

**GENESIS, CLASSIFICATION AND USE POTENTIAL
OF MAJOR SOILS IN TELANGANA REGION
(ANDHRA PRADESH)**

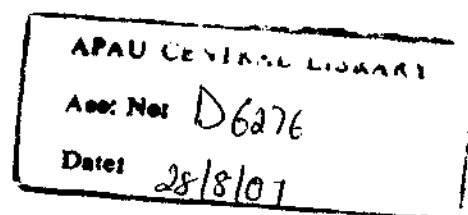
By

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M.Sc. (Ag.), DIIT



THESIS SUBMITTED TO THE
ACHARYA N.G.RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN AGRICULTURE



**DEPARTMENT OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
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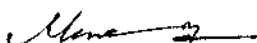
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Mrs. P.L.A.SATYAVATHI has satisfactorily prosecuted the course of research and that the thesis entitled "**GENESIS, CLASSIFICATION AND USE POTENTIAL OF MAJOR SOILS IN TELANGANA REGION (ANDHRA PRADESH)**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

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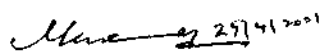
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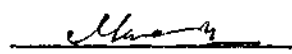
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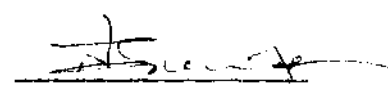
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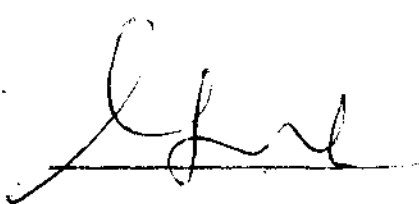
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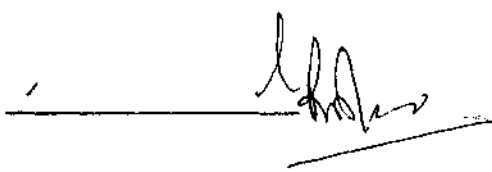

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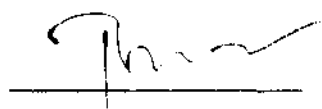
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DECLARATION

I, **Mrs. P.L.A. SATYAVATHI** hereby declare that the thesis entitled **GENESIS, CLASSIFICATION AND USE POTENTIAL OF MAJOR SOILS IN TELANGANA REGION (ANDHRA PRADESH)** submitted to Acharya N.G.Ranga Agricultural University for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** is the result of the original work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

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ABSTRACT

Fourteen representative profiles from Northern Telangana region of Andhra Pradesh under hot, moist, semiarid eco-subregion and eight from Southern Telangana region under hot, dry, semiarid eco-subregion were studied morphometrically and soil samples were analysed for some of the important physical (texture, bulk density, water retention at 33 and 1500 Kpa), chemical [pH, EC, organic carbon, calcium carbonate, cation exchange capacity, exchangeable bases (Ca^{++} , Mg^{++} , Na^+ , K^+)] and mineralogical properties, using standard methods. Available phosphorus content and micronutrient status of the soils were also estimated. The study area comprised of shallow, medium and deep red and black soils occurring in juxtaposition. There is a wide variation in colour, structure, texture, soil reaction and in other physical and chemical properties of the soils between these two broad groups of soils. Nearly all red soil pedons were noncalcareous, whereas black soils were found calcareous. Cracks and slickensides were the characteristic features of black soils whereas significant increase in clay content in deeper horizons and occurrence of clay cutans were the characteristic features in red soils. Water logging in black soils and soil erosion in red soils are the important adverse characteristics found.

Sand minerals were identified under petrographic microscope. Light minerals (specific gravity $< 2.85 \text{ gcm}^{-3}$) like quartz, feldspars, and mica constituted the bulk of the sand fraction (more than 90 percent) and heavy minerals (specific gravity $> 2.85 \text{ gcm}^{-3}$) consisted of the remaining smaller fraction viz., epidote,

garnet, zircon, amphibole, pyroxenes and opaque minerals (ilmenite, limonite, magnetite and haematite). The x-ray diffraction peaks of clay fraction in both soils indicated the presence of kaolinite, smectite, mica and vermiculite. However, in red soils the dominant clay mineral was kaolinite followed by micas, whereas in black soils the dominant clay mineral was smectite followed by kaolinite. In red soils under intensive leaching conditions prevailing over long periods, kaolinite was formed from montmorillonite by loss of bases and iron. Black soils are less weathered compared with red soils. The topography seems to have played a major role in the development of these soils, whereas the parent material played a passive role. Hydrolysis, leaching, eluviation and illuviation are some of the important processes operative. Vertisols and vertic intergrades occurred in lower piedmont plains or valleys or microdepressions whereas red soils occur on higher elevations.

As per soil taxonomy, the Northern Telangana soils were grouped into Typic Haplustalfs, Typic Ustipsamments, Typic Haplustepts, Calcic Haplustepts, Vertic Haplustepts, Vertic Calcustepts, Typic Haplusterts, Chromic Haplusterts and Sodic Haplusterts. The soils of Southern Telangana region were classified as Typic Haplustalfs, Typic Rhodustalfs, Vertic Haplustepts, Fluventic Haplustepts, Typic Haplusterts and Chromic Haplusterts at subgroup level. At family level, the soils were of sandy to clayey particle size classes, kaolinitic, mixed and smectitic mineralogy class and isohyperthermic soil temperature class.

As per Riquier *et al.* (1970) rating, the actual productivity of red soils is between poor to average and for black soils it is from average to good. In some instances, development of sodicity in black soils and chemical degradation by loss of bases in red soils were observed. Suitable management practices were recommended to improve the potential productivity of these soils.

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LIST OF ABBREVIATIONS

A°	:	Angstrom (10^{-8} cm)
ARS	:	Agricultural Research Station
ANGRAU	:	Acharya N.G. Ranga Agricultural University
AWC	:	Available water capacity
&	:	and
BS	:	Base saturation
CaCO ₃	:	Calcium carbonate
CEC	:	Cation exchange capacity
°C	:	Degree centigrade
cm	:	centimetre
cmol(p+) kg ⁻¹	:	Centimole per kilogram
dSm ⁻¹	:	deci-Siemens per metre
EC	:	Electrical conductivity
<i>et al.</i>	:	and others (Latin <i>et alii</i>)
etc	:	et cetera (Latin)
fig.	:	Figure
g	:	gram
g cm ⁻³	:	grams per cubic centimetre
>	:	Greater than
ha	:	hectare
ICAR	:	Indian Council of Agricultural Research
ICP	:	Inductively coupled plasma
i.e.	:	that is (Latin <i>id est</i>)
kg	:	kilogram
kg ha ⁻¹	:	kilogram per hectare

LGP	:	Length of growing period
<	:	Less than
MSL	:	Mean sea level
Mg m ³	:	Megagram per cubic metre
µm	:	micrometre
m	:	metre
m.e	:	milli equivalent
mg	:	milligram
mg kg ⁻¹	:	milligram per kilogram
mm	:	millimetre
m ha	:	million hectare
NBSS & LUP	:	National Bureau of Soil Survey and Land Use Planning
NTZ	:	Northern Telangana zone
OC	:	Organic carbon
ppm	:	parts per million
%	:	per cent
STZ	:	Southern Telangana Zone
viz.	:	namely
USDA	:	United States Department of Agriculture
XRD	:	X-ray diffraction

Introduction

CHAPTER I

INTRODUCTION

The world population is projected to grow to 7.2 billion by year 2010 from 5.3 billion recorded in 1990, an increase of 1.9 billion or 36 per cent in 20 years (Nikos Alexanderatos, 1996). The necessity for potential and effective utilization of natural resources including soil, increases to fulfil the needs of growing population for food, fibre and forage. No country can afford to waste its limited resources, like soil. For proper utilization of soils, extensive studies are required. Pedological studies of soils are a part of those studies.

The soil classification framework provides a basis for predicting the class characteristics. Thus, soil classification is essential as a means of communication among soil scientists in the different places of the world. Soil classification is also important to identify the most efficient use of soils by estimating their productivity potential and extrapolating the knowledge thus gained at one location to other similar soil for technological transfer.

Soils from Telangana Region, one of the three broad socio-economic and administrative regions of Andhra Pradesh, have been selected for the present investigation.

The cropped area (including both food and non-food crops) in Andhra Pradesh is estimated to be 12,783,111 hectares. Out of this, the per cent cropped

areas are 41.94, 22.70 and 35.36 in coastal Andhra, Rayalaseema and Telangana regions, respectively. The per cent area occupied by food crops in Telangana region out of total in the state is 40.36, by pulses 39.79 and by cotton 57.67. But the per cent out turn of food grains, pulses and cotton is only 35.31, 29.07 and 44.70, respectively out of total in the state (Statistical Abstract, 1995).

The above data show that although there is significant area out of total occupied by crops in Telangana area, the per cent out turn of the respective crops is low indicating that the soils are not well exploited. Therefore, systematic in depth studies have to be carried out in Telangana area which are essential for crop planning by Administrators. Systematic detailed studies, will help to develop cropping sequences in Telangana area for sustainable agriculture and to increase agricultural production.

Keeping in view of the above importance of work, present investigation was carried out on soils of Telangana region of Andhra Pradesh with the following objectives:

- * To study pedons of representative sites morphometrically
- * To characterize the soils horizonwise for physical, chemical and mineralogical properties

- * To study the factors and processes that may be responsible for the formation of soils
- * To classify soils of the study area upto family level, and
- * To evaluate the production potential of soils for optimising crop production

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Review
of
Literature

CHAPTER II

REVIEW OF LITERATURE

Andhra Pradesh, covering a land area of 2,74,400 sq km with a population of 663.5 lakhs (1991), is the fifth largest state in India, accounting for 8.4 per cent of the country's area.

Based on the total quantity and distribution of rainfall, irrigation, soil types and cropping patterns, Andhra Pradesh is broadly divided into 7 Agro-climatic zones (Fig.1).

These are

Krishna - Godavari zone

North coastal zone

Southern zone

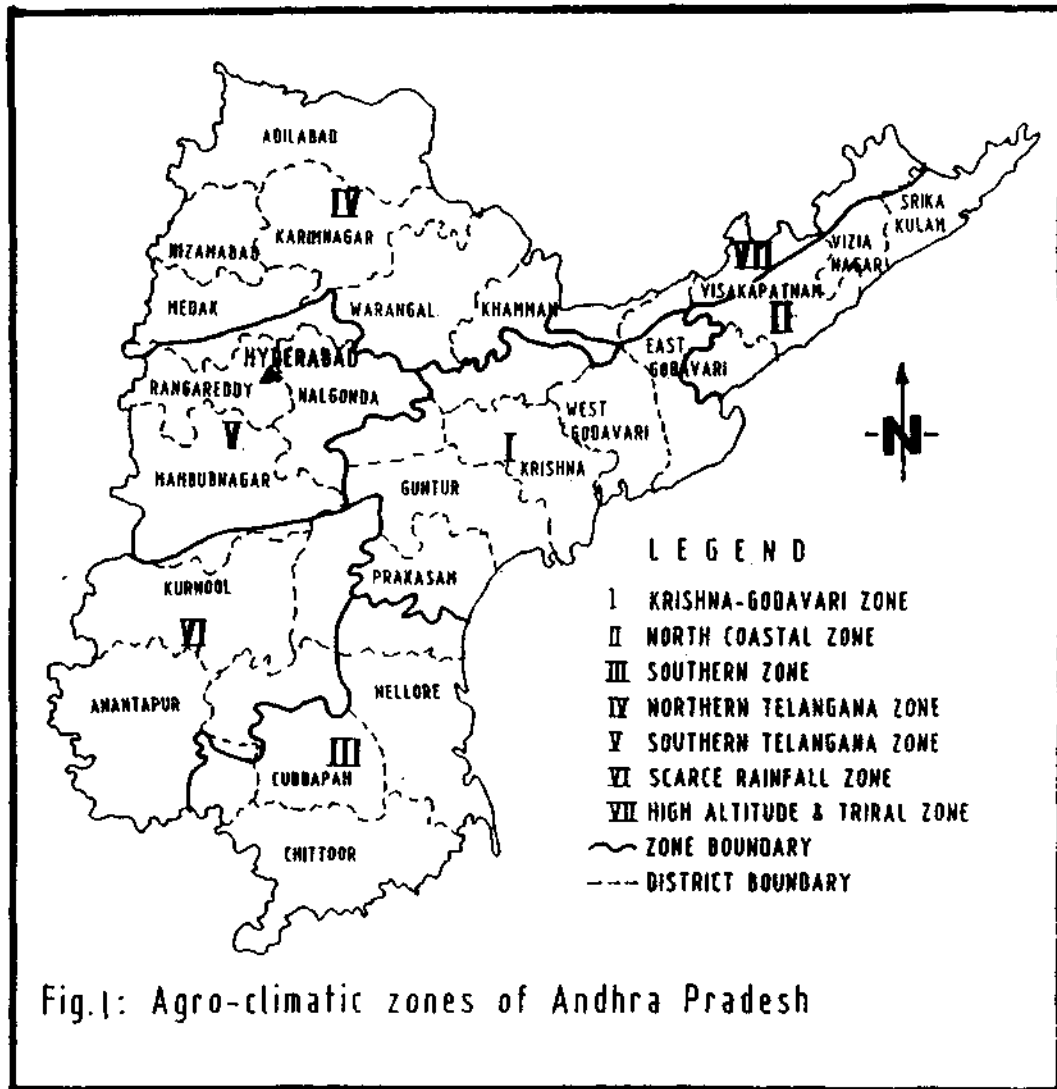
Northern Telangana zone

Southern Telangana zone

Scarce rainfall zone

High altitude and tribal zone

The present study area comprises of Northern and Southern zones of Telangana region. Northern Telangana Zone (NTZ) spreads over 63,350 sq kms accounting for 22.9 per cent of the area in the state. This zone consists of Adilabad, Karimnagar, Nizamabad, Medak (except southern part), Warangal



(except western portion), North eastern tip of Nalgonda and most of Khammam districts. Southern Telangana zone (STZ) comprises the districts of Hyderabad, Ranga Reddy, Mahaboobnagar (except southern part), Nalgonda (except eastern part) and north-western and southern parts of Warangal.

The available literature on Telangana region of Andhra Pradesh has been reviewed and discussed keeping in view of the objectives of the present study and are presented as follows:

- 2.1 Geology
- 2.2 Geomorphology
- 2.3 Climate
- 2.4 Land use
- 2.5 Soils
 - 2.5.1 Morphometric characteristics
 - 2.5.2 Physical and chemical properties
 - 2.5.3 Minerological properties
 - 2.5.4 Genesis
 - 2.5.5 Classification

2.1 GEOLOGY

Various geological formations viz., Archaean, Precambrian, Paleozoic, carboniferous, Triassic, cretaceous, mesozoic, Tertiary, Miocene, Pliocene,

Pleistocene and Recent, are found in Andhra Pradesh (Plate 1). The Archaean or Peninsular gneiss cover about two-thirds area of Telangana and Rayalaseema regions. They are igneous rocks, partially metamorphosed, which have remained stable as a "shield" area for a very long time. The important rock types are granites, granodiorites, and banded gneisses. In some areas, the peninsular gneisses are traversed by a number of dolerite dykes.

The Dharwars consist mainly of schists and quartzites, and are folded and highly metamorphosed. They extend in a north-south band, about 30 to 40 km wide from interior of Nellore district through Prakasam and Guntur districts into Krishna and Khammam districts. In Anantapur and Mahbubnagar districts, they occur in very narrow and elongated patches. The Charnockites and Khondalites are folded igneous formations, which have metamorphosed to metamorphic rocks due to great pressure and heating.

The Cuddapahs and Kurnools (The Puranas) are of upper precambrian and lower palaeozoic and are exposed in a large crescent shaped basin in the central part of Andhra Pradesh covering an area of about 42000 sq km. The Cuddapahs are spread over a vast north-south old basin, which extends from the Tirupati hills in the south to Huzurnagar of Nalgonda district in the north. Another belt of Cuddapahs occurs in Telangana in the Godavari trough in the northern parts of Adilabad, Narasampet of Warangal district, and Burgampahad, yellandu and Kothagudem of Khammam district. Small patches are found to occur

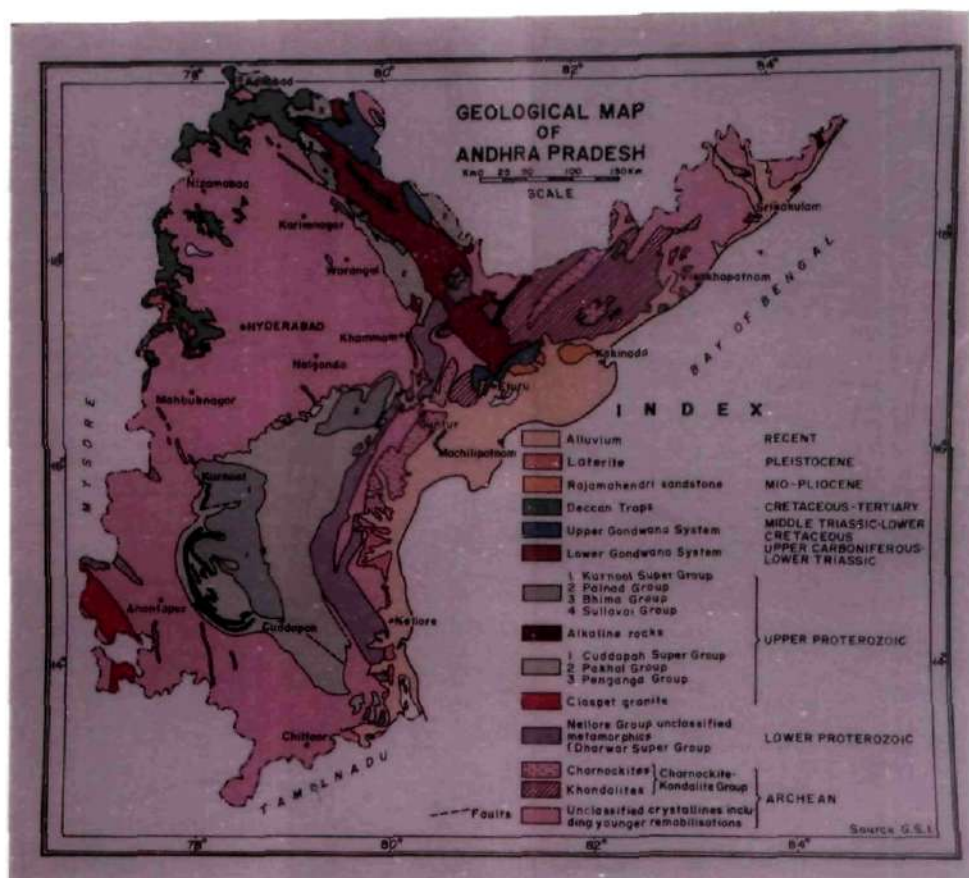


Plate 1: Photograph of the Geology map of Andhra Pradesh

in the interior of East and West Godavari and isolated patches in Nagari and Nagalapuram in Chittoor district. The major rock types are limestones, sandstones, shales and slates.

Compared with the Cuddapahs, the Kurnools are more restricted in their occurrence and are found in the central part of the crescent in the eastern part of Kurnool district and Jammalamadugu taluk of Cuddapah district and Huzurnagar taluk of Nalgonda district. Narrow elongated patches occur in Karimnagar, Warangal and Khammam districts.

The Gondwanas, the faulted trough occupied by the Pranhita and the Godavari rivers along the eastern margin of Telangana, are mainly composed of Gondwana rock formations. They are fossiliferous and fluviatile sediments mostly free from folding, though they have undergone faulting, particularly in the Godavari valley.

The lower Gondwanas are economically important as they contain coal-seams among sandstones and shales in the areas of Kothagudem and Yellandu in Khammam district, Bellampalli in Adilabad district and Godavarikhani in Karimnagar district.

The upper Gondwanas consist of shales and sandstones extending from Rajahmundry to Vijayawada and also as patches along the Godavari trough in eastern Adilabad and Karimnagar districts. Though economically not important, they are valued for the numerous plant and animal fossils.

The Deccan Trap formations occur in the western and north western partsof the state, adjoining Karnataka and Maharashtra and occupy about 10,000 sq km. They are mostly remnants of huge lava flows that poured out from extensive fissures. They form flat-topped hills with step-like trappean topography. The common rock is basalt. The intertrappeans overlie granite, Bhima limestone or other sedimentaries. The Deccan traps occurring in East and West Godavari districts are covered by thick deposits of deltaic alluvium.

The Tertiary formations are represented by low hills and plains composed of Rajahmundry sandstones and conglomerates covering small areas north of Rajahmundry in East Godavari district and Chintalapudi and Kovvur taluks in West Godavari district.

The laterites occur as caps (50-60 m thick) over Deccan Traps in Western Telangana, Nellore and Prakasam districts.

Recent alluvium of marine and riverine nature occurs all along the major rivers and coast. They are wide (80-100 km) in the deltas of Godavari and Krishna and narrow (20-40 km) elsewhere in the coast. There is a near total absence of alluvium in Visakhapatnam district.

The Archaean gneisses, Dharwars, Lower Gondwanas, Upper Gondwanas and Deccan Traps are the geological formations found in Telangana region of Andhra Pradesh (Table 1).

Table 1: Geological formations in Andhra Pradesh

Formation	Age	Occurrence (Districts)
The Archaean gneisses	Lower Precambrian	Telangana and Rayalaseema
The Dharwars	Lower Precambrian	Nellore, Prakasam, Guntur, Krishna, Khammam
The Charnockites	Precambrian	Srikakulam, Vizianagaram, Visakhapatnam, East and West Godavari, Krishna, Guntur, Prakasam
The Khondalites	Precambrian	Srikakulam, Vizianagaram, Visakhapatnam, East and West Godavari, Krishna, Guntur, Prakasam
The Cuddapahs	Upper Precambrian	Cuddapah, Kurnool, Nalgonda, Adilabad, Warangal, Khammam, Karimnagar, East and West Godavari, Guntur
The Kurnools	Lower Palaeozoic	Cuddapah, Kurnool, Nalgonda, Adilabad, Warangal, Khammam, Karimnagar, East and West Godavari, Guntur
The Lower Gondwanas	Upper carboniferous	Khammam, Adilabad, Karimnagar
The Upper Gondwanas	Middle Triassic-Lower Cretaceous	East Godavari, Krishna, Adilabad, Karimnagar
The Deccan Traps	Mesozoic-Lower Tertiary	Medak, Ranga Reddy, Nizamabad, Adilabad
Tertiary formations	Miocene-Pliocene	East and West Godavari
Laterites	Pleistocene	Medak, Ranga Reddy, Nellore, Prakasam, Vizianagaram
Alluvium	Recent	Krishna, East and West Godavari, Guntur, Prakasam, Nellore

Source: NBSS & LUP (1996)

2.2 GEOMORPHOLOGY

The rocks with varied lithological and structural characters respond differentially to the action of the natural agencies such as water, wind and temperature. The study of the development of landforms is, thus, an aspect of geology.

2.2.1 Landforms

Based on their genesis, the landforms in Andhra Pradesh can be classified into four broad genetic classes.

2.2.1.1 Fluvial landforms: Found all along the major rivers of Andhra Pradesh viz., Godavari, Krishna and Pennar. The prominent landforms in this category are Godavari and Krishna deltas, their flood plains and alluvial plains, inter-deltaic lakes, picturesque gorges, numerous valleys and valley fills.

2.2.1.2 Coastal landforms: Found all along the 900 km long east coast of Andhra Pradesh. The prominent landforms in this category are beach ridges, coastal plains, mud flats, lagoons, brackish water lakes, spits, beaches and beach dunes.

2.2.1.3 Denudational landforms: The interior Andhra Pradesh which is predominantly an old pediplain is made up of deeply dissected plateau of granites and Archaean gneisses. Prominent landforms in this category are pediments,

pediplains, erosion surfaces, residual hills, denudational hills and inselbergs, seen largely in Telangana region and parts of Rayalaseema and also around the capital city of Hyderabad.

The denudational landforms result due to long periods of sub-aerial denudation leading to erosional landforms, inselbergs. They are isolated, residual steep sided hills, standing above pediments typically seen around Hyderabad and other parts of Telangana districts. They are barren and rocky. In association with pediments, they form pediment-inselberg complex. Further, weathering of granites along joint planes have produced the typical tor and boulder topography. Tors are essentially tower like, tabular and hemispherical smaller forms, whereas inselbergs are domal and stack type larger forms.

2.2.1.3.1 Pediment: A pediment is a gently sloping rock-cut surface adjacent to a hill, with or without a veneer of debris. Pediment covered with thick alluvial/ colluvial material or weathered rock is called buried pediment. Coalescence of pediments marked by a large area forms pediplain. Depending on the weathering status, it can be locally classified. They occur all over the state in various geological environments right from peninsular gneisses to Deccan volcanics. They are absent in coastal plain.

2.2.1.3.2 Residual hills: Residual hills are essentially isolated low relief hills formed mainly due to erosion. The prominent ones are seen in Chittoor and Anantapur districts in the South.

2.2.1.3.3 Dissected plateau: Mesa and Butte Hills: A dissected upland underlain by Deccan volcanic rocks occurring west of Hyderabad, forms dissected plateau. The elevation of the plateau varies between 600 and 800 metres. Mesa hills capped with resistant horizontal lava flows and buttes are commonly found in this area.

Mesa is an isolated table land capped with a protective cover which is essentially horizontal in attitude. Similar features with limited areal extent are called butte. Typical mesa and butte forms are present in the Kurnool formation of the Cuddapah basin and also in the Deccan volcanic terrain.

