Kattampally.

12.4 Soil pH in 0.01 M $CaCl_2$ solution (1:1)

Mean soil pH in 0.01 $CaCl_2$ solution ranges between 2.15 and 5.65. They are in the decreasing order at Kattampally > Kattukambal > Moncompu > Mathikayal > Karumadi > Vytilla.

Table 6.4 Shift in soil pH by different methods from wet soil pH (H_2O) 1:1 of the acid sulphate soils

Location	Kari soil Karumadi I				Karapadam soil Moncompu I				Kayal soil Mathikayal I			
Horizons	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
Depth in cm	0-9	9-35	35-58	58-100+	0-14	14-34	34-65	65-100+	0-10	10-22	22-46	46-100+
1. Wet Soil pH pH(H_2O) 1:1	3.0	2.5	2.6	2.4	4.1	3.6	3.0	3.0	4.1	3.3	3.1	3.1
2. Shift in air dried soil pH (H_2O) 1:1	-0.5	-0.7	-0.6	-0.2	-1.1	-1.4	-1.0	-0.2	-0.9	-0.7	-0.8	+0.1
3. Air dried 30% H_2O_2 treated soil pH pH(H_2O_2)1:2	-1.2	-1.0	-1.2	-1.0	-1.7	-1.6	-1.4	-1.4	-2.1	-1.5	-0.9	-1.2
4. Shift in soil pH in 0.01 M $CaCl_2$ solution	-0.2	-0.4	-0.1	-0.2	-1.3	-1.6	+0.8	-0.1	-0.3	-0.2	-0.3	-0.2

Table 6.5 Shift in soil pH by different methods from wet soil pH (H_2O) 1:1 of the acid sulphate soils

Soil Profile / Location	Kari soil Karumadi II				Karapadam soil Moncompu II				Kayal soil Mathikayal II			
Horizons / Depth in cm.	h1 0-12	h2 12-38	h3 38-60	h4 60-100+	h1 0-10	h2 10-35	h3 35-60	h4 60-100+	h1 0-9	h2 9-26	h3 26-45	h4 45-100+
1. Wet soil pH (H_2O) 1:1	2.8	2.6	2.5	2.5	3.9	3.7	3.0	2.8	3.7	3.0	3.0	3.1
2. Air dried soil pH pH(H_2O) 1:1	-0.5	-0.5	-0.6	-0.5	-0.9	-1.2	-0.8	+0.2	-0.2	-0.4	+0.5	+0.2
3. Air dried 30% H_2O_2 treated soil pH 1:2	-1.2	-0.8	-1.1	-1.0	-1.5	-1.6	-1.0	-1.3	-1.5	-1.1	-0.5	-1.1
4. Soil pH in 0.01M $CaCl_2$ solution	-0.2	-0.2	-0.1	-	-0.7	-1.4	+0.6	+0.6	+0.3	-1.5	-	+0.4

Table 6.6 Shift in soil pH by different methods from wet soil pH, $pH(H_2O)$ 1:1 of the acid sulphate soils

Soil profile / Location	Pokkali soil / Vytilla II				Kole soil / Kattukambal I				Kaipad soil / Kattampally I			
Horizons Depth in cm	h1 0-16	h2 16-33	h3 33-60	h4 60-100+	h1 0-16	h2 16-29	h3 29-66	h4 66-100+	h1 0-9	h2 0-22	h3 22-36	h4 36-100+
1. Wet soil pH $pH(H_2O)$ 1:1	2.9	2.9	3.2	3.3	4.4	4.6	4.4	4.4	3.1	4.6	3.5	6.4
2. Air dried soil pH $pH(H_2O)$ 1:1	-0.1	-0.3	-0.8	-0.4	-0.6	-0.7	-0.6	-0.9	-0.7	-0.8	-0.7	-0.3
3. Air dried 30% H_2O_2 treated soil pH $pH(H_2O_2)$ 1:2	-1.3	-1.5	-1.6	-1.7	-2.2	-2.4	-2.4	-2.2	-0.9	-2.6	-1.7	-3.1
4. Soil pH in 0.01 M $CaCl_2$	-0.5	-0.6	-1.2	-0.8	-1.0	-1.0	-1.0	-1.4	-1.1	-0.8	-0.7	-0.6

Table 6.7 Shift in soil pH by different methods from wet soil pH, $pH(H_2O)$ 1:1 of the acid sulphate soils

Soil profile / Location	Pokkali soil / Vytilla II				Kole soil / Kattukambal II				Kaipad soil / Kattamaplly II			
Horizons / Depth in cm	h1 0-10	h2 10-30	h3 30-57	h4 57-100+	h1 0-15	h2 15-25	h3 25-60	h4 60-100+	h1 0-9	h2 9-25	h3 25-41	h4 41-100
1. Wet soil pH, $pH(H_2O)$ 1:1	2.9	2.1	3.2	3.4	4.5	4.5	4.4	4.6	3.9	4.1	4.6	5.9
2. Air dried soil pH, $pH(H_2O)$1:1	-0.2	+0.7	-0.4	-0.6	-0.6	-0.7	-0.9	-0.7	-0.7	-1.1	-1.3	-0.3
3. Air dried 30% H_2O_2 treated Soil pH, $pH(H_2O)$ 1:2	-1.1	-1.1	-1.2	-1.9	-2.2	-2.3	-1.5	-2.1	-1.9	-2.6	-2.3	-3.2
4. Soil pH in 0.01M $CaCl_2$ solution.	-0.6	+0.3	-0.9	-1.4	-1.3	-1.0	-1.1	-1.7	-1.7	-1.3	-1.3	-0.4

Locations differ significantly for their soil pH in 0.01 M $CaCl_2$ solution. Significant difference within soil profiles for the same are found only at Moncompu, Mathikayal and Kattampally.

12.5 Shift in soil pH by different methods from wet soil pH (H_2O)(1:1)

The shift in soil pH by different methods from wet soil pH are presented in tables 6.4 to 6.7.

The shift in soil pH of air dried soil pH from wet soil pH ranges between-0.9 to +1.4 units. They are in the increasing order at Moncompu Mathikayal < Kattampally < Kattukambal < Karumadi < Vytilla.

12.5.2. Shift in air dried 30 percent H_2O_2 treated soil pH (1:2)

The shift in soil pH of air dried 30 percent H_2O_2 treated soil pH ranges between - 0.2 and - 0.5 units. They are in the increasing order at Moncompu < Mathikayal < Kattampally < Kattukambal Karumadi < Vytilla.

12.5.3. Shift in soi pH in 0.01 M $CaCl_2$ solution

The shift in soil pH in 0.01 M $CaCl_2$ solution ranges between -1.7 and + 1.4 units. They are in the increasing order at Karumadi < Vytilla < Mathikayal < Moncompu < Kattukambal < Kattampally.

13. **Soil electrical conductivity**

The wet soil electrical conductivity and air dried soil electrical conductivity of the profile samples from different locations are presented in tables 6 to 6.3 and figures 21 and 22.

FIG. 21

COMPARATIVE WET SOIL ELECTRICAL CONDUCTIVITY OF ACID SULPHATE SOILS OF KERALA

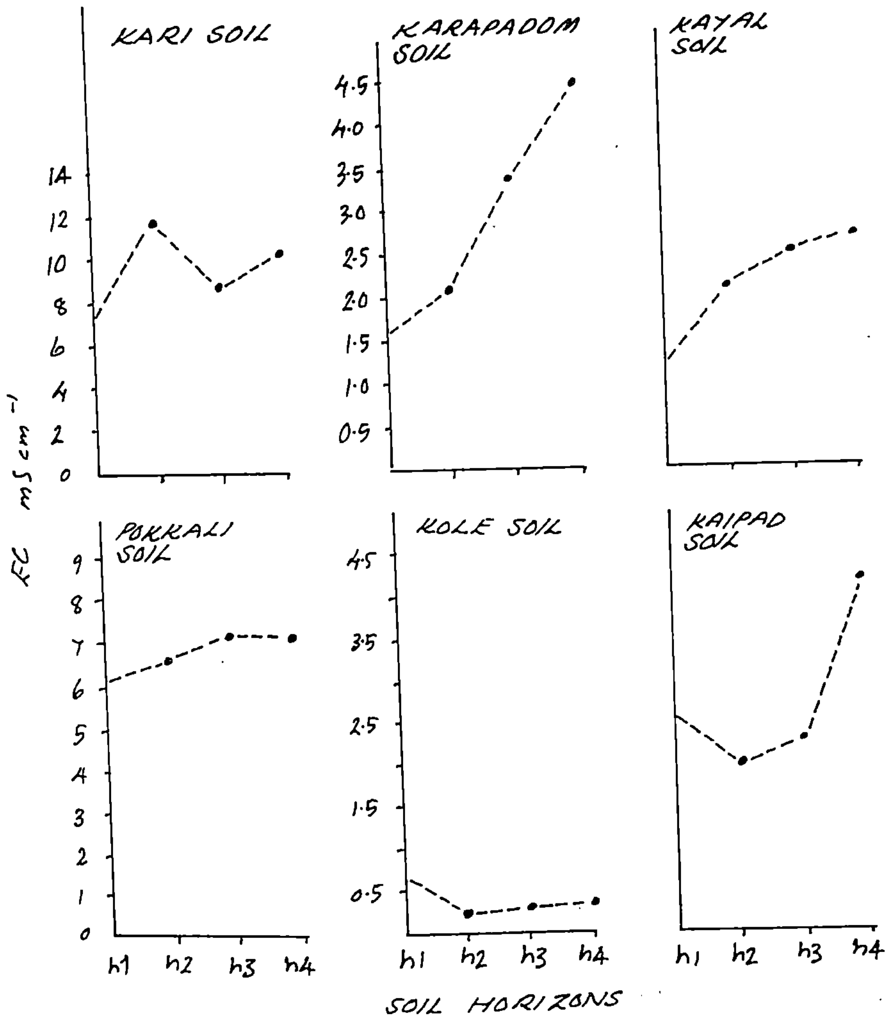


FIG. 22

COMPARTIVE AIR DRIED SOIL ELECTRICAL CONDUCTIVITY OF ACID SULPHATE SOILS OF KERALA

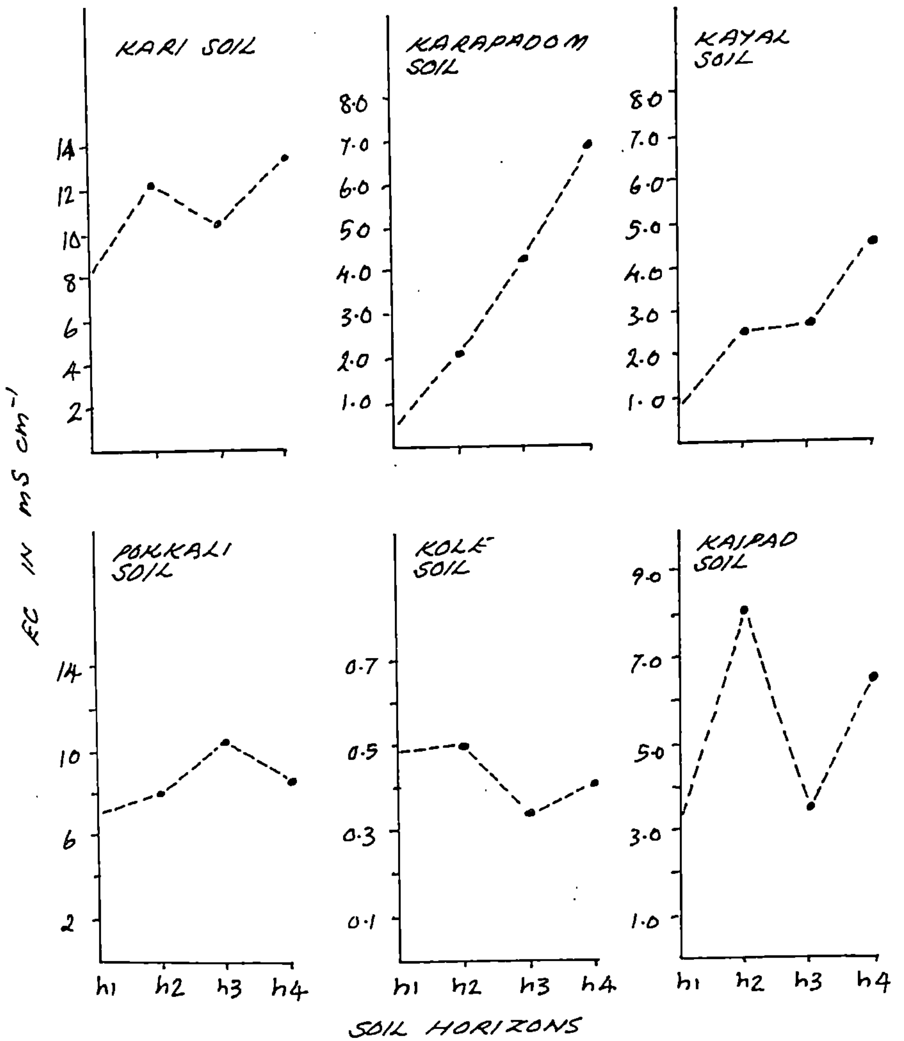


Table 6.8 Shift in Air dried soil electrical conductivity from wet soil electrical conductivity of acid sulphate soils

Soil profile / Location	Kari soil Karumadi I				Karapadom soil Moncompu I				Kayal soil Mathikayal I			
	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
1. Wet soil electrical conductivity $ms\ cm^{-1}$	5.0	12.3	9.0	10.8	1.60	1.68	3.7	4.7	0.89	2.28	2.60	2.64
2. Air dried soil electrical conductivity $ms\ cm^{-1}$	6.2	12.6	10.8	13.8	0.37	2.47	5.9	7.5	0.81	2.67	2.82	4.60
3. Shift in Electrical conductivity of air dried soil from wet soil $ms\ cm^{-1}$	+1.2	+0.3	+1.8	+3.8	-1.23	+0.79	+2.2	+2.8	-0.08	+0.39	+0.22	+1.96

Table 6.9 Shift in Air dried soil electrical conductivity from wet soil electrical conductivity of acid sulphate soils

	Soil profile / Location	Kari soil / Karumadi I I				Karapadom soil / Moncompu II				Kayal soil / Mathikayal II			
		h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
1.	Wet soil electrical conductivity mS cm^{-1}	8.6	11.6	8.5	9.7	1.5	2.6	3.0	4.3	1.50	2.0	2.4	2.8
2.	Air dried soil electrical conductivity mS cm^{-1}	9.8	12.0	10.0	13.0	0.50	1.68	3.5	6.2	0.92	2.3	2.6	4.5
3.	Shift in electrical conductivity of air dried soil from wet soil mS cm^{-1}	+1.2	+0.4	+1.5	+3.3	-1.0	-0.92	+0.5	+1.9	-0.58	+0.3	+0.2	+1.7

Table6.10 Shift in Air dried soil electrical conductivity from wet soil electrical conductivity of acid sulphate soils

Soil profile Location	Pokkali soil Vytilla I				Kole soil Kattukambal I				Kaipad soil Kattampally I			
	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
1. Wet soil electrical conductivity $mS\ cm^{-1}$	5.8	6.7	7.2	7.2	0.75	0.28	0.29	0.34	2.76	1.95	2.28	4.0
2. Air dried soil electrical conductivity $mS\ cm^{-1}$	6.8	8.0	10.5	8.5	0.36	0.49	0.27	0.37	3.30	2.97	3.4	6.4
3. Shift in Air dried soil electrical conductivity from wet soil $mS\ cm^{-1}$	+1.0	+1.3	+3.3	+1.3	-0.39	+0.21	-0.02	+0.03	+0.54	+1.02	+1.12	+2.4

Table6.11 Shift in Air dried soil electrical conductivity from wet soil electrical conductivity of acid sulphate soils

Soil profiles / Location	Pokkali soil Vytilla II				Kole soil Kattukambal II				Kaipad soil Kattampally II			
	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4
1. Wet soil electrical conductivity mS cm^{-1}	6.3	6.5	7.0	6.9	0.52	0.31	0.33	0.40	2.4	2.1	2.4	2.4
2. Air dried soil electrical conductivity mS cm^{-1}	7.4	8.0	10.3	8.2	0.68	0.51	0.40	0.45	2.91	3.3	3.5	6.5
3. shift in air dried soil electrical conductivity from wet soil mS cm^{-1}	+1.1	+1.5	+3.3	+1.3	+0.11	+0.20	+0.7	+0.5	+0.51	+1.2	+1.7	+4.1

13.1 Wet soil electrical conductivity (1:2)

Mean wet soil electrical conductivity ranges between 0.29 and 11.95 mS cm^{-1}. They are in the increasing order at Kattukambal < Mathikayal < Kattampally< Moncompu < Vytilla and < Karumadi. Irrespective of the locations it exhibited significant difference. Within the profiles it exhibited significant differences at Karumadi, Moncompu and Kattampally only.

13.2 Electrical conductivity of air dried soils (1:2)

Mean electrical conductivity of air dried soil ranges between 0.41 and 12.30 mS cm^{-1}. They are in the increasing order Kattukambal< Moncompu < Mathikayal < Kattampally < Vytilla<Karumadi.

Irrespective of the locations it differs significantly within the profiles except at Kattukambal.

13.3 Shift in soil electrical coductivity of air dried soils from wet soil electrical conductivity

The shift in electrical conductivity of air dried soil from that of wet soil is presented in tables 6.8 to 6.11.

The shift in electrical conductivity on air drying of the soils ranges between -1.23 and + 3.8 mS cm^{-1}. They are in the increasing order at Kattukambal < Moncompu < Mathikayal< Kattampally < Vytilla < Karumadi.

Irrespective of the locations the shift in soil electrical condutivity on drying differs significantly. Within the profiles also it differs significantly at all locations except that at Kattukambal.

14. **Redox potential (Eh)**

Redox potential (Eh) of air dried soils are presented in

FIG. 23

COMPARATIVE REDOX POTENTIAL mV 1:1 OF ACID SULPHATE SOILS OF KERALA

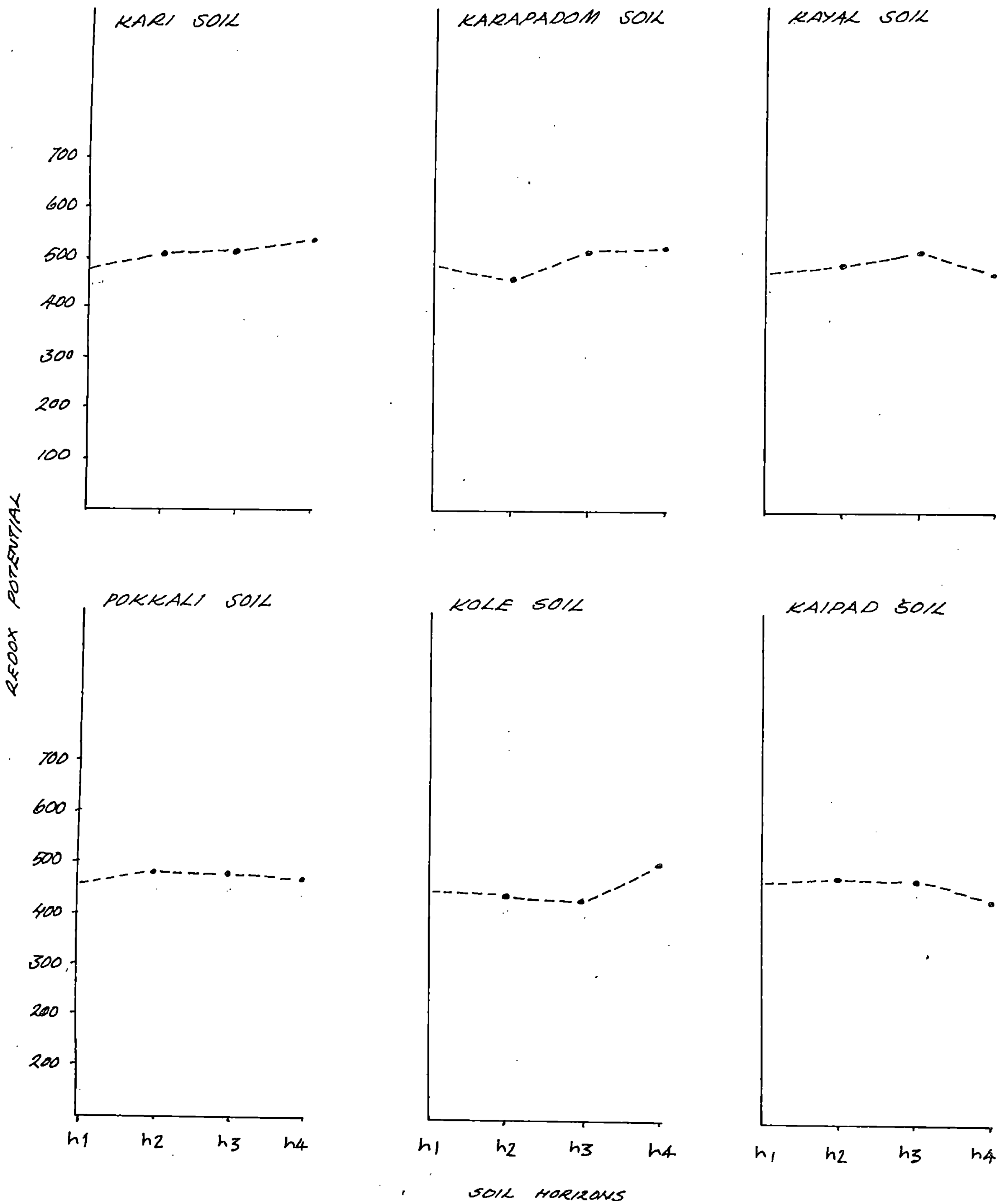
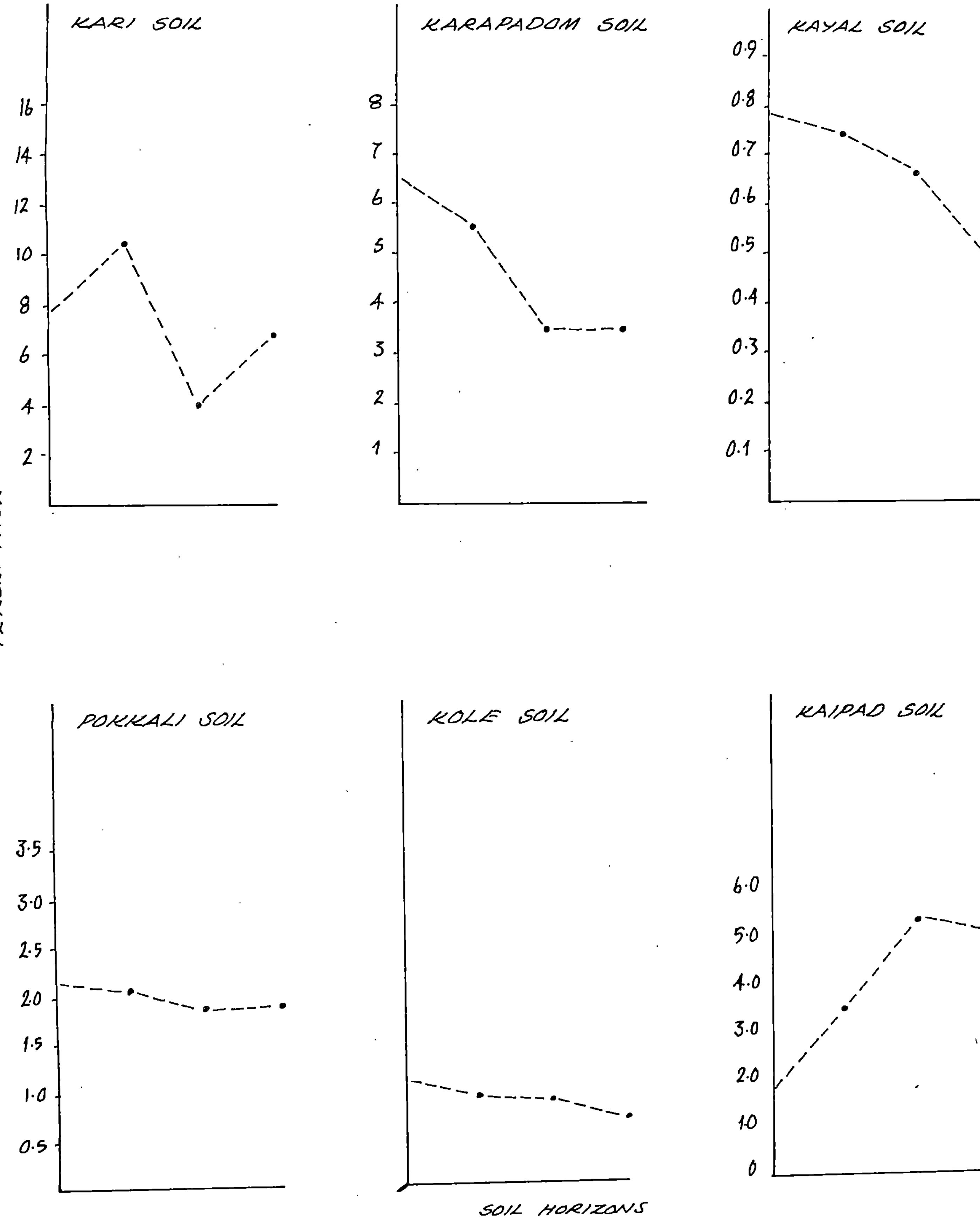


FIG. 14

COMPARATIVE ORGANIC CARBON % OF ACID SULPHATE SOILS



tables 6 to 6.3 and figure 23. Mean redox potential of the soil ranges between +445 and +540 mV. They are in the increasing order at Moncompu Kattampally < Kattukambal < Mathikayal < Vytilla < Karumadi. Irrespective of the locations the redox potential of these soils differ significantly. It differs significantly within the profiles only at Moncompu and Kattukambal.

15. **Organic Carbon**

Organic carbon content of soils are presented in tables 6 to 6.3 and figure 14.

Mean organic carbon content of the soils ranges between 0.50 and 10.35 percent. They are in the increasing order at Mathikayal < Kattukambal< Vytilla<Kattampally < Moncompu <Karumadi.

The soils differ significantly in their organic carbon content irrespective of their locations. Organic carbon content differs signifincantly within the profiles at Karumadi, Moncompu and Kattampally.

16. **Total Iron (Fe_2O_3 percent)**

The total content of Fe_2O_3 of soils are presented in tables 6 to 6.3 and figure 24.

Mean total Fe_2O_3 content of these soils are in the increasing order at vytilla < Kattukambal < Kattampally < Mathikayal < Moncompu < Karumadi.

Irrespective of the locations total Fe_2O_3 content of the soils differed significantly. Significant differences between total Fe_2O_3 content of the soils are found within the profiles at all locations except at Vytilla.

FIG. 24

COMPARATIVE TOTAL Fe_2O_3 % OF ACID SULPHATE SOILS OF KERALA

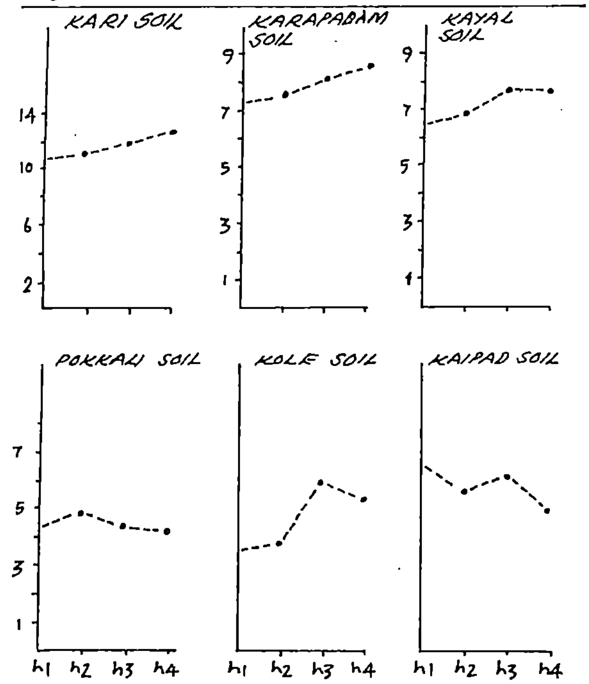


FIG. 25

COMPARATIVE TOTAL Al_2O_3 % OF ACID SULPHATE SOILS OF KERALA

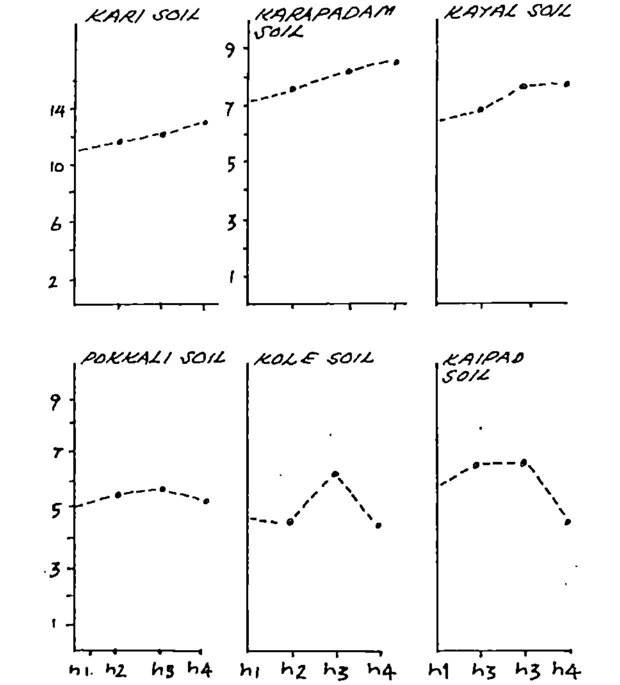
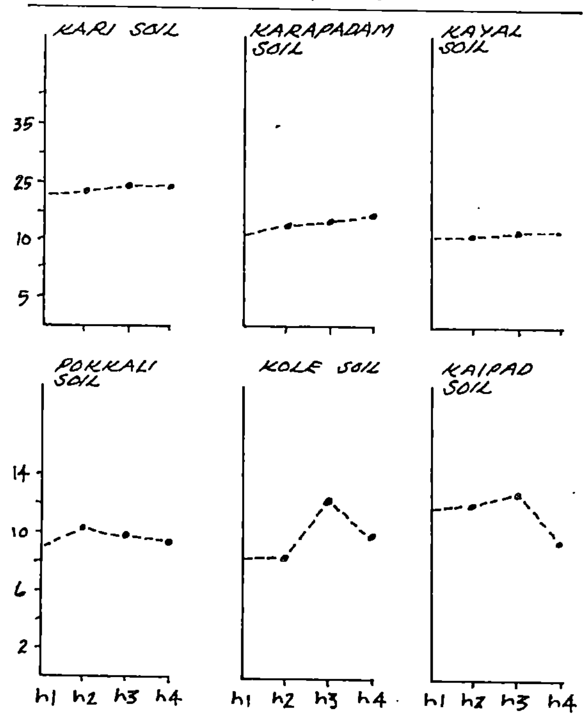


FIG. 26

COMPARATIVE SESQUIOXIDE % OF ACID SULPHATE SOILS OF KERALA



17. **Total Aluminium (Al_2O_3 percent)**

The total Al_2O_3 content of the soils are presented in tables 6 to 6.3 and figure 25.

Mean Al_2O_3 content of the soil ranges between 4.35 and 12.45 percent. They are in the increasing order at Kattukambal < Kattampally < Mathikayal < Moncompu < Vytilla < Karumadi. Total Al_2O_3 content of the soils differs significvantly irrespective of the locations. Except at Moncompu, Kattukambal and Kattampally, its content differ signifincantly within the profiles at all locations.

18. **Sesquioxide Content**

The sesquioxide percent content (percent Fe_2O_3 + Al_2O_3) of the soils are presented in tables 6 to 6.3 and figure 26.

Mean values of sesquioxide soils range between 8.15 and 24.45 percent. They are in the increasing order at Vytilla < Kattukambal < Kattampally < Mathikayal < Moncompu < Karumadi. It differ significantly between locations. Significant differences in the sesquioxide content within the profiles are found only at Mathikayal, Kattukambal and Kattampally.

19. **Exchangeable aluminium**

The exchangeable alumnium content of the soils are presented in tables 6 to 6.3 and figure 29.

Mean exchangeable aluminium content of the soil ranges between 3.4 and 18.5 $Cmol(p+)Kg^{-1}$. They are in the increasing order at Mathikayal < Vytilla < Moncompu < Kattampally < Kattukambal < Karumadi. It differs significantly irrespective of the locations

FIG. 31

COMPARATIVE EXCHANGEABLE Fe ppm OF ACID SULPHATE SOILS OF KERALA

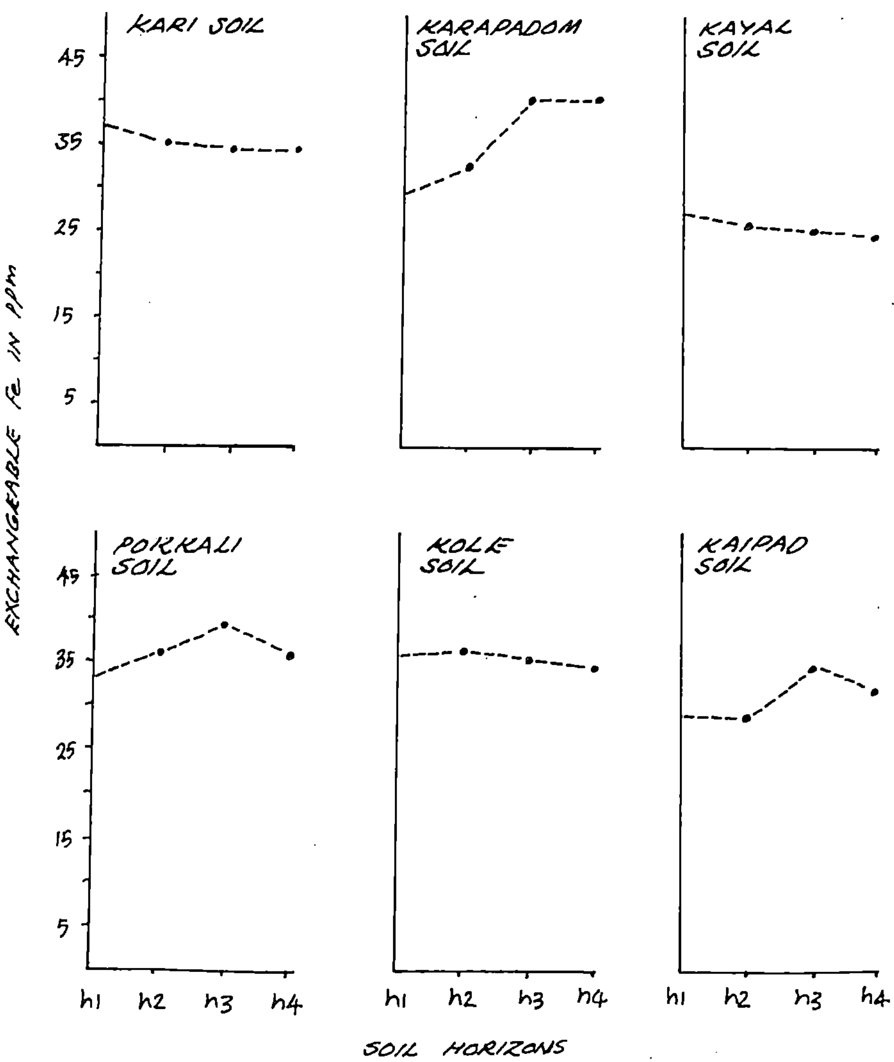
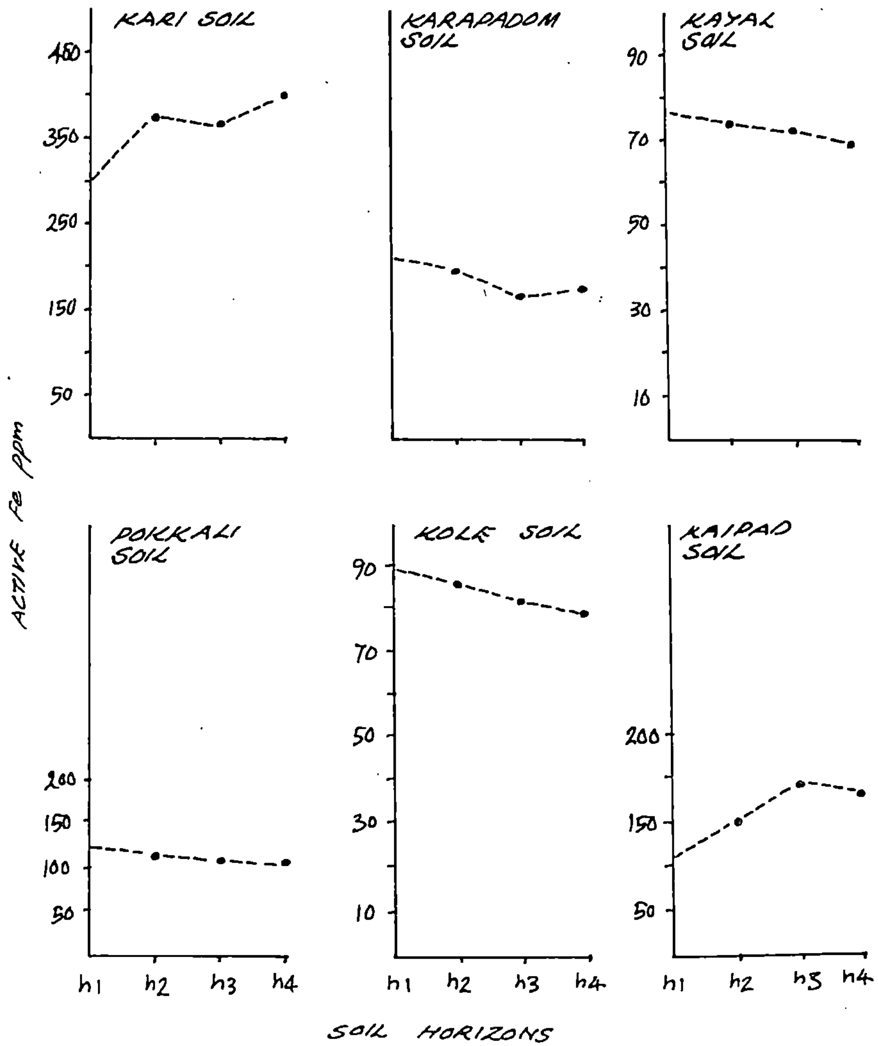


FIG. 32

COMPARATIVE ACTIVE Fe ppm OF ACID SULPHATE SOILS OF KERALA



Exchangeable alumnium content of the soil within the profiles differs significantly only at Kattukambal and Kattampally.

20. **Exchangeable iron**

Exchangeable iron content of the soils are presented in tables 6 to 6.3 and figure 31.

Mean exchangeable iron content of the soil ranges between 24.3 and 40.2 ppm. They are in the increasing order at Mathikayal< Kattampally < Moncompu < Kattukambal< Vytilla < Karumadi.

Irrespective of locations exchangeable iron content of the soil differs significantly. Exchangeable iron content differ within the profile significantly only at Moncompu and Kattampally.

21. **Active iron**

Active iron content of soils are presented in tables 6 to 6.3 and figure 32.

Mean active iron content of the soils ranges between 69.1 and 410.5 ppm. They are in the increasing order at Mathikayal < Kattukambal < Vytilla < Kattampally < Moncompu < Karumadi. Active iron content of the soil differ significantly irrespective of the locations. Within the profiles it differed significantly only at Moncompu and Kattampally.

22. **Cation Exchange Capacity (CEC)**

The cation exchange capacity of the soils are presented in tables 6 to 6.3 and figure 27.

Mean cation exchange capacity of the soils ranges between 11.15 and 46.60 $Cmol(p+)Kg^{-1}$. They are in the increasing order

FIG. 27

COMPARATIVE SOIL CEC Cmol(P+)kg⁻¹ OF ACID SULPHATE SOILS OF KERALA

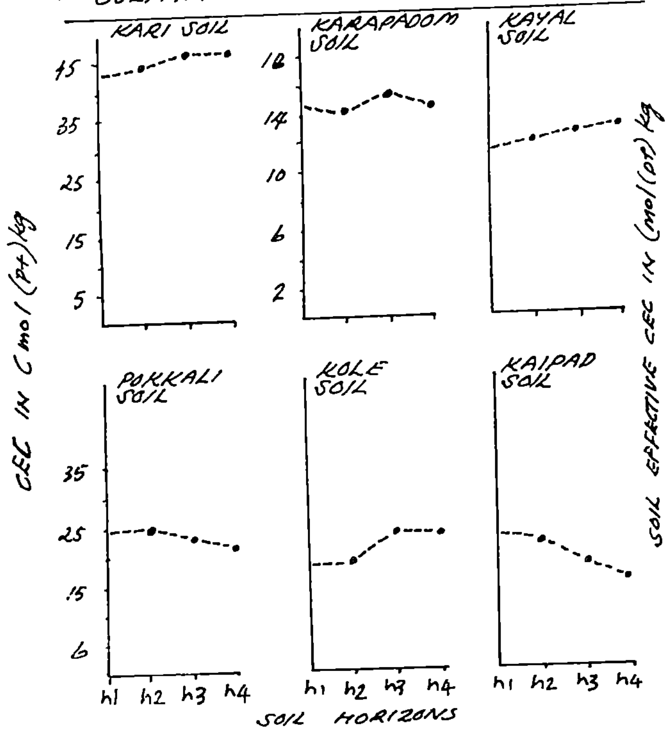


FIG. 28

COMPARATIVE SOIL EFFECTIVE CEC((Mo) (P+) kg.⁻¹ OF ACID SULPHATE SOILS OF KERALA

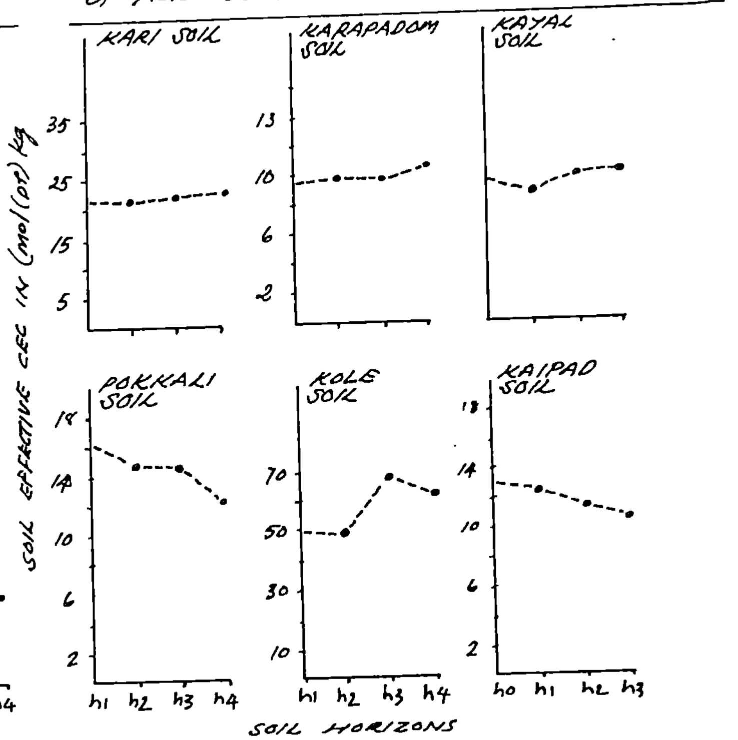


FIG. 29

COMPARATIVE EXCHANGEABLE Al((mol/(P+)kg⁻¹ OF ACID SULPHATE SOILS OF KERALA

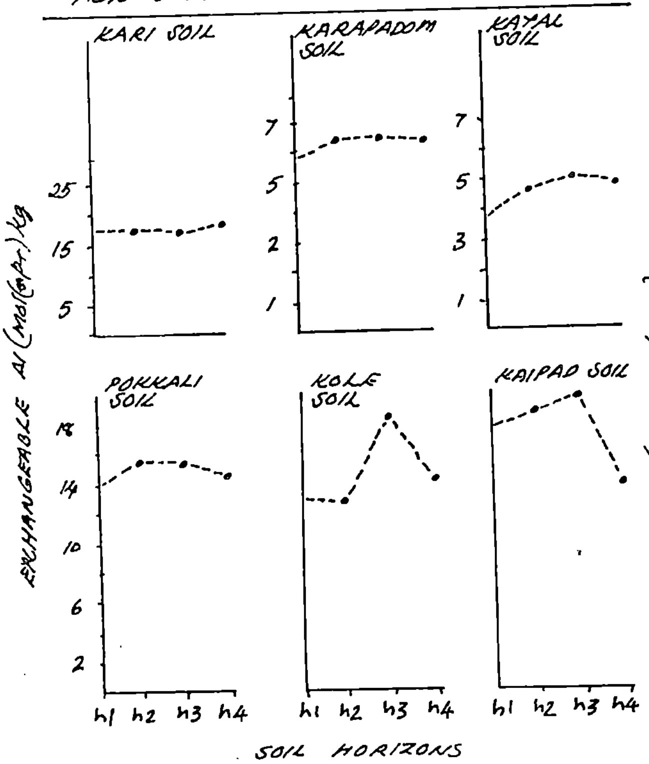
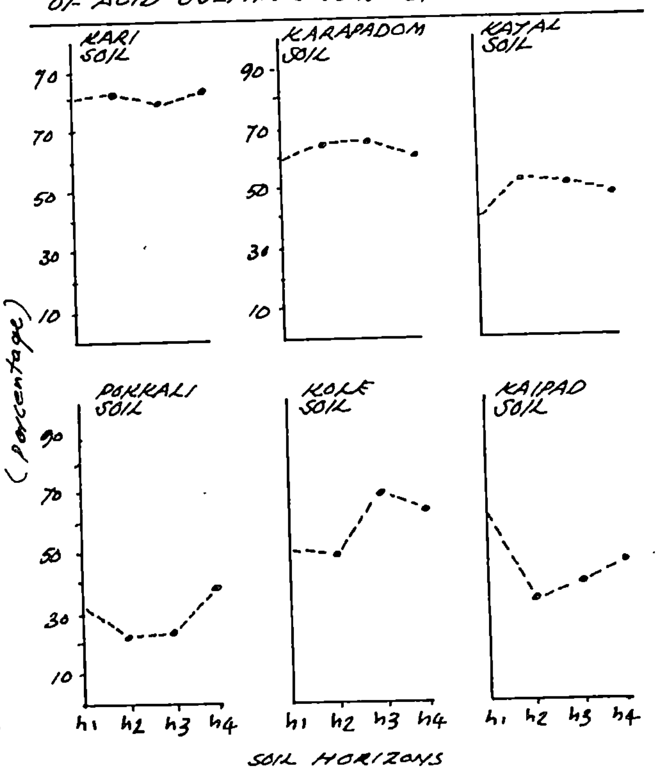


FIG. 30

COMPARATIVE PERCENT OF EFFECTIVE CEC/ OF ACID SULPHATE SOILS OF KERALA



at Mathikayal < Moncompu < Kattampally < Kattukambal < Vytilla < Karumadi.

Cation exchange capacity of these soils differ significantly between locations. Within the profiles it differ significantly only at Karumadi, Vytilla, Kattukambal and Kattampally.

23. **Effective Cation Exchange Capacity (ECEC)**

The effective cation exchange capacity of the soils is presented in tables 6 to 6.3 and figure 28.

Mean effective cation exchange capacity of the soils range between 8.8 and 22.0 Cmol(p+)Kg^{-1}. They are in the increasing order at Mathikayal < Moncompu < Kattampally < Kattukambal < Vytilla<Karumadi.

Effective cation exchange capacity of the soils differ significantly between locations. Within the profiles it differs significantly only at Karumadi, Vytilla, Kattukambal and Kattampally.

24. **Percent aluminium saturation of the effective cation exchange capacity**

They are presented in tables 6 to 6.3 and figure 30.

Mean percent of aluminium saturation of the effective cation exchange capacity of the soil ranges between 23.8 and 83.5. They are in the increasing order at Vytilla < Mathikayal < Kattampally < Moncompu < Kattukambal < Karumadi. It significantly differ between locations. Within the profiles it differed significantly only at Kattukambal and Kattampally.

25. **Distribution of different forms of sulphur in the soil**

The distribution of different forms of soil sulphur are presented in tables 6 to 6.3 and in figures 33 to 37.

FIG. 34

COMPARATIVE TOTAL SULPHUR CONTENT OF ACID SULPHATE SOILS OF KERALA

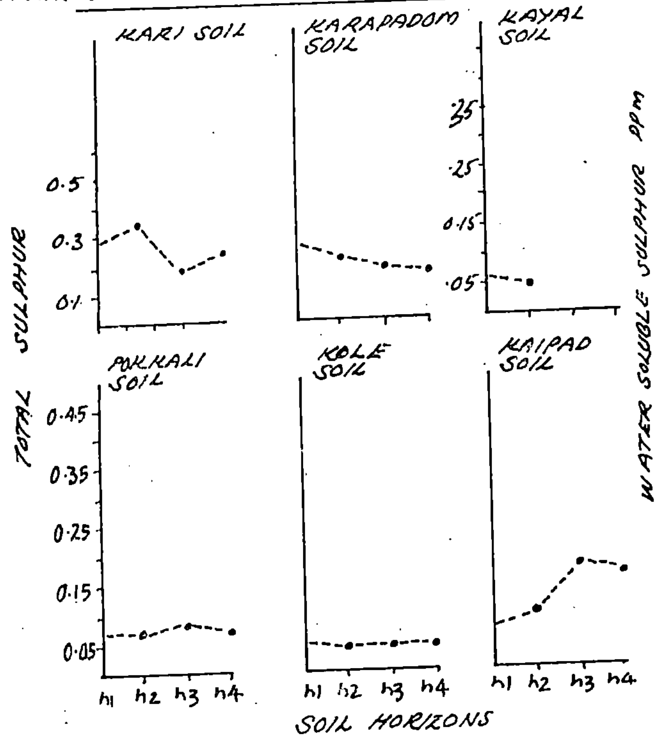


FIG. 35

COMPARATIVE WATER SOLUBLE (ppm) CONTENT OF ACID SULPHATE SOILS OF KERALA

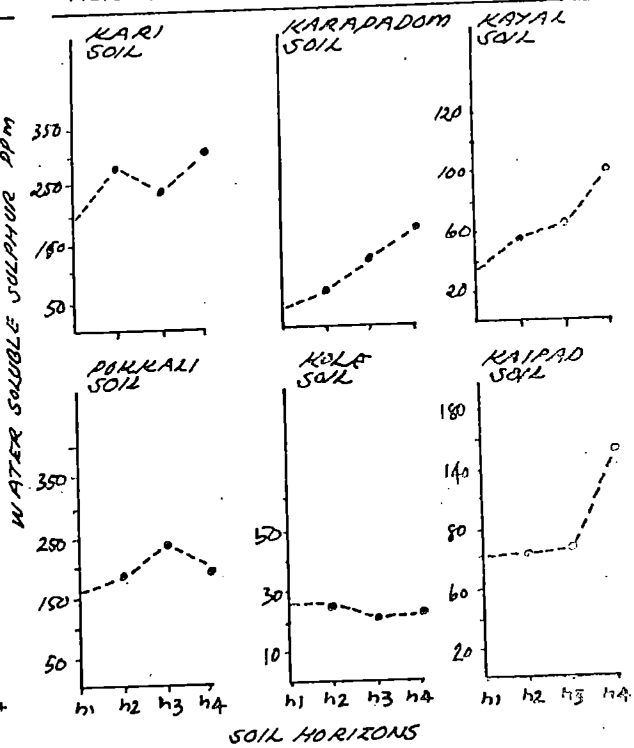


FIG. 36

COMPARATIVE SULPHATE SULPHUR (PPM) CONTENT OF ACID SULPHATE SOILS OF KERALA

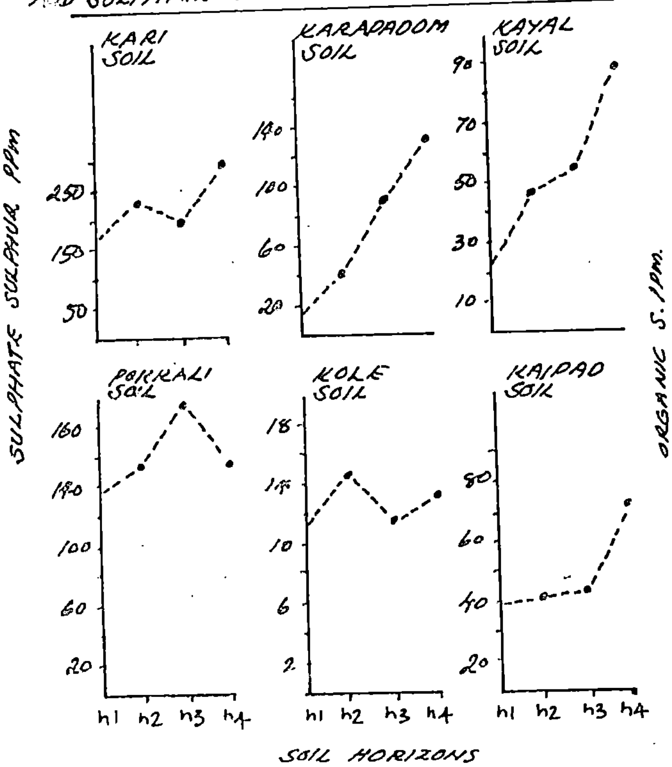


FIG. 37

COMPARATIVE ORGANIC SULPHUR (PPM) CONTENT OF ACID SOILS OF KERALA

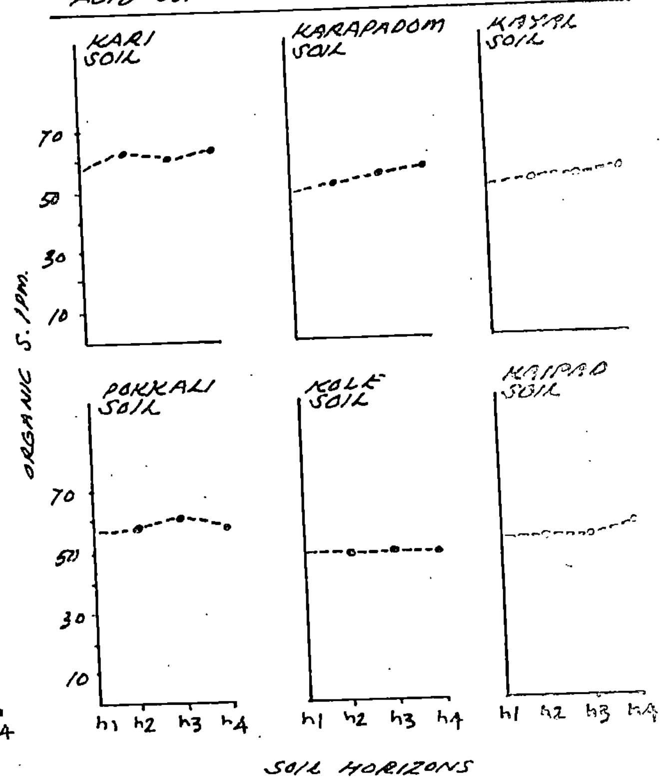
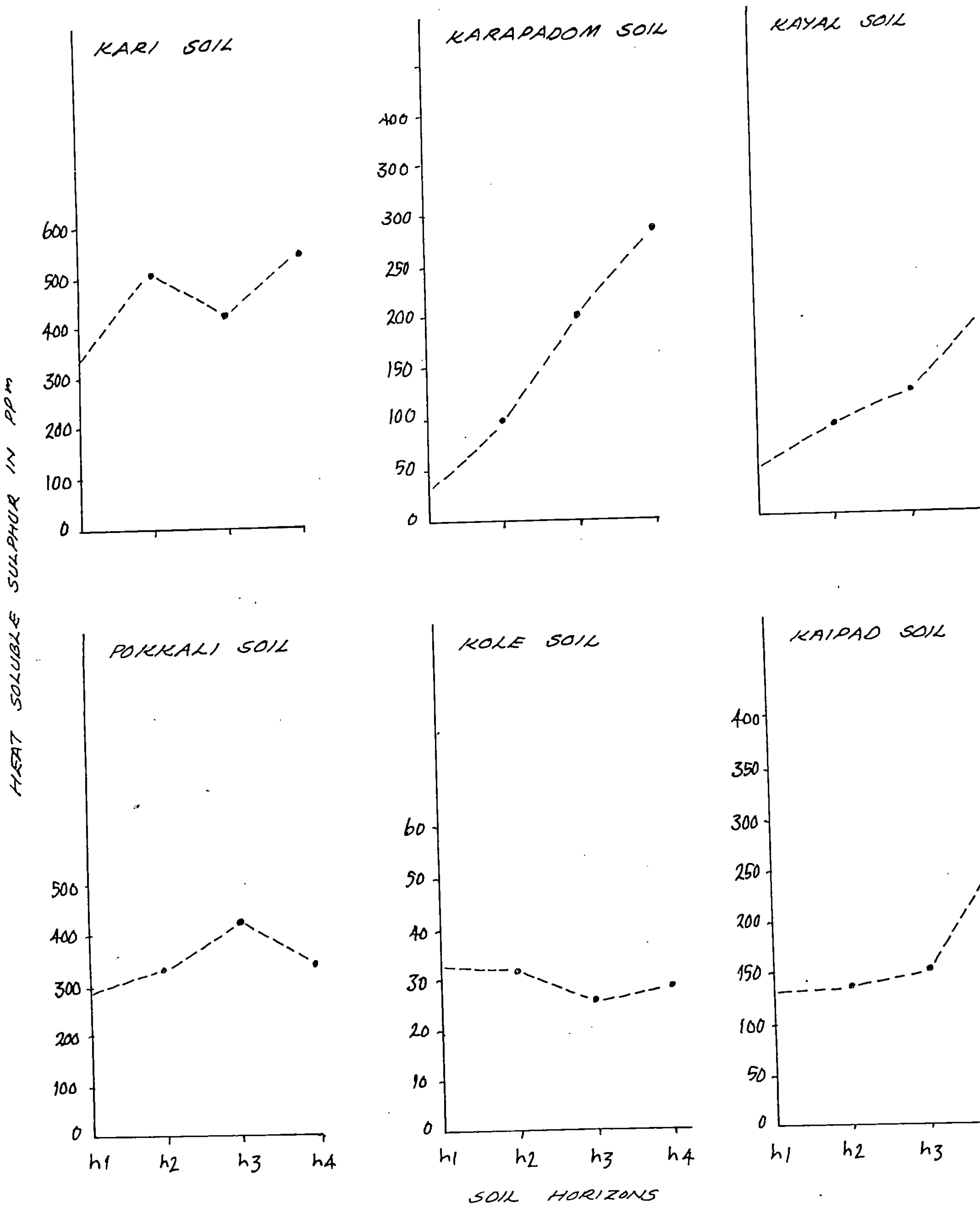


FIG. 33

COMPARATIVE HEAT SOLUBLE SULPHUR (ppm) CONTENT OF ACID, SULPHATE SOILS OF KERALA



25.1 Total sulphur

Mean total sulphur content of the soil ranges between 0.04 and 0.34 percent. They are in the increasing order at Kattukambal < Vytilla < Kattampally < Moncompu < Karumadi < Mathikayal. Total sulphur content of the soil does not differ significantly between locations. Within the profile it differed significantly only at Mathikayal.

25.2 Sulphate sulphur

Mean sulphate sulphur content of the soil ranges between 13.1 and 231.3 ppm. They are in the increasing order at Kattukambal < Mathikayal < Moncompu < Kattampally < Vytilla < Karumadi. Sulphate sulphur content of the soil differs significantly between locations. Within the profile it differs significantly only at Mathikayal and Kattukambal.

25.3 Water soluble sulphur

Mean water soluble sulphur content of the soil ranges between 22.7 and 303.1 ppm. They are in increasing order at Kattukambal <Mathikayal < Moncompu < Kattampally < Vytilla < Karumadi. It differs significantly between locations. Within the profile it differs significantly at all locations except at Kattukambal.

25.4 Organic sulphur

Mean organic sulphur content of the soil ranges between 49.0 and 64.7 ppm. They are in increasing order at Kattukambal < Mathikayal < Moncompu < Kattampally < Vytilla < Karumadi. It differs significantly between locations. Within the profiles it differs significantly at all locations except at Kattukambal.

25.5 Heat soluble sulphur

Mean heat soluble sulphur content of the soils ranges between 26.0 and 547.0 ppm. They are in the increasing order at Kattukambal < Mathikayal < Moncompu <Kattampally < Vytilla < Karumadi.

Heat soluble sulphur content of the soil differs significantly between locations. Within the profiles it differs significantly at all locations except at Kattukambal.

26. **Mineralogy of the coarse sand fraction of soil**

Percent content of coarse sand and percent content of minerals and partially decomposed wood in the coarse sand fraction of the soil from 0-50 cm depth of different locations are presented in table 7.0, figures 38 to 39.1 and plates 156 to 161.

26.1 Coarse sand (0-50cm depth)

Coarse sand content of the soil ranges between 1.25 and 13.0 percent. They are in the increasing order at Mathikayal < Karumadi< Vytilla < Kattukambal < Kattampally < Moncompu. Its content differs significantly between locations.

26.2 Quartz

Mean quartz content of the coarse sand fraction ranges between 85.50 and 93.25 percent. They are in the increasing order at Karumadi <Moncompu <Vytilla <Mathikayal < Kattukambal < Kattampally. Its content differs significantly between locations.

26.3 Feldspar

Feldspar content of the coarse sand fraction of these soils ranges between 0.25 and 0.75 percent. They are in the increasing

Table 7.0

Table 7.0 Coarse sand mineralogy of the acid sulphate soils (0-50 cm depth)

	Locations	Coarse Sand%	Quartz %	Feld-spars %	Bio-tite %	Magne-tite %	Ilme-nite %	Silli-manite %	Rutile %	Pyrite %	Lateri-te nodule %	Partially decompsed wood %
1.	Kari soil Karumadi I	1.6	86.0	0.5	0.1	0.25	0.5	1.0	0.5	0.01	0.04	3.0
2.	Kari soil Karumadi II	1.7	85.0	0.3	0.2	0.1	0.7	0.3	0.3	0.01	0.01	4.8
3.	Karapadom soil Moncompu I	12.5	89.0	0.6	0.1	0.25	0.5	1.0	0.5	0.05	0.08	0.5
4.	Karapadom soil Moncompu II	13.5	88.0	0.2	0.1	0.2	0.5	0.8	0.25	0.05	0.05	1.0
5.	Kayal soil Mathikayal I	1.2	89.0	0.5	0.5	0.5	1.5	1.5	0.5	0.01	0.01	0.4
6.	Kayal soil Mathikayal II	1.3	90.0	0.8	0.3	0.1	0.8	1.0	0.4	0.02	0.05	0.5
7.	Pokkali soil Vytilla I	8.6	88.0	0.5	0.5	0.5	1.0	1.5	0.5	0.01	-	0.5
8.	Pokkali soil Vytilla II	6.7	90.0	1.0	0.2	0.1	0.6	0.7	0.8	0.01	0.01	1.0
9.	Kole soil Kattukambal I	10.0	94.0	0.3	0.05	0.8	1.8	2.0	1.5	0.01	1.0	0.5
10.	Kole soil Kattukambal II	9.1	90.0	0.2	0.05	0.5	1.0	1.3	0.9	0.04	1.4	0.3
11.	Kaipad soil Kattampally I	12.4	92.5	0.5	0.5	0.5	0.5	2.0	0.5	-	0.04	3.1
12.	Kaipad soil Kattampally II	12.1	94.0	0.5	0.3	0.1	0.5	1.5	1.0	0.08	0.03	3.3

FIG. 38

COMPARATIVE COARSE SAND MINERALOGY

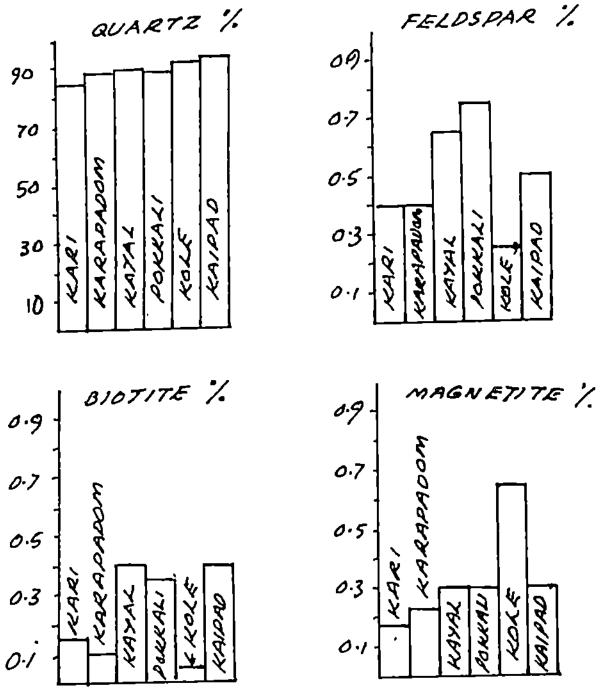
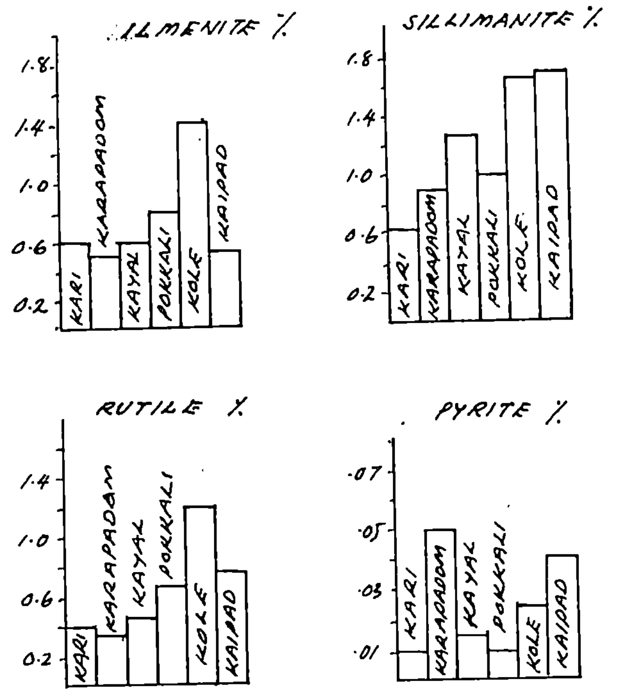


FIG. 39

COMPARATIVE COARSE SAND MINERALOGY



COMPARATIVE COARSE SAND MINERALOGY

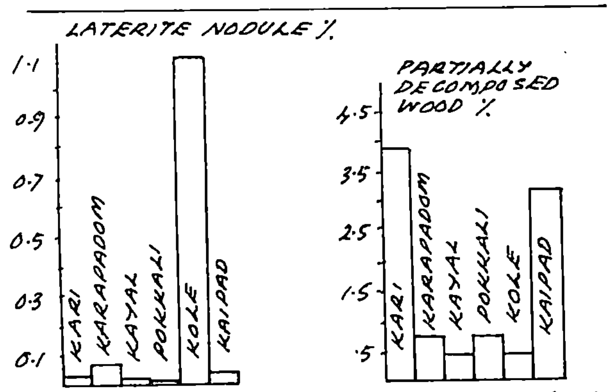
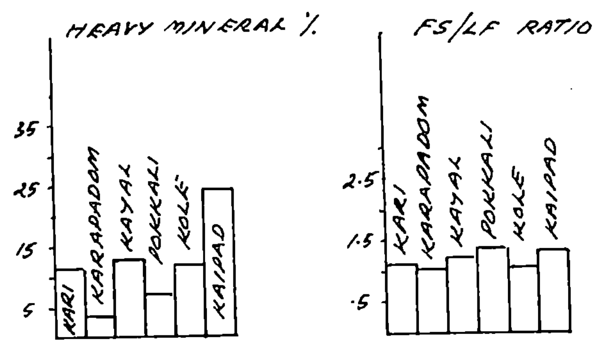
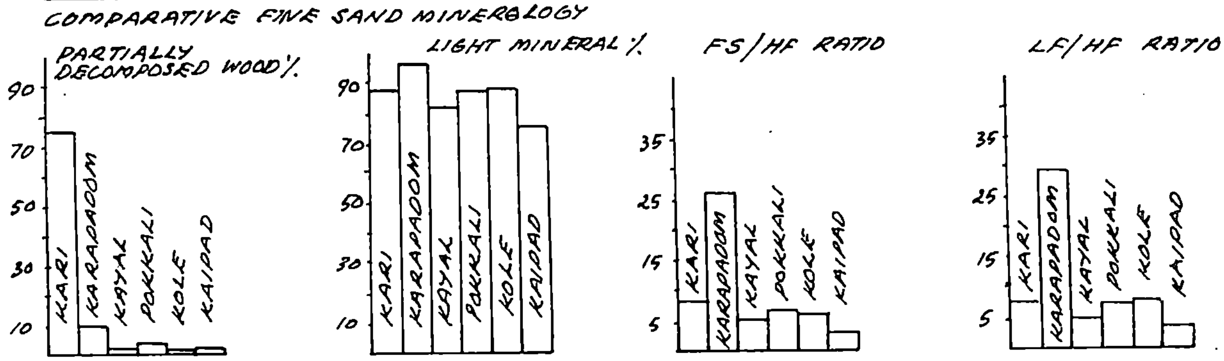


FIG. 40

COMPARETIVE FINE SAND MINERALOGY



COMPARATIVE FINE SAND MINEROLOGY



order at Kattukambal <Moncompu <Karumadi < Kattampally < Mathikayal < Vytilla. Its content do not differ significantly between locations.

26.4. Biotite

Biotite content of the coarse sand fraction ranges between 0.5 and 0.40 percent. They are in the increasing order at Kattukambal < Moncompu < Karumadi < Vytilla < Kattampally < Mathikayal. Its content do not differ significantly between locations.

26.5. Magnetite

Magnetite content of the coarse sand fraction of the soils ranges between 0.18 and 0.65 percent. They are in the increasing order at Karumadi <Moncompu < Vytilla < Mathikayal < Kattampally< Kattukambal. Its content do not differ significantly between locations.

26.6. Ilmenite

Ilmenite content of the coarse sand fractions of these soils ranges between 0.50 and 1.40 percent. They are in the increasing order at Moncompu < Kattampally < Karumadi < Vytilla< Mathikayal < Kattukambal. Its content do not differ significantly between locations.

26.7. Sillimanite

Sillimanite content of the caorse sand ranges between 0.65 and 1.75 percent. They are in the increasing order at Karumadi < Moncompu <Vytilla < Mathikayal < Kattukambal< Kattampally. Its content do not differ significantly between locations.

26.8 Rutile

Rutile content of the coarse sand fraction of the soil ranges between 0.38 and 1.20 percent. They are in the increasing order at

Moncompu < Karumadi < Mathikayal < Vytilla < Kattampally < Kattukambal. Its content do not differ significantly between locations.

26.9. Pyrite

Pyrite content of the coarse sand fraction or the soil ranges between 0.01 and 0.05 percent. They are in the increasing order at Karumadi <Vytilla < Kattukambal < Mathikayal < Kattampally < Moncompu. Its content do not differ significantly between locations.

26.10 Laterite nodule

Laterite nodule content of the coarse sand fraction of these soils ranges between 0.01 and 1.20 percent. They are in the increasing order at Vytilla < Mathikayal < Karumadi < Kattampally < Moncompu < Kattukambal. Its content significantly differs between locations.

26.11 Partially decomposed wood

Content of partially decomposed wood present in the coarse sand fraction of these soils ranges between 0.40 and 3.90 percent. They are in the increasing order at Kattukambal < Mathikayal < Vytilla < Moncompu < Kattampally < Karumadi. Its content differ significantly between locations.

27.0. **Mineralogy of the fine sand fraction of the soil**

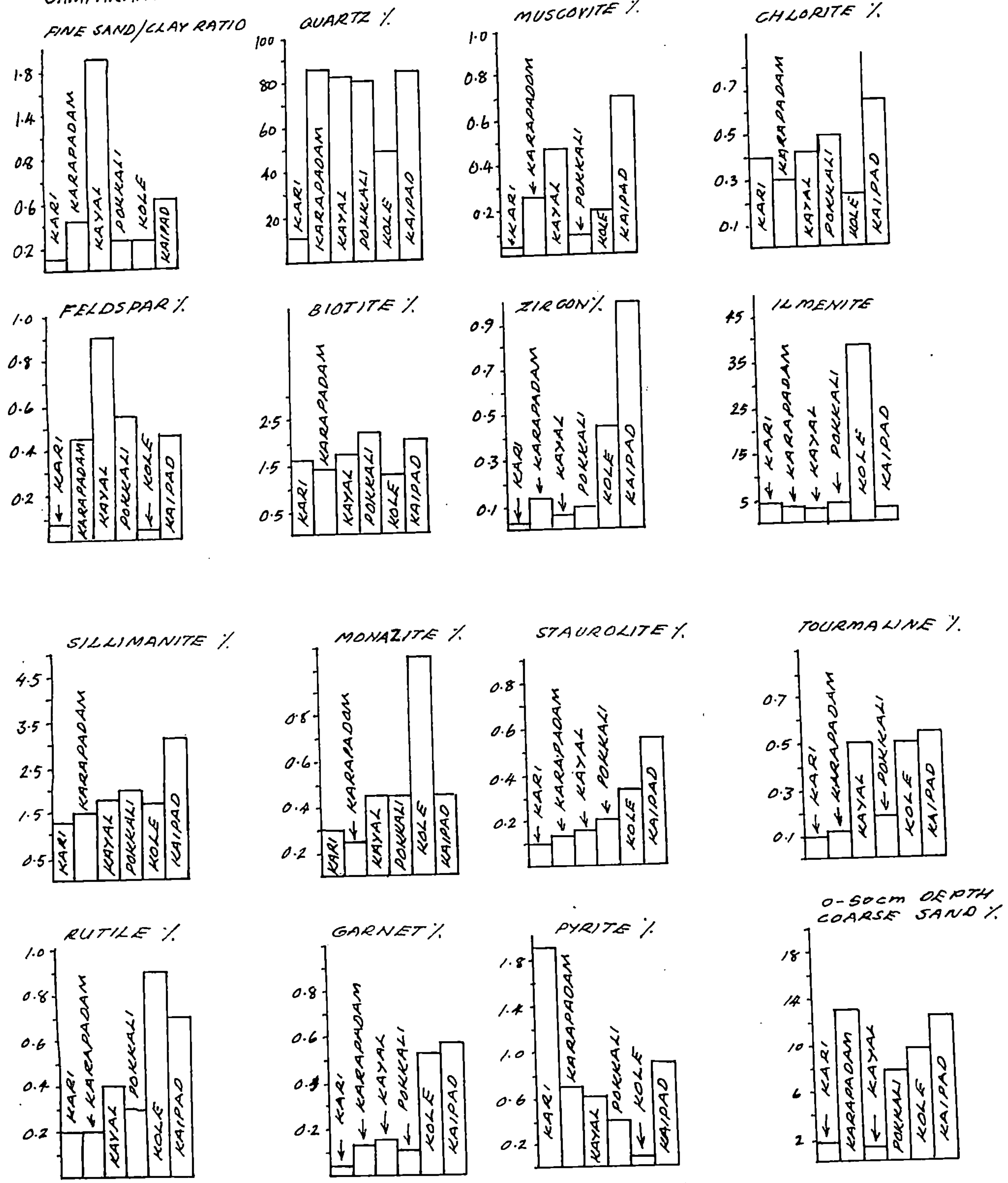
The fine sand content, fine sand ratios, fine sand mineral ratios and content of different minerals and partially decomposed wood in the fine sand fraction of the soil within 50 cm at different locations are presented in table 8, figures 40 to 42 and plates 162 to 173.