2.2.1.4 Structural landforms: Landforms occurring in Cuddapah basin, Eastern Ghats and along Godavari river of Andhra Pradesh are predominantly formed as the result of geologic structures. The prominent landform units are the cuesta and hogback hills, mesa and butte topography, strike and homoclinal ridges, structural and intermontane valleys.

Andhra Pradesh can be divided into certain geomorphic provinces characterised by distinct structural-lithology-landforms (Fig.2) (Naresh Bedi, 1978).

2.3 CLIMATE

By virtue of its location and climate, Andhra Pradesh represents a transition from tropical to sub-tropical India. The climate is predominantly semi-arid to arid, except for the coastal belt, which has humid to sub-humid climate.

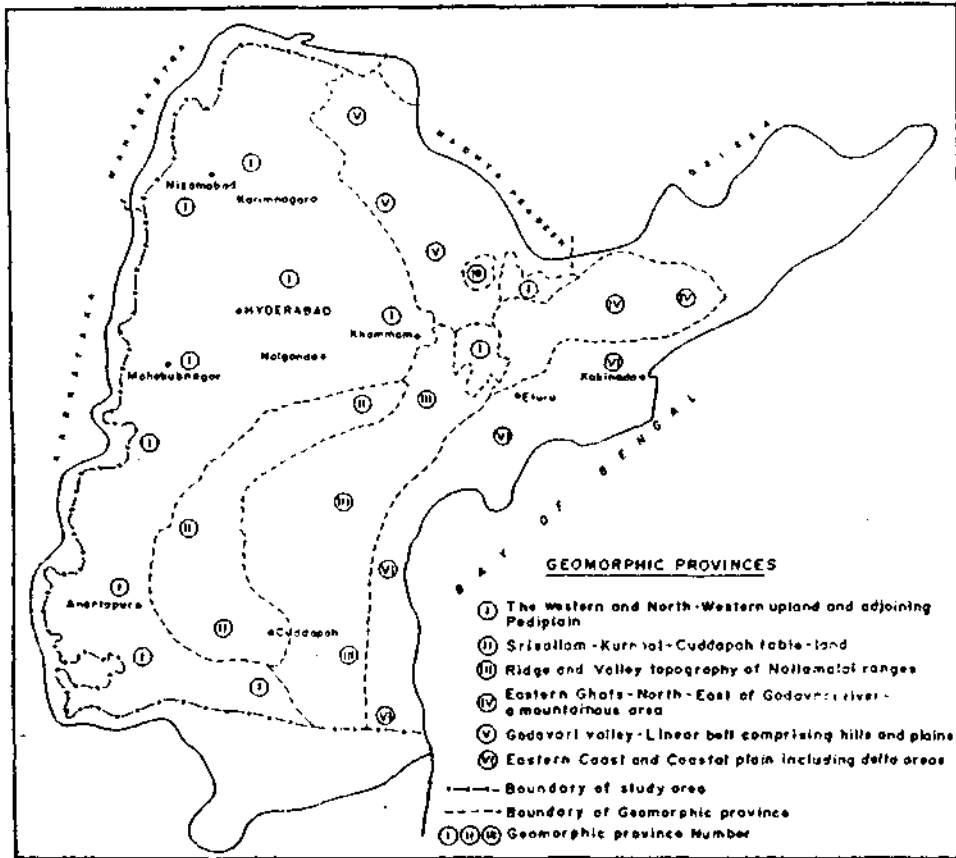


Fig. 3: Landsat image mosaic of Andhra Pradesh showing Geomorphic provinces (Source: Naresh Bedi, 1978)

2.3.1 Temperature

Although the day and night temperatures remain more or less uniform during the south-west monsoon period, day temperatures tend to rise during dry spells. The mean monthly maximum and minimum temperatures in the state vary between 34.2 to 44.8°C and 12.5 to 21.3°C, respectively. In northernmost Telangana districts, temperature goes down to 13 to 15°C, the lowest temperature touching 10°C during winter. Temperatures go as high as 45°C during summer in places like Ramagundam, Rentachintala, Vijayawada, Guntur, Bhadrachalam etc.

2.3.2 Rainfall

2.3.2.1 Northern Telangana Zone

This zone has semi-arid climatic conditions, characterized by heavy rains in *Kharif* season for Adilabad, Nizamabad, Karimnagar and parts of Medak districts during June-September (85.9%). It receives an annual rainfall of 900-1150 mm. Generally the south-west monsoon becomes active during the first week of June. The monsoon is weak, in general, in the month of September when dry spells of 1 to 3 weeks may occur (NTZ status report, 1989).

2.3.2.2 Southern Telangana zone

The climate in this zone is semi-arid with frequent occurrence of drought spells. Four distinct seasons occur. South west monsoon (June-September),

North east monsoon (October-December), winter (January-February) and summer (March-May). The hottest months are March, April and May. The annual rainfall varies from 705 mm in Mahabubnagar district to 987mm in Warangal district. In this zone, certain mandals of Medak and Rangareddy districts are characterized by moderately high rainfall (i.e., more than 800 mm). Generally the onset of monsoon occurs during first fortnight of June. During South west monsoon, two maximum rainfall peaks in the months of July and September with low rainfall in August is a common phenomenon in the zone. Normally about 514 mm to 807 mm rainfall is received during south-west monsoon, 82 to 122 mm during north east monsoon and 51 to 88 mm in winter (STZ status report, 1989).

2.3.3 Agro-climatic classification

The earliest attempt in agro-climatic classification of Andhra Pradesh was done by Subramanyam and Subramaniam (1962) who divided the state into 4 climatic zones. The Acharya N.G. Ranga Agricultural University has divided the state into 7 agro-climatic zones under National Agricultural Research Project for generation and dissemination of agro-technology (NTZ status report, 1989). Sehgal *et al.* (1990) divided the state into 6 agro-ecological regions and 8 subregions. Using Geographical Information system, the 8 agro-ecological subregions map was superimposed on the length of growing period and soils overlay maps and 22 agro-ecological zones map was generated by Naidu *et al.* (1998).

Andhra Pradesh has 8 agro-ecological subregions based on physiography, soils and climate (Sehgal *et al.*, 1990). They are, northern Telangana plateau, southern Telangana plateau, Rayalaseema plateau, south-eastern ghats, north eastern ghats, south eastern coastal plain, delta-plain and north-eastern coastal plain.

The study area falls under Northern and Southern Telangana plateau.

2.3.3.1 Northern Telangana plateau (hot, moist, semi-arid eco subregion)

This region is divided into three zones (Naidu *et al.*, 1998).

Zone 1: It comprises the major parts of Adilabad, Southern and South-western parts of Medak, eastern and north-eastern parts of Warangal and north-western part of Khammam. This zone receives 810 to 1115 mm rainfall.

Zone 2: It comprises the major parts of Nizamabad, Warangal, Khammam, central and western parts of Medak, north and north eastern parts of Karimnagar and southern part of Adilabad. This zone receives 810 to 1135 mm rainfall.

Zone 3: It comprises the central parts of Warangal and a small area in South-western part of Adilabad. This zone receives 980 to 1085 mm rainfall.

2.3.3.2 Southern Telangana plateau (hot, dry, semi-arid eco subregion)

This region is divided into two zones (Naidu *et al.*, 1998).

Zone 4: It comprises the major parts of Mahbubnagar, Ranga Reddy and Nalgonda districts. This zone receives 560-850 mm rainfall.

Zone 5: It comprises the eastern and north-eastern parts of Nalgonda, central parts of Ranga Reddy and central and south-western parts of Mahbubnagar districts. This zone receives 690-970 mm rainfall.

2.4 LAND USE

Andhra Pradesh is one among the country's granaries being surplus in food grains, particularly rice. The state, on an average, contributes 16 to 18 per cent of the country's rice production even though rice growing area is only about 10 per cent of the total rice area of the country. Similar are the area and production situations with respect to sorghum, small millets, groundnut, cotton, chillies, mesta and tobacco. In terms of productivity, although Andhra Pradesh is much above the country's average in major crops such as rice, maize, sorghum, sugarcane, cotton, chillies and blackgram, the yields of finger millet, redgram, bengalgram and castor are far below the country's average. This indicates that there is scope for considerable improvement in production technology for these crops.

Although several cropping patterns have been identified by the National Commission on Agriculture (NCA) as existing in the state, each of the seven agro-climatic zones of the state has its own distinct cropping pattern (Table 2).

Table 2: Major crops and cropping systems in different agro-climatic zones

Name of the zone	Major crops grown	Predominant cropping system
Krishna-Godavari	Rice, cotton, blackgram/greengram, groundnut, fodder, tobacco, sugarcane, chillies, coconut, sesamum	Rice based
North coastal	Rice, groundnut, pearl millet, mesta, finger millet, sugarcane, sesamum, horsegram, greengram, blackgram	Rice, sugarcane, groundnut, pearl millet and finger millet based
Southern	Rice, groundnut, sorghum, pearl millet, redgram, finger millet, horsegram	Rice and groundnut based
Northern Telangana	Sorghum, rice, maize, cotton, groundnut, redgram, bengalgram	Sorghum, rice and maize based
Southern Telangana	Sorghum, rice, castor, groundnut, pearl millet, redgram, horsegram, finger millet, greengram, maize, safflower	Sorghum, rice and castor based
Scarce rainfall zone of Rayalaseema	Groundnut, sorghum, setaria, rice, cotton, coriander, pearl millet	Groundnut, sorghum, setaria, rice and cotton based
High Altitude and Tribal area	Rice, pearl millet, groundnut, finger millet, sesamum, tubercrops, forest trees and horticultural crops	Rice and pearl millet based

Geographically Telangana region occupies maximum area (42%) in the state, but the area under fallows is highest (72%) and net area sown is low. The percentage of current fallows is higher (18 per cent) in Telangana compared to the state (10 per cent). Maximum area under forest in Telangana region is in Khammam district (27%) followed by Adilabad (25 per cent).

The land use in Telangana, Rayalaseema, Coastal Andhra of Andhra Pradesh, and in the state of Andhra Pradesh in percentage is given in Table 3.

Table 3: Land use in Telangana, Rayalaseema, Coastal Andhra and Andhra Pradesh

S.No	Item	Area in percentage			
		Telangana	Rayalaseema	Coastal Andhra	Andhra Pradesh
1.	Net area sown	33.59	41.36	40.34	37.76
2.	Fallow land				
	a) Current fallows	18.06	5.65	4.57	10.48
	b) Other fallow lands	6.71	6.10	4.19	5.71
3.	Forest	24.32	21.93	21.42	22.76
4.	Barren and unculturable land	4.90	10.07	9.21	7.62
5.	Land put to non-agricultural uses	6.53	8.53	12.45	9.02
6.	Culturable waste	1.66	4.23	3.45	2.89
7.	Permanent pastures and other grazing lands	3.55	1.31	3.06	2.84
8.	Land under miscellaneous tree crops and groves not included in net area sown	0.68	0.82	1.31	0.92

Source: Statistical abstract of Andhra Pradesh (1994)

2.5 SOILS

Red sandy soils (*Dubba* and *Chalka*), red earths with loamy sub soils (*chalka*), lateritic soils and black cotton soils (shallow, moderately deep and deep) largely constitute in Telangana zones (NTZ status report, 1989; STZ status report, 1989).

A soil resource map of Andhra Pradesh was prepared by National Bureau of Soil survey and land use planning in cooperation with State Soil Survey, Department of Agriculture, Hyderabad on 1:250,000 scale (1:500,000 publication scale) to know the kinds, distribution and characteristics. The soils identified in the Telangana region were Entisols, Inceptisols, Alfisols and Vertisols (NBSS & LUP, 1996).

2.5.1 Morphometric characteristics

Morphology is the index for identifying the genetic processes in soil development attributing to unique properties of the soils.

2.5.1.1 Soil Colour: Kampf and Schwertman (1983) recommended soil colour which was a function of haematite content as a differentiating character at family level in soil Taxonomy.

The colour indicates the mineralogical nature of the soil. Seshagiri Rao and Chatterjee (1990) reported that the red colour of Alfisols is related to dehydrated iron oxides although manganese dioxide and partially hydrated iron oxides might also be responsible for the red colour. He also reported that the free iron oxides might have imparted red colour to Alfisols under prevailing high temperature of semi-arid climate.

Arun Prasad *et al.* (1989) concluded that soils on the hill top and foot hill uplands were reddish brown (5YR4/4), whereas the soils in depressions had dark brown (10YR 3/3) and 7.5YR4/4) to very dark grayish brown (2.5Y3/2). The reddish brown colour was due to the release of Fe_2O_3 , while brownish and grayish was due to reduction of iron caused by impeded drainage.

Singh *et al.* (1993) found that the colour of sedimentary soils developed on granite-gneiss varied from yellowish red (5YR 4/6) to strong brown (7.5YR 7/6) whereas the colour of the alluvial soils varied from pale yellow

(2.5YR 7/4) to olive (5YR 5/3) due to the degree of hydration of iron oxides. The soils of pediments and colluvial plains are well developed mature Alfisols and Inceptisols with red colours and the soils of low lands are recent Entisols with gray colours (Shiva Prasad *et al.*, 1994).

According to Bhaskar and Subbaiah (1995) the colour of the laterites and associated soils along the east coast of Andhra Pradesh varied from dark yellowish brown to red. Singh *et al.* (1995) concluded that soil colour was the function of free iron oxide to clay ratio.

2.5.1.2 Cracks: Bhattacharjee *et al.* (1977) reported that the width of surface cracks ranged from 2 to 5 cm in Typic Chromusterts and 0.5 to 2 cm in Ustochrepts and the width of cracks decreased with depth.

Subbaiah (1984) also reported that Vertisols of Andhra Pradesh showed 2 to 7 cm wide surface cracks tapered with depth and extended upto 1 meter. Shrikant and Bapat (1993) found 2-3 cm vertical cracks extending upto 50 cm, shining slicken-sides in A13 horizon and prominent intersecting slickensides at A14 and AC horizons of Vertisol. Venkateswarlu *et al.* (1995) identified that the black soils are sticky and plastic exhibiting cracks of about 2 to 5 cm wide extending upto a depth of 65 cm in Kandukur division of Andhra Pradesh.

2.5.1.3 Structure: Subbaiah (1984) reported that the Vertisols of Andhra Pradesh had surface crumb structure followed by subangular to angular blocky structure in deeper layers. The swell shrink soils of semiarid tropics in India had

subangular blocky to angular blocky structure (Rajeev Srivastava and Jagdish Prasad, 1992).

Kaistha and Gupta (1994) found that Inceptisols of north-western Himalayan region had sub-angular blocky structure. Singh *et al.* (1995) noticed that the black soils developed from basalt and basaltic alluvium in Rajasthan had granular to angular blocky or sub-angular blocky to massive structure. Maji and Bandyopadhyay (1995) reported that in Sundarbans, the soils of pedons having pH 4-6 and pH 6-7.5 have subangular blocky structure and platy structure for pedons having pH greater than 7.5.

The black soils of Kandukur division of Andhra Pradesh showed that the surface horizons had loose structure and subsurface horizons had subangular blocky structure (Venkateswarlu *et al.*, 1995). The paddy soils had in general massive structure at the surface, which broke to moderate, medium granular and subangular blocky structure, the non-paddy soils had strong, medium granular and subangular blocky structure.

The clay in Vertisols exhibits significant shrink/swell characteristics to develop unique structure and features like cracks, slickensides, wedge shaped aggregates and gilgai (Soil Survey Staff, 1998).

2.5.2 Physical and chemical properties

Soil physical and chemical properties are the outcome of the process of soil genesis and its development. In physical properties, the particle size

distribution, bulk density and water retention are of prime importance to understand the genesis and use potential of the soils. The chemical properties, viz., pH, organic matter and charge characteristics indicate the leaching of the bases, accumulation of organic carbon and synthesis of the clay minerals in the soils which reflect the genetic processes in the formation of the soils.

2.5.2.1 Particle size distribution: Jenny (1941) reported that clay content of soils increased with increase in temperature and rainfall. Raychaudhuri *et al* (1963) reported that black soils of Andhra Pradesh are heavy textured, with about 80 per cent of fine fractions, while red soils are light in texture, being loamy to sandy but rarely clayey.

Anjaneyulu and Raychaudhuri (1964) studied the red soils of Mandya district of Karnataka and reported that the texture varied from sandy loam to clay at the surface. The subsoil is more clayey.

An increase in clay content between the E and/or A horizon(s) and the underlying Bt horizons occurs in all Alfisols, however, this textural contrast ranges from little to great, i.e, 4 (Torrent *et al.*, 1980) to 40% (Klich *et al.*., 1990).

Alfisols with Bt horizons dominated by fine clay (<0.0002 mm, usually smectitic) display significant volume change between wet and dry states. The Udertic Paleustalf from Texas (Klich *et al.*, 1990) has COLE values > 0.07 for horizons containing 30% or more clay. Because such soils are intergrades to Vertisols and possess similar features such as high subsoil clay content and

shrink/swell potential, and slickensides, they present similar problems for use as construction materials.

Jagannadham *et al.* (1995) reported that the texture of red soils of Kandukur division in Andhra Pradesh varied from sandy loam, sandy clay loam to clay loam. Clay contents varied from 21.5 to 32.3 per cent in surface horizons and from 4.3 to 17.1 per cent in B & C horizons. Higher percentage of clay in surface horizons indicates more advanced weathering than in sub surface horizons.

Dasog and Hadimani (1980) observed that all the black soils formed under semi-arid climate on Deccan trap were heavy textured and the clay content ranged from 59-70 per cent.

Kauraw *et al.* (1983) recorded that fine textured soils had greater than 40 per cent clay. The sand, silt and clay contents of Vertisols varied from 24.6 to 67.4, 6.3 to 23.3 and 23.8 to 56.8 per cent, respectively (Krishna Swamy and Krishnamurthy, 1991).

The soils of Northern Telangana zone of Andhra Pradesh have textures ranging from sandy loam to clay, the clay content of soils varying from 17.4 to 54.1 per cent at surface layers (Vijay Kumar *et al.*, 1994). The saline sodic Vertisols in coastal plains of Gujarat were found to contain as high as 86.7 per cent clay and the clay content decreased with depth (Bhattacharya *et al.*, 1994).

The transportation of soil materials from the upper slope and redeposition at the basin might have resulted in the textural differences of the low land soils and poorly drained condition in the soils might have led to accumulation of silica (Patil and Dasog, 1997).

2.5.2.2 Bulk density (BD): Veihmeyer and Hendrickson (1946) observed that BD of 1.6 to 1.7 g cm⁻³ was critical in clay soils and no roots penetrated in soil with a BD of 1.90 g cm⁻³ or above.

Daji (1970) found that clay soils generally had a lower BD than sandy soils and the BD of soil varied from 1.1 to 1.7 gcm⁻³. Bulk density values of Vertisols at 0.33 Mpa ranges from 0.9 to 1.2 Mg m⁻³ and at 1.5 Mpa from 1.6 to 2.0 Mg m⁻³ (Coulombe *et al.*, 1996a).

Landey *et al.* (1982) found that the bulk density values of black soils varied from 1.5 to 1.8 g cm⁻³.

Brar (1991) reported that bulk density is negatively correlated with organic carbon and clay contents of the soil. Bulk density gradually increases with depth of soil in the profile.

Prasuna Rani *et al.* (1992) noticed that bulk density of Alfisols and associated soils of Kavali canal area under Somasila Project in Andhra Pradesh increased with depth (1.40 to 1.79 g cm⁻³). The soils of Northern Telangana zone

of Andhra Pradesh showed the BD ranging from 1.3 to 1.68 g cc⁻¹ (Vijay Kumar *et al.*, 1994)

Jagannadham *et al.* (1995) also reported that the red soils of Kandūkur division in Prakasam district of Andhra Pradesh showed an increasing trend of bulk density (1.35 to 1.54 g cm⁻³) with depth. Gurumurthy (1995) reported that the BD of soils ranged from 1.25 to 1.67 g cm⁻³ in the soils of Giddalur mandal of Prakasham district of Andhra Pradesh.

2.5.2.3 Moisture retention: Vertisols exhibit high moisture retention characteristics due to their clay content at all water potentials at 0.33 Mpa from 35-75 per cent and at 1.5 Mpa from 15-35 per cent by weight (Ahmed, 1982, Hirekurubar *et al.*, 1991). Under normal field conditions, most of the volume change occurs at water potentials > 1.5 Mpa (Yule and Ritchie, 1980), but it is not clear whether volume change is isotropic or anisotropic.

Subbaiah and Manickam (1986b) found that CEC and clay had significant positive relationship with water at 0.33 bar and 15 bar tensions.

Singh *et al.* (1988) found high water retention capacity in silt loam and clay loam soils compared to the sand and loamy sand soils. Gajbhiye (1990) reported significant positive correlation of water retention at 15 bar with clay, silt and clay plus silt.

Water retained at wilting point could be predicted from the mechanical composition alone whereas for field capacity values inclusion of bulk density data enhanced the accuracy of its prediction (Singa Rao and Prabhu Prasadini, 1998).

2.5.2.4 Soil reaction: Shrikant and Bhapat (1993) revealed that soils at higher elevations were less developed and had low pH compared to that of lower elevations. Singh *et al.* (1993) reported that soils developed from granite-gneiss were relatively more acidic (pH 4.5) than the soils from alluvium (pH 5.7) due to downward movement of bases.

Patil and Dasog (1996) reported that lateritic soils in Uttara Kannada were slightly acidic to highly acidic. The difference between pH measured in KCl and that in water termed as pH was negative in all the cases indicating the presence of silicate clay minerals with relatively constant surface charge. The relatively high pH in 1N NaF compared to that in water and 1N KCl indicated the presence of amorphous alumino silicates.

Vertisols are commonly neutral to alkaline in soil reaction since the majority are derived from calcareous or base rich parent materials. However, acid Vertisols (Ahmed, 1985) also exist. pH in Vertisols ranged from 6.5 (Lugo-Lopez *et al.*, 1985) to 8.2 (HireKurubar *et al.*, 1991).

Subbaiah and Manickam (1992) studied the Vertisols of Andhra Pradesh formed on different parent materials and found the pH values ranging from 7.3 to 9.0

Soil reaction has been found to be the dominant factor in influencing the available zinc content and the extent of its deficiency in soils and rice plants (APAU, 1984-94). Highly significant relationship between soil reaction and available zinc ($r = 0.69$) and zinc content in 3rd leaf of rice ($r = 0.84$) were observed.

2.5.2.5 Electrical Conductivity: Rajkumar *et al.* (1984) reported that the EC values in black soils of Nagpur ranged from 0.1-0.33 dSm⁻¹.

Vijay Kumar *et al.* (1997) reported that the soils of Adilabad district were non-saline with EC values ranging from 0.26 to 0.73 dSm⁻¹.

2.5.2.6 Organic Carbon: Raychaudhari *et al.* (1963) in general, found low organic matter (OM) content in soils of Andhra Pradesh.

Rao and Krishna Murthy (1982) reported that OM content varied from 0.15 to 0.70 per cent in red soils and 0.1 to 1.05 per cent in black soils of Hyderabad region.

Gawande and Biswas (1967) observed that most of the black soils of India contained less than one per cent of organic carbon (OC).

The fertility status of the black soils is higher when compared to red soils as indicated by the organic carbon and similarly some subsoils have higher fertility status than surface soils (Thyagarajan, 1998)

The OC contributes to greater than 50% of the CEC in Entisols and Inceptisols (Drake and Motto, 1982).

2.5.2.7 Calcium carbonate (CaCO_3): Inorganic carbonates accumulate in soils by pedogenic formation or inherited from calcareous parent materials. Some soils in arid and semi-arid areas may contain as much as 40 per cent or more of calcite.

Yaalon (1957) suggested that in calcareous soils where CaCO_3 may be as much as 30-50 per cent of the total weight of soil, not all of it acts as a cementing agent. Most of it is actually present in the soil as distinct limestone or dolomite or calcite particles possessing their own inherent grain size.

Johnson *et al.* (1962) reported that pedogenic carbonates occur in various forms in many Vertisols. In residual profiles, CaCO_3 is formed during the weathering of rocks and it accumulates as soft, powdery or hard forms in the transitional zone between solum and weathering rock. In sedimentary plains, finely divided carbonate may leach from the surface soil and accumulates as soft, powdery lime or hard nodules or concretions below the depth of cracking. Carbonate nodules are a common feature in the Vertisols of India.

All Vertisols are invariably calcareous in nature. The distribution of CaCO_3 may be either uniform throughout the profile or may increase in the lower horizons (Raychaudhuri *et al.*, 1963). The content of CaCO_3 in Indian Vertisols may vary

from traces to 10 per cent or more in the profile. Lime occurs as nodules of varying sizes and colours. These soils had high base saturation with Ca as the predominant exchangeable cation.

Raychoudhury *et al.* (1963) and Devos and Virgo (1969) reported that CaCO_3 content of Indian Vertisols may vary from traces to as high as 10 per cent or even more in the profile and the distribution may be either uniform throughout the profile or may sometimes increase with depth of the profile.

The studies of Biswas *et al.* (1966) also showed an increase in CaCO_3 content with depth in black soil profiles of Kurnool district of Andhra Pradesh.

Govindarajan *et al.* (1972) observed that the CaCO_3 content of Indian Vertisols ranged from 0.5 to 8 per cent. But Sharma and Bhargava (1973) found that in the black soils of Thungabhadra catchment area, the CaCO_3 was upto 24 per cent.

Krishnamurthy and Govindarajan (1977) also reported an increase in CaCO_3 with depth upto 16.4 per cent in black soil profile. But CaCO_3 was absent in the profiles of red soils of Rajolibanda diversion irrigation scheme of Andhra Pradesh. Further, the black soils contained higher amounts of CaCO_3 than red soils formed on Schistose parent rock. Bhattacharjee *et al.* (1977) reported an increase in CaCO_3 content with depth upto 2.5 per cent in Vertisols of Maharashtra.

Kaswala and Deshpande (1983) found that in black soils of South Gujarat, CaCO_3 content varied from 2.3 to 15.7 per cent whereas in the black soils of Cuddapah basin of Andhra Pradesh, it ranged from 15 to 30 per cent (Rao, 1983).

Murthy (1988) noticed that the CaCO_3 content of Indian Vertisols varied from 0.5 to 20 per cent, while those of Saurashtra region of Gujarat had CaCO_3 of 3-36 per cent (Patel *et al.*, 1992).

The morphological, micromorphological and chemical composition of carbonate nodules in some Vertisols of India has been documented by Mermut and Dasog (1986). Further, Nandi and Dasog (1992) studied in detail the origin, properties and distribution of carbonate nodules in Vertisols of Karnataka. Both white and black nodules were identified. The black nodules had less CaCO_3 , more Al, Fe and Mn content than white nodules and decreased with depth. In both types of nodules, calcite was the predominant mineral with small quantity of quartz.

Desai (1942) reported that there was a decrease in CaCO_3 content in red soils and an increase in black cotton soils with depth in erstwhile Nizam state of Andhra Pradesh. Such a trend was also reported in soils of Tamil Nadu. However, Roy and Barde (1962) observed an increase in CaCO_3 content of both red and black soil profiles of Bijapur with depth upto 10.8 and 23.5 per cent, respectively.

Bhatia and Vardani (1982) reported that in red and black soils of Bhundelkhand region of Uttar Pradesh, CaCO_3 content increased with depth. Similar trend was also reported by Saxena and Singh (1982) in the red and black soils of Rajasthan.

Raja Reddy (1986) reported that red and black soils of Andhra Pradesh developed on Schistose parent rock were neutral to alkaline in reaction (pH between 6.7 and 8.5) in the entire area indicating that they were developed from parent materials rich in alkaline earths. The pH tended to increase in the sub-surface layers of all the soils due to corresponding increase in CaCO_3 . However, pH of most of the calcareous soils seldom exceeds 8.5.

Excessive amounts of CaCO_3 decrease the availability of iron to plants and often it is necessary to supply additional iron to plants (Brown *et al.*, 1959). Calcareous soils attribute conditions favourable for zinc fixation and, therefore, most of the zinc disorders in plants occur in calcareous soils.

In red soils, lime concretions in the form of nodules or thick veins are formed, the latter being resulted from the weathering of plagioclase feldspars occurring in massive forms in gneisses and granitic gneisses. Soils containing lime may have a pH as high as 8.4 (Das and Chatterjee, 1982).

2.5.2.8 Cation exchange capacity (CEC): Roy and Barde (1962) observed that the black soils of India developed on basic igneous rocks had CEC values ranging from 47 to 65 c mol (p+) kg^{-1} soil.

Biswas *et al.* (1966) found variation in CEC of black soils of Kurnool district of Andhra Pradesh with values ranging from 31 to 45 c mol (p+) kg⁻¹.

Krishnamurthy and Govindarajan (1977) reported that CEC in black soils of Mahabubnagar district of Andhra Pradesh varied from 39 to 57 cmol(p+)kg⁻¹ soil.

According to Subbaiah and Manickam (1992), Vertisols of Andhra Pradesh were having CEC within the range of 46.3 to 67.8 cmol(p+)kg⁻¹.

Daji (1970) observed that soils rich in montmorillonite clay were higher in CEC while those having kaolinite clay had a low CEC.

Bhattacharjee *et al.* (1977) found that the CEC varied with clay and organic matter contents.

Prasad *et al.* (1987) found that destruction of organic matter in the soil reduced the CEC values, but the removal of iron oxides increased the CEC values.

Srivastava and Srivastava (1991) observed highly positive correlation between CEC and soil pH, the values being increased at the rate of 3.7 cmol(p+)kg⁻¹ soil per unit increase in pH.

Maji and Bandhopadhyay (1995) reported that in red soils CEC of surface horizons was high and those of C horizon was low.

2.5.2.9 Exchangeable cations and per cent base saturation: The exchange complex in most of the soils is dominated by calcium followed by magnesium, sodium and potassium. Exchangeable calcium, magnesium and sodium increased with depth and exchangeable potassium was distributed uniformly due to potassium equilibria in soils (Karale *et al.*, 1969).

Buol *et al.* (1998) reported that soils formed from limestone, dolomite, shales, basalt and diorite were high in base saturation. Soils developed from sandstones, granite, gneiss and unconsolidated coastal plain sediments of alluvial colluvial -deltaic region were low in base saturation.

Daji (1970) reported that black soils contained greater amount of total exchangeable cations than alluvial or lateritic soils and the black soils were richer in exchangeable calcium than the other two.

Ahmed (1985) reported that cations such as Al^{3+} , Mg^{2+} and H^+ may increase and replace exchangeable Ca^{2+} , particularly under soil acidic conditions due to dissolution of minerals. An increase in the concentration of these cations and a decrease in CEC indicate that chemical degradation has occurred.

The critical concentration of Ca in soil and plant was reviewed by Tiwari (1990). Generally, soils containing Ca less than 25 per cent of CEC or less than 1.5 me exchangeable Ca 100 g^{-1} soil have been categorised as a Ca deficient soil.

2.5.2.10 Available nitrogen, phosphorus and potassium contents:

Raychoudhuri *et al.* (1963) stated that the black soils of Andhra Pradesh were poor in nitrogen but contained sufficient quantities of potassium and phosphorus. Red soils were poor in all the major plant nutrients while alluvial soils were rich in potassium and phosphorus.

Krishna Kumari *et al.* (1983) observed that the contents of total nitrogen was higher in black and alluvial soils of Andhra Pradesh than in the red soils of the state.

Subba Rao *et al.* (1984) estimated forms of nitrogen in Vertisols and Alfisols of Andhra Pradesh. Vertisols contained 35.0 to 87.5 ppm $\text{NH}_4\text{-N}$ and 14.0 to 45.5 ppm $\text{NO}_3\text{-N}$ while the Alfisols had 28.0 to 70.0 ppm $\text{NH}_4\text{-N}$ and 21.0 to 94.5 ppm $\text{NO}_3\text{-N}$.

The P fixing capacity of soils was found to increase with size fractions in the order : clay > silt > sand. Wetland soils fixed more K than dry land virgin soils (Habeebuddin, 1978).

According to National Bureau of Soil Survey and Land Use Planning (1996), in Andhra Pradesh about 57 per cent of soils were low in available nitrogen, 80 per cent were low in available phosphorus and only 3 per cent were low in available potassium.

2.5.2.11 Available micronutrients: Soil reaction markedly regulates the availability of micronutrients. In acid soils, due to high solubility, the manganese, iron, zinc and copper are readily available to the plants. In soils having pH ranging from 5.9 to 7.5, the concentrations were sufficient to meet the requirement of the most of plant species. In general, the availability of these micronutrients is reduced in soils with pH above 7.5 (Daji, 1970).

Black soils showed greater capacity to fix added zinc than red soils indicating the need for higher zinc doses for black soils in view of higher clay content to correct a given degree of zinc deficiency. Multiple correlation and regression analyses revealed that clay alone accounted for a greater part of zinc fixed ($R^2=0.93$) in black soils. In association with pH and CaCO_3 , the prediction was improved by 4 per cent only ($R^2=0.97$). In case of red soils, clay content ($R^2=0.88$) accounted for 88 per cent of the variation for the total zinc fixed. But in combination with pH, it was accounted for 93 per cent of the total variation ($R^2=0.93$) (Manohar, 1974).

Manohar (1974) reported that the mobility of zinc was affected by soil pH, adsorption, clay content and organic matter. With increasing clay content, zinc fixation was observed to increase in both the red and black soils from different parts of Andhra Pradesh.

Gopichand *et al.* (1985) reported that available iron and zinc contents in soils of Andhra Pradesh varied between 6 to 11.8 ppm and 0.77 to 3.63, respectively.

Subbaiah and Manickam (1987b) after studying 134 Vertisol profiles of Andhra Pradesh reported that these soils were fairly rich in available copper, iron and manganese but were low in zinc. The available zinc contents varied from 0.14 to 1.55 ppm in these soils.

According to NBSS & LUP (1996), in Andhra Pradesh 53 and 22 per cent of soils were deficient in zinc and iron, respectively. The Vertisols are well supplied with respect to available Fe, Mn and Cu. Zinc deficiency is likely to restrict the crop production under intensive cultivation (Murthy *et al.*, 1997).

Mean available (DTPA) copper content of Alfisols, Entisols and Vertisols of West Godavari district was highest (13.3 ppm) and it was least (1.2 ppm) in light soils (Alfisols) of Nalgonda district. Analysis of soil samples from many of the districts showed copper to be in the deficient range viz., 0.3 ppm (Annual Reports, APAU, 1984-94).

2.5.3 Mineralogical properties

Nagalschmidt *et al.* (1940) from their mineralogical studies of red and black soils in the then Hyderabad state, now a part of the present state of Andhra Pradesh, occurring side by side noted that both the soils are derived from very similar parent rocks. The differences in their mineralogical composition was suggested to be due to their differences in their topography. In many parts of the tropical world, red and black soils are occurring as associated soils. It is the

general observation (Nagalschmidt *et al.*, 1940), where undulating topography prevails, the red soils occur in the upper elements of topography and the black soils on the lower elements. Such conclusions were confirmed by several subsequent workers (Desai, 1942; Biswas *et al.*, 1966; Gawande *et al.*, 1968; Krishnamurthy, 1969; Satyanarayana and Biswas, 1970; Krishnamurthy and Govindarajan, 1977; Murali *et al.*, 1978).

Gawande *et al.* (1963) studied the mineral assemblage of the soils in the catenary sequence of Chhatisgarh basin developed on limestone, clay shales, sandstone and quartzite rocks. Quartz and orthoclase feldspar constituted bulk of the primary materials; the other minerals were zircon, tourmaline, magnetite, mica, hornblende, kyanite, sillimanite, apatite and traces of plagioclase feldspar. Feldspars in the soils of the upper slopes were completely weathered and this alteration decreased down the slope.

Murali *et al.* (1974) studied mineralogy of red soils (Alfisols) of Mysore state. They found that both the silt and clay fractions were kaolinitic and contained considerable amorphous material.

Sahu *et al.* (1983) studied genesis and mineralogy of some red and laterite soils of Orissa. They observed that the red soils developed on charnockite and khondalite rocks of the Eastern Ghat region. Acidic reaction and high permeability had led to the dominance of kaolinite and a higher proportion of potash feldspar and mica were responsible for dominance of illite. Higher

proportion of potash bearing minerals in the sand fraction reflected the prevalence of moderate weathering conditions which was conducive for illite in the laterite soils. Parent rock rich in quartz and orthoclase feldspar subjected to more leaching had resulted in kaolinitic and illitic type clay.

Most Alfisols contain substantial quantities of 2:1 clay minerals such as smectite and hydrous mica, some vermiculite, chlorite and the 1:1 clay mineral kaolinite. For more intensely weathered Alfisols, kaolinite was the dominant clay mineral in the argillic horizon. The most common mineral dominating the sand and silt fractions has been observed to be quartz. As reported by West *et al.* (1984) in Paleustalf and by Vepraskas and Wilding (1983) in Paleudalf sand fraction constitutes more than 90 per cent quartz. In these soils in silt fraction also quartz was found dominating.

In Karnataka red soils, kaolinite was the dominant mineral in clay and silt fractions (Bhattacharya and Ghosh, 1990) and mica and smectite were the other associated minerals in clay fraction while in the sand fractions, quartz was dominant.

Dhar *et al.* (1993) studied mineralogy of some red soils under forests in Karnataka. They observed that the quartz was the most dominant mineral in the sand fractions. The feldspars showed sericitisation and kaolinisation. Zircon, kyanite, staurolite, hypersthene, garnet, hornblende and rutile characterised the

heavy minerals. The soil clays contained both dioctahedral and trioctahedral micas, kaolinite, vermiculite, smectite and mixed layers. Trioctahedral micas appeared to have altered with the formation of smectite through vermiculite and other mixed - layered intergrades.

Seshagiri Rao and Chatterjee (1990) suggested two ways of synthesis of kaolinite in associated Ustalfs and Usterts occurred in toposequence developed on granites. These are: (i) alteration of feldspars through amorphous stage and (ii) alteration of feldspars through mica.

Seshagiri Rao and Chatterjee (1990) suggested the following transformation of mica to chlorite.

Mica $\longrightarrow$ Vermiculite $\longrightarrow$ Montmorillonite $\longrightarrow$ Intergrade Al chlorite

Coulombe *et al.* (1996b) reported silicates (quartz, feldspars and zeolites in the silt fraction and garnet, epidote and zircon in the sand and silt fractions of a Vertisol derived from gneiss in Ghana), oxides-oxyhydroxides of iron, manganese and titanium, carbonates, sulfides (pyrites), sulfates (Jarosite, natrojarosite, gypsum), phosphates etc. as common mineralogical constituents of Vertisols.

2.5.3.1 Sand mineralogy: The general observation by Desai (1942), Rao and Krishna Murti (1984), Subbaiah and Manickam (1986a) is that light minerals like

quartz and feldspars with traces of mica constitute the bulk of sand fraction (>90%) and the heavy minerals constitute the remaining smaller fraction.

Many easily weatherable minerals like augite, epidote etc. are significantly absent in red soils whereas such minerals are fairly abundant in the black soils of lower slope of Rudrur area of Nizamabad district (Satyanarayana and Biswas, 1970). Krishnamurthy and Govinda Rajan (1977) reported comparatively more plagioclase feldspars and ferromagnesian minerals in black soils than the associated red soils under Rajolibanda Diversion irrigation scheme in Mahabubnagar district. The fine sand mineralogy of soils of ICRISAT revealed the occurrence of heavy minerals to be low in red soils and in colluvial soils and high in other soil profiles (Rao and Krishna Murti, 1982). Quartz is the dominant mineral in light fraction ranging between 31.6 and 87.5 per cent with considerable amounts of feldspars. Patancheru, Isnapuram and Kasireddipalli profiles (Ranga Reddy district) are rich in potash feldspars (9.4-19.5%). But, the other profiles are rich in plagioclase feldspars (7.1-42.9%). The red soil profiles have dominance of iron oxide minerals in the heavy fraction and the black soil profiles have higher amounts of ferromagnesian minerals. The contents of pyroxene and biotite decreased down the slope in black soil profiles whereas the plagioclase feldspars increased down the slope.

Lekha *et al.* (1998) studied sand mineralogy and mineral weathering index of selected soils of Kerala. It was observed that the opaque mineral assemblages were dominantly in the heavy sand fraction of all the soils. Biotite,

hornblende, hypersthene, zircon and tourmaline were the dominant minerals among non-opaque fraction. The soils developed over granite gneiss were comparatively younger and consisted of high nutrient reserves followed by the soils developed over granites, charnockites and laterite.

While dealing with associated Ustalfs and usterts occurring in toposequence in Nalgonda and Mahabubnagar districts, Seshagiri Rao and Chatterjee (1990) observed that light mineral fraction was dominated by quartz and orthoclase feldspars with variable amounts of plagioclase, microcline and micas, while the heavy mineral fraction was predominantly zircon with appreciable quantities of chlorite and opaque minerals. Quartz and feldspars were the principal primary minerals in all the pedons developed on the granitic parent rock. The preponderance of quartz in the sand fraction was ascribed to selective accumulation due to its relative resistance to weathering. The abundance of orthoclase feldspars with subordinate amount of plagioclase feldspars was attributed to minor variations in parent rock. Zircon, which is considered as a pointer mineral of granite rock, is consistently high in heavy mineral suite. He reported no appreciable variations in sand mineralogy amongst different profiles developed on granitic parent rock.

According to Pal and Deshpande (1987a) the sand fractions of Patancheru (Red soil) consisted mainly of quartz, microcline, plagioclase and sericite as common minerals with amphibole, pyroxene, chlorite, biotite, chloritised biotite, rutile, zircon and magnetite as accessory minerals. The Kasireddipalli

profile (black soil) sand fractions contained quartz, plagioclase and pyroxene as common minerals with chlorite, microcline, magnetite, chloritised biotite and amphibole and accessory minerals rutile and zircon are present in traces. The mineralogy of sand fractions of the Patancheru (red soils) Pedon, developed on granite-gneiss, is in agreement with the mineralogy of the rock type, although the parent material of Kasireddipalli soil has been earlier reported to be of basaltic alluvium (Murthy *et al.*, 1982), the sand mineralogy data are indicative of granite-gneiss origin. However, it is believed that both gneissic and basaltic rocks have contributed to the primary mineral assemblage of this soil considering the geomorphic position of the pedon in the landscape (Pal and Deshpande, 1987a).

2.5.3.2 Silt mineralogy: Rao and Krishnamurti (1984) studied the silt mineralogy of red and black soils of ICRISAT, Hyderabad. The silt fraction of red soils is dominant in quartz (32.6 - 62.4%) with appreciable amounts of kaolinite (8.2 - 34.1%) and mica (15.1 - 26.4%) and small amounts of feldspars (15.4 - 16.9%) and amorphous material (2.0 - 4.5%). The silt fraction of black soils is also dominant in quartz (17.0 - 85.7%) with appreciable amounts of kaolinite (2.2 - 36.4%) and small amounts of mica (0.6 - 14.0%), feldspars (0.5 - 23.8%) and rutile + anatase (9.0 - 5.6%). The colluvic soils of Kasireddipalli are dominated by quartz. The titanium minerals are high in the profiles developed *in situ* on basalts and lower in the profiles developed in colluvic profiles. Shankardeopalli, Singapur, Jolkal and Icri profiles contained appreciable amounts of smectite even in silt fraction of some horizons.

According to Pal and Deshpande (1987a) smectite, vermiculite, mica, kaolinite, 10-14Å mixed layer minerals, quartz and feldspars were present in the silt fraction of all horizons of the Patancheru soil (red soil) in ICRISAT area. Smectite content increased with depth and became the dominant mineral in BC horizon. In Kasireddipalli (black) soil, smectite, vermiculite, chlorite, mica, 10-14Å mixed layer minerals, kaolinite, quartz and feldspars are present. Smectite increased with depth and became dominant in AC horizon.

2.5.3.3 Clay Mineralogy: According to Nagalschmidt *et al.* (1940), the kaolin in the clays of black soil might have been transported from red soil and not formed in black soil of the red and black soil toposequence of Hyderabad. Presence of small quantities of halloysite, mica and quartz in red soils and kaolinite, mica and amorphous material in black soils was reported by Nagalschmidt *et al.* (1940) and Desai (1942).

Das and Das (1966) studied mineralogy of clays from some black, brown and red soils of Mysore. They found that the black and brown soil clays were similar in their mineralogical composition containing small amount of kaolinite and also degraded illite and vermiculite in some cases, whereas illite constituted the dominant fraction in red soil clays with less quantities of kaolinite and expanding lattice minerals.

During the studies in genesis of soils of Chhatisgarh basin, Gawande *et al.* (1968) observed the gradual decrease in the preponderance of illite with

concurrent increase in montmorillonite as the characteristic mineralogical make up of the clays of the soils in the toposequence. Illite with traces of kaolinite and occasionally quartz were principal mineral constituents of clays of the soils in the upper and mid slopes whereas montmorillonite with traces of illite and kaolinite was predominant in the soils of the lower slope. Illite in the upland soil was mostly degraded.

It is assumed that montmorillonite might have been formed first which may under certain situations, underwent partial decomposition and gave rise to mineral of the kaolinite group by loss of bases and iron (Biswas *et al.*, 1966). These trends were also confirmed by Satyanarayana and Biswas (1970) in their studies on the associated black and red soils near Agricultural Farm, Rudrur, Nizamabad district.

Kantor and Schwertmann (1974) suggested that smectite was the first weathering product of basic rocks. It resists decomposition under poor drainage conditions but can decompose to kaolinite in high leaching conditions.

Pal and Deshpande (1987a) also suggested that kaolinite in red soil has possibly developed at the expense of smectite with progressive weathering. Little or no kaolinite in silt and sand fractions probably precludes the formation of clay kaolinite from particles of break down scenario.

In the soils of the more humid and high rainfall zones, the clay mineral like kaolinite dominated. Montmorillonite more often occurred in heavy soils with

impeded drainage. In high rainfall zones, kaolinite and halloysite made their appearance. The more common clay mineral was illite followed by kaolinite and chlorite with traces of vermiculite. The interstratification was also noticed (Mukherjee *et al.*, 1971).

Tardy *et al.* (1973) pointed out that smectite was the first mineral to form from all rocks that contained weatherable minerals.

Gupta and Raychaudhuri (1973) reported that the predominant clay minerals were montmorillonite and beidellite in black soils, kaolinite and illite in red soils, kaolinite and kaolin like minerals in laterite and lateritic soils and illite and kaolinite in mountain and hill soils.

Ghosh and Raychaudhuri (1974) reviewed the distribution of clay minerals in Indian soils. Red soils of Dhanbad, Singhbhum, Hazaribagh and Ranchi districts of Bihar were dominant in illite with kaolinite, chlorite, goethite and quartz as associated minerals. Red soils of Orissa were dominant in illite, with kaolinite and montmorillonite as associated minerals. Red soil clays from Coorg in Karnataka derived from acid igneous rocks contained kaolinite with halloysite and haematite. Red soils of Shimoga district of Karnataka developed on granite contained montmorillonite in association with chloritised montmorillonite, illite and kaolinite.

Characterisation of clay minerals of major soil groups of Tamil Nadu was attempted by Ramanathan and Krishnamoorthy (1977). They found that the clays from black soils were highly siliceous and clays from lateritic soils were highly

sesquioxidic. The soils could be arranged in the sequence : black, alluvial, red and laterite for decreasing order of montmorillonite. The kaolinite was predominant in red soil clays. The laterite soils were mainly kaolinitic.

According to Murali *et al.* (1978), considerable amounts of smectite were present in the clays of soils on the toeslopes occurring in two toposequences of tropical region of India.

Biswas *et al.* (1978) studied clay mineralogical composition of the soils developed under different climatic regions of India. They observed that soils of high rainfall zone with strongly expressed dry season (Ratnagiri and Panhala of Maharashtra) had preponderance of kaolinite with small amounts of smectites whereas soils of sub-arid to sub-humid zone with alternating dry and wet seasons had dominance of smectites in their clay fractions.

Many researchers (Rengasamy *et al.*, 1978; Murali *et al.*, 1978; Pal and Deshpande, 1987a; Pal, 1988) indicated that the kaolinite was formed in red soils on gneissic rocks during tropical humid climates prevailing earlier to pliocene-pleistocene transition period. Pal and Deshpande (1987b) and Pal *et al.* (1989) suggested that the first weathering product of the metamorphic rocks was dioctahedral smectite during tropical humid climates.

Ghosh and Kapoor (1982) reviewed the occurrence of clay minerals in Indian soils. The dominance of kaolinite minerals followed by illite was reported in the red ferruginous soils.

Predominance of montmorillonitic clays in Vertisols developed on wide variety of parent materials was reported by several workers (Rao and Krishna Murti, 1984; Surekha, 1991). Kaolinite dominates the clay fraction of red soils while smectite group dominates the clay fraction of black soils (Satyanarayana and Biswas, 1970; Krishnamurthy and Govinda Rajan, 1977; Rao and Krishna Murti, 1984; Seshagiri Rao and Chatterjee, 1990).

The clay mineral nature of associated Ustalfs and Usterts developed on granite rock occurring in toposequence in Mahabubnagar and Nalgonda districts of Andhra Pradesh was investigated by Seshagiri Rao and Chatterjee (1990). They reported that the fine clay fraction consisted of smectite, mica and kaolinite, while the coarse clay fraction was composed of small amounts of chlorites, vermiculites, quartz and feldspars, besides the above clay minerals. An important feature noted was that smectite content increased down the topography while that of mica and kaolinite decreased. It was concluded by them that the clay fractions of the soils are mixtures of four or five minerals with smectite as principal mineral in Vertisols and intergrade pedons and kaolinite in Alfisol profiles.

The clay mineralogy of the ferruginous soils of Goa was studied by Raghumohan and Ghosh (1984). The kaolinite was the dominant mineral, formed under conditions of ferralitic weathering in the intertropics irrespective of the parent materials. In spite of advanced weathering, talc was found to persist and was traced to inheritance from the source materials.

Ghosh and Ghosh (1984) studied mineralogy of some soils of Burdwan district of West Bengal. The clay fraction of laterite and red soils, however, was dominantly kaolinite, that of alluvial soil contained mica and smectite in almost equal proportions, and the red transitional soil had smectite and kaolinite in nearly equal quantities. Fairly high amount of smectite and interstratified minerals in the laterite soil and 23 per cent vermiculite in the transitional red soils were other noteworthy features of these clays.

Patil *et al.* (1990) studied the clay mineralogy of the soils of Indrayani river basin, Western Maharashtra. Chemical weathering of basalt of nearly uniform chemical and mineralogical composition led to the development of two contrasting soil types. Red to reddish brown coloured lateritic to semi lateritic soils of the western part of the basin mainly contained kaolinitic clay minerals. Formation of these soils was attributed to free drainage and high rainfall conditions. Greyish black or black cotton soils, mainly had minerals of the smectite group and were formed under poor or restricted drainage and low rainfall conditions in the eastern part of the basin.