Table 7.1 Fine sand mineralogy of the acid sulphate soils (0-50 cm depth)

Locations	Clay %	Fine sand %	Partially decomposed wood %	Light mineral %	Heavy mineral %	RATIOS FS/LF	FS/HF	LF/HF	Fine sand/Clay	LIGHT MINERALS Quartz %	Feldspars %	Biotite %	Muscovite %	Chlorite %	Zircon %	HEAVY MINERALS Black opaques Ilmeninte %	Red opaques Haematite %	Sillimanite %	Monazite %	Rutile %	Garnet %	Staurolite %	Tourmaline %	Pyrite %
Kari soil Karumadi I	50.8	6.4	76.8	87.5	12.5	1.1	8.0	7.0	0.13	10.8	0.05	1.50	0.03	0.5	0.04	4.5	0.08	1.0	0.50	0.10	0.03	0.10	0.09	1.70
Kari Soil Karumadi II	52.6	6.7	74.3	89.0	11.0	1.2	8.3	8.1	0.13	9.5	0.08	1.8	0.04	0.3	0.02	3.9	0.05	1.5	0.30	0.20	0.04	0.09	0.10	2.0
Karapadom Soil Moncompu I	38.9	17.3	4.0	96.3	3.7	1.04	26.7	25.7	0.45	79.8	0.75	1.66	0.21	0.4	0.2	3.3	0.10	1.3	0.30	0.22	0.10	0.15	0.11	0.60
Karapadom soil Moncompu II	38.8	17.7	16.0	97.0	3.0	1.1	25.5	32.3	0.44	81.5	0.15	1.3	0.30	0.20	0.05	3.6	0.09	1.6	0.30	0.25	0.15	0.10	0.13	0.80
Kayal soil Mathikayal I	28.2	53.3	2.8	80.5	9.5	1.24	5.1	4.1	1.89	81.45	1.01	1.50	0.84	0.50	0.05	2.95	0.76	1.80	0.88	0.40	0.10	0.10	0.66	0.65
Kayal soil Mathikayal II	27.2	53.2	3.1	84.0	16.0	1.26	4.9	5.3	1.95	84.1	0.8	2.0	0.10	0.35	0.06	3.05	1.0	1.70	0.50	0.33	0.20	0.20	0.33	0.45
Pokkali soil Vytilla I	51.8	13.6	3.8	86.8	3.2	1.15	6.6	6.6	0.26	82.8	0.6	2.10	0.08	0.48	0.10	3.95	0.80	1.85	0.60	0.20	0.01	0.20	0.20	0.46
Pokkali soil Vytilla II	52.1	13.9	3.5	88.8	11.2	1.2	6.8	7.9	0.27	78.8	0.50	2.30	0.10	0.50	0.08	4.3	0.66	2.2	0.75	0.35	0.20	0.20	0.15	0.28
Kole soil Kattukambal I	51.4	11.9	0.60	86.2	13.8	1.16	6.3	6.25	0.23	35.8	0.05	1.50	0.35	0.25	0.50	50.80	1.85	2.0	1.50	0.75	0.25	0.33	0.75	0.05
Kole soil Kattukambal II	49.5	12.0	1.1	90.0	10.0	1.18	6.1	9.0	0.24	61.5	0.03	1.03	0.05	0.20	0.40	26.8	1.33	1.4	2.2	1.11	0.80	0.33	0.20	0.18
Kaipad soil Kattampally I	36.8	24.7	1.2	73.2	26.4	1.36	2.79	2.79	0.67	82.5	0.85	1.80	0.60	0.75	0.90	2.85	1.50	2.8	0.75	0.60	0.60	0.50	0.78	0.80
Kaipad soil Kattampally II	39.7	23.8	2.2	77.5	22.5	1.4	2.9	3.4	0.60	85.4	0.90	2.3	0.80	0.55	1.10	3.10	1.22	3.3	0.60	0.70	0.54	0.60	0.30	1.0

FIG. 42

CAMPARATIVE FINE SAND MINERALOGY



27.1. Fine sand content of the soil within 50 cm depth of soil

The fine sand content of soil ranges between 6.55 and 53.25 percent. They are in the increasing order at Karumadi < Kattukambal < Vytilla < Moncompu < Kattampally < Mathikayal. Its content differs significantly between locations.

27.2. Light mineral fraction of the fine sand fraction of soil

Content of light mineral ranges between 75.35 and 96.65 percent. They are in the increasing order at Kattampally < Mathikayal Vytilla < Kattukambal < Karumadi < Moncompu. Its content differs significantly between locations.

27.2.1 Fine sand/light mineral fraction ratio

Fine sand/light mineral fraction ratio of the soil ranges between 1.07 and 1.38. They are in the increasing order at Moncompu < Karumadi < Kattukambal < Vytilla < Mathikayal < Kattampally. It differs significantly between locations.

27.2.2 Quartz

Content of quartz present in the fine sand fraction of the soil ranges between 10.15 and 83.95 percent. They are in the increasing order at Karumadi < Kattukambal < Moncompu < Mathikayal < Kattampally < Vytilla . Its content differs significantly between locations.

27.2.3 Feldspar

Feldspar content of fine sand fraction of the soil ranges between 0.04 and 1.47 percent. They are in the increasing order at

Kattukambal < Karumadi < Moncompu < Vytilla < Mathikayal < Kattampally. Their content do not differ significantly between locations.

27.2.4 Biotite

Biotite content of the fine sand fraction of the soil ranges between 1.26 and 2.20 percent. They are in the increasing order at Kattukambal < Moncompu < Karumadi < Mathikayal < Kattampally < Vytilla. Its content do not differ significantly between locations.

27.2.5 Muscovite

Muscovite content of the fine sand fraction of the soil ranges between 0.04 and 0.07 percent. They are in the increasing order at Karumadi < Vytilla < Kattakambal < Moncompu < Mathikayal < Kattampally.

27.2.6 Chlorite

Chlorite content of the fine sand fraction of the soils ranges between 0.23 and 0.65 percent. They are in the increasing order at Kattukambal < Moncompu < Karumadi < Mathikayal < Vytilla < Kattampally. Its content do not differ significantly between locations.

27.3.0 Heavy mineral fraction of the fine sand fraction of soil

Heavy mineral content of the fine sand fraction of these soils range between 3.35 and 24.45 percent. They are in the increasing order ath Moncompu < Vytilla < Karumadi < Mathikayal < Kattampally < Kattukambal. Its content differs significantly between locations.

27.3.1 Fine sand /Heavy mineral fraction (FS/HF)

FS/HF ratio of the soil ranges between 2.85 and 26.10. They are in the increasing order at Kattampally < Mathikayal < Kattukambal

<Vytilla < Karumadi < Moncompu. It differs significantly between locations.

27.3.2 Light mineral fraction/Heavy mineral fraction ratio (LF/HF)

LF/HF ratio of the fine sand fraction of the soil ranges between 3.10 and 29.0. They are in the increasing order at Kattampally < Mathikayal < Vytilla < Karumadi < Kattukambal < Moncompu. It differs significantly between locations.

27.3.3 Zircon

Zircon content of the fine sand fraction of these soils ranges between 0.03 and 0.99 percent. They are in the increasing order at Karumadi < Mathikayal < Vytilla < Moncompu < Kattukambal < Kattampally. Its content differs significantly between locations.

27.3.4 Ilmenite

Ilmenite content of the fine sand fraction of the soils ranges between 2.98 and 38.8 percent. They are in the increasing order at Kattampally < Mathikayal < Moncompu < Vytilla < Karumadi < Kattukambal. Its content differs significantly between locations.

27.3.5 Haematite

Haematite content of the fine sand fraction of the soils ranges between 0.07 and 1.59 percent. They are in the increasing order at Karumadi < Moncompu < Vytilla < Mathikayal < Kattampally < Kattukambal. Its content differs significantly between locations.

27.3.6 Sillimanite

Sillimanite content of the fine sand fraction of the soils range between 1.25 and 3.05 percent. They are in the increasing order at

Karumadi < Moncompu < Kattukambal < Mathikayal < Vytilla < Kattampally. Its content differs significantly between locations.

27.3.7 Monazite

Monazite content of the fine sand fraction of these soil ranges between 0.30 and 1.85 percent. They are in the increasing order at Moncompu < Karumadi < Vytilla < Kattampally < Mathikayal < Kattukambal. Its content differs significantly between locations.

27.3.8 Rutile

Rutile content of the fine sand fraction of the soil ranges between 0.15 and 0.93 percent. They are in the increasing order at Karumadi < Moncompu < Mathikayal < Vytilla < Kattampally < Kattukambal. Its content significantly differs between locations.

27.3.9 Garnet

Garnet content of the fine sand fraction of the soil ranges between 0.04 and 0.57 percent. They are in the increasing order at Karumadi < Vytilla < Moncompu < Mathikayal < Kattukambal < Kattampally. Its content do not differ significantly between locations.

27.3.10 Staurolite

Staurolite content of the fine sand fraction of the soils ranges between 0.01 and 0.55 percent. They are in the increasing order at Karumadi < Moncompu < Mathikayal < Vytilla < Kattukambal < Kattampally. Its content differs significantly between locations.

27.3.11 Tourmaline

Tourmaline content of the fine sand fraction of the soil ranges between 0.01 and 0.54. They are in the increasing order at Karumadi < Moncompu < Vytilla < Kattukambal < Mathikayal < Kattampally. Its content do not differs significantly between locations.

27.3.12 Pyrite

Pyrite content of the fine sand fraction of the soil ranges between 0.12 and 1.87 percent. They are in the increasing order at Kattukambal < Vytilla < Mathikayal < Moncompu < Kattampally < Karumadi. Its content differs significantly between locations.

27.4.0 Partially decomposed wood in the fine sand fraction

Its content range between 0.08 and 75.55 percent. They are in the increasing order Kattukambal < Kattampally <Mathikayal< Vytilla < Moncompu < Karumadi. Its content differed significantly between locations.

28.0 Mineralogy of the silt fraction of the soil

Silt content, silt ratios, partially decomposed wood present in the silt fraction and silt fraction mineral content of 0-50 cm depth soil from different locations are presented in table 8, figure 43 and pates 138 to 143.

28.1.0 Silt content of 0-50 cm depth of soil

It ranges between 16.85 and 28.50 percent. They are in the increasing order at Mathikayal < Kattampally < Moncompu < Vytilla< Karumadi <Kattukamabal. It differs significantly between locations.

28.2.0 Silt/clay ratio

It ranges between 0.43 and 0.56. They are in the increasing order at Vytilla < Mathikayal < Kattampally < Moncompu < Karumadi < Kattukambal. It do not differ significantly between locations.

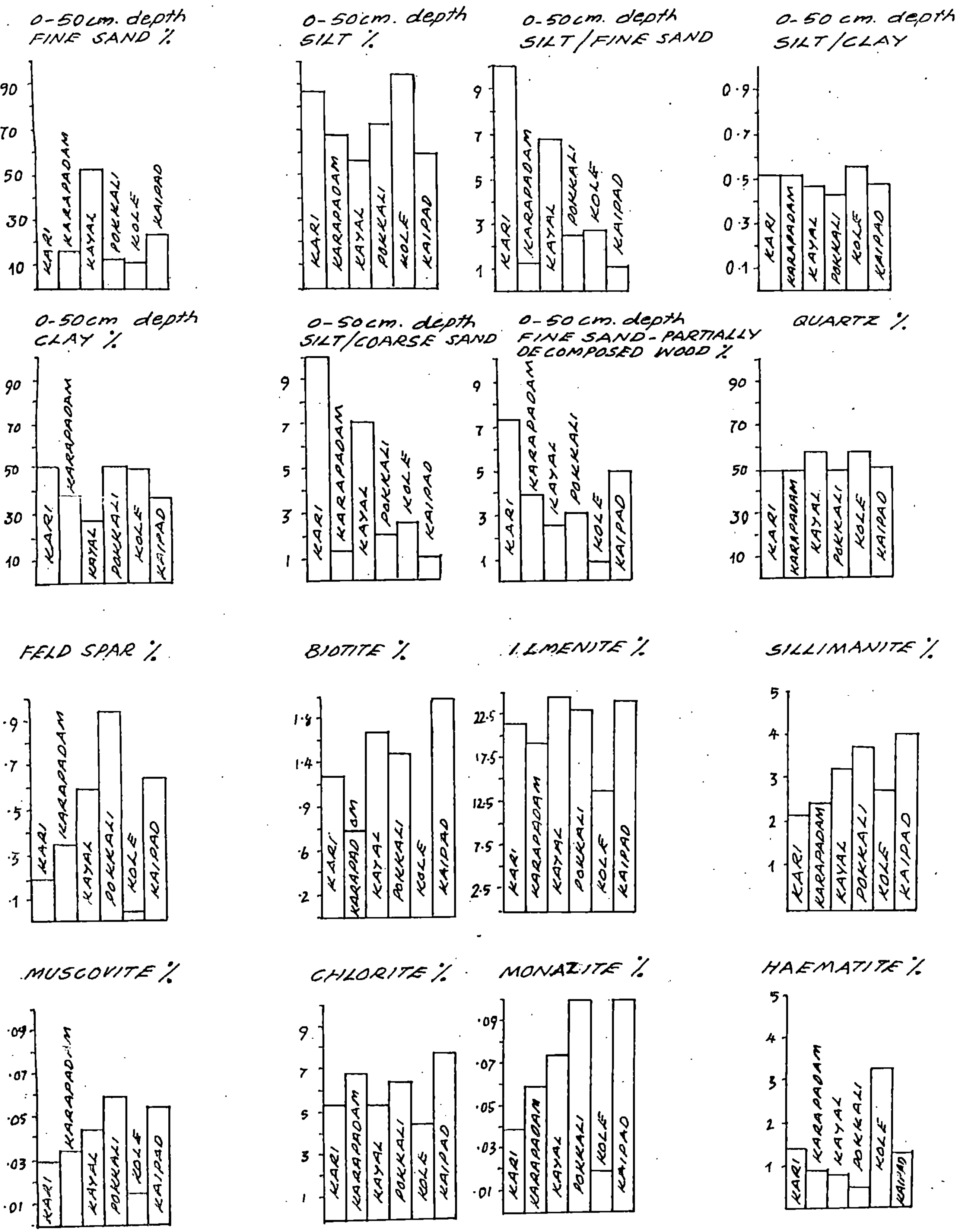
28.2.1 Silt/clay ratio

It ranges between 1.12 and 10.05. They are in the increasing

Table 8.0 Silt mineralogy of the acid sulphate soils (0-50 cm depth)

Sl. No.	Locations	Silt %	Ratios Silt/Clay	Silt/Coarse sand	Silt/Fine sand	Partially decomposed wood %	Quartz %	Feldspar %	Biotite %	Muscovite %	Chlorite %	Ilemenite %	Sillimenite %	Monosite %	Haematite %	Goethite %	Pyrite %
1.	Kari soil Karumadi I	25.7	0.51	16.1	4.01	6.6	48.3	0.3	2.5	0.03	7.0	21.0	3.8	0.05	0.03	2.2	4.6
2.	Kari soil Karumadi II	27.4	0.52	4.1	16.1	8.0	51.0	0.08	0.05	0.03	4.1	22.5	0.5	0.03	2.8	2.7	5.1
3.	Karapadam soil Moncompu I	20.6	0.53	2.6	2.29	4.3	50.5	0.5	1.5	0.02	6.8	18.8	3.2	0.05	0.20	2.1	2.8
4.	Karapadam soil Moncompu II	20.3	0.52	1.2	1.5	3.5	48.5	0.20	0.08	0.05	6.9	20.0	1.8	0.08	1.60	3.0	4.4
5.	Kayal soil Mathikayal II	16.5	0.31	13.8	0.31	2.1	55.8	0.2	2.8	0.05	6.3	23.5	4.1	0.10	0.05	1.8	2.5
6.	Kayal soil Mathikayal II	17.2	0.63	0.32	13.2	3.0	58.3	1.0	0.5	0.04	4.5	26.0	2.4	0.05	1.50	2.2	2.0
7.	Pokkali soil Vytilla I	21.5	0.42	2.5	1.58	3.3	47.5	0.6	2.1	0.05	5.3	20.4	4.5	0.15	0.02	1.3	2.0
8.	Pokkali soil Vytilla II	22.5	0.43	1.6	3.4	2.8	51.0	1.3	0.8	0.07	7.7	25.8	3.0	0.08	1.00	1.8	2.3
9.	Kole soil Kattukambal I	28.4	0.55	2.8	2.39	1.1	59.9	0.05	1.6	0.01	2.8	9.80	2.3	0.03	2.80	4.9	0.5
10.	Kole soil Kattukambal II	28.6	0.57	2.4	3.1	0.80	53.6	0.03	0.4	0.02	6.2	18.3	3.3	0.01	3.8	4.1	0.30
11.	Kaipad soil Kattampally I	18.2	0.49	1.5	0.74	5.5	52.1	0.2	3.1	0.07	7.8	22.50	4.9	0.20	1.1	1.1	3.9
12.	Kaipad soil Kattampally II	18.1	0.46	0.76	1.5	4.3	48.4	1.1	1.0	0.04	7.8	26.0	3.2	0.05	1.50	1.30	5.0

FIG. 43



0-50cm. depth FINE SAND %
0-50cm. depth SILT %
0-50cm. depth SILT/FINE SAND
0-50 cm. depth SILT/CLAY
0-50cm depth CLAY %
0-50cm. depth SILT/COARSE SAND
0-50 cm. depth FINE SAND-PARTIALLY DECOMPOSED WOOD %
QUARTZ %
FELD SPAR %
BIOTITE %
ILMENITE %
SILLIMANITE %
MUSCOVITE %
CHLORITE %
MONAZITE %
HAEMATITE %
KARI
KARAPADAM
KAYAL
POKKALI
KOLE
KAIPAD

order at Kattampally < Moncompu < Vytilla < Kattukambal < Mathikayal < Kàrumadi. It do not differ significantly between locations.

28.2.2 Silt/coarse sand ratio

It ranges between 1.13 and 10.10. They are in the increasing order at Kattampally < Moncompu < Vytilla < Kattukambal < Mathikayal < Karumadi. It differs significantly between locations.

28.3.0 Partially decompoed wood content of silt

Content of partially decomposed wood present in the silt fraction of the soil ranges between 0.95 and 7.30 percent. They are in the increasing order at Kattukambal < Mathikayal < Vytilla < Moncompu < Kattampally < Karumadi. Its content differs significantly between locations.

28.4.0 Quartz

Quartz content of silt fraction of the soil ranges between 49.5 and 57.05 percent. They are in the increasing order at Vytilla < Moncompu < Karumadi < Kattampally < Kattukambal < Mathikayal. Its content do not differ significantly between locations.

28.4.1 Feldspar

Feldspar content of the silt fraction of the soil ranged between 0.04 and 0.65 percent. They are in the increasing order at Kattukambal < Karumadi < Moncompu < Mathikayal < Kattampally < Vytilla. Its content differed significantly between locations.

28.4.2 Biotite

The biotite content of silt fraction of the soil ranges between 0.79 and 2.05 percent. They are in the increasing order at Moncompu

Kattukambal < Karumadi < Vytillas < Mathikayal < Kattampally. Its content do not differ significantly between locations.

28.4.3 Muscovite

The muscovite content of the silt fraction of the soil ranges between 0.02 and 0.06 percent. They are in the increasing order at Kattukambal < Karumadi < Moncompu < Mathikayal < Vytilla < Kattampally. It do not differ significantly between locations.

28.4.4 Chlorite

The chlorite content of the silt fraction of the soil ranges between 4.50 and 7.80 percent. They are in the increasing order at Kattukamabal < Mathikayal < Karumadi < Vytilla < Moncompu < Kattampally. Its content do not differ significantly between locations.

28.4.5 Ilmenite

The ilmenite content of the silt fraction of the soil ranges between 23.10 and 24.75 percent. They are present in the increasing order at Kattukambal < Moncompu < Karumadi < Vytila < Kattampally < Mathikayal. Its content do not differ significantly between locations.

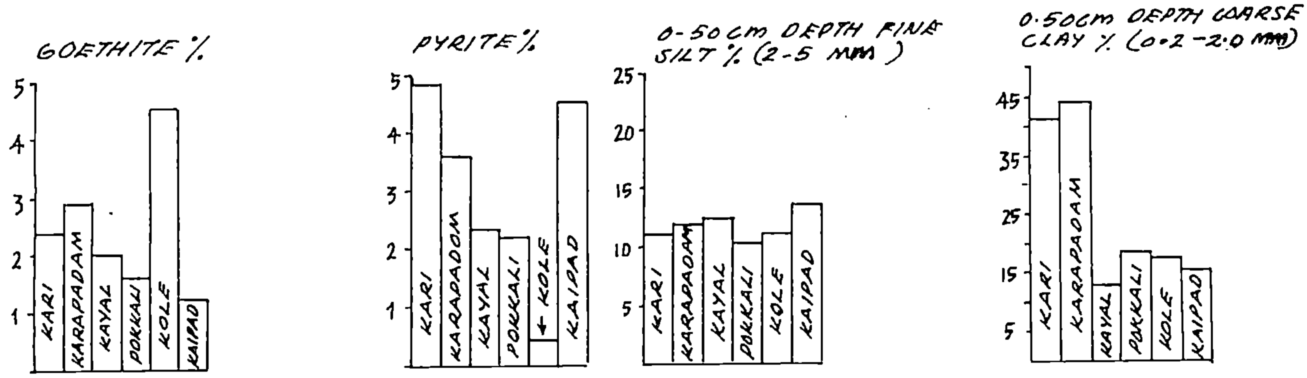
28.4.6 Sillimanite

The sillimanite content of the silt fraction of the soil ranges between 2.15 and 4.05 percent. They are in the increased order at Karumadi < Moncompu < Kattukambal < Mathikayal < Vytilla < Kattampally. Its content do not differ significantly locations.

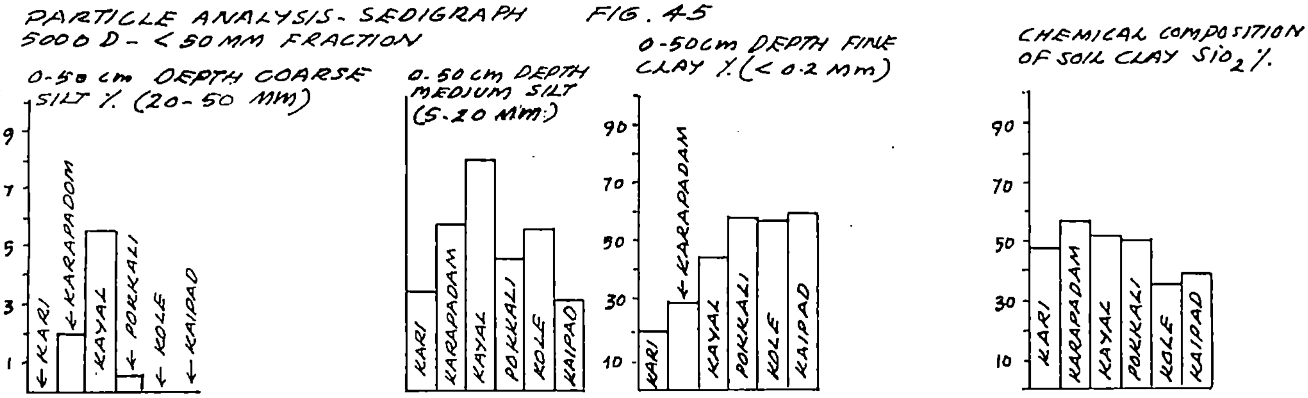
24.4.7 Monazite

The monazite content of the silt fraction of the soil ranges between 0.02 and 0.13 percent. They are in the increasing order at

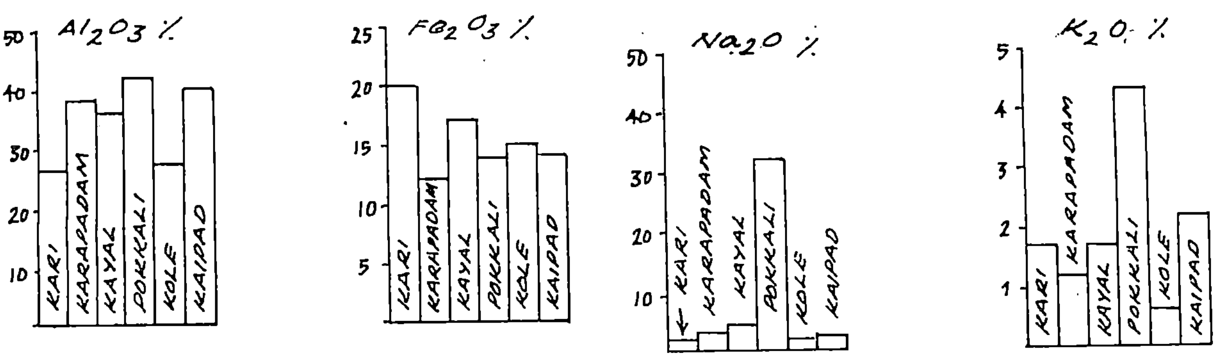
FIG. 44

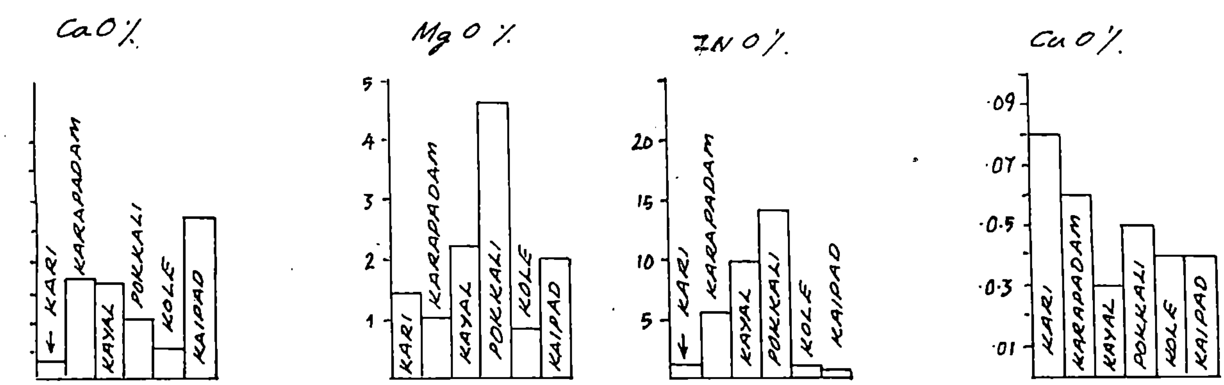


PARTICLE ANALYSIS- SEDIGRAPH 5000 D - < 50 MM FRACTION FIG. 45



CHEMICAL COMPOSITION OF SOIL CLAY - FIG. 46





Kattukambal < Karumadi < Moncompu < Mathikayal < Vytilla < Kattampally. Its content do not differs significantly between locations.

24.4.8 Haematite

The haematite content of the silt fraction of the soil ranges between 0.51 and 3.30 percent. They are in the increasing order at Vytilla < Mathikayal < Moncompu < Kattampally < Karumadi < Kattukambal. Its content do not differ significantly between locations.

28.4.9 Goethite

The goethite content of the silt fraction of the soil ranges between 1.20 and 4.50 percent. They are in the increasing order at Kattampally < Vytilla < Mathikayal < Karumadi < Moncompu < Kattukambal. Its content differs significantly between locations.

28.4.10 Pyrite

The pyrite content of the silt fraction of the soil ranges between 0.40 and 4.85 percent. They are in the increasing order at Kattukambal < Vytilla < Mathikayal < Moncompu < Karumadi. Its content differ signifcantly between locations.

29.0. **Particle analysis of finer soil fractions**

(<0.05 mm soil fractions from 0-50 cm depth)

The results of sedigraphic analysis of finer fractions of the soil from 0-50 cm depth are presented in table 12 and figures 44 and 45.

29.1.0 Coarse silt (20-50 µm)

The coarse silt content of the soils ranges between zero and 5.50 percent. They are in the increasing order at Karumadi <

Table 12.0 Particle size distribution of soil finer fraction of acid sulphate soils (percent) (sedigraph 5000 D particle analysis) (50-0.1 μm) (0-50 cm depth)

Sl. No.	Location	Coarse silt (20-50 μm)	Medium silt (5-20 μm)	Fine silt (2-5 μm)	Coarse clay (0.2-2 μm)	Fine clay (< 0.2 μm)
1.	Kari soil Karumadi I	0.00	12.00	10.50	33.50	6.00
2.	Kari soil Karumadi II	0.00	12.00	11.50	48.50	33.50
3.	Karapadam soil Moncompu I	4.00	23.00	12.00	9.50	52.50
4	Karapadam soil Moncompu II	0.00	5.00	11.50	78.50	6.00
5.	Kayal soil Mathi kayal	10.00	17.50	11.50	13.50	36.50
6.	Kayal soil Mathikayal II	1.00	21.50	13.00	11.50	52.00
7.	Pokkali soil Vytilla I	1.00	11.00	9.00	11.00	65.00
8.	Pokkali soil Vytilla II	0.00	11.00	11.50	25.00	51.00
9.	Kole soil Kattukambal I	0.00	12.00	10.00	14.00	63.00
10.	Kole soil Kattukambal II	0.00	15.00	12.00	20.00	52.00
11.	Kaipad soil Kattampally I	0.00	10.00	13.00	17.50	59.00
12.	Kaipad soil Kattampally II	0.00	5.00	14.00	12.00	59.00

Kattukambal < Kattampally < Vytilla < Moncompu < Mathikayal. They are absent in Karumadi, Kattukambal and Kattampally. It do not order at Karumadi Moncompu Mathikayal Kattukambal Vytilla Kattampally. Its content do not differs significantly between locations.

29.1.1 Medium silt (5-20 µm)

The medium silt content of the soils ranges between 7.50 and 19.50 percent. They are in the increasing order at Kattampally < Karumadi <Vytilla< Kattukambal < Moncompu < Mathikayal. Its content do not differs significantly between locations.

29.1.2 Fine silt (2-5 µm)

The fine silt content of the soils ranges between 10.25 and 13.50 percent. They are in the increasing order at Vytilla< Kattakambal < Karumadi < Moncompu < Mathikayal < Kattampally. Its content at Kattukambal and Karumadi are equal. Its content do not differ significantly between locations.

29.2.0 Coarse clay (0.2-2 µm)

The coarse clay content of the soil ranges between 12.50 and 44.0 percent. They are in the increasing order at Mathikayal < Kattampally < Vytilla < Kattukambal < Karumadi < Moncompu. Its content do not differ significantly between locations.

29.2.1 Fine clay (<0.2 µm)

The fine clay content of the soil ranges between 19.75 and 59.0 percent. They are in the increasing order at Karumadi < Moncompu< Mathikayal < Kattukambal< Vytilla < Kattampally. Its content do not differ signiciantly between locations.

30.0 **Chemical composition of soil clay**

The results of the total chemical analysis of soil clay and their molar ratios are presented in table 13 and figures 46 and 47.

30.1.1 Silica (SiO_2) content of soil clay

The SiO_2 content of soil clay ranges between 35.40 and 56.30 percent. They are in the increasing order at Kattukambal < Kattampally < Karumadi < Vytilla < Mathikayal < Moncompu. Its content differ significantly between locations.

30.1.2 Alumina (Al_2O_3) content of soil clay

The Al_2O_3 content of soil clay ranged between 27.5 and 43.95 percent. They are in the increasing order at Karumadi < Kattukambal < Mathikayal < Moncompu < Kattampally < Vytilla. Its content differs significantly between locations.

30.1.3 Iron (Fe_2O_3) content of soil clay

The Fe_2O_3 content fo soil clay ranges between 12.01 and 20.39 percent. They are in the increasing order at Moncompu < Vytilla < Kattampally < Kattukambal < Mathikayal < Karumadi. Its content differs significantly between locations.

30.1.4 Calcium (CaO) content of soil clay

The CaO content soil clay ranges between 0.02 and 0.27 percent. They are in the increasing order at Karumadi < Kattukambal < Vytilla < Mathikayal < Moncompu < Kattampally Its content differs significantly between locations.

30.1.5 Magnesium (MgO) content of soil clay

The MgO content of soil clay ranges between 0.81 and 4.67

Table 13.0. Chemical composition of clay fraction of acid sulphate soils and molar ratio (0-50 cm depth)

											Molar ratios				
Sl.	Locations	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	ZnO %	CuO %	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{CaO+MgO}$	$\frac{SiO_2}{K_2O}$	$\frac{SiO_2}{Na_2O}$
1.	Kari soil Karumadi I	43.6	27.59	20.19	0.028	1.31	2.39	1.61	1.76	0.088	2.68	5.71	3.96	52.20	42.44
2.	Kari soil Karumadi II	50.0	26.90	20.60	0.023	1.50	2.43	1.75	1.70	0.062	3.15	6.42	4.57	52.67	44.74
3.	Karapadam soil Moncompu I	57.0	37.79	11.67	0.168	1.08	3.16	1.12	5.16	0.050	2.56	12.60	4.57	73.54	79.72
4.	Karapadam soil Moncompu II	55.6	38.20	12.05	0.171	0.99	3.05	1.33	5.88	0.060	2.74	12.21	4.80	77.12	65.63
5.	Kayal soil Mathikayal	53.0	36.66	17.00	0.154	2.10	4.67	1.85	9.85	0.038	2.45	8.22	4.28	31.70	45.01
6.	Kayal soil Mathikayal	49.5	36.80	16.85	0.165	2.36	4.89	1.50	10.11	0.029	2.28	7.77	4.01	31.44	51.82
7.	Pokkali soil Vytilla I	49.0	43.46	13.07	0.098	4.79	37.74	4.47	14.94	0.088	1.91	9.92	3.76	16.09	17.17
8.	Pokkali soil Vytilla II	51.00	44.44	13.33	0.103	4.55	26.80	4.22	13.49	0.093	1.95	10.12	3.83	17.58	18.95
9.	Kole soil Kattukambal I	36.0	27.21	15.23	0.028	0.79	2.0	0.51	0.98	0.038	1.98	5.52	3.25	62.95	48.96
10.	Kole soil Kattukambal II	34.8	28.06	14.98	0.068	0.83	1.89	0.63	1.05	0.050	2.10	6.15	3.51	62.28	86.45
11.	Kaipad soil Kattampally I	38.0	39.68	13.68	0.280	2.06	2.66	2.20	0.047	0.050	1.43	6.48	2.73	22.97	23.85
12.	Kaipad soil Kattampally II	39.2	40.10	13.90	0.251	1.99	2.45	2.28	0.089	0.030	1.43	7.46	3.15	28.13	26.96

percent. They are in the increasing order at Kattukambal < Moncompu < Karumadi < Kattampally < Mathikayal < Vytilla. Its content differs significantly between locations.

30.1.6 <u>Sodium (Na_2O) content of soil clay</u>

The Na_2O content of the soil clay ranges between 1.95 and 32.27 percent. They are in the increasing order at Kattukambal < Karumadi < Kattamplly < Moncompu < Mathikayal < Vytilla. Its content differs significantly between locations.

30.1.7 <u>Potassium (K_2O) content of soil clay</u>

The K_2O content of soil clay ranges between 0.51 and 4.35 percent. They are in the increasing order at Kattukambal < Moncompu < Karumadi < Mathikayal < Kattampally < Vytilla. Its content differs significantly between locations.

30.1.8 <u>Zinc (ZnO) content of soil clay</u>

The ZnO content of the soil clay ranges between 0.7 and 14.22 percent. They are in the increasing order at Kattampally < Kattukambal < Karumadi < Moncompu < Mathikayal < Vytilla. Its content differs significantly between locations.

30.1.9 <u>Copper (CuO) content of soil clay</u>

The CuO content of soil clay ranges between 0.03 and 0.09 percent. They are in the increasing order at Mathikayal < Kattampally < Kattukambal < Moncompu < Karumadi < Vytilla. Its content differs significantly between locations.

30.2.1 <u>SiO_2/Al_2O_3 ratio</u>

The SiO_2/Al_2O_3 ratio of the soil clay ranges between 1.43

FIG. 47

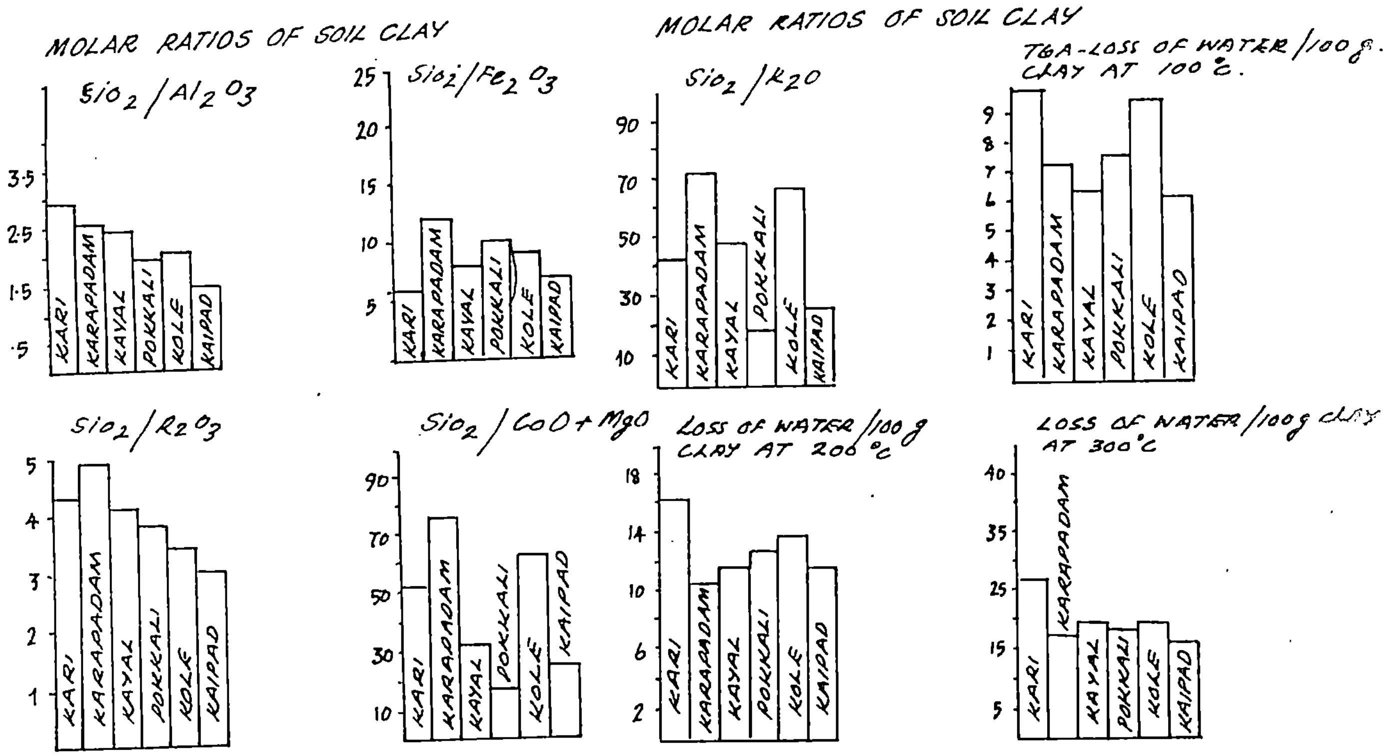
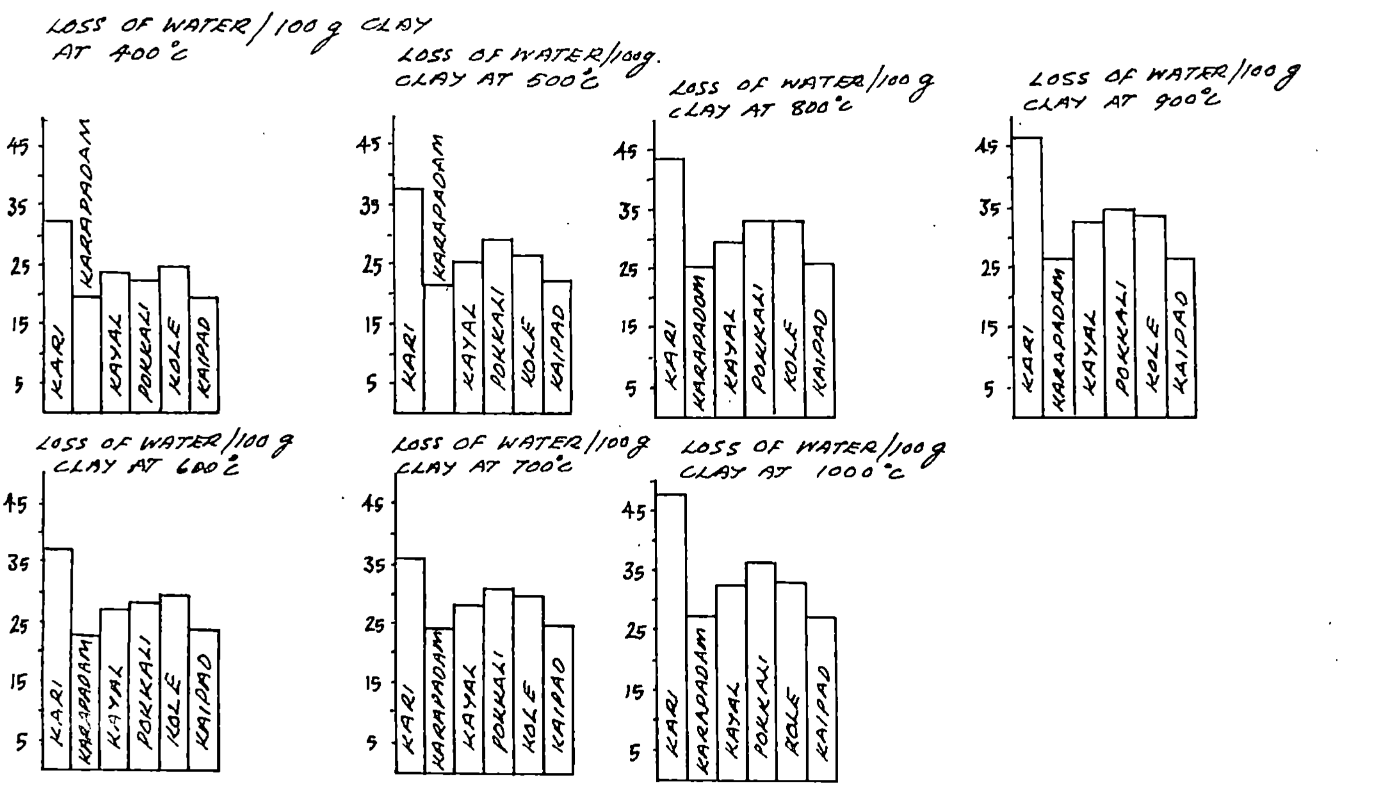

MOLAR RATIOS OF SOIL CLAY
SiO2/Al2O3
SiO2/Fe2O3
MOLAR RATIOS OF SOIL CLAY
SiO2/K2O
TGA-LOSS OF WATER/100 g. CLAY AT 100 °C.
SiO2/R2O3
SiO2/CaO+MgO
LOSS OF WATER/100 g CLAY AT 200 °C
LOSS OF WATER/100 g CLAY AT 300 °C
KARI
KARAPADAM
KAYAL
POKKALI
KOLE
KAIPAD

FIG. 48


LOSS OF WATER/100 g CLAY AT 400 °C
LOSS OF WATER/100g. CLAY AT 500 °C
LOSS OF WATER/100 g CLAY AT 800 °C
LOSS OF WATER/100 g CLAY AT 900 °C
LOSS OF WATER/100 g CLAY AT 600 °C
LOSS OF WATER/100 g CLAY AT 700 °C
LOSS OF WATER/100 g CLAY AT 1000 °C
KARI
KARAPADAM
KAYAL
POKKALI
KOLE
KAIPAD

and 2.92. They are in the increasing order at Kattampally < Vytilla < Kattukambal < Mathikayal < Moncompu < Karumadi. They differ significantly between locations.

30.2.2 SiO_2/Fe_2O_3 ratio

The SiO_2/Fe_2O_3 ratio of the soil clay ranges between 5.84 and 12.41. They are in the increasing order at Kattukambal< Karumadi < Kattampally < Mathikayal < Vytilla < Moncompu. They differ significantly between locations.

30.2.3 SiO_2/R_2O_3 ratio

The SiO_2/R_2O_3 ratio of the soil clay ranges between 2.94 and 4.89. They are in the increasing order at Kattampally < Kattukambal < Vytilla < Mathikayal < Karumadi < Moncompu. They differ significantly between locations.

30.2.4 SiO_2/CaO + MgO ratio

The SiO_2/CaO+MgO ratios of the soil clay ranges between 16.84 and 75.33. They are in the increasing order at Vytilla < Kattampally < Mathikayal < Kattukambal< Moncompu. They differ significantly between locations.

30.2.5 SiO_2/K_2O ratio

The SiO_2/K_2O ratio of the soil clay ranges between 18.06 and 72.68. They are in the increasing order at Vytilla< Kattampally < Karumadi <Mathikayal < Kattukambal <Moncompu.

31.0 **Thermogravimetric Analysis (TGA) of soil clay**

The results of the thermogravimetric analysis of soil clay are presented in table 14 and figures 47 to 54.

31.1.1 Loss of water/100 g clay at 100^{o}-C

The loss of water/100 g clay at 100^{o}-C ranges between 6.17 and 9.92 percent. It is in the increasing order at Kattampally < Mathikayal < Moncompu < Vytilla < Kattukambal < Karumadi. It doesnot differ significantly between locations.

31.1.2 Loss of water/100 g clay at 200^{o}-C

The loss of water/100 g clay at 200^{o}-C ranges between 10.58 and 16.30 percent. It is in the increasing order at Moncompu < Kattampally < Mathikayal < Vytilla < Kattukambal < Karumadi. It doesnot differ significantly between locations.

31.1.3 Loss of water/100 g clay at 300^{o}-C

The loss of water/100g clay at 300^{o}-C ranges between 15.23 and 29.09 percent. It is in the increasing order at Moncompu < Kattampally < Vytilla < Kattukambal < Mathikayal < Karumadi. It differs significantly between locations.

31.1.4 Loss of water/100 g clay at 400^{o}-C

The loss of water/100 g clay at 400^{o}-C ranges between 21.85 and 35.69 percent. It is in the increasing order at Moncompu < Kattampally < Mathikayal < Vytilla < Kattukambal < Karumadi. It differs significantly between locations.

31.1.5 Loss of water/100 g clay at 500^{o}-C

The loss of water/100 g clay at 500^{o}-C ranges between 21.05 and 35.69 percent. It is in the increasing order at Moncompu < Kattampally < Mathikayal < Vytilla < Kattukambal < Karumadi. It differs significantly between locations.

Table 14.0 Thermogravimetric analysis of soil clays from acid sulphate soils (0-50 cm depth) (loss of water/100 g of day)

Sl.	Location	Temperature in - °C									
		100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C
1.	Kari soil Karumadi I	9.52	15.87	25.39	31.75	34.92	36.51	38.09	42.86	46.03	47.62
2.	Kari soil Karumadi II	10.33	16.73	26.78	33.18	36.46	38.10	39.65	44.40	47.53	47.53
3.	Karapadam soil Moncompu I	6.49	11.69	15.58	22.08	22.08	24.68	24.68	25.97	25.97	25.97
4.	Karapadam soil Moncompu II	8.11	9.46	14.86	17.57	21.62	21.62	24.32	25.68	27.03	28.38
5.	Kayal soil Mathikayal I	5.88	10.59	18.82	22.35	24.71	28.24	30.59	31.76	31.76	31.76
6.	Kayal soil Mathikayal II	6.98	12.79	19.77	24.42	25.58	26.74	26.74	27.91	33.72	33.72
7.	Pokkali soil Vyitalla I	7.79	12.99	18.18	22.08	25.97	27.27	31.17	35.06	36.36	37.36
8.	Pokkali soil Vytilla II	7.41	12.35	18.52	22.22	25.93	29.63	30.86	33.33	33.33	34.57
9.	Kole soil Kattukambal I	7.04	11.84	17.11	23.68	26.32	30.26	31.58	34.21	34.21	34.21
10.	Kile soil Kattukambal II	11.90	15.48	202.4	26.19	27.38	28.57	28.57	32.14	33.33	33.33
11.	Kaipad soil Kattampally I	6.89	10.34	17.24	20.69	22.41	24.14	25.86	25.86	25.86	27.59
12.	Kaipad soil Kattampally II	5.45	12.73	16.36	18.18	21.82	23.64	24.25	24.45	27.27	27.27

FIG. 49

THERMOGRAVIMETRIC ANALYSIS CURVE OF CLAY FROM ACID SULPHATE SOILS (0-50cm depth)

SCALE: X AXIS 100°C = 2.0cm
Y AXIS 10% WATERLOSS = 4cm

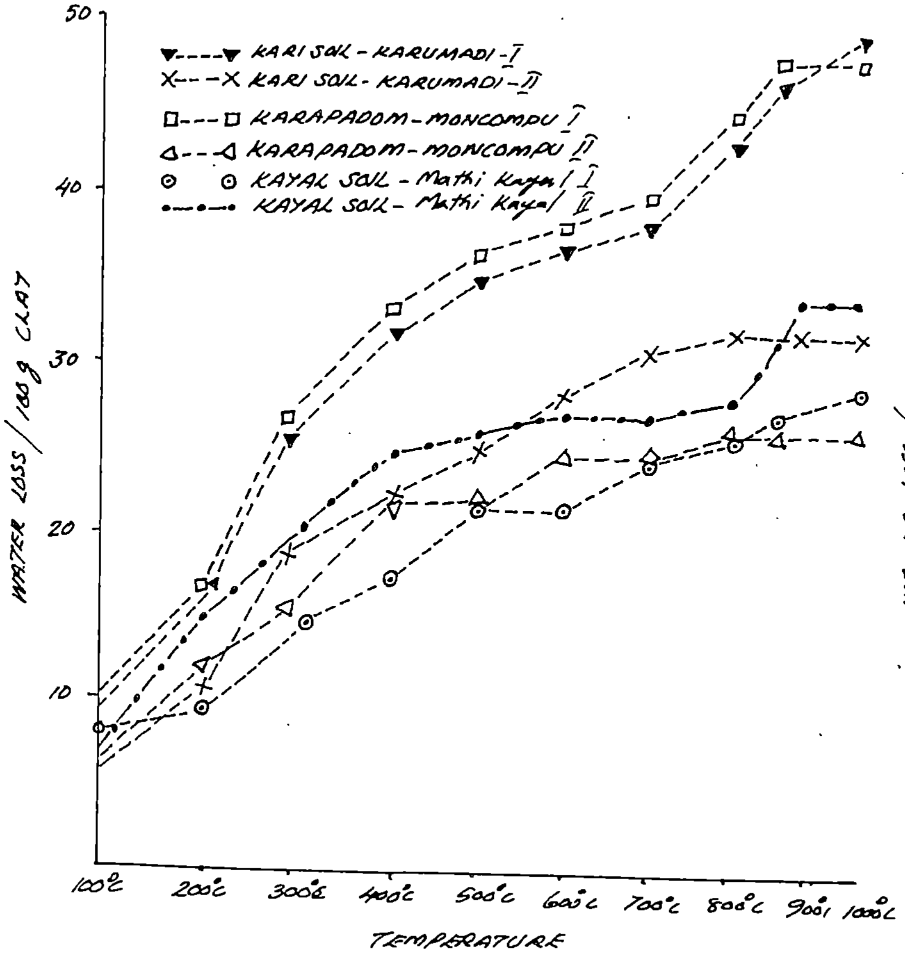
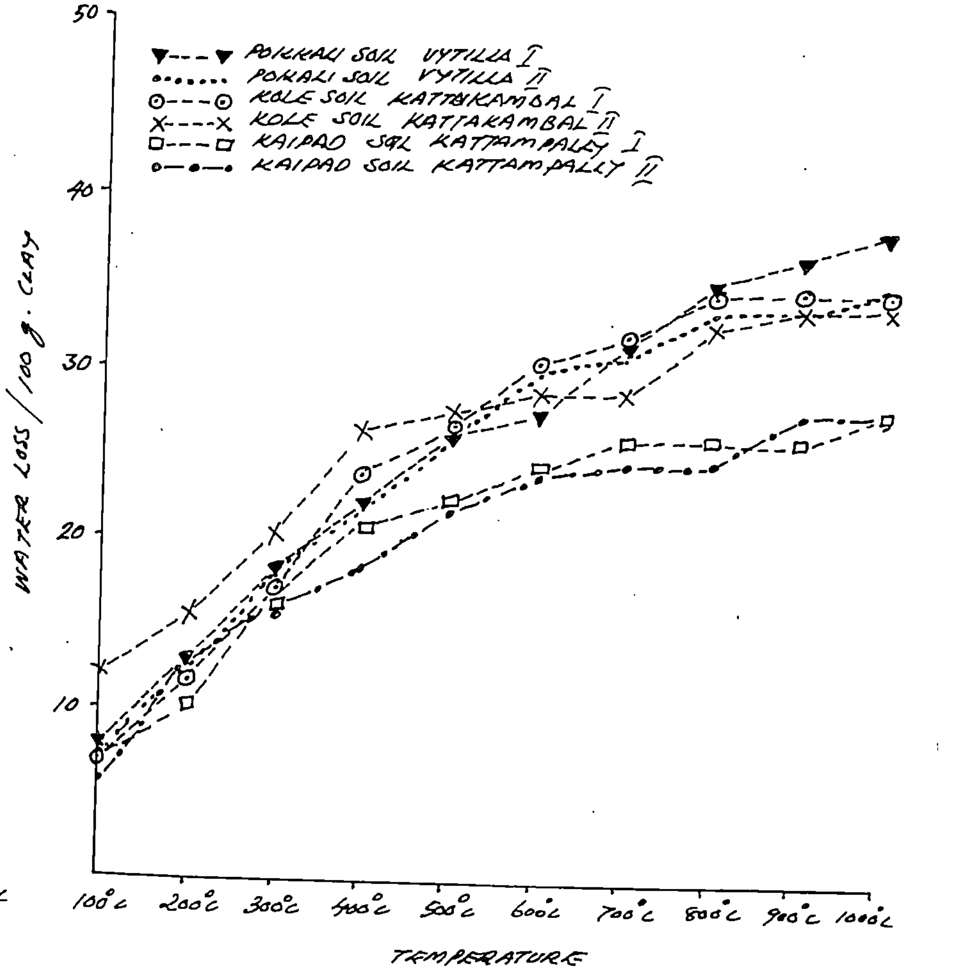


FIG. 50

THERMOGRAVIMETRIC ANALYSIS CURVE OF CLAY FROM ACID SULPHATE SOILS (0-50 cm depth)

SCALE: X AXIS 100°C = 2.0cm
Y AXIS 10% WATERLOSS = 4cm



31.1.6 Loss of water/100 g clay at 600^{o}-C

The loss of water/100 g clay at 600^{o}-C ranges between 23.15 and 37.32 percent. It is in the increasing order at Moncompu < Kattampally < Mathikayal < Vytilla < Kattukambal < Karumadi. It differs significantly between locations.

31.1.7 Loss of water/100 g clay at 700^{o}-C

The mean loss of water/100 g clay at 700^{o}-C ranges between 24.50 and 36.37 percent. It is in the increasing order at Moncompu < Kattampally < Mathikayal < Kattakambal < Vytilla < Karumadi. It differs significantly between locations.

31.1.8 Loss of water/100 g clay at 800^{o}-C

The loss of water/100 g clay at 800^{o}-C ranges between 25.16 and 43.63 percent. It is in the increasing order at Kattampally < Moncompu < Mathikayal < Kattukambal < Vytilla < Karumadi. It do not differ significantly between locations.

31.1.9 Loss of water/100 g clay at 900^{o}-C

The loss of water/100 g clay at 900^{o}-C ranges between 26.50 and 46.78 percent. It is in the increased order at Moncompu < Kattampally < Mathikayal < Kattukambal < Vytilla < Karumadi. It differs significantly between locations.

31.1.10 Loss of water/100 g clay at 1000^{o}-C

The loss of water/100 g clay at 1000^{o}-C ranges between 27.18 and 47.58 percent. It is in the increased order at Moncompu < Kattampally < Mathikayal < Kattukambal < Vytilla < Karumadi. It do not differ signifincantly between locations.

31.2 Categories of water loss of soil clay

The different categories of water loss of soil clay are presented in table 14.1 and figure 54.

31.2.1 Loss of water/100 g clay below 100^{o}-C

The loss of water/100 g clay below 100^{o}-C ranges between 19.60 and 28.14 percent. It is in the increasing order at Mathikayal < Karumadi < Vytilla < Kattampally < Moncompu < Kattukambal.

31.2.2 Loss of water/100 g clay below 300^{o}-C

The loss of water/100 g clay below 300^{o}-C ranges between 50.92 and 61.24 percent. It is in the increasing order at Vytilla, < Karumadi < Kattukambal < Moncompu < Mathikayal < Kattampally. It do not differ significantly between locations.

31.2.3 Loss of water/100 g clay below 600^{o}-C

The loss of water/100 g clay below 600^{o}-C ranges between 78.42 and 87.10 percent. It is in the increasing order at Karumadi < Vytilla,< Mathikayal < Moncompu < Kattukambal < Kattampally. It do not differ significantly between locations.

31.2.4 Loss of water/100 g clay beyond 600^{o}-C

The mean loss of water/100 g clay beyond 600^{o}-C ranged between 12.91 and 21.59 percent. It is in the increasing order at Kattampally < Kattukambal < Moncompu < Mathikayal < Vytilla < Karumadi. It do not differs significantly between locations.

31.2.5 Adsorbed water percent

Absorbed water percent of soil ranges between 61.46 and 71.40 percent. It is in the increasing order at Vytilla < Karumadi <

Table 14.1. Different categories of total water lost (water lost in terms of % total water lose per 100 g of clay)

Sl. No.	Locations	Below 100°C	Below 300°C	Below 600°C	Beyond 600°C	Adsorbed water	Crystal lattice water	Adsorbed water / Crystal Lattice water
1.	Kari soil Karumadi I	19.99	53.32	76.67	23.32	66.67	33.33	2.00
2.	Kari soil Karumadi II	21.73	56.34	80.16	19.84	69.81	30.19	2.31
3.	Karapadam soil Moncompu I	24.99	59.99	95.03	4.97	80.02	19.98	4.01
4.	Karapadam soil Moncompu II	28.58	52.33	76.18	23.82	61.91	38.09	1.63
5.	Kayal soil Mathikayal I	18.51	59.26	88.92	11.08	70.37	29.62	2.37
6.	Kayal soil Mathikayal II	20.69	53.65	79.30	20.10	72.42	27.58	2.63
7.	Pokkali soil Vytilla I	20.69	48.27	72.41	27.59	58.63	41.37	1.42
8.	Pokkali soil Vytilla II	21.43	53.57	85.71	14.29	64.28	32.72	1.80
9.	Kole soil Kattukambal I	20.58	50.01	88.45	11.55	69.22	30.78	2.25
10.	Kole soil Kattukambal II	35.70	60.73	85.72	14.28	78.58	21.42	3.67
11.	Kaipad soil Kattampally I	24.97	62.49	87.50	12.50	74.99	25.01	2.30
12.	Kaipad soil Kattampally II	19.99	59.99	86.69	13.31	66.67	33.33	2.00

FIG. 51

DIFFERENT FORMS (CATEGORIES) OF TOTAL WATER LOST- ADSORBED WATER AND CRYSTAL LATTICE WATER OF CLAYS FROM ACID SULPHATE SOILS (0-50 cm depth)

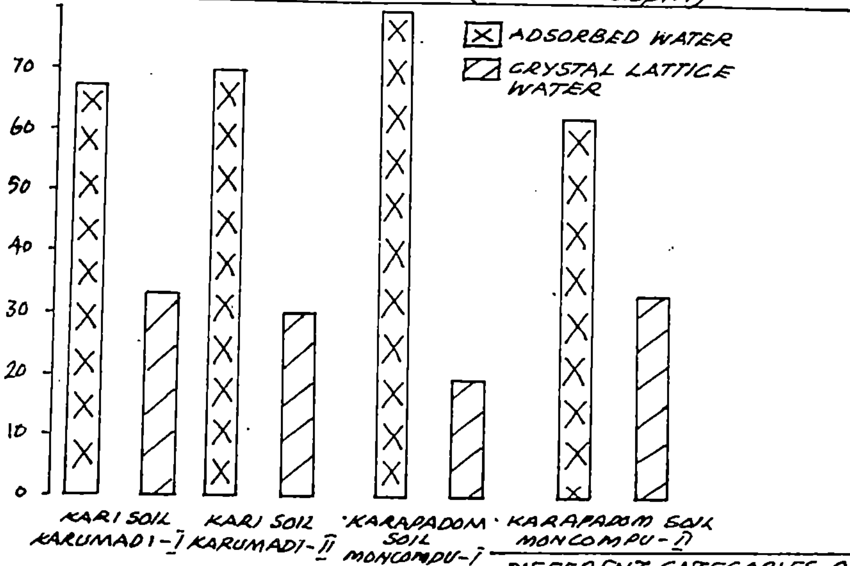
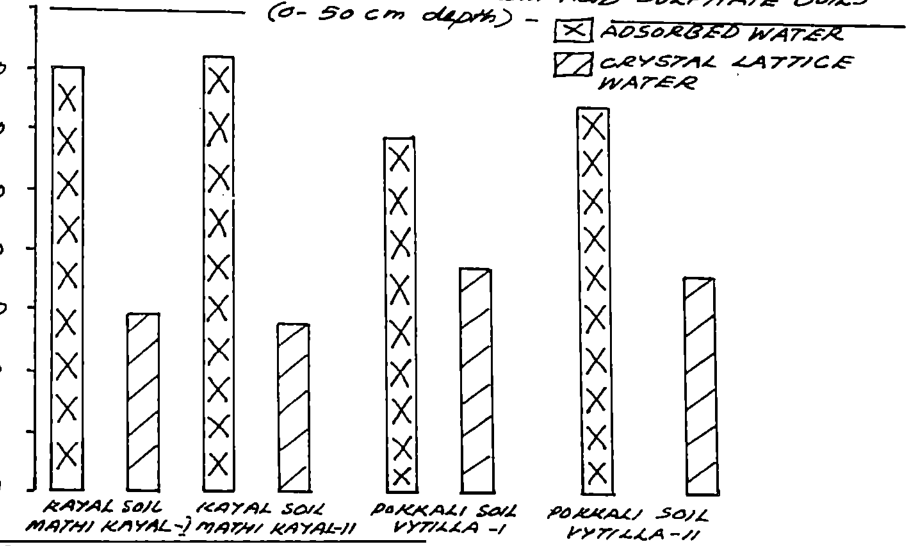


FIG. 52

DIFFERENT CATEGORIES OF WATER LOST- PERCENT OF TOTAL WATER LOST- ADSORBED WATER AND CRYSTAL LATTICE WATER OF CLAYS FROM ACID SULPHATE SOILS (0-50 cm depth)



DIFFERENT CATEGORIES OF TOTAL WATER LOST-ADSORBED WATER AND CRYSTAL LATTICE WATER OF CLAYS FROM ACID SULPHATE SOILS (0-50 cm depth)

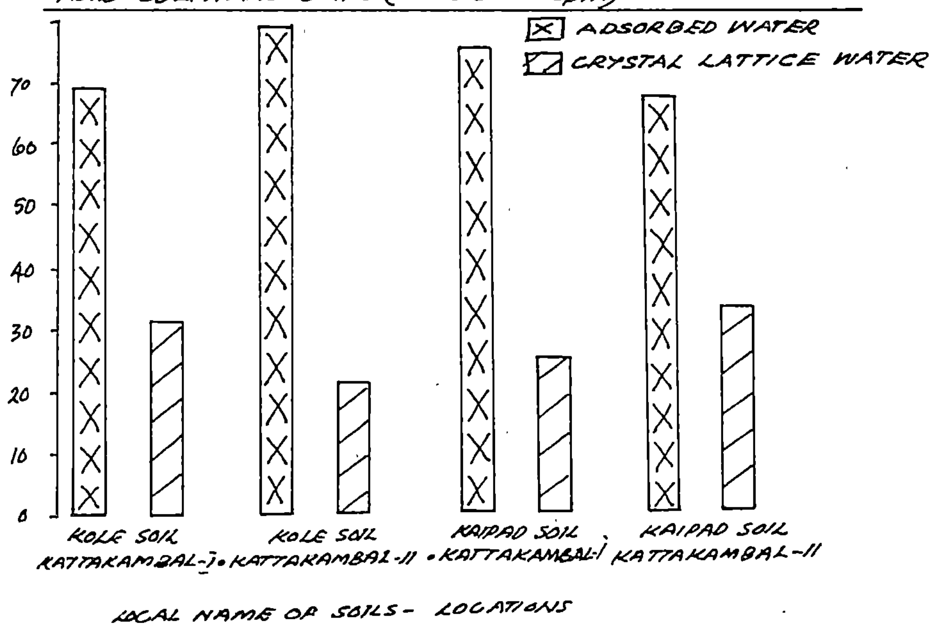
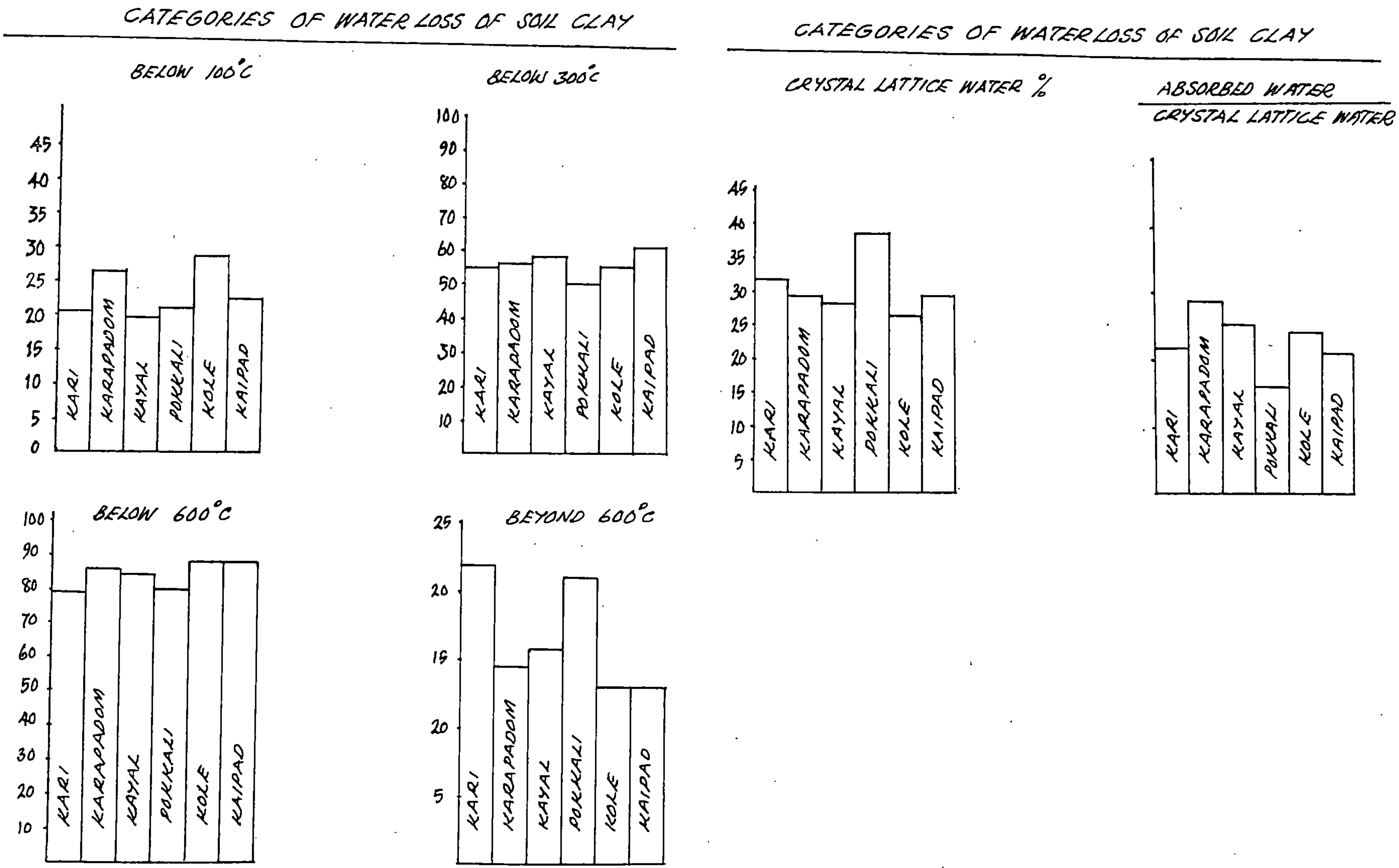


FIG. 53

FIG. 54



CATEGORIES OF WATER LOSS OF SOIL CLAY
BELOW 100°C
45 40 35 30 25 20 15 10 5 0
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD
BELOW 300°C
100 90 80 70 60 50 40 30 20 10
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD
BELOW 600°C
100 90 80 70 60 50 40 30 20 10
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD
BEYOND 600°C
25 20 15 20 5
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD
CATEGORIES OF WATER LOSS OF SOIL CLAY
CRYSTAL LATTICE WATER %
45 40 35 30 25 20 15 10 5
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD
ABSORBED WATER / CRYSTAL LATTICE WATER
KARI KARAPADOM KAYAL POKKALI KOLE KAIPAD

Kattampally < Kattukambal < Moncompu < Mathikayal. It do not differ significantly between locations.

31.2.6 Crystal lattice water percentage

The crystal lattice water percent of the soil clay ranges between 20.10 and 38.55. It is in the increasing order at Kattukambal < Mathikayal < Moncompu < Kattampally < Karumadi < Vytilla. It do not differ significantly between locations.

31.2.7 Adsorbed water/crystal lattice water ratio

The adsorbed water/crystal lattie water ratio of the soil clay ranges between 1.61 and 2.96. It is in the increasing order at Vytilla <Kattampaly < Karumadi < Mathikayal < Moncompu < Kattukambal. It do not differs significantly between locations. Increased loss in as the organic matter in the clays had not been destroyed. All the samples show a decrease in loss of water/100 g clay around or at 600^{0}-C due to the presence of kaolinite. Similarly a small decrease around 700^{0}-C is indicative of chloritic type of minerals. The ratio of absorbed: crystal lattice water in all the clay samples from different locations are more that one indicating the preponderance of 2:1 type of clay minerals.

32.0. X-ray Diffraction Analysis of clay samples (XRDA)

The results of X-ray diffraction analysis of soil clay samples from 0-50 cm depth at different locations are presented in figures 55 and 56 and table 9.

The X-ray diffraction data and the approximate quantities of minerals identified are given in table 9. The major minerals

Table 9.0 X-ray diffraction data of clay fractions (untreated) of the acid sulphate soils (0-50 cm depth)

Soil-Locations	d-spacing A^{o}	Relative intensity (Approximate)	Mineral identified	Approximate composition
	3.34	10	Quartz mica	Mica quartz 50 percent
	4.81	2	chlorite	Kaolinite 30 percent
1. Karisoil	7.2	7	Kaolinite	Chlorite, mica and others
Karumadi-I	3.59	5	Kaolinite	20 percent
	4.03	2	Mica	
	3.34	9	Quartz, mica	Mica quartz 50 percent,
	4.29	2	Quartz, mica	Kaolinite 20 percent and
2. Kari soil	7.2	7	Kaolinite	others 20 percent
Karumadi-II	4.81	2	Chlorite	
	3.34	10	Quartz, mica	Quartz 50 percent, chlorite
3. Karapadom soil	4.81	5	Chlorite	20 percent, Kaolinite
Moncompu-I	7.2	2	Kaolinite	10 percent and others
				20 pecent.
	3.34	9	Quartz, mica	Mica quartz 50 percent,
4. Karapadom soil	4.81	2	Chlorite	Chlorite 10 percent,
Moncompu II	7.2	7	Kaolinite	Kaolinite 20 percent and
				others 20 percent.

Table 9.0 X-ray diffraction data of clay fractions (untreated) of the acid sulphate soils (0-50 cm depth)

Soil-Location	d-spacing A^o	Relative intensity (Approximate)	Mineral identified	Approximate composition
	3.34	10	Quartz, mica	Quartz 50 percent,
5. Kayal soil	4.81	5	Chlorite	Chlorite 20 percent,
Mathikayal-I	7.2	2	Kaolinite	Kaolinite 10 percent,
				Mica and others 20 percent
	3.34	9	Quartz, mica	Quartz 60 percent,
6. Kayal soil	4.81	2	Chlorite	Kaolinite 20 percent,
Mathikayal-II	4.29	2	Quartz	Chlorite and others
	7.2	7	Kaolinite	20 percent
	3.34	10	Quartz, mica	Quartz, mica 60 percent,
7. Pokkali soil	3.59	5	Kalinite	Kaolinite 25 percent
Vytilla-I	7.2	2	Kaolinite	and others 15 percent.
	3.34	9	Quartz, mica	Micaquartz 50 percent,
8. Pokkali soil	3.59	5	Kaolinite	Kaolinite 30 percent,
Vytilla-II	7.2	7	Kaolinite	Chlorite 10 percent and
	4.81	2	Chlorite	Others 10 percent.
	3.59	10	Kaolinite	Kaolinite 60 percent,
9. Kole soil	3.34	7	Quartz, mica	Mica quartz 20 percent,
Kattukambal	4.81	5	Chlorite	Chlorite 15 percent
	7.2	7	Kaolinite	and others 5 percent.

Table 9.0 X-ray diffraction data of clay fractions (untreated) of the acid sulphate soils, (0-50 cm depth)

Soil-Location	d-spacing A^o	Relative intensity (Approximate)	Mineral identified	Approximate composition
10. Kole soil Kattukambal	3.59	5	Kaolinite	Kaolinite 50 percent,
	3.34	9	Mica quartz	Micaquartz 30 and others
	7.2	7	Kaolinite	10 percent.
11. Kaipad soil Kattampally	3.34	10	Quartz,mica	Micaquartz 50 percent,
	3.59	5	Kaolinite	30 percent Kaolinite
	7.2	7	Kaolinite	10 percent chlorite and
	4.81	2	Chlorite	others 10 percent.
12. Kaipad soil Kattampally-II	3.34	7	Micaquartz	50 percent
	3.59	5	Kaolinite	30 percent Kaolinite
	7.2	7	Kaolinite	10 percent chlorite
	4.81	2	Chlorite	and others 10 percent.

Fig. 55

X-RAY DIFFRACTOGRAMS OF THE CLAY FRACTIONS OF ACID SULPHATE SOILS (0. 50 cm)

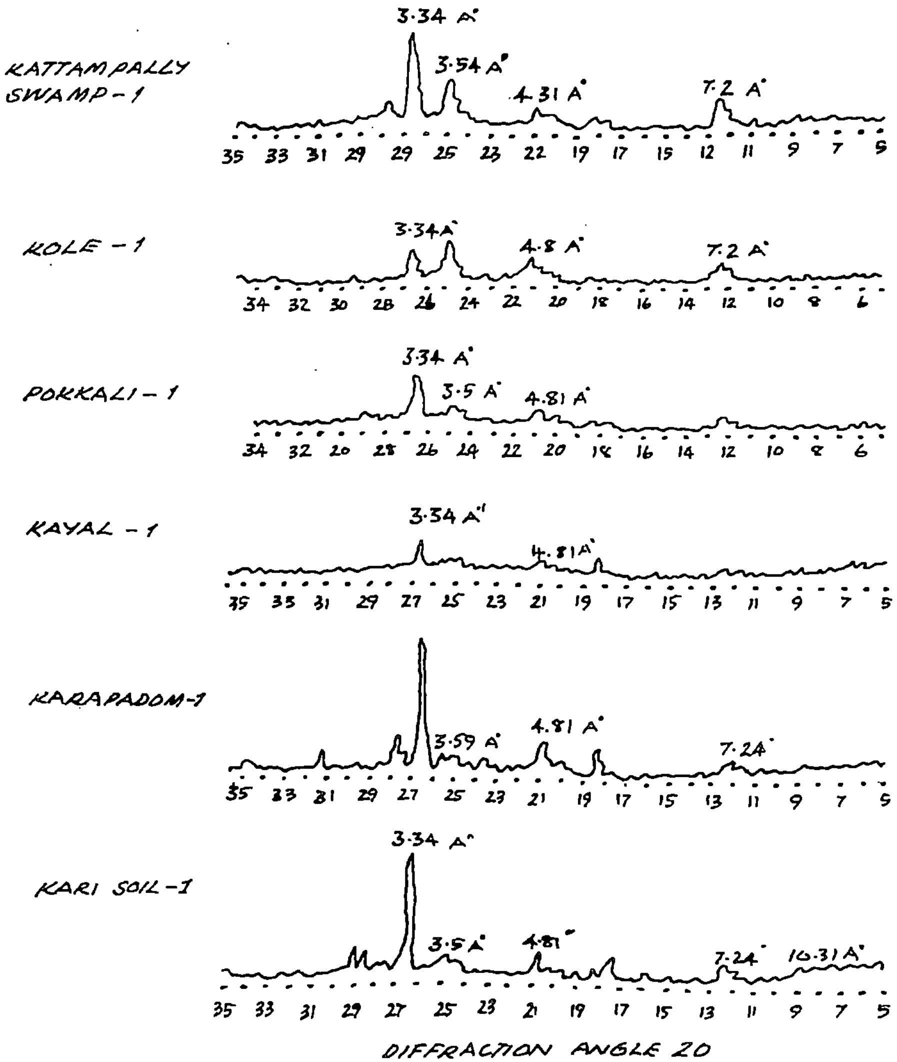
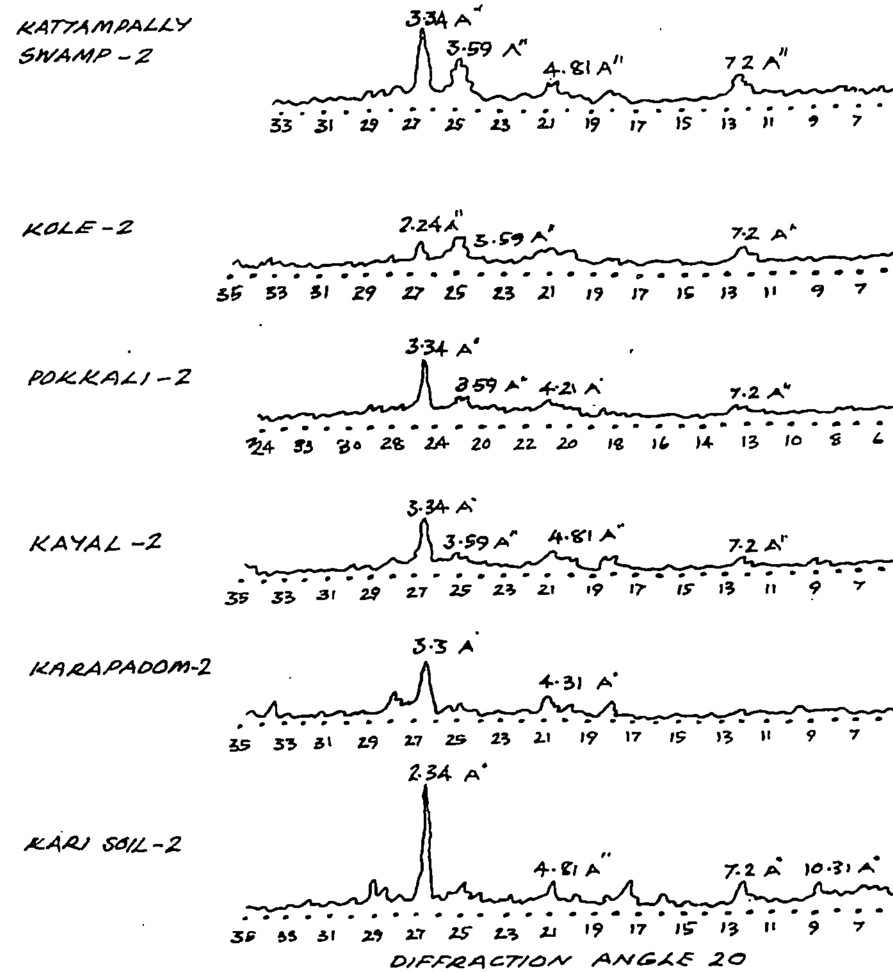


Fig. 56

X-RAY DIFFRACTOGRAMS OF THE CLAY FRACTION OF ACID SULPHATE SOILS (0-50 cm)



identified are micaquartz, chlorite, mica and kaolinite. Minor quantities of smectitie, feldspars, goethite and pyrite are also identified. The content of micaquartz are 50 percent at Karumadi II, Mathikayal II, Vytilla while it is 50 percent in remaining sites and locations, except Kattukambal where it is 30 percent in both the sites. Kaolinite content is 60 percent at both the sites at Kattukambal. It is 30 percent at Karumadi I, Vytilla II and both the sites at Kattampally. At Vytilla I the kaolinite content is 25 percent while at Karumadi II, Moncompu I, Mathikayal I and II it is 20 percent and at Moncompu II. The chlorite content is 10 and 20 at Moncompu I and II Mathikayal I and II Mathikayal I and II respectively. It is 30 percent at Karumadi I, and 15 percent at Kattukambal I.

33. **Mesomorphology**

The comparative mesomorphology of the soil at different locations are presented in Table 7.3.0-7.3.5 and the meso photomicrographs are presented in plates 26 to 52.

33.1. Colour of plasma

At Karumadi the colour of the soil plasma is yellowish brown to brownish yellow in the first horizon followed by pale pinkish white to reddish brown in the second horizon, yellowish red to reddish yellow in the third horizon and is brownish yellow in the fourth horizon. (Plates 26,27,28 and 29).

It is yellow in the first followed by yellowish brown to brownish yellow in the second, yellowish red to reddish yellow in 3rd & fourth horizons at Moncompu (plates 30, 31 32 and 33).

Table 7.B.0 Mesomorphology of the Acid Sulphate Soils

Local name of soils	KARI SOIL			KARUMADI
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellowish brown to brownish yellow coloured	Pale pinkish white to reddish brown	Yellowish red to reddish yellow	Brownish yellow
2. Soil fabric	Skelplasmic	Skelplasmic	Plasmic, Asepic to insepic and rarely isotic	Skelplasmic skelsepic
3. Relative Distribution pattern (RDP)	Granic	Granic	Plasmic	Granic
4. Normal Related Distribution Pattern	Granic to porphyric	Granic to porphyric	Plasmic to porphyric	Granic to grani plasmic
5. Finer/coarser	Coarser	Coarser	Finer	Coarser
6. Skeletons	Shining angular to sub angular sillimanite, ilmenite	Shining angular to sub angular sillimanite , ilmenite	Few or absent	Subrounded to rounded,fractured sillimanite , ilemenite,quartz
7. Voids	Not observable	Not observable	Channels	Not observable
8. Humus	Melanified humus with ferri organan	Opaque shining, dark reddish brown wood fossil in the shape of palm	Ferri organan, organan	Ferriorganan
9. Cutans	Ferran,argillan ferriargillan	Ferran,ferriorganan	Ferran,ferriorganan, geothan,ferriargillan	Ferriorganan,ferran ferriargillan
10. Aggregates	Ferriorganan, quartz aggregates and lateritic micro aggregates	Ferriorganan	Ferriargillan, ferriorganan with quartz	Pyrite with ferriorganan, ilmenite with ferriorganan
11. Laterite nodules / Concretions	Absent	Absent	Opaque present with sharp margins	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosite/pyrite	Finer, shining cubular jarosite crystals present surrounding high relief skeletons and in depressions	Absent	Present Neoquasi jarositan surrounding channels	Jarosite present as neoquasi jarositans. Comparatively more cubular, spheroidal pyrite crystals present in uneven depression and channels surrounding skeletons.
14. Special observations if any	Signs of iron removal and iron enrichment is observed. Opaque fine silt sized pyrite cubular crystals are present. Wook fossils as such are not observable	On the wood fossils ironoxide framboids with very few jarosites are present	The white areas inside the channel are regions of iron removal.The dark red margins and surrounding sub channels are regions of haematite enrichment. The yellowish orange regions with sharp margins are goethites. The yellow to pale yellow are neojarrositans and quasineojarositans. The white spots in and surrounding the channels are quartz . Opaque brownish yellow regions of the channels are accumulation of pyrite crystals, ferriorganan. Layering of reddish regions and sharp margins indicated repeated deposition of ironoxide.	More skeletons, less plasma Signs of iron, ferriorganan, leaching and lessivage in active operation depicting sharp margins to skeletons.
15. Plate number	26	27	28	29

Table 7.3.1 Mesomorphology of the Acid Sulphate Soils

Local name of soils	KARAPADOM SOIL			MONCOMPU
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellow to yellowish red	Yellowish brown to brownish yellow	Yellowish red to reddish yellow	Yellow to yellowish brown
2. Soil fabric	Skelsepic	Skelsepic	Plasmic,Asepic	Skelsepic
3. Relative Distribution patter(RDP)	Granic	Granic	Plasmigranic	Graniplasmic
4. Normal Related Distribution Pattern (NRDP)	Granic to graniplasmic	Granic	Plasmigranic	Graniplasmic to porphyric
5. Finer/Coarser	Coarser	Coarser	Finer	Finer
6. Skeletons	Subangular to subrounded quartz , angular to subangular sillimanite,ilmenite pyrite	Angular weathered and fractured sillimanite, quartz and non weathered sillimanite	Coarse sand and more than coarse sand sized quartz and sillimanite with silt to fine silt sized opaque minerals with abundant pyrite present	Silt sized, subangular, subrounded quartz with striated orientation pattern on the plasma
7. Voids	Planar packing voids with jarosite inside and iron oxide ouside as margins	Not observable	Channels	Few channels and Chambers
8. Humus	Ferriorganan and few organan	Macro aggregation of ferriorganan and organan	Few as ferriorganan	Ferriorganan
9. Cutans	Ferran,ferriorganan ferriargillan, jarositan	Organan,ferriorganan and pale yellowish ferri argillans and ferrijarositans	Ferran,ferriorganan ferrijarositan and goethan	Ferrijarositans,jarositans, ferriorganans, neoquasijarositans
10. Aggregates	Opaque minerals with ferran and ferriorganan	Fractured quartz, opaque minerals with ferriorganan	Opaque minerals with ferran and ferriorganan	Few aggregates of opaque minerals with ferriorganan
11. Laterite nodules/ concretions	Few weahtered silt sized present	Absent	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosite/Pyrite	Jarosite present inside and outside decaying root seen jarosite is also present in the plasma surrounding the skeletons	Present as jarositanic coatings	Fine jarositic neoformations present throughout the plasma and inside channels	Present as neoquasijarositans through out the plasma and on margins of quartz
14. Special observations if any	Silica as diatoms and tubular transparent to bluish colour spicules. Yellowish red plasma with subangular to subrounded quartz pyrite and other opaque skeletons (fine sand to silt sized) and long tubular siliciceous spicules. Jarositans present	Quartz are seen undergoing advanced stages of physical weathering,entangled with ferriorganan and ferrijarositans skeletons more and very few plasma	More than coarse sand sized quartz pitted and fractured bigger channels with accumulation of pyrite and other opaque minerals inside and towards outer boundary of channels. Repeated ironoxide deposition with flacked orientation pattern in the plasma and in the channels	Less than silt sized subrounded to rounded quartz embedded on yellowish plasma with striated orientation pattern. Jarosite present as yellow coloured neoquasijarosittans throughout the plasma. Pyrite also present surrounding the quartz and in channels and chambers
15. Plate number	30	31	32	33

Table 7.3.2 Mesomorphology of the Acid Sulphate Soils

Local name of soils		KAYAL SOIL		MATHIKAYAL
Horizons	h1	h2	h3	h4
1. Colour of plasma	Brownish yellow yellowish red and yellowish black	Reddish yellow	Yellowish black yellowish brown yellowish orange	Reddish brown reddish yellow
2. Soil fabric	Skelsepic	Skelsepic	Skelsepic	Skelvosepic
3. Relative Distribution Pattern(RDP)	Plasmic grenic	Graniplasmic	Granic	Granic
4. Normal Related Distribution Pattern (NRDP)	Granic	Plasmigranic	Granic	Graniplasmic
5. Finer/Coarser	Coarser	Coarser	Coarser	Finer
6. Skeletons	Highly weathered fractured subangular to subrounded quartz, feldspars lateritic nodules	Highly weathered fractured iron oxide coated quartz, sillimanite,ilmenite haematite,pyrite ferrihydrite	Heighly weathered fractured,pitted coarse sand sized quartz and fine sand sized opaque minerals	Highly weathered subrounded to rounded silt sized and less than silt sized quartz, laterite nodule, red opaques ma ferrihydrite and few black opaques
7. Voids	Not observable	Channels ,. chambers and vughs	Not observable	Channels ; chambers and vughs
8. Humus	Present as fine aggregates of ferriorganan	Ferriorganan	Organan, and few ferriorganan, ferriargillan, ferrijarositan	Ferrihydrite
9. Cutans	Organan,ferriorganan and very few jarositan and many minute ferrihydrite	Ferran,ferriargillan goethan,ferriorganan	Organan and few ferriorganan ferriargillan ferrijarositan	Ferran,ferriargillan and ferrijarositan
10. Aggregates	Macro ferriorganan and microferrihydrite	Weathered quartz, ferrihydrite, ferriargillan and ferriorganan	Amoeba shaped pyrite, opaque minerals and ferriorganan form macro aggregates	Ferrihydrite,fine quartz, ferriorganan and ferriargill
11. Laterite nodules/ Concretion s	Silt sized few present. High reliefed sharp margined and weahtered	Absent	Few present, silt sized,low reliefed faint margined	Few less than silt sized low reliefed present
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of jarosite/pyrite	Present as neoquasijarositans	Few neoquasijarositans, pyrite present in channels and surrounding weathered quartz	Very few present as neoquasijarositans. Amoeba shaped more fine sand sized pyrite	Few jarosite and many cubul pyrite in the voids, associated with ferrihydrit
14. Special observations if any	Major portion of the plasma is occupied by highly weathered sub angular to rounded quartz skeletons and feldspars. Numerous minute less than clay sized ferrihydrite and few laterite nodules and neoquasijarositans	Few fine sands and many less than silt sized highly weahtered and fractured iron oxide coated massive channels and chambers, vughs with pyrite haematite and ferrihydrite in it surrounding weathered quartz	Presence of few more than coarse sand sized subangular highly weathered fractured pitted quartz, amoeba shaped pyrite, ferrihydrite black opaques and few red opaques	Very weakly anisotropic matrix, with random distribution of small domai Innumerable fine ferrihydri highly weathered subrounded less than silt sized quartz. laterite nodule, channels and chambers, vughs with pyrite in it
15. Plate number	34	35	36	37

Table 7.3.3 Mesomorphology of the Acid Sulphate Soils

Local name of soil		POKKALI SOIL		VYTILLA
Horizons	h1	h2	h3	h4
1. Colour of plasma	Reddish yellow, highly iron enriched fine grained	Brownish yellow, yellowish brown coarse granular	Yellowish brown, reddish yellow , reddish brown	Highly coarse granular, Yellowish brown
2. Soil fabric	Skelsepic	Skelsepic	Skelsepic	Skelsepic
3. Related Distrtibution Pattern (RDP)	Graniplasmic	Granic	Granic	Granic
4. Normal Related Distribution Pattern (NRDP)	Graniplasmic to porphyric	Granic	Granic	Graniplasmic
5. Finer/Coarser	Coarser	Coarser	Coarser	Coarser
6. Skeletons	Highly pitted and weathered subangular to subrounded, fine sand sized quartz less than silt sized black opaques and pyrite and few laterite nodules	Angular to subangular pitted less than fine sand sized quartz, felspar less than silt sized opaques, pyrite, ferrihydrite	Less than fine sand sized partially weathered angular to subangular quartz, feldspars, opaques, pyrites	More than fine sand sized highly pitted but not fractured quartz, fractured feldspars amoeba shaped less than silt sized pyrite aggregates
7. Voids	Channels,chambers and vughs	Channels and chambers	Channels and chambers few metavughs	Channels and chambers
8. Humus	Few intimately mixed as ferriorganan	Ferriorganan organan	Ferriorganan ferriargillan	Ferriorganan
9. Cutans	Ferren, ferrisiltan, ferriqurtzans ferriargillan	Organan, ferriorganan, ferriargillan, ferrijarositan	Ferriorganan, ferriargillan ferrijarositan	Ferriorganan, ferripyritan and ferrijarositan
10. Aggregates	Micro aggregates are formed by the combination of ferran ferrisiltan, ferriquartzan in ferri argillan with quartz and ferrihydrite	Pyrite,opaques, ferrihydrite with ferriorganan and ferran	Opaques, pyrite, less than silt sized weathered quartz with ferriorganan	Opaques, pyrites, fine quartz with ferriorganan
11. Laterite nodules/ Concretions	More than fine sand sized few present high reliefed sharp margined	Less than silt sized high reliefed with sharp margin and red coloured	Low reliefed yellowish red coloured present with faint margins	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of jarosite/pyrite	Pyrite silt sized skeletons with fine jarositic spheroids present throughout the plasma	Pyrite and neoquasijarositan surrounding bigger skeletons, finer plasma and in channels and chambers	Jarosite present as neojarositans and neoquasijarositans surrounding skeletons and in channels and chambers	Few present as intimately mixed jarositan on the plasma near to pyrite aggregates
14. Special Observations if any	Highly Fe enriched fine granied, granular reddish yellow plasma with highly pitted but not fracutured quartz, silt sized pyrite, fine jarositic spheroid, ferrihydrite and few laterite nodules embedded. Channels, chambers and vughs present			
15. Plate number	38	39	40	41

Table 7.3.4 Mesomorphology of the Acid Sulphate Soils

	Local name of soil	KOLE SOIL			KATTUKAMBAL
	Horizons	h1	h2	h3	h4
1.	Colour of plasma	Reddish yellow, pale yellowish brown, fine grained	Highly coarse grained, reddish yellow	Reddish brown,reddish yellow,coarse grained	Yellowish brown
2.	Soil fabric	Skelsepic	Skelsepic	Skelvosepic	skelsepic
3.	Related Distribution Pattern(RDP)	Granic	Granic	Plasmic	Granic
4.	Normal Related Distribution Pattern (NRDP)	Granic	Granic	Plasmigranic	Granic
5.	Finer/Coarser	Coarser	Coarser	Finer	Coarser
6.	Skeletons	More than coarse sand sized highly pitted but not fractured quartz, and bigger laterite subrounded nodules. Less than silt sized many opaques	Fine sand sized many laterite nodules and concretions. Many silt sized black opaques	Less than silt sized many opaques, few pyrites and very few more than coarse sand sized fractured quartz, haematite,ferrihydrite	Pitted, few coarse sand sized quartz and many fine sand sized quartz, less than silt sized, opaques and few pyrites
7.	Voids	Not observable due to iron oxide masking	Channels and chambers	Bigger chambers and few channels	Chambers and channels
8.	Humus	Ferriorganan	Not observable	Not observable	Ferriorganan
9.	Cutans	Ferran,ferriargillan and few ferriorganan	Ferran,ferriargaillan ferriquartzan,goethan	ferran,ferriargillan	ferriargillan
10.	Aggregates	Absent	Fine quartz,opaques, with ferran and ferriargillan	Opaques,pyrites, haematite,ferrihydrite with ferriargillan	Opaques,pyrites, fine quartz along channels, chambers,skeletons with ferriargillan
11.	Laterite nodules/ Concretions	Bigger subrounded iron oxide enriched laterite nodules with faint margins	Many shining reddish brown coloured present with sharp margins	Absent	More than coarse sand sized orange red coloured quartz rich, sharp margins, iron oxide enriched
12.	Lithorelics	Absent	Present, highly weathered with quartz and opaques noticeably compact, sharp margined	Absent	Absent
13.	Presence of Jarosite/pyrite	Absent but pyrite present along margins of bigger skeletons	Not observable but few pyrites present	Absent,but few pyrite present along with ferrihydrite towards outer margins of bigger chambers	Absent but few pyrites present along and inside voids and skeletons
14.	Special observations if any	Bigger pitted quartz, laterite nodules form more than 90 percent of soil plasma with less than silt sized pyrites and many high reliefed black opaques and red opaques	Coarse grained plasma with many quartz, colour of the plasma is reddish yellow. Latric nodules of fine sand sized are present. Jarosite absent	Iron oxide enriched opaque rich,chambers rich horizon with pyrite, ferrihydrite and haematite	More coarse sand sized laterite nodules with pitted fine sand sized quartz and less than silt sized opaques, pyrites on coarse yellowish brown plasma
15.	Plate number	42	43	44	45

Table 7.3.5 Mesomorphology of the Acid Sulphate Soils

Local name of soil		KAIPAD SOIL		KATTAMPALLY
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellowish brown, coarse grained	Yellowish brown, yellowish black	Yellowish brown, yellowish red	Brownish yellow, reddish brown
2. Soil fabric	Skelsepic to argillasepic	Skelsepic	Skelsepic to skelvosepic	Skelsepic
3. Related Distribution Pattern (RDP)	Granic	Granic	Granic	Granic
4. Normal Related Distribution Pattern (NRDP)	Graniplasmic	Granic	Granic	Granic
5. Finer/Coarser	Coarser	Coarser	Coarser	Coarser
6. Skeletons	Fine sand sized subangular, subrounded quartz and innumerable less than silt sized quartz, opaques and many pyrites and jarosites	More than coarse sand sized pitter, subangular quartz. Many amoeba shaped pyritic aggregates forming more than 30 percent of plasma surrounding skeletons	Non weathered more than coarse sand sized subangular quartz, amoeba shaped pyrite, and many silt sized opaques	Highly pitted, fractured more than coarse sand sized and silt sized quartz with bigger limeshells and valves of molluscs and amoeba shaped pyrites
7. Voids	Channels and chambers	Channels and chambers and few vughs	Chambers and channels	Metavugh and few chambers
8. Humus	Organan and ferriorganan	Organan and few ferriorganan and pyritic organan	Ferriorganan, ferriargilan, ferrijarositan	Organan, ferriorganan
9. Cutans	Organan, ferriorganan ferriargillan	Organan, few ferriorganan , pyritic organan and very few neojarositans	Ferriorganan, ferriargillan, ferripyritan and ferrijarositans	Organan, ferrorganan and ferripyritan
10. Aggregates	Opaques, fine quartz, pyrites and jarosite with ferriorganan	Amoeba shaped pyrites with opaques and organans	Amoeba shaped pyrites, quartz and opaques with ferrijarositans and ferriorganans	Amoeba shaped pyrite and opaque with ferriorganans
11. Laterite nodules/ Concretions	Absent	Few present, yellow coloured	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of jarosite/pyrite	Few jarosite present as neoquasijarositans. Amoeba shaped pyrites few observed	Many amoeba shaped pyritic aggregates forming more than 30 percent surrounidng skeletons and chambers	Many jarosites and pyrites present along channels and skeletons	Absent
14. Special observations if any	Innumerable less than silt sized quartz, opaques, pyrites, jarosites and more than fine sand sized nonweathered subangular quartz on coarse grained yellowish brown plasma	Very less plasma with Skelsepic fabric. More than 30 percent of the plasma is occupied by amoeba shaped pyrite with opaques and organans fomring aggregates along skeletons and voids	Jarositic ferriargillan rich quartzitic horizon with few alteration to ferrihydrite and limeshell microlites and flakes	Many less than silt sized iron oxide spheroids and pyrite spheroids on the lime shell. Highly pitted quartz and amoeba shaped pyrite with ferriorganans forming aggregates. Less plasma
15. Plate number	46	47	48 and 49	50,51 and 52

At Mathikayal it is brownish yellow, yellowish red, yellowish black in the first horizon followed by reddish yellow in the second, yellowish black, yellowish brown, yellowish orange in the second and the third and reddish brown to reddish yellow in the fourth horizons (plates 34,35,36 and 37).

At Vytilla it is greyish yellow in the first horizon followed by gre ish yellow to yellowish brown in the second, brownish yellow to yellowish brown in the third and brownish yellow, yellowish brown and dark brown with less plasma in the fourth horizons (plates 38, 39,40 and 41).

At Kattukambal it is yellowish brown to reddish brown in the first horizon followed by brownish yellow to opaque in the second, dard brown, brownish yellow, or reddish yellow in the third and brownish yellow, gre ish yellow, reddish brown and less plasma in the fourth horizn (plates 42,43,44 and 45).

At Kattampally it is yellowish brown in the first horizon followed by reddish yellow to greyish yellow in the second, greyish brown to brownish grey with less plasma in the third and opaque to greyish brown in the fourth horizon (plates 46,47,48,49,50,51 and 52).

33.2. <u>Soil fabric</u>

At Karumadi the soil fabric in the mesomorphic stage of observation is skelsepic in the first horizon and second horizon. In the third horizon, it is plasmic, asepic to insepic and rarely isotic. In the fourth horizon it is skelsepic (plates 26,27,28 and 29).

At Moncompu the soil fabric is skelsepic throughout the profile except the third horizon where it is plasmic to asepic fabric (plates 30,31,32 and 33).

At Mathikayal meso soil fabric is skelsepic throughout the profile. (plates 34,35,36 and 37).

Meso soil fabric is skelsepic throughout the profile at Vytilla (plates 38,39,40 and 41).

As in the case of Moncompu and Mathikayal, at Kattukambal also the meso soil fabric is skelsepic throughout the profile (plates 42,43,44 and 45).

At Kattampally the meso soil fabric is skelsepic to agrillasepic in the first and third horizons while in the second and fourth horizons it is skelsepic (plates 46,47,48,49,50,51 and 52).

33.3. Relative Distribution Pattern (RDP)

At Karumadi it is granic throughout the profile except the third horizon where it is plasmic (plates 26,27,28,29).

It is granic in the first and second horizon at Moncompu, while in the third horizon it is plasmigranic and graniplasmic in the fourth horizon (plates 30,31,32 and 33).

At Mathikayal the RDP in the meso morphic stage of observations is plasmigranic in the first horizon, graniplasmic in the second horizon. But in the third and fourth horizons it is granic (plates 34,35,36 and 37).

At Vytilla the RDP is granic throughout the profile except the first horizon where it is grani plasmic (plates 38,39,40 and 41).

At Kattukambal the meso morphologic RDP of the soil is granic throughout the profile except their third horizon where it is plasmic

(Plates 42, 43, 44 and 45).

At Kattampally it is granic throughout the profile (plates 46,47,48,49,50,51 and 52).

33.4. Normal Related Distribution Patter(NRDP)

It is granic to porphyric in the first and second, plasmic to porphyric in the second and granic to graniplasmic in the fourth horizon at Karumadi. It is granic to grani plasmic in the first, granic in the second, plasmigranic in the third and grani plasmic to porphyric in the fourth horizon at Moncompu. At Mathikayal it is granic in the first and third, plasmi granic in the second and grani plasmic in the fourth horizon. It is graniplasmic to porphyric in the first, grani plasmic in the fourth and granic in the second and third horizon at Vytilla. It is granic throughout the profile at Kattukambal except the third horizon. It is granic throughout the profile at Kattampally except the first horizon.(Plates 26 to 52).

33.4.1 Coarser/Finer

It is coarser in the first and second and finer in the third and fourth horizon at Karumadi and Moncompu. It is coarser throughout the profile except the fourth horizon at Mathikayal, except third horizon at Kattukambal. It is coarser throughout the profile at Vytilla and Kattampally.

33.5. Skeletons

At Karumadi the soil skeletons are shining subangular to angular, sillimanite and ilmenite in the first two horizon with few quartz grains. They are few or absent in the third horizon. The skeletons in the fourth horizons are subrounded to rounded, factured, sillimanite, ilmenite and quartz (plates 26,27,28 and 29). The skeletons present in the soil are subangular to subrounded quartz, angular to subangular ilmenite and pyrite in the first horizon at Moncompu. In the second horizon angular weathered and fractured quartz and non weathered sillimanite are found. Coarse sand and more than coarse sand sized quartz and sillimanite with silt to fine sand sized opaques with abundant pyrite are present in the third horizon. While in the fourth horizon silt sized subangular to subrounded quartz with striated orientation pattern on the plasma is observed (plates 30,31,32 and 33).

At the Mathikayal the skeletons in the first horizon consisted of highly weathered fractured subangular to subrounded quartz, feldspars and lateritic nodules followed by highly weathered fractured iron oxide coated quartz, sillimanite, ilmenite, hematite, pyrite and ferrihydrite in the second horizon. In the third and fourth horizon the skeletons present are constituted by highly weathered, fractured, pitted coarse sand sized quartz, laterite nodules, red opaques many ferrihydrite and few black opaques (plates 34,35,36 and 37).

At Vytilla highly pitted and weathered subangular to subrounded fine sand sized quartz, silt sized black opaques and pyrite and few laterite nodules are present in the first horizon. In the second horizon angular to subangular, pitted, less than fine sand sized quartz, feldspar, less than silt sized opaques, pyrite and ferriyhydrite are present. Less than fine sand sized partially weathered angular to subangular quartz, feldspars, opaques and pyrites are found in third horizon, while in the fourth horizon more than fine sand sized highly piited but not fractured quartz, fractured feldspars, amoeba shaped less than silt sized pyrite aggregates are present (plates 38,39 and 40).

The skeletons present in the first horizon at Kattukambal are coarse sand sized highly pitted but not fractured, quartz and bigger subrounded laterite nodules and less than silt sized many opaques. Fine sand sized, many laterite nodules and concretions, many silt sized black opaques are present in the second horizon. In the third horizon less than silt sized many opaques, few pyrites and very few, more than coarse sand sized fractured quartz, hematite, ferrihydrite are present in the third horizon followed by pitted, few coarse sand sized quartz and many fine sand sized quartz, less than silt sized opaques and few pyrites in the fourth horizon (plates 42,43,44 and 45).

At Kattampally the skeletons present in the first horizon are fine sand sized subangular and subrounded quartz and less than silt sized quartz, opaques and many pyrites and jarosites followed by more than coarse sand sized, pitted subangular quartz, many amoeba shaped pyrite aggregates forming more than 30 percent of plasma surrounding the skeletons in the second horizon. In the third horizon non weathered more than coarse sand sized subangular quartz, amoeba shaped pyrite, many silt sized opaques are present while in the fourth horizon highly pitted, fractured more than coarse sand sized and silt sized quartz with bigger limeshell pieces and valves of molluscans and amoeba shaped pyrites are present. (plates 46,47,48, 49,50, 51 and 52).

33.6. Voids

Specific type of voids are not observable at first, second and fourth horizons of Karumadi profiles, while channels are observed in third horizon (plates 26,27,28 and 29). Plannar packing voids with jarosite inside and iron oxide outside are observed in the first horizon at Moncompu, while in the second horizon specific void types are not observable. Channels are present in the third horizon and few channels and chambers are present in the fourth horizon (plates 30,31,32 and 33).

At Mathikayal specific voids are not observable in the first and third horizons, while channels & chambers are present in the second horizons and fourth horizons (plates 34,35,36 and 37).

Voids are dominantly channels, chambers and V ughs in all the horizons at Vytilla. V ugh s are few or absent in the second and fourth horizons. Few metavughs are also found in the third horizon (plates 38,39,40 and 41).

Voids are not observable due to iron oxide masking up by coating in the first horizon at Kattukambal. There are channels and chambers in all the other horizons. Bigger chambers and only few channels are present in the third horizon (plates 42,43,44 and 45).

At Kattampally there are dominantly channels, chambers and vughs throughout the profiles. Vughs are few in the second horizons but in the first and third horizons channels are absent Vughs and metavughs are present in the fourth horizon (plate 46,47,48,48,49,50, 51 and 52).

33.7. Humus

Humus present are in various stages of decomposition and are highly iron oxide coated. It is highly humified with ferriorganan in the first horizon at Karumadi followed by opaque shining dark reddish brown, coloured wood fossil structures in the shape of 'palm' in the second horizon, highly decomposed organan with intimately mixed ferriorganan in the third horizon, highly mixed ferriorganan in the fourth horizon (plates 26,27,28 and 29).

It is present as ferriorganan with few organans in the first horizon at Moncompu followed by macro aggregates of ferriorganan and organan in second horizon. Humus is present as ferriorganan in the third horizon followed by intimately organised, mixed ferriorganan in the fourth horizon (plates 30,31,32 and 33).

The humus present in the first horizon at Mathikayal is as fine aggregated ferriorganan followed by patchy ferriorganan in the second horizon, as organan, and few ferriorganan mixed with ferrargillan and ferrijarositans in third horizon. In the fourth horizon humus is not observable by enrichment of horizon with ferrihydrite (plates 34,35,36 and 37).

At Vytilla few humus particles are present as intimately mixed ferriorganan in the first horizon followed by similar organisation in the second horizon. In the fourth horizon it is present as ferriorganan (plates 38,39,40 and 41).

Humus is not clearly observable in subsurface horizons except their observed presence as ferriorganan in the first horizon at Kattukambal (plates 42,43,44 and 45).

At Kattampally humus is present as organan, ferriorganan in the first horizon. In the second horizon it is dominantly organan with few ferriorganan, pyritic organan and few neojarositans. In the third horizon humus is present as ferriorganan with ferriargillan and ferrijarositan followed by organan and ferriorganan in the fourth horizon (plates 46,47,48,49,50,51 and 52).

33.8. Cutans

Ferrans, argillans and ferriargillans are the type of cutans present surrounding skeletons or as aggregated materials on plasma in the surface horizons at Karumadi. Ferriorganan and ferriargillan are found in subsurface horizons also, while goethan is found only in the third horizon and ferran and ferriargillan in third and fourth horizons (plates 26,27,28 and 29).

Cutans present are dominantly ferran, ferriorganan, organan, ferriargillan and ferrijarositan in all the horizons at Moncompu, while goethan is present only in the third horizon and neoquasi-jarositans in the fourth horizons (plates 30,31,32 and 33).

There are ferrioriganan, ferran, ferriargillan in all the horizons at Mathikayal. Organon are present only in the first and third horizon, goethan only at second horizon, ferrijarositan in the first, third and fourth horizons. Aggregates of many minute ferrihydrite spheroids are observed only in the first horizon (plates 34,35,36 and 37).

The cutans present at Vytilla in all the horizons are ferriorganan, ferran and organan. Ferriargillan is present in all the horizons except the fourth one. Ferrisiltans and ferriquartzans are present only in the first horizon while ferrijarositans are present in all the horizons except the first (plates 38,39,40 and 41).

Ferriargillans are present in all the horizons at Kattukambal, ferran is present in the first three horizons. Few ferri organan are present only in the first horizon. Ferriquartzan and goethan are present only in the third horizon (plates 42,43,44 and 45).

At Kattampally organan followed by ferriorganan are present in all the horizons. Ferriargillans are present in the first and third horizons. Pyritic organan is present ony in the second horizon. Ferrijarositans and ferripyritans are present in the third and fourth horizons (plateds 46,47,48,49,50,51 and 52).

33.9. Aggregates

Ferriorganan forms the dominant aggregate on the soil plasma in all the horizons at Karumadi. Nucleus of aggregation is of quartz and laterite microaggregates in the first horizon, while they are absent in the second and fourth horizons. Ferriargillan and quartz are present in the aggregates in the third horizons, Pyrite and ilmenite forms aggregate with ferriorganan in the fourth horizon (plates 26,27, 28 and 29).

At Moncompu aggregate in the first horizon are composed of ferran, ferriorganan, ferriargillan and jarositans followed by organan, ferriorganan, pale yellowish ferriagillan, ferrijarositans organise the aggregates in the second horizon. In the third horizon ferran, ferriorganan, ferrijarositan and goethan form the aggregates followed by the aggregates of ferrijarositans, jarositans, ferriorganans and neoquasijarositans in the fourth horizon (plates 30,31,32 and 33).

Macro ferriorganan and micro ferrihydrite constitute the aggregaters in the first horizon at Mathikayal. It is also observed along with weathered quartz, ferrihydrite, ferriargillan and ferriorganan in the second horizon. In the third horizon amoeba shaped pyrite, and minerls such as quartz, ferrihydrite, ferriargillan and ferriorganan form aggregates , amoeba shaped pyrite, opaque minerals and ferriorgnan form macro aggregates followed by aggregates of ferrihydrite, fine quartz, ferriorganan and ferriargillans in the fourth horizon (plates 34,35,36 and 37).

Micro aggregates are formed by the combinations of ferran, ferrisiltan, ferriquartzan, ferriargillan, quartz and ferrihydrite in the first horizon at Vytilla. The aggregates in the second horizon are constituted by pyrite and other opaques, ferrihydrite with ferriorganan and ferran. Opaques, pyrites less than silt sized quartz with ferriorganan constitute the aggregates of the third horizon followed by aggregates of the fourth horizon with opaques, pyrites, fine quartz and ferriorganans (plates 38,39,40 and 41).

At Kattukambal aggregates are absent in the first horizon, in the second horizon it is composed of fine quartz, opaques with ferran. In the third horizon the aggregates are constituted of opaques, pyrites, hematite, ferrhydrite with ferriargillan followed by aggregates of opaques, pyrites, fine quartz along channels, chambers, skeletons with ferriargillan in the fourth horizon (plates 42,43,44 and 45).

Opaques, fine quartz, pyrites, jarosites from aggregates with feriorganan in the first horizon at Kattampally. Aggregates in the second horizon are organised by the combination of amoeba shaped pyrites with opaques and organans. In the third horizon the aggregates consist of amoeba shaped pyrites, quartz, opaques, ferrijarositans and ferriorganans followed by aggregates of amoeba shaped pyrites, opaques with ferriorganan in the fourth horizon (plates 46,47,48,49 and 50).

33.10 <u>Laterite nodules/Concretions</u>

At Karumadi where opaques, laterite nodules with sharp margins are present (plate 26,27,28 and 29).

At Moncompu they are absent in the subsurface horizons. In the first horizon few weathered silt sized laterite nodules are present (plates 31,32 and 33).

They are present in all the horizons except the second horizon at Mathikayal. They are silt sized, high reliefed sharp margined weathered and few in number in the first horizon. Similarly in the third and fourth horizons few laterite nodules are present (plates 34,35,36 and 37).

They are present in all the horizons except the fourth horizon at Vytilla. In the first horizon few more than fine sand sized high reliefed, sharp margined laterite nodules are present. In the second horizon less than silt sized, high reliefed, sharp margined red coloured few laterite nodules are present. Few yellowish coloured, low reliefed, laterite nodules are present in the third horizon with faint margins (plates 38,39,40 and 41).

At Kattukambal they are present in all the horizons except the third horizon. Bigger sub rounded iron enriched laterite nodules with faint margins are present in the first horizon. Many shining, reddish brown coloured, sharp margined laterite nodules are present in the second horizon while the laterite nodules present in the fourth horizon are more than coarse sand sized, orange red coloured, quartz rich, iron enriched and sharp margined (Plates 42,43,44 and 45).

Laterite nodules are present only in the second horizon at Kattampally and they are sharp margined and yellow coloured (plates 46,47,48,49,50,51 and 52).

33.11 Lithorelics

They are absent in all the profiles (Plates 26 to 41 and 46 to 52) except the second horizon at Kattukambal. They are highly weathered compact, sharp margined with quartz and opaques (Plates 43,44 and 45).

33.12 Presence of jarosite/Pyrite

They are present in all the horizons except the second horizon at Karumadi. Finer shining, circular, jarosite crystals are present surrounding high reliefed skeletons and in depressions on the soil plasma of the first horizon. In the third horizon neoquasijarositans are present surrounding the channel while in the fourth horizon jarosites are present as neoquasijarositans comparatively more cubular, spheroidal, Pyrite crystals are present in the depressions and channels surrounding the skeletons (Plates 26,27,28 and 29).

Jarosites are present in all the horizons at Moncompu. In the first horizon jarosites are present inside and outside the decaying plant roots and in the surrounding plasma along the margins of the skeletons. In the second horizons they are present as jarositanic coatings along the wood fossil, voids and skeletons. In the third horizon fine jarositanic neoformations are present throughout the plasma and on the margins of quartz in the fourth horizon (plates 30,31,32 and 33).

At Mathikayal neojarositans are present in the first horizon. In the second horizon few neoquasijarositans and pyrites are present in channels and surrounding the weathered quartz Very few neoquasijarositans and less than fine sand sized amoeba shaped pyrites are present in the third horizon. Few jarosites and many cubular pyrites are present in the voids associated with ferrihydrite in the fourth horizon (plates 34,35,36 and 37).

At Vytilla less than silt sized pyrite with fine jarositic spheroids present throghout the plasma in the first horizon. In the second horizon pyrite and neoquasijarositans are present surrounding the bigger skeletons, finer plasma, in channels and chambers. In the third horizon jarosites are present as neoquasijarositans surrounding skeletons and in channels and chambers. In the fourth horizon jarositan present on the plasma near the pyrite aggregates (plates 38,39,40 and 41).

Jarosites are absent but pyrites are present along the margins of bigger skeletons in the first horizon at Kattukambal. Similarly only few pyrites are found in third and fourth horizons also. In the third horizon pyrites are present along with ferrihydrite towards the outer margins of bigger chambers while in the fourth horizon

107180

they are present along and inside voids and skeletons (plates 42,43,44 and 45).

At Kattampally few jarosites are present as neoquasijarositans and few amoeba shaped pyrites are also found in the first horizon. In the second horizon many amoeba shaped pyritic aggregates from more than 30 percent surrounding skeletons and channels. In the third horizon many jarosites and pyrites are present along channels and skeletons. Both jarosites and pyrites are absent in the fourth horizon. (plates 46,47,48,49,50,51 and 52).

33.13. Special mesomorphological observations

Signs of iron removal and iron enrichment are observed in the first horizon at Karumadi. Opaque, fine silt sized cubular pyrite crystals are observed. Wood foosils under various stages of decompositions are also found. In the second borizon, on the wood fossils iron oxide framboids with very few jarosites are present. As in the case of first horizon in the third horizons also iron removed white areas inside the channels and iron enriched margins surrounding channels are found. The yellowish orange regions with sharp margins are with goethites. The yellow to pale yellow regions are with neojarositans and neoquasijarositans. The white spots in and surrounding the channels are quartz. Opaque, brownish yellow regions of channels are pyrite crystals and ferriorganan. Layering of reddish regions of sharp margins are indicative of repeated iron oxide deposition. In the fourth horizon more skeletons and less plasma are observed. Signs of iron oxide, ferriorganan, leaching and lessivage in active operation depicting sharp margins to skeletons (plates 26,27, 28,29).

Silica is present in the form of diatoms, tubular transparent blue coloured spicules in the first horizon at Moncompu. Yellowish red plasma with subangular to subrounded quartz, pyrite and other opaque skeletons are also present. Jarositans are also present in the second horizon. Quartz are seen undergone advanced stages of physical weathering entangled with ferriorganan and ferrijarositans. Very less plasma and more skeletons are another observation found in this horizon. In the third horizon the special observation noticed are the presence of more than coarse sand sized pitted and fractured quartz, bigger channels with accumulation of pyrite and other opaque minerals inside and towards outer borders of channels. Another special observation of the horizon is repeated iron oxide deposition with flecked orientation pattern with in the plasma and in the bigger channels. In the fourth horizon less than silt sized rounded to subrounded quartz embedded on yellow coloured plasma with flecked orientation pattern. Jarosites are present as neoquasijarositans throughout the plasma. Pyrites are also present surrounding the quartz, channels and chambers (plates 30,31,32 and 33)

At Mathikayal in the first horizon major portion of the plasma is occupied by highly weathered subangular to subrounded quartz skeletons, and feldspars. Other specific observations are presence of numerous minute clay sized ferrihydrite, neoquasijarositans and few laterite nodules. In the second horizon few fine sand sized, many less than silt sized, highly weathered and fractured quartz are present. Iron oxide coated channels, chambers, vughs with pyrite, hematite and ferrihydrite in it and surrounding the weathered quartz are also present. Special observation noticed in the third horizon is the presence of few more than coarse sand sized subangular, highly weathered, fractured, pitted quartz, amoeba shaped pyrite, ferrihydrite, black opaques and few red opaques. In the fourth horizon very weakly isotropic matrix with random distribution of small domains are noticed. Innumberable fine ferrihydrite, highly weathered subrounded less than silt sized quartz, laterite nodules, channels, chamber and vughs with pyrites are also noticed in the fourth horizon (plates 34,35,36, and 37).

At Vytilla in the first horizon highly iron enriched, fine grained, granular reddish yellow plasma with highly pitted but not ffractured quartz, silt sized pyrite, fine jarosite spheroid, ferrihydrite and few laterite nodules embedded in voids channels, chambers and vughs. In the second horizon skeletons formed the major portions of the soil plasma. Signs of iron oxide removal at the margins of skeletons are observed. Less than silt sized pyrites, opaques, organans, laterite nodules and neoquasijarositans are also present. In the fourth horizon the soil fabric is skelsepic. Fine sand sized, highly pitted, weathered but not fractured quartz present in this horizon. Jarosite is present as intimately mixed jarositan on the plasma near to pyrite aggregates (plates 38,39,40 and 41).

Bigger, pitted quartz, and laterite nodules form more than 90 percent of the soil plasma of the first horizon at Kattukambal. It is with less than silt sized pyrite and high reliefed black and red opaques. In the second horizon, the soil plasma is coarse grained, quartz rich and reddish yellow coloured with many fine sand sized laterite nodules. Jarosites are absent. In the third horizon, the plasma is iron enriched with opaques, pyrite, ferrihydrite, hematite and chambers. In the fourth huorizon more than coarse sand sized laterite nodules with pitted, fine sand sized quartz and less than silt sized opaques, pyrites on coarse yellowish brown plasma (plates 42,43,44 and 45).

At Kattampally in the first horizon innumerable silt sized quartz, opaques, pyrites, jarosite and fine sand sized nonweathered subangular quartz are present on the coarse grained yellowish brown plasma. The soil fabric of the second horizon is skelsepic and plasma present is very less. Amoeba shaped pyritic aggregates occupies more than 30 percent of the soil plasma along with opaque organan, skeletons and voids. The third horizon is rich in jarositic ferriargillan, quartz, with few accumulation of ferrihydrite. Special observation noticed in this horizon is the presence of pieces of lime shell. In the fourth horizon many iron oxide spheroids and pyrite spheroids less than silt sized are present on the lime shell. Quartz are highly pitted. Amoeba shaped pyrite present as aggregates with ferriorganan forming more than 30 percent of the plasma (plates 46,47, 48,49,50, 51, and 52).

34. Soil Micromorphology

The comparative micromorphological description of the soils are presented in tables 8 to 8.5 and detailed photomicrographs are presented between plates 52 to 100.

Table 8.0 Micromorphology of the Acid Sulphate Soils

Local name of soil		KARI SOIL		KARUMADI
Horizons	h1	h2	h3	h4
1. Colour of plasma	Blueish yellow, yellowish brown. Less plasma and not easily recognisable	Yellowish brown to reddish yellow	Brownish yellow to reddish yellow. Very less plasma and is not easily recognisable	Opque,reddish brown,yellowish brown,less plasma
2. Soil fabric	Voskelsepic	Voseklsepic	Vosepic	Vosepic
3. Related Distrubution Pattern (RDP)	Granic	Dominantly granular followed by intertextic and porphyroskelic	Granular to chalmydomorphic	Granular
4. Normal Related Distribution Pattern (NRDP)	Phyric	Granular	Granular	Granular
5. Finer/Coarser	Finer	Coarser	Coarser	Coarser
6. Skeletons	Very few less than silt sized quartz opques	Very few less than silt sized quartz and opaques. Opaques dominantly cubular pyrites	Innumerable number of cubular silt sized and less than silt sized pyrite in and on spongy plasmafide and raw humus and in vughs and channels	Less than silt sized innumerable number of framboidal pyrites and few ilmenite present
7. Voids	Chambers and channels	Chambers and channels with iron oxide enriched raw and plasmafide humus on the margins	Vughs and few channels and chambers	Chambers and very few channels
8. Humus	Raw humus in different stages of plasmification, dark brown to opque in colour,fragments present	Raw humus in different stages of plasmafication, dark brown to opaque with fragments present as irregular shaped masses in the interangular spaces of skeletons	Major portion of the S-matrix is occupied by raw and plasmafide humus with iron oxide enriched retained cellular structure	Organans and ferriorganans
9. Cutans	Ferriargillan, ferrijarositan and ferran	Organan and ferriorganans	Ferriorganan, organan and ferripyritan	Organans and ferriorganans
10. Aggregates	Raw humus, ferriargillan, fine quartz, pyrites and opaques	Organans and ferriorganans with pyrites and few opaques	Ferriorganans and ferripyritans	Framboidal pyrite with ferriorganans and ferriargillans
11. Laterite nodules/ Concretions	Absent	Absent	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of jarosite/pyrite	Few present as voidneoquasijarositans, pyritan inside decayed plant cells and in the plasma	Very few jarosites and pyrite present in and on raw and plasmafide organic matter. Pyrites are cubular in shape	Innumerable cubular and framboidal pyrite masses on raw and plasmafide organic matter	Jarosite absent but innumerable crowdy less than silt sized framboidal pyrites present
14. Special Observations if any	Basic structure is characterised by voids with relatively less than silt sized skeletons,compact plasma not easily recognisable. Bigger chambers and channels and many cubular phytoliths,jarosites, pyrites present on humus and along and in chambers and channels	Plasma very less.The basic structure is characterised by dominance of voids entangled by irregular shape masses of raw and plasmafide organic matter with in and on cubular pyrites. Margins of voids and skeletons are iron oxide enriched	Fine framboids of jarosites are present on the plasmafide cellwalls of organic materials with iron oxide enrichment. Porous,humus rich, pyrite rich and jarosite rich horizon	Raw organic matter rich less than silt sized framboidal pyrite rich porous horizon with iron enrichment and ferriargillan deposition in the form of hexagons. Ferrihydrite is absent
15. Plate number	53 and 54	55 and 56	57 and 58	59 and 60

Table 8.1 Micromorphology of the Acid Sulphate Soils

Local name of soil	KARAPADOM SOIL			MONCOMPU
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellowish brown, plasma less	Brownish yellow to opaque, less plasma	Reddish yellow, yellowish brown	Brownish yellow, reddish yellow
2. Soil fabric	Skelsepic to skelargillasepic	Vosepic	Vosepic	Vokelsepic
3. Related Distribution Pattern(RDP)	Granic	Ganular	Granular	Granular to plasmigranic
4. Normal Related Distribution Pattern(NRDP)	Graniplasmic to phyric	Granular	Granular	Plasmigranic to intertextic
5. Finer/Coarser	Coarser	Coarser	Finer.	Finer
6. Skeletons	Fine sand sized to less than silt sized subangular quartz,pyrites,other opaques and feldspars	High relief angular ilmenite and cubular pyrite.They are less than silt sized	Few coarse sand sized opaques,pyrites framboids,fracturing, subrounded quartz, many less than silt sized quartz and mica,cubular and framboidal jarosites	Silt sized subangular quartz, less than silt sized innumerable number of cubular and framboidal pyrite,few jarosite and very few ilmenite
7. Voids	Not observable	Plasma highly compact specific shapes of voids not observable but few small channels	Voids not observable	Channels,vughs and chambers
8. Humus	Ferriorganan	Ferriorganans,Clusters of plasmafide organic matter present on decaying plants cells enriched with repeated deposition of iron oxide on cell walls	Ferriorganans,clusters of plasmafide organic matter and opaques	Organan,ferriorganan and ferriargillan
9. Cutans	Ferriorganan, ferrihydrite,jarositan and pyritan	Ferriorganon, organan and few ferriargillan	Organan ferriorganan, ferriargillan form incomplete marginal coatings of skeletons	Ferran,ferriorganan and ferriargillan
10. Aggregates	Framboidal jarosite, pyrite and ferrihydrite with ferriorganan	Quartz,mica, feldspars with clusters of plasmafide organic matter and ferriargillan	Jarosite,ferrihydrite, pyrite and phytolith with ferriargillan and ferriorganan	Silt sized iron oxide coated quartz,haematite and other opaques with ferriorganan form clusters and finer ones form incomplete marginal coatings of skeletons
11. Laterite nodules/ Concretions	Absent	High reliefed long quartz rich,iron oxide enriched opaques,more than coarse sand sized present with sharp margins	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of jarosite/pyrite	Jarosite few present many fine pyrite framboids present in the interangular margins of quartz skeletons	Innumerable minute framboids and poly framboids of jarosites on the raw and plasmafide organic material along with near by cubular and spheroidal ferrihydrite crystals	Many cubular and framboidal jarosite and few pyrites present on the plasma enriched towards voids	Jarosite present as fine framboids and on retained cellular structures, specifically cell walls of plasmafide plant materials
14. Special observations if any	Ferriargillan covering subangular quartz rich horizon. Less plasma and is partly birefreingent many fine pyrite and jarosite framboids present in the interangular margins of quartz skeletons	Void rich,humus rich fine framboidal jarosite rich ferrihydrite rich horizon with some silt sized ilmenite and pyrite. The horizon is highly iron oxide enriched	Granular,reddish yellow,wide rich cubular jarosite rich horizon with few coarse sand sized ilmenite,pyrite framboid and quartz. Ferrihydrite present along the margins of voids. The granular structure reveal current active faunal activity	Fine pyrite rich,organic matter rich, iron enriched compact and granular horizon with few ilmenite and quartz
15. Plate number	61 and 62	63 64	65 and 66	67 and 68

Table 8.2 Micromorphology of the Acid Sulphate Soils

Local name of soil		KAYAL SOIL		MATHIKAYAL
Horizons	h1	h2	h3	h4
1. Colour of plasma	Greyish brown, Brownish yellow, reddish yellow	Greyish yellow to yellowish brown less plasma	Bronish yellow, to opaque	Brownihs yellow, greyish brown
2. Soil fabric	Vosepic to Voskelsepic	Skelsepic to Skelargillasepic	Skelsepic to Skelargillasepic	Skelspic to Argillasepic
3. Related Distribution Pattern (RDP)	Granic	Granic	Granic	Granic
4. Normal Related Destribution Pattern (NRDP)	Granic to granular	Granic	Granic	Graniplasmic
5. Finer/Coarser	Coarser	Coarser	Coarser	Coarser
6. Skeletons	Few subrounded fine sand sized quartz and many less than silt sized ilmenite. Innumerable framboidal jarosite,pyrite, ferrihydrite on decaying fresh roots and near the margins of these roots	Less than silt sized angular quartz , feldspars ilmenite and few more than coarse sand sized quartz,biotite mica, muscovite mica	Fractured few feldspars and many subangular to subrounded fine sand sized quartz. Few pyrites,opaques and less than silt sized jarosite and ferrihydrite framboids	Slender subangular more than fine sand sized quartz, silt sized mica, opaques , iron oxide coated quartz haematite, pyrite and other black opaques
7. Voids	Vughs and planar packing voids	Chambers,vughs	Vughs and channels	Vughs and meta vughs
8. Humus	Ferriorganan with ferriargillan	Organan, ferriorganan.	Ferriorganan	Organan, ferriorganan
9. Cutans	Ferriorganan, ferriargillan cover the skeleton margins as incomplete coatings	Organan,ferriorganan ferrijarositan, ferrihydrite and ferran	Ferriorganan and newquasijarositan, ferrihydrite	Organan,ferrorganan and ferran
10. Aggregates	Pyrite,ferriargillan jarosite and ferriorganan	Jarosite framboids ferrihydrite with ferriorganans and ferran	Fine aggregates with ferriorganan, neoquasijarositan, ferrihydrite and fine quartz	Pyrite and jarosite with ferriorganan and fine quartz
11. Laterite nodules/ Concretions	Absent	Absent	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosites/Pyrites	Very fine innumerable framboidal jarosites and pyrites are present on the decaying fresh roots of paddy plant	Very few jarosite framboids in the interangular spaces of skeletons and on cell walls of plant material.Few pyrites are also present	Few jarosite and pyrite framboids and many ferrihydrite are present in the interangular spaces of quartz and other skeletons. Pyrite is also present on decaying plants cells. They are framboidal and cubular	Less than silt sized framboidal and cubular pyrite present along quartz and other soil coatings
14. Special observations if any	Porous rootzone of paddy plant with innumerable framboidal jarosite and pyrite on the root cells and near the outer margins of root hairs. Innumarable number of ferrihydrite framboids are also present on the root cells	Less than silt sized quartz rich,skelsepic horizon with clusters of plasmafide organic matter in and on the cells of decaying plant parts	Compact,quartz rich, skelsepic horizon with few fractured more than fine sand sized feld spars, silt sized mica less than silt sized framboidal pyrite,jarosite and ferrihydrite	Skelargillasepic fabric with shinging and grainy unoriented whole soil coatings surrounding fine sand sized angular and slender quartz
15. Plante number	69 and 70	71 and 72	73 and 74	75 and 76

Table 8.3 Micromorphology of the Acid Sulphate Soils

Local name of soil		POKKALI SOIL		VYTILLA
Horizon	h1	h2	h3	h4
1. Colour of plasma	Greyish yellow	Greyish yellow, yellowish brown	Brownish yellow to yellowish brown	Brownish yellow yellowish brown dark brown, less plasma
2. Soil fabric	Voskelsepic	Skelargillasepic	Argillasepic to Skelargillasepic	Argillasepic
3. Related Distribution Pattern (RDP)	Granic	Granic	Graniplasmic	Aglomeroplasmic to chlamydomorphic
4. Normal Related Distribution Pattern (NRDP)	Graniplasmic	Graniplasmic	Graniplasmic	Intertextic to Chlamydomorphic
5. Finer/Coarser	Finer	Coarser	Finer	Coarser
6. Skeletons	Silt sized and less than silt sized low reliefed subrounded to rounded quartz. Few more than coarse sand sized quartz present	Coarse sand to fine sand sized subangular to subrounded quartz, fine sand sized highly fractured few feldspars present	Silt sized faint margined low reliefed subangular quartz with more than quartz sand sized lateritic concretions	Less than fine sand sized and silt sized many number of subangular quartz, framboidal pyrite, quartz rich lateritic concretions of 0.39 mm diameter
7. Voids	Chamber	Channels and chambers	Channels and chambers	Voughs and few channels
8. Humus	Highly plasmafide and less iron oxide coated	Highly plasmafide and ferriargillan coated	Ferriorganan	Ferriorganan and ferriargillan
9. Cutans	Argillan, ferriorganan	Highly plasmafide organan and ferriargillan coated and silt sized soil coatings	Ferriorganan and ferriargillan spread on the matrix and surrounding completely voids, skeletons and concretions	Ferriorganan and ferriargillan surrounding, bridging skeletons voids and concretions
10. Aggregates	Fine quartz and opaques with ferriargillan	Shining, grainy silt sized skeletons with ferriargillans in the interangular spaces of quartz as complete bridging	Ferriorganan, ferriargillan with pyrite and other opaques	Quartz with ferriargillan
11. Laterite nodules/ Concretions	More than coarse sand sized iron oxide enriched quartz rich shining subrounded nodules with sharp margins	Absent	Laterite concretions of 0.38 mm diameter present	Few 0.39 mm diameter laterite concretions present with quartz rich margins and quartz rich inner core
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosite/pyrite	Very few pyrite present	Silt sized pyrite framboids in the interangular spaces of quartz with little conversion to jarosite and ferrihydrite	Jarosite absent but few silt sized pyrite present in the chambers	Jarosite absent silt sized clusters of framboidal pyrite surrounding inner and outer margins of channels present
14. Spcial Observations if any	Voskelsepic fabric silt sized ferriargillceous plasma with shining silt sized and less than silt sized subrounded to rounded quartz and few runic(wusten)quartz	Skelargillasepic fabric, coarse sand to fine sand sized quartz, highly fractured fine sand sized feldspars, less than silt sized pyrite framboids. Ferriargillan and soil coatings are present in the interangular spaces forming bridges between skeletons	Skelargilasepic fabric with bigger concretions and silt sized subrounded quartz, and few pyrite framboids and other opaques in the chambers. Concretions are relatively homogeneous in shape having outer coating of ferriorganan ferriargillan and inner coating with organan and quartz	Argillasepic fabric with many quartz silts sized framboidal pyrite complete interangular briding of skeletons with ferriargillan and ferran. Outer margins of concretions are with linearly arranged subspherical quartz. Concretions are in intimate conctact with plasma
15. Plate number	77 and 78	79 and 80	81 and 82	83 and 84

Table 8.4 Micromorphology of the Acid Sulphate Soils

Local name of soils	KOLE SOIL			KATTUKAMBAL
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellowish brown to reddish brown	Brownish yellow to opaque	Dark brown, brownish yellow, reddish yellow	Brownish yellow, greyish yellow, reddish brown, less plasma
2. Soil fabric	Argillasepic	Argillasepic to Vosepic	Argillasepic to Voskelsepic	Argillasepic, concretionary, compact
3. Related Distribution Pattern (RDP)	Plasmigranic	Plasmic	Plasmigranic	Graniplasmsic
4. Normal Related Distribution Pattern (NRDP)	Plasmigranic to porphy roskelic	Plasmic	Plasmigranic	Graniplasmic
5. Finer/Coarser	Coarser	Finer	Finer	Coarser and gritty
6. Skeletons	Fine sand to less than fine sand sized subangular quartz, 0.63 mm dia meter lateritic nodules with sharp margins	Spherical, iron oxide enriched, quartz rich laterite nodule of 0.25 mm diameter and silt sized ilmenite and subrounded quartz	Less than silt sized subrounded to rounded quartz, few coarse sand sized subangular quartz and 0.38 mm length laterite nodules	Few 0.50 mm diameter and many 0.13 mm diameter laterite concretions, few opaque and less than silt sized to very fine subrounded to rounded innumerable quartz
7. Voids	Fine channels and bigger chambers	Chambers and few vughs of 0.38 mm length present with fine argillaceous margins (bleached)	Fine chambers running diagonally	Channels and fine chambers
8. Humus	Ferriorganan	Intmately mixed as ferriorganan and fine quartz	Ferriorganan with ferriargillan	Ferriorganan surrounding concretions
9. Cutans	Ferriargillan, argillan, ferriorganan and ferran	Ferriorganan, ferriargillan	Voids and skeletons surrounded by ferran, ferriargillan and Jarositans	Ferran, ferriargillan, ferriorganan form complete bridging between skeletons and voids
10. Aggregates	Fine quartz and ferriargillan	Ferriorganan and ferriargillan with fine quartz and opaques	Ferran, ferriargillan, ferriorganan and Jarositans with fine quartz	Fine quartz and opaques with ferrargillans
11. Laterite nodules/ Concretions	Sharp margined iron enriched 0.63 mm diameter laterite nodules with fractured quartz	0.25 mm diameter spherical iron enriched quartz riched laterite nodules	Sharp margined iron enriched opaque 0.38 mm length laterite nodules with quartz	Few 0.50 mm diameter and many 0.13 mm diameter lateritic concretions
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosite/Pyrite	Jarosite absent but few less than silt sized framboidal pyrite presents in the vughs and channels	Jarosite absent but very few less than silt sized pyrites	Jarosite present as jarositanic deposition surrounding the voids as hallow, aureole	Jarosite absent but very few fine cubular and framboidal pyrites
14. Special observations if any	Thin sections shows both the signs of translocations and accumulation of iron oxide and argillaceous materials in the same horizon. Argilasepic fabric with big oval lateritic nodules and few less than silt sized pyrite fram,boids. Few fractured hornblende biotite feldspar The S-matix is iron oxide enriched	Plasma rich less porous horizon with argillasepic to Vosepic fabric with laterite nodules. The dark brown colour shows the regions of ferriargillan and organan accumulation while the yellow and yellowish brown regions indicate signs of translocations of these materials	Compact, iron oxide enriched argillasepic with fine chambers and jarosite surrounding the porse. The white areas penetrating red iron enriched matrix without proper orientation closer to the fissures. Jarosites has been transformed to ferricoxides masking the colour of the clay	Highly compact concretion rich fine quartz rich argilasepic horizon with complete skeleton bridging with ferriargillan
15. Plate number	85 and 86	87 and 88	89 and 90	91 and 92

Table 8.5 Micromorphology of the Acid Sulphate Soils

Local name of soils	KAIPAD SOIL			KATTAMPALLY
Horizons	h1	h2	h3	h4
1. Colour of plasma	Yellowish brown	Reddish yellow to greyish yellow	Greyish brown to brownish grey, less plasma	Opaque to greyish brown
2. Soil fabric	Argillasepic	Vosepic	Skelsepic	Argillaskelsepic
3. Related Distribution Pattern(RDP)	Plasmigranic to graniplasmic	Plasmic	Granic	Plasmigranic
4. Normal Related Distribution Pattern(NRDP)	Plasmigranic to graniplasmic	Plasmic to granular	Granic	Plasmigranic
5. Finer/Coarser	Coarser	Coarser	Coarser	Coarser
6. Skeletons	0.32 mm diameter sharp margin quartz rich slender iron enriched porous concretions and less than fine sand sized subrounded to rounded quartz	Very fine quartz ,pyrite and othe ropaques in the channels	Slender subangular more than fine sand sized quartz with ferriargillan marginal coatings. Few fractured feldspars and opaques	Limeshells, valves of molluses, ferrihydrite spheriods and less than silt sized pyrites and other opaques
7. Voids	Fine channels and bigger chambers of 0.80 mm width	Bigger chambers and channels of 0.80 mm width	Less voids but at pockets bigger chambers	Compact with few fine channels and vughs
8. Humus	Ferriorganan	Ferriorganan and organan	Ferriorganan	Organan,ferriorganan and few ferriargillans
9. Cutans	Ferriorganan, ferriargillans	Ferriorganan and organan	Ferriorganan, ferriargillan forming marginal coatings of skeletons	Organan,ferriargillan. ferriorganan
10. Aggregates	Fine quartz, ferriargillan and ferriorganan	Faecal material of soil fauna with ferriorganan	Fine opaques with ferriorganan and ferriargillan	Ferriorganan and ferriargillan with pyrites and other opaques
11. Laterite nodules/ Concretions	0.32 mm diameter sharp margined quartz rich iron enriched slender concretions with cracks running through the whole or only in the outer pheripheral coatings	Absent	Absent	Absent
12. Lithorelics	Absent	Absent	Absent	Absent
13. Presence of Jarosite/Pyrite	Jarosite absent but very few pyrite framboids present	Jarosite absent but many fine pyrite framboids present in the chambers along with faunal fecal materials	Jarosite absent but very few fine cubular and framboidal pyrites present	Jarosites absent but many fine framboidal pyrites present along with ferriorganan
14. Special observations if any	Dense bleached plasma with concretions and many less than fine sand sized subrounded to rounded quartz. Concretions are irregular shape quartz rich iron oxide coated opaque iron cracked	Orthoagrotubules and bigger chambers filled with founal faecal materials are signs of active faunal activity. These chambers are coated with ferran and ferriargillans on the outer margins and spongy faecal materials in the inner margins. Silica deposition in the form of hexagonal shape is also present	Skelsepic fabric with less plasma and complete marginal coatings of skeletons by ferriargillans. Very few pyrites, jarosites and fine sand sized subangular quartz	Lime shells and valves are being attacked by silty soil and ferriorganan leading to marginal and surficial cracking
15. Plate number	93 and 94	95 and 96	97 and 98	99 and 100

34.1. Colour of Plasma

At Karumadi in the first horizon the plasma is blueish yellow to yellowish brown coloured and is scarce and not easily recognisable. In the second horizon yellowish brown to reddish yellow plasma is present, while in third horizon colour of the soil plasma is brownish yellow to reddish yellow. Plasma is very less and it is not easily recognisable. In the fourth horizon the plasma is opaque, reddish brown coloured. Plasma is very less (plates 53,54,55,56,57,58, 59, and 60).

At Moncompu soil plasma of the first horizon is less and yellowish brown coloured. In the second horizon it forms less than 40 percent and is brownish yellow to opaque. In the third horizon plasma is reddish yellow to yellowish brown coloured, while in the fourth horizoon it is brownish yellow reddish yellow coloured (plates 61,62,63,64,65,66,67 and 68).

Colour of the soil plasma are greyish brown, brownish yellow and reddish yellow in the first horizon at Mathikayal, while in the second horizon it is very less and greyish yellow to yellowish brown coloured. In the third horizon the colour of the soil plasma is brownish yellow to opaque and in the fourth horizon it is brownish yellow to greyish brown (plates 69,70,71,72,73,74,75, and 76).

At Vytilla the colour of the soil plasma is greyish yellow in the first, greyish yellow to yellowish brown in the second, browinish yellow to yellowish brown in third and fourth horizons. It is less and also in some places dark brown in colour (plates 77,78, 79,80,81,82,83 and 84).

It is yellowish brown to reddish brown coloured in the first, brownish yellow to opaque in the second, dark brown, brownish yellow and reddish yellow coloured in the third and less plasma with brownish yellow, greyish yellow, and reddish brown coloured in the fourth horizons at Kattukambal (plates 85,86,87,88,89,90,91 and 92).

At Kattampally it is yellowish brown in the first, reddish yellow to greyish yellow in the second and less plasma with greyish brown to brownish grey in the third and opaque to greyish brown in the fourth horizons (plates 93,94,95,96,97,98,99 and 100).

34.2. Soil fabric

It is Voskelsepic plasmic farbic in the first and second horizons followed by Vosepic fabric in the third and fourth horizons at Karumadi (plates 53,54,55,56,57,58,59 and 60).

The soil fabric is skelargillasepic in the first horizon, Vosepic in the second and third horizon and Voskelsepic in the fourth horizon at Moncompu (plates 61,62,63,64,65,66,67 and 68).

At Mathikayal it is Vosepic to Voskelsepic to Skelargillasepic in the first, second, third and fourth horizons (plates 69,70,71,72,73, 74,75 and 76).

At Vytilla it is Voskelsepic in the first, Skelargillasepic in the second, Argillasepic to Skelargillasepic in the third and fourth horizons (plates 77,78.79,80,81,82,83 and 84).

It is Argillasepic in the first, Argillasepic to Vosepic in the second, Argillasepic to Voskelesepic in the third and Argillasepic, concretionary and compact in the fourth horizons at Kattukambal (plates 85,86,87,88,89,90,91 and 92).

At Kattampally the soil fabric is Argillasepic in the first, Vosepic in the second, Skelsepic in the third and Argillaskelsepic in the fourth horizons. (plates 93,94,95,96,97,98,99 and 100).

34.3. Related Distribution Pattern (RDP)

It is granic in the first followed by intertextic to porphyroskelic in second, granular to chlamydomorphic in the third and granular in the fourth horizon at Karumadi (plates 53,56,57,58,59 and 60).

At Moncompu the RDP is granic in the first, granular in the second and third followed by granular to plasmigranic in the fourth horizon (plates 61,62,63,64,65,66,67 and 68).

At Mathikayal the RDP is granic throughout the profile (plates 69,70,71,72,73,74,75 and 76).

It is granic in the first and second, graniplasmic in the third and aglomeroplasmic to chlamydomorphic in the fourth horizon at Vytilla (plates 77,78,79,80.81.82.83 and 84).

The soil RDP at Kattukambal is plasmigranic in the first and third, plasmic in the second and graniplasmic in the fourth horizon (plates 85,86,87,88,89,90,91 and 92).

At Kattampally it is plasmigranic to graniplasmic in the first, plasmic in the second, granic in the third and plasmigranic in the fourth horizon (plates 93,94,95,96,97,98,99 and 100).

34.4. Normal Related Distribution Pattern (NRDP)

At Karumadi the soil NRDP is phyric in the first and granulur in the second, third and fourth horizons (plates 53,54,55,56,57,58, 59 and 60).

It is graniplasmic to phyric in the first, granular in the second and third and plasmigranic to inter textic in the fourth horizon at Moncompu (plates 61,62,63,64,65,66,67 and 68).

At Mathikayal the NRDP is granic to granular in the first, graniplasmic in the second , third and fourth fourth horizon (plates 69,70,71,72,73,74,75 and 76).

It is graniplasmic in the first, second and third horizons and intertextic to chlamydomorphic in the fourth horizon at Vytilla (plates 77,78,79,80,81,82,83 and 84).

At Kattukambal the NRDP is plasmigranic to porphyroskelic in the first, plasmic in the second. plasmigranic in the third and graniplasmic in the fourth horizon (plates 85,86,87,88,89,90,91 and 92).

The soil NRDP at Kattampally is plasmigranic to graniplasmic in the first, plasmic to granular in the second, granic in the third and plasmigranic in the fourth horizon (plates 93,94,95,96,97,98,99 and 100).

34.5. Finer/Coarser

Except the first horizon all the horizons at Karumadi is coarser (plates 53,54,55,56,57,58,59 and 60).

At Moncompu it is coarser in the first and second and finer in the third and fourth horizons (plates 61,62,63,64,65,66,67 and 68).

At Mathikayal it is coarser throughout the profiles (plates 69,70,71,72,73,74,75 and 76).

It is finer followed by coarser in the alternating horizons at Vytilla (plates 77,78,79,80.81.82.83 and 84).

At Kattukambal it is coarser in the first, finer in the second and third and coarser and gritty in the fourth horizon (plates 85, 86,87,88,89,90,91 and 92).

It is coarser throughout the profiles at Kattampally (plates 93,94,95,96,97,98,99 and 100).

34.6. Skeletons

Very few less than silt sized skeletons of quartz and opaques are present in the first and second horizons at Karumadi, opaques are dominantly cubular pyrites. In the third horizon innumerable numbers of cubular silt sized and less than silt sized pyrite on spongy plasmafied and raw wood fossils and in vughs and channels present. In the fourth horizon less than silt sized framboidal innumerable crowdy pyrite and few il menite are present (plate 53,54,55,56,67, 58,59 and 60).

At Moncompu the skeletons present are fine sand sized to silt sized quartz, subangular pyrite and few other pyrites and feldspars in the first horizon. In the second horizon ilemenite and cubular pyrite are present. They are high reliefed and are less than silt sized. Less than silt sized quartz and ferrihydrite are also present. In the fourth horizon silt sized subangular quartz, less than silt sized innumerable number of cubular and framboidal pyrite, few jarosites and very few ilmenites are present (plates 61,62,63,64,65, 66,67 and 68).

Few subrounded, fine sand sized quartz and many less than silt sized ilmenite on soil S-matrix are found in the first horizon at Mathikayal. Innumerable framboidal jarosite, pyrite, ferrihydrite are present on the decaying roots and near or on the margins of such roots in this horizon. In the second horizon less than silt sized angular quartz, feldspars, ilmenite and few more than coarse sand sized quartz, biotite muscovite and mica are present. In the third horizon fractured few feldspars and many subangular to subrounded fine sand sized quartz, few pyrites and opaques and less than silt sized jarosite framboids and ferrihydrite are present. In the fourth horizon slender, subangular more than fine sand sized quartz, silt sized mica, opaques, iron coated quartz, haematite, pyrite and other black opaques are present (plates 69,70,71,72,73,74,75 and 76).

At Vytilla, silt sized and less than silt sized low reliefed sub rouned to rounded quartz, few more than coarse sand sized laterite nodules are also present in the first horizon. In the second horizon coarse sand to fine sand sized subangular to subrounded quartz with few fine sand sized highly fractured feldspars are present. In the third horizon silt sized, faint margined low reliefed subangular quartz with more than coarse sand sized lateritic concretions are present. In the fourth horizon less than fine sand sized and silt sized many number of quartz, framboidal pyrite, quartz rich laterite concretions of 0.39 mm diameter are present (plates 77,78,79,80,81,82,83 and 84).

At Kattukambal fine sand to less than fine sand sized subangular quartz 0.6 mm diameter laterite nodules with sharp margins are present in the first horizon. In the second horizon spherical iron enriched quartz rich laterite nodules of 0.25 mm diameter and less than silt sized ilmenite and subrouned quartz are present. In the third horizons less than silt sized, few subrounded to rounded quartz and many 0.13 mm diameter laterite concretions, few opaques and less than silt sized very fine subrounded to rounded innumerable quartz are present (plates 85,86,87,88,89,90,91 and 92).

The skeletons present in the first horizon at Kattampally are 0.32 diameter sharp margined quartz, slender, porous, iron rich concretions and less than fine sand sized subrounded to rounded quartz are present. In the second horizon fine quartz, pyrite and other opaques are present in the channels. In the third horizon slender subangular more than fine sand sized quartz with ferriargillan marginal coating and few fracturing feldspars and opaques are present. In the fourth horizon lime shells, valves of molluscs, ferrihydrite spheroids, less than silt sized pyrite and other opaques are present (plates 93,94,95,96,97,98,99 and 100).

34.7. <u>Voids</u>

Voids present in the first horizon of Karumadi soil profile are chambers and channels. In the second horizon chamber and channels are present with iron enriched raw and plasmafide humus margins. Vughs and few channels and chambers are present in the third horizon. They are dominantly chambers followed by few channels in the fourth horizon (plates 53,54,55,56,57,58,59 and 60).

At Moncompu they are not observable in the first and second horizons. The second horizons are highly compact with finer materials.

Voids present in the third horizons are also not observable while channels, vughs and chambers are present in the fourth horizon (plates 61,62,,63,64.65.66,67 and 68).

Few Vughs and planar packing voids are present in the first horizon at Mathikayal. They are chambers, vughs and metavughs in the second horizon followed by vughs and channels in the third horizon and vughs and metavughs in the fourth horizons (plates 69,70,71,72, 73,74,75 and 76).

At Vytilla voids present in the first horizon is chambers. Similar observation is found in the second horizon also. Channels and chambers are present in the fourth horizon (plates 77,78,79,80, 81,82,83 and 84).

They are fine channels and bigger chambers in the first horizon at Kattukambal. In the second horizon chambers and few vughs of 0.38 mm length are present. They are with fine argillaceous margins. In the third horizon fine chambers and in the fourth horizon fine channels are present (plates 85,86,87,88,89,90,91 and 92).

At Kattampally fine channels and bigger chambers with 0.8 mm width are present in the first and second horizon followed by bigger chambers and channels with 0.8 mm width in the third horizons. In the fourth horizons they are fine channels and vughs. The horizon is compact and only few voids are present (plates 93,94,95,96,97, 98,99 and 100).

34.8 <u>Humus</u>

Dark brown to opaque fragments of raw humus and humus at different stages of plasmafication are present in the first horizon at Karumadi. In the second horizon dark brown to opaque fragments of humus under different stages of plasmafication are present in the interangular spaces of skeletons and voids. They are irregular in shape. Iron enriched raw and plasmafied humus with cellular structure formed the major portion of the third horizon, while in the fourth horizon they are organans and ferriorganans (plates 53,54,55,56,57,58, 59 and 60).

They are present as ferriorganans in the first horizon at Moncompu. Ferriorganan clusters of plasmafied opaque organic matter are present in the second horizon on decaying plant cells, enriched with repeated deposition of iron oxide on the cell walls. In the third horizon also similar observations are noticed. They are present as organans, ferriorganans, ferriargillans in the fourth horizon (plates 61, 62,63,64,65,66,67 and 68).

At Mathikayal they are present as ferriorganans with ferriargillans in the first horizon followed by organans with ferriorganans in the second horizon. In the third horizon they are ferriorganans followed by organans with ferriorganans in the fourth horizon (plates 69,70,71,72,73,74,75 and 76).

The humus are highly plasmafied and less iron oxide coated in the first horizon at Vytilla. In the second horizon they are highly plasmafied with ferriargillan coating. They are present as ferriorganans in the third and as ferriorganans with ferriargillans in the fourth horizon (plates 77,78,79,80,81,82,83 and 84).

At Kattukambal they are present as ferriorganans throughout the profiles. In the second horizon it is noticed to be intimately mixed with fine quartz. In the third horizon ferriargillans are present along with ferriorganans. In the fourth horizons the ferriorganans are present surrounding the concretions (plates 85,86,87,88,89,90, 91 and 92).

The humus present in the soil profile at Kattampally are as ferriorganans. Along with ferriorganans, organans are present in the second and fourth horizons. Along with these, few ferriargillans are also present within the fourth horizons (plate 93,94,95,96,97,98 99 and 100).

3.4.9 Cutans

They are ferriargillan, ferrijarositan and ferran in the first, organan and ferriorganan in the second, ferriorganan, organan and ferripyritan in the third and organan and ferriorganan in the fourth horizons at Karumadi (plates 53,54,55,56,57,58,59 and 60).

At Moncompu the cutans present in the first horizon are composed of ferriorganan, ferrihydrite, jarositan and pyritan. They are ferriorganan, organan with few argillan in the second horizon. In the third horizon they are ferriorganan, ferriargillan and ferran as complete marginal coating of skeletons. Cutans of the fourth horizon are composed of ferran, ferrorganans and Ferriargillans (plates 61,62, 63,64,65,66,67 and 68).

In the first horizon at Mathikayal the cutans present are ferriorganan and ferriargillan. They are present as incomplete marginal coating of skeletons. Organans, ferriorganans, ferrijarositans, ferrihydrite and ferrans are present in the second horizon. In the third horizon they are ferriorganans, neoquasijarositans with few ferrihydrite. Cutans present in the fourth horizon are organans, ferriorganans and ferrans (plates 69,70,71,72,73,74,75, and 76).

At Vytilla cutans present in the first horizon are argillans and ferriorganans. Highly plasmafied organans, ferriargillans and silt sized soil coatings are present in the second horizon. In the third horizon ferriorganans and ferriargillans are noticed on the soil plasma and surrounding completely voids, skeletons and concretions. Cutans present in the fourth horizons are ferriorganans and ferriargillans surrounding, bridging skeletons, voids and concretions (plates 77,78,79,80,81,82, 83 and 84).