Pacharne *et al.* (1996) studied spatially associated ferruginous and black soils of Nagpur district, Maharashtra. It was observed that in ferruginous soils, smectite was dominant followed by kaolinite whereas Vertisols were having predominantly smectite. Geomorphic and climatic history of the area suggested

that although both the soils did start forming during the earlier tropical humid climate, transformation of smectite to kaolinite could not be attained.

Pillai *et al.* (1996) also studied spatially associated red ferruginous (Lithic Ustorthent and Typic Ustochrept) and black soils (Lithic Ustorthent and Typic Haplustert) occurring under similar topographic situation in close proximity in the basaltic Malegaon plateau of Nagpur district at an elevation of about 480 m MSL. The presence of interstratified smectite - kaolin (sm/k), even though in small amount, in the clay fractions suggested the formation of kaolin from smectite. Minor amounts of sm/k and kaolin in ferruginous soils indicated a probable truncation of upper layer rich in these minerals. The formation of smectite and sm/k in both the soils suggests that these soils were formed under humid climate of the geological past.

Bhattacharya *et al.* (1997) studied spatially associated red (Typic Hapludalf) and black (Vertic Eutropept) soils developed on the Deccan plateau in the Western Ghats for clay mineralogy and also physical properties. The fine clay mineralogy of the red soil was dominated by interstratified smectite/kaolinite with a little amount of smectite, but had low cation exchange capacities and other associated non-vertic physical properties. Some of the smectite was interlayered with chlorite. This red soil was grouped into the kaolinitic mineralogy class. The fine clay mineralogy of the black soil was dominated by highly interstratified

smectite/kaolinite and smectite, which also showed some interlayering with chlorite. This soil had vertic physical properties but had a mixed mineralogy.

Patil and Dasog (1997) studied the clay mineralogy of the soils of the Western Ghats area of Karnataka. Clays of the soils were rich in silica followed by aluminium and iron. Kaolinite was the dominant mineral in clay fraction that decreased with depth. Significant quantity of 2:1 type clay minerals were detected in the clay fraction. Restricted drainage might have caused stabilization of 2:1 type clay minerals.

Pharande *et al.* (1997) studied clay mineralogy of Sawargaon soil series developed from weathered basalt in Ahmednagar district of Western Maharashtra. It was observed that the fine clay fraction contained predominance of smectite with beidellite - montmorillonite series. The coarse clay fraction showed the mixture of minerals consisting of smectite followed by kaolinite, quartz, feldspar, illite, chlorite and vermiculite in the decreasing order.

Preethi *et al.* (1998) studied some selected soils of Kozhikode, Palghat and Ernakulam areas of Kerala. The high amount of easily weatherable minerals such as biotite, hypersthene and hornblende in soils developed over charnockite and granitic gneiss and of opaque mineral assemblages in the heavy mineral fractions of soils developed over laterite, indicated that these soils differ in evolution and the former was comparatively younger in age. The clay mineralogy

of soil fractions indicated the dominance of kaolinite possibly due to intense kaolinisation in the finer fractions of biotite.

Bhattacharya *et al.* (1993) studied genesis and transformation of minerals in the formation of red and black soils on Deccan basalt in the Western Ghats area. Clay mineralogical investigation indicated that interstratified smectite-kaolin (sm/k) was dominant in red soils whereas smectite was dominant in black soils. The genesis of sm/k and smectite in red and black soils, respectively suggested that these soils formed through a progressive landscape reduction process.

The clay mineralogy, iron oxides and pedogenic processes were studied in ten Vertisols and Alfisols pedons from Kenting region, Southern Taiwan by Chen and Liu (1993). Illite and kaolinite were the major clay minerals but gibbsite, vermiculite, quartz and irregular interstratified clay in the clay fraction were also present. The iron oxide in the clay fraction was predominantly goethite with some lepidocrocite and haematite.

Smectite has been considered a major component of Vertisols in most reviews, with kaolinite of secondary importance. However, Coulombe *et al.* (1996b) reported Vertisols containing abundant kaolinite, illite, halloysite, hydroxy-interlayered smectite, or a combination of interstratified clay minerals from various regions of the world. Montmorillonite, beidellite and nontronite were smectites reported in Vertisols.

Shirsath *et al.* (2000) concluded that minimum threshold value of smectite for vertic properties is 20 per cent.

2.5.4 GENESIS

Dokuchaev (1883) was the first to appreciate the combined influence of the natural agencies in pedogenesis and established that the soils would develop as a result of the interaction of fine soil forming factors namely, parent material, climate, organisms, topography and time.

Following early work by Dokuchaev (1883) in Russia and Hilgard (1906) in the United States, Jenny (1941) formulated an equation to relate properties of soils to the major soil forming factors, isolated as apparently individual variables (Birkeland, 1974). It is

$$S = f(cl, o, r, p, t, \dots)$$

Where S denotes the soil property of interest

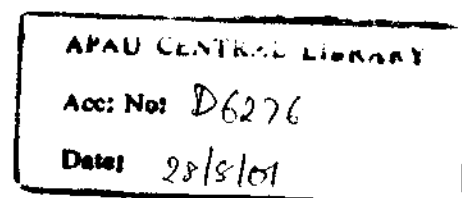
Cl, the climatic factor

o, the biotic factor

r, the topographic factor

p, the parent material factor and

t, the time factor



The equation allows, through the dots, for other locally important factors to be included. The equation was recently described (Hudson, 1992) as a powerful paradigm in soil science.

In the studies on the soils of the Bijapur district, Roy *et al.* (1962) observed that the relief, vegetation and the physical conditions of the underlying rock which modify drainage had largely influenced the soil forming processes.

Tamhane and Karale (1967) studied the soils developed over basaltic parent material under varied rainfall in Bombay Deccan. The variable factor climate in conjunction with topography had predominantly effected the genesis of the soils.

The influence of climate and parent material and also relative merits of the two factors on the processes governing soil development were studied by Karale *et al.* (1969). Clay, silica and sesquioxide contents of the soils were more related to parent material. The climatic factors appeared to be decisive in characterizing the soils through their influence on weathering reaction. However, potential ability of the parent material, particularly under the mild reaction processes, as under low to medium rainfall, played an important role in soil development.

According to Patil and Dasog (1997) eluviation, illuviation and transformation were the main pedogenic processes involved in the genesis of

iron oxide concretions in Alfisols, Ultisols and Oxisols of the Western Ghats region of north Karnataka.

According to Pal and Deshpande (1987b) the similar mineralogy and geomorphological position of five benchmark Vertisols indicated that the minerals were inherited primarily from alluvium derived from weathering of Deccan Basalt and from metamorphic rocks by multicycle erosion.

2.5.4.1 Factors of soil formation

2.5.4.1.1 Parent material: A high base status favours formation and stability of clay minerals abundant in Vertisols. The parent materials of Vertisols must provide from weathering a high content of clay with high surface area and generally with a high base status (Dudal, 1965; Probert *et al.*, 1987; Coulombe *et al.*, 1996a). However, the base status may be relatively low in certain types of parent materials (eg. Volcanic tuffs, granite, gneiss and schists). With time, the base status may increase due to release of bases from mineral weathering and/or from external sources eg. leaching from uplands, flood waters, base rich water tables, or aeolian deposits.

Black clay soils were reported to develop on basalt, charnockite, granite and granite-gneiss parent material (Karale *et al.*, 1969), on basalt, augite and dolorite (Roy and Barde, 1962) and on limestone and gneiss on Deccantrap of India (Dasog and Hadimani, 1980). Arid and semi arid region soils of India were

developed from alluvial and aeolian parent material (Sehgal *et al.*, 1986), on sandstone in Sudan (Yousif *et al.*, 1988), on chlorite schist (Hirekurubar *et al.*, 1991), on alluvium/colluvium in California (Southard and Graham, 1992) and on granite, granite-gneiss, shale, limestone and charnockite in Andhra Pradesh (Subbaiah and Manickam, 1992);

Venkateswarlu *et al.* (1995) reported that the black soils of Kandukur division of Andhra Pradesh had developed on granite-gneiss.

Foss *et al.* (1983) stated that Inceptisols develop on geologically young sediments or landscapes and/or under environmental conditions that inhibit soil development (viz., coarse-textured siliceous deposits that are resistant to weathering or parent materials within cool climates that inhibit pedogenesis). Given the above constraints, parent materials include almost all types of igneous, metamorphic and sedimentary materials (residuum, alluvium, colluvium, loess/aeolian, glacial drift etc.).

2.5.4.1.2 Climate: Dasog and Hadimani (1980) observed that the Vertisols were formed under sub-tropical semi arid climatic conditions characterised by hot summer and mild winter. Godse and Sannigrahi (1988) reported that the black soils of India were mostly derived under semi arid climatic conditions.

Subbaiah and Manickam (1992) reported that the semi arid monsoonic climate with moderate rainfall ranging from 574-906 mm per annum was conducive for the formation of black soils in coastal Andhra Pradesh.

Most Alfisols were reported to have developed under deciduous forest vegetation in humid climates and grass or savannah vegetation in drier regimes. They occur in semi-arid to humid climates. Vertisols are found under a wide range of climatic conditions with annual temperatures varying from 0 to 25°C (Cryic to hyperthermic), annual precipitation ranging from 250 to 3000 mm but most commonly 500-1500 mm.

2.5.4.1.3 Topography: Krishnamurthy and Govinda Rajan (1977) reported that granite-gneiss in Mahabubnagar district of Andhra Pradesh under similar set of overhead climate favoured the development of red soils on gently to moderate slopes and black soils on rolling plains.

Working with seasonally saturated Alfisols in a toposequence on the Texas coastal plain, Vepraskas and Wilding (1983) found soil pH generally increased as did base saturation and exchangeable Na levels from upper to lower topographic positions. Cremeens and Mokma (1986) also found smectite in the wettest sites of their study with its absence in the better drained soils.

The soils developed on hills and hill ranges are very shallow, some what excessively drained, loamy-skeletal and on moderately steep slopes with severe to very severe erosion having LGP 90 to 120 days, BSP 70 to 90, classified as Lithic/Typic Ustochrepts under forest and *kharif* crops with low productivity potentials while the soils on plateaus, plains, valleys are deep, well to moderately well drained, clayey on gently to very gently sloping lands with moderate erosion

which are classified as Typic/Udic/Chromic Haplusterts, Ustochrepts, Haplustalfs and Vertic Ustochrepts. They are under *Kharif*, *Rabi* crops and vegetables and patches of mixed forest and plantation (Tamgadge *et al.*, 1999).

The effect of topography is also indicated by the tendency for the more 2:1 layer silicates to occur in the lowest part of toposequence (foot slope soil) (Zueng Sang Chen, 1999).

The topography associated with many Inceptisols is a sloping landscape subject to erosion rates that are equal to or greater than soil formation rates. Many Inceptisols occur on hillsides of major mountains throughout the world.

2.5.4.1.4 Living organisms (Vegetation and Fauna):

(i) **Vegetation:** According to Daniels *et al.* (1983), the 'B' horizons of pastures were deeper, higher in clay content and weaker in structural grade than forest 'B' horizons. Raj Kumar *et al.* (1984) observed a wide variety of natural vegetation viz., *Cynodon dactylon*, *Zizyphus jujuba*, *Phoenix sustetrates*, *Acacia arabica*, and *Azadirachta indica* on black soils of Deccan trap of Madhya Pradesh.

The mountain soils formed under deciduous forest ecosystem had developed a mollic epipedon underlined by a cambic horizon (Sehgal *et al.*, 1985). Singhal and Sharma (1985) observed that the soils of Doon valley forest ecosystem under sal and mixed miscellaneous vegetation were less developed Lithic Haplustolls.

Most Alfisols were reported to have developed under deciduous forest vegetation in humid climates and grass or savannah vegetation in drier regimes.

Srinivas (1990) observed grasses, *Calotropis* sp., *Prosopis* sp., neem and palmyrah as natural vegetation on black soils under Somasila project in Andhra Pradesh.

According to the study conducted in Himachal Pradesh, the organic carbon and total nitrogen content in surface horizons of forest soils increased with increase in altitude while the cultivated soils contained lower amount of these constituents (Minhas *et al.*, 1997).

(ii) **Fauna:** Fauna dwelling in Alfisols have also been credited with affecting soil formation. Nielson and Hole (1964) found earthworm population masses of 2218 kg ha⁻¹ under a deciduous forest and earthworm middens numbering 274,000 ha⁻¹. Essentially all annual leaf fall was moved to the middens by earthworms. Hugie and Passey (1963) described burrowing activity of western cicadas crediting them with development of cylindrical soil structure as they burrowed through loamy soils. Their numbers were greatly reduced on coarse and fine textured materials. Ant, termite and crustacean activity have also been described (Thorp, 1949). Arkley and Brown (1954) observed sufficient rodent activity to suggest that mima mounds in the western states as the result of pocketgophers.

In well drained soils termites and earthworms had the greatest influence on soil micromorphology (Venugopal, 1992).

2.5.4.1.5 Time: Buol (1965) reported ^{14}C dating of carbonate carbon in carbonate rich (caliche) layers in and below an Aridisol in Arizona. At a depth of 100 cm, the carbon was 2300 years old, at 150 cm, 9800 years old and at 213 cm, 32,000 years old. The conclusion was drawn that the uppermost carbonate rich layer is related to the modern soil and that the buried carbonate rich layers are related to former soil regimes.

In experiments using ^{14}C labelled organic matter added to soils, 80 per cent or more of the organic matter was removed in a very few years (Jenkinson, 1966). Most organic matter decomposition is in the upper layer of soil. Thus, a pattern of increasing organic matter age with depth is present in soil profiles. Measurement of the natural radiocarbon at various depths in different soils can provide estimates of minimum soil age (Scharpenseel, 1972).

Radiocarbon dating of buried wood overlying an ancient Entisol at the forest bed in Wisconsin between the Cary and so-called Valdres tills has given date of about 11,000 years (Hole 1967).

Judging by material in solution in rivers, Clarke (1924) concluded that the land surface of the earth is being lowered by one foot in every 30,000 years.

The time required for the development of Alfisols is incumbent upon the formation of argillic and kandic horizons. Bilzi and Ciolkosz (1977) believed that 2000 to 12000 years were required to develop fragipan like features and argillic horizons in alluvium in Pennsylvania under udic soil moisture and mesic soil temperature regimes.

Wakatsuki and Rasyidin (1992) used mass balance calculations of seven elements in parent material, soil and river waters to calculate that global soil foundation averaged 178 yr cm^{-1} . From specific watersheds, they calculated a soil formation rate of 50 yr cm^{-1} in granite at Hubbard Brook, New Hampshire, and 25 yr cm^{-1} in basic pyroclastic parent material in Japan. Rates of soil formation clearly differed among them.

2.5.4.2 Pedogenic Processes:

The principal soil forming process that initiates development of Entisols is melanization (Buol *et al.*, 1998).

According to Jenny (1980) the movement of clay from A and E horizons to Bt horizons can be viewed as the net result of three subprocesses: dispersion, transport and deposition.

Although illuviation of clays is diagnostic for the argillic horizon, much or even most clay in the Alfisol Bt horizons originates from other sources to

include inheritance from parent material, clay neoformation, *in situ* weathering of lithogenic minerals, and dissolution of silt and sand sized carbonates (Smeck and Wilding, 1980).

Coulombe *et al.* (1996b) reviewed three models proposed for the genesis of features and structure in Vertisols. The first model, proposed by Hilgard (1906) concerned the formation of "hog-Wallows". This model was known as "haploidization by argillopedoturbation". The second model proposed was the "differential loading model" which states that the overburden loads exceed the shear strength of the underlying material and enable flow to occur. Coulombe *et al.* (1996b) stated that at the present time, the application of the coulomb-Mohr theory of shear failure constitutes the best model to account for the formation and occurrence of features and structure in Vertisols. Shear failure was more likely to occur under moist or wet than dry conditions, since a lower normal stress was found to promote shear failure.

Eventhough shrink/swell phenomena are significant in Vertisols, other pedogenic processes occur such as accumulation of salts (eg. salic, natric, calcic and gypsic great groups), silica (duric great group) and depth of saturation by water (epi and endo great groups).

2.5.5 Classification

The objective of soil classification is to provide a conceptual framework to accommodate the current knowledge of soils and concepts of soils derived

from this knowledge in an organised manner. In "Basic Principles of soil classification" Cline (1949) stated: "The purpose of any classification is to so organize our knowledge that the properties of objects may be remembered and their relationships understood most easily for a specific objective. The process involves formation of classes by grouping the objects on the basis of their common properties. In any system of classification, groups about which the greatest number, most precise and most important statements can be made for the objective serve the purpose best".

With the advent of 7th approximation (Soil Survey Staff, 1960), soil scientists started using the system of soil classification in India too. Thus, a decision was taken for the adoption of the system nationwide in an All India Workshop held at New Delhi (IARI, 1969).

The US system of soil classification known as Soil Taxonomy completed the half century by revising and redefining the various taxa of the system, even though the classification of tropical soils had lagged behind. Still the soils of the tropical regions could not find a proper place in the present system of soil classification.

Bhattacharyya *et al.* (1993) studied non calcareous soils occurring on the basaltic terrain of the western Ghats area of Maharashtra and classified the

red soils as Typic Haplustalfs and black soils as Vertic Ustropepts of the Bhimashankar plateau which is experiencing humid tropical climate. The black soils of the semi arid zone were classified as Typic Chromusterts and Typic Ustropepts.

Red soils are considered to be those which have colour hues of 5 YR of redder in the soil series control section. Such soils are moderately to highly weathered, enriched in secondary forms of iron or aluminium or both, and generally may have a clay enriched B horizon. In India, most typical red soils of the semi-arid sub-tropical regions were Rhodustalfs (Sehgal, 1998).

Swell-shrink soils of semiarid tropics in India classified as Typic Chromusterts/Pellusterts (Rajeev Srivastava and Jagdish Prasad, 1992).

The red soils with clay base were Alfisols, coastal sands were Entisols, alluvial soils were either Vertisols or Entisols and red loamy soils were Alfisols or Entisols or Inceptisols (Soils of Andhra Pradesh, Publication No.2, 1972).

Jagdish Prasad *et al.* (1998) stressed the importance to accommodate the soils having all Vertisol properties, except with <25 cm slickenside layer into the Vertisol order.

Few studies have been carried out so far on the classification of soils in Telangana region of Andhra Pradesh. Twelve soils in Northern Telangana were

studied by Vijay Kumar *et al.* (1994) and classified as Inceptisols (with ochric epipedon), Alfisols (with argillic horizon), Vertisols (with deep and wide cracks) and Entisols (with no profile development). The soils of the Telangana area as has been reported belong to four soil orders, viz., Entisols, Inceptisols, Alfisols and Vertisols (NBSS and LUP, 1996).

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Materials
and
Methods

CHAPTER III

MATERIALS AND METHODS

Present investigation was concentrated on the soils of Northern and Southern Telangana agro-climatic zones of Andhra Pradesh.

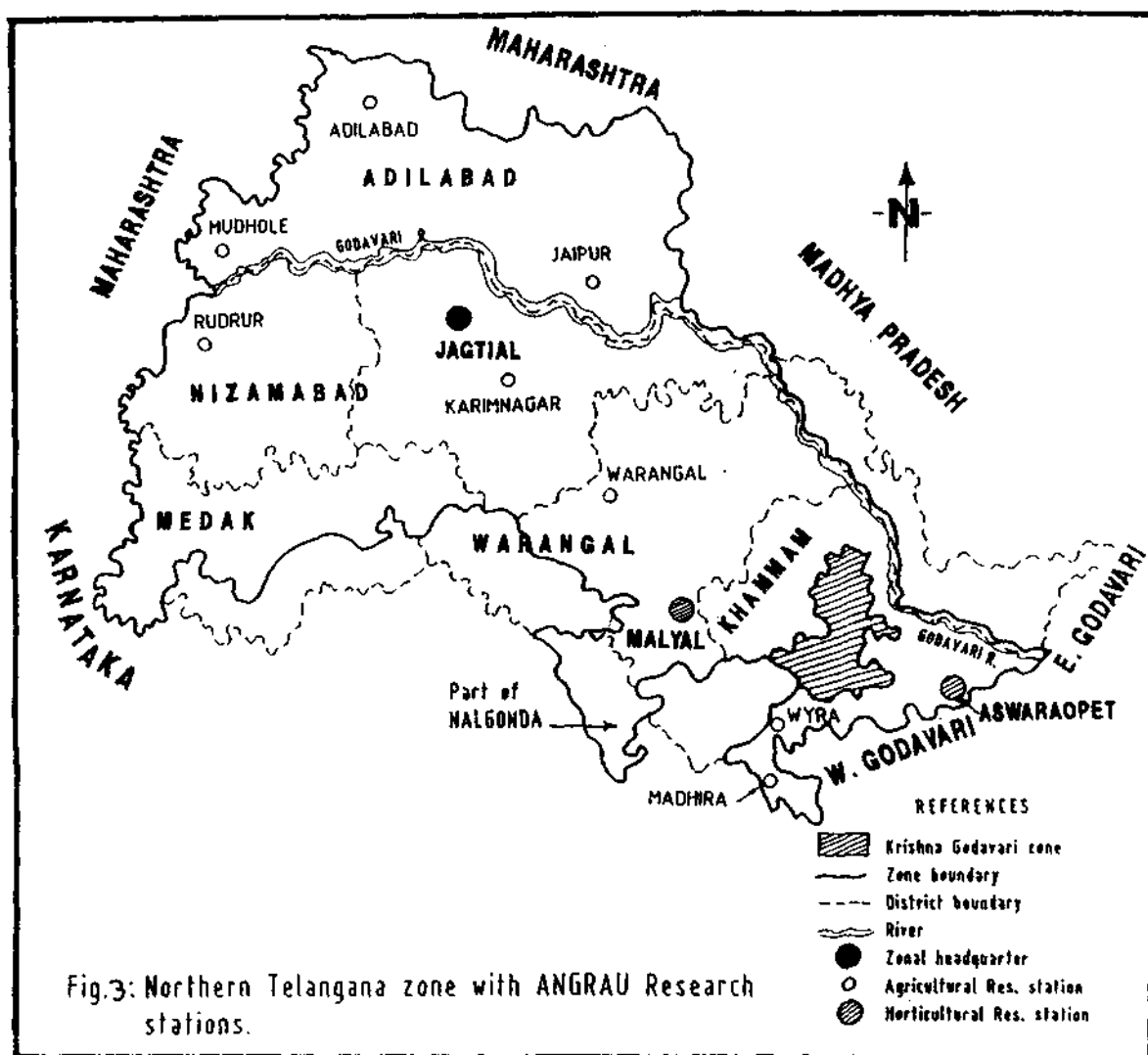
Northern Telangana Zone (NTZ)

This zone consists of districts of Adilabad, Karimnagar, Nizamabad, Medak (except Southern parts), Warangal (Except Western portion), North eastern tip of Nalgonda and most of Khammam (Fig.3).

Southern Telangana Zone (STZ)

This zone consists of districts of Hyderabad, Ranga Reddy, Mahabubnagar (except Southern parts), Nalgonda (except eastern part) north-western and southern parts of Warangal (Fig.4).

Soils in the Agricultural Research Stations of Acharya N.G. Ranga Agricultural University (ANGRAU) located in NTZ and STZ represent the major soil groups of this area. Research stations located in these two zones are given in the Table 4.



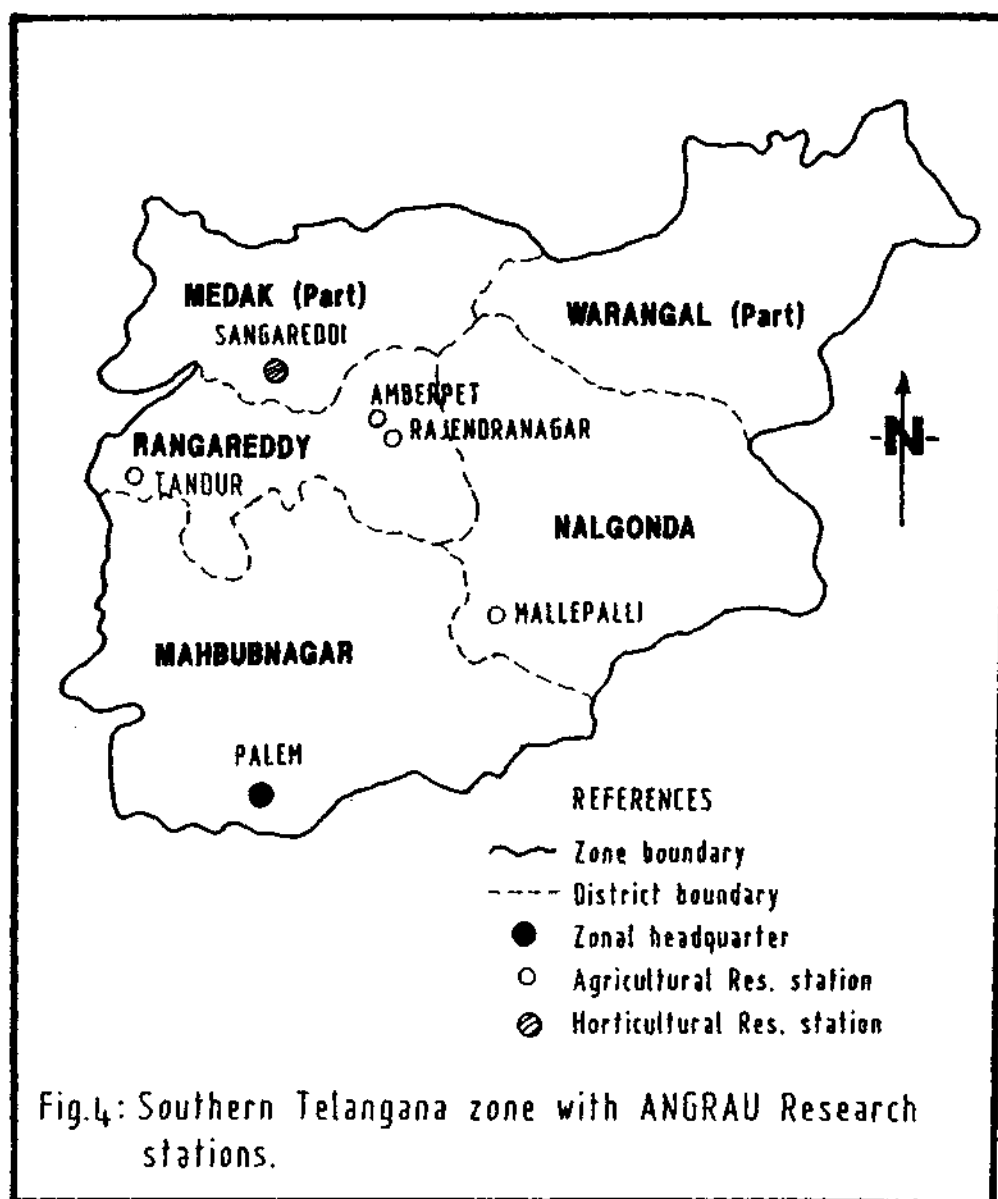


Table 4: Location of Agricultural Research stations in different districts of Telangana region

Agro-climatic zone	District	Location of Research station
NTZ	Karimnagar	Jagtial, Karimnagar
	Nizamabad	Rudrur
	Adilabad	Jaipur, Adilabad, Mudhol
	Warangal	Warangal, Malyal
	Khammam	Wyra, Madhira, Aswaraopet
STZ	Mahabubnagar	Palem
	Rangareddy	Rajendranagar, Tandur
	Hyderabad	Amberpet
	Medak	Sangareddy
	Nalgonda	Mallepalli

3.1 GEOLOGY

The study area is covered by igneous (pink and gray granites and basalt), metamorphic (granite gneiss and hornblende schist) and sedimentary (sandstone and limestone) depositions. Location of Agricultural Research Stations in various geology setups is given in Table 5. Photographs of rock samples collected from various pedons were depicted in plates 2 to 7.

3.2 PHYSIOGRAPHY

Physiographically Andhra Pradesh is divisible into five regions (Dutt, 1981).

Table 5: Geology and dominant minerals of the sampling locations

S.No.	Location	Formation	Series (Age)	Geology	Composition
1.	Jagtial	Archaean gneisses	Lower precambrian	Granite	Quartz, feldspar, mica
2.	Karimnagar	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
3.	Rudrur	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
4.	Jaipur	Lower Gondwana	Upper carboniferous	Sandstone	Quartz, feldspar
5.	Adilabad	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
6.	Mudhol	Archaean gneisses	Lower precambrian	Granite, Banded iron formation (BIF)	Quartz, feldspar
7.	Warangal	Archaean gneisses	Lower precambrian	Granite	Quartz, feldspar
8.	Malyal	Archaean gneisses	Lower precambrian	Granite	Quartz, feldspar
9.	Wyra	Dharwars	Lower precambrian	Schist	Amphibole, biotite, quartz, altered feldspar
10.	Madhira	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
11.	Aswaraopet	Lower Gondwanas	Upper carboniferous	Sandstone, Shale	Quartz, feldspar, very little of mica
12.	Palem	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
13.	Rajendranagar	Archaean gneisses	Lower precambrian	Granitic alluvium	Quartz, feldspar
14.	Tandur	Deccan traps	Mesozoic Lower Tertiary	Granite, Limestone Basalt	Quartz, feldspar, pyroxenes
15.	Amberpet	Archaean gneisses	Lower precambrian	Granite/granite gneisses	Quartz, feldspar
16.	Sangareddi	Archaean gneisses	Lower precambrian	Granite, Intertrappeans	Quartz, feldspar
17.	Mallepalli	Archaean gneisses	Lower precambrian	Granite	Quartz, feldspar



Plate 2: Photograph of weathered grey granite (from pedon 1)



Plate 3: Photograph of weathered pink granite (from Pedon 11)



Plate 4: Photograph of vein quartz (from pedon 5)



Plate 5: Photograph of horn blende schist (from pedon 12)



Plate 6: Photograph of indurated red soil with quartz and feldspar pebbles (from pedon 14)



Plate 7: Photograph of sandstone (from pedon 14)

1. The South-central upland (Cuddapah basin)
2. The North western plateau
3. The interior rugged plain
4. The eastern ghats
5. The coastal plain

The study area comprised of North Western plateau and Interior rugged plain. North-western plateau and plains form the Telangana region in Andhra Pradesh, which is a part of India's Peninsular shield (Ramam and Murty, 1997).

The North Western Plateau: This is geologically the Deccan trap terrain, consisting of terraced plateaus in the north western and northern parts of the state. It presents a stepped topography, the flats being formed of compact basalt lava flows, and the slopes of less resistant vesicular portions of lavas and the intertrappean sediments. They generally lie between altitudes of 620 m and 700 m.

The interior rugged plain: This forms part of the Godavari, Krishna and Pennar river basins. The northern part of the plain to the north of the Krishna river is crossed by three E-W water divides, which rise to the altitudes of 600-700 m and trend parallel to the course of the Krishna in its Western part. They are from North to South. The interior rugged plain is formed predominantly of granite-gneiss.

S.No.	Physical region	Elevation in meters	Percentage area
1.	Coastal plains	Sea level - 150	35
2.	Peninsular plateau	150 - 300	15
		300 - 600	37
		600 - 900	10
3.	Eastern ghats	900 - 1200	2.5
		Above 1200	0.5

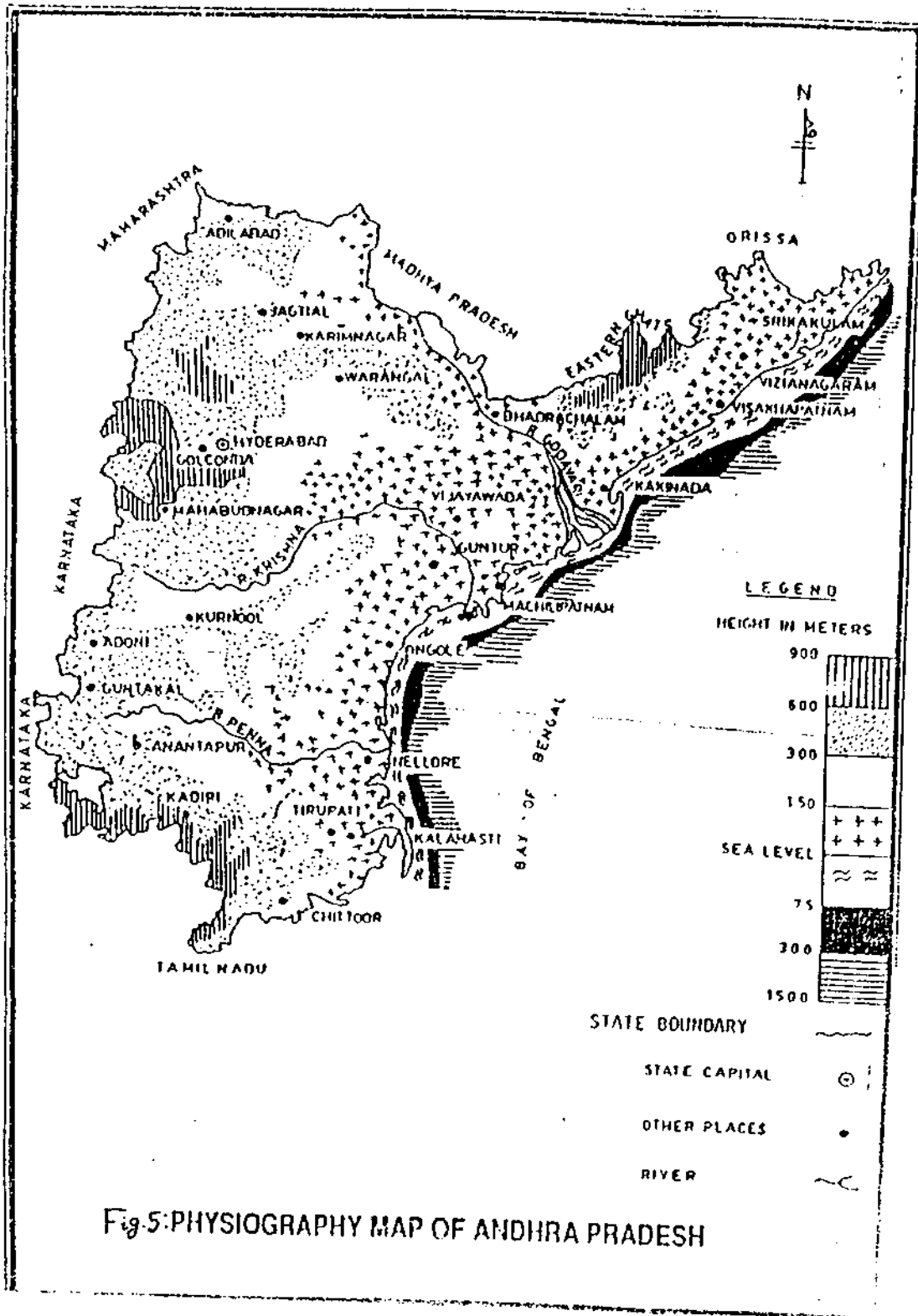
The figures given above indicate that Andhra Pradesh state is essentially a low relief terrain with a few pockets of moderate relief in the Eastern Ghats and Nallamalai hills.

The physiography map of Andhra Pradesh (High altitude and tribal area zone status report, 1994) is depicted in Fig.5.

3.3 CLIMATE

The climatic data of Rajendranagar and Ibrahimpatnam representing Southern Telangana zone and of Warangal and Rudrur representing Northern Telangana zone are given in Table 6.

Annual rainfall in Northern Telangana zone (Rudrur and Warangal) is around 1000 mm, of which more than 90 per cent is received during June to November in a year. The mean annual temperature in Rudrur and Warangal



is 26.6°C and 27.9°C, respectively. The mean maximum temperature was in the month of May, whereas the mean minimum temperature was in the month of December. Climatically NTZ falls under semi-arid (moist) tropics.

Annual rainfall in Southern Telangana zone (Rajendranagar and Ibrahimpatnam) was around 740 mm, of which about 90 per cent is received during June to November in a year. The mean annual temperatures in Rajendranagar and Ibrahimpatnam were 26.3°C and 25.4°C, respectively.

The mean maximum and minimum temperatures were in the months of May and December, respectively. Climatically STZ falls under semi-arid (dry) tropics.

The major difference between NTZ and STZ is the quantum of rainfall.

The soil water balance was calculated using the meteorological data (Normals of Agroclimatic Observations in India, 1991) according to the procedure proposed by Thornthwaite and Mather (1955) for the above four places (Figs.6a to 6d).

Water balance diagrams of Adilabad in NTZ and of Mahbubnagar, Nalgonda and Hyderabad in STZ are depicted in Figs.7a to 7d (NBSS and LUP, 1996).

Table 6: Climatic data of Rudrur, Warangal, Rajendranagar and Ibrahimpatnam stations

Month	Rudrur		Warangal		Rajendranagar		Ibrahimpatnam	
	P	T	P	T	P	T	P	T
January	12.2	22.3	5.4	23.8	2.2	22.0	3.6	21.5
February	3.9	25.7	9.1	26.8	8.6	25.3	6.5	24.9
March	15.2	28.7	8.7	29.5	9.8	29.2	13.4	27.6
April	11.1	31.6	16.6	32.1	18.4	30.5	11.0	30.0
May	15.3	32.9	17.2	34.0	22.3	31.4	29.7	30.3
June	57.1	29.9	61.6	32.2	61.9	29.6	62.9	28.2
July	213.9	27.4	204.3	28.2	110.5	27.3	99.0	26.5
August	300.0	26.4	262.2	27.4	176.8	26.3	128.5	25.5
September	219.5	26.4	167.4	27.6	154.4	26.2	100.3	25.3
October	103.6	25.0	168.7	27.1	126.9	25.3	219.8	23.9
November	47.3	23.1	57.7	24.1	34.9	22.5	44.3	21.4
December	5.1	20.4	15.7	22.6	15.1	20.1	13.4	19.3
Total	1004.2	319.8	994.6	335.4	741.8	315.7	732.4	304.4
Mean		26.6		27.9		26.3		25.4

P - Precipitation (mm); T - Temperature (°C); Average data for 32 years (1950-1981)
(Source : Normals of Agroclimatic observatories in India, 1991).

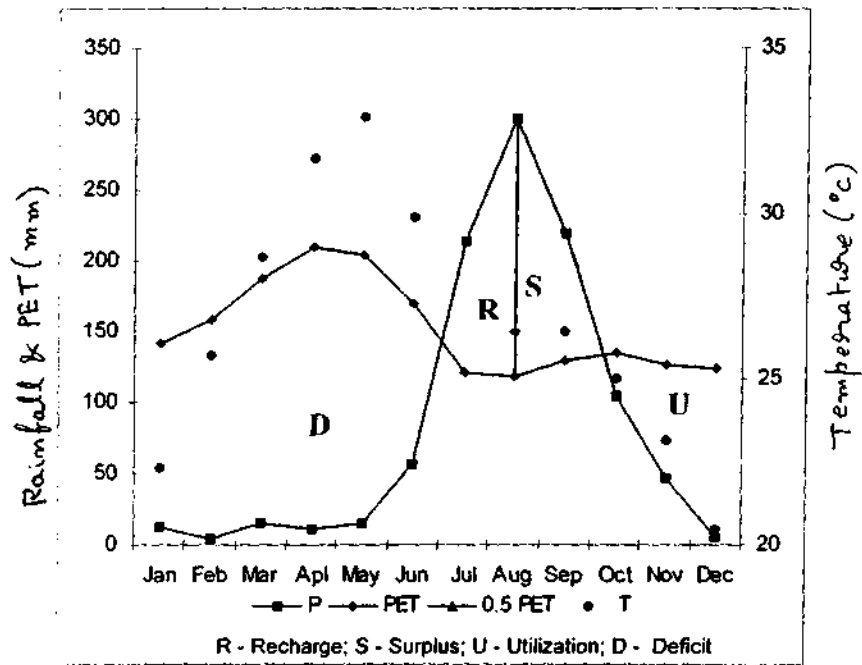


Fig 6a: Water balance diagram for Rudrur

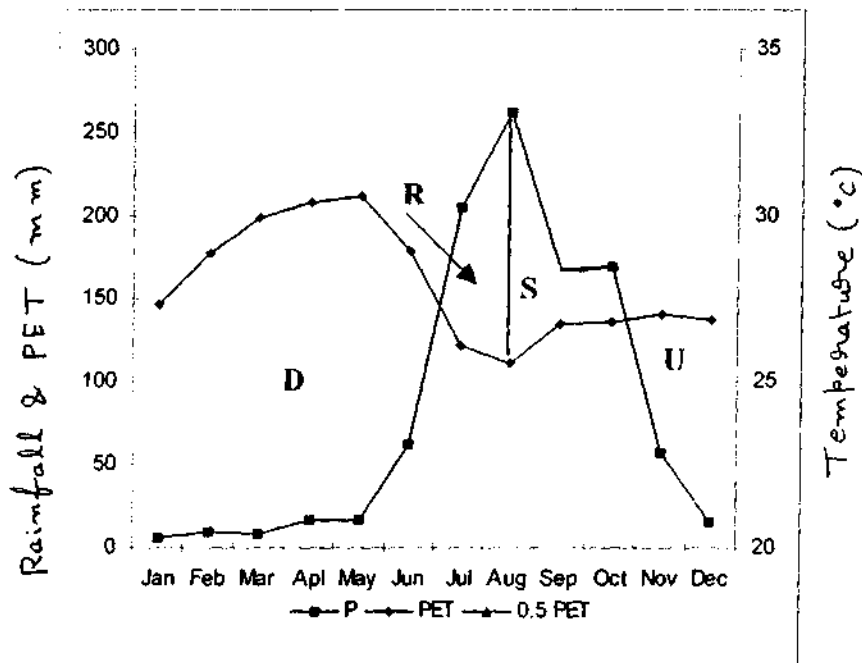


Fig 6b: Water balance diagram for Warangal

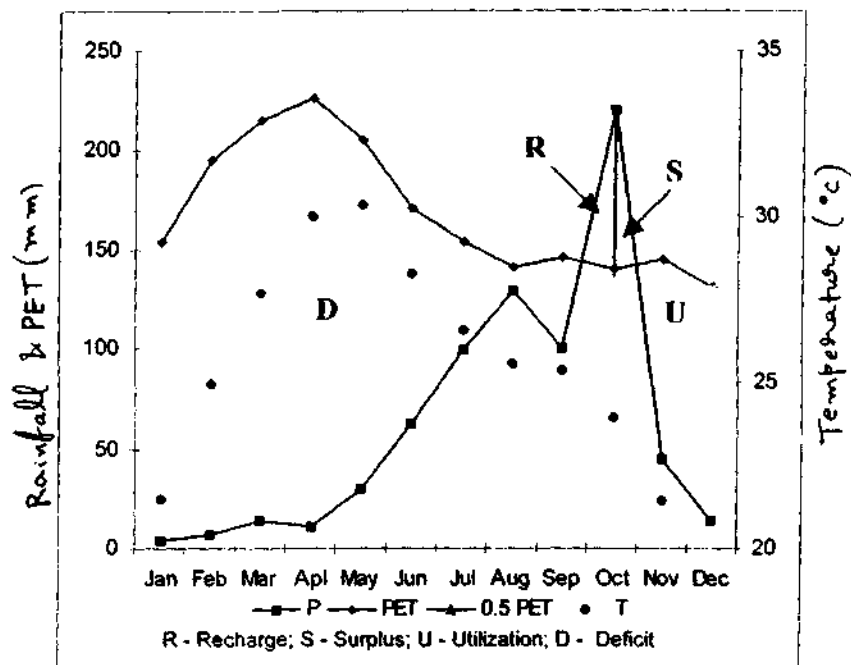


Fig 6c: Water balance diagram for Ibrahimpatnam

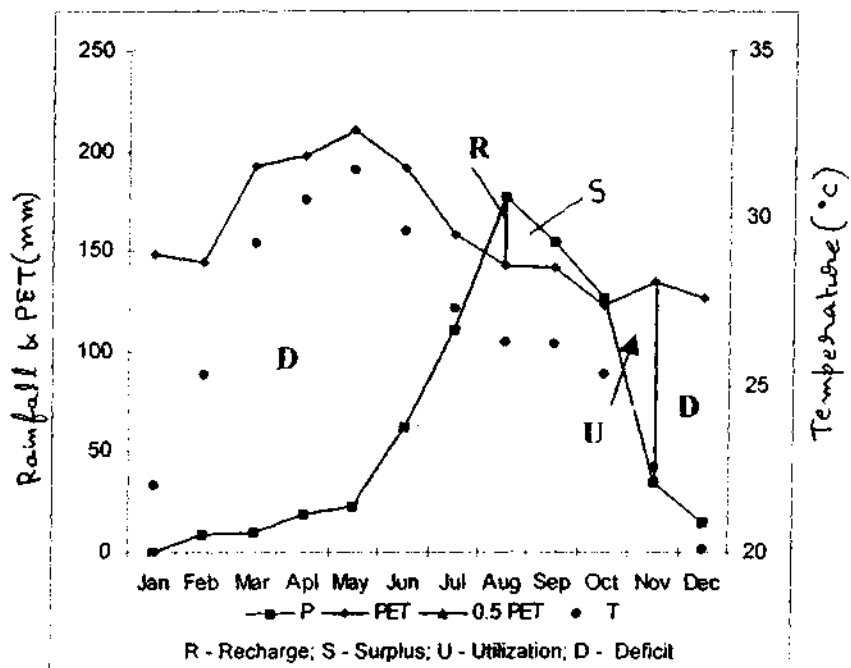


Fig 6d: Water balance diagram for Rajendranagar

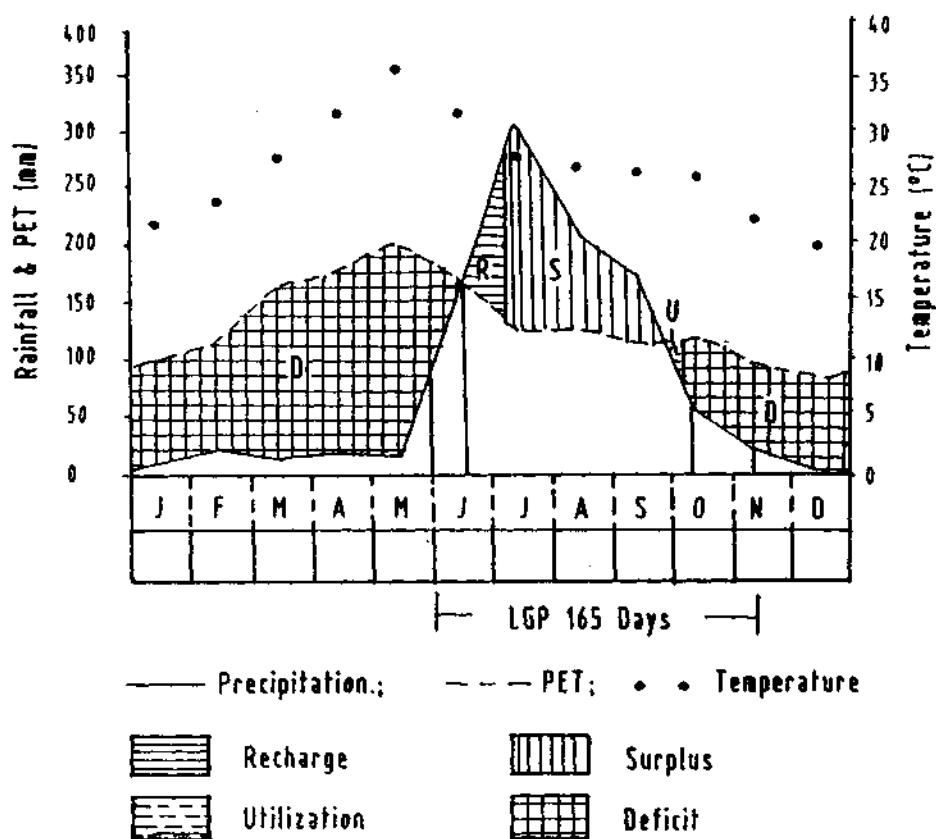


Fig. 7a: Water balance diagram for Adilabad.

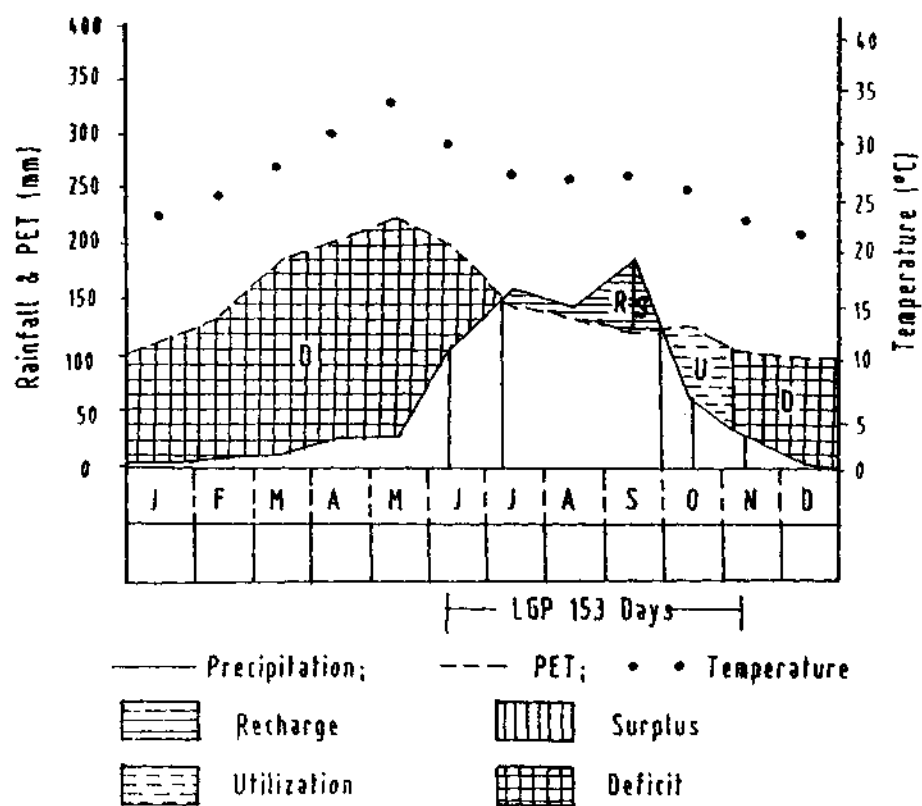
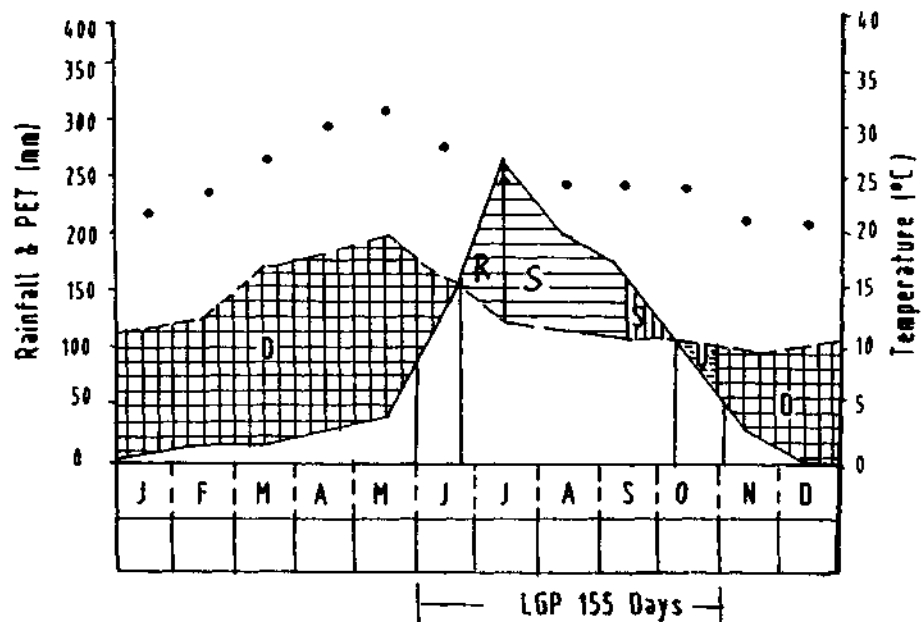


Fig. 7b: Water balance diagram for Hyderabad.