They are ferriargillans, argillans, ferriorganans and ferrans in the first horizon, ferriorganans and ferriargillans in the second horizon. Ferriargillan and jarositans are seen surrounding voids, skeletons in the third horizon, ferrans, ferriargillans and few ferriorganans are present in the fourth horizon at Kattukambal. Ferriorganans form complete bridging between skeletons and voids (plate 85,86,87,88,89,90,91 and 92).

At Kattampally cutans present are ferriorganans and organans in the first horizon and second horizon. Ferriargillans and ferriorganans are present as marginal coatings of skeletons in the third horizon. In the fourth horizon the cutans present are organans, ferriargillans and ferriorganans (plates 93,94,95,96,97,98,99 and 100).

34.10 Aggregates

Soil microaggregates present in the first horizon at Karumadi is composed of raw humus, ferriargillans, fine quartz, opaques and pyrites. While in the second horizon they are composed of organans, ferriorganans, pyrites with few opaques. In the third horizon ferriorganans with ferripyritan constituted the soil microaggregates. Framboidal pyrite with ferriorganans and ferriargillans constituted the microaggregates in the fourth horizon (plates 53,54,55,56,57,58, 59 and 60).

At Moncompu they are formed by the combination of framboidal pyrite, jarosite, ferrihydrite with ferriorganans in the first horizon, while in the second horizon they are with quartz, feldspars and clusters of plasmafied organic matter and ferriorganans. In the third horizon the soil microaggregates are organised by the combination of jarosite, ferrihydrite and pyrite with ferriargillans and ferriorganans. In the fourth horizon they are with silt sized iron oxide coated quartz, hematite with ferriorganans forming clusters with finer fractions of soil. They are with incomplete marginal coatings of skeletons(Plates 61, 62,63,64,65,66,67 and 68).

At Mathikayal they are with pyrites, other opaques and ferriorganans in the first horizon followed by jarosite framboids, ferrihydrite with ferriorganans and ferrans constituting the soil microaggregates in the second horizon. In the third horizon they are formed with ferrorganans, neoquasijarositans, ferrihydrite and fine quartz. Pyrite with ferriorganans and fine quartz form microaggregates in the fourth horizon (plates 69,70,71,72,73,74,75 and 76).

They are with fine quartz, opaques and ferriargillans in the first horizon at Vytilla. Microaggregates of second horizon are present in the interangular spaces of quartz as complete bridges. They are with shiny grainy silt sized skeletons and ferriargillans. In the third horizon they are with pyrites and other opaques, ferriorganans and ferriargillans. In the fourth horizon they are with quartz and ferriargillans (plates 77,78,79,80,81,82,83 and 84).

At Kattukambal the soil microaggregates are with fine quartz and ferriargillans in the first horizon followed by the aggregates with ferriorganans, ferriargillans, fine quartz and opaques in the second horizon. It is with ferrans, ferriargillans, ferriorganans and jarositans with fine quartz in the third horizon. They are with fine quartz, opaques and with some ferriargillans in the fourth horizon (plates 85,86,87,88,89,90,91 and 92).

At Kattampally they are with fine quartz, ferriorganans and ferriargillans in the first horizon. Faecal materials of soil fauna with some ferriorganans formed the microaggregates in the second horizon. It is with opaques, ferriorganans and ferriargillans in the third horizon. In the fourth horizon they are with ferriorganans, ferriargillans, pyrites and other opaques (plates 93,94,95,96,97,98, 99 and 100).

34.11 <u>Laterite nodules/Concretions</u>

They are absent in the soil profiles at Karumadi (plates 53,54, 55,56,57,58,59 and 60). At Moncompu they are present only in the second horizon. More than coarse sand sized, high reliefed, sharp margined few opaque laterite nodules are present in this horizon. They are quartz rich and iron oxide enriched (plates 61,62,63,64,65, 66,67 and 68).

They are absent throughout the profiles at Mathikayal (plates 68, 69,70,71,72,73,74,75 and 76).

More than coarse sand sized iron oxide enriched, quartz rich subrounded laterite nodules are present in the first horizon at Vytilla. Their margins are sharp. They are absent in the second horizon. In the third horizon few numbers of 0.38 mm diameter laterite concretions are present. Few laterite concretions of 0.39 mm diameter are present in the fourth horizon with an inner core of quartz. Quartz is also present in their margins (plates 77,78,79,80,81,82,83 and 84).

At Kattukambal they are present in all the horizons. In the first horizon 0.63 mm diameter iron oxide enriched laterite nodules are present. Inside these nodules fractured quartz are seen. In the second horizon spherical, quartz rich, iron oxide enriched laterite nodules of diameter 0.25 mm are present. Opaque, sharp margined, quartz rich, iron oxide enriched 0.38 mm length laterite nodules are present in the third horizon. Few 0.50 mm diameter and many 0.13mm diameter lateritic concretions are present in the fourth horizon (plates 85,86,87,88,89,90,91 and 92).

Sharp margined, quartz rich slender, iron oxide enriched, 0.32 mm diameter porous laterite concretions are present in the first horizon at Kattampally. Cracks running through the whole of the peripheral coatings of lateritic concretions are noticed. Laterite nodules/concretions are absent in the fourth horizons (plates 93,94, 95,96,99 and 100).

34.12. Lithorlics

They are absent throughout the profiles at Karumadi(plates 53, 54,55,56,57,58,59 and 60), Moncompu (plates 61,62,63,64,65,66,67 and 68), Mathikayal (plates 69,70,71,72,73,74,75 and 76), Vytilla (plates 77,78,79,80,81,82,83 and 84), Kattukambal (plates 85,86,87, 88,89,90,91 and 92) and at Kattampally (plates 93,94,95,96,97,98,99 and 100).

34.13. Presence of jarosite/pyrite

Irrespective of the locations they are present in all the horizons. In some, the jarosites are dominant and in others pyrites. In certain horizons and profiles both the jarosites and pyrites are present in abundant quantities. In the first horizon at Karumadi few jarosites are present as neoquasijarositans. Pyrite cubular crystals are present in the decayed plant cells and on the soil plasma. Jarosites are not observable in the second horizon but cubular shaped pyrites are present in and on the raw and plasmafied organic matter. Innumerable cubular and framboidal pyrite masses are present on raw and plasmafied organic matter of the third horizon. Similarly silt sized framboidal pyrites are present in the fourth horizon (plates 53, 54,55,56,57,58,59 and 60).

In the first horizon at Moncompu framboidal jarosites and pyrites are present. Pyrite framboids are present in the interangular regions of quartz skeletons of the first horizon while in the second horizon innumerable framboidal and polyframboidal jarosites are present on the raw and plasmafied organic matter. Surrounding these cubular ferrihydrite and iron oxide spheroids are present in abundant quantities. Many cubular and framboidal jarosites and few pyrites are present on the soil plasma towards the voids in the third horizon. In the fourth horizon fine framboidal pyrites are present inside the retained cellular structures especially cell walls of plasmafied organic matter (plates 61,62,63,64,65,66,67 and 68).

At Mathikayal very fine innumerable framboidal jarosites and pyrites are present on the decaying roots of paddy plant in the first horizon. Very few jarosite framboids are present in the interangular spaces of skeletons and on the cell walls of plant materials in the second horizon. Few pyrites are also present in the third horizon. Few jarosite and pyrite framboids and many ferrihydrite framboids are present in the interangular spaces of quartz and other skeletons. Both cubular and framboidal pyrites are also present on the decaying plant cells. In the fourth horizon silt sized cubular and framboidal pyrites are present along quartz skeletons and in soil coatings (plates 69,70,71,72,73,74,75 and 76).

At Vytilla only few pyrites are present in the first horizon. In the second horizon silt sized framboidal pyrites are present in the interangular spaces of quartz skeletons. They are with little conversion to jarosites and ferrihydrites. In the third horizon jarosites are absent but silt sized few pyrites are present in the chamber shaped voids. Similarly jarosites are absent in the fourth horizon but silt sized framboidal pyrites are present surrounding the channels along their margins (plates 77,78,79,80,81,82,83 and 84).

Jarosites are absent but few less than silt sized framboidal pyrites are noticed to be present in the vughs and channel of the first horizon at Kattukambal. Similarly in the second horizon also only very few less than silt sized pyrites are present. Jarosites are present as jarosite depositions surrounding the voids. In the third horizon as in the case of upper horizons only very few cubular and framboidal pyrites are present. Similar observations are also made in the fourth horizon (plates 85,86,87,88,89,90,91 and 92).

At Kattampally jarosites are absent but very few framboidal pyrites are present in the first horizon. Similarly many fine framboidal pyrites are present in the chambers along with faunal faecal materials in the second horizon. Only few jarosites and fine cubular and framboidal pyrites are present along with few organans in the third and fourth horizons. Ferriorganans are seen associated with these in the fourth horizon (plates 93,94,95,96,97,98,99 and 100).

34.14. <u>Special micromorphological observations</u>

Basic structure is characterised by voids with relatively few silt sized skeletons in the first horizon at Karumadi. Plasma is compact and is not easily recognisable. Bigger chambers and channels and many tubular phytoliths are present in this horizon. Jarosite and pyrites are present on the humus, and along and in chambers and channels. In the second horizon, the plasma is less and the basic structure is characterised by the dominance of voids entangled by irregular shaped masses of raw and plasmafied organic matter. Within these and on these structures cubular pyrites are present, surrounded by iron enriched zones. Fine framboidal jarosites and pyrites are present in the humus present in the third horizon. They are present on the plasmafide plant cell walls enriched with iron. The fourth horizon is a horizon of raw organic matter rich, silt sized framboidal pyrite rich, porous with iron enrichment, and ferriargillan deposition in the form of hexagons. Ferrihydrites are absent. (plates 53,54, 55,56,57,58,59 and 60).

The first horizon at Moncompu is with ferriargillan surrounding subangular quartz and other skeletons. Fine and partially birefringent plasma. Many fine framboidal pyrite and jarosites are present in the interangular margins of skeletons. The horizon is with phyric RDP. The second horizon is void rich, humus rich, fine framboidal jarosite, ferrihydrite rich with some silt sized ilmenite, pyrite framboids and quartz. It is iron enriched with few ferrihydrite along the margins of the voids. The structure reveal faunal activity. In the fourth horizon the characteristic feartures observed are the presence of abundant humus, abundant fine pyrite, iron enrichment. It is compact, with few ilmenite and quartz (plates 61,62,63,64,65, 66,67 and 68).

The first horizon of Mathikayal soil profile is porous. Root zone of paddy field is with innumerable framboidal jarosite and pyrite on the root cells and near the outer margins of roots and root hairs.

More than these is the presence of abundant ferrihydrite spheriods and framboids on the roots. Plasma are less porous in the second horizon. It is rich with less than silt sized abundant quartz. The soil fabric is skelsepic with coating of plasmafied organic matter and amoeba shaped pyrite mass in and on the cells of decaying plant roots. The third horizon was compact with Skelsepic fabric, abundant quartz, few fractured more than fine sand sized feldspars and less than silt sized framboidal pyrite, jarosite and ferrihydrite. The soil fabric of the fourth horizon is Skelargillasepic with shining and grainy dark coloured whole soil coatings surrounding fine sand sized angular, slender quartz skeletons. (plates 69 to 76).

At Vytilla the soil fabric of the first horizon is Voskelsepic with silt sized ferriargillaceous plasma, shining silt sized and less than silt sized subrounded to rounded quartz, few runic quartz are also present. It is with Skelargillasepic soil fabric in the second horizon with coarse sand to fine sand sized quartz, highly fractured fine sand sized quartz, highly fractured fine sand sized feldspars, less than silt sized pyrite framboids. Ferriargillan and whole soil coatings formed bridges between skeletons within their interangular spaces. In the third horizon the soil fabric is Skelargillasepic with bigger calcite concretion and silt sized subrounded quartz. Few pyrite framboids and other opaques are present in the chambers. Concretions are relatively homogenous in shape having outer coatings of ferriorganan, ferriargillan and inner coatings of organans and fine quartz. Soil fabric of the fourth horizon is Argillasepic. It is with abundant quartz, less than silt sized framboidal pyrite and complete interangular bridging of skeletons, concretions with ferriargillan, ferran on their margins. They are with characteristically linearly arranged quartz concretions and are with intimate contact with the plasma. (plates 77,78, 79,80.81.82,83 and 84).

At Kattukambal the first horizon is characterised with signs of both translocation and accumulation of iron and argillaceous materials with in the same horizon. The soil fabric is Argillasepic with high oval laterite and lateritic nodules and few less than silt sized pyrite framboids. Few fractured hornblende, biotite and feldspars are also noticed in the iron oxide enriched plasma of this horizon. The second horizon is plasma rich, compact, less porous with Argillasepic to Vosepic soil fabric with lateritic nodules. The dark brown coloured zones are regions of fine ferriagillan and organan accumulation, while the yellow and yellowish brown regions indicate the translocalation of these materials. In the third horizon the special observations noticed are compactness, iron enrichment, Argillasepic soil fabric with jarosite aureoles surrounding the pores. Jarosites of this horizon are noticed to be transformed to ferrihydrite. The fourth horizon was highly compact with abundant concretions and abundant fine quartz. The soil fabric is Argillasepic with complete skeletal bridging with ferriargillan (plates 85,86,87,88,89,90,91 and 92). The pecularity of the first horizon at Kattampally is the presence of bleached plasma and many less than fine sand sized subrounded to rounded quartz. Concretions are irregular shaped, quartz rich, iron oxide coated and cracked. In the second horizon the peculiar observation noticed are the presence of orthoaggrotubules and bigger chambers filled with faunal faecal materials indicating current faunal activity. These chambers are coated with ferran and ferriargillan on the outer margins and 'spongy' faecal materials in the inner margins. Silica deposition in the hexagonal shape was also observed in this horizon. The soil fabric of the third horizon was Skelsepic with less plasma and complete marginal coating of skeletons with ferriargillan, very fine pyrite, jarosite and fine sand sized subangular quartz. The special observations noticed in the fourth horizon are the action of silty soil mass and ferriorganon on the limeshell, valves of mollucs leading to their marginal, surficial craking (plates 93,94,95,96,97,98,99 and 100).

35. Scanning Electron Microscopic Analysis of Soils, Silts and clays (Submicroscopy of the Soils,Silts and Clays)

35.1. Scanning electron microscopy of soils

The SEM Photographs of the soils of different locations are presented as plates 101 to 137. The description together with the interpretation of the observation are follows:

At Karumadi in the kari soil profile first horizon a thick iron oxide accummulation on both sites are seen. Soil wood fossils coated with 1.0 mu sized jarosite framboids and few other opaques coated with thick flakes of iron oxide are observed. Thickly iron oxide coated jarosite framboids of 1 to 10 m μ size are present on thickly iron oxide coated wood fossils and other soil skeletons. Few iron oxide coated cubular pyrites, is also seen (plates 101,102).

In the second horizon on the wood fossiils highly thick iron coated, hexagonal and spherical shaped regions with 5 m μ sized polyframboids of jarosites within them are seen. The marginal iron coating is of 10 m u thickness. Highly shirnked wood fossil fabric with ridge and furrow structure with opaque thick iron encrustations on these ridges and furrows are also noticed. Highly iron oxide enriched framboidal jarosites of 7 m μ diameter, are observed on these wood fossils (plate 103,104). Iron oxide smeared thick, dense, soil fabric with 10 m μ diameter polyframboidal jarosite, characteristic spherical nodules of pyrite and jarosites, showing separable hexagonal shaped microcrystals of framboids are the characteristic feature of the third horizon. The soil is with Skelsepic fabric with thick iron coating of skeletons with few 30 m μ diameter framboidal pyrites. Highly iron oxide coated, porous soil matrix lead to the Skelvosepic fabric. 260 m μ dia highly iron oxide coated pyrite framboid showing cracks and multifaced microcrystals of the framboid. Framboids shows cracking and trapping of a flake like diatomaceous material in this horizon. Highly shrinked iron coated ridge and furrow structured fabric of wood fossils showing innumerable number of 1 to 2 m μ diameter pyrite framboids and many 10 m μ diameter pyrite framboids on the wood fossil are also present. A richly iron oxide deposited, Vosepic S-matrix with few framboidal pyrites of 2 m μ diameter is another feature noticed (plates 105,106,107,108 and 109). In the fourth horizon hexagonal shaped marginal iron oxide deposition in wood fossils with few numbers of 2 m μ diameter pyrite framboids and innumerable numbers of 1 m μ pyrite framboids are noticed. In the partially decomposed root channels innumerable number of spherical unattached 20 m μ diameter pyrite framboids are present. Some of the framboids are smooth while others are rough and porous. The margins of the roots are with repeated ferric iron oxide deposition and are free of pyrites. (plates 110, 111,112).

At Moncompu karapadam soil profile in the first horizon the soil fabric is Skelvosepic with high iron oxide coating and flaky wood fossils opaque minersls, and few jarosite framboids of 3 m μ diameter, flaky diatomaceous materials (plate 113). In the second horizon highly iron oxide coated Skelvosepic fabric with densely iron oxide coated wood fossils showing cellular structure with many opaque minerals and many 2 m μ diameter framboidal jarosites. One flaky diatomaceous material of about 100 m u is also noticed (plate 114). In the third horizon cellular type of repeated ferric iron oxide deposition on the wood fossils, with 2 m μ diameter innumerable number of jarosite framboids and pyrite framboids seen. The wood fossils with cellular structure exhibit a striated orientation pattern. Hexagonal shaped broken pouch like structures of iron oxide with many number of euhedral crystals of pyrite and gypsum and authigenic quartz are also noticed in this horizon (plate 115,116,117). In the fourth horizon the sub microtopography is "undulating" with striated orientation pattern of skeletons. The soil fabric is Skelvosepic with innumberable number of oval shaped flakes of diatoms and lateral discontinuous irreguar shaped iron deposition. (plate 118)

At Mathikayal kayal soil profile the first horizon is iron oxide coated, high reliefed skeleton rich soil with 10 m μ

diameter paddy roots and root hairs. The skeletons include subangular quartz, few mica and many opaques, dominantly ilmenite (plate 119). The second horizon is com paratively compact, more iron oxide coated, skeleton rich with few 10 m μ diameter jarosite framboids. The soil fabric is Skelvosepic (plate 120). While the third horizon is highly iron oxide coated with Skelvosepic fabric. Thick iron encrustations with many number of 10 m μ diameter pyrite framboids, highly undulating submicrotopography are the charasteristic features of this horizon. On the wood fossils cellular type localised iron deposited surface fabric with spots of repeated ferric iron oxide deposited regions, few 5 m μ diameter pyrite framboids and iron oxide coated skeletons are present (plate 121,122). In the fourth horizon the soil is highly dense, repeatedly ferric iron oxide deposited with uneven submicroscopic topography. The soil fabric is Vosepic with 10 to 20 m μ width channels, chambers and quartz and many 3 m μ diameter, pyrite framboids are present. Here on the same horizon high reliefed iron oxide coated, pitted and weathering ilmenite are also noticed (plates 123,124,125).

At Vytilla <u>pokkali</u> soil profile the first horizon soil fabric is Skelsepic. Few higher reliefed undulating, ilmenite and many 20 m u sized ilmenite, other opaques, few numbers of 0.5 m μ size jarosite framboids are present. Dense iron oxide coated skeletons with very few non coated or incompletely coated skeletons is the specific feature observed. Few oval and flaky diatomaceous materials are also present (plate 126).

In the second horizon dense ferric iron oxide coated sodium sulphate salt rich Vosepic fabric with flaky mica, diatomaceous material and few densely iron oxide coated 1 m μ diameter jarosite framboids. Vughs and chambers are the dominant voids. Iron oxide coating is noticeably repeated (plate (127). While in the third horizon wood fossils are present with few more than 30 m μ width ilmenite, other opaques and many 10 m μ sized densely iron oxide coated pyrite on the ridge and furrow structures of shrinked wood fossil fabric. In the third horizon repeated dense ferric iron oxide coating on ridge and furrow structured surface of wood fossil and on jarosite framboids and on the skeletons are noticed (plate 128, 129).

At Kattukambal kole soil profile first horizon is with iron oxide coated ilmenite and other opaque minerals. Soil fabrics is Skelsepic to Skelargillasepic. Iron oxide coating on the opaques are peripheral and marginal, but not surficial (plate 130). In the second horizon iron oxide coated 10 m μ size opaque mineral rich, Skeargillasepic soil with few jarosite framboids, 100 to 200 m μ sized laterite nodules and quartz skeletons present. Iron oxide coating is with a fibrous pattern (plate 131). In the third horizon the soil is with thick iron oxide deposition, marginal and peripheral iron oxide coatings of skeletons. Many 1.0 m μ diameter pyrite framboids are present. Macro channels, filled with iron oxide coated skeletons, silt sized opaques present (plate 132). The fourth horizon soils is with highly localised dense narrow iron oxide coated nodule rich. Iron oxide deposition is peripheral and marginal with few patches on the skeletons. Skeletons and nodules are above 50 m μ size (plate 133).

At Kattampally kaipad soil profile in the first horizon many flaky, slender wood fossil pieces with repeatedly ferric iron oxide coating present. Ilmentite and other opaques and few iron oxide coated jarosite framboids of 10 m µ diameter. (plate 134) are present. The soil of the second horizon is flaky, fibrous, localised iron deposited and wood fossil rich. The soil fabric is Voskelsepic with cellular type of iron oxide deposition on shrinked wood fossils.Many ilmenite, opaques and few 10 m u sized pyrite and jarosites with iron oxide coating present (plates 135). The third horizon is with densely iron oxide coated, Skelsepic fabric, partially decomposed, slender pieces of wood fossils, few 10 m µ sized iron oxide coated pyrite framboids and other opaques (plates 136). The soils of the fourth horizon is highly iron oxide coated. The soil fabirc is Skelsepic. Majority of skeletons are opaques, smeared with sharp iron oxide coating. Other skeletons are high reliefed and devoid of iron oxide coating. Many microlites of calcium carbonate, fine (5 m µ sized) pyrite framboids, ferric hydrite spherioids are present. (plates 137).

35.2. Scanning electron microscopy of less than 0.05 mm soil fraction from 0-50 cm depth

Karumadi kari soil profile densely iron oxide coated, high reliefed, angular ilmenite, sillimanite, quartz and wood fossil pieces of 50 m µ length and 5 m µ breadth with few gypsum crystals and framboidal iron oxide coated jarosites present (pate 138).

At Moncompu karapadam soil profile densely iron oxide coated subangular to subrounded ilmenite, sillimanite, quartz, framboidal jarosites and few pieces of densely iron oxide coated wood fossils are present (plate 139).

In the Mathikayal kayal soil profile densely iron oxide coated 15 m µ sized ilmenite, sillimanite, quartz, many angular to subangular and 3 m µ diameter jarosite framboids, ferrihydrite spheriods, and few pieces of densely iron oxide coated wood fossils are present (plate 140).

At Vytilla pokkali soil profile iron oxide coated ilmenite, quartz of 10 m µ size, few 15 m µ sized sillimanite, few 5 m µ sized densely iron oxide coated jarosite framboids and 2 m µ sized ferrihydrite spheroids are present (plate 141).

At Kattukambal kole soil profile completely densely ferric iron oxide coated, subrounded to rounded 10 m µ sized quartz, ilmenite haemetite and goethite are present. (plate 142).

At Kattampally kaipad soil profile densely iron oxide coated, high reliefed, 100 m µ sized sillimanite, ilmenite, quartz, 5 m µ diameter frambidal jarosite and few pieces of lath shaped wood fossils are present (plate 143).

35.3. Scanning Electron Microscopy of Clay (<0.002 mm fraction from 0-50 cm depth

At Karumadi kari soil profile highly dense clustered ferric iron oxide coated angular to subangular quartz, framboidal jarosite, ferrihydrite, pyrite, haematite and goethite and few pieces of densely iron oxide coated flaky wood fossils, flakes of webby diatoms are present (plate 144,145).

At Moncompu karapadam soil profile densely ferric iron oxide coated subangular to subrounded 10 m µ sized quartz, sillimanite, ilmenite, many 3 m µ sized framboidal jarosites, haematite and goethite are present (plate 146).

At Moncompu <u>karapadam</u> soil profile few 20 m µ sized angular quartz and many 10 m µ sized angular to subangular densely ferric iron oxide coated quartz, ilmenite, 3 m µ dia framboidal densely iron oxide coated jarosites, haematite and goethite are present (plate 147).

At Mathikayal <u>kayal</u> soil profile densely ferric iron oxide coated, angular to subangular, about 10 m µ sized quartz, sillimanite, ilmentite, 2 m µ diameter spheroidal iron oxide coated framboidal jarosites are present (plate 148,149).

In the Vytilla <u>pokkali</u> soil profile densely ferric iron oxide coated, sodium sulphate coated 5.15 m µ sized angular quartz, 6 m µ sized ilmenite, very few 5 m u diameter framboidal jarosite and many 2 m µ framboidal jarosite and many 2 m µ sized framboidal jarosites are present (plate 150,151).

In the Kattukambal <u>kole</u> soil profile angular to subangular densely iron oxide coated quartz, ilmenite, few framboidal jaroisites of 2 m µ size are present (plates 152,153).

At Kattampally <u>kaipad</u> soil profile densely ferric iron oxide pherpherially coated subrounded quartz of 15 m µ size, many 5 mµ sized densely iron oxide coated high reliefed quartz, ilmenite, haematite, many 2 m µ sized framboidal jarosite, ferrihydrite are present. The quartz skeletons are seen to be highly flaky, mica quartz (plate 153,154,155).

36. **Forms and distribution of pyrite**

The results of the observation of the forms and distribution of pyrite bodies by the polarised and scanning electron microscopy is presented in table 10.

Three types of pyrites viz primary pyrite, secondary pyrite and teritiary pyrite identified in these soils.

Primary pyrites are present as pyrite bodies as spheres, similar to a bunch of grapes. These framboidal bodies of different diamensions mixed with clay and silt particles occur in the subsurface horizons. At Karumadi, Moncompu and Mathikayal they are present in the fourth horizons. At Vytilla and Kattampally they are present in the lower parts of the third horizons and in the fourth horizons. They are not observed in any of the horizons at Kattukambal.

Secondary pyrites are found as pyrite bodies more or less cubes, spheres, strings of spheres and framboidal spheres in the cells of plant tissue remnants of the soil organic matter. They are present inside the walls of partially decomposed plant tissue remnants of the second and third horizons of all locations except Kattampally where they are noticed to be present in the first, second and rarely in the third horizons within the partially decomposed plant tissue remnants and on the shells of molluscs.

Tertiary pyrites are similar to secondary pyrite microscopically but are present with in the surface horizons of these soils. At Karumadi, Moncompu, Mathikayal and Kattampally they are present in the first and second horizons while at Vytilla and Kattukambal they are present in the second and third horizons. The

Table 10. Pyrite content, distribution, size classification, fibre content, bulk density and 'n' value of the acid sulphate soils.

Sl. No.	Soil profile/ Location	Pyrite content%		Depth of Max.	Depth of Min.	Size classes and distribution 2mµ	2-7 mµ (percent)	7-15 mµ	15 mµ	Rubbed fibre%	Bulk density	'n' Value (Mean)
1.	Kari soil	1.20	1.27	10-36	36-59	76.9	15.4	7.7	-	12.6	1.9	
	Karumadi	1.12	1.25	II horizon	III horizon	23.3	46.5	23.3	6.9	14.5	2.2	
						36.7	-	63.3	-	16.9	2.3	
						6.7	14.5	43.6	38.2	14.3	2.0	1.2
2.	Karapadam soil	0.66	0.72	63-100	0-12	68.2	22.7	9.1	-	13.2	1.8	
	Moncompu	0.81	0.90	IV horizon	I horizon	100.0	-	-	-	9.1	1.6	
						100.0	-	-	-	8.7	1.9	
						100.0	-	-	-	5.5	1.5	1.1
3.	Kayal soil	0.66	0.72	24-46	0-10	89.0	11.0	-	-	1.6	1.6	
	Mathikayal	0.78	0.76	III horizon	I horizon	95.0	5.0	-	-	1.4	1.5	
						91.3	6.5	2.2	-	1.1	1.5	
						82.0	10.0	8.0	-	1.4	1.5	1.0
4.	Pokkali soil	0.96	1.02	32-59	0-13	100.0	-	-	-	6.8	1.9	
	Vytilla	1.07	1.02	III horizon	I horizon	96.5	3.5	-	-	0.9	1.1	
						91.0	7.0	2.0	-	7.6	1.6	
						88.0	12.0	-	-	3.2	1.3	1.0
5.	Kole soil	0.40	0.37	39-100	0-29	98.0	2.0	-	-	0.9	1.2	
	Kattukambal	0.26	0.20	IV horizon	I horizon	97.0	3.0	-	-	1.1	1.1	
						84.0	10.0	6.0	-	0.7	1.1	
						96.0	3.0	1.0	-	0.8	1.2	0.6
6.	Kaipad soil	0.76	0.74	39-100	9-24	92.0	6.0	2.0	-	1.6	1.2	
	Kattampally	0.75	0.92	IV horizon	II horizon	96.0	4.0	-	-	2.6	1.3	
						92.0	8.0	-	-	11.4	1.8	
						90.0	3.0	7.0	-	3.4	1.3	0.8

only difference of the tertiary pyrite from secondary pyrite is that it occurs in remnants of all kinds organic matter (paddy roots at Mathikayal first horizon) similar to its occurrence in mangroves roots and other tidal dominant vegetation.

Among the forms secondary pyrite is mainly responsible for the acid sulphate soils in the present study.

36.1. Quantity, size and distribution of pyrite in the soils

The results of the polarising and scanning electron microscopic observations on the quantity, size and distribution of pyrite bodies in the soils are presented in table 11.

At Karumadi mean pyrite content ranges between 1.12 and 1.27 percent. Maximum is observed in the second horizon and the minimum is in the third horizon. Among the three size classes of classification of pyrite bodies made under 2 m μ diameter class mean content ranges between 3.3 and 76.9 percent, the maximum being in the first horizon and the minimum in the second horizon. Similarly under the size class 7-15 m μ diameter it ranges between zero and 46.5 percent, the maximum being in the second horizon and the mimimum in the third horizon. While under size class of more than 15 m μ diameter it ranges between 7.7 and 63.3 percent, the maximum being in third horizon and minimum in the first horizon.

At Moncompu mean pyrite content of the soil profile ranges between 0.66 and 0.90 percent, maximum is recorded in the fourth horizon and the minimum in the first horizon. Under 2 m μ diameter size class mean content ranges between 68.2 and 100 percent. The maximum is at second, third and fourth horizons and the minimum

Table 11.0 Forms and distribution of pyrite bodies in the acid sulphate soils (Polarising and scanning electron microscopic observations)

Soil-Locations	Primary Pyrite	Secondary Pyrite	Tertiary pyrite
Kari soil Karumadi I Kari soil Karumadi II	Occurs mixed with clay and silt in the IV horizon	Observed in the II and III horizons inside the partially decomposed plant tissue remnants	Observed in the I and II horizons
Karapadom soil Moncompu I Karapadom soil Moncompu II	occurs mixed with clay and silt in the IV horizon	observed in the II and III horizons inside the partially decomposed plant tissue remnants	observed in the I and II horizons
Kayal soil Mathikayal I Kayal soil Mathikayal II	Occurs mixed with clay and silt in the IV horizon	observed in the II and III horizons inside the partially decomposed root tissues	observed in the I and II horizons
Pokkali soil Vytilla I Pokkali soil Vytilla II	Occurs in the part of the III horizon and in the IV horizon mixed with clay and silts	Observed in the II and III horizons inside partially decomposed plat tissue remnants	Observed in the II and III horizons
Kole soil Kattukambal I Kole soil Kattukambal II	Not observed in any of the horizons	Observed in the II and III horizons within the partially decomposed plant tissue remnants	Observed in the III horizons
Kaipad soil Kattampally I Kaipad soil Kattampally II	Occurs mixed with silt and clay in the III and fourth horizons	Observed in the I, II and rarely in the III horizons within the partially decomposed plant tissue remnants and on the shells of molluscs	Observed in the II horzons

in the first horizon. Under the 7-15 m μ diameter class and more 15 m μ diameter class it ranges between zero and 22.7 and 9.1 percent respectively. They are nil under these size classes in the second, third and fourth horizon.

At Mathikayal mean pyrite content of the soil ranges between 0.66 and 0.78 percent, the maximum content being in the third horzon and the minimum in the first horizon. Under 2 m μ diameter size class it ranges between 82.0 and 95.0 percent with maximum in the second horizon and minimum in the fourth horizon, under 7-15 m μ diameter size class it ranges between 5.0 and 11.0 percent with maximum in the first horizon and minimum in the second horizon. While under more than 15 m μ diameter size class it ranges between zero and 8.0 percent. The maximum is recorded in the fourth horizon and zero in the first and second horizon.

At Vytilla it ranges between 0.96 and 1.07 percent.Maximum is recorded in the third horizon and minimum in the second and fourth horizons. Under 2 m μ diameter size class it ranges between 91.0 and 100 percent, the maximum being in the first horizon and minimum in the third horizon. Under 2-7 m μ size class it ranges between zero and 2.0 percent, with the maximum in the third horizon and minimum in the first horizon, and under 7-15 m μ size class it ranges between zero and 6.0 percent with the maximum being in the third horizon and zero in the first and second horizons. Under 15 m μ size class it ranges between zero and 2.0 percent. The maximum being in the third horizon and zero in the first, second and fourth horizons.

At Kattukambal it ranges between 0.12 and 0.40 percent. The minimum is recorded in the third horizon and the maximum is in the fourth horizon. Under the 2 m µ diameter size class it ranges betwen 84.0 and 98.0 percent.The maximum is observed in the first horizon and minimum in the third horizon. Under 2-7 m µ diameter class it ranges between 2.0 and 10.0 percent. The maximum is in the third horizon and the minimum in the second and fourth horizons. Under 15 m µ diameter size classes it ranges between zero and 6.0 percent with the maximum in the third horizon and zero in the first and second horizon.

It ranges between 0.74 and 0.92 percent in the soil profiles at Kattampally. The maximum is recorded by the soils in the fourth horizon and the minimum by the second horizon. Under the size class 2 m µ diameter it ranges between 90.0 and 96.0 percent with the maximum in the second horizon and the minimum in the first and third horizon under 2-7 m µ diameter size class it ranges between 3.0 and 8.0 percent with maximum in the third horizon and minimum in the first horizon, under 7-15 m µ diameter size class it ranges between zero and 7.0 percent, with the maximum being in the fourth horizon and zero in the other horizons. Uner the size class of more than 15 m µ diameter is nil at all the horizons.

37. Soil Classification

Acid sulphate soils studied from different locations have been observed to be associated with sets of characteristics.

37.1. Kari soil-Karumadi

Peats soils with high salinity and acidity, poor aeration, innundation by sea water, woody materials in various stages of decomposition, deep black colour, Sulphaquent with sapric soil material underneath.

37.2. Karapadom soil-Moncompu

Typical saline acid sulphate soils with higher order of salinity and acidity with fair amounts of organic matter. Sulphuric horizon has its boundary within 50 cm of the surface, presence of jarosite mottle lad en layer within 50 cm depth.

37.3. Kayal soil-Mathikayal

Saline, slightly acid to acid, low to medium level of organic matter with lime shells or lime shell layer, Aquent with mean summer (March, April, May) and winter (November, December) temperature within 50 cm depth differ by less than $5^{o}C$, with jarosite mottles within 50 cm depth .

37.4. Pokkali soil-Vytilla

Exist in the mouths of streams of rivers subjects to tidal innundation, over grown with mangroves and other salt loving plants representing acid saline marshes. Aquents with sulphidic materials that has its upper boundary within top 50 cm. Only jarosite mottles and narrow jarosite layer with 50 cm depth.

37.5. Kole soil-Kattukambal

Saline, slighty acid, low to medium in organic matter with gravelly laterite lower horizons, exists near streams and lakes, Aquent with mean summer (March, April, May) and winter (November, December) temperature of 50 cm depth differ by less than $5^{o}C$. Only very few jarosite mottles within 50 cm depth.

37.6. Kaipad soil - Kattampally

Exist in mouths of streams and rivers subjected ot tidal innundation, these are over grown by mangroves and other salt loving plant and represent acid saline marshes (Swamps), Aquent with sulphidic material has its upper boundary within top 50 cm. Narrow jarosite layer with jarosite mottles within 50 cm depth.

All the soil have more than 1.05 (1.05-17.90) percent organic matter. The total sulphur content of all the soils studied have more than 0.04 (0.04-0.34) percent. All these have low chromas except at Karapadam, and Kattampally, where high chromas are noticed in these soils irrespective of locations (2.5Y, 5Y, 5YR, 7.5 YR). Jarosite mottle and jarosite mottle ladden layers are pale yellow coloured with hue 2.5 Y and value and chroma ranges between 6 & 7.

DISCUSSION

DISCUSSION

In Kerala the saline and acid sulphate soils occur along the West coast occupying marhsy depressions and lagoons. They are locally known as kari, karapadam, kayal, pokkali, kole and kaipad soils. They represent different acid sulphate soil environments in the state. Earlier work on these soils reveal that they are clay to clay loam in texture, highly acidic and saline with partially decomposed wood in the various stages of decomposition. These soils are with fossil limeshells and other molluscan shells. Forms of sulphur, Fe and Al are high. Clay minerals are dominantly kaolinite with minor quantitiy of 2:1 types. Wadia (1966) and Geological survey of India (1976) reported the presence of pyrite in the West coast soils and the macasite and pyritous clay in the lignite layer of 'Warkalli' formation. Detailed and integrated methods of stage by stage morphology with mineralogical and physico-chemical analysis of soils and soil fractions are essential to characterise these unique soils. The study of their micro morphological variation, location of centres of acidity and studying the morphology, distribution and forms of pyrite and its quantity are necessary to study the micro-pedogenesis operated in these soil formation and development. In order to ascertain and bring of out detailed information on the above, the present study was conducted. This study encompassed different locations in the State along the West coast namely Karumadi, Moncompu, Mathikayal, Vytilla, Kattukambal and Kattampally.

1. **Geology and Gemorphology**

As per the field observations it is indicated that along the West coast where the acid sulphate soils are confined the significant geological formation is the 'Warkalli' formation (Wadia, 1966; Bhargava and Abrol, 1984; Soil Survey Staff, 1978). At places these formation lies over fossil lignite layer and limestone strata.

2. **Climate**

These soils are situated in the low lands. The substantial rain fall received in this region and these lands are submerged throughout the year. The climatic parametres recorded represented a humid tropical climate.

3. **Natural vegetation and fauna**

The observed near by mangrove vegetation in the swamps and that in the brackish conditions nearer to these profile sites are remnants of earlier mangrove vegetation classified as 'Tidal forest'. Mangrove fauna are seen living and active in the near by swamps and brackish water and in the surface horizons of these soils, though fossil arthropods and molluscan shells are observed in the lower layers dominantly at Vytilla and Kattampally. In all the locations in fresh water region, vegetation of reed community is observed indicated by the presence of Phragmites, Typha, and Scirpus taxa.

4. **Agriculture**

Rice is the crop of choice of this region. As already discussed the major hazards in this regions to agriculture is saline water intrusion, floods, soil acidity and Fe and Al toxicity. Saline water intrusion hazards of this region for rice cultivation and fish culture is prevented by the construction of Thanneermukkom barrage and Thottapally spillway at Kuttanad, and Kattampally spillway at Kattampally.

5. **Drainage**

The drainage of this region is poor, as the lagoons are flooded with fresh rain water received from the up lands during rainy season. Further it is compounded by seawater ingression with alternate high and ebb tides.

6. **Soil macro morphology**

6.1 Soil colour

The dark grey to black soil matrix colour observed in these soils can be atributed to the partially decomposed wood fossil present (Money and Sukumaran, 1973; Bhargava and Abrol, 1984 The oxidation of the organic matter by 30 percent v/v H_2O_2 resulting in oxidation of dark coloured organic matter as well us pyrite still leaves black coloured residues. Examination of these residues reveals higher concentration of opaque grains such us ilmenite and haematite. The soil thin sections (plate 57 to 83 and 94) and sand mineralogy (plate 163,165,167 and 169 to 171,173) reveal the existance of abundant opaque minerels. The soil matrix colour with hue 2.5 indicate distinctly wet gleyed and reduced nature of the soils (plates 1 to 6 and 7 to 25). In the field the increased occurrence of reduced mottles with depth are due to shallow ground water level. Only one type of water regime is recognised in these soils that is ground water.

6.2 Colour mottles

The observed colour mottles of the hue 5 YR, 7.5 YR and

10 YR in the epipedons of these soils is indicative of the alluviation of lateritic soil material up to a depth of 1m (Plates 7 to 25).

6.3 Soil texture

Though the surface horizons are coarser, the observed fine texture in the subsurface horizons suggests that only fine sediments have been deposited to give rise to these soils (Plates 7 to 25 and table 2.0 to 2.3).

In all the locations closer morphological observation indicate the presence of stratification at Moncompu, Mathikayal, and Karumadi (Plates 7 to 14) and absence of stratification at Kattampally, Kattukambal and Vytilla (Plates 15 to 23). Faunal homogenisation is suggested due to the absence of stratification. Homogenisation in the upper horizons and presence of fossil founa in the lower horizons especially at Mathikayal and Kattampally (Plates 3,69 to 76 and 6,93 to 100) is observed. This suggests that the subsoils of these soils are very poorly drained, too wet and never dry enough for a sufficiently long period of time to be colonised by the fauna. It may also be due to the high acidity prevalent in these subsoils, limiting the funal habitation.

6.4 Soil coatings

Of the observed clay and soil coatings in the field (Plate

7 to 25) the soil coatings appear as that with shining grained surfaces covering the surfaces.

Kawaguchi and Kyuma (1969), Amimuddin (1981) studied the clay coatings and soil coatings in the fluvial soils of Malaysia. Clay coatings are observed as cutans in the voids and surrounding skeletons with different colour and composition. Brammer (1971) suggested that a suspension of soil material in irrgation or flood water will flow into cracks formed during dry season and form coatings. This will be repeated in the following years. Another plaussible explanation is the colloidal leaching of soil material including lower sized fractions of clay dimensions which get coated over other particles and interspaces. It is also possible that the constituents of clay materials like colloidal slica and alumina under waterlogged conditions may be getting synthesised to clay sized partilcles. The types of soils and clay coatings are not clearly observable in the fields.

6.5 Structure

Field observations show that all the soil pedons have structured B horizons and C materials are either weakly structured or massive. At Kattukambal (plates 5,18,19) and Moncompu (plates 2,11,12) profiles the observed subangular blocky structure confirms this view. In the subsurface horizons the fomration of prismatic structure begins to appear in Karumadi (plates 1,8,9) and Moncompu (plates 2,11,12) pedons. They have subangular blocky prismatic structure (Plates 1,2,8,9,11,12).

6.6. Effect of rice cultivation

Being cultivated soils all pedons have plough layers, the depth of its occurrance and thickness differs from location to location. The plough layers are strongly reduced with characteristic brown mottles on ped faces, consistency of peds range from firm to friable (plates 1 to 6).

The plough pans have brighter colour and are very firm as compared to the plough layers(plates 1 to 6). The absence of well defined plough pans in some of these profiles is because, these soils have become cultivable and under rice only within the last 50 years.

6.7 Stickiness and Plasticity

The observed variation in the stickiness and plasticity can be attributed to the variation in clay content, electrical conductivity, finer fractions and content of partially decomposed wood fossils.

6.8 Boundary of horizons

The gradual smooth boundary observed in these soils(plates 1 to 6) is due to lack of stratification and more intimate homogenising of soil materials while the gradual wavy boundary (plates 1 to 6) are suggested to be formed due to stratification, mass flow and presence of fossil remnants of wood fossils and fauna (plates 1 to 6). The abrupt wavy boundary observed at Kattukambal (plate 5) and Kattampally (plate 6) suggests that they are formed due to the presence of relic gravelly laterite layer and stratification of fossils of wood and fauna (plate 1 to 6).

6.9 Presence of roots

Medium fine to very fine abundant roots in the upper horizons of these soils are due to continuous paddy cultivation and weeds present in these fields. The observation of fossil pneumatophores and barks in subsurface horizons can be due to silting up and neoformation on an earlier mangrove vegetation, in the recent geologic past. The observed partial decomposition or raw stage of these root materials is due to the waterlogged nature, together with the retardation of decomposition by micro organisms due to higher salinity and acidity (Plates 67 to 70 and 72).

6.10 Permeability

The observed variation in the internal soil profile permeability is due to the variation in their granulometric composition and the variation in the presence and distribution of partially decomposed wood fossils. Accumulation of finer fractions and compactness of the horizons prevent the flow of water through the profile. The occurrence of a sandy layer or horizons with sand pockets accelerated the water flow though some of the profiles resulting in moderate permeability (plates 1,2,3,4,6).

6.11 Concretions/Nodules

Laterite concretions and nodules present in these pedons, especially at Kattukambal (platess 5,18,19) with hue 10 YR, 7.5 YR, 5 YR confirm the views on soil colour mottles discussed earlier (6.2)

6.12. Jarosite rich horizon - depth of occurrence, thickness and colour

Irrespective of the locations the occurrence of jarosite mott les or the diffiused jarosite mottled layer within 50 cm depth indicates recent deposition (plates 1 to 4 and 6). In the last 30-40 years the Kuttanad and other coastal regions, due to more intensive rice cultivation are not subject to wet fallowing as was the practice in some of these acid sulphate soil regions of the State. This lack of wet fallowing has drastically decreased the extent of stratification in the regions (plates 1 to 6). Further it leads to greater disturbance of the surface soils and aeration leading to the accumulation of jarosites near the surface(plates 1 to 6). In effect the human influence possibily has been decreasing the acid sulphate nature of these soils. Higher Eh and higher Fe content may be reason for their lower content or absence in the Vytilla (plate 4) and Kattukambal (plate 5). The observation of jarosite mottlings and its enriched layer at a shallow depth at Karumadi (plate 1), Moncompu(plate 2), Mathikayal (plate 3), Kattampally (plate 6), and Kattukàmbal (plate 5) and deeper and thinner occurrence at Vytilla (plate 4) can be attributed to be due to the observed variation in electrical conductivity, redox potential and Fe content. High salt concentration even masks the observation of jàrosite at Vytilla (plates 4,15,16) in the field.

6.13. Drainage

The observed variation in internal drainage of the pedons at different location can be due to a wide variation in their granulometric composition, distribution of partially decomposed fossil (plates 1 to 26)& table 2.0-2.3 organic matter.Presence of sand pockets and less homogenisation of soil materials (plates 1to 23) can be attributed as the reasons for the variation in soil drainage observed.

7. Granulometric composition

The observed variation in the content and distribution of different mechanical fractions in these soil pedons resulted in several soil textures. Irrespective of the locations the finer texture resulted by the accumulation of silt and clay fractions (Table 2.0 to 2.3, plates 1 to 23).

7.1 Partially decomposed fossil wood

The observed variation in quantity, stage of decomposition and distribution of partially decomposed wood in the pedons at differents locations (plates 1 to 23 and Table 2.0 to 2.3) are due to variation in soil pH (Table 6.0 to 6.3), stratification and soil homogenisation processes by the faunal activity. The observed lack of significant difference within the profiles at Karumadi (plates 1, 7 to 9), Mathikayal (plates 3,13,14), and Kattukambal (plates 5,18, 19) are due to their similar profile distribution as they might have been deposited in the same recent geologic period with little or no stratification between the horizons. Over a stretch of varied land feature along the West coast of Kerala, the marine vegetation in the recent geologic past got incorporated as a peat layer. Due to continuous process of alluviation, silty, sandy and often clayey material got deposited giving rise to the present day soils of this region. The variation observed relates to the stage of decomposition of the partially decomposed wood fossils (plates 67 to 70 and 72).

8. **Textural ratios**

The observed lower silt/clay, clay ratios and higher fine sand/coarse sand ratios of the pedons irrespective of locations (Tables 3.0 to 3.3) confirm earlier generalisation that these soils are formed with finer deposits in the more recent geologic past.

9. Structural indices of soils

9.1 Percentage of aggregates more than 0.25 mm diameter.

The observed significant differences in the content of soil aggregate percentage more than 0.25 mm diameter between locations and their distribution within the profiles at Karumadi and Moncompu are (Tables 4.0 to 4.3) due to the observed difference in their electrical conductivity (Tables 6.0 to 6.3) and the content of partially decomposed wood fossils (Tables 2.0 to 2.3).

9.2 Stability index

Significant differences in the soil stability index between locations, within profiles observed at Karumadi (Tables 4.0 to 4.3) can be due to the corresponding variation in the content of partially decomposed wood (Tables 2.0 to 2.3).

10. Soil moisture characteristics

10.1 Soil moisture retained at 0.3 bars

The observed significant difference between the percentage of soil moisture retained at 0.3 bars between locations and within the profiles at all locations except Vytilla (Tables 5.0 to 5.3) can be attributed to the corresponding variation in the contents of fine sand, silt and clay ratios (Tables 2.0 to 2.3 and 3.0 to 3.3) and the content of clay, soil organic matter and partially decomposed wood (Tables 2.0 to 2.3).

10.2 Soil moisture retained at 15.0 bars

The observed significant differences in the percent content of soil moisture retained at 15.0 bars between locations and within the profiles at Karumadi (Tables 5.0 to 5.3) are due to the corresponding difference in the content of coarse sand,fine sand and clay ratios(Tables 2.0 to 2.3 and 3.0 to 3.3) and corresponding moisture retained at 0.3 bars (Tables 5.0 to 5.3).

10.3 Soil available water

The significant differences in the percent content of available water at different locations and within the profiles at Mathikayal, Kattukambal and Kattampally can be atributed to the percent moisture retained at 15.0 bars (Tables 5.0 to 5.3), and content of soil organic matter (Tables 6.0 to 6.3).

11. **Organic matter**

The observed significant difference in the content of soil orpanic matter between location and with in the profiles at Karumadi, Moncompu and Kattampally (Tables 6.0 to 6.3) can be atributed to the corresponding variation in their wet and dry soil EC, sesquioxide content, active iron content, total and exchangeable aluminium content and soil CEC (Tables 6.0 to 6.3).

12. **Measurement of soil acidity and related chemical properties**

12.1. Wet soil pH

Significant difference the wet soil pH between locations are noticed (Tables 6.0 to 6.3). Within the profiles also significant difference is noticed at all locations except that at Karumadi and Kattukambal (Tables 6.0 to 6.3). These observed variation in wet soil pH of soil samples may be due to corresponding variation in soil Eh, Exchangeable aluminium, SO_4- sulphur and water soluble sulphur contents (Tables 6.0 to 6.3). Wet soil pH is indicative of the active acidity of the soil. Active acidity in turn depends on CEC, exchange acidity, exchangeble Al, exchangeble Fe and such other facters contributing to acidity. Sulphide sulphur by its capacity to oxidise and hydrolyse to mineral sulphuric acid is another factor. This is in conformity with the findings reported by Marykutty (1986).

12.2. Airdried soil pH

The observed significant variation in air dried soil pH between locations and within the soil profiles at Moncompu, Mathikayal and Kattampally (Tables 6.0 to 6.3) are due to the corresponding concentration of H^+ realeased due to the oxidation pyrite and subsequent hydrolysis to sulphuric acid. These variation can be attributed to the corresponding increasing in water soluble sulphur, sulphate sulphar and organic sulphur, CEC (Tables 6.0 to 6.3). As in the case of wet soil pH similar observations are also reported by Marykutty (1986). High acidity of kari soils have been reported as due to the production of sulphur by sulphur reducing bacteria (Subramoney, 1960). The cause of this is also can be attributed as due to production of organic acid by decomposition of organic matter (Varghese, 1973).

12.3. Air dried, hydrogen peroxide treated soil pH

As in the case of air dried soil pH the observed variation of these between location and within the profiles only at Moncompu and Kattampally (Tables 6.0 to 6.3) are due to the release of still higher concentration of H^+ by the further oxidation of pyrite and subsequent hydrolysis of the oxidised products of pyrite present in these soils as revealed by corresponding variation in the content of sulphate sulphur, water soluble sulphur and organic sulphur and

CEC (Tables 6.0 to 6.3). This is in conformity with the observations reported by Dent (1986) and Paramanathan (1987).

12.4. Soil pH in 0.01 M $CaCl_2$ solution

The observed significant difference in soil pH in 0.01 M $CaCl_2$ solution between locations and within the profiles at Moncompu Mathikayal and Kattampally (Tables 6.0 to 6.3) are due to the corresponding variation in soil CEC and soil effective CEC, Sulphate sulphur content (Tables 6.0 to 6.3). This is in agreement with the observations reported by Varghese (1973).

12.5. **Shift in soil pH by different methods from wet soil pH**

12.5.1 Shift in air dried soil pH (Tables 6.4 to 6.7)

The observed variation in the shift in air dried soil pH from wet soil pH may be due to the H^+ ions and SO_4^{-2} ions released by sulphuric acid formed by the oxidation and subsiquent hydrolysis of pyrite present in these soils. Kurup and Aiyer (1973) reported seasonal fluctuation in soil pH of kari soils.

12.5.2 Shift in airdried H_2O_2 treated soil pH (Tables 6.4 to 6.7

As in the case of shift in air dried soil pH here further higher shift observed in the samples between locations and with in the soils at all locations is due to increased release H^+ due to further oxidation pyrite and subsiquent hydrolysis to more sulphuric acid. Similar observation are reported by Brinkman and Pon s (1973), Dent (1986) and Paramanathan and Noordin Daud (1986).

12.5.3 Shift in soil pH in 0.01 M $CaCl_2$ solution (Tables 6.4 to 6.7)

The observed difference in shift in soil pH between locations and within the profiles is due corresponding variation in Sulphate Sulphur, CEC and effective CEC (Table 6.0 to 6.3).

13. Soil electrical conductivity

13.1. Wet soil electrical conductivity

The observed significant difference in wet soil electrical conductivity between locations, within the profiles except at Mathikayal, Vytilla and Kattukambal (Tables 6.0 to 6.3) may be due to corresponding variation in their partially decomposed wood (Tables 2.0 to 2.3), organic matter, exchangeable aluminium, soil CEC, soil effective CEC, Al saturation of effective CEC and forms of Sulphur (Tables 6.0 to 6.3). Similar high electrical conductivity have been reported for kari soil by Kurup and Aiyer (1973)

13.2 Air dried soil electrical conductivity

The observed significant difference in the airdried soil electrical conductivity of soils between locations and within the profiles except at Kattumkambal (Table 6.0 to 6.3) can be atributed to the addition of further H^+ and SO_4^{-2} ions of high mobility from the sulphuric acid released by the oxidation and hydrolysis of pyrite in these soils (Tables 6.0 to 6.3). Raju (1988) also observed similar difference in change soil EC of some of these soils due to drying.

13.3. <u>Shift in air dried soil from wet soil electrical conductivity</u> (Table 6.8 to 6.11)

The observed variation in shift in between locations and within profiles is due to increased release of H^+ and SO_4^{-2} ions to the soil solution by the oxidation and hydrolysis of pyrite present in these soils (Tables 6.0 to 6.3).

14. **Redoxpotential (Eh)**

The observed significant difference in soil Eh between locations and within profiles at Moncompu and Kattukambal (Tables 6.0 to 6.3) is due to corresponding variation in the content of total iron, Alumina, sesquioxide, sulphate sulphur, water soluble sulphur organic sulphur and heat soluble sulphur (Table 6.0 to 6.3). As reported by Dent (1986) these soils satisfy the Eh conditions of +400 mV with pH less than 3.7 to occur jarosite along with solid solution of natrojarosite and hydronium jarosite.

The Eh of the air dry soils ranges between +445 to +540 mV. Submerging these soils in water for a period upto 1 month reveals that the Eh of the soils are not decreased to +380 to +420 mV. This indicates that the natro and hydronium jarosites along with jarosites are not easily reduced to corresponding sulphidic materials. Their submergence to 3 months also indicate that equillibrium Eh values are not attained. Further intrinsic Eh values of these soils are still on the oxidative side. This shows that the acid sulphate soils due to human influence in the last few years have sufficiently been oxidised on the surface to jarosite and other oxidised products. A rice cropping season, of 3 to 4 months and is sufficiently low, anaerobic situation is not attained. This attainment is also prevented in agricultural operations by periodic letting in and letting out of water.

15. **Organic carbon**

Significant difference in their organic carbon content between locations and within profiles at Karumadi, Moncompu and Kattampally observed (Tables 6.0 to 6.3). The reason for this variation can be attributed to the corresponding variation in their partially decomposed wood (Tables 2.0 to 2.3) content.

16. **Total Iron (Fe_2O_3)**

The observed significant difference in the total iron oxide content between locations and with in profiles at all locations (Table 6.0 to 6.3) can be attributed to the corresponding variation observed in the partially decomposed wood content (Tables 2.0 to 2.3). The relationship with partially decomposed wood content reveals its relationship with iron pyrites in the wood fossils of these soils.

17. **Total Aluminium (Al_2O_3)**

The total Al_2O_3 content soils differed significantly between locations and within profiles at all locations except at Moncompu, Kattukambal, and Kattampally (Table 6.0 to 6.3). This observed difference may be due to relative variation in coarse sand, partially decomposed wood content (Tables 2.0 to 2.3) and wet soil pH, total iron content in these soils (Tables 6.0 to 6.3). Increased acidity below pH 3.5 will release more Al^{+++} to soil solution from Aluminium silicate clay minerals. This is in conformity with the findings reported by Marykutty (1986).

18. **Sesquioxide content of soils**

The observed significant difference in the sesquioxide content of soils between locations and within profiles at Mathikayal, Kattukambal and Kattampally (Tables 6.0 to 6.3) can be attributed to the correspondingvariartion in partially decomposed wood content (Tables 2.0 to 2.3) and wet soil pH (Tbales 6.0 to 6.3). As in the case of the relation of total Al_2O_3 and wet soil pH noticed here also it confirms that the low pH releases of more and more Al^{+++} from aluminosilicate clay minerals. Similar observations are also reported by Marykutty (1986) on these soils.

19. **Exchangeable aluminium content of the soil**

Significant difference is noticed in the soil exchangeable aluminium content between locations and within the profiles at Kattukambal and Kattampally (Tables 6.0 to 6.3). It can be attributed to the corresponding variation in the Partially decomposed wood (Tables 2.0 to 2.3), total aluminium, total iron, wet soil pH soil CEC, soil effective CEC, Al saturation percent of effective CEC and forms of sulphur - sulphate, sulphur water soluble sulphur, organic sulphur and heat soluble sulphur (Tables 6.0 to 6.3). Negative relation with wet soil pH indicalts that the soil pH of these soils are more due to exchangeable Al (Tables 6.0 to 6.3).

20. **Exchangeable iron content of the soil**

The observation of significant difference in the exchangeable iron between locations and within profiles at Moncompu and Kattampally (Tables 6.0 to 6.3) may be due to the corresponding variation in their fine sand, silt,clay (Tables 2.0 to 2.3). The relationship with finer fraction (Silt and clay) is indicative of its orgin from the silt and clay sized lateritic fells and out wash from the near by upland lateritic hills.

21. **Active iron content**

Significant difference in the soil active iron content between locations and within profiles (Tables 6.0 to 6.3) is due to the corresponding variation to their partially decomposed wood content (Table 2.0 to 2.3), Al saturation of soil effective CEC, soil effective CEC and forms of sulphur -- sulphate sulphur, water soluble sulphur, organic sulphur and heat soluble sulphur (Tables 6.0 to 6.3).

22. **Cation exchange capacity of soils**

Significant difference in soil cation exchange capacity between locations and within profiles at Karumadi, Vytilla, Kattukambal, and Kattampally (Tables 6.0 to 6.3) reveals that their dependence on silt, clay, partially decomposed wood (Table 2.0 to 2.3), wet soil pH, wet soil EC, total Fe_2O_3, exchangeable Al, active iron, Al saturation of effective CEC, and forms of sulphur sulphate sulphur, water soluble sulphur, organic sulphur and heat soluble sulphur (Tables 6.0 to 6.3). Kurup (1967), Venugopal (1969) Sreedevi and Aiyer (1973), Marykutty (1986) observed high cation exchange capacity for kari soils.

23 **Effective cation exchange capacity of soils**

The observed significant difference in the effective cation exchange capacity of soils between location and within profiles at Vytilla, Kattukambal and Kattampally (Tables 6.0 to 6.3) are found to be due to the corresponding variation in the partially decomposed wood (Tables 2.0 to 2.3), active iron, Al saturation percent of effective CEC, silt and clay content and forms of sulphur- sulphate sulphur, water soluble sulphur, organic sulphur and heat soluble sulphur (Tables 6.0 to 6.3).

24 **Aluminium saturation of effective soil CEC**

Significant difference observed between locations and within profiles at Kattukambal and Kattampally in the aluminium saturation of effective CEC (Table 6.0 to 6.3) be due to corresponding variation in Silt partially decomposed wood (Table 2.0 to 2.3), total aluminium, soil CEC and active iron (Tables 6.0 to 6.3).

25. **Distribution of different forms of sulphur in the soils**

25.1. Total sulphur

Lack of significant difference in soil total sulphur content between location and within the profiles except at Mathikayal (Tables 6.0 to 6.3) can be attributed to the relationship between total iron and aluminium (Tables 6.0 to 6.3) indicating that the total sulphur content is contributed not only the wood fossils and by the pyrite present in the soils but also due to the major contribution from sea water.

25.3. Sulphate sulphur

It exhibited significant difference between locations and within the profiles at Mathikayal and Kattukambal (Table 6.0 to 6.3). It can be atributed to the observed corresponding variation in the clay, partially decomposed wood (Table 2.0 to 2.3), wet soil pH, air dried H_2O_2 treated soil pH, wet soil EC, total iron, soil CEC, and active iron (Tables 6.0 to 6.3).

25.4. Organic sulphur

The observed significant variation in the organic sulphur content between locations, within the profiles except at Kattukambal (Table 6.0 to 6.3) is may be due to the relative variation in the clay, partially decomposed wood (Table 2.0 to 2.3) ,air dried H_2O_2 treated soil pH, total iron, active iron content (Tables 6.0 to 6.3). Its relationship with total and active iron is indicative of its occurence in combination with iron as iron pyrites than other compounds.

25.5. Heat soluble sulphur

They differed significantly between location and within the profiles except at Kattukambal (Table 6.0 to 6.3) is may be due to the corresponding relative variation observed in clay, partially decomposed wood (Table 2.0 to 2.3) content, wet soil pH and air dried H_2O_2 treated soil pH, active iron (Tables 6.0 to 6.3).

Close relationship of total sulphur with organic carbon have been reported by Varghese (1973). Similar profile pattern was reported by Subramoney (1960), [illegible] Leela (1967) and Varghese (1973).

26. **Coarse sand mineralogy of the soils** (Table 7.0)

Locations are different significantly for their quartz, laterite nodules and partially decomposed wood content. It indicates that these soils are transported and silted at significantly different rate between locations, wide difference between location in terms of rate, frequency laterite fells and outwash brought to these soils. Wood fossils are under wider rate of decomposition between locations. Another important information that can be obtained is that all these soils are formed on the similar parent materials but with different soil forming environments. In the specific study of coarse sand minerology of acid sulphate soils, wood fossils also come into the analysis along with lateritic nodules. This study was done to utilize the data for fibre analysis for classification purposes.

27.0 **Fine sand mineralogy of the soils** (Table 8.0)

Among the constituents of fine sand fraction and ratios it differed significantly between locations except that for feldspars, Biotite, Muscovite, Chlorite, Garnet and Tourmaline indicating the uniformity of parent materials with wider rate and frequency of its sedimentation in different locations. Acidity prevalent in all these soils uniformly weather their minerals.

28.0 **Silt fraction mineralogy of the soils** (Table 9.0)

Among the constituents of silt fractions, its ratios, silt/clay, silt/fine sand, quartz, biotite, chlorite, sillimanite, monazite, Haematite do not differ significantly between locations indicating still uniformity of parent materials of these locations. Significant difference noticed between silt/coarse ratio, contents of partially decomposed wood, feldspars, goethite and pyrite is indicative wider rate of decomposition and weathering between locations.

29.0. **Soil ripening** (Table 10.0)

The observed variation in 'n' the soil in value indicate their comparitive ripening. The concept of soil ripening embraces all the physical, chemical and biological procesess by which a freshly deposited mud is transformed into a dry land soil (Dent, 1986). He also found that physical ripening was complete up to

60 cm within 40 years.

30. **Particle analysis of finer fractions ($<$ 0.005 mm) of soils from 0-50 cm depth** (Table 12.0)

As there is no significant difference in the finer sub fraction of the soils between locations, it can concluded that all these soils though formed in different environments. They are formed in same recent geological past from finer deposits. This observation is confirmatory of earlier generalisation in this study. By mechanical analysis Money and Sukumaran (1973) and Bhargava and Bhattacharjee (1982), and Bhargava and Abrol (1984) conjectured that these soils are formed from finer deposits.

31. **Chemical composition of soil clays** (Table 13.0)

Chemical compositions, and molar ratios of the soil clay samples differ significantly beetween locations. Silica occurs in the soils mainly in the form of aluminium silicates (Grim 1953). Beckweath and Reeve (1964) observed that silica may also occurs as sorbed by sesquioxides, further free silica may also be present. Here in these soils free silica exits in the three forms. The free silica occurs as spongy transparent (plate 54) or blue coloured microscopic spicules (plate 30) and diatomaceous materials of translucent platy (plates 107,113,114 and 127), oval structures (plate 118).

The iron and aluminium are found to be more concentrated in the clay fraction as compared to the whole soil. Mc Farlane (1976) has observed that Fe_2O_3 content being matched by a decrease in Al_2O_3 and vice versa. The results of present study also shows also the same trend. It is in agreement with results obtained by Venugopal and koshy (1982) for paddy fields in toe slopes of some lateritic catenary sequences in the state. The higher amounts of Al at Vytilla, Kattukambal, and Kattampally are indicative of the presence of smectite minerals, intermedite values of Al at Mathikayal indicates illite type of mineral and the lower values observed at Moncompu and Karumadi are indicative of the comparitive dominance of kaolinites. Needless to state that in all these soils the dominent clay mineral is kaolinite. In addition to this miner quantities of other type of minerals present it include chlorites, smectite and illite. From the chemical analysis (Table 13.0) it is seen that the alumina and iron oxide content is around 40 to 50 percent. This can be considered to be a high value. However their silica alumina ratio (Table 13.0) is less than 4.69 which is typical for pure vermiculite. This indicates the possible pres. ence of miner amounts of vermiculite. A physical breakdown of chlorite mica from out of the silt fraction into the clay fraction is probable. In acid soils liming is well known to result in chloratisation. In micro locations of these soils conditions suitable for chloratisation suggests excessive bases leading to precipitation of ferric hydroxides, aluminium hydroxides functioning as the nucleii for chloratisation may be an aspect worth considering. Varghese (1973) conjectured the presence of 2:1 type of clay minerals in the <u>kari</u> soils by the high Sa value. Similarly Pillay and Subramoney (1967) reported the possible presence of more than 2.0 SS value indicating the predominance of montmorillonite clay minerals in these soils.

Comparatively high potash and low CaO + MgO (Table 13.0) suggest the absence of montmorillonite clay mineral as a minor

Compara tively high potash and low CaO + MgO (Table 13.0) suggest the absence of montmorillonite clay mineral as a minor constituent in these soils. Higher sodium, calcium, and magnisium (Table 13.0) content of clay samples is also indicative of the probable presence of minor amounts of amphiboles and pyroxenes. High sodium and calcium content also indicate the presence of plagioclase feldspars. High iron indicates the probable presence of goethite, while the high aluminium content indicate the presence of gibbsite. Comparatively high content of zinc and copper (Table 13.0) increases the probability of the presence of pyroxenes, biotite, mica and hornblende.

31.1 X-ray diffraction and Thermogravimetric analysis of soil clays

X-ray and thermogravimetric analysis of clay samples (Tables 9,14, and figs.53,55,56) show the predominance of mica quartz followed by kaolinite and 2:1 type of minerals in all locations. However the presence of pyroxenes, biotite, mica, smectite is also indicated. However, the presence of chlorite, mica, smectite is also indicated. According to Millot (1970) kaolinisation develops when lessivage accelerates and the medium becomes more acid. The kaolinite present in these soils is a neo formation from the alluvial laterite fells and outwash silted up in these regions. The conditions prevailing in the waterlogged soils are not suitable to give a high degree of crystallinity to kaolinite and chlorite when formed in situ. The present observation of a high degree of crystallinity to the dominant kaolinite mineral and also to the minor mineral chlorite (Figures 55 and 56), indicates the relic nature of these minerals. The widening of the basal spacing of the peaks of chlorite indicate changes in chlorite induced by waterlogged acid soil situation.

32.0 Microscopic morphological observations and soil pedogenesis

32.1. Nature of sediments/deposits

The field observation and microscopic morphological observations at all levels indicated iron oxide coated wood fossils throughout the soil profiles (Plates 23,30,55 to 60,67 to 69,72,74,109 to 115,122,128,129,134 to 155). The occurrence of wood fossils in abundance in the acid sulphate soils, and there parent material like role in these soils has been discussed later.

The soils vary in their granulometric composition as observed by a coarse texture for the surface horizons (Tables 2.0 to 2.3 and Plates 7,8,11,13,15,17,20,26,30,34,38,42,46,53,54,61,62,64,70,77,78,85, 86,93 and 94) and fine compact ed lower horizons (Tables 2.0 to 2.3 Plates 9,12,16,19,22,29,33,37,41,45,50,51,52,59,60,67,68,75,76,83,84,91, 92,99 and 100). Microscopic observation on the frequency of sketetons (grains) confirms this observation.

The higher content of fossil wood at all locations prominently at Karumadi and Kattampally (Table 2.0 to 2.3) indicate their stratification and lesser degree of homogenisation. Their dominance in the physico-chemical properties of these soils indicate the parent material like role attributed to them.

The shape of grains in the surface horizons and in pockets in the lower horizons with lack of mechanical, abberation and a high degree of angularity (Plates 26 to 173) show their transportation over short distances. It is indicative of the lesser chances of mutual attrition of the particles had undergone during the transport. It is thus conjectured to be as due to the short distances over which they have been transported. The Kuttanad base where in the major acid sulphate soils are located as well as the kole and kaipad lands of Kattampally are regions into which some of the major rivers of the state empty themselves. However it has to be realised that the average width of the state is only of the order of 80Km. The lack of mutual attrition in the particles transported and deposited in these regions are mainly due to the short distaces over which they are moved. The existance of the bright coloured lateritic nodules and concretions as discussed could be carried from the midland regions of the state which are well known lateritic belts and only 30-40 kilometer away from the site of the profiles. The arrangement of grains in the profile as revealed by all the levels of microscopic observations (Plates 26 to 173) suggest stratification. This view is strengthened as lamination in each horizon with minor changes in both its composition and horizontal anisotropic pattern. The predominent minerals throughout the profiles are quartz and opaques (Ilmentite and pyrite). The highly pitted nature and irregular margins of the opaques as revealed by mesomorphology (Plates 26 to 52) indicate the inetensity of the chemical weathering environment which has left its indelible marks on even the opaques, known to be resistant minerals.

32.2 Soil homogenisation

The absence of stratification observed in the soil profiles at Vytilla and Kattampally are strengthened by microscopic observations. This can be attributed to various processes of soil homogenisation. The effects of fauna as the main homogenising agents around the profile sites at Vytilla and Kattampally, has been recognized and recorded (Table 1). From micromorphological soil studies, features like distribution of grains in circles and clusters (Plates 53,54,60 to 64,75,76) vermicular clusters (Plates 65,66) the anisotropic vermiforms and passages (Plates 65,66) and faecal orthotubules (Plates 95,96) have been pointed out as signs of the effects of fauna. These observations are dominant in the upper horizons at Vytilla and Kattampally only, but the subsoil is stratified which can be recognized even in the field. This feature is also weakly indicated in all the upper and lower horizons of other locations. In short there is homoegenisation in the upper horizons with stratification in the lower horizons. One possible explanation is the sequential nature of the deposits taking place over a long geological period, so that biological activity in the subsoil might have ceased. This cessation might have triggered by the deposition of an unsuitable and non conducive conditions for faunal habitation. This has been revealed by field and microscopic morphological observations of fossil fauna, especially at Mathikayal and Kattampally fourth horizons (Plates 51,52,99 and 100). The extreme acidity (Tables 6.0 to 6.3) in these horizons which constitute the environments of the habitat might have rendered it uninhabitable for the soil fauna.

32.3. Soil Colour

The colour characteristics in thin sections of these soils confirm many of the field observations. The soil variation in soil colour matrix, frequency and distribution of reduced and bright mottles are also observed in the thin sections. (Table 1) Changes in soil colour are mainly a function of the water regime. Moisture is responsible for dissolving certain constituents from certain location, facilitate their oxidation, and reduction of some these and deposition. In thin sections the profile colour variations due to changes in water regime could be observed. As observed in the field the range of colours vary from black, yellow, brown, olive yellow and white.

32.4. Matrix anisotropism

Matrix anisotopism is the prominent feature observed at all levels of microscopic morphological observations (Plates 26 to 173). It is related to the moisture conditions in the soil, and is to a higher degree near the ground water level. The matrix anisotropism are influenced by variation in texture, stress, biological activity and soil colour in addition to wetness. The lack of matrix anisotropism in the surface layer is more due to cultivation and consiquent homogenisation. Th difference in field texture is revealed by the variation in the organisation of domains in thin sections. They are due to reorientation of clay particles. The direction of orientation is mostly due to the direction of the movement of water. Larger domains and anisotropic zones are not observed, in the coaser textured surface horizons and sand pockets. It can be attributed to the comparatively prolonged wetness in all these soil horizons, as all are below one to two metres from mean sea level. The role of stress in the formation of matrix anisotropism can be illstrated by genesis of anisotropic lines. These are produced by soil movement along slip surfaces due to stress which was responsible for orienting the clays. These are insignificant in all the layers except the lower part of the first horizon and the upper part of the second horizons. In the surface horizons the anisotropic lines can be interpreted as being related to shearing produced by cultivation operation such as ploughing, levelling etc. The presence of lines in the subsoils on the other hand, can be interpreted as related to the stresses produced by the shrink-swell mechanism of these soils due to periodically wetting and at times partial drying . The role of pressure in the genesis of anisotropic aureoles around the grains is doubtful. The presence of aureoles around grains has been interpreted as due to the reorientation of clay on the hard surfacess of grains as a result of pressure (Brewer, 1976). However, in all the sandy pockets and sandy horizons it is observed that aureoles are mostly found around segregations/concretions (Plates 77,78,81 and 84 to 94) and not around grains, although the surface of the latter are harder. This suggests that other factors beside pressure are responsiuble for the formation of aureoles around segregations and concretions. The absence of aureoles are markedly observed in the surface horizons around circular pores due to the pressure exerted by gas bubbles generated by the decomposition of organic matter and coming out of the system. The absence of aureoles around the pores of other shapes especially in the lower horizons seem to lend support to the view that circular pores are formed by gas bubbles. Stress and wetness may account for the genesis of anisotropic zones, but it can also be possible that the zones of relics are assimilated soil or clay coatings, or depositional laminations. The presence of zones with colours slightly different from the surrounding matrices seems to support this suggestion. In all the profiles the anisotropy is better developed in the gleyed or reduced areas of the soil profile. Weakly anisotropic yellowish brown mottles are nearly the isotropic red mottles. This suggests that the presence of amorphous hydrated iron oxides mark the development of matrix anisotropism. It is possible that the cultivation and ploughing of the surface soil to a puddled condition in these soils results disorientation of the clays and the very method of domaiin formation. These observations stengthen the major role of organic matter and forms of iron and their transformationos.

32.5. <u>Forms of iron and its distribution</u> (Plates 26 to 173)

Iron occurs as intim ately mixed with organic matter in the surfacce as iron coatings, iron ochre (ferran and ferriorganon with few goethan) in the subsurface horizons. The enrichment of iron in the subsurface has been shown by the occurrence of thick ochre on the ped faces during the micromorphological observations. This is been to be to a greater extent at Moncompu profile followed by Kattampally profiles. The microscopic studies also reveal the occurrence of haemetite in association with bright orange coloured mottlies of goethite (Plates 28,30,38 and 42 to 44). The present day occurrence of a layer of ochre on the ped faces up to a depth 1 m in the Moncompu soils indicates their possible role as electron acceptor/donor in the oxidation and formation of pyrites.

Pyrite (cubular FeS_2, hexagonal pyrrohtite FeS), its oxidation products, jarosite and intermediate products, ferrichydroxide and gypsum, are all present, dominantly in the fossil woods, root channels and as free grains or as cutans in the margins of voids (channels and chambers) and skeletons (Plates 30 to 173). This has been observed at all levels of microscopic morphological examination of soils. This confirmed the closer association between iron oxide coatings of organic matter in particular and root channels and fossilised wood remnants with formation of pyrites in it. This has been observed within 50 cms and upto a depth of 90 cm. This association is due to the physico-chemical relationship among these constituents. Below 50 cm depth, the jarosite framboids retain their pyrite nucleus indicating incomplete oxidation of pyrite framboids or intermediate. Pyrite and jarosite present in the plant tissues (Plates 57,67 to 70, 72,74,102 to 117, 122 to 124, 128,129,137,144,146 and 150) and limeshells (Plate 51) are dominantly framboidal followed by cubular crystals. SEM studies clearly revealed the polycrystalline framboidal feature of pyrite and jarosite present in association with iron oxide coated fossilised wood remains (Plates 105,107,111 and 112).