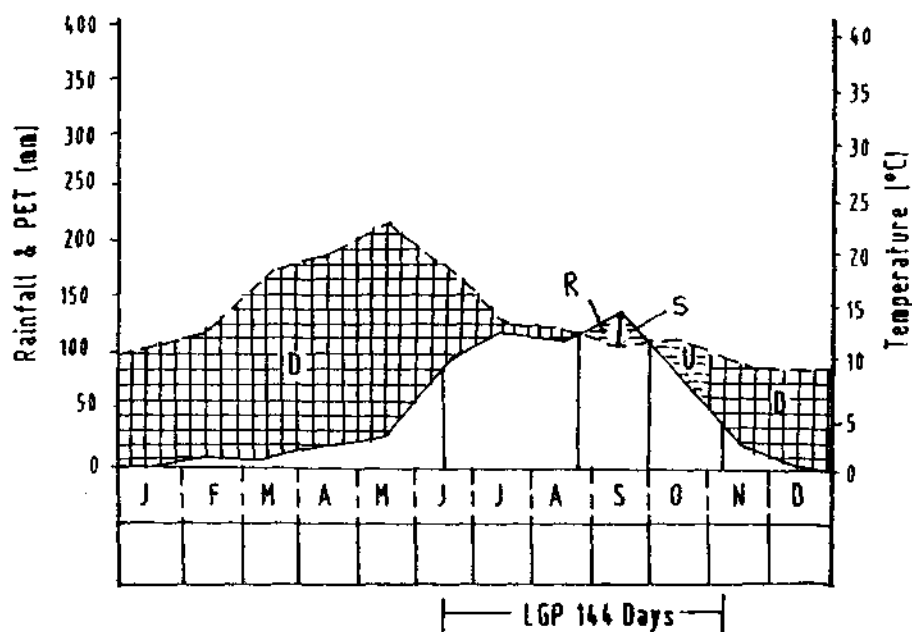


— Precipitation; --- PET; • • Temperature

Recharge Surplus

Utilization Deficit

Fig. 7C: Water balance diagram for Mahbubnagar.



— Precipitation; --- PET; • • Temperature

Recharge Surplus

Utilization Deficit

Fig. 7d: Water balance diagram for Nalgonda.

Soil samples were collected from the representative pedons of the above mentioned research stations. Whereever red and black associated soils are occurring in juxtaposition, soil samples were collected from representative pedons of both (red and black) the areas in the research stations. Jagtial, Rudrur, Warangal, Rajendranagar and Sangareddi are the five locations from where both red and black soils were collected. A total of 22 soil profiles were studied.

Field examination and sample collection

Soil profiles were dug at selected sites and the detailed morphological examination was carried out as per USDA Soil Survey Manual (Soil Survey Staff, 1951). The horizon designations as outlined in the Keys to Soil Taxonomy (Soil Survey Staff, 1998) were used.

Soil samples were collected horizonwise. The soil samples were air dried. A wooden pestle and mortar were used to break clods to pass through a 2 mm sieve. The sieved samples were well mixed and stored. The portion of the samples retained in the sieve larger than 2 mm has been weighed and recorded as coarse fragments larger than 2 mm of the whole soil. A small portion of the soil less than 2 mm size was ground to pass through a 100 mesh sieve for organic carbon determination.

3.5 LABORATORY ANALYSIS

3.5.1 Physical properties

3.5.1.1 Particle size analysis

The soil samples were dried to 105°C to a constant weight to express soil data on oven dry basis. The particle size distribution was carried out as per the Robinson pipette method following the removal of organic matter, calcium carbonate and free iron oxide. Sand (2-0.05 mm), silt (0.05-0.002 mm) and clay fractions (< 0.002 mm) were separated using the procedure as outlined by Jackson (1979).

3.5.1.2 Bulk Density

It was determined by clod coating technique (for dry clods) as suggested by Soil Conservation Service (1967).

3.5.1.3 Water Retention

Water retention at 33 Kpa and 1500 Kpa soil moisture tensions of less than 2 mm size soil samples was determined by using pressure plate and pressure membrane apparatus as per method outlined by Richards (1954).

3.5.2 Chemical properties

3.5.2.1 Soil Reaction

The hydrogen ion activity, expressed as pH was measured in the suspension of a 1:2.5 soil-water ratio using a pH meter (Jackson, 1979).

3.5.2.2 Electrical conductivity

The soil to water extract (1:2.5) was used for electrical conductivity measurement using a conductivity bridge (Jackson, 1979).

3.5.2.3 Organic carbon

Modified Walkley and Black's rapid titration procedure was followed for estimating the organic carbon content (Jackson, 1979).

3.5.2.4 Calcium carbonate equivalent

Calcium carbonate equivalent was determined by acid neutralisation method (Piper, 1966).

3.5.2.5 Cation Exchange Capacity

The CEC was determined by using ammonium acetate (pH 7.0; 1.0 N) for saturating the exchange sites. Removing excess ammonia with alcohol, adsorbed

ammonia in soil was estimated by displacing with KCl (10%) and distilling it. Leachate was used for the estimation of extractable bases (SCS, USDA, 1967).

3.5.2.6 Extractable bases

In calcareous soils, the soils less than 2 mm size was leached with 1N KCl-triethanolamine buffer solution at pH 8.2. The suspension was filtered and the extract was used directly for the determination of extractable Ca^{2+} and Mg^{2+} with ICP (Inductively coupled plasma analysis).

Ammonium acetate extract was used to determine Ca^{2+} and Mg^{2+} in non calcareous soils and Na^+ and K^+ in all soils (NBSS and LUP, 1987). ICP (inductively coupled plasma) was used for the estimation of Ca^{2+} , Mg^{2+} and K^+ and AAS (Atomic Absorption Spectrophotometer) for Na^+ .

3.5.2.7 Available phosphorus

Available phosphorus was extracted with 0.5 M sodium bicarbonate (pH 8.5) and estimated colorimetrically (Jackson, 1979).

3.5.2.8 Available Micronutrients

Available micronutrients, iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted with AB-DTPA (Ammonium bicarbonate - Diethylene

Triamine Penta-Acetic acid) solution and determined with ICP (Soltanpour *et al.*, 1979).

3.5.3 Mineralogical characteristics

Thirty two samples were chosen for sand, silt and clay fractions separation (Jackson, 1979) from the twenty two pedons so as to represent the important characteristics of the pedons. Sand fractions of these 32 samples were studied for sand mineralogy with petrographic microscope (Cady, 1965). From these, only 16 clay samples from 6 pedons (Pedon nos 3, 7, 12, 14, 20, 21) were taken for clay mineral identification by X-ray Diffractometry (XRD).

3.5.3.1 Sand Mineralogy

Sand obtained during clay separation was suspended in bromoform (sp. gr. 2.82) in a separating funnel. After allowing it for 30 minutes, light and heavy mineral fractions were separated, washed with acetone, dried and weighed to determine percentages of light and heavy mineral fractions according to Marshall and Jeffries (1945).

Mineralogy of the sand fraction was interpreted following the criteria given by Cady (1965) using Petrographic microscope.

3.5.3.2 Clay mineralogy

The clay fractions (<2 μm) separated as per the procedure outlined by Jackson (1979), were subjected to X-ray Diffraction (XRD) analysis using a Philips diffractometer with Ni-filtered Cu K alpha radiation at a scanning speed of $2^\circ/20/\text{min}$. Samples were saturated with Ca and K, solvated with ethylene glycol, and heated to 110°C , 300°C and 550°C . Minerals present in the clay fractions of soils were identified following the criteria of Jackson (1979). Semi-quantitative estimates of clay minerals were made by the method of Gjems (1967).

3.6 LAND EVALUATION

The parametric method for land evaluation proposed by Riquier *et al.* (1970) was followed.

This system suggests the calculation of a productivity index considering nine factors for determining soil productivity, viz., moisture (H), drainage (D), effective depth (P), texture/structure (T) base saturation (N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity / nature of clay (A), and mineral reserve (M).

$$\text{Productivity index} = H \times D \times P \times T \times N \text{ or } S \times O \times A \times M$$

Each factor is rated on a scale from 0 to 100, the actual percentages multiplied by each other. The resultant index of productivity, also lies between 0 and 100 was set against a scale placing the soil in one or other of following five productivity classes.

Productivity (P)	Classes	Rating	Potentiality (P')
1	Excellent	100-65	I
2	Good	64-35	II
3	Average	34-20	III
4	Poor	19-8	IV
5	Extremely poor to nil	7-0	V

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Results

CHAPTER IV

RESULTS

4.1 MORPHOMETRIC CHARACTERISTICS

Morphometric characteristics (horizon number, sequence and thickness, depth of pedon, soil colour, texture, structure, consistence, boundary, cracks, concretions, mottles and slickensides) of studied pedons are presented in Table 7.

4.1.1 Depth of pedons (cm)

The area of the study comprised of shallow, moderately deep and deep, red and black soils. Among the black soil pedons, pedon 12 was shallow (<50 cm), pedons 2,6,13 and 21 come under the category of moderately shallow to moderately deep (50-100 cm), pedons 5,7,8,10,17, 18 and 19 with a depth of >100 cm were categorised under the deep black soils. Among the various red soils, pedons 3,5 and 22 were shallow with a thickness of solum ranging from 8 to 50 cm while the pedons 1, 9, 11, 16 and 20 with a depth of 50-100 cm were moderately deep. Pedons 4 and 14 were deep with a solum thickness of more than 100 cm.

4.1.2 Horizon number

Total number of horizons varied from 4 to 8 in black soil pedons and 2 to 7 in red soil pedons.

4.1.3 Horizon sequence

A, B and C horizon sequence was observed in all the pedons, except pedon 3. Sub-division of B horizon was noticed. Transitional horizon BC was also present in some of the pedons.

4.1.4 Horizon thickness (cm)

The thickness of the surface horizons of black soil pedons varied from 21 to 35 cm while the surface horizons of red soil pedons varied from 6 to 24 cm, the sub-surface horizons of all the pedons had varying thicknesses, ranging from 12 cm to 35 cm.

4.1.5 Horizon boundary

Most of the pedons had a clear/abrupt and smooth boundary. However, gradual/diffused and wavy boundaries were also noticed in some of the pedons.

4.1.6 Soil colour

The soils varied in their colour characteristics ranging from a hue of 10YR to 2.5YR with different values and chromas.

The black soils had colours in the hue of 10YR except in pedon 2. This pedon had 7.5YR with 10YR in BC horizon. The values ranged between 3 to 6 and chromas between 1 to 4. The red soils had colours in the hue of 7.5YR to 2.5YR. But the surface soils in Rudrur, Warangal and Rajendranagar had

10YR hue. Generally the colour grades to redder hues with depth. The values ranged between 3 to 6 and chromas between 3 to 8.

4.1.7 Soil structure and consistence

The surface horizons of black soils generally had moderate medium subangular blocky structure and hard to very hard (dry) and friable to very firm (moist) consistence. The sub soil horizons had moderate to strong, medium to very coarse angular blocky structures and hard to extremely hard (dry) and firm to extremely firm (moist) consistence.

The surface horizons of red soils generally had weak to moderate, fine to medium and granular to sub-angular blocky structures with soft to slightly hard (dry) and loose to friable (moist) consistence. The bottom layers of most of the red soil pedons were grading to weak to moderate, fine to medium subangular blocky structure and soft to hard (dry) and friable to firm (moist) in consistence.

4.1.8 Cracks (cm)

The black soil pedons were characterised by the presence of cracks varying in width from 1 to 12 cm, generally extending to depths more than 50 cm. The cracks remained open for periods varying from 90 to 150 cumulative days. However, there were no cracks in red soil pedons.

4.1.9 Mottling

Pedon 1 had common fine reddish yellow mottles in the B horizon. Few medium gray mottles were seen in the Bss horizon of pedon 7. Pedons 18 and 19 also had few fine reddish mottles in the Bss horizon.

4.1.10 Calcium carbonate concretions (%)

Secondary calcium carbonate was present as irregularly shaped kankars in most of the pedons studied. The content of concretions increased downwards. All black soil pedons were calcareous. No calcium carbonate accumulation was seen in red soil pedons, except in pedons 1 and 4.

4.1.11 Dark concretions

Iron and manganese concretions were found in pedons 8, 14, 18 and 19. Pedon 8 had few fine round Fe-Mn concretions in the Ap horizon and the size and abundance of these concretions increased with depth. The pedon 14 was found to have Fe-Mn concretions throughout the pedon below Ap horizon. Similar trend was observed in pedon 16 also. Pedons 18 and 19 were found to have few fine Fe-Mn concretions in the BC horizon.

4.1.12 Slickensides

Slickensides were occurring in the black soil pedons except pedons 12, 13 and 22. Moderately deep and deep soils were exhibiting slickensides. The

depth of occurrence of intersecting slickensides was 70 cm in pedon 2, 105 cm in pedon 5, 50 cm in pedon 7, 120 cm in pedon 8, 100 cm in pedons 10, 17 and 18, and 75 cm in pedon 19.

Morphological descriptions of the pedons are given in Appendix and their photographs were depicted in Plates 8 to 24.

4.2 PHYSICAL PROPERTIES OF PEDONS

The data pertaining to physical properties of studied pedons are presented in Table 8.

4.2.1 Coarse fragments (%)

In general, the per cent coarse fragments increased with depth. The coarse fragments constituted mainly of quartz gravel. In case of calcareous soils, lime concretions were also observed in coarse fragments. Among red soils, pedons 14 and 11 had insignificant amount of gravel (2-10%) in A and B horizons. Pedons 10 and 19 among black soils had insignificant amount of coarse fragments (5-10%) in the whole profile.

4.2.2 Soil texture

4.2.2.1 Sand (%): The sand content of red soils varied between 30.0 to 84.4 per cent, the per cent sand decreasing with depth in pedons 9, 11, 14, 15 and

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
4	Ap	0-24	10 YR 3/3	gsl	2m sbk	sh	fr	ss ps	e	f	f	as	-
	Bw1	24-68	7.5 YR 4/6	gsl	1 f sbk	s	fr	so po	e	f	f	ds	-
	Bw2	68-120	7.5 YR 4/6	gsl	1 f sbk	s	fr	so po	e	f	f	gs	-
	Bw3	120-170	7.5 YR 4/6	gsl	1 f sbk	s	fr	so po	e	f	f	as	-
	BC	170-200	10 YR 7/4	gsl	1 f sbk	s	fr	so po	e	c	m		-
5	Ap	0-31	10 YR 3/1	gc	2 m sbk	h	fr	sp	e	f	f	cs	30 mm wide cracks
	Bw1	31-62	10 YR 3/1	gc	2 m sbk	h	fr	sp	e	f	f	cs	20mm wide cracks
	Bw2	62-97	10 YR 3/1	gc	2 m sbk	vh	fi	sp	e	f	f	cs	Shiny pressure faces
	Bss1	97-135	10 YR 3/1	gc	2 m abk	vh	vfi	sp	e	f	f	cs	Slicken sides close enough to intersect
	Bss2	135-172	10 YR 5/4 with 10 YR 3/1	gc	2 m abk	vh	vfi	sp	es	c	f	cs	
Weathered bedrock with calcium carbonate accumulation													
6	Ap	0-25	10 YR 5/6	gsl	1 m gr	s	fr	ss po	e	f	f	cw	-
	Bw1	25-54	10 YR 5/8	gsl	2 m sbk	sh	fr	ss po	e	c	f	cs	-
	Bw2	54-95	10 YR 6/8	gsl	2 m sbk	sh	fr	ss po	es	m	c	cs	-
	Bck	95-132	10 YR 5/6	gsl	2 m sbk	sh	fr	ss ps	ev	m	c	cs	-
	Crk	132+											
Weathered material with abundant quantities of calcium carbonate													

Contd..

Pedon No.	Hori- zon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boun- dary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
7	Ap	0-24	10 YR 3/2	gc	2 msbk	h	fi	ss ps	e	f	f	cs	1-2 cm wide cracks
	Bw	24-43	10 YR 3/2	c	2 msbk	h	fi	ss ps	e	c	f	cs	
	Bss1	43-79	10 YR 3/2	gc	2 msbk	sh	fi	sp	es	c	f	cs	few, medium, grey nodules, shiny pressure faces, slickensides close enough to intersect
	Bss2	79-115	10 YR 3/2	gc	2 mabk	sh	fi	sp	es	c	f	gs	
	Bss3	115-152	10 YR 5/4	gc	2 mabk	sh	fi	sp	es	c	f	cs	
8	Bss4	152-200	10 YR 5/4	gsic	2 mabk	sh	fi	sp	ev	m	m		
	Ap	0-18	10 YR 4/3	c	2 msbk	sh	fr	sp	e	f	f	cs	8-10 cm wide cracks
	Bw1	18-48	10 YR 4/3	c	2 msbk	sh	fi	sp	e	f	f	cs	5-8 cm wide cracks
	Bw2	48-90	10 YR 4/3	c	2 msbk	sh	fi	sp	e	f	f	cs	Shiny pressure faces
	Bss1	90-136	10 YR 5/4	c	2 mabk	sh	vfi	vs vp	e	f	f	cs	Slickensides close enough to intersect
9	Bss2	136-185	10 YR 5/4	c	2 mabk	sh	vfi	vs vp	es	c	m	cs	
	Bss3	185-200	10 YR 5/4	gc	2 mabk	sh	vfi	vs vp	es	c	m	cs	
	Ap	0-30	10 YR 5/3	scl	2 msbk	sh	fr	so po	-	-	-	gw	-
	Bw1	30-60	10 YR 6/3 and 7.5 YR 5/8	gscl	2 msbk	sh	fr	ss ps	-	-	-	cs	-
	Bw2	60-90	10 YR 5/8 with 10 YR 6/3	gscl	2 msbk	sh	fr	ss ps	-	-	-	cs	-
	Cr	90+											
Weathered granite													

Weathered granite

Contd.

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
10	2	3	4	5	6	7	8	9	10	11	12	13	14
	Ap	0-14	10 YR 3/1	c	2 m sbk	sh	fr	sp	-	-	-	cs	5-6 cm wide cracks
	Bw1	14-48	10 YR 3/1	c	2 m sbk	sh	fi	sp	-	-	-	cs	3-4 cm wide cracks
	Bw2	48-82	10 YR 3/1	c	2 m sbk	h	fi	vs vp	-	-	-	cs	Shiny pressure faces
	Bss1	82-110	10 YR 3/1	c	2 m abk	h	fi	vs vp	-	-	-	cs	Slickensides
	Bss2	110-144	10 YR 3/1	c	2 m abk	vh	fi	vs vp	-	-	-	as	close enough to intersect
	Bss3	144-200	10 YR 4/3	c	2 m abk	vh	fi	vs vp	e	f	f		
11	Ap	0-6	5 YR 4/6	ls	2 m sbk	s	fr	so po	-	-	-	as	-
	Bt1	6-30	2.5 YR 4/6	scl	2 m sbk	sh	fi	ss ps	-	-	-	cs	-
	Bt2	30-60	2.5 YR 4/6	scl	2 m sbk	h	fi	ss ps	-	-	-	cs	-
	Bt3	60-90	2.5 YR 4/6	sc	2 m sbk	h	fi	ss ps	-	-	-	cs	few thin clay films
	Cr	90+	2.5 YR 4/8	gsc									
	Ap	0-21	10 YR 4/1	gc	2 m sbk	h	fi	sp	e	c	f, m	cs	4-5 cm wide cracks
	Bw	21-34	10 YR 4/2	gcl	2 m sbk	vh	fi	sp	es	m	f, m	cs	1-2 cm wide cracks
12	Bck	34-64	10 YR 4/2	gcl	2 m sbk	vh	fi	sp	ev	m	m, c	as	-
	Crk	64-104											

Weathered hornblende schist with calcium carbonate accumulation

Contd..

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
13	Ap	0-20	10 YR 3/2	gc	2 msbk	h	fi	ss ps	es	f	vf	cs	6-8 cm wide cracks
	Bw1	20-64	10 YR 3/2	gc	2 msbk	h	fi	sp	es	f	vf	cs	2-4 cm wide cracks
	Bw2	64-105	10 YR 3/2	gc	2 mabk	h	fi	sp	es	c	f, vf	cs	Shiny pressure faces
	Ck	105-162	10 YR 3/2										
Weathered bedrock with calcium carbonate accumulation													
14	Ap	0-21	7.5 YR 3/4	ls	1 f gr	s	fr	so po	-	-	-	as	
	Bt1	21-50	2.5 YR 4/6	sl	1 f sbk	s	vfr	so po	-	-	-	cw	
	Bt2	50-79	2.5 YR 4/6	l	1 f sbk	s	vfr	so po	-	-	-	gs	Few thin clay films
	Bt3	79-123	2.4 YR 4/6	scl	2 m sbk	s	vfr	so po	-	-	-	gs	Few thin clay films
	Bt4	123-152	2.5 YR 4/6	scl	2 m sbk	sh	vfr	so po	-	-	-	as	
	Cr	152-200											
Weathered ferruginous sandstone													
15	Ap	0-15	5 YR 6/6	ls	1 f gr	s	fr	so po	-	-	-	as	-
	Bt1	15-31	2.5 YR 4/8	gscl	1 m sbk	s	fr	so po	-	-	-	as	-
	Bt2	31-50	2.5 YR 5/6	gscl	1 m sbk	s	fr	so po	-	-	-	as	-
	Cr	50+											
Weathered granite													

Contd.

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	Ap	0-21	10 YR 3/3	gsl	1 f gr	s	vfr	so po	-	-	-	as	-
	Bw1	21-40	7.5 YR 5/4	gsl	1 m sbk	s	vfr	so po	-	-	-	as	-
	Bw2	40-60	7.5 YR 5/4	gsl	1 m sbk	sh	fr	so po	-	-	-	gw	-
	Bw3	60-81	7.5 YR 5/4	gsl	1 m sbk	sh	fr	so po	-	-	-	as	-
	Bw4	81-95	5 YR 4/6	gsl	2 m sbk	sh	fi	so po	-	-	-	-	-
17	Ap	0-20	10 YR 3/2	gc	2 m sbk	h	fi	vs vp	es	m	f	cs	10-12 cm wide cracks
	Bw1	20-50	10 YR 3/2	c	3 c sbk	vh	vfi	vs vp	es	m	f	cs	6-8 cm wide cracks
	Bw2	50-80	10 YR 3/2	gc	3 c sbk	eh	vfi	vs vp	es	m	f	cs	3-4 cm wide cracks. Shiny pressure faces
	Bss1	80-120	10 YR 3/2	gc	3 vc abk	eh	efi	vs vp	es	m	f	cs	Shiny pressure faces. Slickensides close enough to intersect
	Bss2	120-152	10 YR 3/2	gc	3 vc abk	eh	efi	vs vp	es	m	f	gs	Slickensides close enough to intersect
18	Bss3	152-185	10 YR 3/3	gc	3 vc abk	eh	efi	vs vp	es	m	f	-	-
	Ap	0-269	10 YR 4/3	gc	2 m sbk	h	fi	s p	-	-	-	cs	8-10 cm wide cracks
	Bw1	26-60	10 YR 4/3	c	2 m sbk	h	fi	s p	e	f	f	cs	5-6 cm wide cracks
	Bw2	60-97	10 YR 4/3	c	2 m sbk	h	fi	s p	e	f	f	cs	3-4 cm wide cracks, shiny pressure faces
	Bss1	97-136	10 YR 4/3	c	2 m abk	h	vfi	s p	e	f	f	cs	Few fine reddish mottles; Slickensides close enough to intersect
	Bss2	136-170	10 YR 4/3	c	2 m abk	h	vfi	s p	e	f	f	gs	-
	Bss3	170-200	10 YR 4/3	c	2 m abk	h	vfi	s p	es	c	m	-	-

Contd.