A field observation of orange coloured mottles in the moist subsurface horizons of the profile at Karumadi, Moncompu, Kattukambal and at Kattampally (plates 1,2,5 and 6), when examined mesomorphologically (Plates 26,33,40,41 and 44) indicated as a "green rust". This was found to be due to lepidocrocite (Fe-O-OH). In acid sulphate soils, though several oxides and hydroxide forms of iron have been reported earlier (Tarzi and Protz, 1972, Schwertmann and Taylor, 1977) no significant observation on lepidocrocite has been made. Lepidocrocite appears to be another intermediate product between the stages of oxidation of pyrite or pyrrohtite to jarosite. They are significantly present in the chambers and channels. The chemical relationship between pyrrohtite (FeS) and lepidocrocite (Fe-O-OH) as compared to Pyrite (FeS_2) and lepidocrocite suggest that the predominant occurence of Pyrrohtite in the acid sulphate soils of Kerala might be partially responsible for the observed occurrence of lepidocrocite, its oxidation product. In the acid sulphate soils around the globe Pyrrohtite has not been reported so far though acid sulphate soils have been examined for their mineralogy Eswaran, 1967; [illegible] and Dent, 1986).

Another possibility is the reported observation of Schwertmann and Taylor (1977) on the occurrence of lepidocrocite (Fe-O-OH) in lateritic hydromorphic soils. The occurrence of lateritic fells,nodules and concretions have been observed abundantly in the meso and micromorphological studies of all the horizons and of all locations (Plates 53 to 100 and 156 to 173). The present observation and the occurrence of lepidocrocite therefore needs to be connected. The specific occurrence of these materials at Karumadi, Moncompu, Kattukambal and Kattampally and its absence in the other locations has to be investigated. More detailed studies have to be made on the ramifications of iron in waterlogged and acid sulphate soils. The mineralogy and chemistry of Fe has to be studied both thermodynamically and kinetically.

The jarosite occurs mainly as neo and quasi cutans along channels and chambers. The quasijarositans are also associated with neoferrans observed in the structure of jarosite framboidds as shown in plates 32,79 and 82). The amorphous ferric hydroxides occur regularly throughout the soil as channel and chamber neoferrans (Plate

26-100), and as iron impregnated wood fossil remains (Plates 53 to 49, 67 to 70 and 74). Locally admixed ferric hydroxides occur along with some goethite and gibbisite in channels, wood fossil remains and on lime shells. Ferric hydroxides (Ferrihydrite) appear as spheroids or associated with pyrite and jarosites, especially in root channels, (plates 26 to 100). Certain measurements of the size of the framboids of the ferric hydroxides, jarosites and pyrites indicate that they have a similar size and less than 2 μ. Even the individual crystals of the framboidal structure have the same size and shape. Further the absence of disrupted relics of either the ferric hydroxide or pyrite or several of its oxidation products is marked and significant. These observations irrespective of the locations leads one to conjecture as follows:

The isometric nature with the existence of sharp margins of both framboids and individual crystals suggest the relic nature of the pyrite in the soil. Their existence as framboids and different oxidised and reduced products indicates the possibility of chemical changes to these isometric crystals in the solid phase. The formation of ferric hydroxides from jarosites at higher pH values in an immobile form and formation of jarosites from pyrite at low pH values in a mobile state has been indicated that mobile iron hydroxides are produced at low pH values from pyrite. These observations when viewed in the light of the earlier discussion suggest the need for more clear information on their formation. The occurrence of pyrite and its oxidised products near (Plates 82,91), in (Plates 61,72,74) and on (Plates 111 to 116,122 to 124, 128 to 139) fossil woods (Plates

57,58,63), limeshells (Plates 51,52) and molluscan shells (Plates 99, 100) is a universal feature in the Kerala acid sulphate soils. The occurrence of pyrite with limeshells has however been considered as mutually exclusive by Dent (1986). The present observation on the occurrence of pyrite framboids on the limeshell in the fourth horizon at Kattampally and Mathikayal indicate partial oxidation of some of the microcrystals of the framboidal pyrite to ferric hydroxide (Plates 51,52,102,104 to 108, specifically plate 107). While in the first two layers of the soils the stages of oxidation to jarosite stage could be noticed. Their predominant absence in the fourth layer has to be attributed to the lack of electron acceptors such as oxygen and also ferric ions in view of the close presence of limeshells (Plates 51,52,102,104 to 108). The present observation appears to suggest that they are not rigidily mutually exclusive. This may be due to the non reactiveness between the limeshells and the pyrite framboids. The non reactivity, it is conjectured, might have to be attributed to some of acid resistant organic constituents secreted to cement together the $CaCO_3$ microlites of the molluscan shells.

The gleyed feature observed in the subsurface horizons at Kattukambal, Kattampally, Moncompu and Karumadi and the reddish mottles in these and other locations are indicative of regions of iron removal and iron accumulation respectively (Plates 1 to 100). The two types of iron mottles namely those found on pedfaces and those found within the soils are essentially iron impregnations and coatings, as revealed by micromorphological observations. Mottles occuring within the peds, in the subsoil horizons have uneven staining, small subspherical clusters in thin sections. Mottles on the ped faces are formed as a result of cultivation, while the other forms of mottles support the suggestion that they are formed as a result of iron accumulation. Other informations regarding the iron enriched segregations and concretions present in these soils are indicated in the meso and micromorphological observations (plates 26 to 100). The bright red colour and sharp margins reveal their relic nature, while the subrounded to rounded shape reveal the alluvial nature of their deposition, and composition indicate that they are from the laterite fells and outwash of the nearby laterite hills and hillocks.

The occurrence of pyrite in the shape of amoeba under mesomorphological observation (Plates 30,31,34 to 41,45 to 50 and 52) could not be confirmed in the micro and submicro morphological levels of observations. At higher resolution it is possible that the mesomorphological observation became non significant.

All the levels of microscopic observations indicate the isometric nature of pyrite, jarosite and ferric hydroxide crystals. Further they are highly interrelated to one another. In view of this, atleast one of them is allochthonous in nature. This evidently is the most reduced one among them namely the pyrite. The isometric nature of all the three minerals is revealed by the fact that they have the same size, shape and polycrystalline framboidal feature. This is in agreement with the observation reported by Carsow and Dixon (1985). The retention of the uniform shape, size and structure of pyrite, pyrrohtite, ferric hydroxide and jarosites leads one to visualise the probability of oxidation reactions of pyrite and pyrrohtite to jarosites through the intermediate stages of ferric hydroxides in the solid state itself, however this requres detailed and confirmatory studies.

32.6. <u>Soil Translocations:</u>

Micromorphological observation confirmed the existance of two types of coatings, whole soil coatings appear as grainy and oriented (Plates 26 to 100). True clay and other colloidal coatings which can be considered as clay coatings are present on the walls of channels, chambers and vughs of lesser size range (Plates 26 to 100). They are formed in the illdrained subsurface horizons by the slowly percolating water. Soluble constituents of chemical weathering is deposited by this flow of water. The lamellation/layering of these features indicates that this depositon occurs slowly, disruptedly and repeatedly. The fragments of these coatings observed in the lower horizons are due to the activated action of percolating water by the sudden drainage to the ground water as well as fluctuating movement of the ground water due to tidal actions. One more type of soil coating is observed in the field and in micromorphology from the soils of Karumadi,Mathikayal, Kattukambal and Kattampally. These coatings are seen as dark coloured, grained but unoriented whole soil coatings. Genetically they can be interpreted as having been formed by a process of mass flow (Brammer 1971). In addition to the fragments of clay coatings, yellow to red and rounded are seen in the subsoil horizons at all locations except at Mathikayal and Kattampally. These coatings retained a bright colour and have sharp margins suggesting their alluvial origin. Considering the soil coatings as a whole four types of coatings are observed.

1. Light coloured, grainy, oriented whole soil coatings,
2. Dark coloured, grainy unoriented whole soil coatings,
3. Clay coatings of different colour and composition and
4. Fragments of yellow and red rounded clay coatings of allocthonous nature.

The colour mottles observed in the field appear as Fe impregnation/coatings mostly occurring around voids and rarely assimilated in the matrix. The bright colour and sharp margins suggest that they are relatively recent in origin. Kawaguchi and Kyuma (1969), and Aminuddin (1981) have recorded the occurrence of similar soil and clay coatings in the fluvisols of Malaysia.

32.7. Soil Structure

Structureless surface followed by progressive compaction in the subsurface horizons at all locations in the field are confirmed by the meso and micromorphological observations (Plates 26 to 100) as free grained coarse textured surface with less plasma which is progressively enriched by finer fractions and plasma in the subsurface horizons. The observation of cutanic materials, organan, ferran, ferriorganan and ferriargillan with coalesced margins and dull colour in the subsurface horizon indicate slow, active, elluviation of colloidal sized materials in these soils. Here the composition and structural features still strengthens the view that there has been leaching in these soils. In thin sections blocky, prismatic structure is observed especially in the locations Karumadi,Moncompu, Mathikayal, Kattukambal and Kattampally. It is also noticed that the higher compaction of the iron ochre at Moncompu and Kattampally as composite, subangular prismatic structure with complete bridging by haemetite and goethite. In the meso and micromorphology the peds of the compacted subsurface are observed to be mostly incomplete. It is a phenomenon not noticed in the field indicating that the field structure is constituted by the combination of such multi micropeds.

32.8. Effect of Cultivation

As discussed earlier in the context of macromorphology except at Kattampally all the locations are under continuous rice cultivation for a period of about 50 years only. Hsü (1964) reported that one plough layer will be formed in ever 60 to 70 years. In none of the locations a clear plough pan is observed in the field, However weak plough layers have developed. This is maximum at Moncompu and least at Kattampally. These observed differences in the field, under microscopy appear as mottles of Fe impregnations/coatings mostly occuring around micro voids and organic matter and rarely assimilated to the matrix (Plates 54,55,62,63,70,71,78,79,85,86,93,94). The iron impregnation/coatings around microvoids are relatively of recent orign resulting from ploughing operations in the field. Thin sections also revealed the presence of a massive structure, fracture of microvoids and a surface crust. The plough pans though insignificant and disrupted appear as bright yellowish brown coloured zones. In the micromorphology these plough pans appear as zones with few clearer and larger domains and weakly developed anisotropic lines (Plates 54,55,62,63,70,71,78,79,85,86,93,94). The least presence of these features at Kattampally is indicative of lesser distrubance at the surface horizons, due to cultivation (Plates 93,94)

As already indicated and discussed the chemical and physical changes taking place in the soil at a depth upto and beyond the plough pan are significant than the changes caused by the destruction of the structure due to cultivation. Further these soils, it appears from micro-morphology, has not been cultivated sufficiently for long period of time to create a significant plough pan.

32.9. Biological Activity

Field observations of the nearby salt loving and other mangrove under root faunal population, indicate the activity by molluscans, gastropods and shell fishes. As discussed earlier, though they are not observed in the field in these soils, their living presence in nearby areas, and the relic features of their habitation and activity in the immediate geological past of these soils has been observed from lower horizons (Plates 6,12,21,22,25,51,52,99 and 100). In thin sections the faunal activity are characterised/noticed as distribution of skeleton grains in circles and clusters (Plates 53,54,60 to 64 75 and 76). Vermicular structures (Plates 65,66) of anisotropic nature formed by the combination of faunal faecal materials and soil materials, passages with orthotubules of black and white coloured faunal faecal and soil materials (Plates 95,96). The orthotubules are prominently noticed at Kattampally (Plates 95,96). As already explained the fossil limeshells, valves of shell fish observed in the fourth horizon at Mathikayal and Kattampally respectively with miniumum disturbance on shell structure with less chemical weathering and presence of ferric hydroxide and pyrite framboids on their surface

(Plates 51,52,99 and 100) as revealed by meso and micromorphological observations strengthen these faunal habitation in a recent geological past in these soils. The high acidity observed in these soil horizons (Tables 6.0 to 6.3) even do not whether these resistant relic structures. A plausible suggestion is that they are not entirely composed of $CaCO_3$ as already discused.

The micro and submicro morphological observation reveal the presence of free silica as diatomaceous materials in these soils. As already discussed these are due to the water-logged nature of the soils, a highly suitable meilieu for diatoms. The diatomaceous bioliths found as colourless tranparent tubular spicules, blue coloured transparent spicules, oval platy materials, flaky mica like materials. Oval like materials are observed in abundant quantitites in the surface horizon of Moncompu (plate 118) while the coloured (Plate 30) and colourless (Plates 53,54) spicules are observed at the subsurface horzons of Moncompu, Karumadi, Mathikayal and Vytilla profiles. The high reduction. higher acidity, high soil temperature favour the accumulation of these forms (Giesking 1974).

At Mathikayal fossil foraminiferers are also observed. The presence of diatomaceous materials and foraminiferers in acid sulphate soils have been reported by Eswaran (1967), Stoops and Eswaran (1985)

33. **Chemical transformation of pyrite**

When oxygen enters this soil system pyrite oxidation starts according to the reaction.

$$3\ FeS_2 + 6H^+ + 10\frac{1}{2}\ O_2 + 3H_2O \rightarrow 3Fe^{2+} + 12H^+ + 6SO_4^{2-}$$

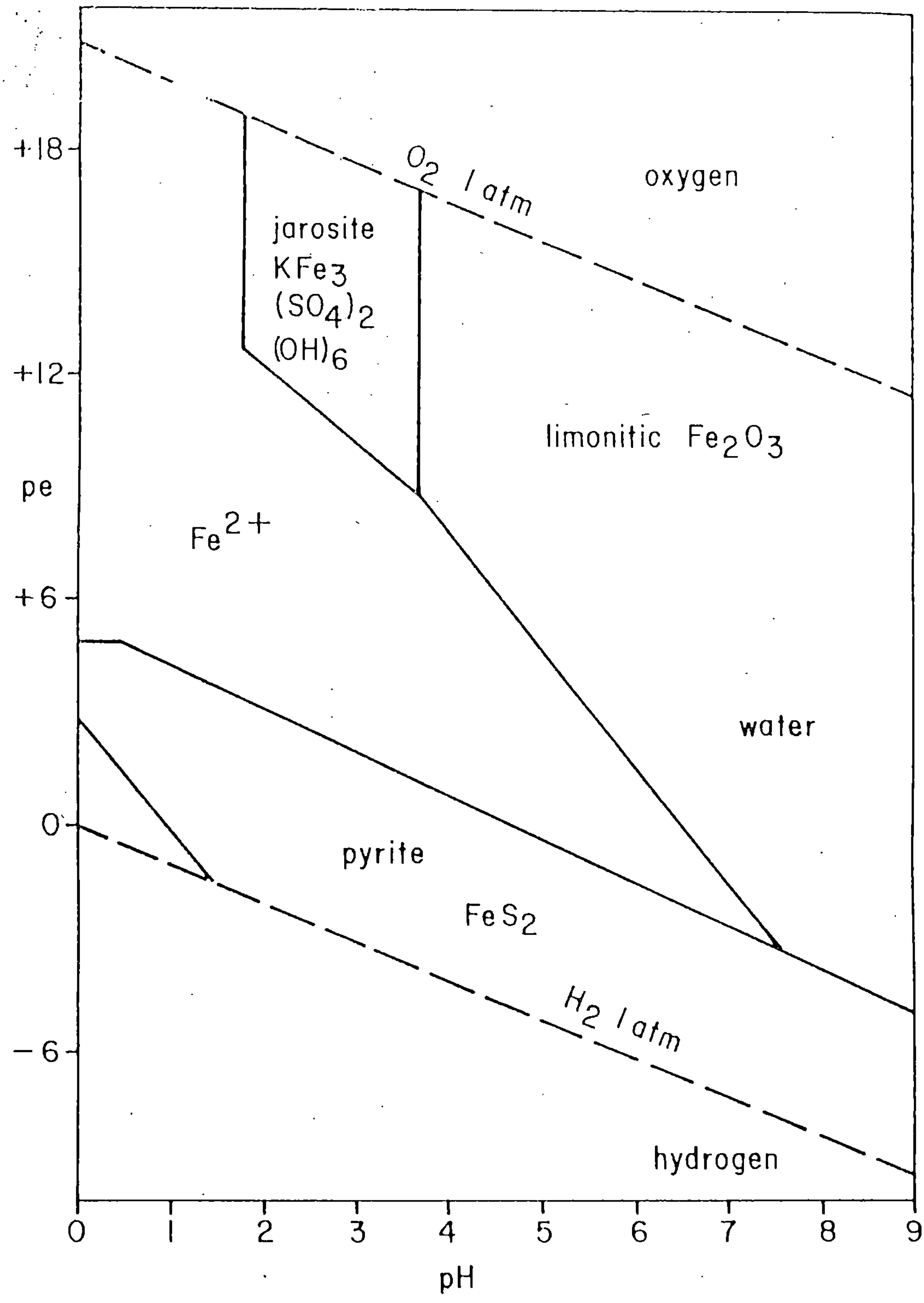


Figure 58. pe: pH diagram of pyrite, limonitic Fe_2O_3, jarosite and dissolved K^+, SO_4^{2-}, Fe^{2+} and Fe^{3+} at log $[SO_4^{2-}]$ = -2.3, log $[K^+]$ = -3.3, log $[Fe^{2+} + Fe^{3+}]$ = -5 and 1 atm total pressure. (Derived from van Breemen, 1972).

This leads to a decrease in the pH of the soil system when it is devoid of $CaCO_3$ deposits.

As the figure 58 indicates basically two processes may occur:

(a) When oxygen enters the soil relatively slowly the pH is also lowered slowly, the ferrous iron produced according to the above reaction are oxidised into ferric hydroxides. As the pH continues to decrease under oxidative (aerobic) conditions the ferric hydroxides are transfomed into jarosite.

$$3\ Fe(OH)_3 + K^+ + 2\ SO_4^{2-} + 3H^+ \longrightarrow KFe_3(SO_4)_2(OH)_6 + 3\ H_2O$$

The sulphate ions necessary for this reaction originate from the first reaction, the potassium ions may be derived from the soil solution and/or soil complex. When the hydrogen ions are removed by percolation the jarosite is hydrolyzed into relatively immobile ferric hydroxides (above reaction in the reverse direction). The potassium and sulphate ions are removed by percolation. The final ferric hydfroxides occur in other places than the original pyrite. This follows from the fact that ferrous and ferric compounds present before the formation of jarosite, occur at low pH levels and consequently are mobile in solution. The ferric hydroxides formed from jarosite, however, occur at relatively high pH levels and are relatively immobile. Thus there are mobile and immobile ferric hydroxides, the former formed from pyrites and the latter from jarosite.

(b) During dewatering and dry fallow situations and also during ebb tide the oxygen enters the soil system fairly quickly and the pH is lowered rather abruptly. The system is not in

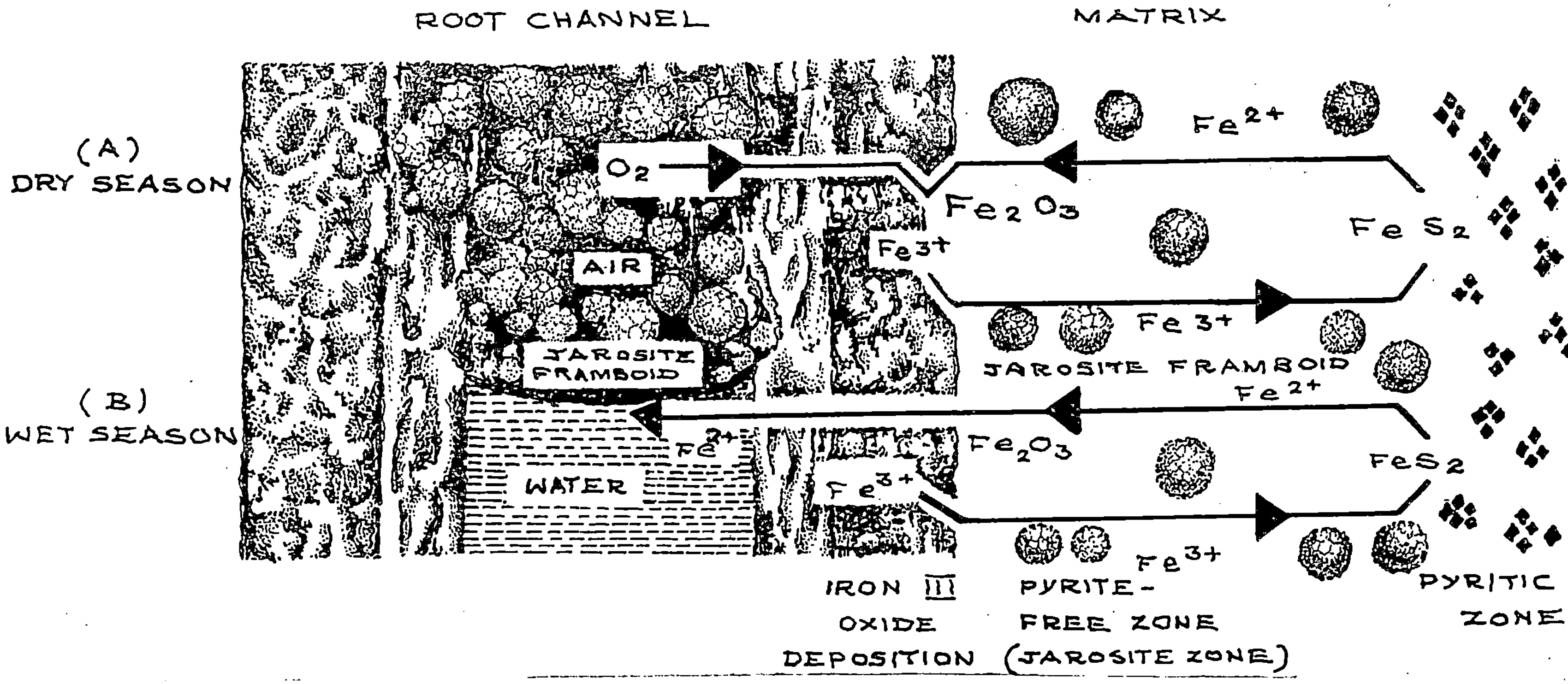


Figure 57 Model of pyrite oxidation taking place in the root channel in an acid sulphate soil (Modified after van Breemen 1976)

a) During the dry season, Oxygen diffuses into the soil through the pores and fissures. Fe^{2+} ions in solution are oxidised to Fe^{3+} ions which remain partly in solution and partly get precipitated. At low pH, some Fe^{3+} remains in solution, diffuses to the pyrite surface where it is again reduced to Fe^{2+}, liberating acidity. Fe^{2+} diffuses back towards the oxidation from where it is again oxidised, liberating more acidity. This process thus continuously make the system a proton source.

b) Some oxidation of pyrite can continue under acid, waterlogged conditions, using the reserve of iron III oxides. In this case, Fe^{3+} ions function as the intermediate electron acceptor permitting oxidation of pyrite to jarosite and finally to liberation of free sulphuric acid. This system function as a proton source.

equillibrium and formation of jarosite occurs at the same place as the original pyrite. The jarosite finally is transformed into ferric hydroxides as the hydrogen ions are removed by percolation under oxidative conditions. The SEM observations on the framboidal pyrites indicate an inner core of pyrite with outer ring of jarosite with an intermediate in between region of ferric hydroxide (plate 107). This zonation of the products of pyrite oxidation are black coloured inner core of poly crystals with outer coating of white coloured jarosite and an in between region of grey coloured ferric hydroxide under SEM (plate 107).

At the walls of the root channels the ferrous ions are oxidised to the ferric hydroxides (Figure 57 and plates 111,112). This is followed by the movement by diffusion of ferrous ions from the surrounding ground maass to the walls of the root channel. This results in the process of the formation of neoferrans and iron impregnated wood fossils. This process has not been active and long enough in all locations to lower the pH to such a level in the field that appreciable amounts of jarosites could be formed. Ferric hydroxide occurring as neoferrans are consequently dominant in these soils. The neoferrans present in these locations have been transformed either totaly into neojarositans or partially into neoquasijarositans. The irregular bodies of jarosite containing skeleton grains and wood fossils remain at all locations especially at Vyṭilla (Plates 77 to 84) and Kattampally (plates 93 to 100) can be assumed to have been transported mechanically as pieces of neojarositans at or near the surface horizons of these profiles.

Along the most aerated voids and sandy pockets these processes proceed with greater intensity than the surrounding ground mass. This may be the reason for the wavy boundary observed in the lower horizons of these soils in the field. In the voids this type of tonguing phenomenon may occur which result from the rapid oxidation of pyrites and consequently rapid pH lowering. The jarosite formation with pyrite nucleus observed in these soil is by insitu formation by a rapid oxidation. It may happen during sudden drainage of ground water as is observed at Karumadi subsurface horizons. The occurrence of gypsum in the suface horizons of these soils are due to the reaction of free sulphuric acid formed with $CaCO_3$ applied in experimental fields where profile studies were conducted at Karumadi (Plate 117). Goethites formed in and out of the voids in these soils especially as Moncompu (plates 30 to 33 and 61 to 68) and Karumadi (plates 26 to 29 and 53 to 60) might have been formed from the amorphous ferric hydroxides by dehydration according to

$$6\ Ca^{+} + 6\ SO_4^{2-} + 12\ H_2O \longrightarrow 6\ CaSO_4.2H_2O$$

The goethite is found in the larger channels. The initial stages of pyrite oxidation operating in these soils thus appear to be through the following reactions:

1. $3\ FeS_2 + 6\ H^{+} + 10\frac{1}{2}\ O_2 + 3\ H_2O \longrightarrow 3\ Fe^{2+} + 12H^{+} + 6\ SO_4^{2-}$
2. $12\ Fe^{2+} + 30\ H_2O + 4\ O_2 \longrightarrow 12\ Fe(OH)_3 + 24\ H^{+}$
3. $6\ CaCO_3 + 12\ H^{+} \longrightarrow 6\ Ca^{2+} + 6\ H_2O + 6\ CO_2$
4. $6\ Ca^{2+} + 6\ SO_4^{2-} + 12\ H_2O \longrightarrow 6\ CaSO_4.2H_2O$

In this context it is noteworthy that in the kayal and kaipad lands (Mathikayal and Kattampally), there are lacustrine deposites of calcium carbonate in the form of molluscan shells in the fourth horizon. Pyrrohtite and pyrite framboids occur closely and at times on the $CaCO_4$ shells.

When oxygen enters the pyrite containing calcareous horizon that is when the gound water level is lowered, the pyrite is expected to be oxidised.

$$3\ FeS_2 + 6\ H^+ + 10\tfrac{1}{2}\ O_2 \longrightarrow 3\ Fe^{2+} + 12\ H^+ + 6\ SO_4^{2-}$$

Situations like this are likely to occur in completely bunded areas like the R block in Kuttanad in summer where the ground water level could get lowered to a level below the calcareous deposits. However, both at Mathikayal and Kattampally at the time of study the calcareous layer were just above the ground water level (plate 3,6,51,52,99 and 100).

The oxidation reactions (1) and (2) in a calcareous environment do not give rise to a lowering of pH. However the calcareous fourth layer has a soil which is highly acidic and non reactive with the lime shells. In view of this though under the conditions of liming in the surface layers formation of gypsum by the reaction with the H_2SO_4 produced from reaction (1) take place (plate 117) in the fourth horizon at Mathikayal, the reaction between the $CaCO_3$ molluscan shells and the H_2SO_4 does not appear to take place (plates 11,12,21,22,25,51,52,99 and 100). Attempts to locate gypsum crystals in thin section of soils from the fourth horizon has not succeeded. Further in the fourth horizon though framboids of ferric hydroxide as the oxidation product have been located jarosite framboids have not been located.

34. **Soil Genesis and Weathering**

The 'n' values of all the locations reveal that these soils are half ripe to ripe acid sulphate soils or soils with a reserve pyrite accumulation in the subsurface horizons. Comparatively the ripeness of these soils are of the increasing order at Karumadi < Moncompu < Mathikayal < Vytilla < Kattampally and < Kattukambal. It indicates that except at Kattukambal all these soils have reserve of pyrites in the subsurface horizons as confirmed by the earlier discussion on pyrite accumulation by microscopic morphological observations. This may lead to continuous progressive potential acidity problems in these soils in the years to come which cannot be neutralised even with several tonnes of liming materials. Water management and flushing with rain water in the rainy season and maintaining the waterlogged state in summer are some of the acidity alleviating measures. More than 90 percentage of pyrite framboids are < 2 μm sized, irrespective of locations (Table 11 and plates 57,60,69,72,74,79,82,83,102 to 112, 115 to 117,122 to 124, 128,129,134,137 to 154). As the pyrites are finer they enter the oxidation process more easily than when they are larger sized the more easily the release of free mineral sluphuric acid and consequently their management more difficult. Further these microframboids are seen to be associated with wood fossils (Plates 57,58,67,69,72 and 74) and root channels (plates 111,112) and soil channels (Plates 79,82). It is to be noted that these microframboids of pyrites observed in these soils have a size of less than 2 μm as compared to 50 μm reported in the majority of the acid sulphate soils of the world.

Finer fractions (silt + caly) and angularity of their grain as revealed by microscopic studies indicate that the soils are formed from soil deposition in the recent geological past. The differential accumulation of fossil wood and fauna are indicated due to the statification observed in these soils.

From the data and observations in the present study there are indications to assu me that inspite of variations in the locations the genetic pattern of the development of these acid sulphate soils is similar with microvariations.

Another important observation noticed in this study is the presence of free silica as diatomaceous materials of different shapes like coloured and colourless transparent spicules, oval platy structures, and flaky structures.

Among the oxidation products of these soils lepidocrocite (Fe-O-OH) was the specific form of ferric hydroxide noticed. It is an intermediate oxidation product during the oxidation of pyrite to jarosite.

Another important specific observation noticed in the present investigation is the formation of authigenic euhedral quartz. Gypsum formation in the surface horizon at Karumadi and Vytilla are also the result of lime application in the experimental fields where these investigations were conducted.

The pedognesis started with stratification of coarse structured sediments followed by soil sediments over it with lesser stratification with fossil and faunal shells and faecal pellets. This is followed by acretion of sediments by elluviated materials. During these sedimentation phases, formation of channels, neocutans, biological homogenisation, accumulation and stratification of wood fossils, pyrite accumulation, partial oxidation and precipitation of Fe as ferric hydroxides occurs. These are some of the sequential and simultaneous pedogenic processes operating in these soils.

In the brackish water phase pyrite accumulation, mass eluviation and slow eluviation are the major pedogenic processes operating. During this phase part of the pyrite oxidation and continuation of oxidation and precipitation of Fe as ferric hydroxides occurs. They crystallise into goethite. Pyrite becomes finally oxidised resulting in the formation of jarosite, gypsum, silica and ferric hydroxides.

Though the saline sea water ingression and higher acidity and soil reduction are the major forces operating in these soils, from the soil development point of view their operation is significant only in the surface horizons. Some of these processes have lesser influence in the development of the lower horizons.

35, Soil Classification

As per the informations gathered during the study an attempt is made to classify these soils as per ILRI system (Dent, 1986), Soil Taxonomy (USDA 1975) ORSTOM Classification (Segalen, 1979) and as per FAO/UNESCO Soil Map of the World Legned (FAO/UNESCO 1974).

35.1 ILRI System of Classification

As per the ILRI nomenclature, the acid sulphate soils of Kerala can be classified as:

At Kattukambal the soil profiles are classified as ripe clay

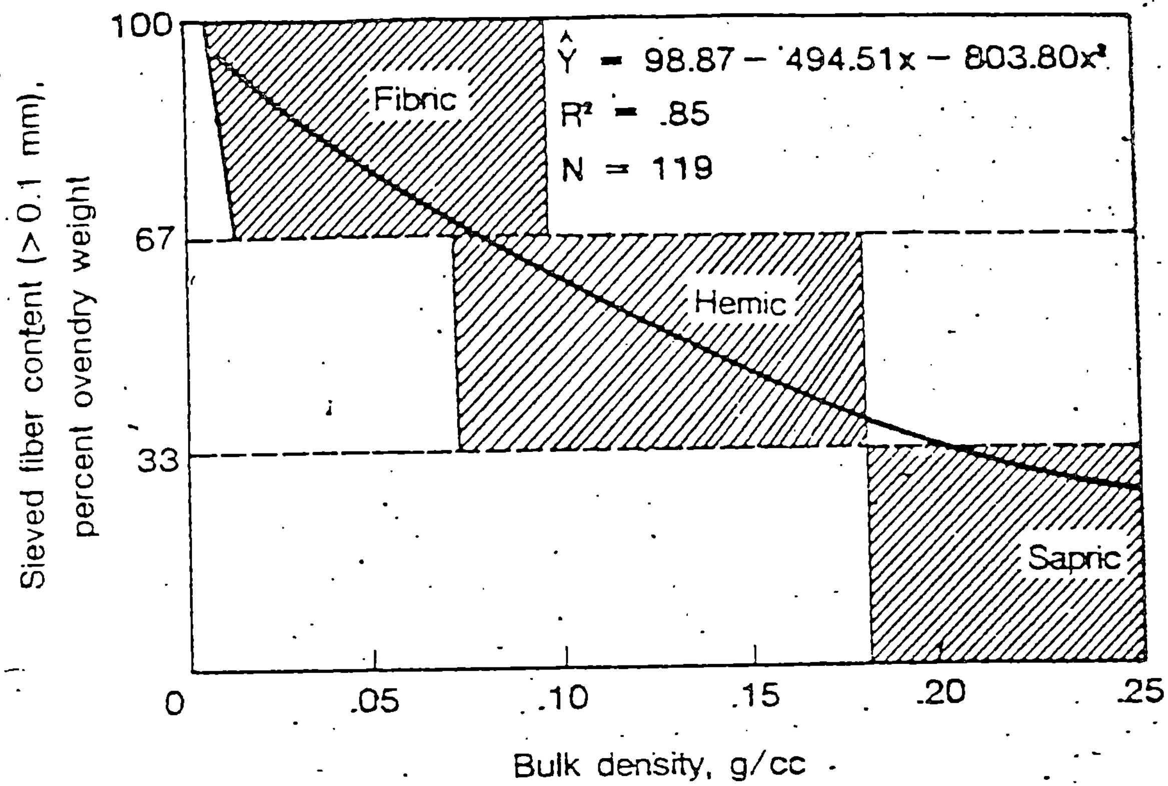


Fig. 5 9. Bulk density as a function of fiber content. Ranges given in Soil Taxonomy (Soil Survey Staff, 1975). (Modified from Boelter, 1969.)

with acid sulphate subsoil. The profiles at Karumadi Moncompu and Kattampally is unripe, saline, sulphidic clay and they come under the principal soil groups of potential acid sulphate soils. While the profiles at Mathikayal and Vytilla are ripe, sulphidic sand in the ILRI system of soil classification. They are classified in the principal soil groups of potential acid sulphate soils.

35 .2. Soil Taxonomy (USDA, 1975)

Though the content of sulphidic sulphur (organic) in all these soils are less than 0.75 per cent, their change in pH due to H_2O_2 oxidation recognised all the locations as potential acid sulphate soils in the increasing order Kattukambal $<$ Kattampally $<$ Mathikayal $<$ Vytilla $<$ Moncompu and $<$ Karumadi. At Karumadi as per Soil Taxonomy the soil profiles are classified as sulphosapric though the content of organic matter is less than 30 percent with the presence of sapric fetures. The observed feature in the present is not hemic as reported by Bhargava and Abrol (1984) for Ambalapuzha location of Kerala but is sapric as revealed by the relationship between the bulk density and partially decomposed fibre material content of the soil (plates 55 to 59 and figure 59).

At Moncompu, the soil profiles are classified as sulfaquents while the soil at Mathikayal and Vyttilla are classified as sulfofluvaquent. At Kattukambal the soil profile are clayey in nature in the subsurface horizons with acid sulphate subsoil and is classified as Sulfic Tropaquepts.

35 .3. ORSTOM Classification (Segalen, 1979)

As per the ORSTOM Classification all the soil profiles of acid sulphate soils investigated can be classified as Thiosols though they do not satisfy the requirement of total sulphur content.

35..4. FAO/UNESCO Soil Map of the World Legend (FAO/ UNESCO, 1974)

As per this system all the soil profiles studied can be classified as Thionic Fluvisols, though they do not satisfy the requirement of total sulphur content.

As per the suggestion of Brinkman and Pons (1973) a tentative limit for dangerous acid sulphate soil is soils with pH 2.5 after H_2O_2 treatment. In the present study at all locations the pH after H_2O_2 treatment is below 2.5. for a depth up to 50 cm. It can be suggested that the acid sulphate soils of Kerala along the West coast are dangerously acid sulphate soils. The earlier discussions and present attempt on classification has generalissed that these soils have reserves of fine pyrites. The lime requirement to bring these soils to a pH suitable for growing arable crops and fish culture is normally prohibitive and the pyrite willl continue to generate mineral sulphuric acids over many years.

Soil Taxonomy classifications of these soils were attempted earlier by Bhargava and Bhattacharjee (1982) and Bhargava and Abrol (1984). In the present study it is seen that in the majority of soil profiles no typical sulphuric horizon is observed. Though in these profiles jarosite mottles are present they are masked/buried in the subsoils by the cambic epipedon, especially at Kattukambal and Vyttilla. Though on the basis of the sulphur content and the requirement of sulphuric horizon these soils cannot be called as

'Acid Sulphate Soils', its pH change on the H_2O_2 oxidation and attainment of pH 2.5 to qualify them as dangerously acid sulphate soils (Brinkman and pons 1973). Though they do not have a sulphuric horizon they do have sulphidic materials within a depth of 50cm. The present day occurrence of a layer of ochre on the ped faces up to a depth of about 30 to 50 in the Moncompu soils indicates their possible role as an electron aceptor in the oxidation of pyrites.

Pyrite (cubular FeS_2, hexagonal pyrrohtite FeS) its oxidation products, jarosite and intermediate products, ferric hydroxide and gypsum are all present dominant in the fossil woods, roo t channels and as free as cutans in the margins of voids (channels and chambers) and skeletons. This has been observed at all levels of microscopic morphological examination of soils. This confirmed the close association between iron oxide coatings of organic matter in particular and root channels and fossilised wood remnants with formation of pyrites in it. This has been observed within 50 cm and upto a depth of 90 cm. This association is due to the physicochemical relationship among these constituents. Below 50 cm depth, as already mentioned the jarosite framboids retain their pyrite nucleus indicating incomplete oxidation of pyrite framboids to jarosite framboids. Pyrite and jarosite present in the plant tissues and lime shells are dominatly framboidal followed by cubular crystals. SEM studies clarly revealed the polycrystalline framboidal feature of pyrite and jarosite present in association with iron coated fossilised wood remains.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

In Kerala saline and acid sulphate soils occur along the West coast occupying an area of 0.2 million hectares in marshy depressions on the fringes of lagoons, and flood-plains of rivers especially near estuaries and deltas. They are locally known as kari, karapadom, kayal, pokkali, kole and kaipad soils based on soil factors or location or type of cultivation practiced. They represent the major acid sulphate soil environment of the Kerala region. Earlier work on these soils gathered information on their morphology, chemistry, agronomy and microbiology. No specific information on the comparative morphological characteristics of these soils, and micromorphological variations, location of centres of acidity or proton sources in the soils and their genesis had been made earlier in relation to evolving suitable methods of management. Though reports on the possible existence of pyrites had been conjectured no demonstration of their actual presence, estimate of quatities, morphology, and transformations to various iron compounds like ferric hydroxides, jarosites, etc had been made earlier. Comparison of their characteristics with other acid sulphate soils around the globe had also not been attempted. For filling up this objective a well integrated study was undertaken on the stage by stage morphology, physico-chemical and mineralogical properties of the acid sulphate soils of Kerala taking two soil profiles each from Karumadi, Moncompu, Mathikayal, Vyttilla, Kattukambal and Kattampally along the West coast. The salient observations and conclusions of the investigations conducted are as follows:

1. The major geological formations of the acid sulphate soils along the West coast of Kerala are the Warkalli formations followed by lateritic hills and hillocks. At places the Warkalli formations lie over fossil lime stone and lignite strata.

2. The natural mangrove vegetation in and around the acid sulphate soils are dominantly *Rhizophora* sp., *Avicennia* sp. and *Sonneratia* sp. and even *Bruquiera* sp. with associated brackish water vegetation of *Acrostichum*, *Acanthus* sp. and fresh water vegetation of *Phragmites*, *Typha* and *Scirpus* taxa.

3. Rice is the agricultural crop of choice for these regions. Floods, saline water intrusion, soil acidity, Al and Fe toxicity are some of the major hazards to agriculture in this region.

4. The drainage of this region is poor, water logging compounded by ingression of sea-water during high and ebb tides makes the soils moderately saline.

5. Wide variation in field morphology was noticed in the acid sulphate soils at different locations in the State. Soil colour ranges from dark yellowish brown to black with intermediate colours of greyish brown and very dark grey.

6. The soil texture ranges between silty clay loam and clay with intermediate texture of clay loam. Surface horizons are coarser while the lower horizons are finer and compacted. Surface horizons are structureless to weakly structured due

to continuous rice cultivation, while the subsurface horizons have coarse prismatic to subangular blocky structure.

7. Sesquioxide concretions and lateritic nodules of hue 5 YR and 7.5 YR are observed in all the epipedons and horizons lower to it. Partially decomposed wood fossils under different stages of decomposition are present in abundant quantities as homogenised or as a stratified layer. They are intensely coated with iron oxide.

8. Jarosite mottles or a layer of enriched jarosite mottles are found within 50 cm from the surface. Its thickness ranges from 6 to 50 cm. The colour of the mottles is pale yellow with 2.5 Y hue and less than 6 value and chroma. Wetness, high soluble salt concentration and coating of finer opaques and coloured grains of colloidal sized material mask their identification in the field. Such a mottled enriched jarosite rich horizon is buried to subsurface layers by other epipedons like cambic epipedon and umbric epipedon, etc. Thus though sulphuric horizons are absent, sulphidic materials are present up to a depth of 50 cm. A sulphuric horizon of jarosite material typical of acid sulphate soil could not be observed in any of the locations.

9. Dark grey to black soil matrix colour is observed due to the presence of abundant quantities of fossil wood, opaque minerals admixed with quartz. The predominant soil matrix colour of hue 2.5 Y indicate the reduced and gleyed nature

of the soil. The dominance of the hue 5 YR, 7.5 YR, 10 YR for soil mottles, laterite nodules and concretions indicate alluviation of lateritic soil material from the midland region of Kerala.

10. Size, shape and frequency analysis of soil fractions (skeletons) indicate the formation of these soils with recently deposited fine sediments after a short distance of alluviation.

11. Size and frequency of wood fossil, skeleton distribution and presence and nature of horizon boundaries leads one to conclude the sequential nature of the deposits. Micromorphological studies revealed the admixed relic features of fauna and their faecal materials, reveal the earlier role of fauna as a soil homogenising agent.

12. The nature, composition, and deposition of whole soil coatings and colloidal sized clay and cutanic coatings, matrix anisotropism etc indicate the role of mass flow of water from the surface to ground water, sudden drainage of ground water, slow movement of percolating water and the direction of such moving water in soil development.

13. Compaction, presence of composite prismatic sub angular blocky structure and presence of illuvial cutans in lower horizons indicate active slow percolation, at times disrupted, and at times the activated leaching of clay and colloidal sized materials.

14. Abundant quantities of partially decomposed fossil wood and root channels under different stages of decomposition in association with pyrite and pyrrohtite and its oxidation products are present. Presence of partially decomposed wood fibre in all soil fractions, organan and ferriorganan observed in association with soil skeletons established the parent material like role of wood fossil in soil formation and development.

15. High shift in acidity on air drying and H_2O_2 treatment of the soils and similar shift in EC on air drying has been observed. The finer nature of the framboidal pryrite and pyrrohtite ($< 2\ \mu$) indicate easy oxidation of these sulphidic materials to free sulphuric acid and subsequent ionisation resulting in the release of H^+ and SO_4^{2-} accounting for the shift of both pH as well as electrical conductivity.

16. The soils in general have a high total and exchangeable Al, high total, exchangeable and active Fe.

17. High Cation Exchange Capacity, Effective Cation Exchange Capacity, percent Al saturation of the effective CEC are all indicative of the role of organic matter and 2:1 type of clay minerals on CEC. Aluminium plays a significant part in the exchange complex in storing the high acidity generated.

18. Iron sulphide is present as cubular and framboidal pyrite primary, secondary, and tertiary pyrite along skeletons as neojarositans and neoquasijarositans and pyritan while the

framboidal iron sulphide is present in the root channels dominantly as pyrrohtite (FeS).

19. The oxidation products of pyrite and pyrrohtite are Ferric hydroxide, jarosite and gypsum in non-calcareous acid horizons while in the calcareous horizon the oxidation of pyrite to ferric hydroxide with little further oxidation to jarosite is noticed. Calcium Sulphate and jarosite are noticeably absent due to various reasons like lesser acidity, non reactivity of $CaCO_3$ shells with acidity produced etc.

20 Lepidocrocite is the form of ferric hydroxide noticeable in these soils followed by usual oxidised product of pyrite and jarosite viz. goethite (ferric hydroxide). The observation of lepidocrocite confirm the chemical possibility of the existence of iron sulphide as framboidal pyrrohtite than pyrite as observed in fossil root channels under SEM.

21. Free silica is present in the surface horizons of these waterlogged acid sulphate soils as different forms of diatomaceous materials like colourless and coloured (blue) transparent, spongy spicules, oval platy structures and flaky mica like strutures indicating a conducive milieu for its habitation. Authegenic formation of euhedral quartz is also noticed.

22. Type and shape of sand and silt minerals suggest the uniformity of parent material (material) of these deposits and their recent deposition after a short distance of alluviation. Sedigraph analysis of finer fractions exhibit constancy

in the frequency of occurrence of sub size fraction in all these soils. The higher content of pyrites in the silt fraction and clay fraction establish the finer nature of pyrite present in these soils as confirmed by their SEM analysis.

23. Lateritic nodules and concretion, relic lateritic cutanic materials present in the sand and silt fraction and in the polished block and thin section with bright colour, angular to sub-angular shape with sharp margins are indicative of the alluviation of lateritic fells and their influence in the pedogensis of these soils.

24. Clay mineral analysis by XRD and TGA indicated the dominance of non-clay fraction like mica quartz, followed by predominence of clay mineral of kaolinite type followed by minor amounts of other type of minerals which include chlorite, chloratised smectite, illite and vermiculite. Minor amounts of feldspars, amphiboles, pyroxene, goethite and gibbsite were also observed. The presence of pyrite, pyrrohtite, jarosite and wood fossil fibre in the clay has been revealed by the SEM analysis of clay. The SEM analysis of silt and clay established the preponderance of quartz and minor amounts of ilmenite.

25. The chemical transformation of pyrite at low pH ranges in waterlogged situations under mild aeration to ferric hydroxide and then to jarosite has been indicated. Under abrupt aerobic situations with a quick drop of pH, pyrite is oxidised to

jarosite in the place of the original pyrite (jarosite with retained pyrite nucleus) which finally is transformed to ferric hydroxide. Transformation of pyrite to ferric hydroxide stage alone is observed in the $CaCO_3$ shell layer with the absence of $CaSO_4$ formation. This may be due to non-reactive nature of the $CaCO_3$ shells.

26. The 'n' value of these soils revealed that all of them are half to full ripe acid sulphate soils.

27. The pedogenesis of these soils started with the stratification to fossil fauna, fossil wood, and pyrite which now exists as the lowest layer. Above this are found some of the lesser stratified sediments and actively tranformed and translocated relics of organic matter, pyrite and colloidal sized products. Superimposed on this are the structureless, disturbed, coarser surface soil sediments, recently deposited.

This study on the genesis, physico chemical and mineralogical properties of the acid sulphate soils of Kerala, has enabled them to be placed as a class separate from other reported typical acid sulphate soils from the rest of the world. Thus these soils are now recorded to be more dangerously acid sulphate than others though they do not satisfy either the total sulphur or the presence of typical sulphuric horizon. Further the pyrite framboids have a size range of only 1/25th of the framboids reported elsewhere from the globe. This has made them much more dangerously acid. All the same, they require to be placed as soils with sulphidic materials rather soils with sulphuric horizon as per Soil Taxonomy(USDA, 1975). Nevertheless, the fact remains that these soils are highly acidic with considerable amounts of reserve pyrites and hence reserve acidity. These soils call for utmost care in their management. The acid sulphate soils of Kerala, are thus to be continuously managed under a waterlogged milieu to enable optimum productivity with minimum problems due to acidity and related aspects. The possibility of growing perennial crops such as rubber and oil palm in these require partial to fully aerobic situations. These conditions are likely to result in oxidation of the pyrite laden layer generating enormous quantities of free sulphuric acid. The pyrite laden layer extends up to 90 cm in the present study.

The acid sulphate soils of Kerala are definitely different from the Malaysian acid sulphate soils in that the surface layer is not completely free of pyrites. In view of the fact that the surface soil contains only jarosite and no pyrites the Malaysian acid sulphate soils have been subjected to cultivation with oil palm and rubber. However, the Malaysian experience cannot be transplanted as such to Kerala in view of the very serious initial problems likely to be thrown off by the generation of acidity by the oxidation of pyrites under aerobic situations.

Being half to unripe, the acid sulphate soils of Kerala are still dangerously acid as to warrant the continuation of the existing management practices and cropping systems.

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APPENDICES

Appendix I

Mean Values of Physico-Chemical Properties of the Acid Sulphate Soils

Sl. No.	Soil name, location / Property	Kari soil Kerumadi				Karapadom soil Moncompu				Kayal soil Mathikayal				Pokkali soil Vytilla				kole soil Kattukambal				kaipad soil Kattampally				CD for soils	CD for horizons
		h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4	h1	h2	h3	h4		
1.	Coarse sand %	1.55	1.70	1.60	1.85	16.5	16.5	3.85	1.75	1.15	1.50	1.10	0.53	12.55	7.90	2.50	1.65	12.00	8.75	7.90	12.50	13.85	15.85	7.05	12.40	1.08	2.17
2.	Fine sand %	6.90	5.20	7.15	11.80	24.85	24.00	3.50	2.95	50.70	53.15	54.85	55.70	16.15	13.35	11.10	14.95	12.70	11.30	11.75	12.75	23.30	29.60	15.15	14.65	1.58	3.16
3.	Silt %	27.15	25.75	26.70	28.20	17.50	16.30	27.50	27.65	18.95	17.70	13.95	12.40	21.00	23.05	22.05	20.90	24.65	25.1	28.90	23.75	23.80	17.25	17.90	20.75	1.99	3.98
4.	Clay %	51.80	52.90	47.60	43.80	28.35	32.00	56.50	62.15	27.65	26.30	29.15	28.70	44.00	55.10	56.80	59.80	49.75	50.90	50.80	50.10	31.50	34.75	48.55	49.30	1.80	3.61
5.	Partially decomposed wood %	12.60	14.45	16.95	14.35	13.15	9.05	8.65	5.50	1.55	1.35	0.98	1.35	6.80	0.95	7.55	3.15	9.90	1.05	0.65	0.40	1.55	2.55	11.35	3.40	2.11	4.22
6.	Fine sand/Corse sand	4.45	3.05	4.50	6.40	1.50	1.25	0.91	1.85	44.65	35.40	50.25	131.85	1.30	1.75	4.55	9.15	1.08	1.80	1.50	1.05	2.10	1.85	2.20	1.20	18.04	36.09
7.	Silt/Clay	0.53	0.49	0.56	0.64	0.62	0.51	0.49	0.45	0.69	0.68	0.48	0.43	0.48	0.42	0.39	0.35	8.49	0.49	0.57	0.47	0.76	0.49	0.37	0.43	5.45	0.11
8.	Clay ratio	0.69	0.62	0.75	0.96	2.10	1.85	0.62	0.53	2.55	2.75	2.40	2.40	1.12	0.81	0.63	0.63	0.99	0.89	0.96	0.98	2.14	1.79	0.84	0.97	9.27	0.19
9.	% aggregates more than 0.25 mm	52.10	49.65	56.15	52.90	52.75	55.00	53.00	58.20	57.80	59.25	58.75	57.65	60.00	58.45	58.85	58.70	57.70	58.90	59.15	68.00	55.20	55.45	54.60	58.55	1.80	3.60
10.	Stability index	8.00	8.89	7.20	9.45	7.05	6.35	6.30	5.85	5.65	5.55	5.30	5.00	5.90	6.70	5.70	5.50	5.55	5.55	5.70	6.05	5.55	6.35	6.95	6.35	0.80	1.60
11.	Organic matter %	13.40	17.90	6.95	11.80	11.45	8.70	6.10	6.10	1.40	1.30	1.15	0.85	4.0	3.85	3.70	3.15	2.25	1.90	1.70	1.05	2.95	6.20	8.70	8.70	0.34	0.68
12.	Moisture retained at 0.3 bars (%)	5.95	5.55	6.25	9.39	13.60	16.9	11.30	10.75	25.10	26.10	30.00	25.45	17.55	16.90	17.75	15.20	22.55	19.45	20.85	15.50	23.40	24.30	19.95	16.25	1.18	2.35

Appendix I

Mean Values of Physico-Chemical Properties of the Acid Sulphate Soils

Sl. No.	Soil name, location / Property	Kari soil Karumadi h1	h2	h3	h4	Karapadom soil Moncompu h1	h2	h3	h4	Kayal soil Mathikayal h1	h2	h3	h4
13.	Moisture retained at 15.0 bars (%)	5.40	3.55	5.55	8.10	12.55	15.80	8.85	8.65	22.65	22.90	26.90	24.75
14.	Available water(%)	0.55	2.00	0.70	1.30	1.05	1.10	2.45	2.10	2.45	3.20	3.90	0.70
15.	Wet soil pH(H_2O)1:1	2.90	2.55	2.55	2.45	4.0	3.65	3.00	2.90	3.90	3.15	3.05	3.10
16.	Air dried soil pH (H_2O) 1:1	2.40	1.95	1.95	2.25	3.00	2.35	3.90	3.10	3.35	2.60	3.70	3.25
17.	Air dried 30% H_2O_2 treated soil pH 1:2	1.70	1.65	1.40	1.45	2.40	2.05	1.80	1.55	2.10	1.85	2.35	1.95
18.	Wet soil EC mS Cm^{-1}	6.80	11.95	8.75	10.25	1.55	2.14	3.35	4.50	1.19	2.14	2.50	2.72
19.	Air dried soil EC mS cm^{-1}	8.00	12.30	10.40	13.40	0.44	2.08	4.70	6.85	0.87	2.49	2.71	4.55
20.	Soil pH ($CaCl_2$) 1:2	2.70	2.25	2.45	2.35	3.00	2.15	3.70	3.15	3.90	2.30	2.90	3.20
21.	Redox pottential(Eh) (mV)	+497.50	+517.50	+520.00	+540.00	+492.50	+415.00	+512.50	+520.00	+477.50	+495.00	+510.00	+485.00
22.	Organic carbon %	7.75	10.35	4.00	6.80	6.60	5.05	3.50	3.50	0.80	0.75	0.60	0.50
23.	Total Fe_2O_3 %	10.75	11.15	11.75	12.55	7.25	7.60	8.10	8.45	6.50	6.90	7.65	75.55
24.	Total Al_2O_3 %	11.80	12.45	12.35	11.85	8.75	9.75	10.60	10.85	8.60	8.80	8.70	9.20
25.	Sesqui oxide %	22.55	23.60	24.10	24.40	16.00	17.35	18.70	19.30	15.10	15.70	16.35	16.75
26.	Exchangeable Al. Cmol (p^+) kg^{-1}	17.80	17.75	17.35	18.50	5.25	6.35	6.50	6.40	4.05	4.55	5.00	4.75

Sl. No.	Soil name, location / Property	Pokkali soil Vytilla h1	h2	h3	h4	kole soil Kattukambal h1	h2	h3	h4	kalpad soil Kattampally h1	h2	h3	h4	CD for soils	CD for horizons
13.	Moisture retained at 15.0 bars (%)	16.55	14.55	16.75	13.90	16.65	15.25	16.40	12.80	17.55	21.15	34.40	12.65	5.13	10.26
14.	Available water(%)	1.00	2.35	1.00	1.30	5.90	4.2	4.45	2.40	5.70	3.00	3.55	2.60	0.61	1.21
15.	Wet soil pH(H_2O)1:1	2.90	2.50	3.20	3.45	4.45	4.55	4.40	4.50	3.50	4.35	4.05	6.15	0.28	0.56
16.	Air dried soil pH (H_2O) 1:1	2.75	2.70	2.60	2.85	3.85	3.85	3.65	3.70	2.80	3.55	3.05	3.85	0.23	0.47
17.	Air dried 30% H_2O_2 treated soil pH 1:2	1.70	1.70	1.80	1.55	2.25	2.20	2.55	2.35	2.10	1.75	2.05	3.00	0.24	0.47
18.	Wet soil EC mS Cm^{-1}	6.05	6.60	7.10	7.05	0.64	0.29	0.31	0.37	2.58	2.03	2.34	4.20	0.63	1.26
19.	Air dried soil EC mS cm^{-1}	7.10	8.00	10.40	8.35	0.52	0.50	0.34	0.41	3.11	3.14	3.45	6.45	0.73	1.45
20.	Soil pH ($CaCl_2$) 1:2	2.35	2.35	2.15	2.25	3.30	3.55	3.35	3.95	2.10	3.30	3.05	5.65	0.35	0.70
21.	Redox pottential(Eh) (mV)	475.00	+490.00	+490.00	+480.00	+455.00	+452.50	+445.00	+515.00	+480.00	+487.50	+485.00	+450.00	16.97	33.93
22.	Organic carbon %	2.20	2.10	2.45	1.90	1.10	0.98	0.81	0.71	1.90	3.50	5.85	5.05	0.25	0.51
23.	Total Fe_2O_3 %	4.25	4.75	4.35	4.30	3.45	3.65	5.95	5.35	6.40	5.50	6.05	4.90	0.40	0.80
24.	Total Al_2O_3 %	4.90	5.30	5.45	5.10	4.70	4.60	6.20	4.35	5.55	6.50	6.60	4.50	0.43	0.86
25.	Sesqui oxide %	8.85	10.05	9.80	9.39	8.15	8.25	12.15	9.70	11.95	12.00	12.65	9.39	0.70	1.41
26.	Exchangeable Al. Cmol (p^+) kg^{-1}	5.30	3.40	3.45	4.55	5.60	5.10	8.00	8.39	8.05	4.90	4.55	4.85	0.79	1.57

Appendix I

Mean Values of Physico-Chemical Properties of the Acid Sulphate Soils

Sl No.	Soil name, location / Property	Kari soil Karumadi h1	h2	h3	h4	Karapadom soil Moncompu h1	h2	h3	h4	Kayal soil Mathikayal h1	h2	h3	h4
27.	Exchangeable Fe ppm	36.20	35.20	34.90	34.75	29.35	32.90	40.20	40.80	26.90	25.90	25.00	24.30
28.	Soil CEC Cmol $(p^+)\ kg^{-1}$	43.55	44.60	46.00	46.60	14.60	14.20	15.25	14.45	11.15	11.80	12.15	12.65
29.	Effective CEC Cmol $(p^+)\ kg^{-1}$	21.90	21.45	22.00	22.00	9.79	9.85	9.85	10.50	9.39	8.80	9.89	10.05
30.	Active Fe ppm	298.85	373.85	366.00	410.45	209.10	199.30	167.90	178.25	76.85	73.90	72.60	69.10
31.	Al. saturation of effective CEC %	81.30	81.75	78.85	83.50	53.30	64.35	65.85	60.90	42.90	51.55	50.45	47.10
32.	Total Sulphur %	0.28	0.34	0.18	0.24	0.26	0.21	0.18	0.16	0.06	0.05	0.52	0.46
33.	Sulphate Sulphur ppm	152.35	231.30	196.40	293.20	13.50	43.60	91.80	131.25	21.40	47.60	55.30	74.50
34.	Water soluble Sulphur ppm	187.20	279.45	238.70	303.05	31.75	66.05	115.85	162.55	34.08	68.85	73.65	113.15
35.	Organic Sulphur ppm	58.25	63.35	61.10	64.70	49.20	51.15	54.30	56.85	49.70	50.90	51.90	54.15
36.	Heat soluble Sulphur ppm	331.65	503.15	427.35	547.00	30.00	95.35	200.05	285.75	47.10	86.95	120.70	194.10

Sl No.	Pokkali soil Vytilla h1	h2	h3	h4	kole soil Kattukambal h1	h2	h3	h4	kaipad soil Kattampally h1	h2	h3	h4	CD for soils	CD for horizons
27.	39.75	36.30	39.95	37.60	35.90	36.70	35.60	34.55	28.95	28.40	34.60	31.75	2.35	4.71
28.	24.95	24.05	23.65	21.55	18.00	18.20	23.20	23.00	22.50	21.10	17.15	14.90	0.81	1.62
29.	16.15	14.90	14.50	12.05	11.00	10.35	11.55	13.25	13.05	12.70	11.60	10.85	0.77	1.54
30.	118.05	115.45	111.60	110.30	89.70	86.50	82.25	79.55	110.30	151.45	199.05	188.80	17.34	34.62
31.	32.70	43.50	23.75	37.75	50.95	49.35	70.45	63.15	61.65	38.80	39.40	44.70	8.30	16.59
32.	0.07	0.07	0.08	0.07	0.05	0.04	0.05	0.05	0.07	0.14	0.17	0.16	0.20	0.90
33.	135.85	152.40	196.40	156.0	15.10	14.75	11.70	13.05	59.65	63.10	68.85	123.90	20.32	40.64
34.	167.85	187.20	238.65	194.70	26.65	26.25	22.70	24.35	82.00	82.75	89.55	153.95	15.60	31.19
35.	57.15	58.20	61.05	58.65	49.30	49.30	49.00	49.15	52.35	52.40	52.80	56.35	0.91	1.82
36.	295.75	331.70	42.70	34.60	33.30	32.55	26.00	29.00	136.25	137.65	150.20	269.80	30.44	60.87

Appendix II

Mean values of physico-chemical and mineralogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu-kambal	Kaipad soil Kattam-pally	CD for soils
1.	Coarse sand minerology Quartz %	85.50	88.50	89.50	89.00	92.00	93.25	3.55
2.	Feldspars %	0.40	0.40	0.65	0.75	0.25	0.50	0.52
3.	Biotite %	0.15	0.10	0.40	0.35	0.05	0.40	0.30
4.	Magnetite %	0.18	0.20	0.30	0.30	0.65	0.30	0.16
5.	Ilmenite %	0.60	0.50	1.15	0.80	1.40	0.50	0.82
6.	Sillimanite %	0.65	0.90	1.25	1.10	1.65	1.75	1.04
7.	Rutile %	0.40	0.38	0.45	0.65	1.20	0.75	0.64
8.	Pyrite %	0.01	0.05	0.02	0.01	0.33	0.04	0.01
9.	Laterite nodule %	0.03	0.07	0.02	0.01	1.20	0.04	0.29
10.	Partially decomposed wood %	3.90	0.75	0.45	0.75	0.40	3.20	1.38
11.	Fine sand mineralogy partially decomposed wood %	75.55	10.00	2.95	3.65	0.85	1.70	8.70
12.	Light mineral %	88.25	96.65	82.25	87.80	88.10	75.35	5.09
13.	Heavy mineral %	11.75	3.35	12.75	7.20	11.90	24.45	8.32
14.	Fs/LF ratio	1.15	1.07	1.25	1.18	1.17	1.38	0.01
15.	FS/HF ratio	8.15	26.10	5.00	6.70	6.20	2.85	0.91

Mean values of Physico-Chemical and mineralogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD for Soils
16.	Fine sand/clay ratio	0.13	0.45	1.92	0.27	0.24	0.64	0.07
17.	Quartz %	10.15	80.65	82.78	80.80	48.65	83.95	18.64
18.	Feld spars %	0.07	0.45	0.90	0.55	0.04	0.47	0.77
19.	Biotite %	1.65	1.48	1.75	2.20	1.26	2.05	0.70
20.	Muscovite %	0.04	0.26	0.47	0.09	0.20	0.70	0.59
21.	Chlorite %	0.40	0.30	0.43	0.49	0.23	0.65	0.27
22.	Zircon %	0.03	0.13	0.05	0.09	0.45	0.99	0.19
23.	Ilmenite %	4.20	3.45	3.00	4.13	38.80	2.98	16.93
24.	Haematite %	0.07	0.10	0.88	0.73	1.59	1.36	0.46
25.	Sillimanite %	1.25	1.45	1.75	2.03	1.70	3.05	0.74
26.	Mona zite %	0.40	0.30	0.69	0.68	1.85	0.68	0.60
27.	Rutile %	0.15	0.24	0.37	0.28	0.93	0.65	0.30
28.	Garnet %	0.04	0.13	0.15	0.11	0.53	0.57	0.42
29.	Staurolite %	0.01	0.13	0.15	0.20	0.33	0.55	0.11

Mean values of Physico-Chemical and mineralogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD for Soils
30.	Tourmaline%	0.01	0.12	0.50	0.18	0.48	0.54	0.57
31.	Pyrite %	1.85	0.70	0.55	0.37	0.18	0.90	0.36
32.	Coarse sand	1.65	13.00	1.25	1.65	9.55	12.25	1.66
33.	Fine sand %	6.55	17.45	53.25	13.75	11.95	24.25	0.79
34.	Silt %	26.55	20.45	16.85	22.00	28.50	18.15	1.50
35.	Clay %	51.70	38.85	27.70	51.95	50.45	38.25	2.86
36.	Silt/Clay ratio	0.52	0.52	0.47	0.43	0.56	0.48	0.23
37.	Silt/coarse sand ratio	10.10	1.40	7.06	2.05	2.60	1.13	12.78
38.	Silt/fine sand ratio	10.05	1.35	6.78	2.49	2.75	1.12	12.57
39.	Fine sand mineralogy partially decomposed wood %	7.30	3.90	2.55	3.05	0.95	4.90	1.61
40.	Quartz %	49.65	49.50	57.05	49.25	56.75	50.25	6.44
41.	Feldspar %	0.19	0.35	0.60	0.95	0.04	0.65	1.02
42.	Biotite %	1.28	0.79	1.65	1.45	1.00	2.05	3.23

Mean values of Physico-Chemical and mineralogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD for Soils
43.	Muscovite %	0.03	0.04	0.05	0.06	0.02	0.06	0.003
44.	Chlorite %	5.50	6.85	5.40	6.50	4.50	7.80	3.84
45.	Ilmenite %	21.75	19.40	24.75	23.10	14.05	24.25	7.85
46.	Sillimanite %	2.15	2.50	3.25	3.75	2.80	4.05	3.30
47.	Monazite %	0.04	0.07	0.08	0.02	0.02	0.13	0.13
48.	Haematite %	1.42	0.90	0.78	0.51	0.30	1.30	2.63
49.	Goethite %	2.45	2.90	2.00	1.55	4.50	1.20	1.40
50.	Pyrite %	4.85	3.60	2.25	2.15	0.40	4.45	1.48
51.	Coarse silt (20-50 um)%	0.00	2.00	5.50	0.50	0.00	0.00	6.99
52.	Medium silt (5-20 um)%	8.50	14.00	19.50	11.00	13.50	7.50	14.53
53.	Fine silt(2-5 um) %	11.00	11.75	12.25	10.25	11.00	13.50	2.71
54.	Coarse clay(0.2-2 um) %	41.00	44.00	12.50	18.00	17.00	14.75	51.19
55.	Fine clay(0.2 um) %	19.75	29.25	44.25	58.00	57.50	59.00	41.65
56.	Chemical composition of soil clay SiO_2 %	46.80	56.30	51.25	50.00	35.40	38.60	5.56

Mean values of Physico-Chemical and mineralogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD for Soils
57.	Al_2O_3 %	27.25	37.99	36.73	43.95	27.64	39.89	1.12
58.	Fe_2O_3 %	20.39	12.01	16.95	13.20	15.11	13.79	0.44
59.	CaO %	0.03	0.17	0.16	0.10	0.05	0.27	0.04
60.	MgO %	1.41	1.04	2.23	4.67	0.81	2.03	0.30
61.	Na_2O %	2.41	3.11	4.78	32.27	1.95	2.56	7.73
62.	K_2O %	1.68	1.23	1.68	4.35	0.57	2.24	0.37
63.	ZnO %	1.73	5.52	9.97	48.23	1.02	0.07	1.16
64.	CaO %	0.08	0.06	0.03	9.05	0.04	0.04	0.003
65.	$SiO_2Al_2O_3$	2.92	2.52	2.37	1.93	2.04	1.43	0.37
66.	$SiO_2Fe_2O_3$	6.07	12.41	7.99	10.02	5.84	6.97	1.06
67.	SiO_2/R_2O_3	4.27	4.89	4.15	3.79	3.38	2.94	0.61
68.	SiO_2/CaO+MgO	52.44	75.33	31.57	16.84	62.65	25.55	4.60
69.	SiO_2/K_2O	43.59	72.68	48.42	18.06	67.71	25.41	28.54
70.	Thermogravimetric analysis of clay loss of water/100 g clay at 100^oC	9.92	7.30	6.43	7.60	9.47	6.17	3.89

Mean values of Physico-Chemical and minerqlogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD For Soils
71.	Loss of water/100 g clay at 200^{o}C	16.30	10.58	11.69	12.67	13.66	11.54	3.86
72.	Loss of water/100 g clay at 300^{o}C	26.09	15.23	19.29	18.35	16.05	16.80	2.65
73.	Loss water/100 g clay at 400^{o}C	32.47	19.83	23.39	22.15	24.94	19.44	4.43
74.	Loss water/100 g clay at 500^{o}C	35.69	21.85	25.15	25.95	26.85	22.12	1.56
75.	Loss of water/100 g clay at 600^{o}C	37.31	23.15	27.49	28.45	29.42	23.89	3.37
76.	Loss of water/100 g clay at 700^{o}C	36.37	24.50	28.67	31.02	30.08	25.16	5.87
77.	Loss of water/100 g clay at 800^{o}C	43.63	25.83	29.84	34.20	33.18	25.16	1.05
78.	Loss of water/100 g clay at 900^{o}C	46.78	26.50	32.74	34.84	33.77	26.57	3.09
79.	Loss water/100 g clay at 1000^{o}C	47.58	27.18	32.74	36.12	33.77	27.43	3.17
80.	Categories of water loss of soil clay below 100^{o}C	20.86	26.79	19.60	21.06	28.14	22.48	11.71

Mean values of Physico-Chemical and minerqlogical properties of the Acid Sulphate soils (0-50 cm depth)

Sl. No.	Soil name location Property	Kari soil Karumadi	Karapadam soil Moncompu	Kayal soil Mathikayal	Pokkali soil Vytilla	Kole soil Kattu kambal	Kaipad soil Kattam pally	CD for Soils
81.	Below 300°C	54.83	56.18	58.85	50.92	55.37	61.24	10.41
82.	Below 600°C	78.42	85.60	84.11	79.06	87.09	87.10	17.94
83.	Beyond 600°C	21.59	14.40	15.89	20.94	12.92	12.91	17.94
84.	Adsorbed water %	68.44	71.01	71.40	61.46	73.90	70.83	16.23
85.	Crystal lattice water%	31.76	29.04	28.61	38.55	26.10	29.17	16.27
86.	Adsorbed water/ crystal lattice water	2.16	2.82	2.50	1.61	2.96	2.15	2.01

Appendix III

GLOSSARY OF MICROMORPHOLOGICAL TERMS

ACCUMULATION: The build-up or increase in the amount of one or more constituents in the soil at a given position as a result of translocation. The build-up may be a residue due to the translocation of material out of the horizon or may be due to an addition of material. Usually refers to soluble substances and clay particles.

Agglomeroplasmic (A related distribution pattern). The plasma occurs as loose or incomplete fillings in the intergranular spaces between skeleton grains.

AGGREGATE: Small loose structural bodies of various origin, formed in nature with variable shape and origin often called crumbs. Aggregates are either true crumbs, or small fragments, or small clods or droppings of small soil animals.

Aggregates: Soil material separate from and only touching other soil material, divided into fragments and crumbs.

ANISOTROPIC: 1. Possessing different physical properities in different directions.

Argillans: Cutans composed dominantly of clay minerals.

Argillasepic Fabric: A type of Asepic Plasmic Fabric. The plasma of this fabric consists dominantly of anisotropic clay minerals and exhibit a flecked orientation pattern with recognisable domains. Sea Asepic Plasmic Fabrics.

Asepic Plasmic Fabrics: These fabrics have dominantly anisotropic plasma with anisotropic domains that are unorientated with regard to each other; that is, they have a flecked extinction patter; There are virtually no plasma separations. There are two types; see Argillasepic Fabric and Sillasepic Fabric of. Scaly fabric..

ASSIMILATE: Make similar, absorb into the system, become alike, refers mainly to the assimilation of various features in the matrix.

Basic distribution pattern: The distribution pattern of like individuals with regard to each other.

Basic fabric: The fabric of the S-matrix, that is the arrangements and relationships of the plasma, skeleton grains and voids.

Basic orientation pattern: The orientation pattern of like individuals with regard to each other.

Basic Structure: The structure of the S-matrix, that is, the size, shape, and arrangement of the simple grains (plasma and skeleton grains) and voids in primary peds or apedal soil material, excluding pedological features other than plasma separations.

BLOCKY: Many sided with angular or rounded corners, used for describing peds.

CHAMBER: A relatively large circular or ovoid pore with smooth walls and an outlet through channels fissures or planar pores.

CHANNEL: A tubular-shaped pore. of. Faunal passage, root passage.

Chlamydomorphic fabric: Mineral grains are surrounded by uniform colloidal coatings which may grow together at the points where the grains touch each other. The intergranular spaces are generally empty.

COATING: A layer of a substance completely or partly covering a surface. Coatings are composed of a variety of substances separately or in combination. They include clay coatings (clay skins), calcite coatings, gibbsite coatings, gypsum coatings, salt coatings, hematite coatings, organic coatings, while soil coatings, etc. Coatings may become incorporated into the matrix or be fragmented.

Concentration. The process and state of accumulation of mineral and or organic material. See ACCUMULATION.

CONCRETION: 1. A feature caused by local concentrations of compounds that irreversibly cement the soil grains together.

CRYSTAL VERMIFORM: A tube filled with secondary crystalline material such as calcite. The arrangement of the crystals may vary from loosely to densely packed.

Cutan: A modification of the texture, structure, or fabric at natural surfaces in soil meterials due to concerntration of particular soil constituents or in situ modification of the plasma; cutans can be composed of any of the component substances of the soil material. They include Ferri-argillans, Gibbsans, Goethans, Gypsans, Halans, Hematans, Humicans, Kalinans, Mangans, Matrans, Organas, Organo-Argillans, Palygorskans, Quartzans, Sesquans, Silans, Skeletans.

DEPOSITION: The sedimentation of material on the surfaces of pores Some deposited materials eventually become integrated or amalgamated into the matrix.

DETRITAL GRAIN: Individual mineral grains originally present in the parent material.

DOMAIN: 1. Small units of parallel oriented clay about one micron diameter and randomly arranged in the matrix.

EUHEDRAL: From of mineral grains bounded by distinct (own) crystallographic faces. of. ANHEDRAL and SUBHEDRAL

FAUNAL PASSAGE: A tubular pore produced by faunal activity.

FERRAN: A sesquan (cutan) consisting of iron oxides or hydroxides.

FERRI-ARGILLAN: A cutan consisting of a mixture of clay minerals and iron oxides and hydroxides, coloured in shades of yellow, red, green or blue depending on the degree of hydration and oxidation of the iron oxides or hydroxide.

FINE MASS: Micromorphologically indistinguishable part of the soil, composed mainly of clay particles sesquioxides and humus, can be moved and/or reorganised.

FINE MATERIAL: Soil material in thin sections comosed of particles less than about 2 u which are difficult or impossible to resolve with the petrological microscope.

FOSSIL FORMATIONS: Preserved features resulting from biological activity such as borrows and root channels. These may or may not be filled with various materials.

FRAGMENTS: Irregular shaped aggregates of soil material prodced by physical disturbance such as ploughing.

GLAEBULE: A three dimensional unit within the S-matrix of the soil material, and usually approximately prolate to equant in shape; its morphology (especially size, shape, and/or internal fabric) is incompatible with its present occurence being within a single void in the present soil material. It is recognised as a unit either because of great concentration of some constiituents and/or differences in fabric compared with the enclosing soil material, or because it has a distinct boundary with the enclosing soil material.

GRAIN CUTANS: Cutans associated with the surfaces of skeleton grains or other discrete units such as nodules, concretions, etc.

GRANULAR: (A related distribution pattern). There is no plasma or all the plasma occurs as pedological features.

GYPSAN: A cutan composed of gypsum.

HISTON: A natural aggregation of different tissues (grown together in a plant or animal body) such as a leaf, branch, root, seed, fruit, etc. or the remains of that if these are larger than 2 mm. Present organic plasma is part of the histon unless it has been formed into a pedological feature. Pedological features can occur within histons. They are subdivided into brancohist - derived from branch; foliohist - derived from a leaf; histonoids - aggregates of tissues smaller than 2 mm.

HISTONIC: The O-matrix is mainly composed of intact, or apparently intact tissue. Plasma is not present, neither in the cell lumena nor in the cell walls.

HUMICAN; An organan consisting almost entirely of humic substances.

HUMICOL: Plasmic material consisting of strongly decomposed organic residues of colloidal size.

HUMON: 1. The collection of macroscopically and/or microscopically (magnifications up to 200:1) observable organic bodies in soil which are characterized by a specific morphology and spatial arrangement;

it is a "natural, three-dimensional, genetic, organic individual" existing in soil.

HUMUS FORM: Refers always to the humus formation as a whole i,e, it includes particular chemical and physical characteristics as well as a particfular profile development with all its horizons, their internal structure and the totality of their life.

ILLUVIATION CUTANS: Formed by movement of cutanic material in solution or suspension and subsequent deposition.

INTERCALARY CRYSTALS: Crystallaria that consist of a single large crystal or groups of a few large crystals set in the soil material and apparently not associated with voids of equivalent size or shape to that of the crystallaria as a whole, the crystals are euhedral to subhedral having at least some well developed crystal faces.

INTERTEXTIC (related distribution): 1. Bare mineral grains united by intergranular braces or embedded in a porous mass of flocculated or crumbled colloids.

2. The skeleton grains are linked by intergranular braces or are embedded in a porous groundmass (matrix in the semdimentary petrological sense).

MANGAN: A cutan composed of manganess oxides.

MATRIX: The fine material (generally 2 μ m) forming a continuous phase and enclosing coarser material and/or pores.

I-MATRIX: The mineral material within this unit of study being simplest (primary) peds, or composing apedal soil materials (in which pedological features occur), or pedological features. It consiss of mineral plasma and/or mineral skeleton grains.

S-MATRIX: The material (plasma and/or skeleton grains and associated voids) within the simplest (primary) peds, or composing apedal soil material that does not occur as pedological features other than plasma separations; it may be absent in some soil materials, for example, those that consist entirely of pedological features.

MELANONS: Glaebules formed by melanosis of histons, or remains of histons, or melanized soil materials, which may be unrecognizable remains of sclerotia. If part of a histon is melanized, only this is the melanon.

METAVUGHS: Vughs whose walls appear to be significantly smoother than would result from the normal random packing of plasma and skeleton grains.

MICROSTRUCTURE: Soil structure that can be seen only with optical means.

MODER: Well decomposed aerobic organic matter containing numerous faecal pellets.

MULL: An intimate blend of organic and mineral material crumb or granular structure.

NEOCUTANS: Occur subcutanically immediately adjoining the natural surface with which they are associated. They include: neocalcitans, neoargillans, neocalcans, neoferrans, neomangans, neomatrans, neo-organans, neosesquans, neostrians.

NEOFERRAN: A neocutan composed of a concentration of iron oxides.

NEOMANGAN: A neocutan composed of a concentration of manganese oxides.

NEOORGANAN: A neocutan composed of a concentration of organic matter.

NODULES: Glaebules with an undifferentiated internal fabric; in this context undifferentiated fabric includes recognisable rock and soil fabric.

OPTICAL ANISOTROPY: All crystalline materials except those belonging to the cubic crystal system are optically anisotropic as is expressed by their birefringence. Interference colours can be observed when the substances are examined between crossed polarizers. see ANISOTROPY and SOIL ANISOTROPY

ORGANAN: A cutan composed of a concentration of organic matter.

ORGANIC PLASMA/O-PLASMA: That part of the organic soil material which is capable of being or has been moved, reorganized and/or concentrated by processes of soil formation. It includes all organic material of colloidal size smaller than 2 μ m and relatively soluble organic material, which is not bound up in the skeleton grains or tissues. The colloidal-sized material is composed of high molecular weight constituents and of very small fragments of tissue.

ORGANIC SKELETON GRAINS: Individual organic grains which are relatively stable and not readily translocated, concentrated or reorganised by soil-forming processes; they include fragments of aggregations of tissues, spores, pollen grains, and fragments of fungal hyphae; they are larger than μ m and commonly smaller than 2 mm.

ORIENTATION PATTERN: See the three major groups viz basic, referred and related orientation patterns.

ORTHOTUBULES: The tubulic material has been derived from the soil material of the horizon in which they occur.

PACKING VOIDS: Voids due to random packing of individuals.

PAPULES: Glaebules composed dominantly of clay minrals with continuous and/or lamellar fabric; they have sharp external boundaries. Most commonly they are prolate to equant and somewhat rounded.

PASSAGE: A tubular pore which has a circular or ovoid cross section. see CHANNEL.

PED: A ped is an individual natural soil aggregate consisting of a cluster of primary particles, and separated from adjoining peds by surfaces of weakness which are recognizable as nature voids or by the occurrence of cutans.

PEDOLOGICAL FEATURES: Recognizable units whthin a soil material which are distinguishable from the associated material for any resason, such as origin (deposition as an entity), differences in concentration of some fractions of the plasma, or differences in arrangement of the constituents (fabric).

PEDORELICS: Features formed by erosion, transport and deposition of nodules of an older soil material or pedological features from it, or by preservation of some part of a previously existing soil horizon within a newly formed horizon.

PLANAR PORES: Pores that appear in thin sections to be linear or sinuous but are planar in three dimensions.

PLASMA: 1. All the material of colloidal soze, and relatively soluble material that is not bound up in skeleton grains; it consists of mineral (amorphous and crystalline) and organic material.

2. That part of a soil material which is capable of being or has been moved, reorganised, and/or concentrated by the processes of soil formation. It includes all the material, mineral or organic, of colloidal size and relatively soluble material which is not bound up in the skeleton grains.

PLASMA CONCENTRATIONS: Concentrations of any of the fractions of the plasma in various parts of the soil material. Examples of these are carbonate nodules, iron oxide nodules and clay mineral coatings.

PLASMA SEPARATION: Features characterised by a significant change in the arrangement of the constituents, rather than a change in the concentration of some fraction of the plasma. An example of this is the c_hange in orientation of the clay mineral fraction near the surface of slickensides. Plasma separations are not three-dimensional entities, but their internal organization can be described and related to that of the rest of the soil material.

PLASMIC FABRIC: The fabric of the plasma of the s-matrix, that is, the arrangement of the plasma grains and intergranular voids. see Asepic plasmic fabrics, Sepic plasmic fabrics, Undulic plasmic fabricsm, Isotic plasmic fabrics, Crystic plasmic fabrics.

PORES: Spaces in the soil filled or partly filled with the soil solution or soil atmosphere. They can be discrete or continuous. With time they may become filled with clay, crystalline material or other substances.

POROUS STRUCTURE: Isolated cavities and devoid of aggregates.

PORPHYROSKELIC (related distribution): The plasma occurs as a dense ground mass in which skeleton grains are set after the manner of phenocrysts in a porphyric rock.

QUASI-CUTAN: A pedological feature that occurs within the S-matrix, not immediately adjoining natural surfaces, but with an obvious relationship to them.

RELATED DISTRIBUTION: Plasma occurs as uniform coatings covering skeleton grains or pedological features.

RELATED DISTRIBUTION PATTERN: The distribution pattern of like individuals with regard to the distribution of groups of individuals of a different kind; it can usually be inferred from the referred distribution pattern of the two groups of individuals exhibiting the relationships.

ROOT PASSAGE: Circular or ovoid pores formed by roots. The roots may be alive or dead and present or they may have decomposed leaving the pore unoccupied but it may be filled later by a variety of other substances including clay, calcite gypsum, and jarosite.

SEPIC FABRICS: Plasmic fabrics in which patches and/or zones of plasma have striated extinction patterns under crossed polarisers. The following types are recognised:

1.	Insepic:	isolated patches with a striated extinction pattern.
2.	Mosepic:	Frequent patches.
3.	Vosepic:	zones associated with voids.
4.	Skelsepic:	zones associated with grains and or glabules.
5.	Masepic:	elongated zones through the plasma.

6. Bimasepic: elongated zones in two directions through the plasma.

7. Omnisepic: all the plasma has a complex striated extinction pattern.

8. Compound fabrics can also occur such as skel-ma-insepic fabric in which several fabric elements are present; in these the weaker elements are named first (skel-in the example) and the stronger elements last (insepic in the example). Sepic fabrics can also be fompounded with other types, e.g. Skel-masepic undulic fabric.

SEPIC PLASMIC FABRICS: These fabrics have recognizable anisotropic domains with various patterns of preferred orientation; that is, plasma separations with a striated extinction pattern are present. They can subdivided on the characteristics of the plasma separation into seven types; Insepic, Mosepic, Vosepic, Skelsepic, Masepic, Lattisepic, Omnisepic fabrics.

SESQUAN: A cutan composed of sesquioxides or hydroxides.

SIMPLE PACKING VOIDS: Voids due to random packing of individuals (either single grains or such compound units as peds).

SKELETAN: A cutan composed of skeleton grains.

SKELETAN: Grains of rock forming minerals, rock fragments and bioliths.

SKELETON GRAINS: 1. Individual grains larger than colloidal size; they consist of imineral grains orginally present in the parent material and resistant siliceous and organic bodies.

SKELSEPIC FABRIC (A type of Sepic Plasmic Fabric): Part of the plasma has a flecked orientation pattern, but plasma separations with striated orientation occur subcutanically to the surface of the skeleton grains; the striated orientation of the plasma separation is dominantly parallel to the surfaces of the skeleton grains.

SOIL ANISOTROPY: The occurrence of a vertical horizon sequence in soils causes vertical anisotropy to be an essential characteristic. Frequently this vertical anisotropy can also be observed in thin sections. see ANISOTROPY AND OPTICAL ANISOTROPY.

SOIL FABRIC: The arrangement, size, shape and frequency of the individual soil constituents.

SOIL FABRIC: 1. The structural arrangement of the soil constituents. Used not only in the narrow sense to refer to aggregate formation but also in a general sense to refer to the inner fabric of dense soil masses, the effect of the process of precipitation and solution, the movement of substances, the alterations caused by organisms and the like.

SOIL NODULES: Nodules with recognisable soil fabric.

SPONGY FABRIC: Biologically favourable soil fabric consisting of aggregates bound to each other in such a way that a system of connected cavities is formed, as in a sponge. The inner structure of the aggregates is generally porous, not dense.

STREAKS (doubly refractive): Strikingly prominent, irregular, striped to flame-like fabric parts of higher double refraction produced by arrangement of particles in the clay substance either by movement (fluidal structures) or by deposition of drying out colloidal masses on walls of cavities, shrinkage cracks, earthworm, channels, surface of granulees, concretions, etc.

STRUCTURE: The spatial distribution and total organisation of the soil system as expressed by the degree and type of aggregation and the nature and distribution of pores and pore space.

VOIDS: Entities, which are interconnected with each other either through voids of dissimilar size and shape, through narrow necks, or through intersection with voids of similar size and shape PORES.

VOSEPIC FABRIC: A type of Sepic Plasmic Fabric. Part of the plasma has a flecked orientation pattern, but plasma separations with striated orientation occur subcutanically associated with the walls of voids; the striated orientation of the plasma separations is dominantly parallel to the walls of the voids, especially planes.

VUGHS: Relatively large voids, other than packing voids, usually irregular and not normally interconnected with other voids of comparable size; at the magnification at which they are recognised they appear as discrete entities.

WUSTENQUARTZ: Sand grains with a red coating of intimately mixed clay minerals and iron oxides; presumed to have a presedimentary origin.

APPENDIX

PHOTO PLATES

1. Karumadi kari soil profile

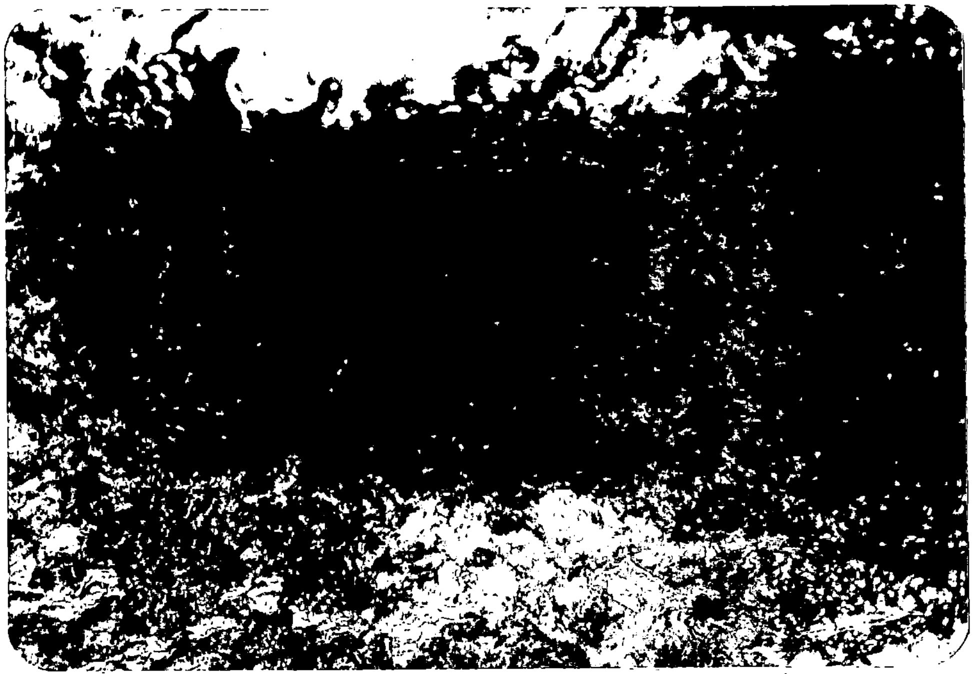
The profile is moderate to slowly drained, with slow internal permeability. Black and dark grey coloured, with silty clay texture throughout the profile. Partially decomposed wood present throughout the profile which are under various stages of decomposition. Pale yellow jarosite mottles of hue 2.5 Y and less than 6 value and chroma is scantly present up to 25 cm depth and at a greater concentration of frequency below 25 cm. The other mottles below 25 cm depth are dark yellowish brown and light olive brown. Decayed and iron coated mangrove roots are present throughout the profile. Water level is from 76 cm.

2. Moncompu karapadom soil profile

Soil is very deep, poorly drained, dark grey to very dark grey with clay loam surface and silty clayloam subsurface horizons. The subsoils show the presence of gley horizons, streaks and abundant mottles of olive yellow, olive brown, dark brown and few red. Presence of concretions and small "sand pockets" and iron ochre in the sub surface horizons is another specific feature of karapadom soils. Fair amounts of decaying organic matter and iron encrustations on the ped faces is present throughout the profile. Pale yellow jarosite mottlings and pyrite are present in the surface and subsurface horizons within 50 cm depth.

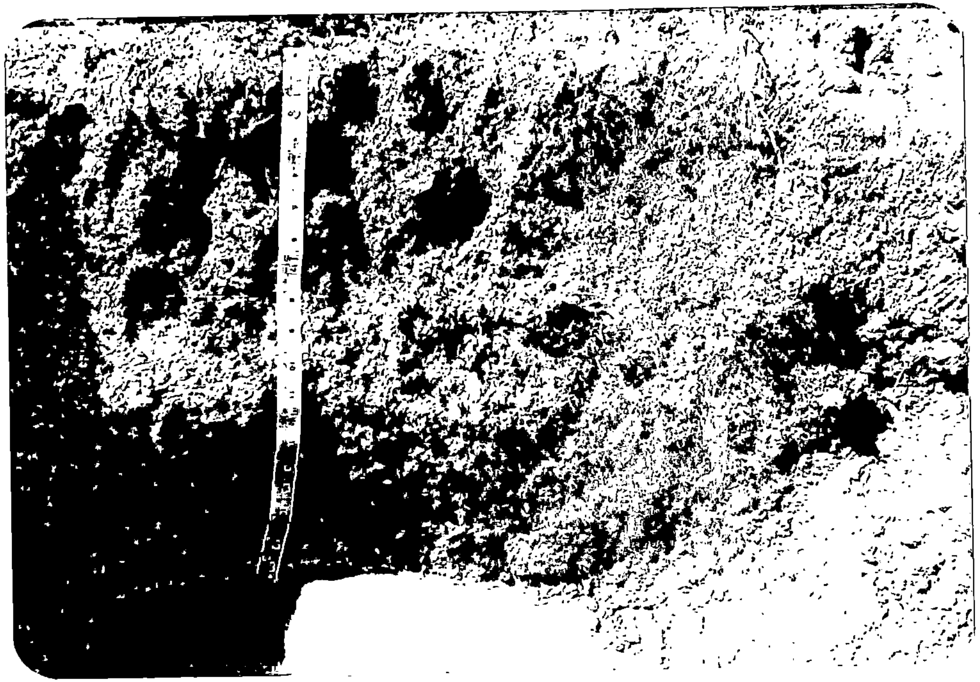
3. Mathikayal kayal soil profile

Soils are very deep poorly drained, dark greyish brown to very dark greyish brown in colour having silty loam to silty clay loam texure. The subsoil shows limeshells, limeshell layer with silt and clay infillings. The subsoils exhibit prominent yellowish brown, strong brown, yellowish red, brownish yellow mottles and streaks. The subsoils are comparatively sandy in nature. Fair amounts of organic matter is present. Jarosite and pyrite mottles are present even in the surface horizons. Biotite mica is present in abundant quantities on exposed profile face. Ground water level is at 40 cm



4. Vytilla pokkali soil profile

The soil is deep, poorly drained, highly saline, very dark grey to very dark greyish brown in colour, with silty clay texture throughout the profile. Fair amounts of decaying organic matter is present. Throughout the profile is soft, plastic, sticky, with shining ped faces, indicating salt enrichment in the profile. Very few yellowish brown, olive brown, brownish yellow mottles are present in the subsurface horizons. Ground water level is at 61 cm.

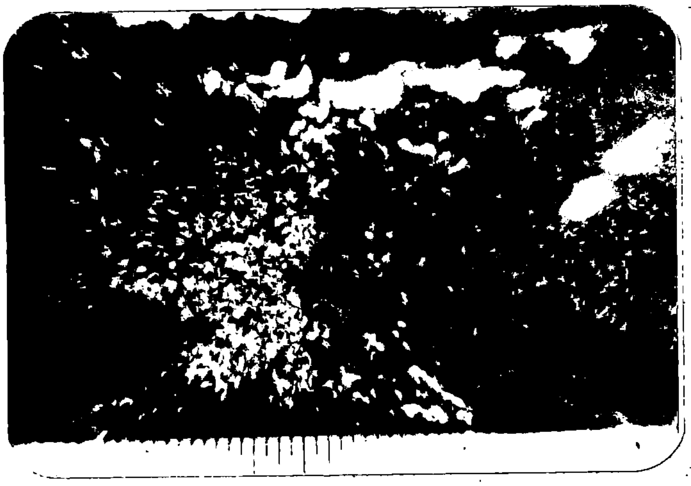


5. Kattukambal kole soil profile

Soil is shallow, poorly drained, yellowish brown to dark grey coloured with wide difference in texture between horizons. These are accumulation of lateritic-alluvial material over red to dark brown gravelly, hard sub angular blocky laterite layer. Gravels are also present in surface layers. The subsurface horizons indicate the presence of highly gleyed horizons with streaks and trapped partially decomposed organic matter and abundant prominent yellowish brown, yellow, brownish-yellow and dark brown mottles. Biotite mica are present on the ped faces of subsurface horizons and hard laterite layer.

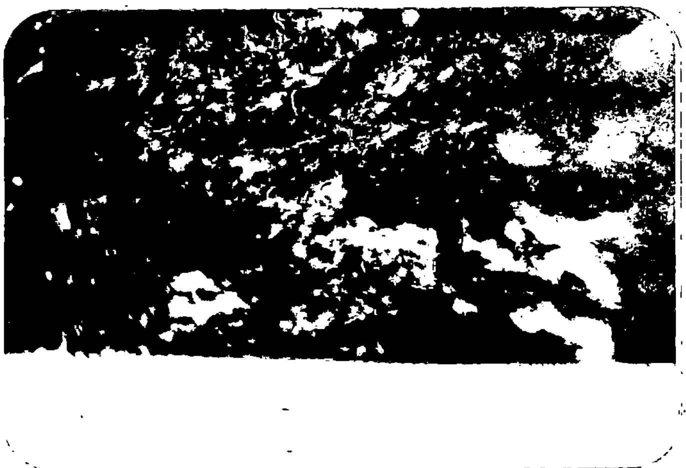
6. Kattampally kaipad soil profile

Soil is very deep, moderately drained with moderate to slow internal permeability. Dark grey to dark greyish brown in colour with abundant amounts of partially decomposed fibrous woody materials, in the subsurface horizons. Below 60 cm depth there is a conspicuous abrupt limeshell layer admixed with partially decomposed wood and silt and clay. Iron pipes and thick sharp margined small concretions are present in the profile. Iron mottles are more in the partially decomposed wood and limeshell layer. Gravels are present in the surface horizons but not in the subsurface layers. In between the horizons sandy layered pockets are present. Ground water level is from 61 cm



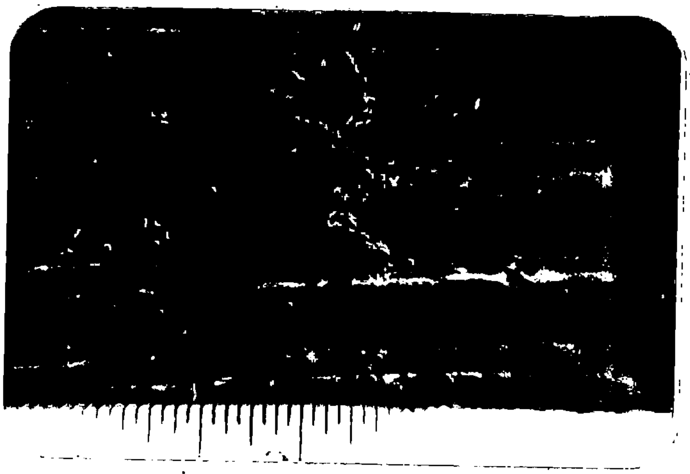
7. Air dried surface horizon Karumadi kari soil profile Mgf 2X

Sand admixed with partially decomposed wood-barks of "Kandamaram" with more infilled jarositic materials (pale yellow coloured with hue 2.5 Y)



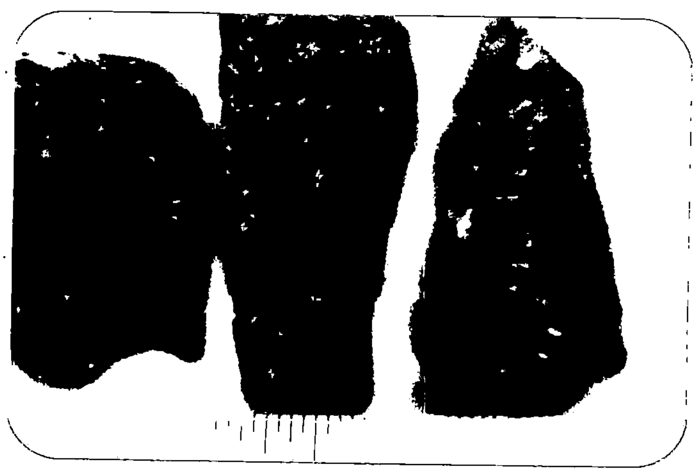
8. Air dried surface horizon Karumadi kari soil profile. Another, view Mgf 2X

Pale yellow coloured jarosite present in and between air dried peels, flakes of 'Kandamaram' wood fossil.



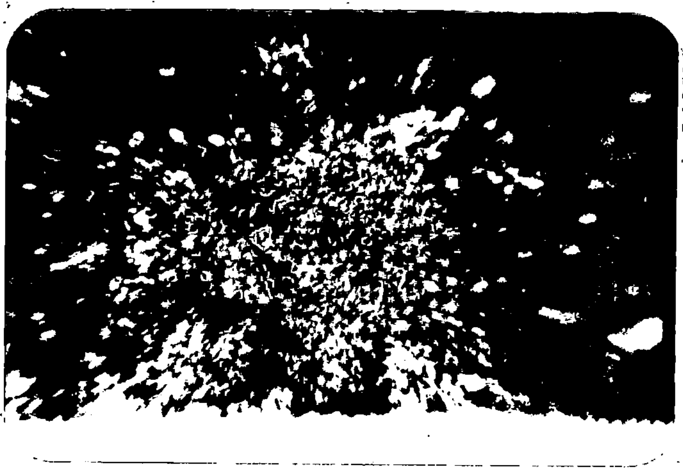
9. Air dried third horizon Karumadi kari soil profile Mgf 2X

Channels, with inner ferric iron oxide incrustations (reddish yellow) followed by innermost coating of goethitic incrustations (yellowish orange) are present. These are the key sites of oxidation and reduction in the active acid sulphate soil horizons, due to alternate wetting and drying. Inside the channels and root channels jarosites are present.



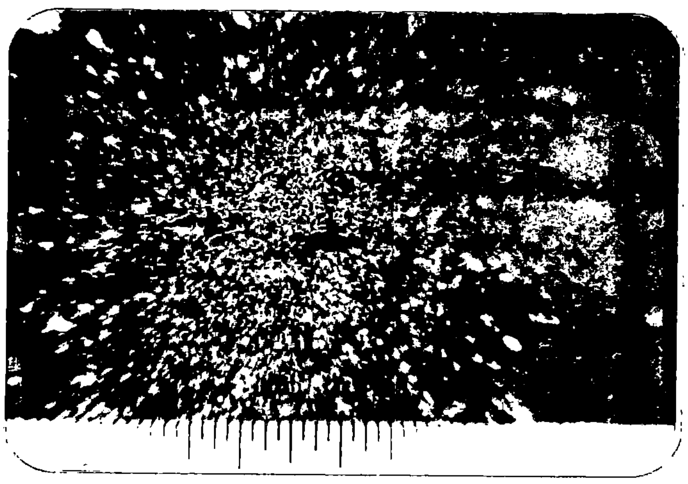
10. Air dried wood fossil pieces from second layer Karumadi kari soil profile Mgf 2X

Moist wood fossils are soft with flesh coloured internal core and soiled outcore. On drying the whole mass becomes dark grey to black coloured and moderately hard and brittle.



11. Air dried surface horizon of Moncompu karapadam soil profile Mgf 2X

Dark grey to greyish brown colour, sandy showing cracks due to drying. The white spots are quartz without iron oxide coating. The dark areas are regions with partially decomposed organic matter under different stages of decomposition.



12. Air dried second horizon of Moncompu karapadam soil profile Mgf 2X

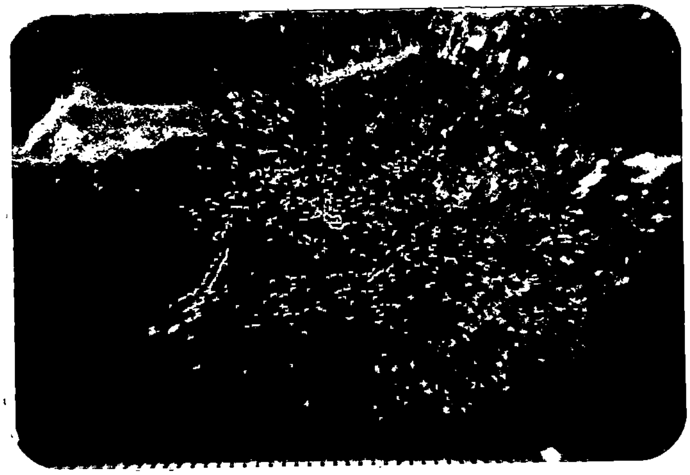
Sandy texture with reddish lateritic nodules with high relief yellow coloured iron coated (limonitic) quartz. The cracks observed are the regions with more partially decomposed wood. The white spots are non-coated quartz and limeshell pieces.

13. Air dried second hoiozon of Mathikayal kayal soil profile Mgf 2X .

Yellowish brown coloured with prominent sharp margined channels and coalesced channels with irregular margins. The channels are with bright reddish ferric iron oxide and dull light reddish hydrated ironoxide coatings. The yellowish brown to brownish yellow encrustations of the channels are geothite depositions. The peculiar shape of some of the channels indicate the operation of faunal activity in the horizon. The admixed black and white coloured vermiform observed in the channels are faecal materials.

14. Another view of air dried second horizon of Mathikayal kayal soil profile Mgf 2X

Brownish yellow coloured, with sandy loam texture with few brownish yellow mottles with faint margins.

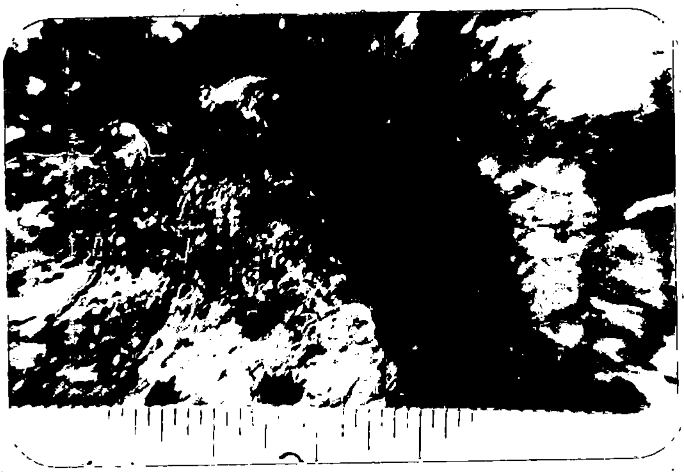


15. Air dried surface horizon of Vytilla pokkali soil profile Mgf 2X

Sandy textured light grey to dark grey coloured with fine, small, white, skeletons of sodium sulphate and calcium sulphate encrustations. The cracks are due to drying, where partially decomposed organic matter enrichment is noted. Very few, small lateritic nodules are present embedded on the soil.

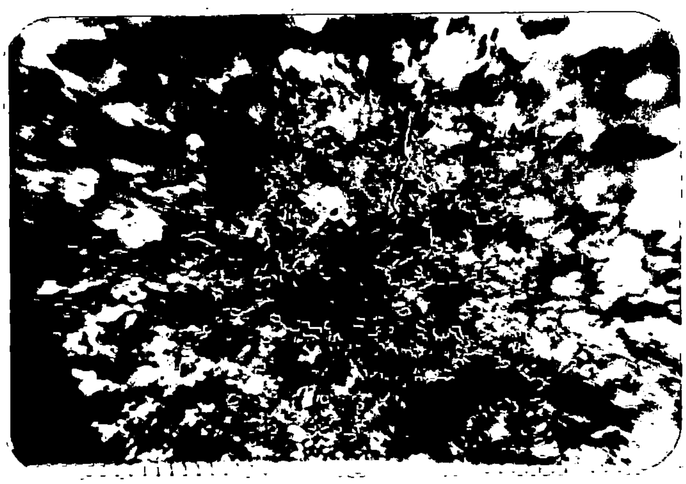
16. Air dried second horizon of Vytilla pokkali soil profile Mgf 2X

Soil is sandy in texture with brownish grey to grey colour. Mottles of yellowish brown and orange brown ironoxide is also noted. The cracks seen are due to air drying, where partially decomposed organic matter enrichment are seen.



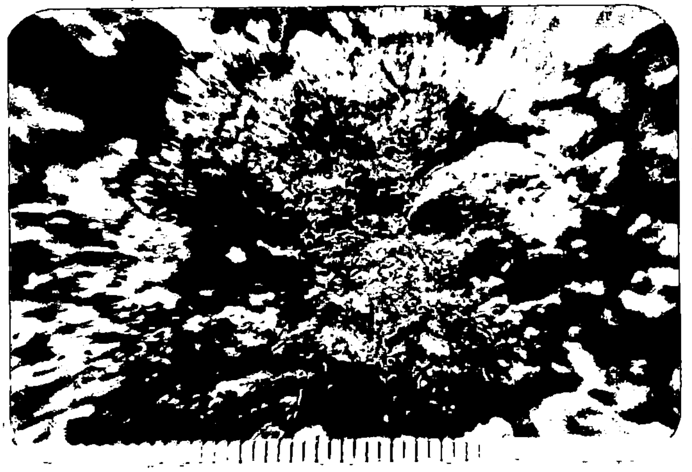
17. <u>Air dried second horizon of Kattukambal kole soil profile Mgf 2X</u>

Silty loam textured, yellowish brown coloured soil showing cracks. Inner core of the soil is yellowish orange with sharp margined natural channels. The yellow to orange yellow ferriargillanic cutans are present in and out of these channels.



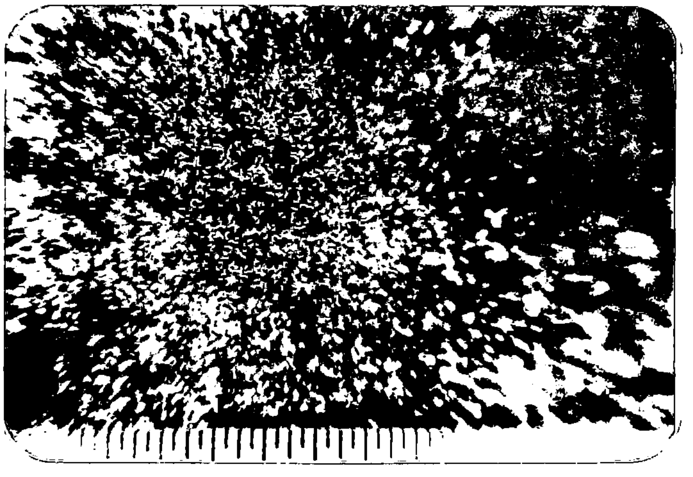
18. <u>Air dried third horizon of Kattukambal kole soil profile Mgf. 2X</u>

Gleyed soil with irregular oriented ferri-argillan are intimately mixed while, in general, they are with sharp separable margins.



19. Air dried fourth horizon of Kattukambal kole soil profile Mgf. 2X

Compact, reddish yellow coloured, gravelly lateritic horizon, without alteration by overlying soil material.

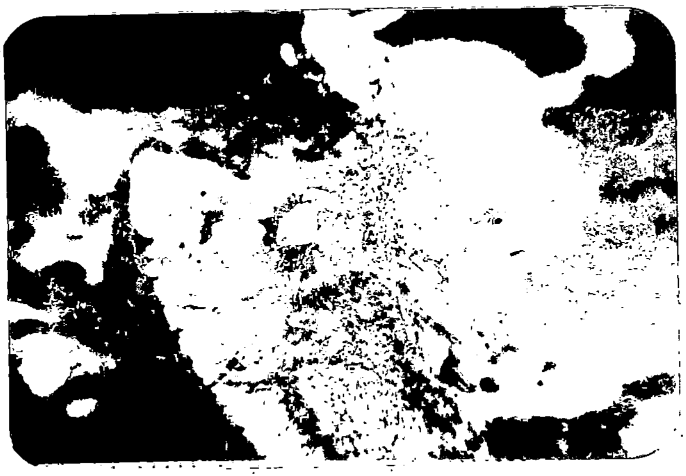


20. Air dried surface horizon of Kattampally kaipad soil profile Mgf 2X

Light grey to grey coloured, sandy, with many sharp high reliefed reddish brown and brownish yellow lateritic nodules.

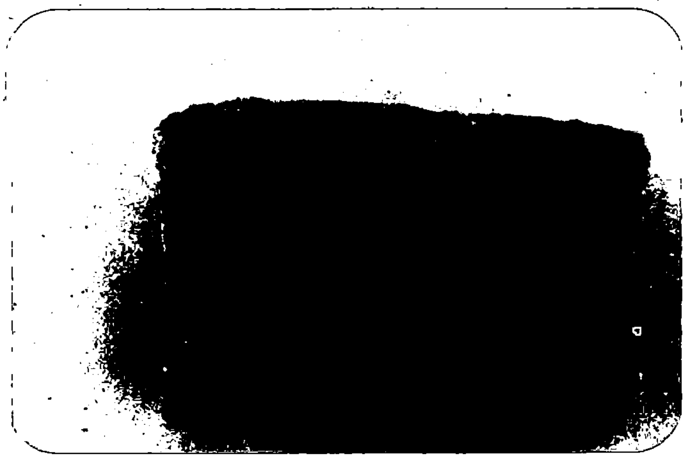
21. Air dried third horizon of Kattampally kaipad soil profile Mgf 2X

Light grey coloured loamy sand enriched with partially decomposed wood. Cracks due to air drying, presence of partially decomposed wood, limeshells are also present.



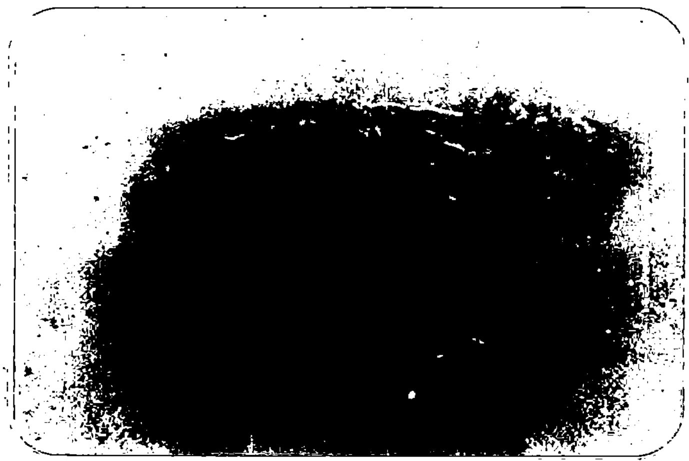
22. Air dried fourth horizon of Kattampally kaipad soil profile Mgf 2X

Light grey or greyish brown limeshell layer. Limeshells are present with irregular stacking. Soil finer fractions and decomposed wood are present inside and in between these lime shells. Reddish brown iron oxide mottles with faint margin covering about 5-10 per cent of the area observed. The limeshells



23. Another view of airdried third horizon of Kattampally kaipad soil profile Mgf 2X

Compact, sandy, loam grey coloured soil with natural root channels and chambers with remains of decomposed roots with iron oxide coating.

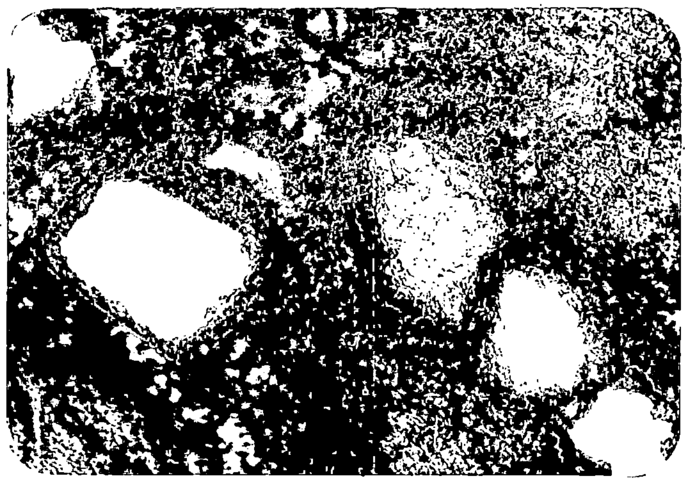


24. Air dried wood fossils from Kattampally kaipad soil profiles Mgf 2X

Wood fossils are of roots of 'Kandamaram' with advanced internal decomposition indicated by shrinking and infilling of finer soil materials.

25. Air dried valve type molluscs from fourth horizon of Kattampally kaipad soil profile Mgf 2X

White to light grey coloured mica like opaque valves with finer (silt and clay) infillings between these valves of molluscs.

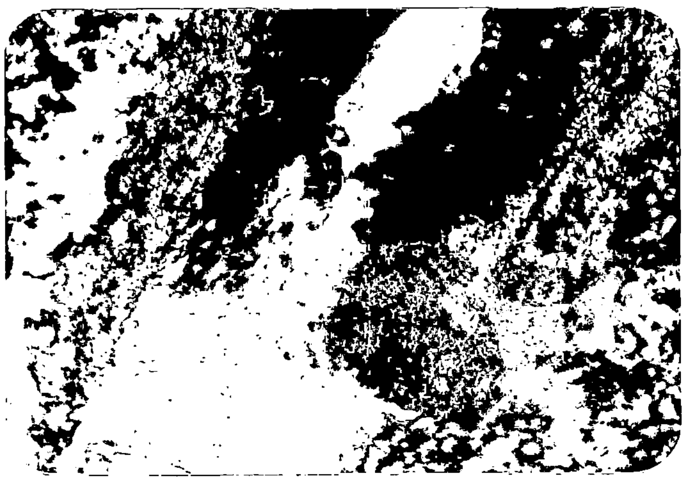


26. Karumadi kari soil first horizon polished black in reflected light Mgf 100X

Signs of iron removal and iron enrichment is observed. Opaque fine silt sized pyritic cubular crystals are present in the wood fossils.

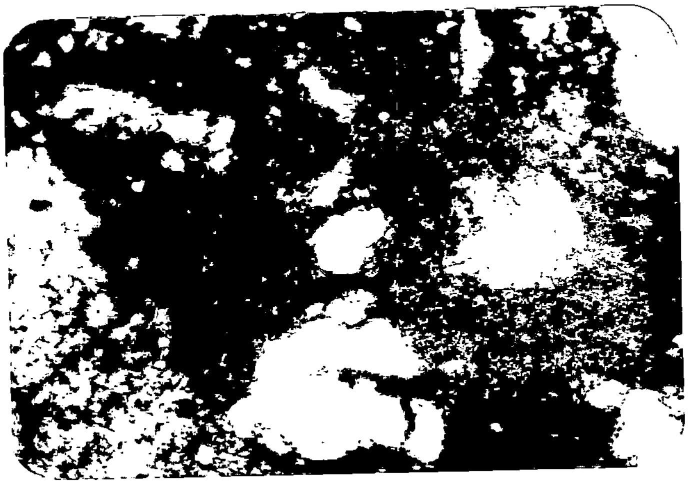
27. Wood fossils from second horizon of Karumadi kari soil profile polished block in reflected light Mgf. 100X

On the wood fossils deposits of iron oxide framboids with very few jarosites are present.



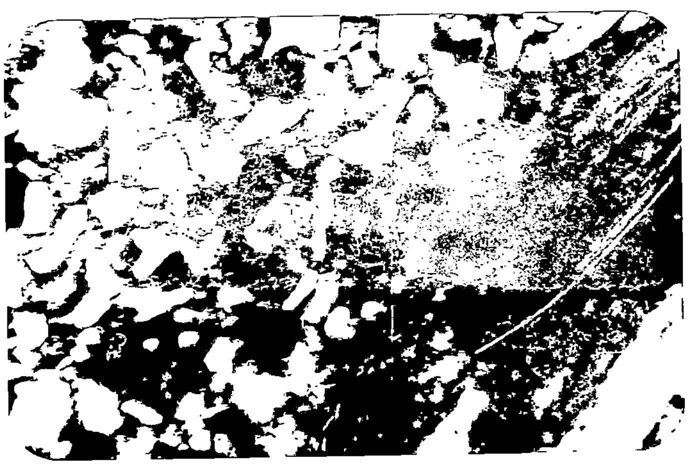
28. Karumadi kari soil profile third horizon polished block in reflected light Mgf. 100X

The white areas inside the channel are regions of iron removal, the red margins are haematite surrounded by orange regions with sharp margins of geothite. Yellow to pale yellow regions are neojarositans. The white spots in and surrounding the channels are fine quartz. Opaque brownish yellow regions of the channels are accumulations of pyrite crystals and ferriorganan. Layering of reddish region and sharp margin indicate repeated



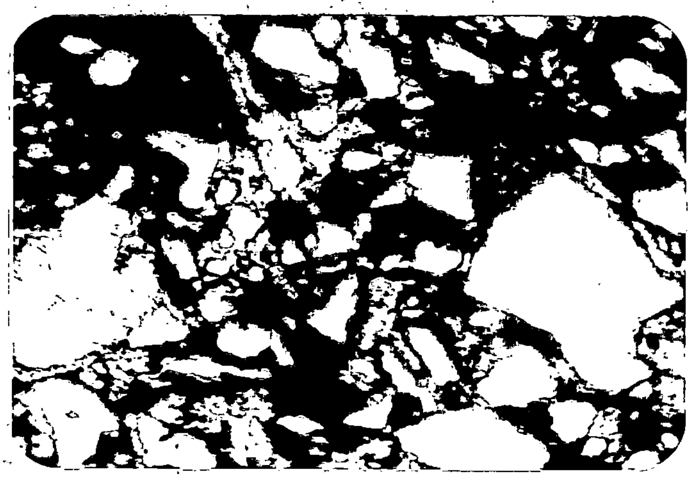
29. Karumadi kari soil profile fourth horizon polished block in reflected light Mgf 100X

More skeletons, less plasma. Signs of iron, ferriorganan leaching and lessivage in active operation depicting sharp margins to skeletons.



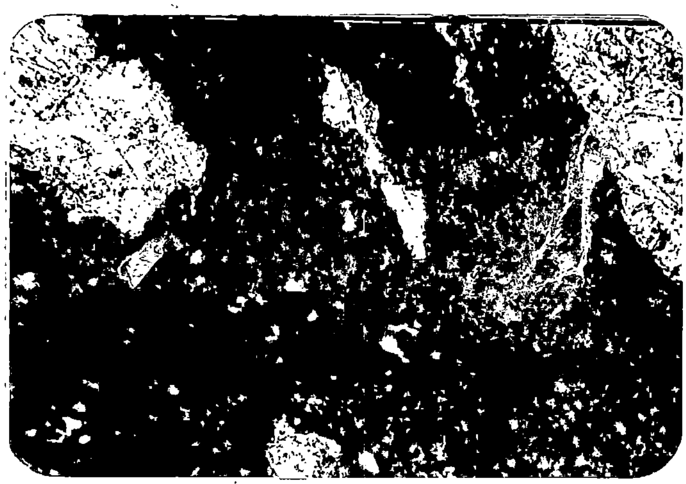
30. Moncompu karapadam soil profile first horizon polished block in reflected light Mgf. 100X

Yellowish red plasma with sub angular to subrounded quartz, pyrite and other opaque skeletons (fine sand to silt sized) and long tubular silicicious spicules, yellow jarositans are seen.



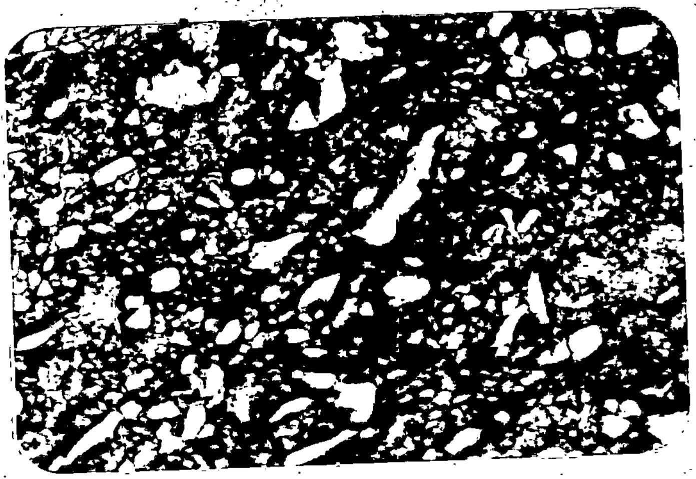
31. Moncompu karapadam soil profile second horizon polished block in reflected light Mgf. 100X

Quartz are seen undergoing advanced stages of physical weathering, entangled with ferriorganan and ferrijarositans. Skeletons are more and plasma is very less.



32. Moncompu karapadom soil profile, third horizon polished block in reflected light Mgf 100X

More than coarse sand sized pitted fractured quartz, bigger channels with accumulation of pyrite and other opaque minerals inside and towards outer boundary of the channels. Repeated iron oxide deposition with flecked orientation pattern in the plasma and in the channels are seen.



33. Moncompu karapadam soil profile fourth horizon polished block in reflected light Mgf 100X

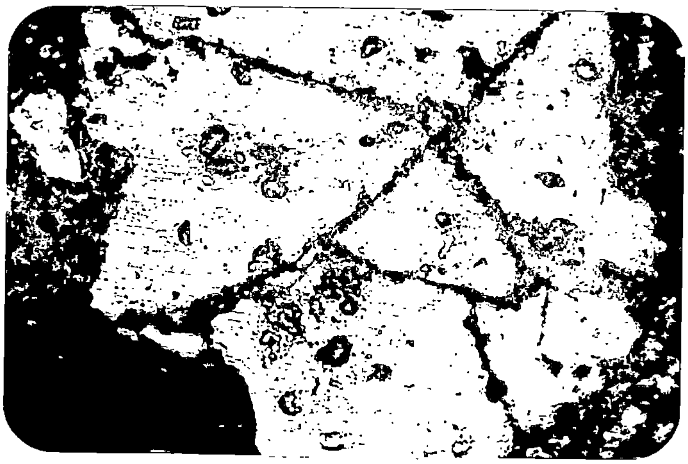
Less than silt sized, subrounded to rounded quartz embedded on yellowish plasma with striated orientation pattern. Jarosite present as yellow coloured neoquasijarositans throughout the plasma. Pyrite also present surrounding the quartz and in channels and chambers.

34. Mathikayal kayal soil profile first horizon polished block in reflected light Mgf 100X

Major portion of the plasma is occupied by highly weathered subangular to rounded quartz and feldspar skeletons. Numerous minute, less than clay sized ferrihydrite and few laterite nodules and neoquasijarositans are present.

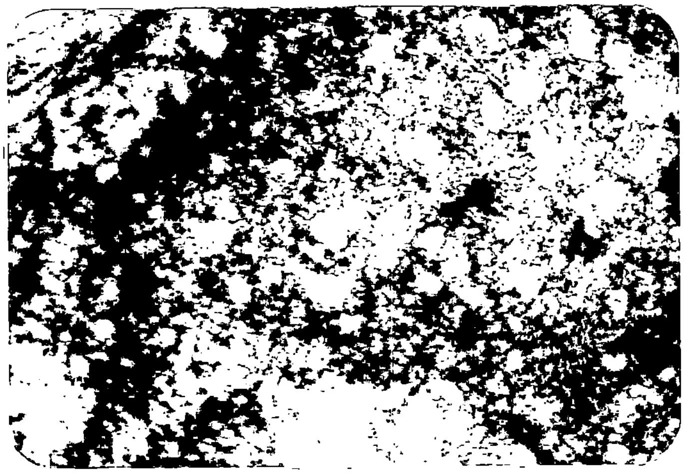
35. Mathikayal kayal soil profile second horizon polished block in reflected light Mgf. 100X

Few fine sand sized and many less than silt sized highly weathered and fractured iron oxide coated quartz, massive channels and chambers are present. Vughs with pyrite, haematite and ferrihydrite surrounding weathered quartz are present.



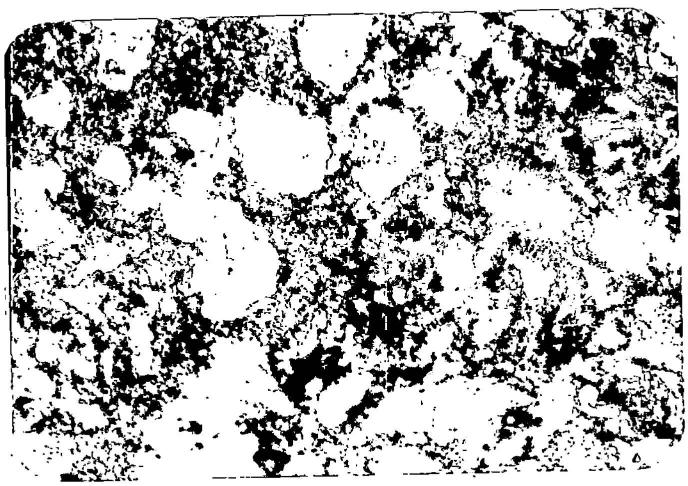
36. Mathikayal kayal soil profile third horizon polished block in reflected light Mgf 100X

Presence of few greater than coarse sand sized subangular highly weathered, fractured, pitted quartz, amoeba shaped pyrite, ferric hydrite, black opaques and few red opaques are present.



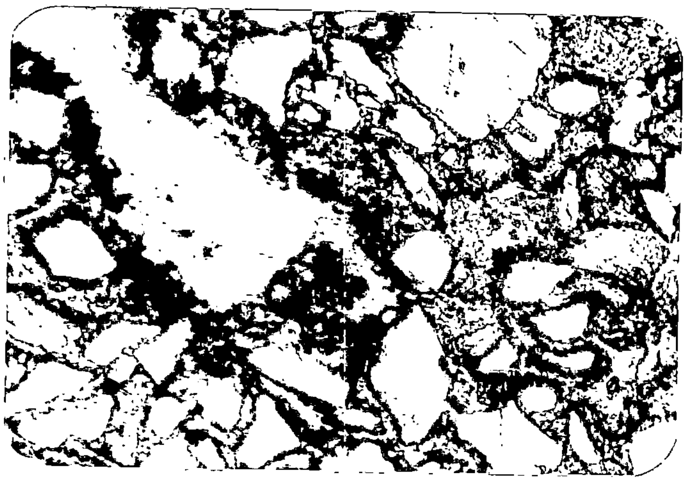
37. Mathikayal kayal soil profile fourth horizon polished block in reflected light Mgf 100X

Very weakly anisotropic matrix, with random distribution of small domains. Innumerable fine ferrihydrite, highly weathered subrounded, less than silt sized quartz, laterite nodule, channels and chambers; vughs with pyrite in it are present.



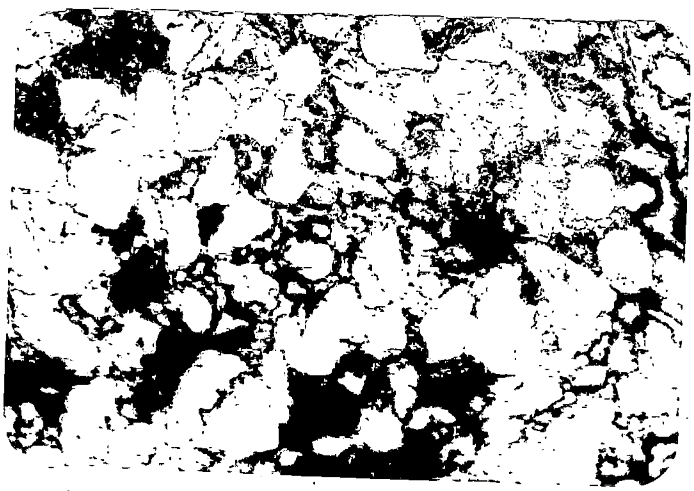
38. Vytilla pokkali soil profile first horizon polished block in reflected light Mgf 100X

Highly iron enriched fine grained granular reddish yellow plasma with highly pitted but not fractured quartz, silt sized pyrite, fine jarosite spheroid, ferrihydrite and few laterite nodules present. Channels and chambers and vughs are the voids present.



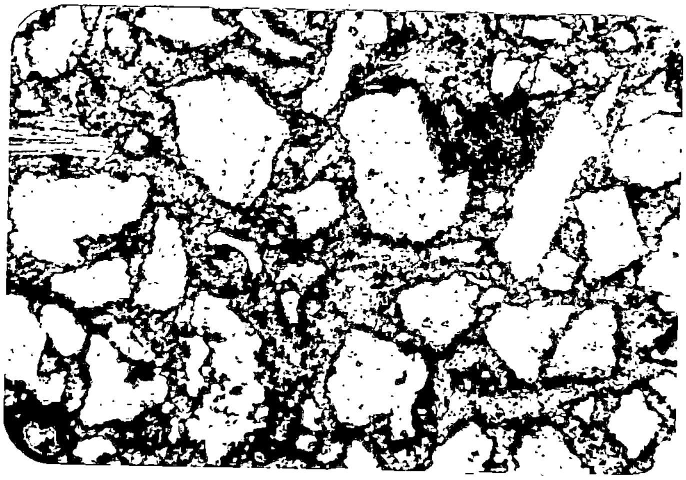
39. Vytilla-pokkali soil profile second hirozon polished block in reflected light Mgf 100X

Skeletons form a major portion of the plasma. Signs of iron removal at margins of skeletons and voids, less than silt sized pyrites opaques and few ferrihydrites are seen.



40. Vytilla pokkali soil profile third horizon polished block in reflected light Mgf 100X

Skelesepic fabric, signs of iron removal, enrichment of pyrite, opaques ferriorganan aggregation presence of laterite nodule and neoquasijarosites are seen.



41. Vytilla pokkali soil profile fourth horizon polished block in reflected light Mgf 100X

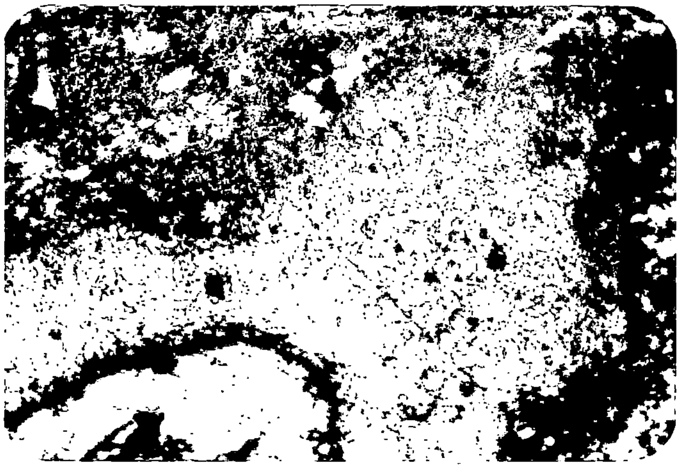
Skelsepic, fine sand sized, highly pitted but not fractured quartz, fractured feldspar on yellowish brown coloured coarse grained plasma are present.

42. Kattukambal ·ole soil profile first horizon polished block in reflected light Mgf 100X

Bigger, pitted quartz and laterite nodules form more than 90 per cent of soil plasma with less than silt sized pyrite and many high relief black opaques and red opaques.

43. <u>Kattukambal kole soil profile second horizon polished block in reflected light Mgf 100X</u>

Coarse grained, quartz rich, reddish yellow plasma with many laterite nodules of fine sand size are seen.

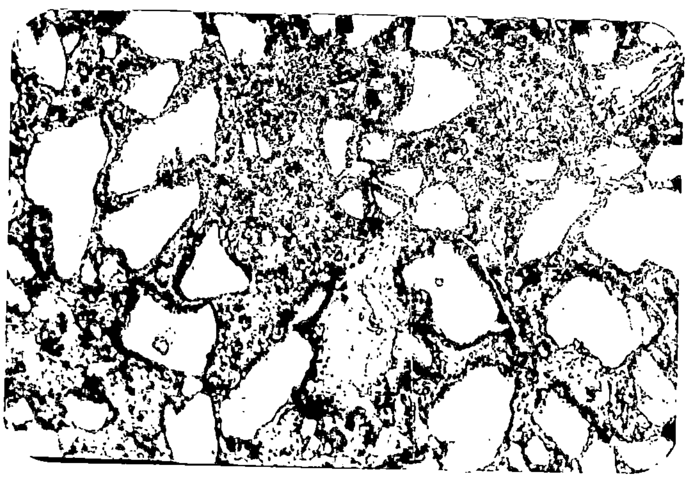


44. <u>Kattukambal kole soil profile third horizon polished block in reflected light Mgf 100X</u>

Iron enrichment, abundant opaque, chambers with pyrite, ferri hydrite and haematite are seen.

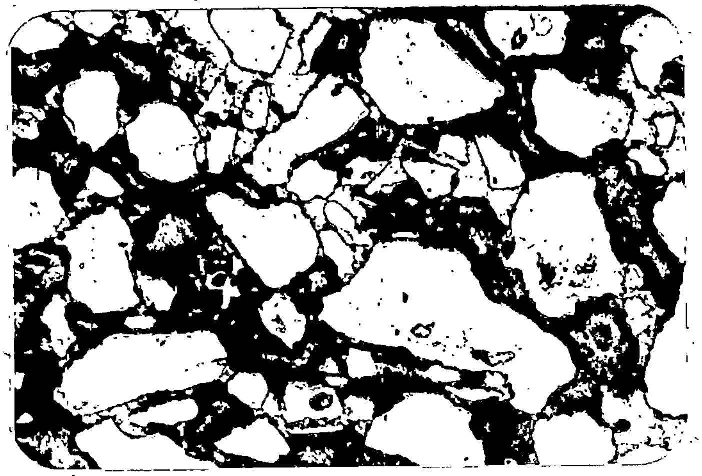
45. Kattukambal kole soil profile fourth horizon polished block in reflected light Mgf 100X

Greater than coarse sand sized laterite nodules with pitted, fine sand sized quartz and less than silt sized opaques, pyrites on coarse yellowish brown plasma is present.



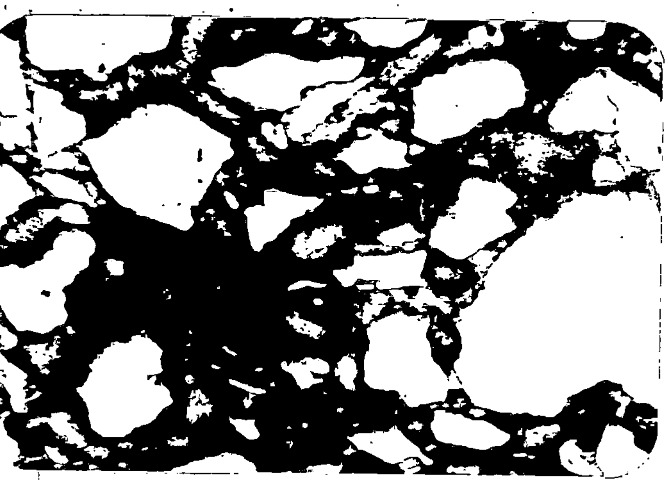
46. Kattampally kaipad soil profile first horizon polished block in reflected light Mgf 100X

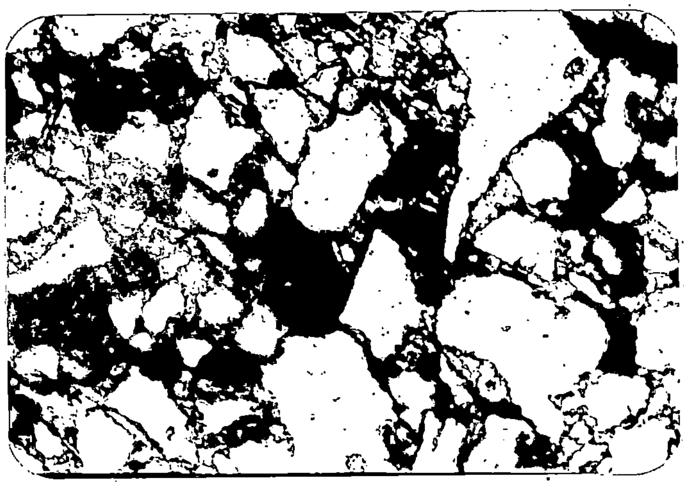
Innumerable less than silt sized quartz, opaques, pyrites, jarosite and less than fine sand sized non weathered sub angular quartz on coarse grained yellowish brown plasma is noticed.



47. Kattampally kaipad soil profile second horizon polished block in reflected light Mgf 100X

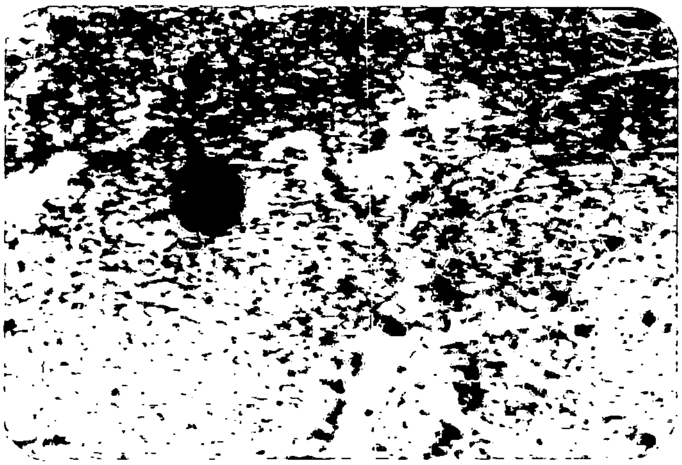
Skelsepic, plasma very less, greater than 30 per cent amoeba shaped pyrite with opaque organan forming aggregates along skeletons and voids.

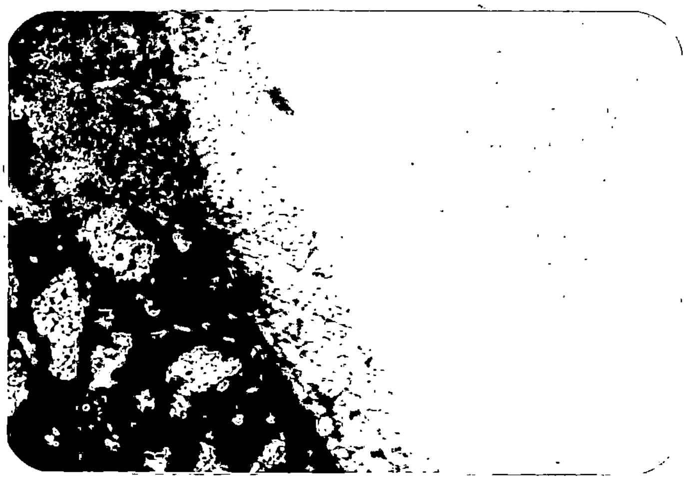




48 & 49 Kattampally kaipad soil profile third horizon polished block in reflected light Mgf 100X

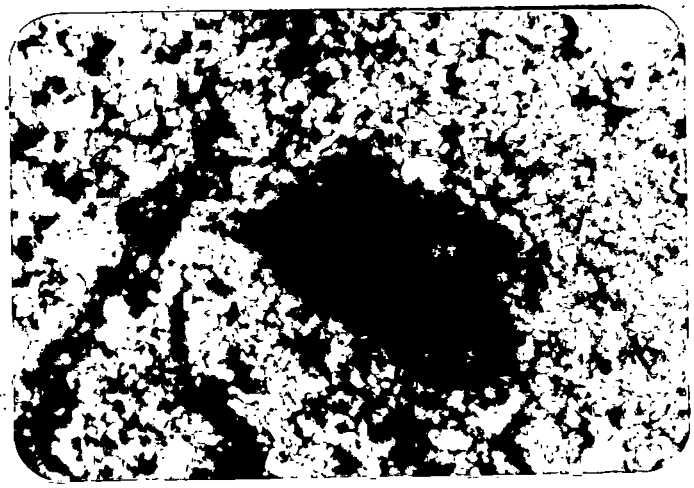
More jarosite, ferriargillan, quartz with few alterations to ferrihydrite limeshell microlites and flakes are present.



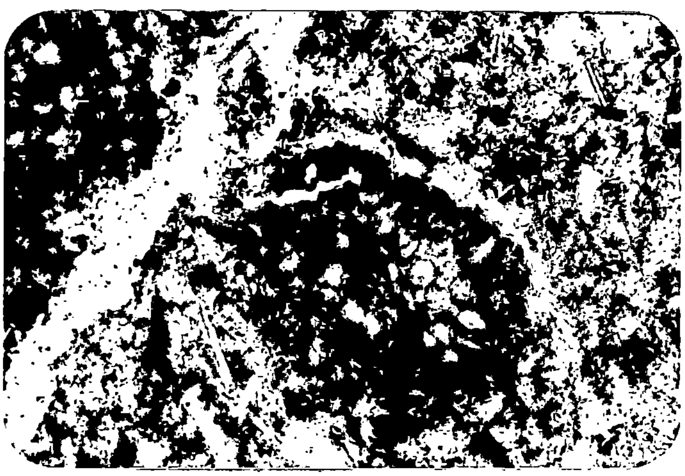


50,51 & 52 Kattampally kaipad soil profile, fourth horizon (limeshell horizon) polished block in reflected light Mgf. 100X

Note the presence of many iron spheroids and pyrite spheroids (less than silt sized) on the limeshell, highly pitted quartz, amoeba shaped pyrite with ferriorganan aggregate forming 30 per cent, less plasma.

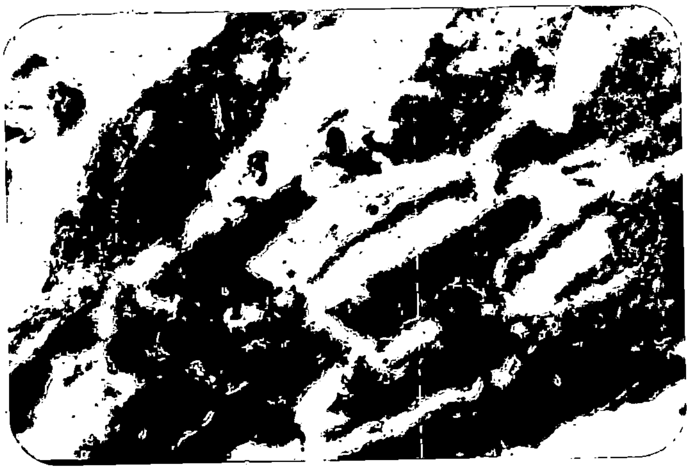


53. Karumadi kari soil profile first horizon soil thin section in plane polarised light Mgf 160X

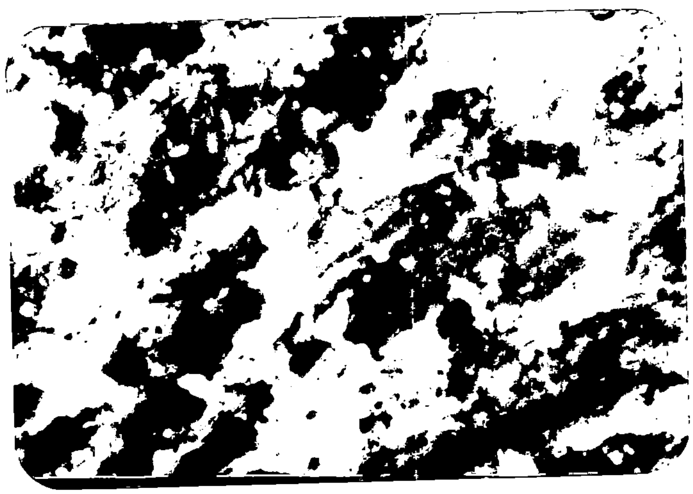


54. Karumadi kari soil profile first horizon thin section under crossed polarisers Mgf 160X

Basic structure is characterised by voids with relatively few skeletons of silt sized, compact plasma not easily recognised. Bigger chambers and channels and many tubular phytolithes present, jarosite and pyrite present on humus and along chambers and channels.

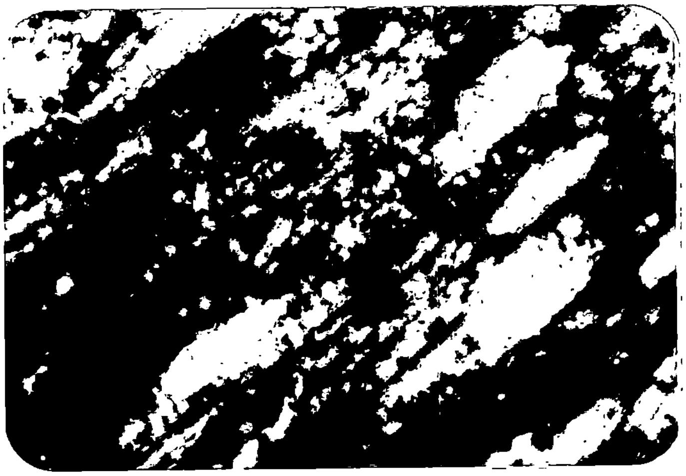


55. Karumadi kari soil profile second horizon thin section in plane polarised light Mgf 160X

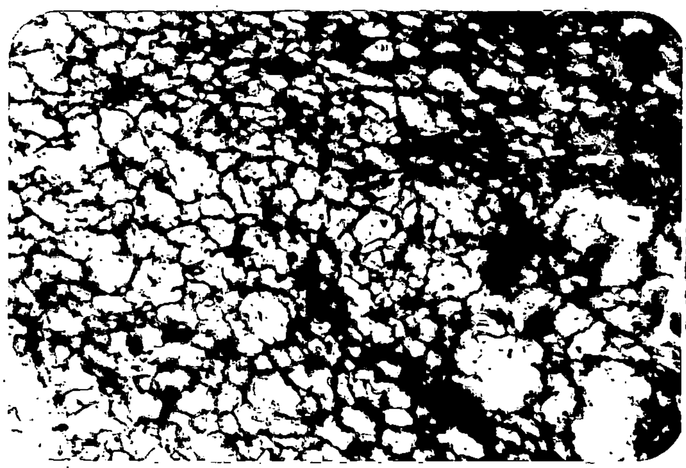


56. Karumadi kari soil profile second horizon thin section under crossed polarisers Mgf 160X

Plasma is very less. The basic structure is characterised by dominance of voids entangled by irregular shaped masses of raw and plasmafide organic matter within and on cubular pyrite on iron enriched margins.

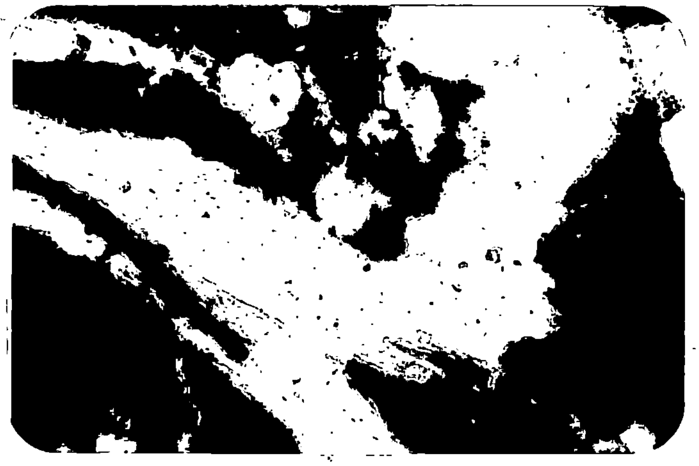


57. Karumadi kari soil profile third horizon thin section in plane polarised light Mgf 160X

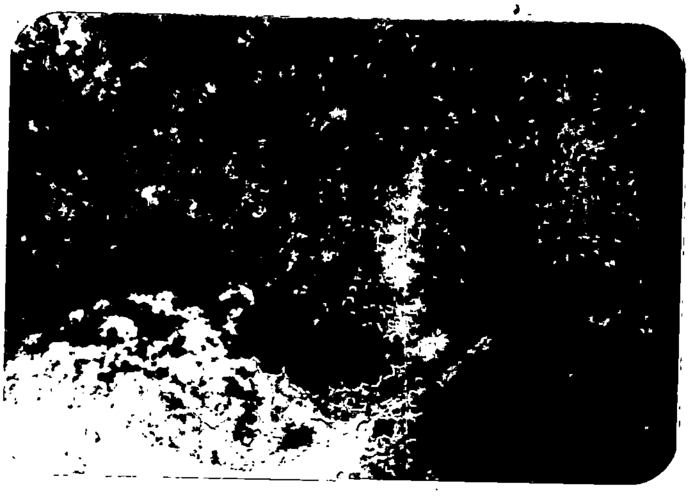


58. Karumadi kari soil profile third horizon thin section in plane polarised light Mgf 160X

Cell walls of organic material with iron enrichment, porous, humus rich pyrite and jarosite rich horizon.

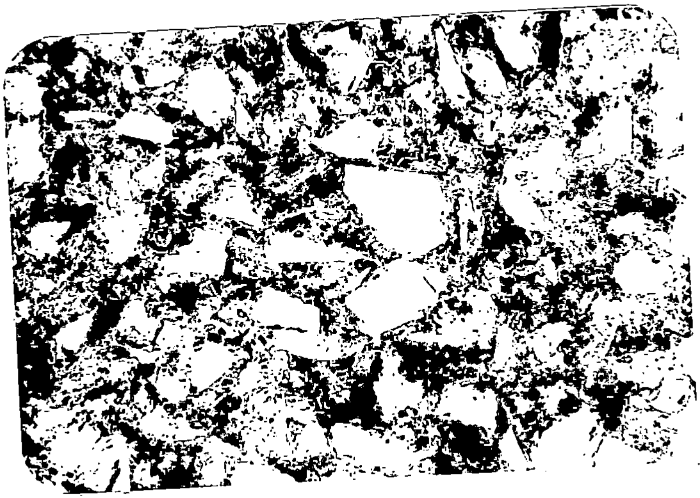


59. Karumadi kari soil profile fourth horizon thin section in plane polarised light Mgf 160X

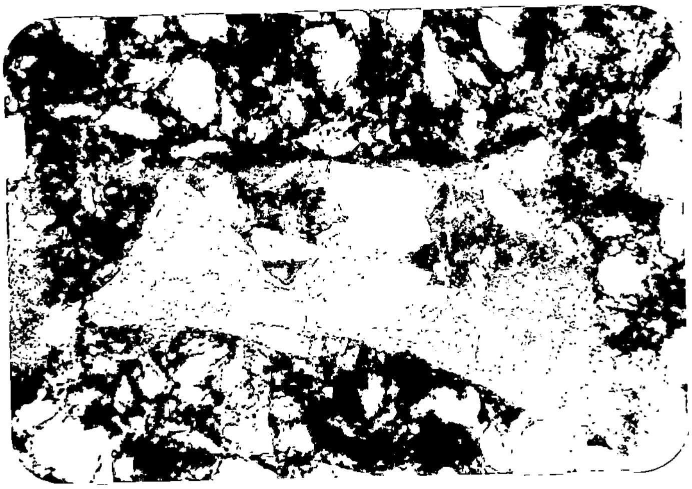


60. Karumadi kari soil profile fourth horizon thin section in plane polarised light Mgf 160X

Raw organic matter rich silt sized framboidal pyrite rich, porous horizon with iron enrichment and ferriargillan deposition in the form of hexagons.