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
19	Ap	0-20	10 YR 4/1	c	2 m gr	vh	vfi	vs vp	e	f	f	cs	8-10 cm wide cracks
	Bw1	20-40	10 YR 4/1	c	2 m sbk	vh	vfi	vs vp	e	f	f	cs	3-4 cm wide cracks
	Bw2	40-60	10 YR 4/1	c	2 m sbk	vh	vfi	vs vp	e	f	f	cs	1-2 mm wide cracks. Shiny pressure faces
	Bss1	60-80	10 YR 4/1	c	2 m sbk	eh	efi	vs vp	e	f	f	gw	Stickensides close enough to intersect
	Bss2	80-110	10 YR 4/1	c	2 m sbk	eh	efi	vs vp	e	f	f	cs	
20	Bss3	110-140	10 YR 4/1	c	2 m sbk	eh	efi	vs vp	e	f	f	gs	
	Bss4	140-165	10 YR 4/1	c	2 m sbk	eh	efi	vs vp	e	f	f	aw	
	Bss5	165-200	10 YR 3/1	c	2 m sbk	h	vfi	vs vp	e	f	f		
	Ap	0-14	5 YR 4/6	gscl	1 f gr	s	fr	ss ps	-	-	-	as	
	Bw	14-26	2.5 YR 4/6	gscl	1 m sbk	s	fi	s p	-	-	-	as	
	Bt1	26-50	2.5 YR 3/6	gc	2 m sbk	sh	fi	s p	-	-	-	cs	
	Bt2	50-69	2.5 YR 3/6	gc	2 m sbk	sh	fi	ss ps	-	-	-	as	
	Bt3	69-80	2.5 YR 3/6	gc	2 m sbk	h	fi	ss ps	-	-	-	as	Few thin clay films
	Bt4	80-95	2.5 YR 3/6	gc	2 m sbk	h	vfi	s p	-	-	-	gs	
	BC	95-120	2.5 YR 5/6	gc	2 m sbk	h	fi	ss ps	-	-	-		

Contd..

Pedon No.	Horizon	Depth (cm)	Soil colour (moist)	Texture	Structure	Consistence			Effervescence	Concretions CaCO ₃		Boundary DT	Remarks
						Dry	Moist	Wet		Q	S		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
21	Ap	0-15	10 YR 3/1	gc	2 m sbk	sh	fi	s vp	e	c	f	cs	1-2 cm wide cracks
	Bw1	15-35	10 YR 3/1	gc	2 m sbk	h	vfi	s vp	es	c	m	gs	0.3-0.5 cm wide cracks
	Bw2	35-52	10 YR 3/1	gc	2 m sbk	vh	vfi	s p	es	c	m	gs	-
	Bw3	52-71	10 YR 4/1	gc	2 m sbk	vh	vfi	s p	es	c	m	gs	Shiny pressure faces
	Bw4	71-97	10 YR 4/1	gc	2 m sbk	vh	vfi	vs vp	es	c	m	as	-
22	BC	97-120	10 YR 4/1	gc	2 m sbk	h	fi	s p	ev	m	c	as	-
	Ck	120+			Weathered parent material with calcium carbonate accumulation								-
	Ap	0-15	5 YR 5/6	gls	1 m gr	s	fr	so po	-	-	-	cs	-
	Bt	15-28	2.5 YR 3/6	gscl	1 m sbk	s	fi	ss ps	-	-	-	as	-
	C	28+											

Note: Abbreviations used are according to Soil Survey Staff (1995)

Texture: g - gravel; ls - loamy sand; sl - sandy loam; l - loam; si - silt; sil - silt loam; cl - clay loam; scl - silty clay loam; scl - sandy clay loam; sic - silty clay;

c - clay; gc - gravelly clay; gls - gravelly loamy sand; gscl - gravelly sandy clay loam; gsl - gravelly sandy loam.

Structure: a) Grade : 0 - structureless; 1 - weak; 2 - moderate; 3 - strong

b) Size : f-fine; m - medium; c - coarse; vc - very coarse

c) Type : abk - angular blocky; sbk - subangular blocky; gr - granular; sg - single grain

Consistence: Dry soil : 1 - loose; s - soft; sh - slightly hard; h - hard; vh - very hard; eh - extremely hard

Moist soil : 1 - loose; ufr - very friable; fr - friable; fi - firm; vfi - very firm; efi - extremely firm

Wet soil : so - non sticky; ss - slightly sticky; s - sticky; vs - very sticky; po - non plastic; ps - slightly plastic; p - plastic; vp - very plastic

Effervescence: e - slight; es - strong; ev - violent

Concretions : Q - Quantity; f - few; c - common; m - many; S - size; vf - very fine; f - fine; m - medium; c - coarse

Boundary : D - distinctness; a - abrupt; c - clear; g - gradual; d - diffuse; T - Topography; s - smooth; w - wavy; i - irregular; b - broken