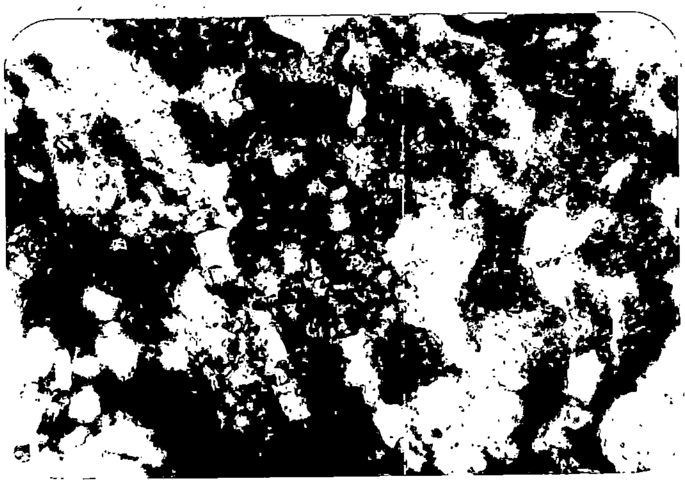


61. Moncompu karapadam soil profile first horizon thin section in plane polarisers Mgf 160X

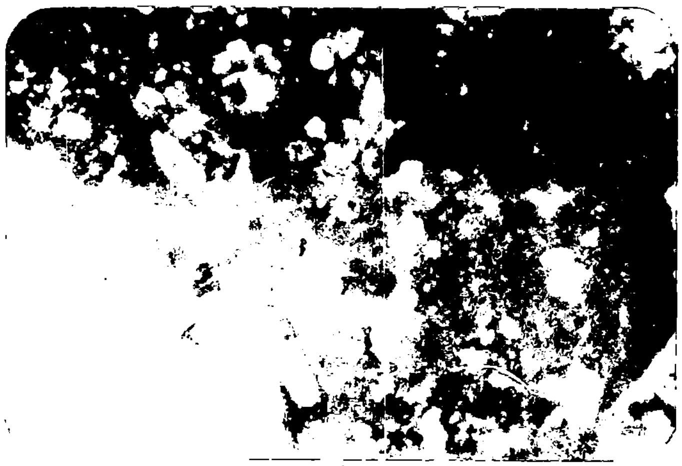


62. Moncompu karapadam soil profile first horizon thin section under crossed polarisers Mgf 160X

Ferriargillan and sub angular quartz rich horizon. Skeletons are partly birefringent. Few plasma, many fine pyrite and jarosite framboids in the interangular margin of quartz skeletons. Phyric RDP.

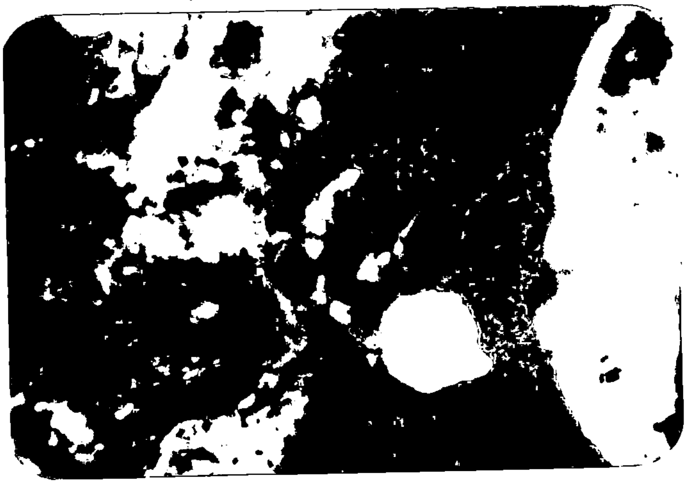


63. Moncompu karapadam soil profile second horizon thin section in plane polarised light Mgf 160X

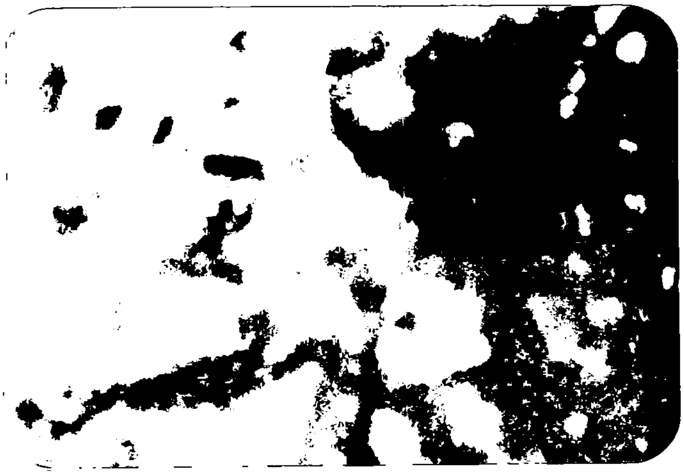


64. Moncompu karapadam soil profile second horizon thin section under crossed polarisers Mgf 160X

Void rich, humus rich, fine framboidic and polyframboidic, jarosite rich, ferri hydrite rich horizon with some silt sized ilmenite and pyrite.



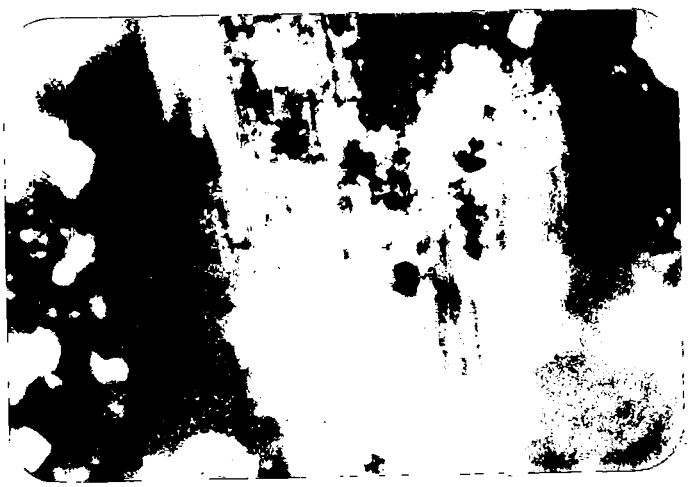
65. Moncompu karapadam soil profile third horizon thin section in plane polarised light Mgf 160X



66. Moncompu karapadam soil profile third horizon thin section under crossed polarisers Mgf 160X

Reddish yellow to yellowish brown plasma with vosepic plasmic fabric, few coarse sand sized opaques, pyrite frameboids, subrounded quartz silt sized quartz, and cubular and framboidal jarosite, vughs and channels are present. Ferriorganan and neoquasijarositan are present. Few ferrihydrite, jarosite and ferrihydrite framboids are present on the margins of voids and skeletons. Humus present as ferriorganans.

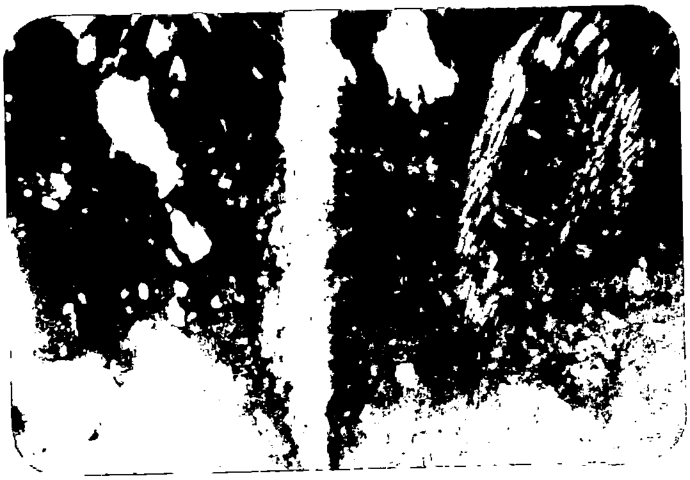
67. Moncompu karapadam soil profile fourth horizon thin section in plane polarised light Mgf 160X



68. Moncompu karapadam soil profile fourth horizon thin section under crossed polarisers Mgf 160X

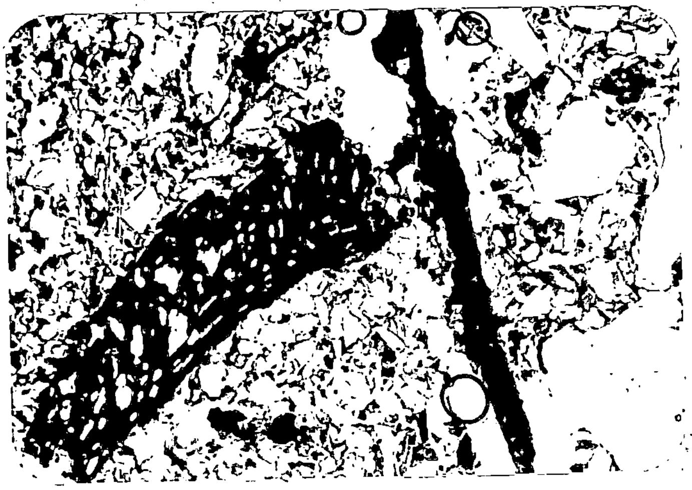
Brownish yellow to reddish plasma, with voskelsepic plasmic fabric. The NRDP is plasmigranic. Silt sized subangular quartz, silt sized innumerable number of cubular and framboidal pyrite and very few ilmenite are present. Voids are vughs and metavughs. Humus present as organan and ferriorganan. Pyrite is present in the framboidal form around and on cellular retained structure of partially decomposed wood fossils.

69. Mathikayal kayal soil profile first horizon soil thin section in plane polarised light Mgf 160X

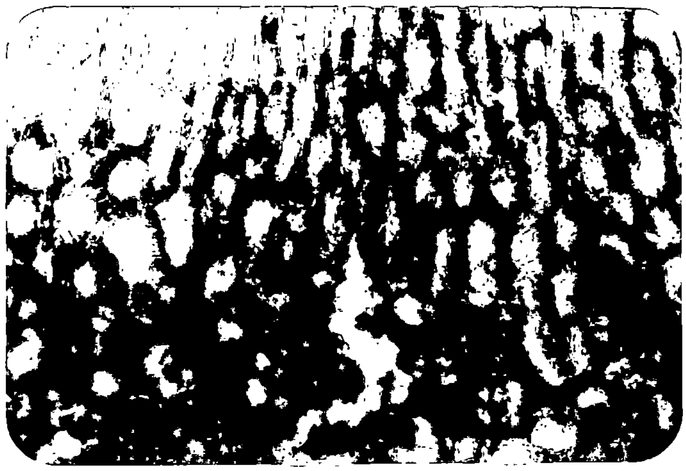


70. Mathikayal kayal soil profile first horizon soil thin section under crossed polarisation Mgf. 160X

The colour of the plasma is greyish brown, brownish yellow and reddish yellow, and the plasmic fabric, is vosepic to voskelsepic and the NRDP is granic. Humus present as ferriorganan. Very fine innumerable framboidal jarosite and pyrite on the decaying roots of paddy are present. Few ferrihydrite framboids are also present.

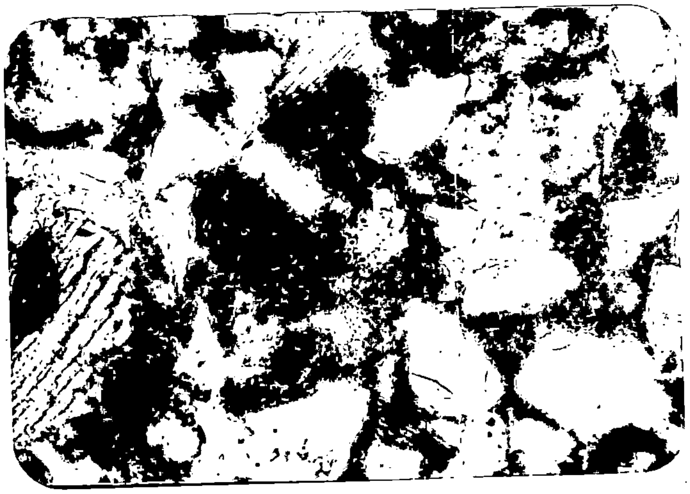


71. Mathikayal kayal soil profile second horizon soil thin section in plane polarised light Mgf 160X

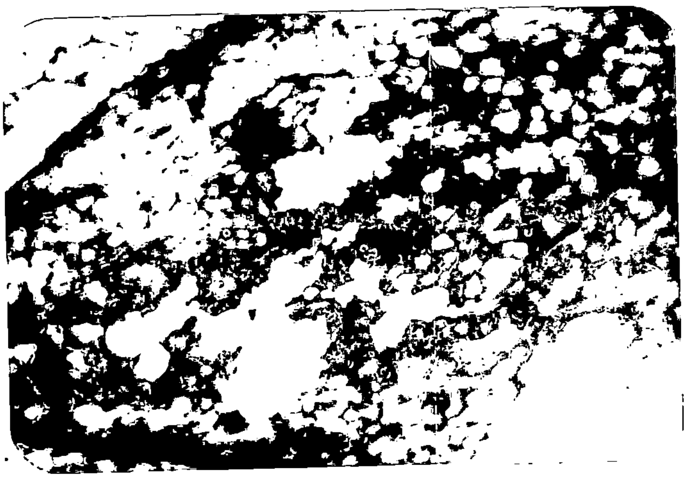


72. Mathikayal kayal soil profile second horizon soil thin section in plane polarised light Mgf 160X

Greyish yellow to yellowish brown plasma. Plasma form very less portion of the soil S-matrix. The plasmic fabric is skelsepic to skelargillasepic and NRDP is granic. Silt sized angular quartz, feldspars, ilmenite and few coarse sand sized quartz and biotite mica are present. Specific type of voids are not observable but few numbers of fine channels are noticed. Humus present as clusters of ferriorganan. Plasmafied organic matter on decaying plant parts are with repeated ferric iron oxide deposition. Very few jarosite and pyrite framboids in the interangular spaces of skeletons and on the cellwalls of decaying plant material are seen.



73. Mathikayal kayal soil profile third horizon soil thin section in plane polarised light Mgf 160X



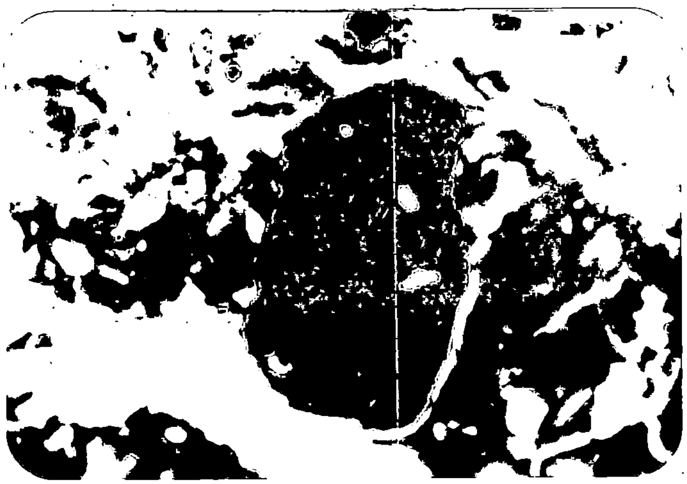
74. Mathikayal kayal soil profile third horizon soil thin section in plane polarised light Mgf 160X

Brownish yellow to opaque plasma, skelsepic to skelargillasepic plasmic fabric, with granic NRDP. Fractured fine sand sized few feldspars and many subangular to subrounded fine sand sized quartz present. Few pyrite and other opaques are also present. Framboidal jarosite pyrite, and ferrichydrite are present in the inter angular spaces of skeletons and in decaying plant cells.

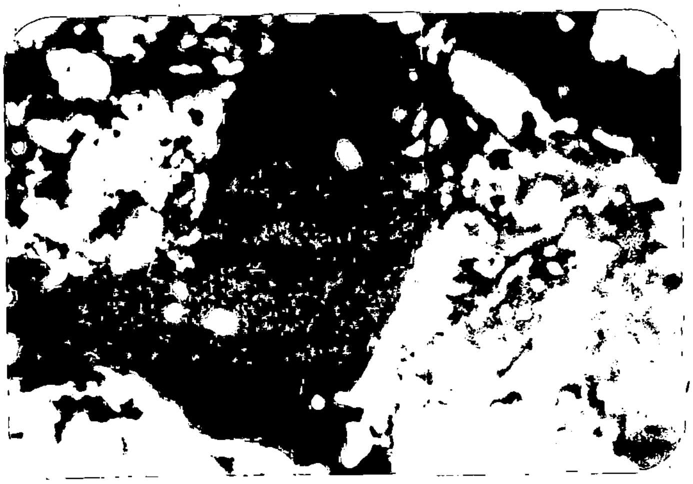
75. Mathikayal kayal soil profile fourth horizon soil thin section in plane polarised light Mgf 160X

76. Mathikayal kayal soil profile fourth horizon soil thin section under crossed polarisers Mgf 160X

Skelvosepic fabric with yellowish brown plasma. Subangular to sub rounded coarse sand sized, many silt sized quartz, agregates of fine quartz, pyrite and other opaques with ferri-organan, organan, ferran and few ferriargillan present. Certain bigger quartz are highly fractured and iron oxide coated. Voids are vughs, chambers and few fine channels.



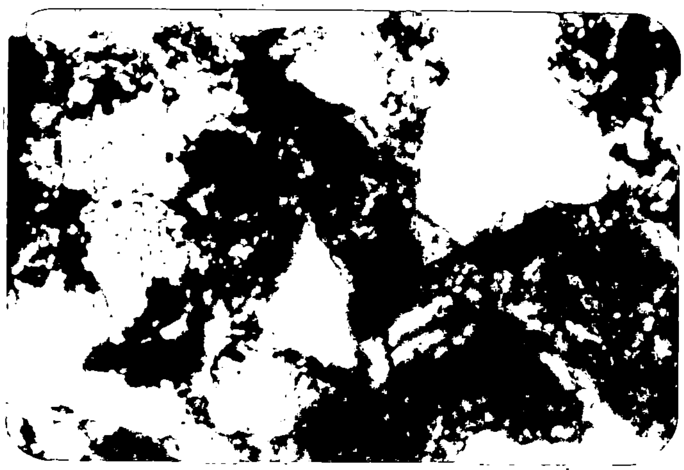
77. Vytilla pokkali soil profile first horizon soil thin section in plane polarised light Mgf 160X



78. Vytilla pokkali soil profile first horizon soil thin section under crossed polarisers Mgf 160X

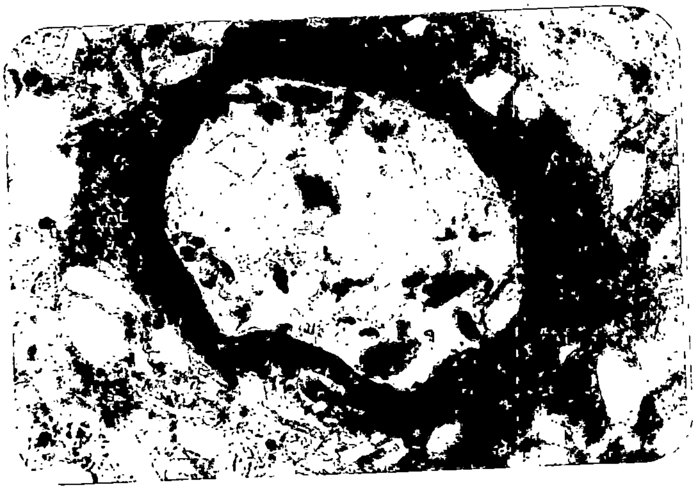
Greyish yellow to grey coloured plasma with Voskelsepic soil fabric. Voids are bigger chambers and channels. Few fine sand sized and less than sized silt sized subrounded to rounded faint margined quartz and few more than coarse sand sized sharp margined reddish brown laterite nodules present, Very few pyrite and other opaques are present.

79. Vytilla pokkali soil profile second horizon soil thin section in plane polarised light Mgf 160X

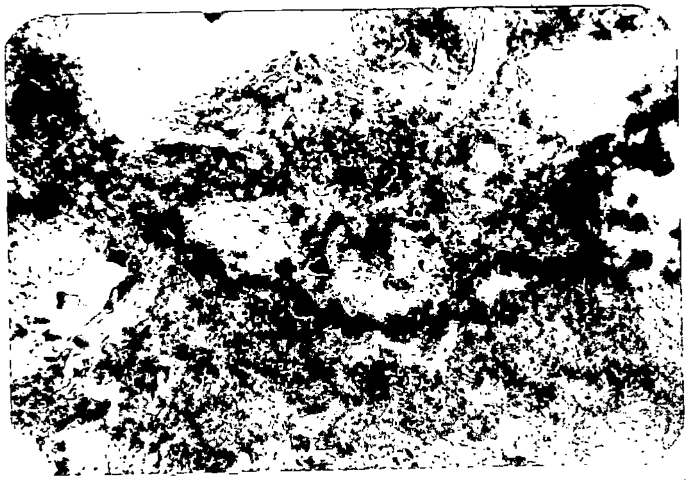


80. Vytilla pokkali soil profile second horizon soil thin section under crossed polarisers Mgf 160X

Greyish yellow to yellowish brown plasma with skelargillasepic plasmic fabric. The NRDP is graniplasmic. Coarse sand sized to fine sand sized subangular to subrounded quartz, few fine sand sized highly fractured feldspars, silt sized pyrite framboids in the interangular spaces of quartz with their oxidation products jarosites and ferrichydrite present. Humus highly plasmafied, ferric iron oxide coated. The conversion of pyrite to its oxidation product, jarosite and ferrihydrite is less. Ferriargillan and soil coating form interangular bridges between skeletons.



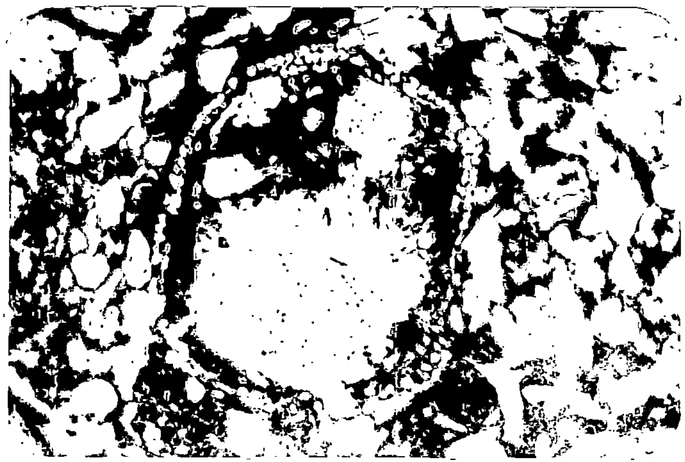
81. Vytilla pokkali soil profile third horizon soil thin section in plane polarised light Mgf 160X



82. Vytilla pokkali soil profile third horizon soil thin section in plane polarised light Mgf 160X

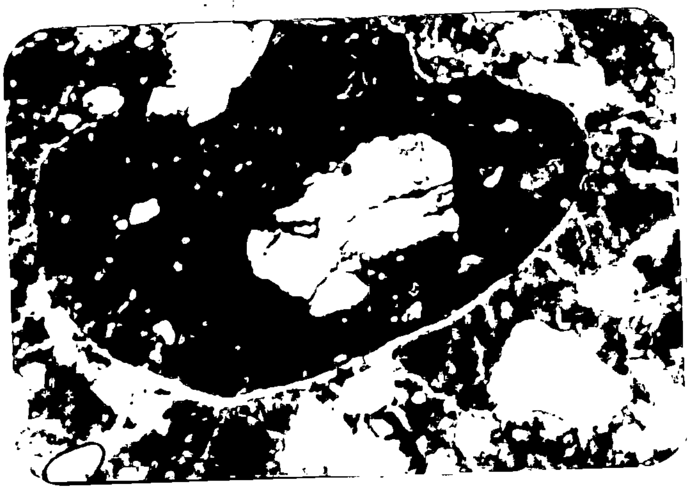
Brownish yellow to yellowish brown plasma with argillasepic to skelargillasepic plasmic fabric. The NRDP is graniplasmic. The skeletons are silt sized, faint margined, low reliefed, subangular quartz. Voids spherical and fine channels. Humus present as ferriorganan Laterite concentrations of 0.38 dia few number present. Silt sized jarosites and pyrites are present in the channels.

83. Vytilla pokkali soil profile fourth horizon soil thin section in plane polarised light Mgf. 160X

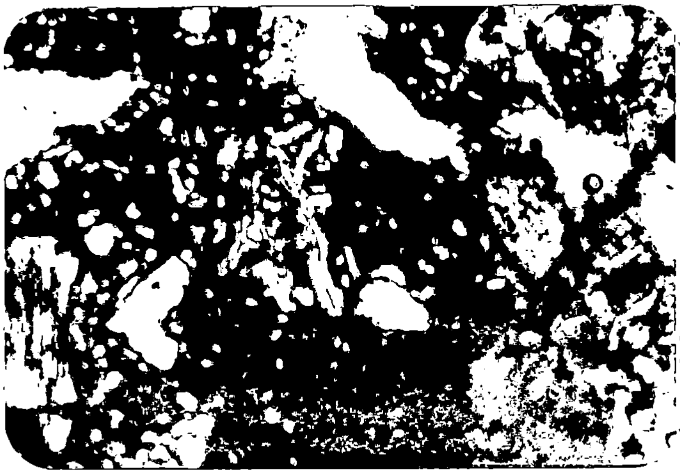


84. Vytilla pokkali soil profile fourth horizon soil thin section in plane polarised light Mgf 160X

Plasma forms very less portion of the soil S-matrix and is with brownish yellow, yellowish brown and dark brown colour. The plasmic fabric is argillasepic with agglomeroplasmic to chlamydomorphic RDP. Fine sand sized and silt sized many number of subangular quartz, framboidal pyrite, quartz rich laterite concretions are present. Vughs and few channels present. Humus present as ferriorganan in combination with ferriargillan. Laterite concretions of 0.39 mm diameter, few present. Silt sized clusters of framboidalpyrites

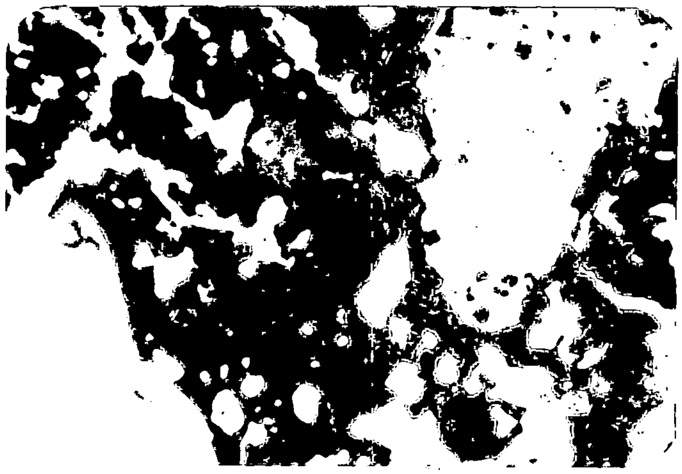


85. Kattukambal kole soil profile first horizon soil thin section in plane polarised light Mgf. 160 X

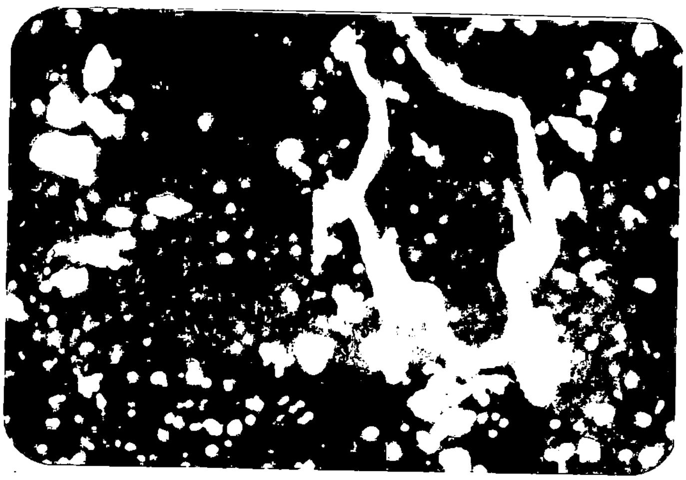


86. Kattukambal kole soil profile first horizon soil thin section in plane polarised light Mgf. 160 X

Yellowish brown to reddish brown coloured plasma with argillasepic plasmic fabric. The NRDP is plasmigranic to porphyroskelic. The skeletons present are fine sand sized and less than silt sized quartz. Laterite nodules with sharp margins, very fine channels and bigger channels present. Humus present as ferriorganan. 0.63 mm dia, sharp margined laterite nodules. They are iron enriched, quartz rich and fractured. Few framboidal silt sized pyrite present in the vughs and channels.

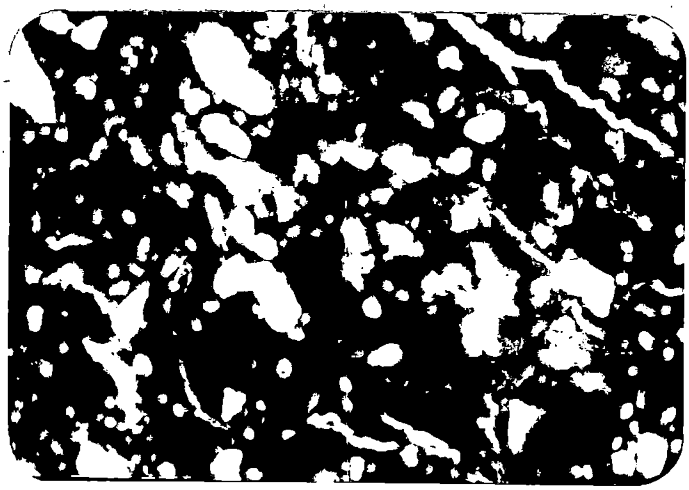


87. Kattukambal kole soil profile second horizon soil thin section in plane polarised light Mgf. 160 X

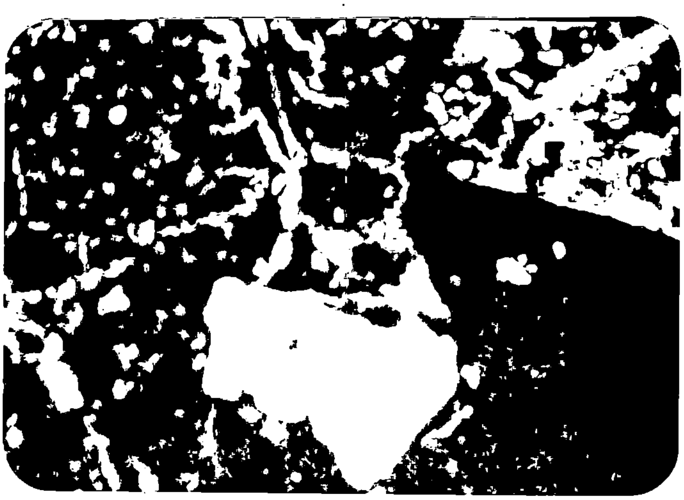


88. Kattukambal kole soil profile second horizon soil thin section under crossed polarisers Mgf. 160X

Brownish yellow to opaque plasma with argillasepic to vosepic plasmic fabric. The NRDP is plasmigranic. Spherical iron oxide coated quartz rich laterite nodules of 0.25 mm diameter and silt sized quartz is present. Voids are channels and few vughs. Humus present as intimately mixed ferriorganan and fine quartz. Few silt sized pyrite present.

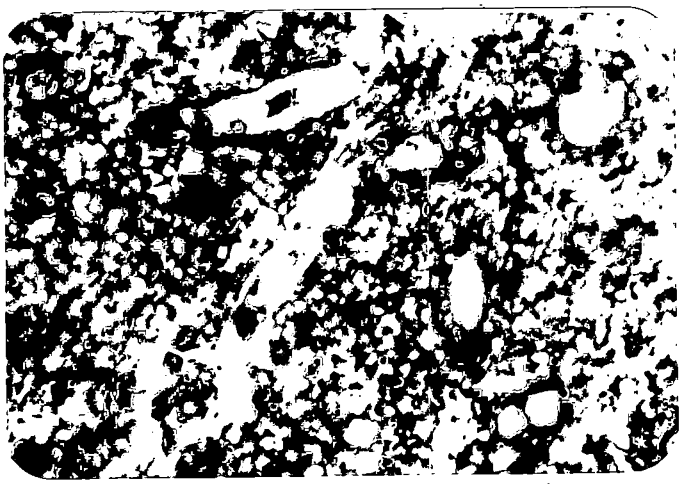


89. Kattukambal kole soil profile third horizon soil thin section in plane polarised light Mgf 160 X

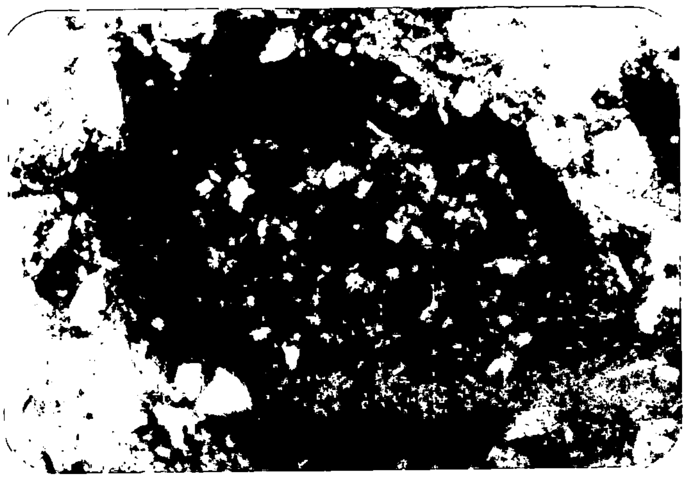


90. Kattumkambal kole soil profile third horizon soil thin section under crossed polarisers Mgf 160X

Dark brown, brownish yellow, and reddish yellow coloured plasma with argillasepic to voskelsepic plasmic fabric. The NRDP is plasmigranic. Many silt sized subangular to sub rounded quartz. Few subangular quartz, and laterite nodules of 0.38 mm diameter are present. Voids present are chambers running diagonally giving a striated orientation pattern. Humus present as ferriorganan, in combination with ferriargillan. Jarosite present as jarositic deposition surrounding the pores as yellow halo, aureole.

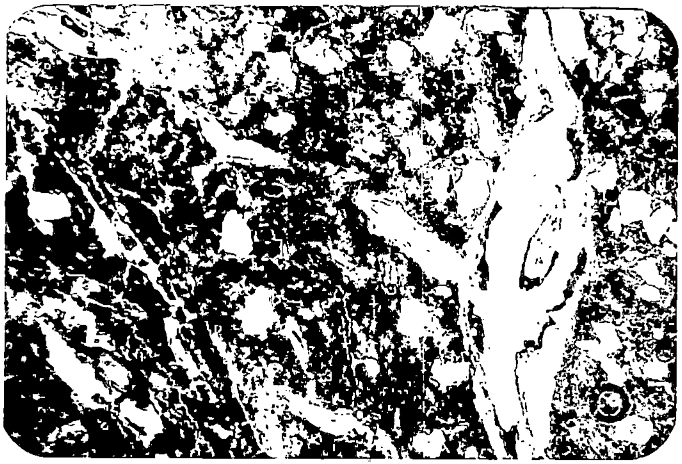


91. Kattukambal kole soil profile fourth horizon soil thin section in plane polarised light Mgf 160X .

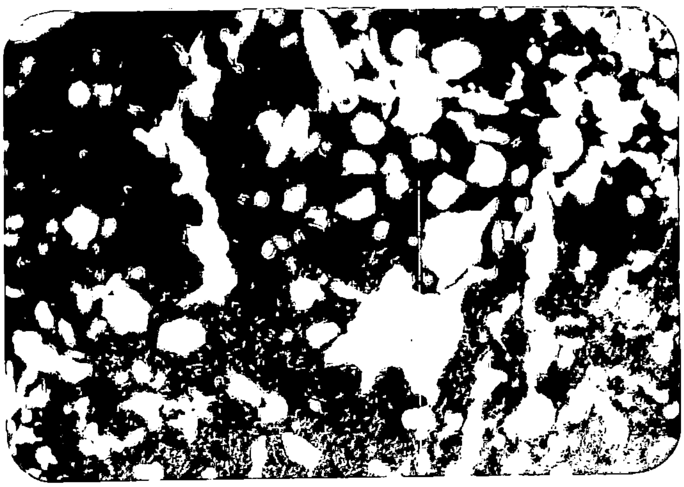


92. Kattukambal kole soil profile fourth horizon soil thin section .under crossed polarisers Mgf 160X

Brownish yellow, greyish yellow, and reddish brown plasma forming very less portion of soil matrix. The soil fabric is argillasepic and concretion rich. The NRDP is graniplasmic. 0.13 to 0.50 mm sized subangular laterite concretions, few opaques and silt sized, very fine subrounded to rounded quartz are present. Voids present are channels and fine chambers. Humus present as ferriorganan surrounding the concretions. Very fine cubular and framboidal

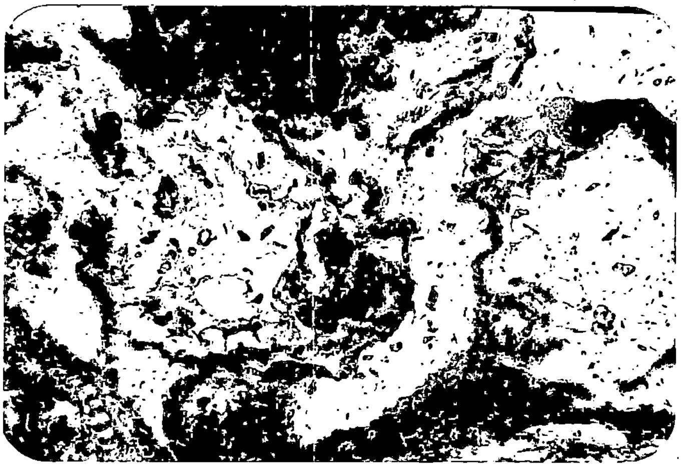


93. Kattampally kaipad soil profile first horizon soil thin section in plane polarised light Mgf 25X

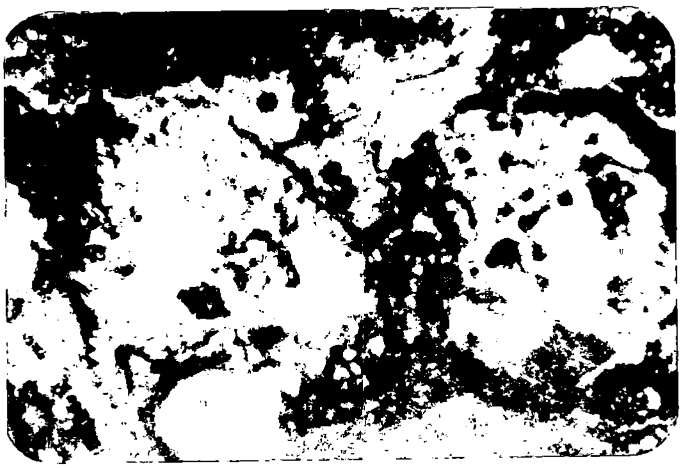


94. Kattampally kaipad soil profile first horizon soil thin section in plane polarised light Mgf 25X

Yellowish brown plasma with argillasepic plasmic fabric. The NRDP is plasmic granic to graniplasmic. Sharp margined quartz rich porous laterite nodules with cracks running through whole or only on the outer, peripheral coatings are present. Framboidal jarosite and pyrite present. fine sand sized sub rounded to rounded quartz are seen. Fine channels and bigger chambers present. Humus present as ferriorganan.

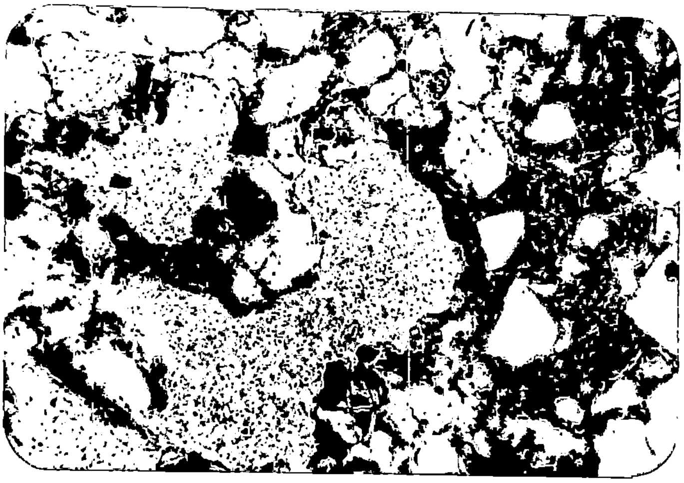


95. Kattampally kaipad soil profile second horizon soil thin section in plane polarised light Mgf 25X



96. Kattampally kaipad soil profile second horizon soil thin section in crossed polarisers Mgf 25X

Reddish yellow to greyish yellow plasma with vosepic plasmic fabric. The NRDP is plasmic to granular. Very fine quartz, pyrite and other opaques are seen in the channels. Bigger channels and chambers present. Humus present as organan and ferriorganan. Many framboidal pyrite present, along with the faunal faecal material. Ortho agrotubules and bigger channels filled with faunal faecal material are signs of active current faunal activity.



97. Kattampally kaipad soil profile third horizon soil thin section in plane polarised light Mgf 25X

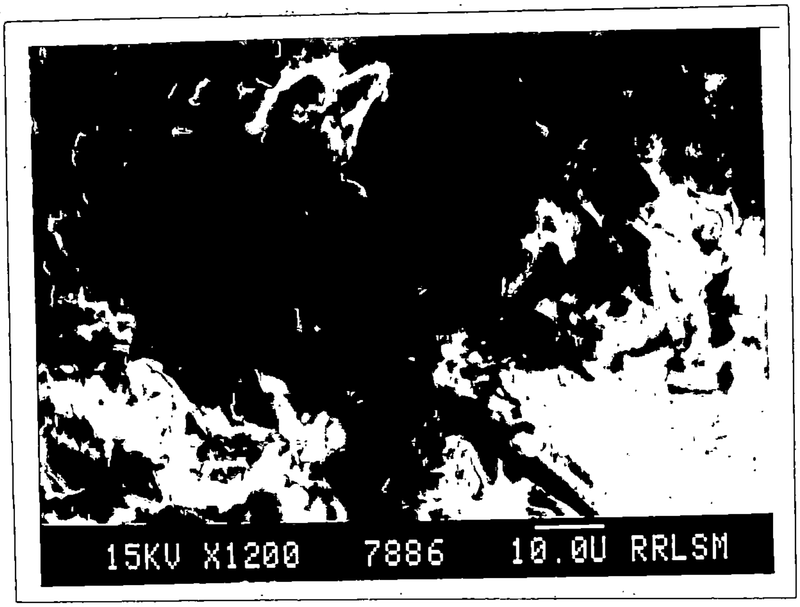
98. Kattampally kaipad soil profile third horizon soil thin section in plane polarised light Mgf 25X

Greyish brown, brownish grey plasma forms less portions of the soil matrix. The plasmic fabric is skelsepic and NRDP is granic. Sub angular fine sand sized, ferriorganan marginal coated, fractured quartz, feldspars and opaques. Few bigger channels present. Humus present as ferriorganan. Few fine cubular pyrite present.

99. Kattampally kaipad soil profile fourth horizon soil thin section in plane polarised light Mgf 25X

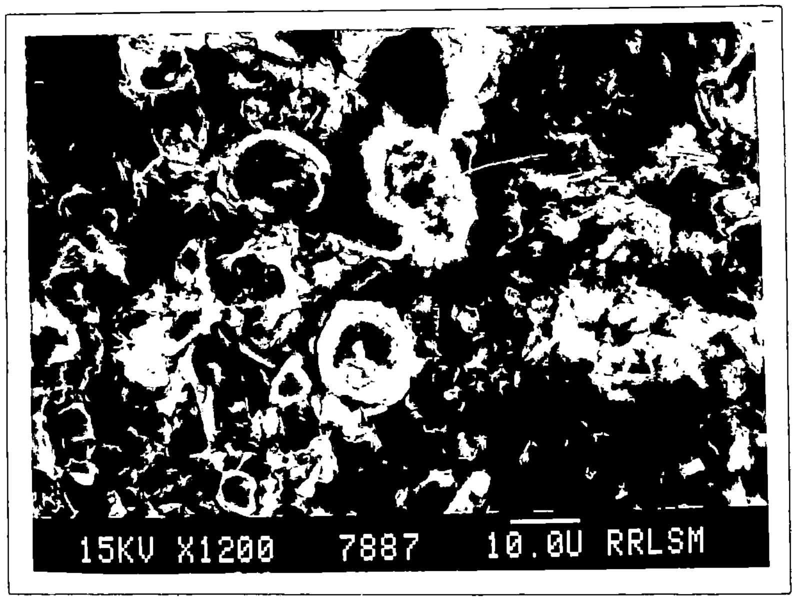
100. Kattampally kaipad soil profile fourth horizon soil thin section under crossed polarisers Mgf 25X

Greyish yellow to brown plasma with argillaskelsepic plasmic fabric. NRDP is plasmigranic. Few fine sand sized, sub angular quartz, many fine sand sized spheroidal ferrichydrite pyrite and few opaques are present. Humus present as organan. Few framboidal pyrite and many framboidal ferrihydrite present on and around the shells of molluscs and on the limeshell pieces.



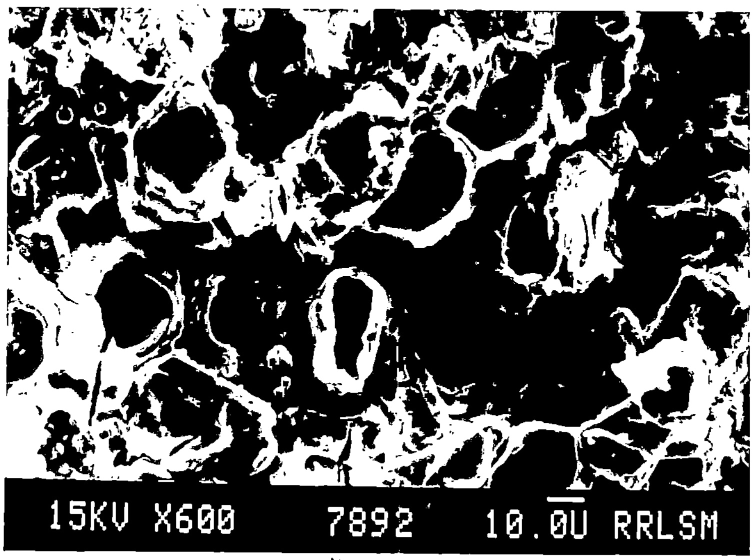
101.Scanning electron photomicrograph of Karumadi kari soil profile first horizon Mgf 1200X

Thick iron accumulation on soil and wood fossils, with 1.0m/u sized many number of jarosite framboids. Few opaque coated with thick flakes of iron oxide are also present.



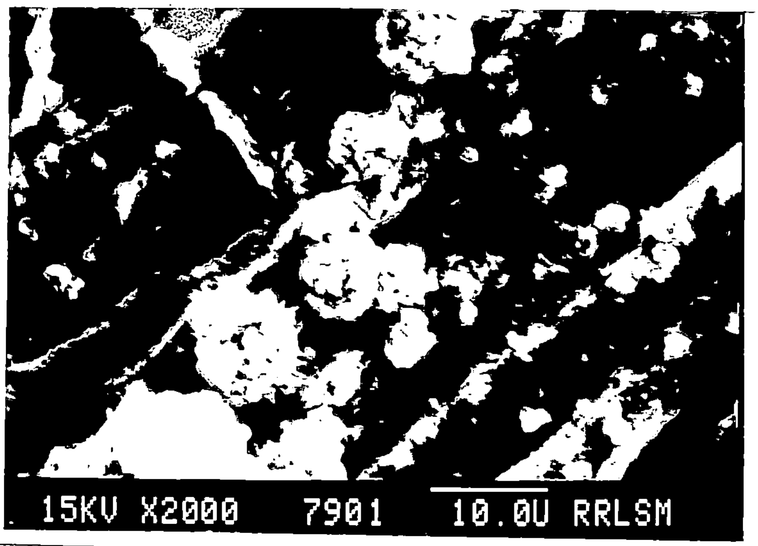
102.Scanning electron photomicrograph of Karumadi kari soil profile first horizon Mgf 1200X

Thickly iron coated jarosite framboids of 1 to 10 m/u size are present on thickly iron coated wood fossils and other soil skeletons. Few iron coated cubular pyrites is also seen.



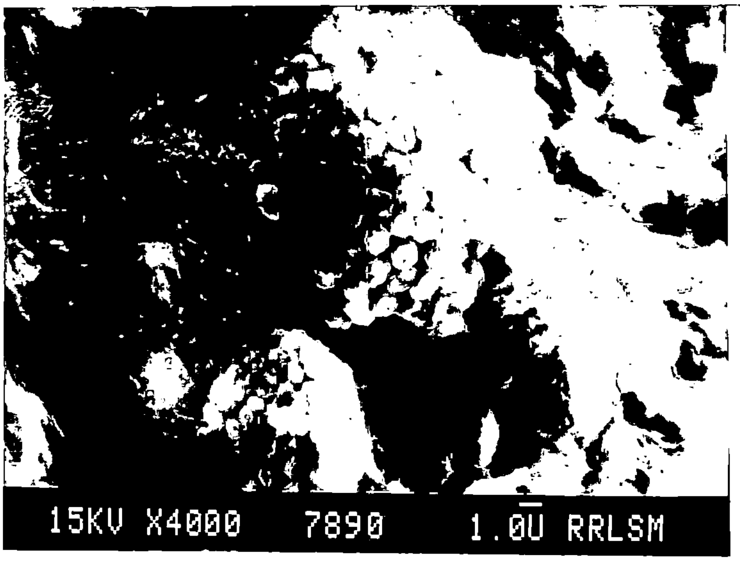
103. Scanning electron photomicrograph of Karumadi kari soil profile second horizon Mgf 600X

Highly thick iron coated, hexagonal and spherical shaped regioned soil fabric with 5 m/u sized polyframboids of jarosites within them. The marginal iron deposition is of 10 m/u thickness. These encrustations are on the wood fossils.



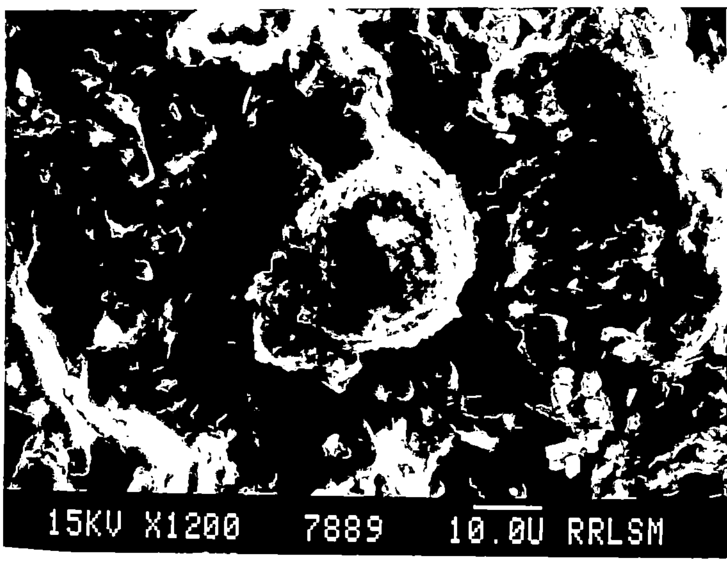
104. Scanning electron photomicrograph of Karumadi kari soil profile second horizon Mgf 2000X

Highly shrinked wood fossil with ridge and furrow structure opaque thick iron encrustations on these ridges and furrows. Highly iron enriched framboidal jarosites of 7 m /u diameter are present on these structures.



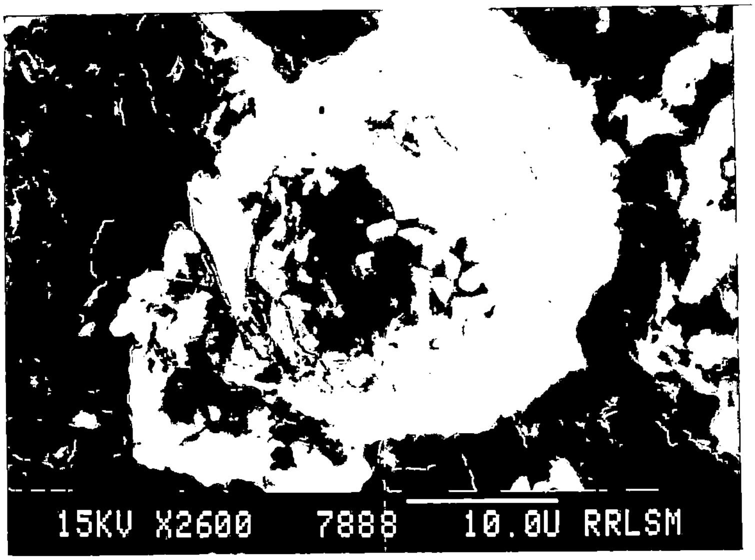
105. Scanning electron photomicrograph of Karumadi kari soil profile third horizon Mgf 4000X

Iron oxide smeared thick, dense, soil fabric with 10 m u dia polyframboidal jarosite, characteristic spherical nodules of pyrite and jarosites, showing separable hexagonal shaped microcrystals of framboids.



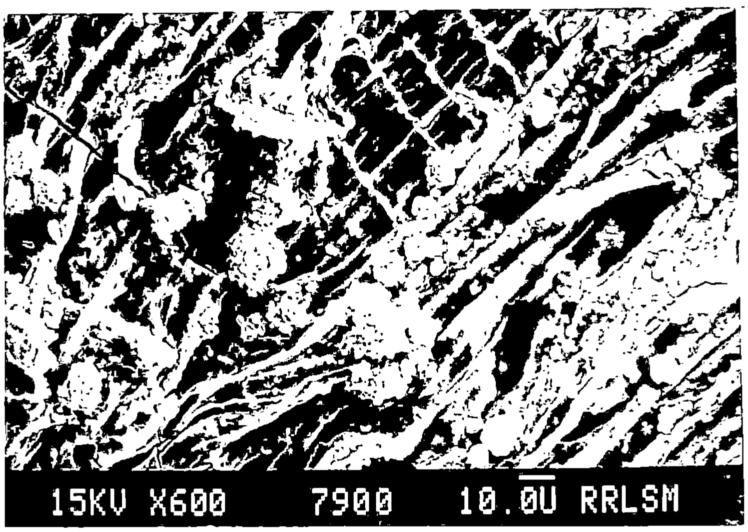
106. Scanning electron photomicrograph of Karumadi kari soil profile third horizon Mgf 1200X

Skelsepic fabric with thick iron coating of skeletons with few 30 m/u dia framboidal pyrites. Highly iron oxide coated, porous soil matrix leading to skelvosepic fabric.



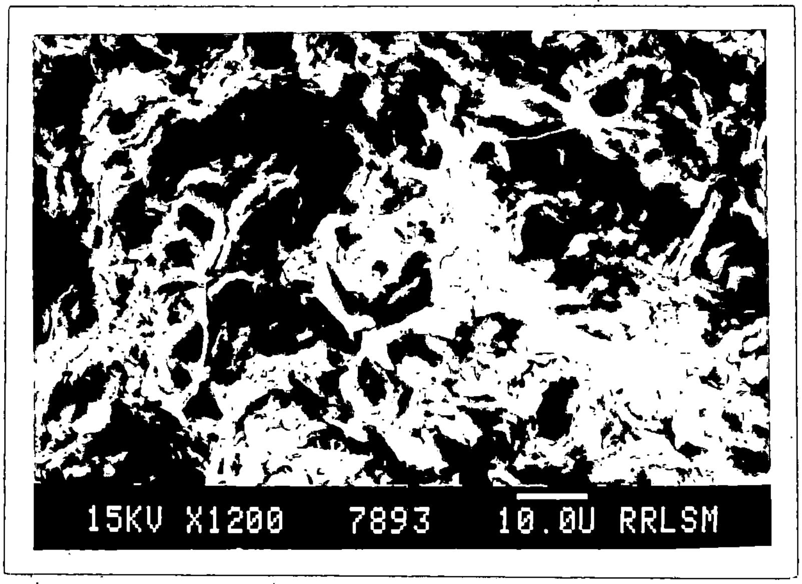
107. Scanning electron photomicrograph of Karumadi kari soil profile third horizon Enlarged view of pyrite framboid Mgf 2600X

260 m/u dia highly iron coated pyrite framboid showing cracks and multifaced micro-crystals of the framboid. Framboids shows cracking and trapping of flake like diatomaceous material.



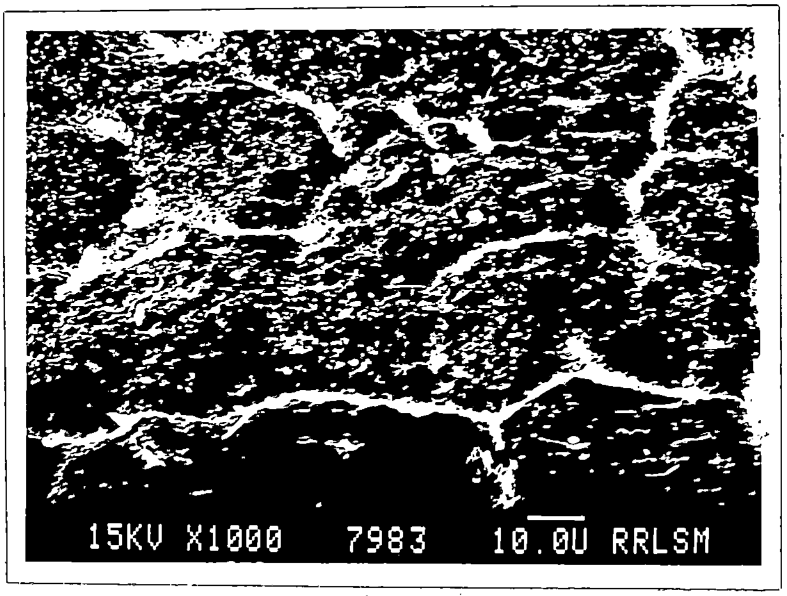
108. Scanning electron photomicrograph of Karumadi karis soil profile third horizon showing fabric of wood fossil with framboidal pyrites Mgf 600X

Highly shrinked iron coated ridge and furrow structured fabric of wood fossil showing innumerable number of 1 to 2 m/u dia pyrite framboids and many 10 m/u dia pyrite framboids on the wood fossil.



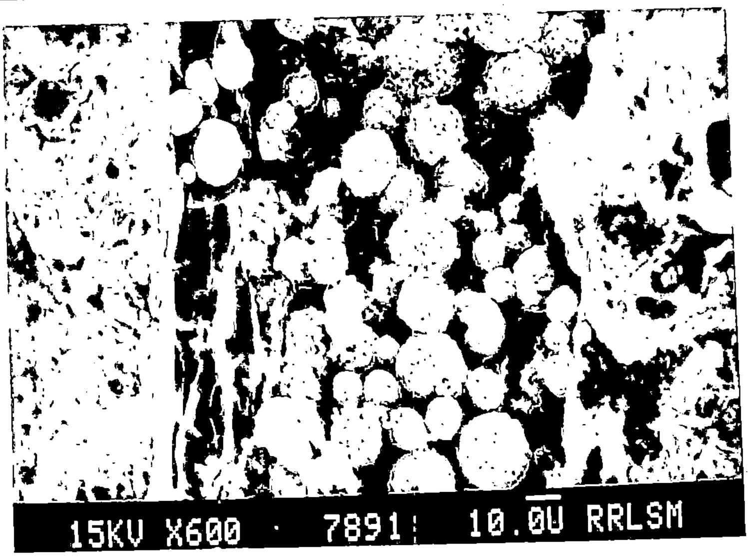
109. Scanning electron photomicrograph of Karumadi kari soil profile third horizon Mgf 1200X

Repeatedly iron oxide deposited, Vosepic, S-matrix with few framboidal pyrites of 2 m/u dia.



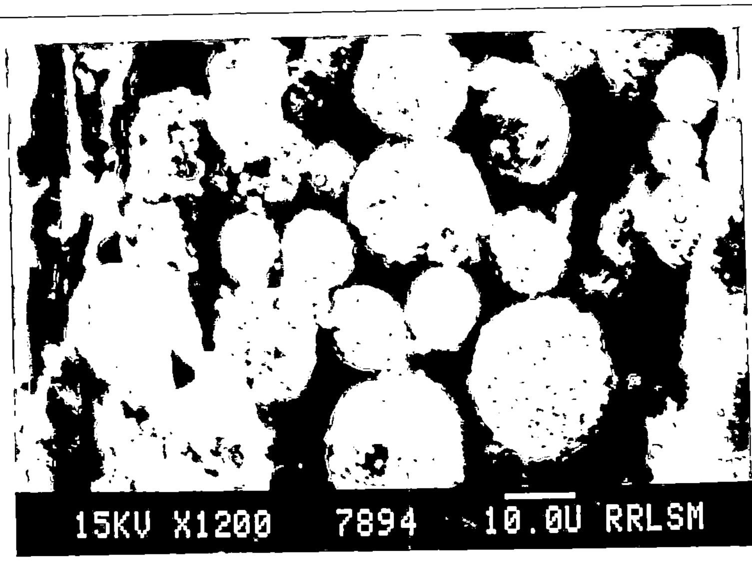
110. Scanning electron photomicrograph of Karumadi kari soil profile fourth horizon Mgf 1000X

Hexagonal shaped marginal iron oxide deposition in wood fossils with few numbers of 2 m/u dia pyrite framboids and innumerable numbers of 1 m/u pyrite framboids inside these structures.



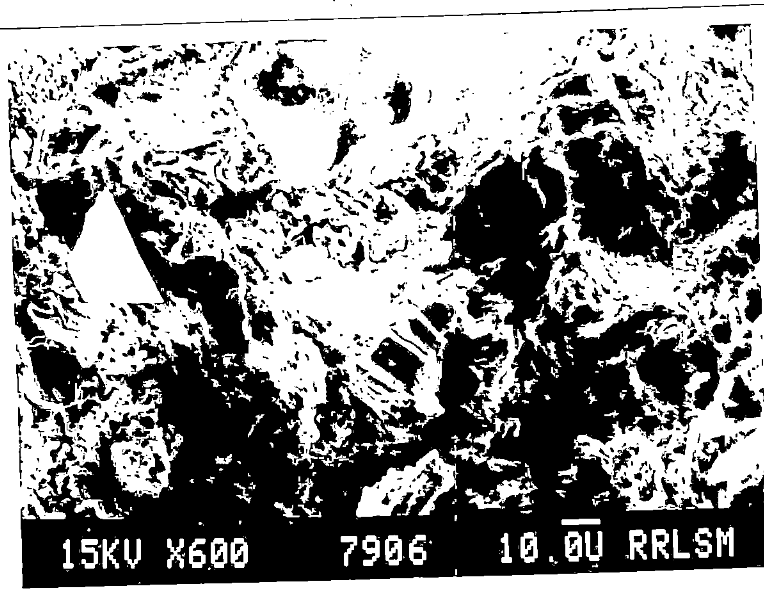
111. Scanning electron photomicrograph of Karumadi kari soil profile fourth horizon showing mangrove root section Mgf 6000X

Root channel partially decomposed with innumerable number of spherical unattached 20 m/u dia pyrite framboids. Some of the framboids are smooth while others are rough and porous. The margins of the root is with repeated ferric iron oxide deposition and are free of pyrites.



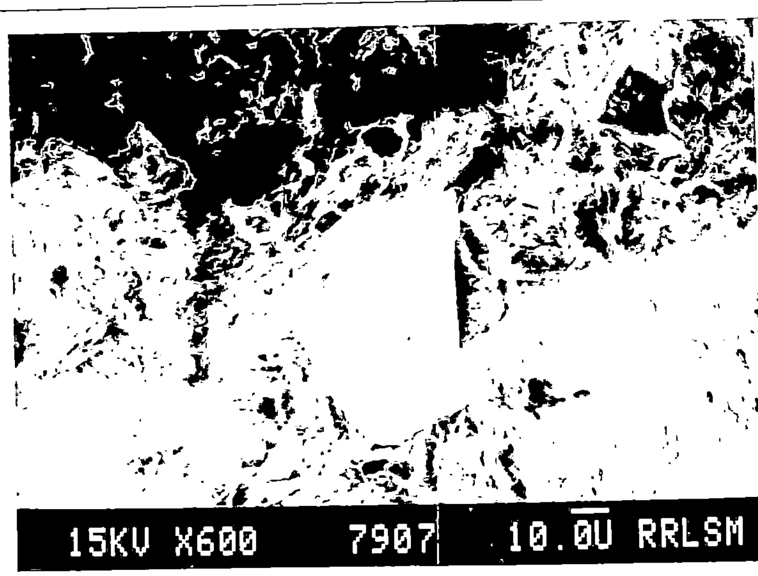
112. Scanning electron photomicrograph of Karumari kari soil profile fourth horizon An enlarged view of Photomicrograph no. 111.

An enlarged view showing porous framboidal and non porous smooth surface framboidal pyrite inside the mangrove root.



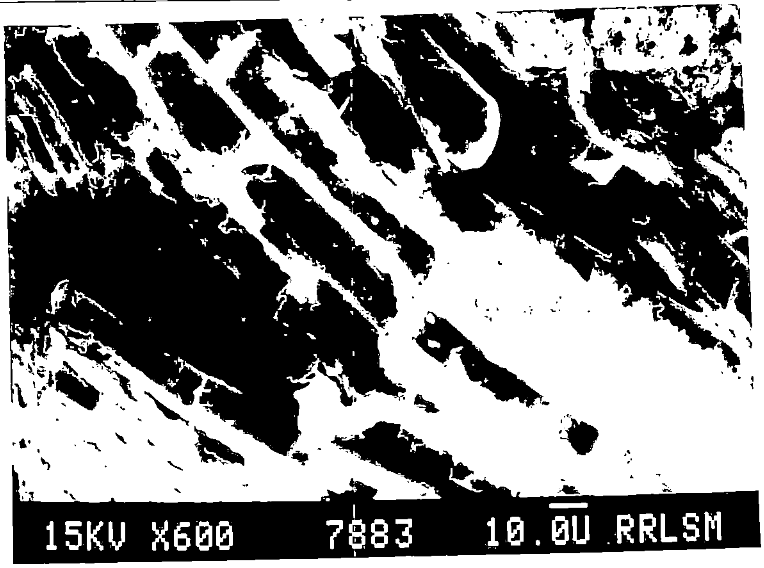
113. Scanning electron photomicrograph of Moncompu karapadam soil profile first horizon Mgf 600X

Highly iron oxide coated, skelvosepic soil fabric with flaky wood fossils, opaque minerals, and few jarosite framboids of 3 m/u dia flaky diatomaceous materials are also noticed.



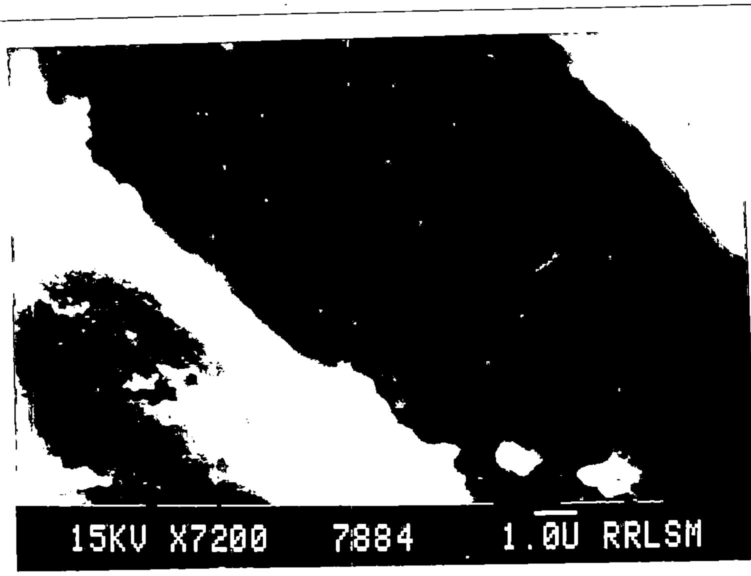
114. Scanning electron photomicrograph of Moncompu karpadam soil profile second horizon Mgf 600X

Highly iron oxide coated skelvosepic fabric with wood fossils showing cellular structure with many opaque minerals and many 2 m/u dia framboidal jarosites on dense iron oxide coating of skeletons and wood fossils. One flaky diatomaceous material of about 100 m/u is also seen.



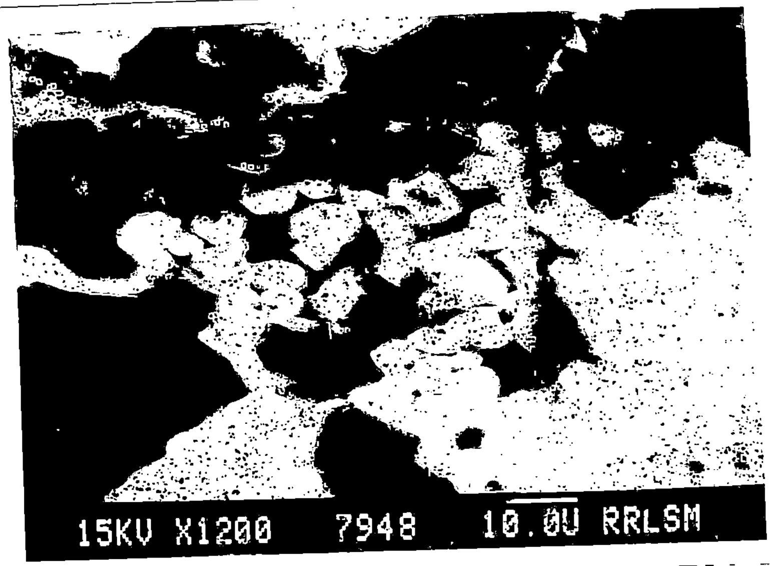
115. Scanning electron photomicrograph of Moncompu karapadam soil profile third horizon Mgf 600X

Repeated ferric iron oxide deposition on the wood fossils, cellular type deposition with 2 m/u dia innumerable number of jarosite framboid and pyrite framboid inside these cellular structures. The wood fossils with cellular structure exhibit a striated orientation pattern.



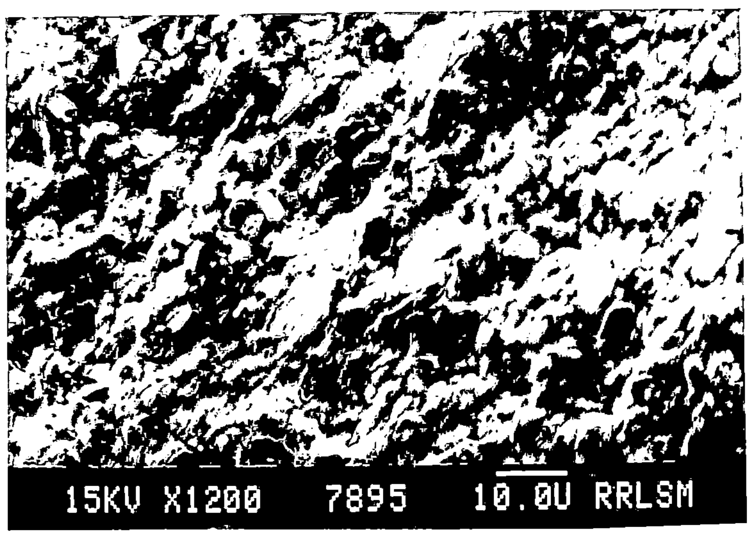
116. Scanning electron photomicrograph of Moncompu karapadom soil profile third horizon an enlarged view Mgf 7200X

Ferric iron oxide deposited cellular shaped structure on wood fossil with innumerable number of unattached framboidal pyrite of 0.5 m/u dia.



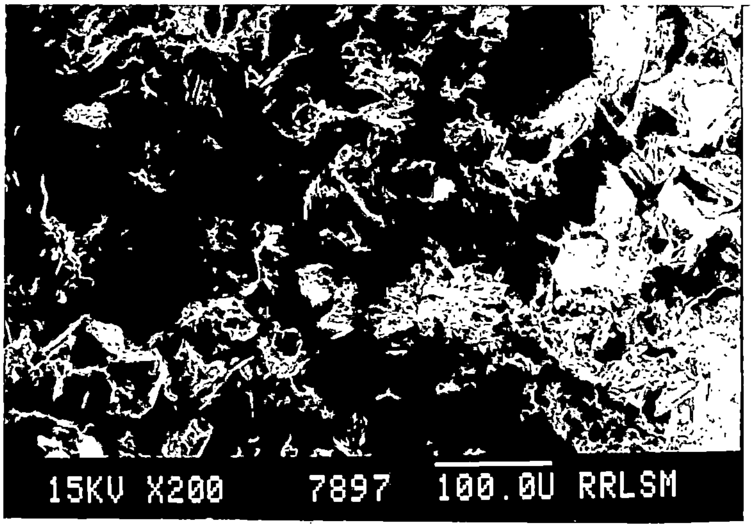
117. Scanning electron photomicrograph of Moncompu karapadam soil profile third horizon Mgf 1200X

Broken pouch of iron oxide with many number of euhedral crystals of pyrite and gypsum, quartz are seen.



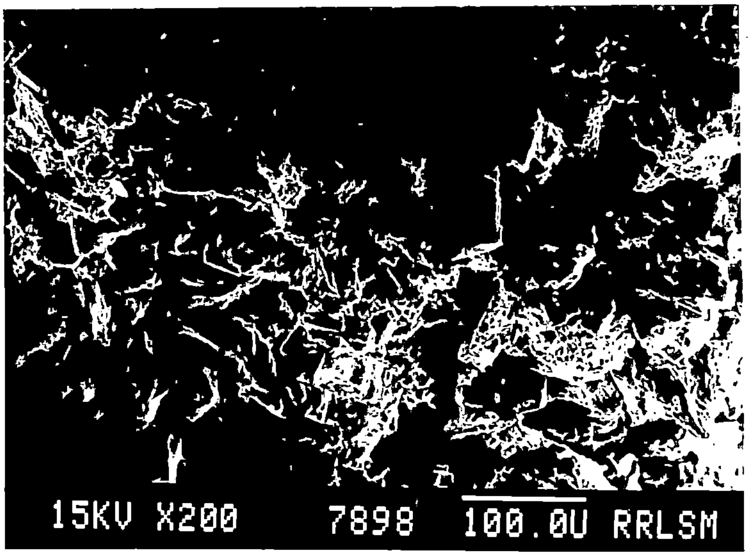
118. Scanning electron photomicrograph of Moncompu karapadam soil profile fourth horizon Mgf 1200X

The sub microtopagraphy is "undulating" with straited orientation pattern of skeletons. Skelvosepic fabric with innumerable number of oval shaped flakes of diatoms and lateral discontinious irregular shaped iron deposition.



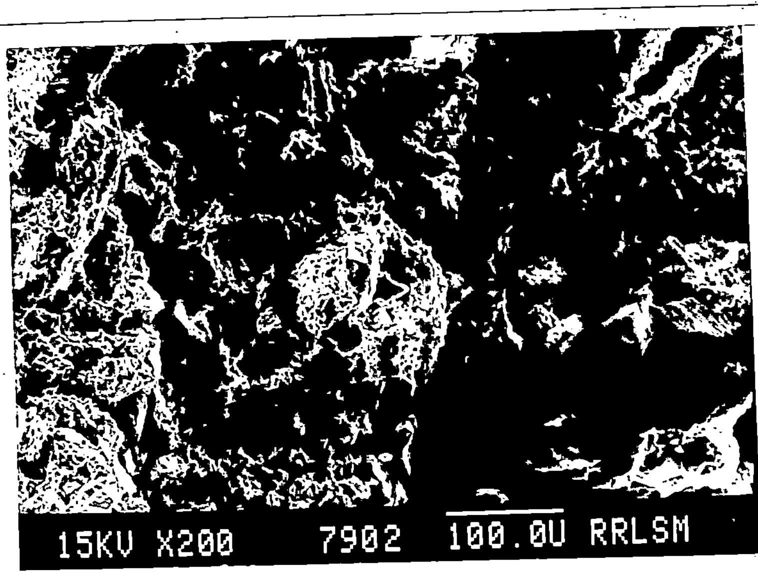
119. <u>Scanning electron photomicrograph of Mathikayal kayal soil profile first horizon Mgf 200X</u>

Thin marginal iron oxide coated, high reliefed skeleton rich soil with 10 m/u dia paddy roots and root hairs. The skeletons are subangular quartz, few mica and many opaques, dominantly ilmenite.



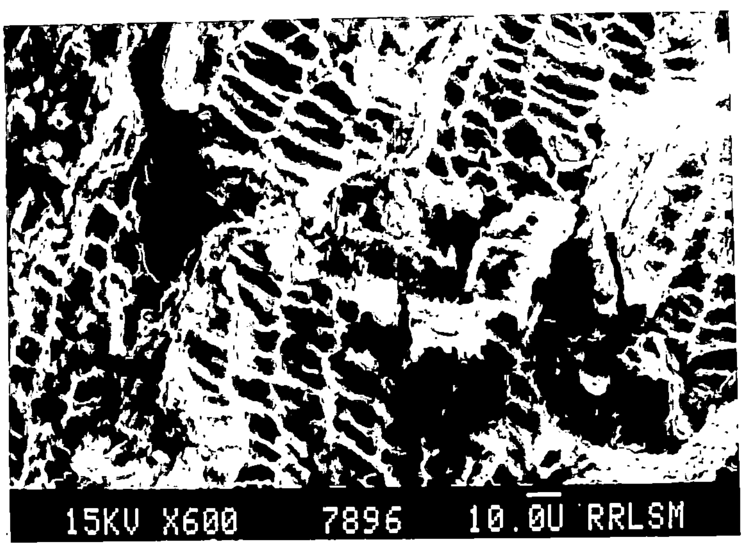
120. <u>Scanning electron photomigrograph of Mathikayal kayal soil profile second horizon Mgf 200X</u>

Comparatively compact, more iron oxide coated, skeleton rich soil with few 10 m/u dia jarosite framboids. Skelvosepic fabric.



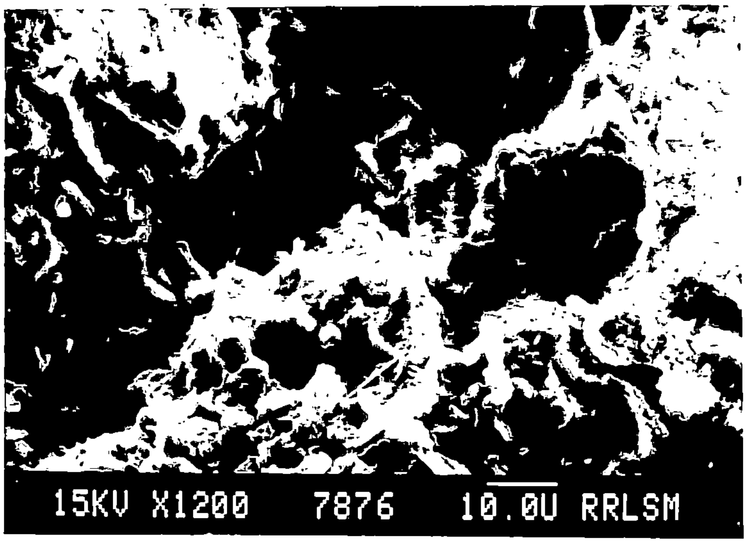
121. Scanning electron photomicrograph of Mathikayal kayal soil profile third horizon Mgf 200X

Highly iron oxide coated skelvosepic fabric with thick iron encrustations and many numbers of 10 m/u dia, pyrite framboids. Highly undulating sub microtopography.



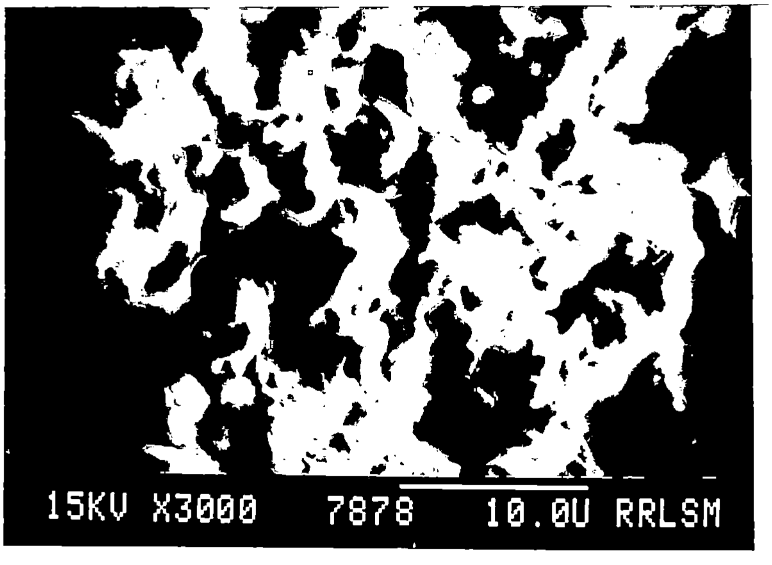
122. Scanning electron photomicrograph of Mathikayal kayal soil profile third horizon Mgf 600x

Wood fossils with cellular type localised iron deposited surface fabric with spots of repeated ferric iron oxide deposited regions, few 5 mu dia pyrite framboids and iron oxide coated skeletons present.



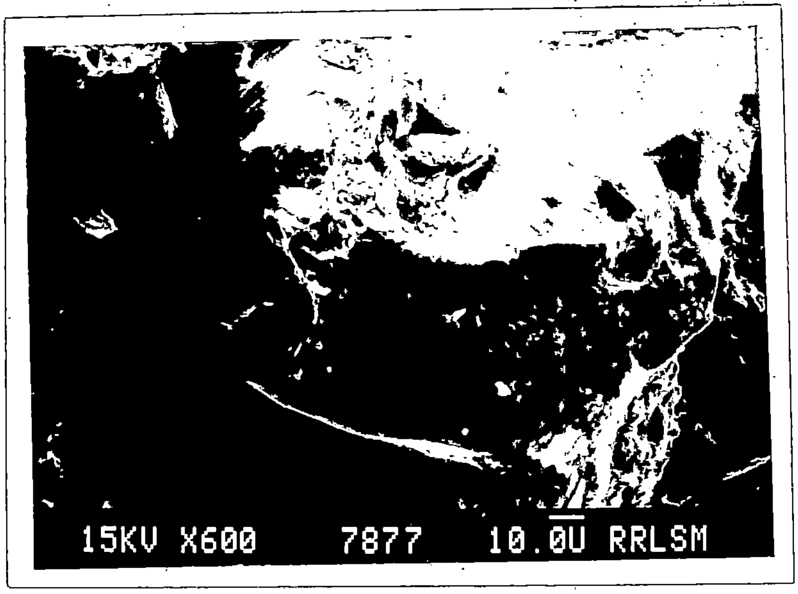
123. Scanning electron photomicrograph of Mathikayal kayal soil profile fourth horizon Mgf 1220X

Highly dense, repeatedly ferric iron oxide deposited soil with uneven submicro-topography. Vosepic fabric with 10 to 20 m u width channels and chambers, quartz 3 m u dia and many framboids.



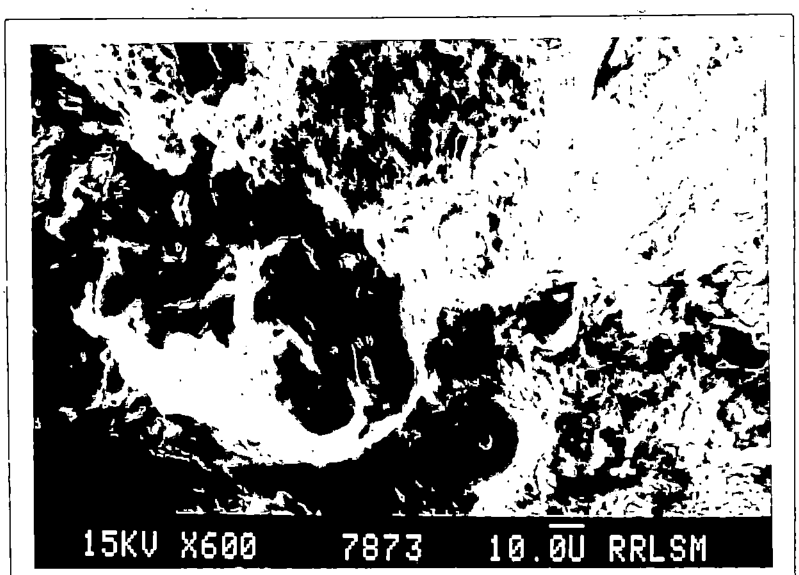
124. Scanning electron photomicrograph of Mathikayal kayal soil profile fourth horizon enlarged view Mgf 3000 X

Highly dense ferric iron oxide coated soil with skelvosepic fabric and with innumerable number of dense ironoxide coated, (Smeared) unattached pyrite framboids of 5m u dia.



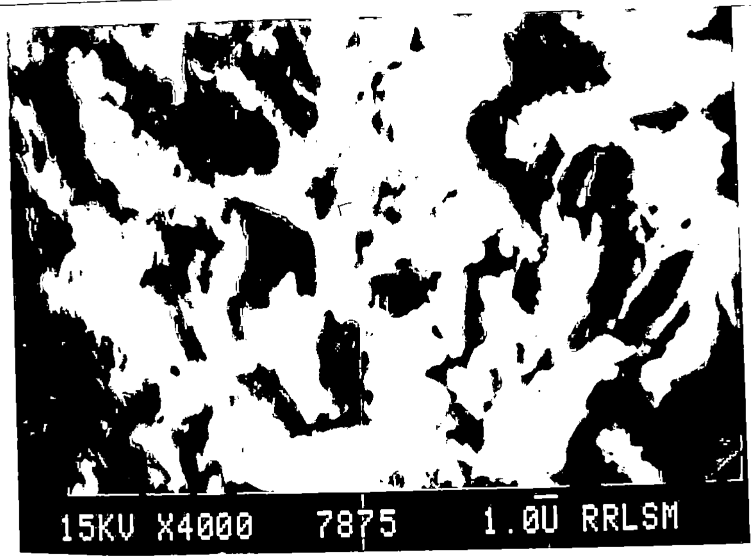
125. Scanning electron photomicrograph of Mathikayal kayal soil profile fourth horizon - showing the weathering of ilemenite Mgf 600X

High relief, iron oxide coated, pitted and weathering ilmenite of the fourth horizon of the kayal soil profile.



126. Scanning electron photomicrograph of Vytilla pokkali soil profile first horizon Mfg 600X

Skelesepic fabric with few higher reliefed, undulating, ilmenite, many 20 mu sized ileminite, other opaques and 0.5 m u size few number of jarosite framboids. Dense iron oxide coated skeletons with very few non coated or incompletely coated skeletons. Few oval and flaky diatomaceous material present.

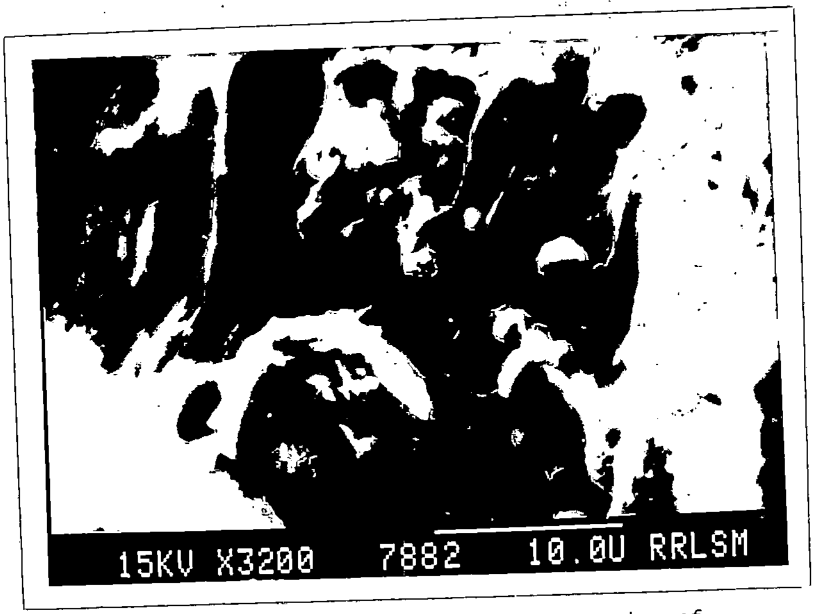


127. Scanning electron photomicrograph of Vytilla pokkali soil profile second horizon Mgf 4000 X

Dense ferric iron oxide coated sodium sulphate salt rich Vosepic fabric with flaky mica, diatomaceous material and few densely iron oxide coated 1 m u dia jarosite framboids. Vughs and chambers are the dominant voids. Iron Oxide coating is noticeably repeated. repeated.

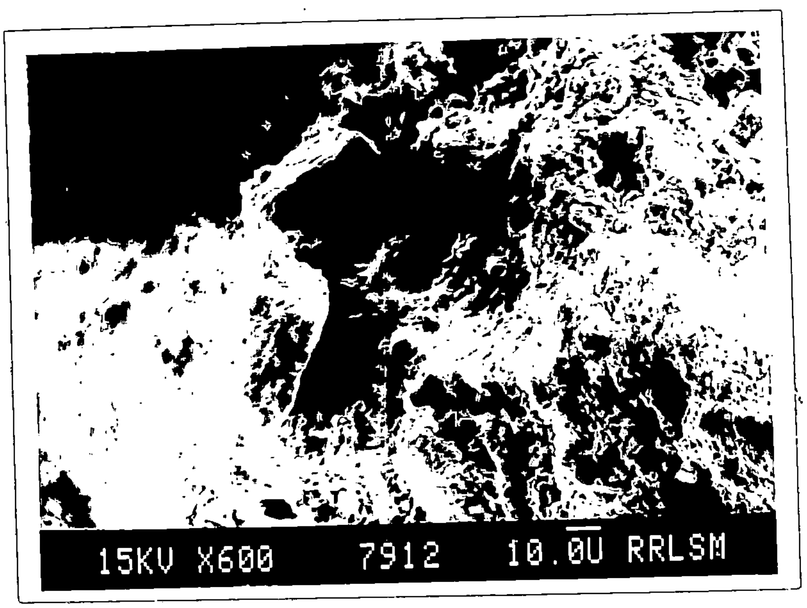
128. Scanning electron photomicrograph of Vytilla pokkali soil profile third horizon Mgf 1200 X

Wood fossils with few 30 m u width ilmenite and other opaques and many 10 m u sized densely ironoxide coated jarosite framboids on the wood fossils. Wood fossils show ridge and furrow, shrinked fabric.



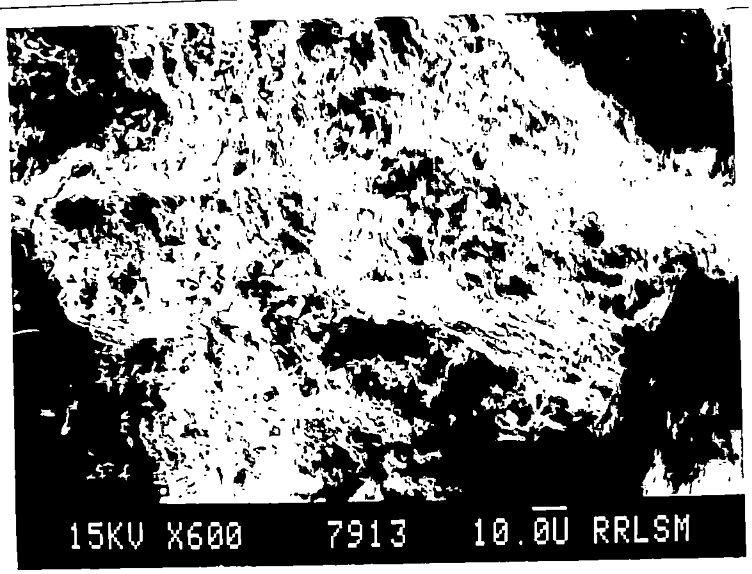
129. Scanning electron photomicrograph of Vytilla pokali soil profile third horizon, enlarged view Mgf 3200 X

Repeated dense ferric iron oxide coating on ridge and furrow structured surface of wood fossil and on jarosite framboids and other skeletons.



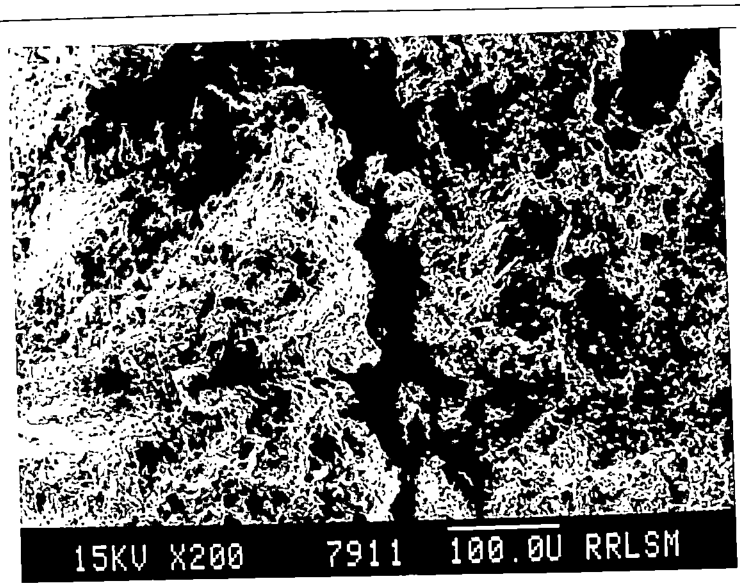
130. Scanning electron photomicrograph of Kattukambal kole soill profile first horizon Mfg 600 X

Iron oxide coated angular ilmenite and other opaque mineral rich soil with skelsepic fabric to skelargillasepic fabric. Ironoxide coating on the opaques are peripheral and marginal, but not surficial.



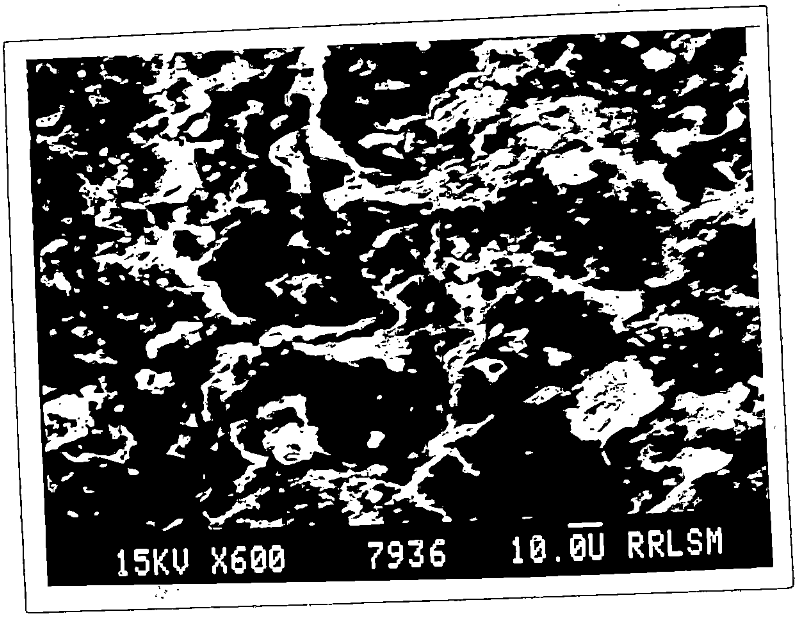
131. Scanning electron photomicrograph of Kattukambal kole soil profile second horzon Mgf 600 X

Iron oxide coated 10 m u sized many opaque mineral rich skelagillasepic soil with few jarosite framboids and 100 to 200 m u sized laterite nodules and quartz skeletons. Iron-oxide coating is with fibrous pattern.



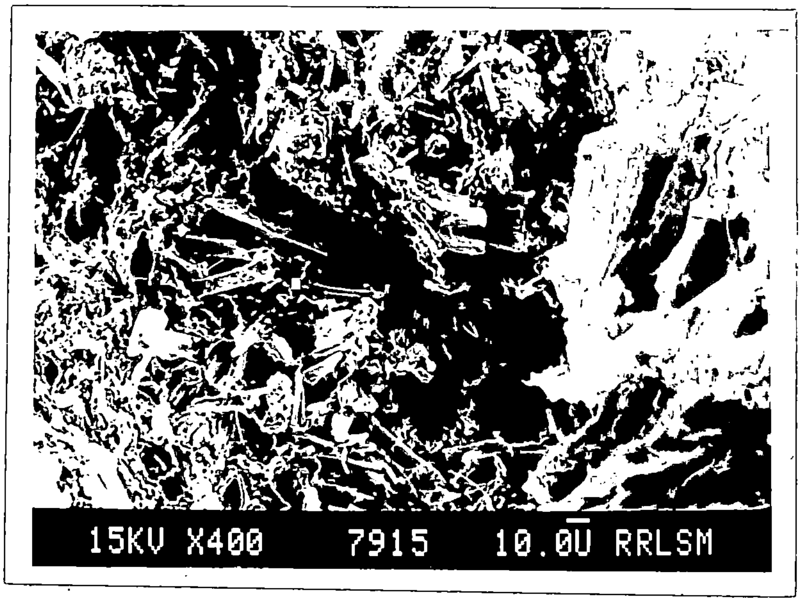
132. Scanning electron photomicrograph of Kattukambal kole soil profile third horizon Mgf 200 X

Soil with thick iron oxide deposition and marginal and peripheral ironoxide coatings of skeletons with many 1.0 m u dia pyrite framboids. Macro apedal channels, filled with iron oxide coated skeletons of silt sized opaques.



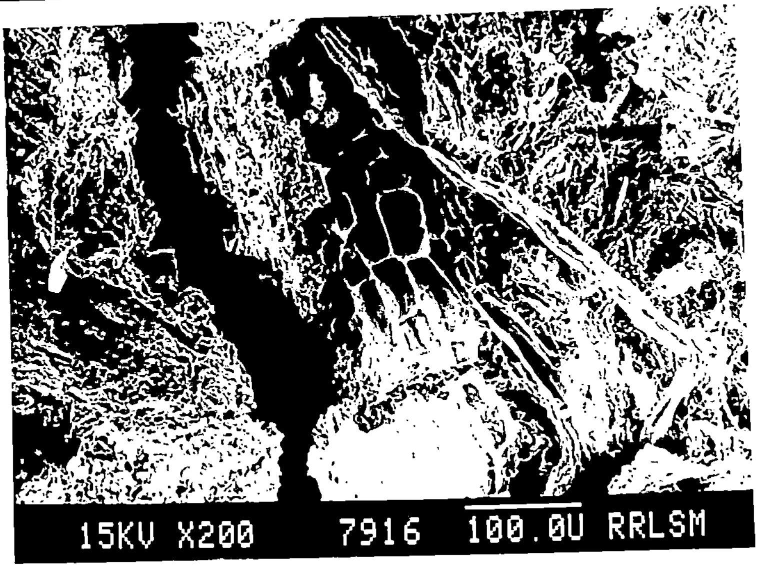
133. Scanning electron photomicrograph of Kattukambal kole soil profile fourth horizon Mgf 600 X

Highly localised dense narrow iron coated gravel and nodule rich soil. iron oxide deposition is peripheral and marginal with few patches on the skeletons. Skeletons and nodules are about and above 50 m u sized.



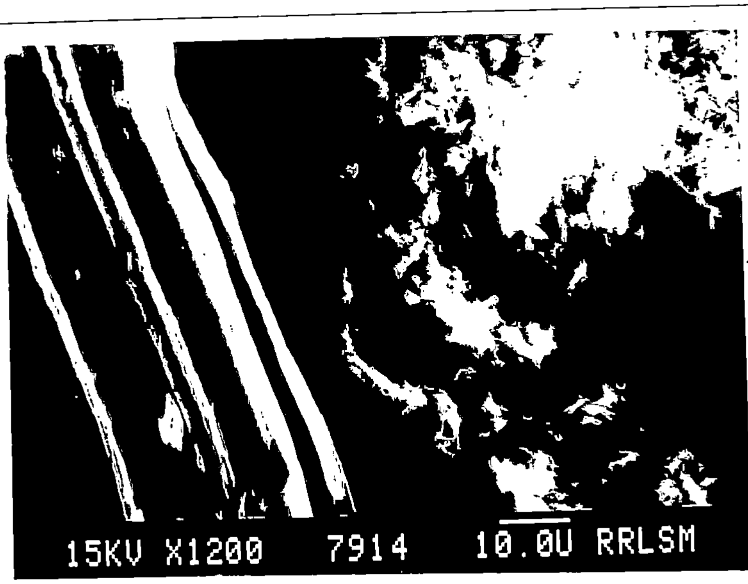
134. Scanning electron photomicrograph of Kattampally kaipad soil profile first horizon Mgf 400X

Flaky, slender wood fossil pieces rich, repeatedly ferric ironoxide coated soil with ilmenite and other opaques, and iron oxide coated jarosite framboids of 10 m u dia.



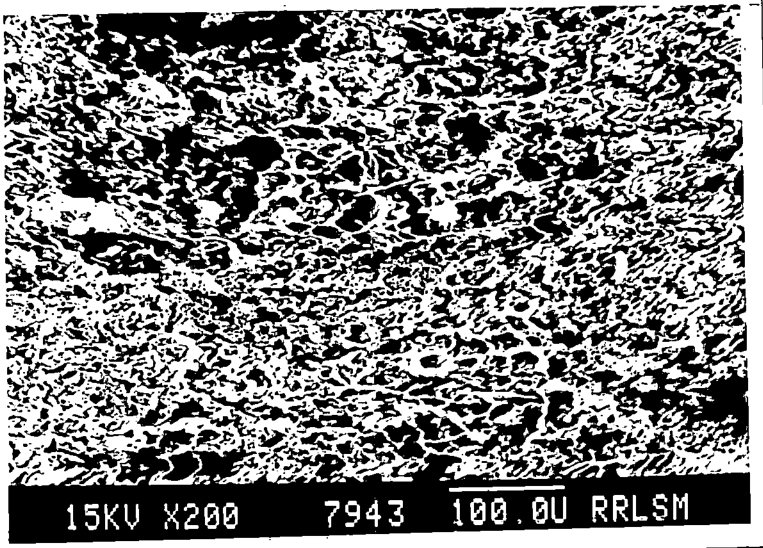
135. Scanning electron photomicrograph of Kattampally kaipad soil profile second horizon Mgf 200X

Wood fossil rich, flaky, fibrous, localised iron deposited, voskelsepic fabric with cellular type of iron oxide deposition on shrinked wood fossils. Many ilmenite, opaques and few 10 m u sized pyrite and jarosites with iron oxide coating present.



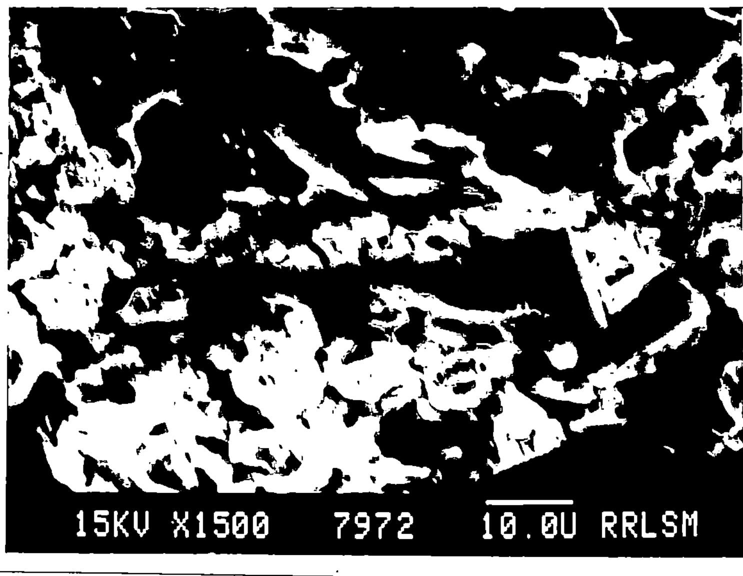
136. Scanning electron photomicrograph of Kattampally kaipad soil profile third horizon Mgf 1200X

Densely iron oxide coated, skelsepic fabric with partially decomposed, slender pieces of wood fossils with few 10 m u sized iron oxide coated pyrite framboids and other opaques.



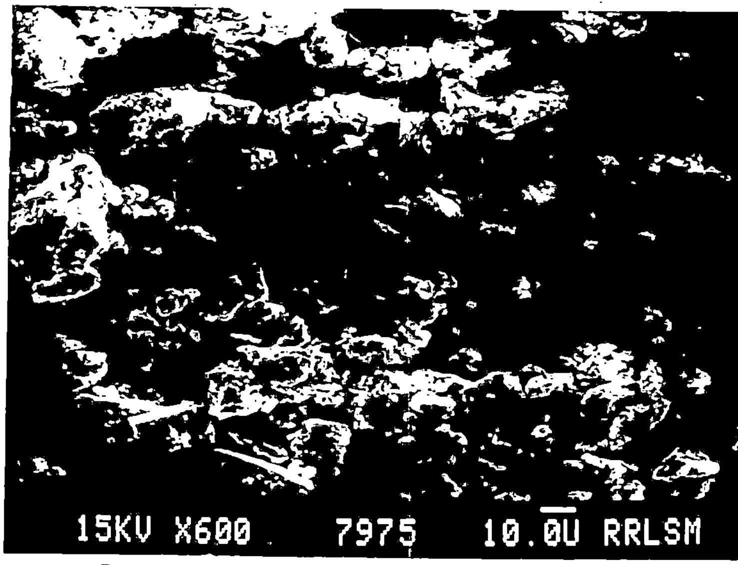
137. Scanning electron photomicrograph of Kattampally kaipad soil profile fourth horizon Mgf 200X

Highly iron coated localised deposited skelsepic fabric. Skeletons are opaques, smeared with sharp ironoxide coating. The skeletons are high reliefed and devoid of iron oxide coating. Many microlites of Calcium carbonate, fine (5 m u sized) pyrite framboids, ferri hydrite spheroids are present.



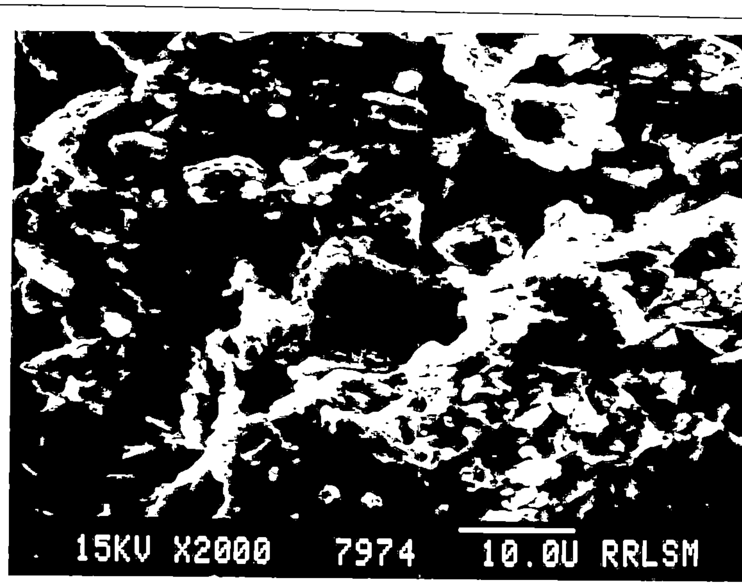
138. Scanning electron photomicrograph of less than 0.05 mm soil fraction from 0-50 cm depth of Karumadi kari soil profile Mgf 1500X

Densely iron oxide coated, high reliefed angular, ilemenite, sillimanite, quartz and wood fossil pieces of 50 m u length and 5 m u breadth with few gypsum crystals and framboidal ironoxide coated jarosites present.



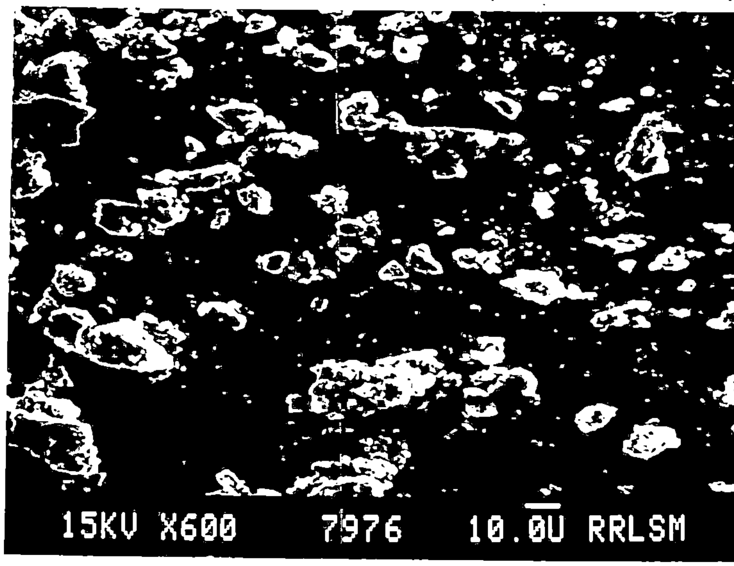
139. Scanning electron photomicrograph of less than 0.05 mm soil fraction from 0-50 cm depth of Moncompu karapadam soil profile Mgf 600X

Densely iron oxide coated subangular to subrounded ilmenite, sillimanite, quartz, framboidal jarosites and few pieces of densely iron oxide coated wood fossils present.



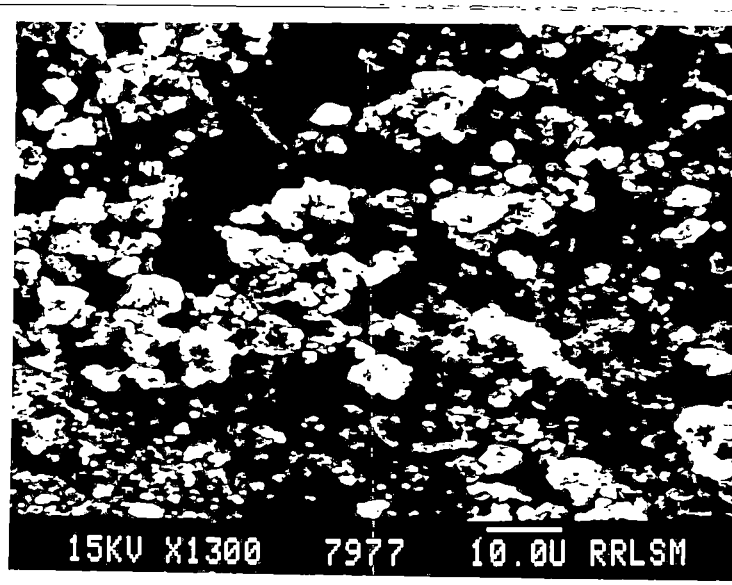
140. Scanning electron photomicrograph of less than 0.05 mm soil fraction from 0-50 cm depth of Mathikayal kayal soil profile Mgf 2000X

Densely iron oxide coated 15 m u size angular to subangular ilmenite, sillimanite quartz and many 3 m u dia jarosite framboids and ferrihydrite spheroids, and few pieces of densely iron oxide coated wood fossils are seen.



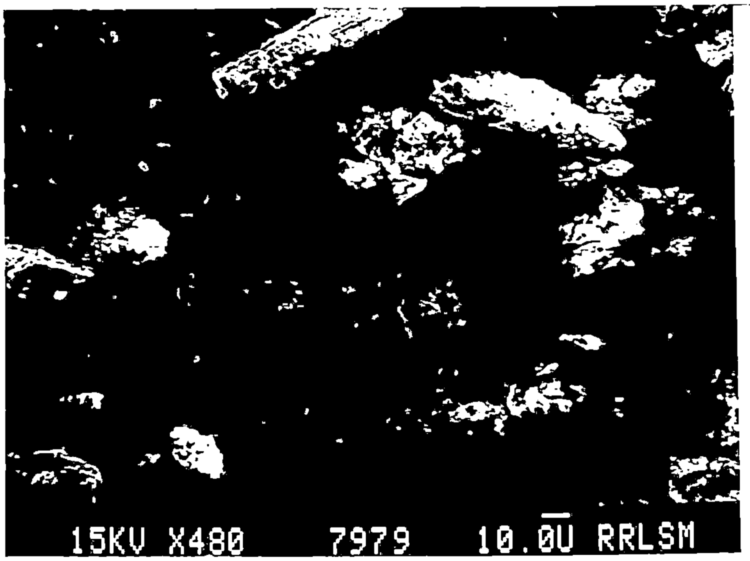
141. Scanning electron photomicrograph of less than 0.05 mm. soil fraction from 0-50 cm depth of Vytilla pokkali soil profile Mgf 600X

Densely iron oxide coated ilmenite and quartz of 10 m u sized and 15 m u sized, few syllimanite 5 m u sized, densely iron oxide coated few jarosite framboids and 2 m u sized ferrihydrite spherioids are present.



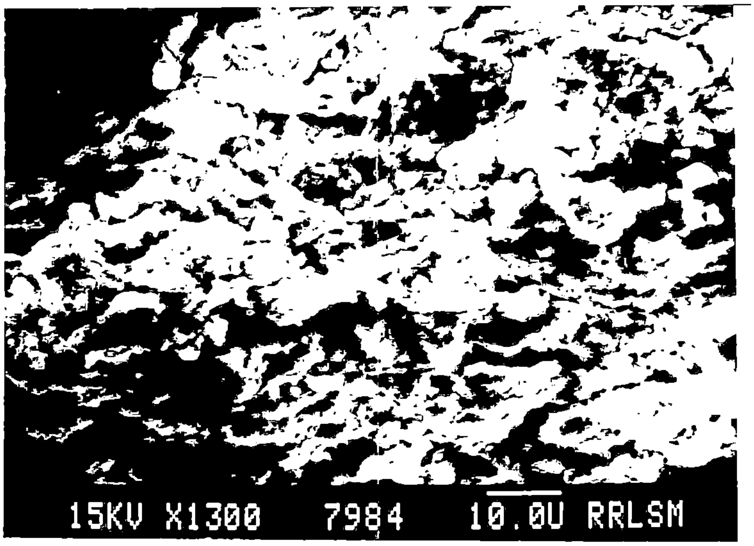
142. Scanning electron photomicrograph of less than 0.05 mm soil fraction from 0-50 cm depth of Kattukambal kole soil profile Mgf 1300X

Completely, densely ferri-iron oxide coated, subrounded to rounded 10 m u sized quartz, ilmenite, haemetite and goethite present.



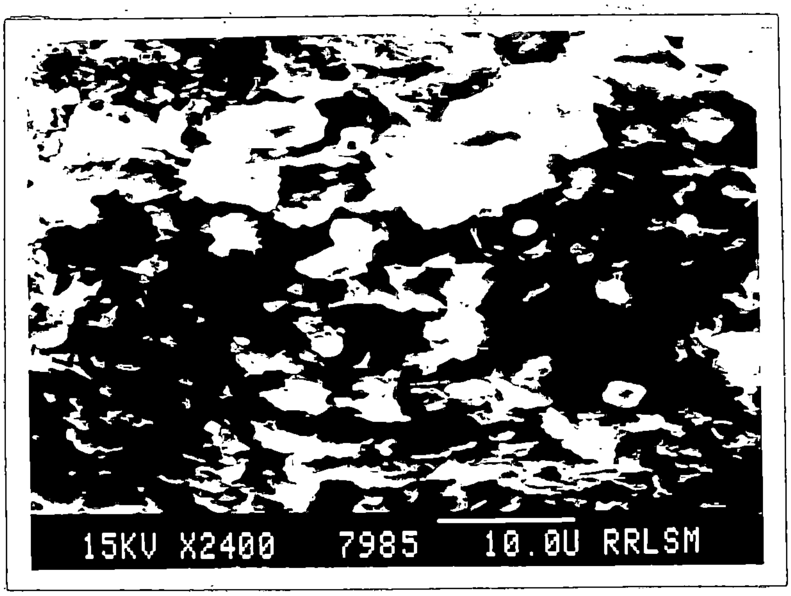
143. Scanning electron photomicrograph of less than 0.05 mm soil fraction from 0-50 cm depth of Kattampalli kaipad soil profile Mgf 480X

Densely ferric iron oxide coated high reliefed uneven 100 m u sized syllimanite, ilmenite, quartz and 5 m u dia tramboidal jarosite and few pieces of lath shaped wood. fossils are seen.



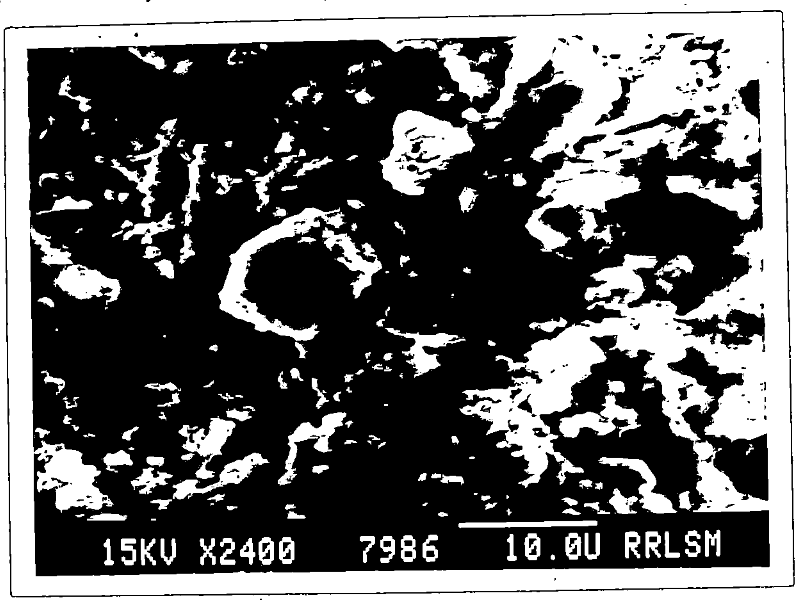
144. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0-50 cm depth of Karumadi kari soil profile Mgf 130X

Highly dense clustered ferric iron oxide coated angular to subangular quartz, framboidal jarosites, ferric hydriete, pyrite, haematite and goethite and few pieces of densely iron-oxide coated flaky wood fossils are present.



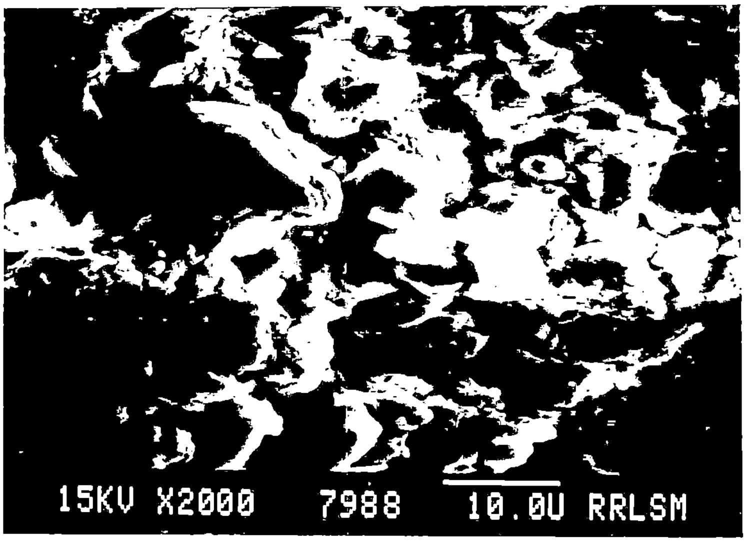
145. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0-50 cm depth of Karumadi kari soil profile Mgf 2400X

Densely and completely ferric iron oxide coated subangular quartz of size 10 m u, many high releifed angular non iron oxide coated opaques dominantly ilminite,haematite,goethite, framboidal, 2 m u dised jarosite flakes of webby diatoms are present.



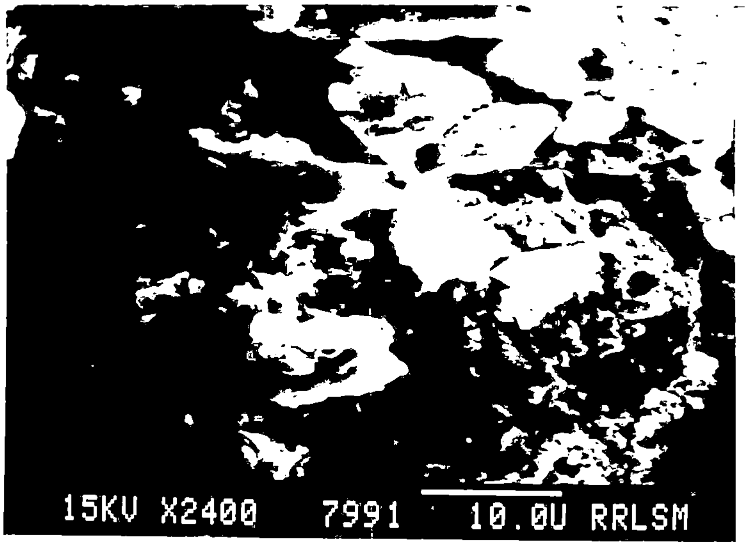
146. Scanning election photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Moncompu karapadam soil profile Mgf 2400X

Densely ferric iron oxide coated subangular to subrounded 10 m/u sized quarts, sillimanite, ilmenite, many 3 m/u sized framboidal jarosites, haematite and goethite are present.



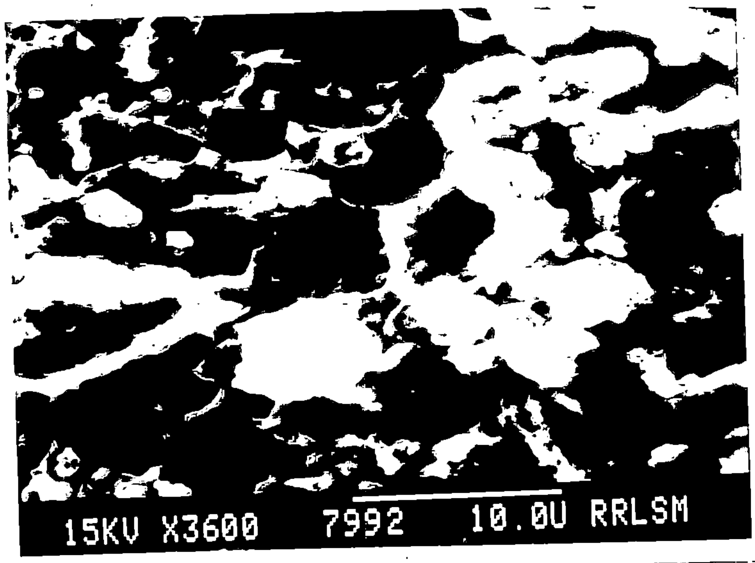
147. Scanning electron photomicrograph of 0.002 mm soil fraction from 0 - 50 cm depth of Moncompu karapadam soil profile Mgf 2000X

Few 20 m/u sized angular quartz, 10 m/u sized many angular to subangular densely ferric iron oxide coated quartz, ilmenite, 3m/u dia framboidal densely iron oxide coated jarosites, haematite



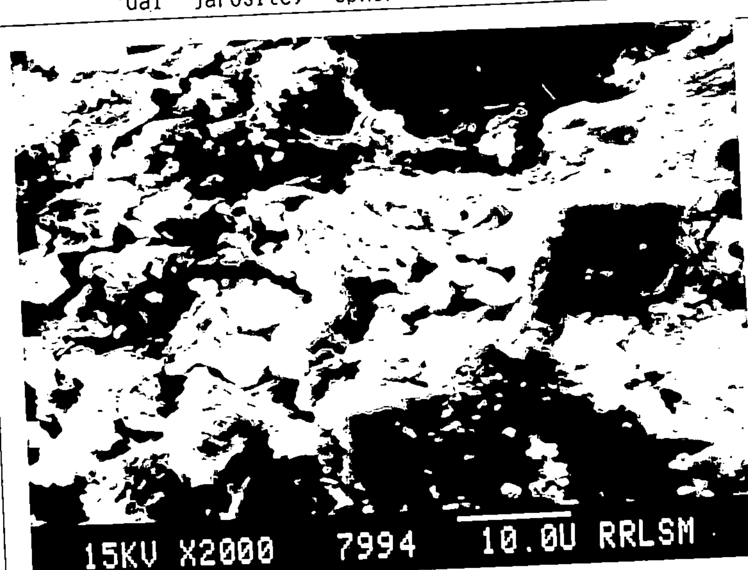
148. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Mathikayal kayal soil profile Mgf 2400X

Densely ferric liron oxide coated, angular to sub angular, about 10 m/u sized quartz sillimanite, ilmenite, 2 m/u dia spheroidal haematite, goethite, ferrihydrite



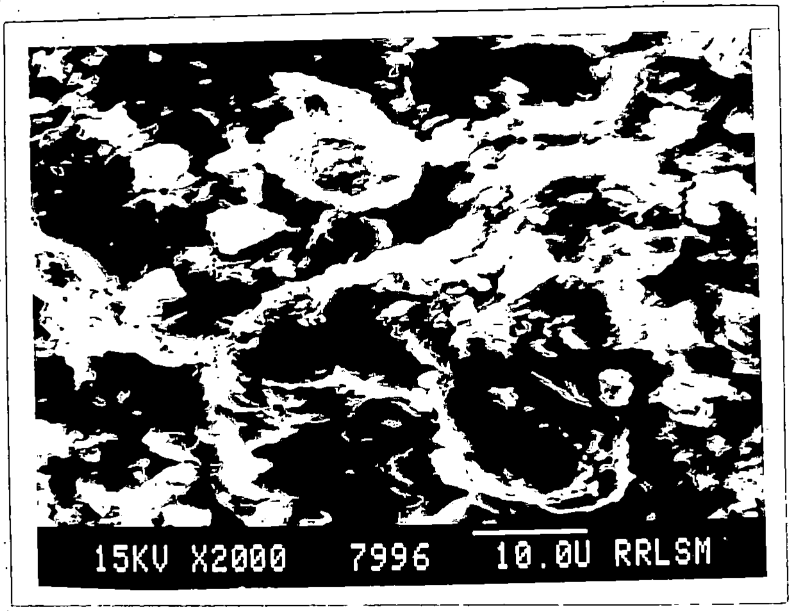
149. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Mathikayal kayal soil profile Mgf 3600X

Densely ferric iron oxide coated subangular to sub rounded quartz, many number of 5 m/u sized ilmenite, few gypsum, few densely iron oxide peripherally coated sillimanite, less than 3 m/u dia framboidal jarosite, spheroidal ferrihydrite,



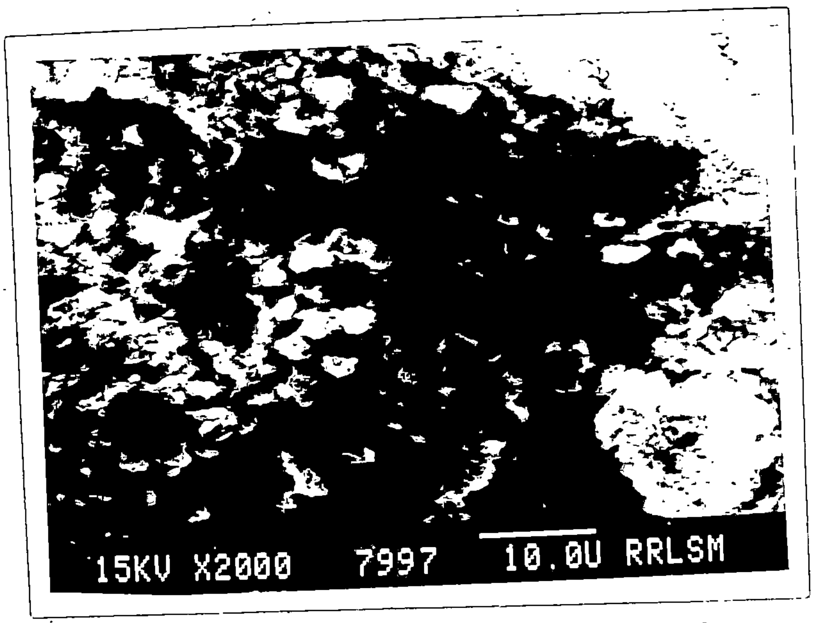
150. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Vytilla pokkali soil profile Mgf 2000X

Densely ferric iron oxide coated, sodium sulphate coated 5 - 15 m/u sized angular quartz. 5 m/u sized ilmenite, 5 m/u dia very few framboidal jarosite and many 2 m/u sized framboidal jarosite are seen.



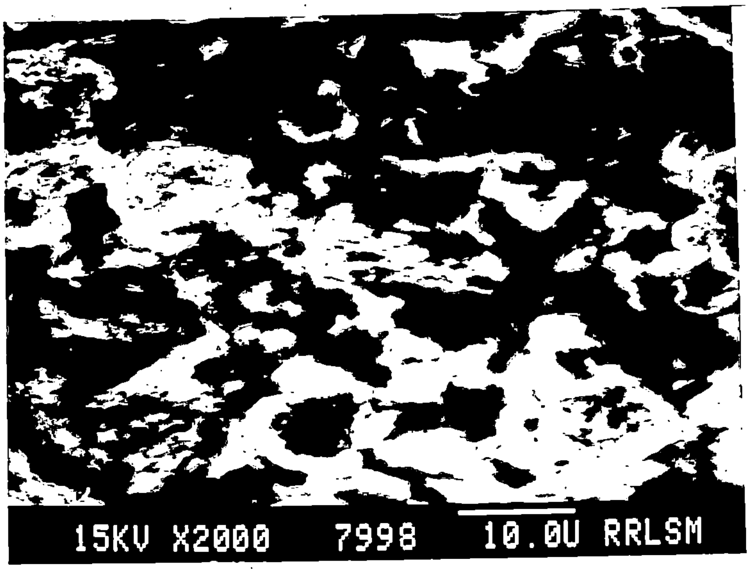
151. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Vytilla pokkali soil profile Mgf 2000X

Densely ferric iron oxide and salt coated 15 m/u sized, high reliefed quartz, ilmenite, sillimanite, 5 m/u sized densely iron oxide coated, coated, framboidal jarosite are seen.



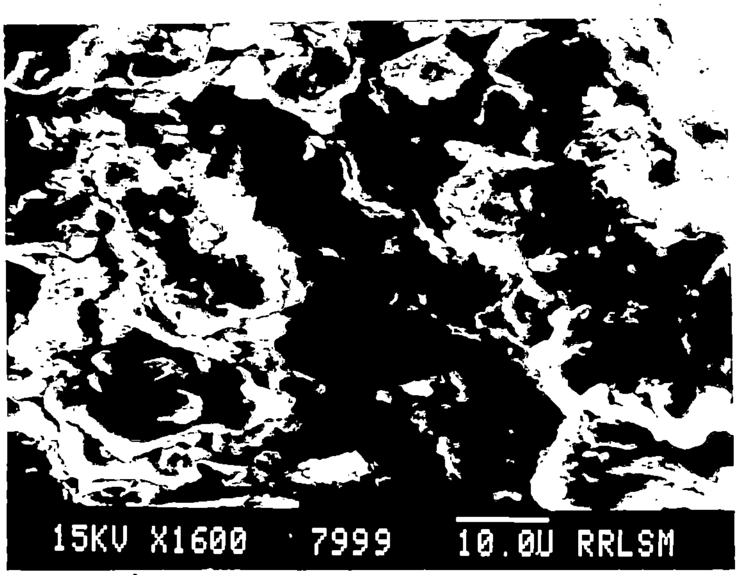
152. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Kattukambal kole soil profile Mgf 2000X

Angular to sub angular densely iron oxide coated quartz, ilmenite, few framboidal jarosite of 5 m/u size are present.



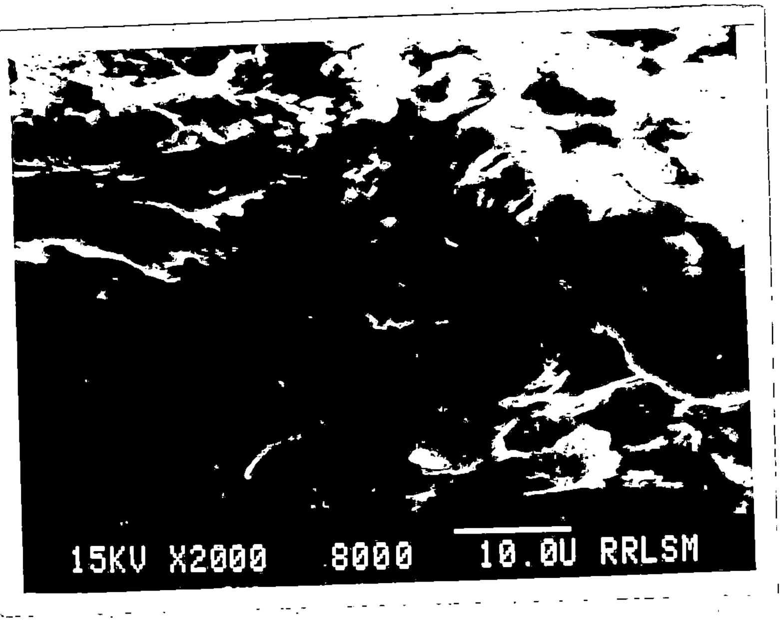
153. Scanning electron photomicrograph of less than 0.002 mm soil fraction from 0 - 50 cm depth of Kattukambal kole soil profile Mgf 2000X

Densely ferric iron oxide coated sub angular 15 m/u sized quartz and ilmenite are seen.



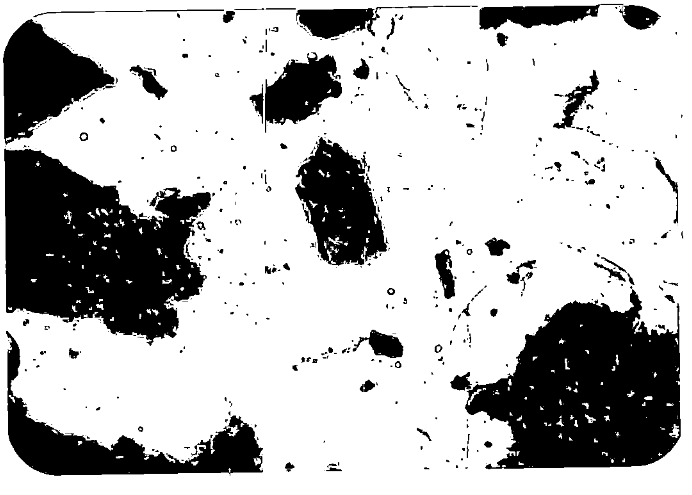
154. Scanning electron photomicrograph of less than 0.002 mm soil fraction, from 0 - 50 cm depth of Kattampally kaipad soil profile Mgf 1600X

Densely ferric iron oxide peripherally coated subrounded quartz of 15 m/u size, many 5 m/u sized densely iron oxide coated high reliefed quartz, ilmenite, haematite, many 2 m/u sized framboidal jarosite ferrihydrite are present. The quartz skeletons are seen to be highly flaky mica like - mica quartz.



155. Scanning electron photomicrograph of 0.002 mm sized soil fraction from 0 - 50 cm depth of Kattampally kaipad soil profile Mgf 2000X

Densely iron oxide coated, flaky, 20 m/u sized quartz and ilmenite are seen.

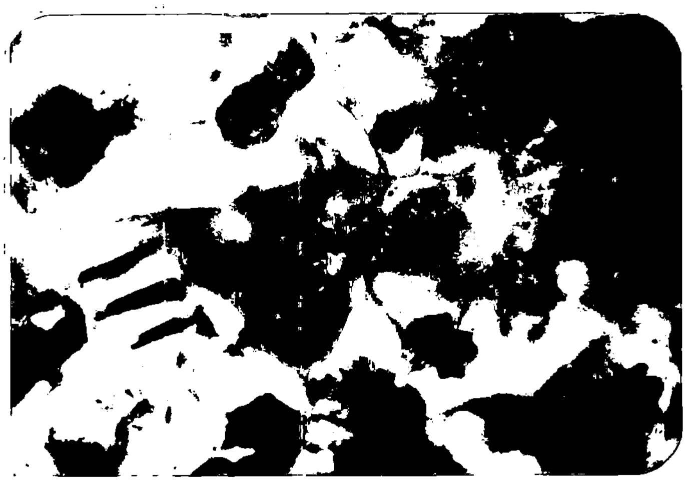


156. Karumadi kari soil profile 0 - 50 cm depth coarse sand fraction photomicrograph in plane light Mgf 63X

Angular to subangular 0.56 mm sized quartz, 0.36 mm size to 0.07 mm size. Quartz are with high relief, wood fossils are with low relief, iron oxide coated. Few iron oxide and organan coated sillimenite are also noticed.

157. Moncompu Karapadam soil profile 0 - 50 cm depth coarse sand fraction, photomicrograph in plane light Mgf 63X

Sub angular to sub rounded 0.48 mm sized flaky iron oxide coated wood fossil, 0.24 mm sizeed low relief ilmenite, 0.71 mm sized quartz, 0.24 sized reddish brown mica, irregular shaped brownish yellow flaky wood fossils of 0.16 mm size are present.



158. Mathikayal kayal soil profile 0 - 50 cm depth, coarse sand fraction photomicrograph in plane light Mgf 63X

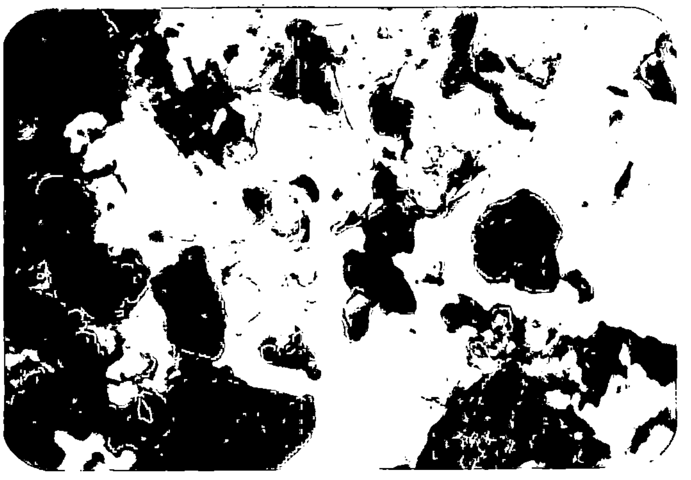
Angular to sub angular high relief, iron oxide coated quartz of 0.48 mm size, ilmenite of 0.32 mm size, biotite mica of 0.16 mm size and very few highly fractured feldspars of 0.32 size. Slender reddish brown coloured 0.16 mm length wood fossil pieces are present.

159. Vytilla pokali soil profile 0 - 50 cm depth, coarse sand fraction, photomicrograph in plane light Mgf 63X

High heterorel, sub angular to sub rounded quartz of 0.32 mm size, followed by few ilmenite and biotite of 0.32 mm size. Few pieces of flaky, iron oxide coated, plant materials are present.

160. Kattukambal kole soil profile 0 - 50 cm depth coarse sand fraction, photomicrograph in plane light Mgf 63X

Highly iron oxide coated, high reliefed sub angular sharp margined quartz, ilmenite, biotite mica, flaky iron oxide coated plant materials are noticed.



161. Kattampally kaipad soil profile 0 - 50 cm depth coarse sand fraction photomicrograph in plane light Mgf 63X

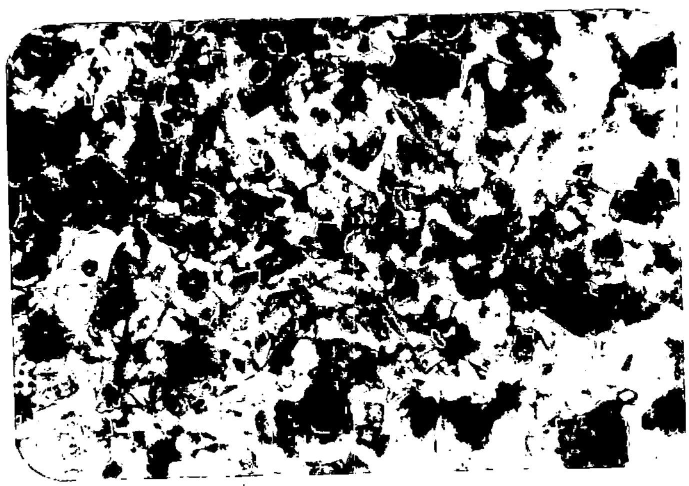
Few highly iron oxide coated, high reliefed quartz of 0.63 mm size, and many 0.24 mm size hetero and high reliefed iron oxide coated quartz, ilmenite, biotite mica, flaky, iron oxide coated wood fossils are present.

162. Karumadi kari soil profile 0 - 50 cm depth photomicrograph of fine sand light mineral fraction in plane light Mgf 25X

Highly iron oxide coated flaky wood fossils, tubular phytoliths, sub angular quartz, very few sub angular ilmenite are present.

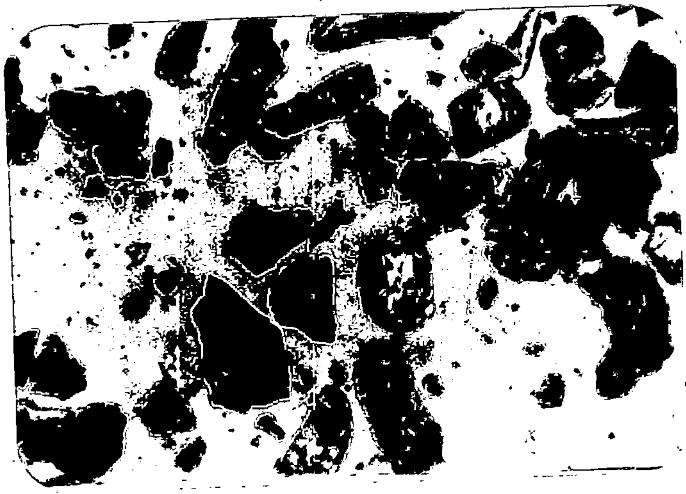
163. Karumadi kari soil profile 0 - 50 cm depth photomicrograph of fine sand heavy mineral fraction in plane light Mgf 25X

Abundant, sub angular to sub rounded moderately reliefed ilmenite, sillimanite followed by high reliefed angular to sub angular quartz and very few Zircon are present.



164. Moncompu karapadam soil profile 0 - 50 cm depth photomicrograph of fine sand, light mineral fraction in plane light Mgf 25X

Abundant angular to sub angular moderate reliefed, sharp margined quartz, followed by many sub rounded ilmenite, angular sillimanite, and very few biotita mica are present. Quartz skeletons have surficial iron coating, rather than peripheral [illegible].

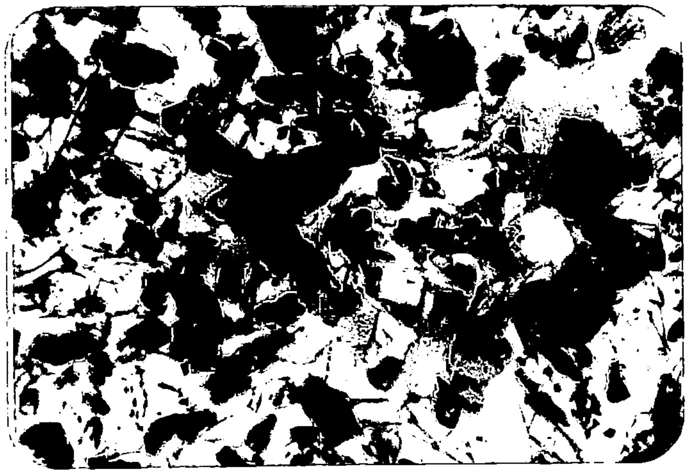


165. Moncompu karapadam soil profile 0 - 50 cm depth . photomicrograph of fine sand, heavy mineral fraction in plane light Mgf 25X

Slightly heteroreliefed angular to sub angular iron oxide coated quartz followed by many number of sub angular lath shaped ilmenite and few iron oxide coated angular sillimanite.

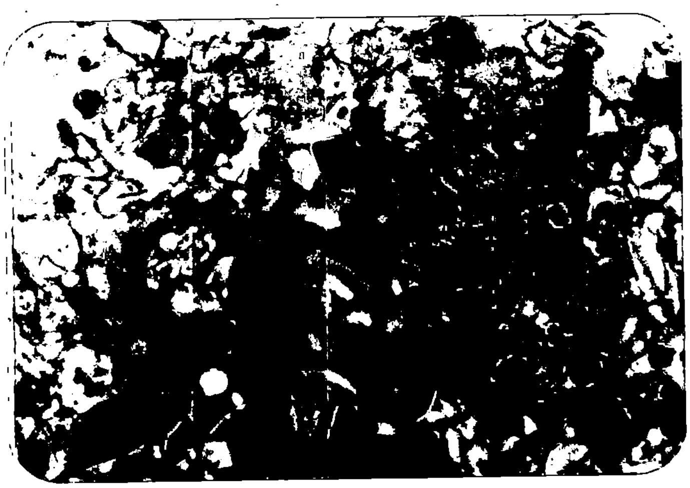
166. Mathikayal kayal soil profile 0 - 50 cm depth photomicrograph of fine sand light mineral fraction in plane light Mgf 25X

Abundant angular to sub angular iron xide coated quartz, sillimanite, biotite mica, iron oxide coated flaky plant material, and few marginal shadowed long zorcon are present.



167. Mathikayal kayal soil profile 0 - 50 cm depth photomicrograph of fine sand heavy mineral fraction in plane light Mgf 25 X

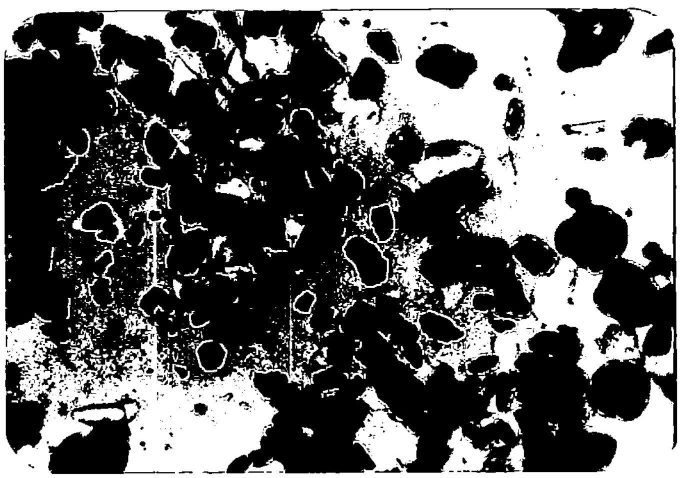
Abundant high reliefed, angular to sub angular quartz, followed by ilmenite, few Zircon and sillimanite are present.



168. Vytilla pokkali soil profile 0 - 50 cm depth photomicrograph of fine sand light mineral fractions in plane light Mgf 25X

Abundant high reliefed angular to sub angular slender quartz, sillimanite, followed by sub angular to sub rounded ilmenite.

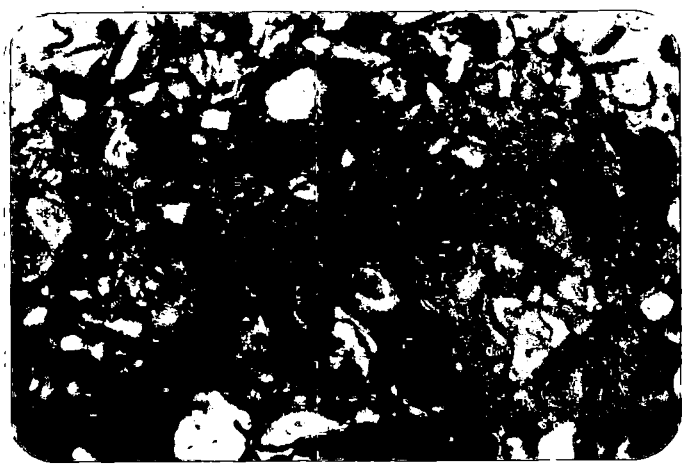
169. Vytilla pokkali soil profile 0 - 50 cm depth photomicrograph of fine sand heavy mineral fraction in plane light Mgf 25X
Abundant flaky and high reliefed angular to sub angular quartz, few with iron oxide coating, followed by abundant sub angular to sub rounded slender ilmenite and few Zircon, sillimanite and monazite are present.



170. Kattukambal kole soil profile 0 - 50 cm depth photomicrograph of fine sand light mineral fraction in plane light Mgf 25X
Abundant sub angular sub rounded and even, rounded opaques, dominantly ilmenite followed by flaky high reliefed sub angular many quartz, sillimanite and very few to few sub rounded laterite micronodules are present.

171. Kattukambal kole soil profile 0 - 50 cm depth photomicrograph of fine sand heavy mineral fraction in plane light Mgf 25X

Abundant high reliefed sub angular to sub rounded highly iron oxide coated quartz sillimanite followed by abundant sub rounded to rounded and few sub angular ilmenite other opaques and very few laterite micro nodules are present.



172. Kattampally kaipad soil profile 0 - 50 cm depth photomicrograph of fine lsand light mineral fraction in plane light Mgf 25X

Abundant heteroreliefed slender, flaky sub angular sub rounded and even, rounded quartz, followed by few faint margined subrounded to rounded ilmenite and very few sub angular biotite, sillimanite, zircon are present.

173. Kattampally kaipad soil profile 0 - 50 cm depth photomicrograph of fine sand heavy mineral fraction in plane light Mgf 25X

Abundant sub angular to rounded, ilmenite and other opaques followed by high reliefed striated kyanite, sillimanite, zircon and few slender subrounded to rounded flaky quartz are present.

STUDIES ON

MACRO MESO AND MICROMORPHOLOGY AND CLAY MINERALOGY OF THE ACID SULPHATE SOILS OF KERALA

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

DOCTOR OF PHILOSOPHY IN AGRICULTURE

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ABSTRACT

The acid sulphate soils of Kerala cover an area of approximately 0.2 million hectares on the West coast of Kerala.

A well integrated study on the genesis, morphology, mineralogy and certain physico-chemical properties of these soils was conducted. Aspects of its genesis, position in the global system of classification, macro, meso and micro morphology, mineralogy both macro and micro as well as primary and secondary, physical and physico-chemical properties relevant to classification and management have received attention. The salient points of the study are highlighted emphasising conclusions pertinent to the expanding frontiers of our knowledge on these soils.

The acid sulphate soils occurring along the West coast of Kerala based on morphological observations as well as stage by stage microscopical study are indicated to have been formed by sedimentation of finer material overlying and often impregnating wood fossils, faunal and floral relics in the recent geological past. The extent of alluviation, stage of degradation of the fossilised wood and incorporation of sediments and formation of secondary products vary from location to location as indicated in the study.

In almost all the acid sulphate soils around the globe, pyrite is the major mineral component contributing to acidity. They have

framboidal micro structure with size ranging from 15-50 u, However, in the acid sulphate soils of Kerala pyrrohtite (FeS) is the predominant sulphide mineral with a size range $< 2\mu$ along with small amounts of pyrite (FeS_2) which also are $< 2\mu$. These minerals have been formed in the recent geological past, under the anaerobic environment releasing ferrous iron from the alluviated soil materials especially laterite falls and the sulphur from the sulphates added by the ingress of sea water, fossilised wood and decaying organic matter.

The pyrite (FeS_2) and pyrrohtite (FeS) undergo oxidation especially when the aeration is encouraged by tidal influences, and acidity conditions. As has been demonstrated in the present study they are oxidised initially to ferric hydroxides and then to jarosites. The end product of oxidation of pyrite, however, varies from situation to situation in Kerala. Thus it may be jarosites as encountered in the surface soils of all the locations while the oxidation may be only to the stage of ferric hydroxide as observed in the fourth horizon of Mathikayal and Kattampally where the pyrite occurs overlying a bed of lime shells.

The ripeness of the acid sulphate soils generally are decided by the extent of acidity generated on oxidation with H_2O_2 and also the 'n' value of the soil which is related to the pH as well as the organic matter and clay content. On this basis all the acid sulphate soils of Kerala vary from half ripe to fully ripe. The ripe soils have been encountered only at Kattukambal in the kole area. Another factor, is the depth of occurrence of the jarosite mottle laden layer. In the acid sulphate soils of the present study, the jarosites have been located, within 50 cm. Below 50 cm pyrite and pyrrohtite are the dominant sulphur containing minerals. Among the oxidation products, the mineral lepidocrocite (Fe-O-OH) a variant of goethite has been found to be associated with pyrrohtite especially at the Karumadi location. The occurrence of lepidocrocite in acid sulphate soils has not been reported earlier. It is possible that it is the intermediate stage in the oxidation of pyrrohtite to jarosite.

The lower layers of the acid sulphate soils have lime shells in some locations such as Mathikayal, other kayal areas of Kuttanad and some of the pokkali and kaipad soils. The pyrites are found to be closely overlying the lime shells without suffering major alterations to either of them. Thus the pyrite framboides have been transformed partly in a few of its microcrystals to the oxidised form of ferric hydroxides, but the acidity of the embedding soils has neither dissolved nor reacted with the lime shells.

X-ray diffraction, thermogravimetric as well as chemical studies conducted with the clay indicate kaolinite as the dominant mineral in these soils. Minor quantities of mineral viz., smectite, chlorite and illite have been detected. Mica and quartz have been found in quantities equal to that of kaolinite. It is possible that like laterite falls, fine quartz also is alluviated into these soils from the midland regions of Kerala.

Soils which attain pH of 2.5 by oxidation with 100 per cent H_2O_2 have been considered to be dangerously acid sulphate soils. The soils in the present study attain pH values less than 2.5 even with 30 per cent H_2O_2. Though the upper layers are half to fully ripe, they are still found to be dangerously acid. The lower layers with more of reserve pyrites are much more dangerously acid. These observations on the acid sulphate soils are a pointer to the cropping patterns and water management to be pursued in these areas in the foreseeable future. Thus the rice crop in a waterlogged situation is possibly the only crop that may throw up lesser problems in soil management. The dangerous nature of the potential acidity especially in the lower layers have to be considered in ruling out all propositions of tree crop alternatives such as rubber and oil palm.

From the present studies it has been found that these soils have only a sulphidic enrichment within 50 cm from the surface, instead of a sulphuric horizon. Further the sulphur content is also not sufficient enough to include them in the category of soils with sulphuric horizon. Soils with sulphuric horizon only are considered to attain a pH of 4 by airdrying and 2.5 by H_2O_2 treatment. The soils in the present study despite an enrichment, only with sulphidic materials attain a pH of 2.5 to 3.0 by mere airdrying and pH as low as 2.0 by H_2O_2 oxidation. Thus the lack of a sulphuric horizon but in its place a mere sulphidic enrichment makes them almost dangerously acid. Evidently this has to be attributed to the pyrrohtitic (FeS) nature and the smaller size ($< 2\mu$) of the framboid conferring it to be placed as a class separate from typical acid sulphate soils reported from the rest of the world. Thus these soils from the present study are found to be more dangerously acid sulphate than others though they do not satisfy the requirement of either the total sulphur content or the presence of a typical sulphuric horizon. Further the pyrite framboids have a size range of only 1/25th of that of the framboids reported elsewhere from the globe. This has made them more dangerously acid. All the same, they require to be placed as soils with sulphidic materials rather than the soils with sulphuric horizon as per Soil Taxonomy. (USDA, 1975). Nevertheless, the fact remains that these soils are highly acidic with considerable amounts of reserve pyrites and hence reserve acidity. These soils call for utmost care in their management. The acid sulphate soils of Kerala are thus to be continuously managed under a waterlogged milieu to enable optimum productivity with minimum problems due to acidity and related aspects. The possibility of growing perennial crops such as rubber and oil palm require partial to fully aerobic situations. These conditions are likely to result in oxidation of the pyrite laden layer noticed up to 90 cm in the present study. This can generate an enormous quantity of free sulphuric acid. The pyrite laden layer extends up to 90cm in the present study.

The acid sulphate soils of Kerala are definitely different from Malaysian acid sulphate soils in that the surface layer is not completely free of pyrites. In view of the fact that the surface soil contains only jarosite and no pyrites, the Malaysian peats and acid sulphate soils have been subjected to cultivation with oil palm and rubber. However the Malaysian experience cannot be transplanted as such to Kerala inview of the very serious initial problems likely to be thrown off by the generation of acidity by the oxidation of pyrites under aerobic situations.

Being half to full ripe, acid sulphate soils of Kerala are still dangerously acid to warrant the continuation of the existing management practices and cropping systems.