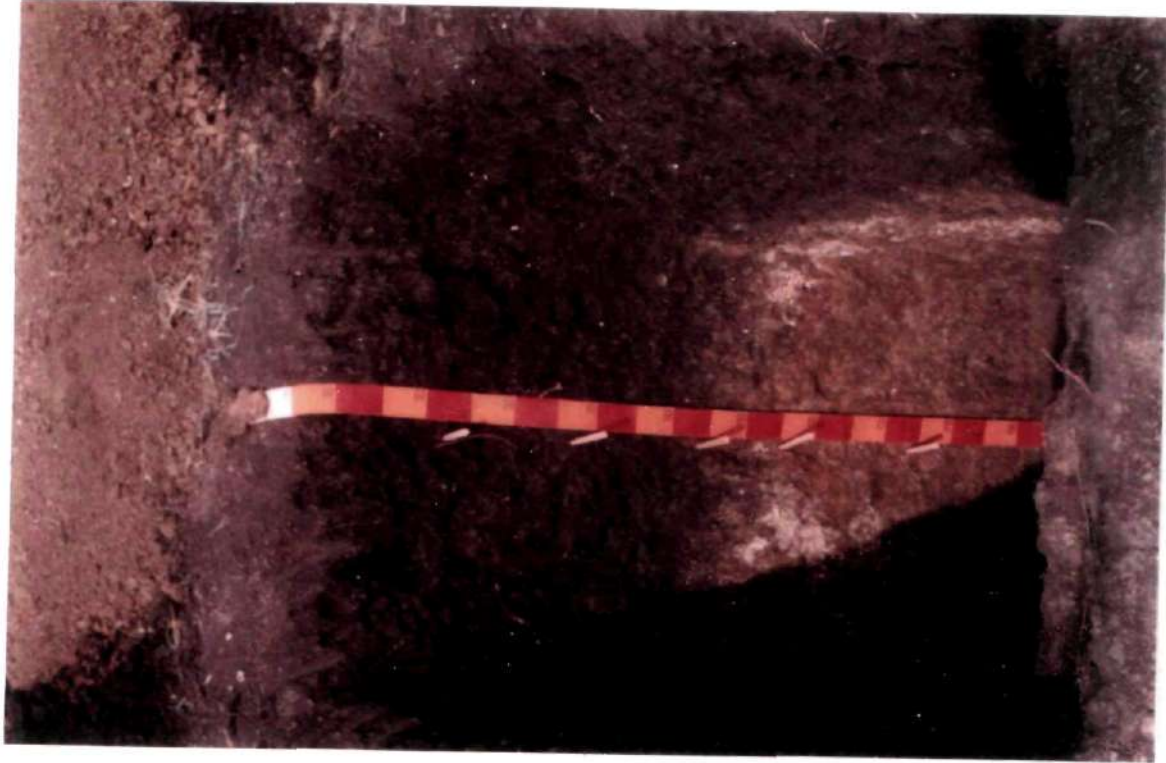


Plate 9: Photograph of pedon 2

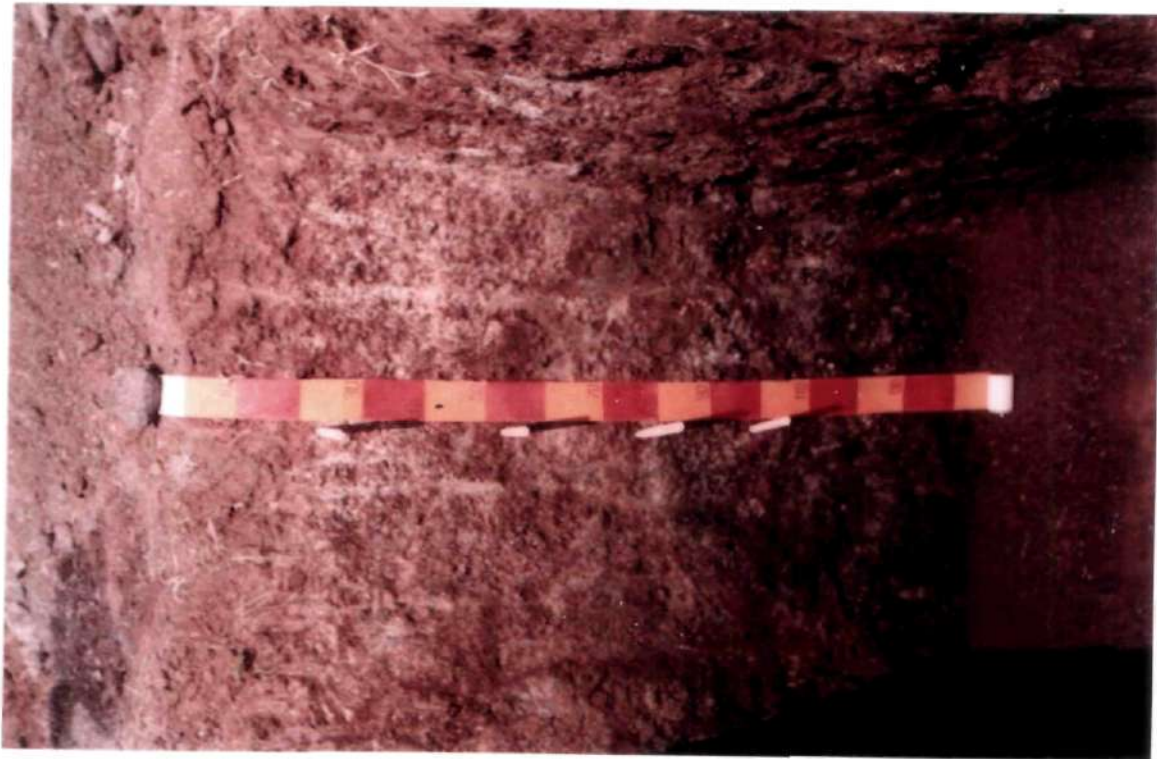


Plate 8: Photograph of pedon 1

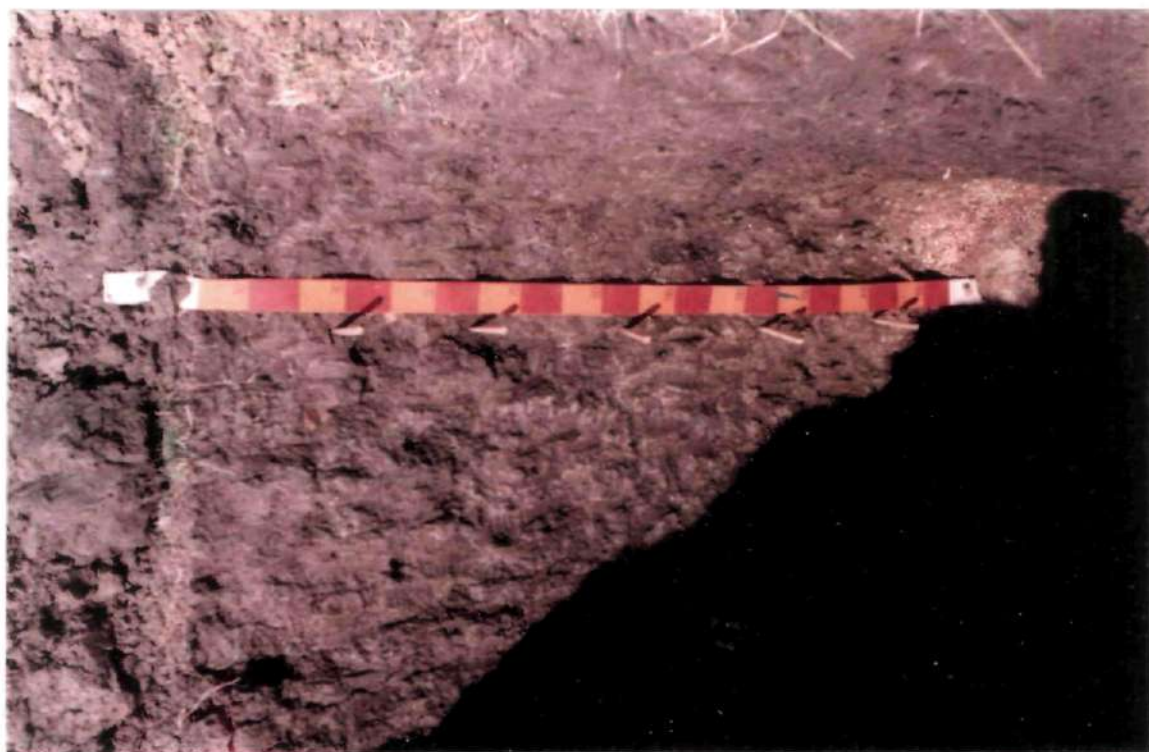


Plate 11: Photograph of pedon 5

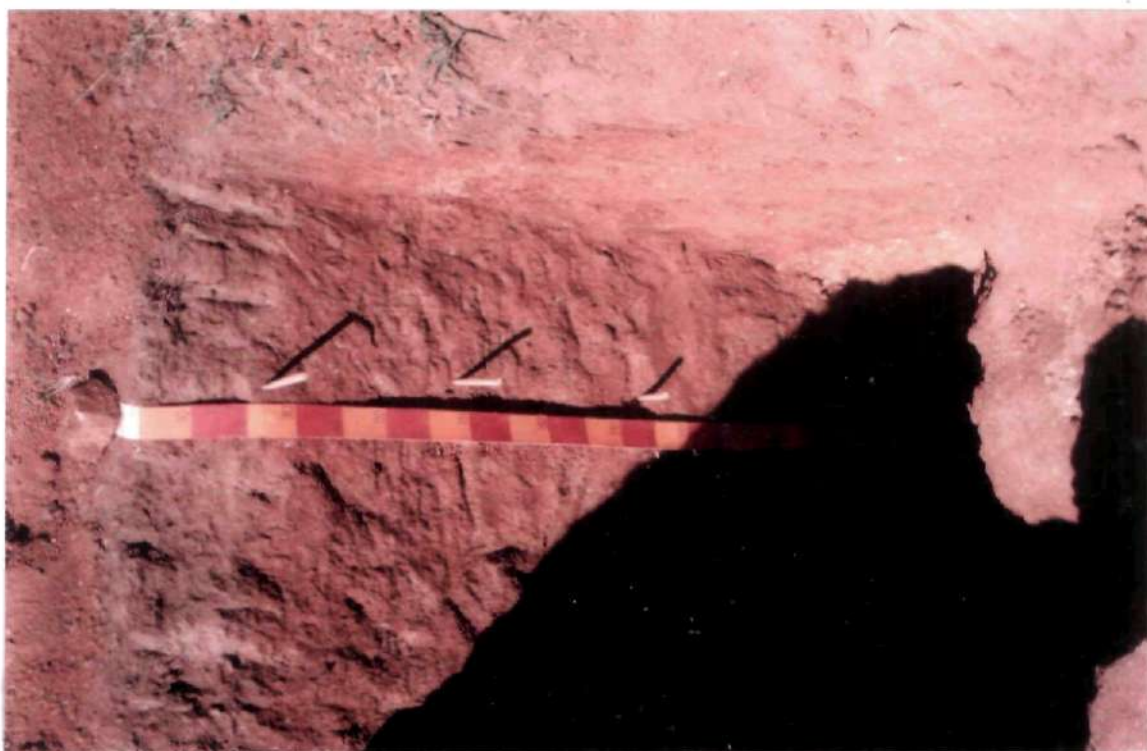


Plate 10: Photograph of pedon 4

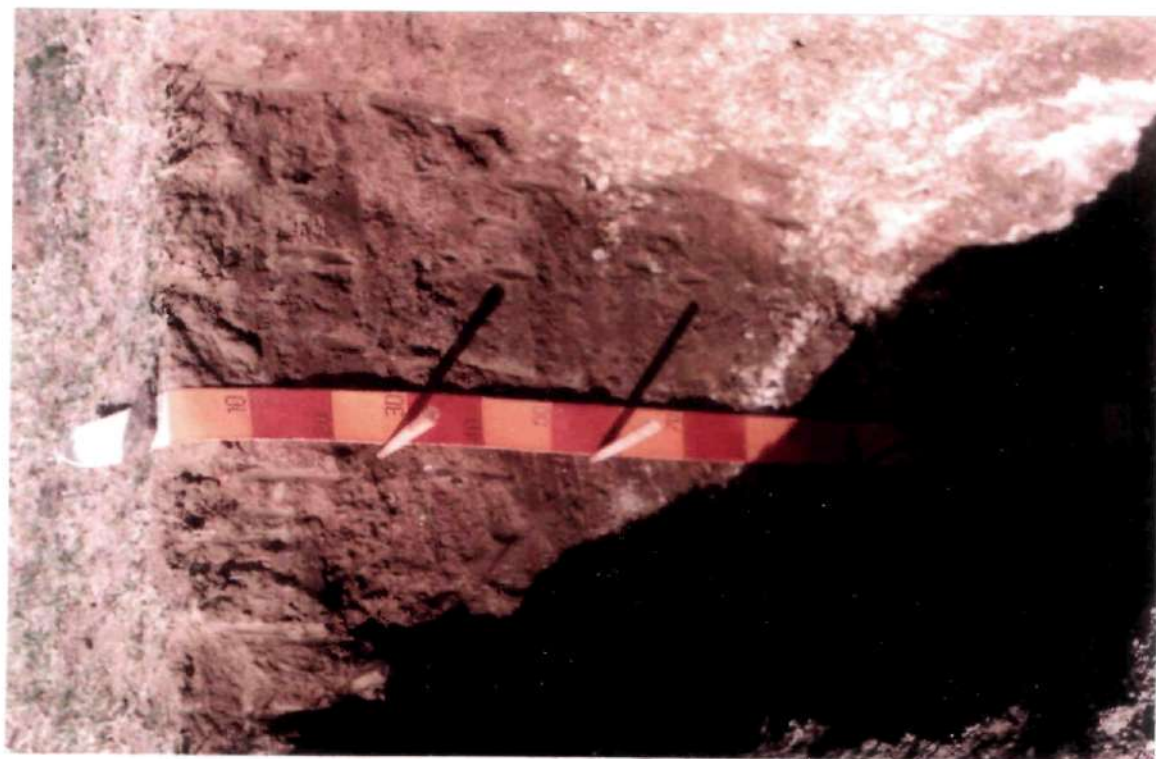


Plate 13: Photograph of pedon 6

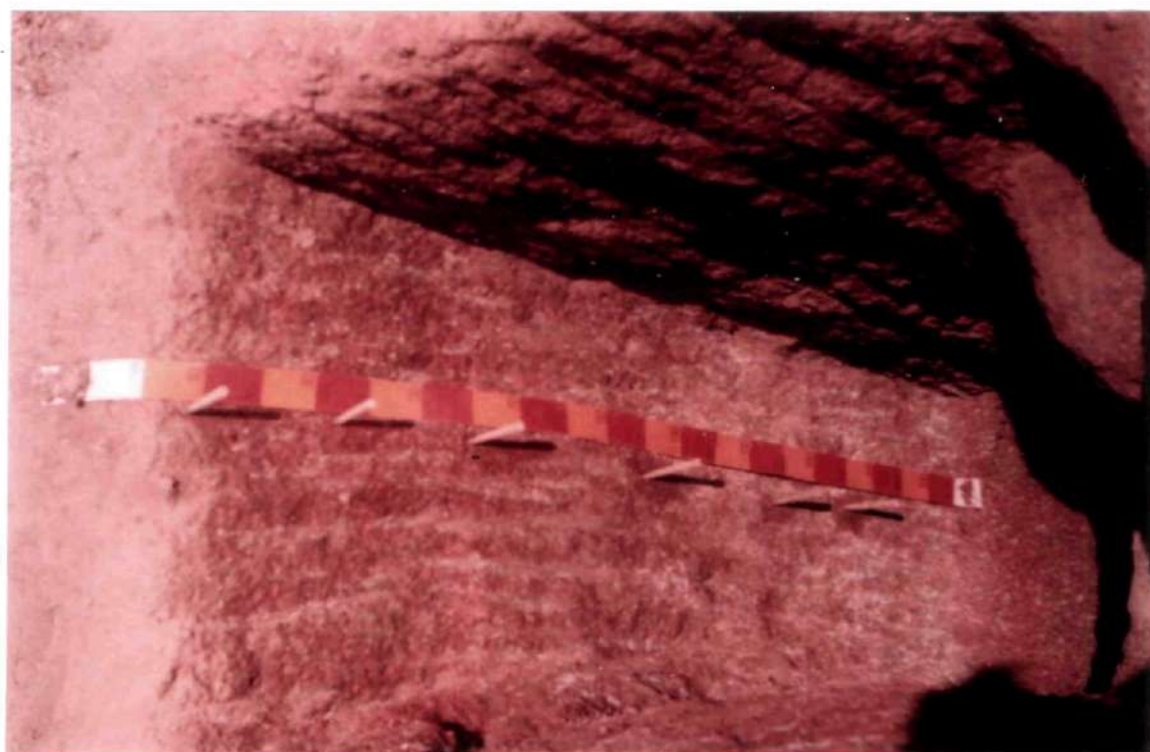


Plate 12: Photograph of pedon 3

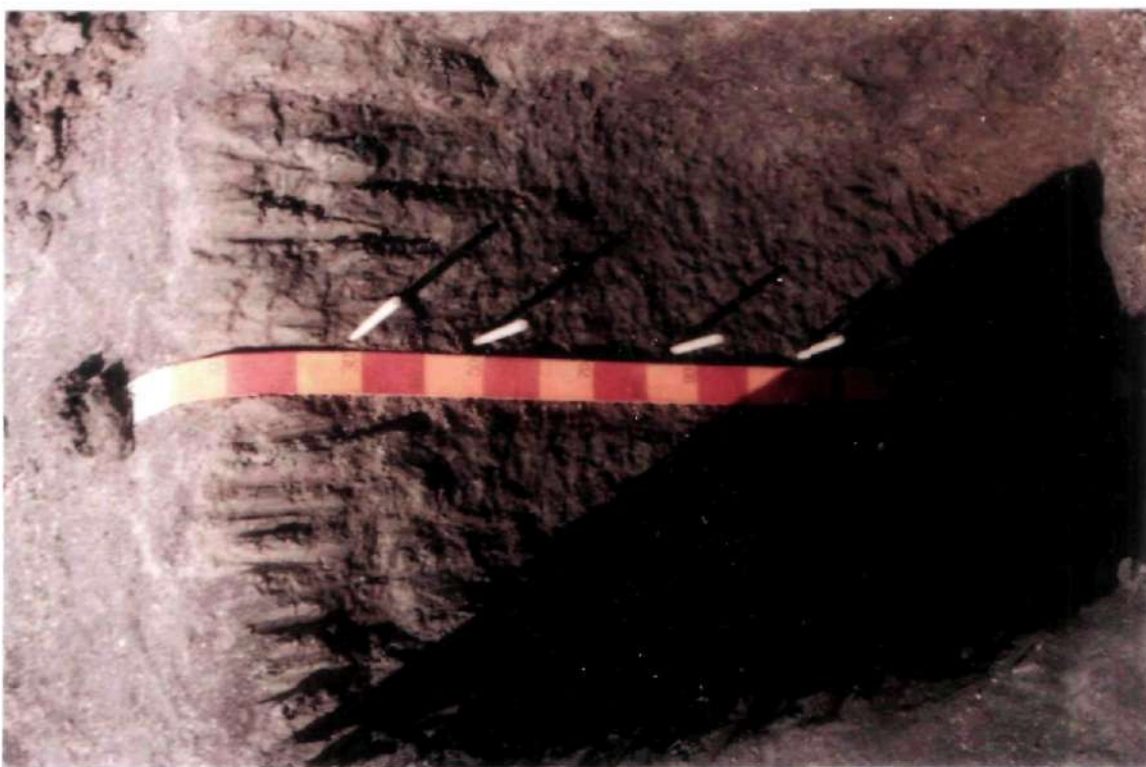


Plate 14: Photograph of pedon 7

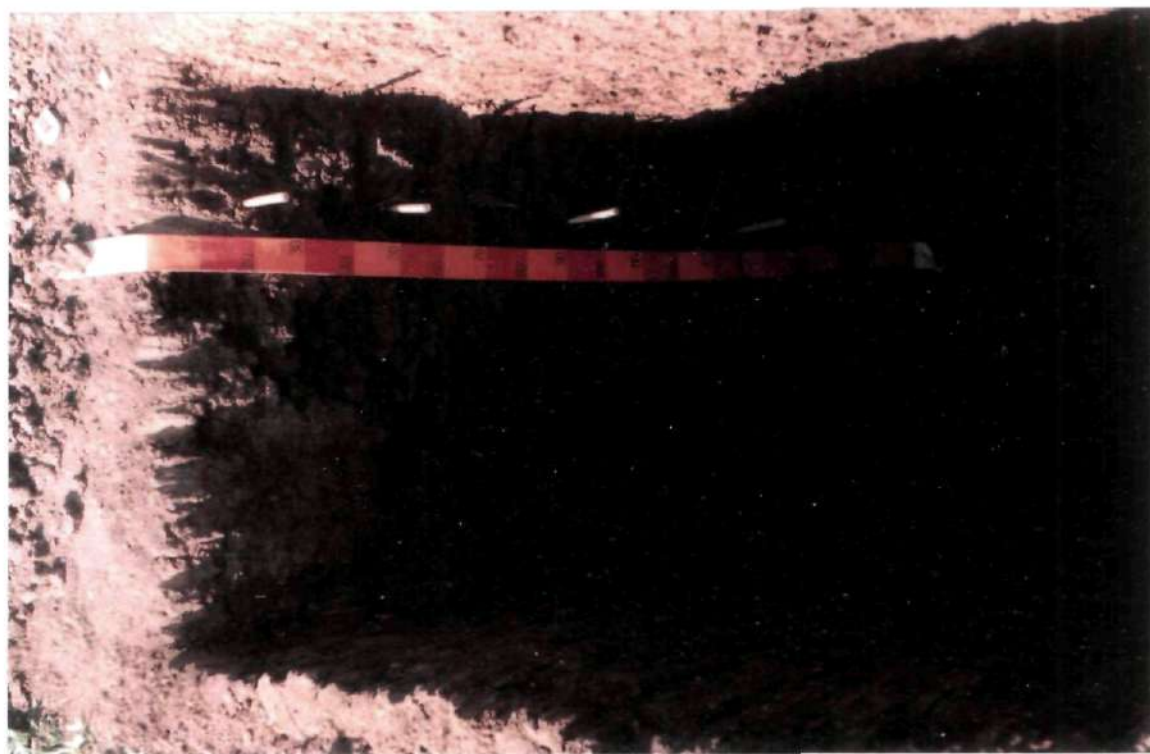


Plate 15: Photograph of pedon 8

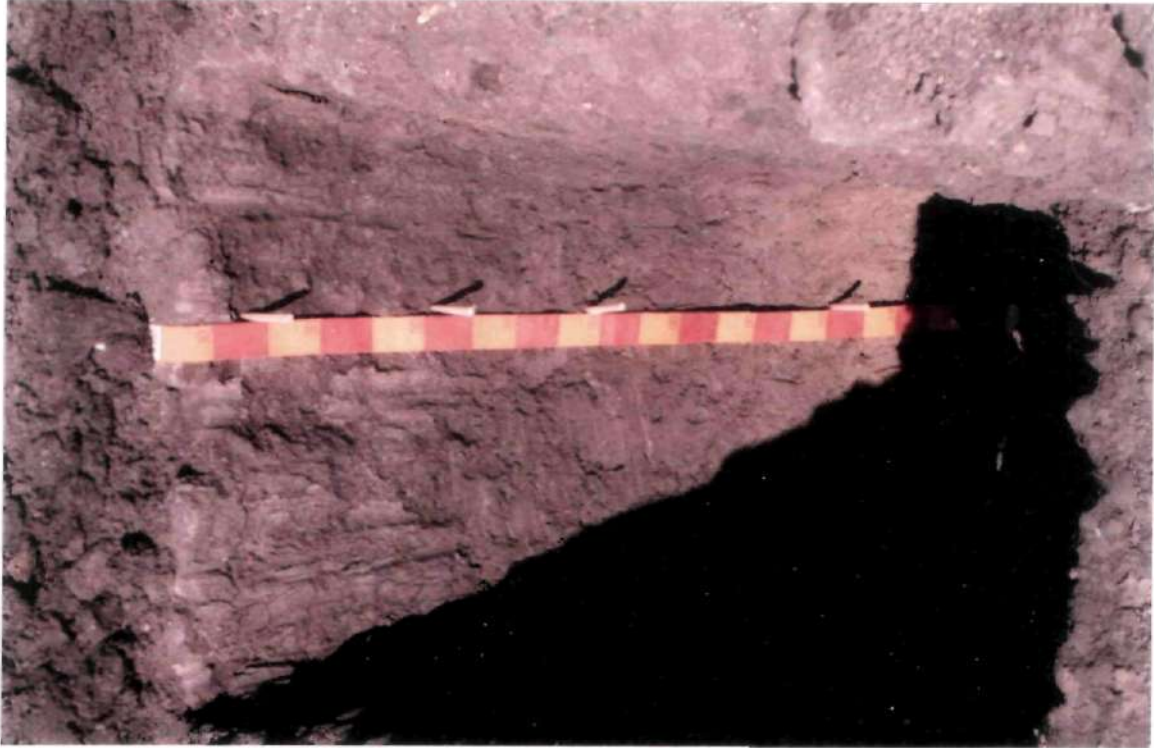


Plate 17: Photograph of pedon 10

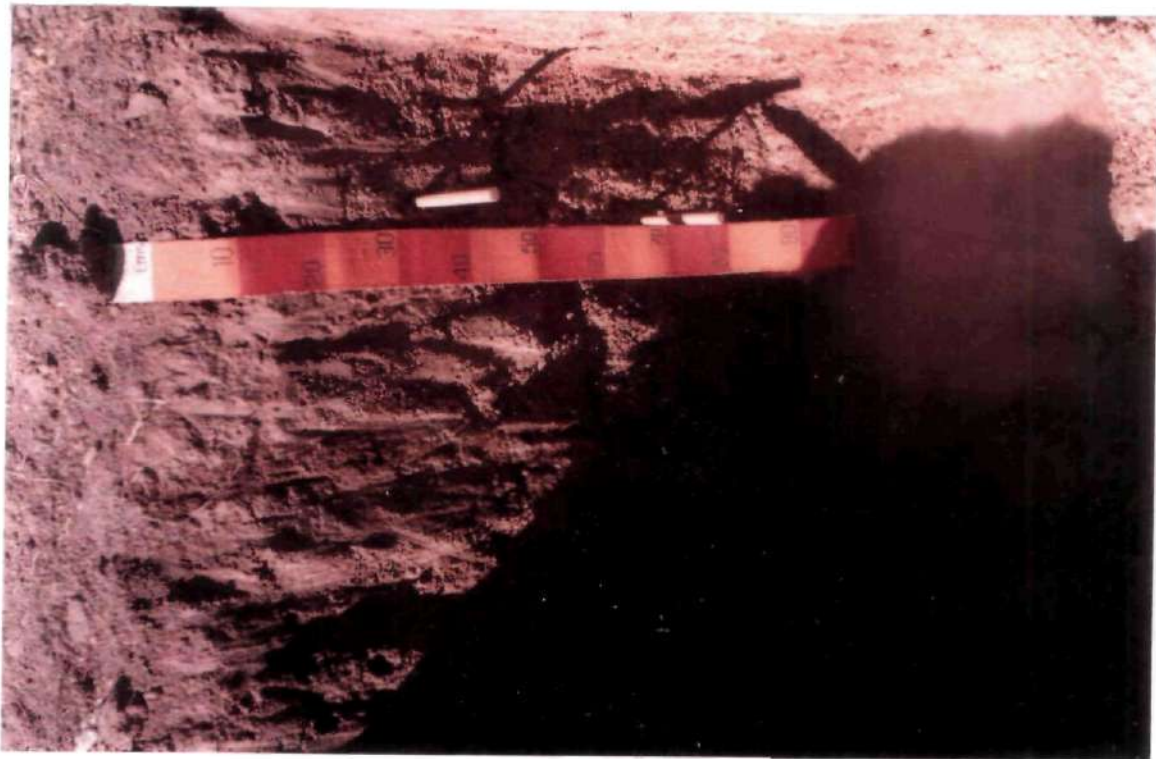


Plate 16: Photograph of pedon 9

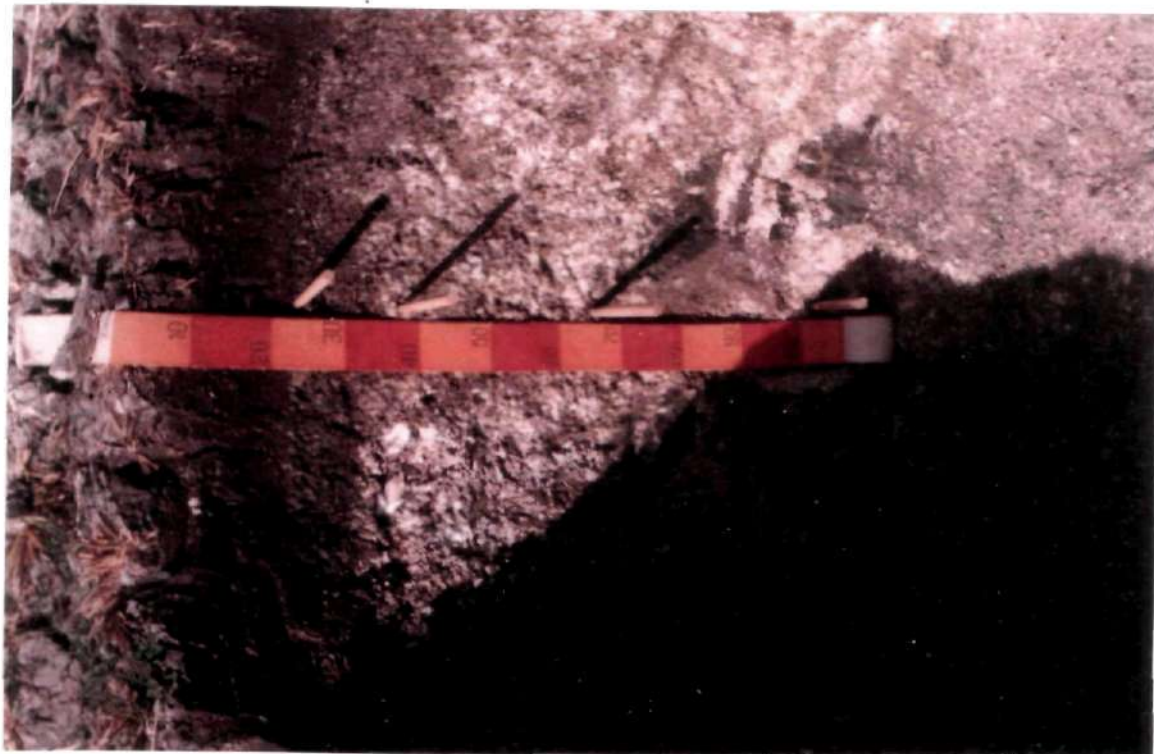


Plate 19: Photograph of pedon 12

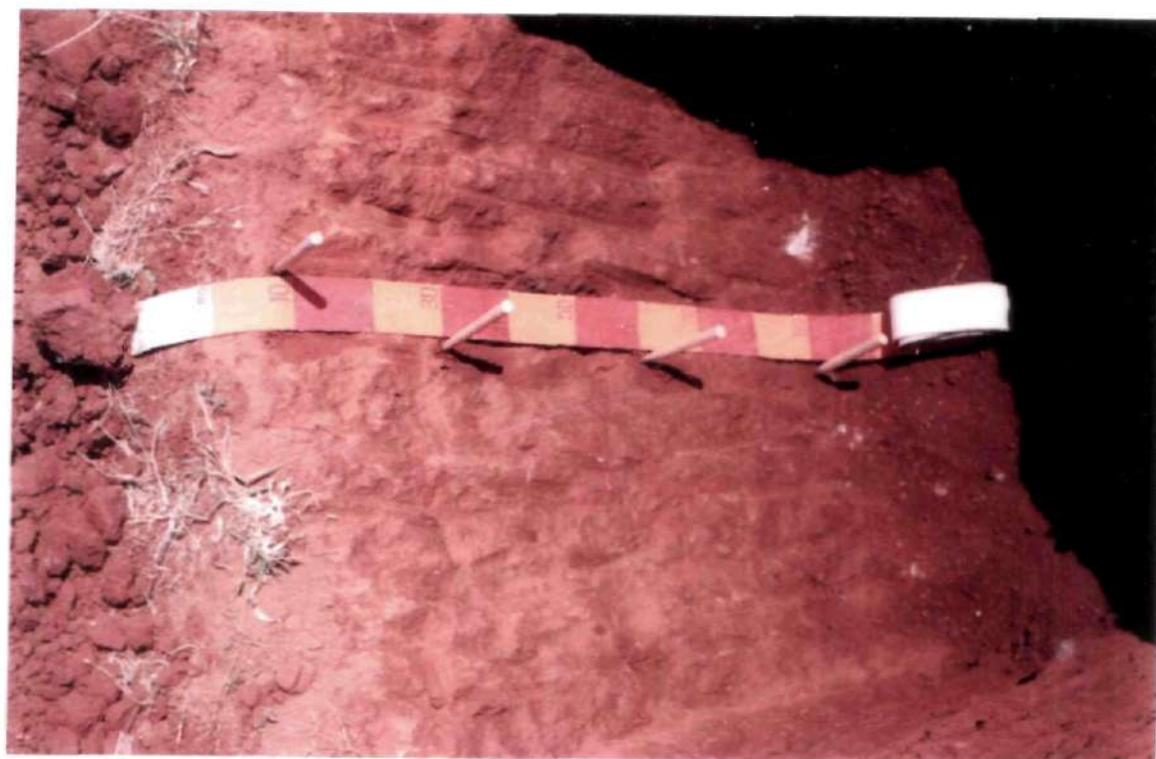


Plate 18: Photograph of pedon 11

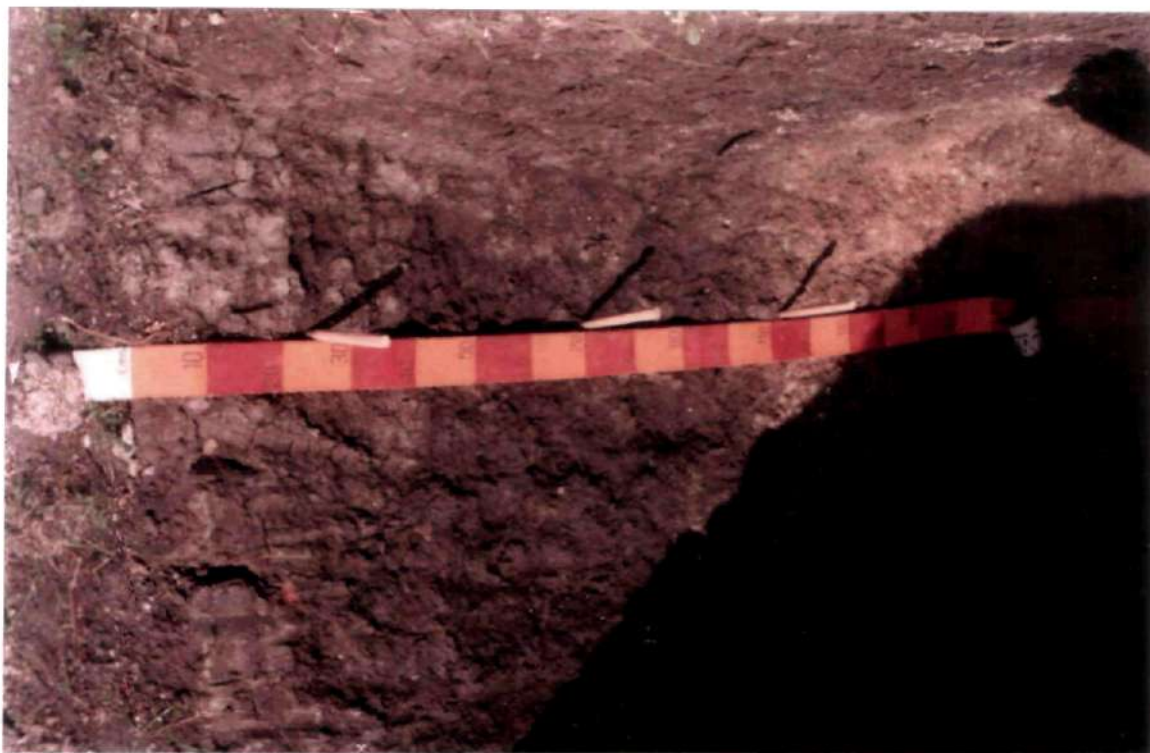


Plate 20: Photograph of pedon 13

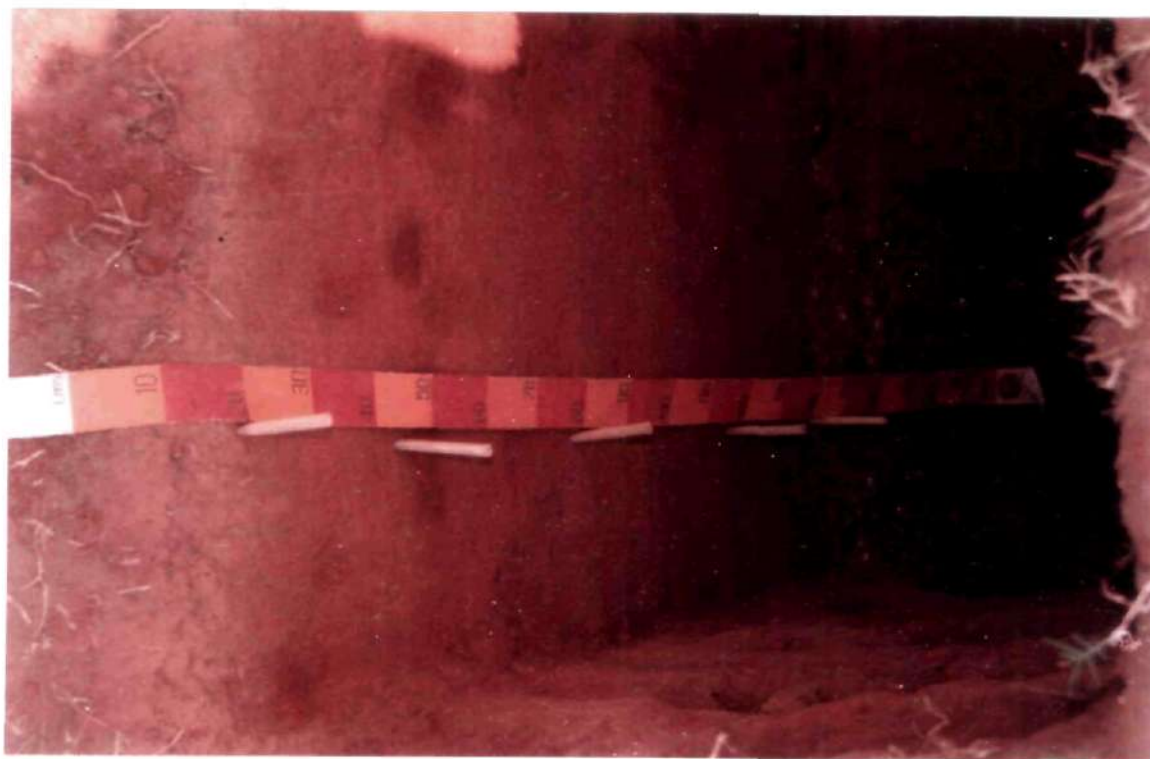


Plate 21: Photograph of pedon 14

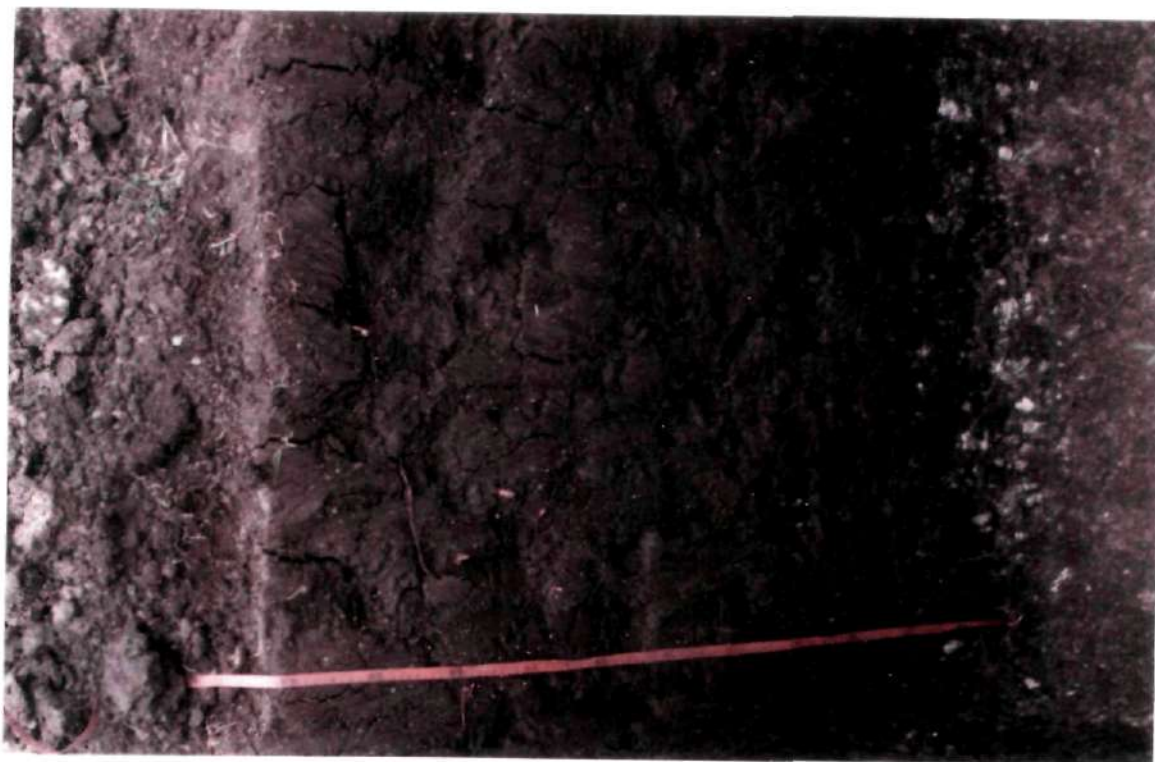


Plate 23: Photograph of pedon 21



Plate 22: Photograph of pedon 20

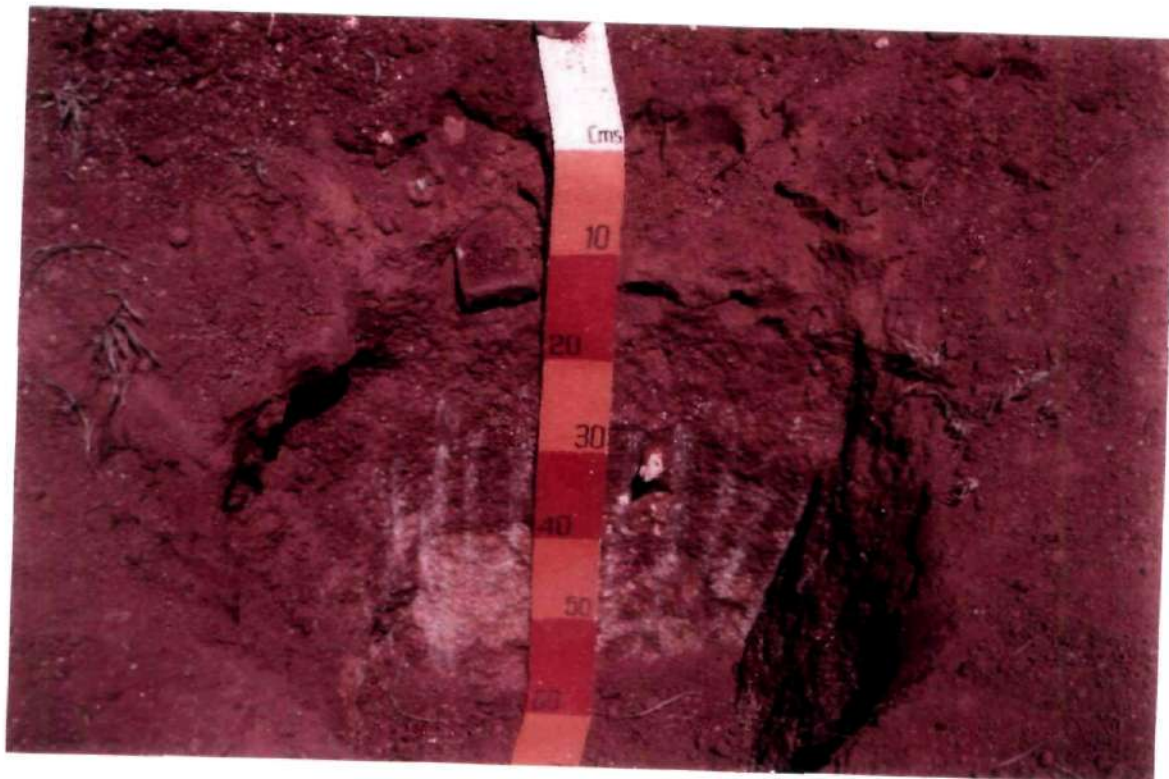


Plate 24: Photograph of pedon 22

22. In pedon 16 the sand content increased with depth, but its content was low in Bw4 horizon. The content of sand varied from 30.0 to 52.7 per cent in pedon 20 with irregular depth distribution. In pedons 1 and 4, the sand content increased with depth. The sand content of black soils varied between 3.2 to 60.1. Pedon 6 had the highest sand content of 53.5 to 60.1, which decreased with depth while in C horizon, it increased. In pedons 2, 8 and 12, the content of sand was observed to increase with the depth, whereas in pedons 7, 13 and 17, it decreased with the depth. Sand content varied from 25.8 to 36.5 per cent in pedon 5, 19.6 to 29.1 in pedon 10, 19.0 to 22.7 in pedon 18 and 18.5 to 21.5 in pedon 19 with no specific trend. It was observed that the pedon 17 had the lowest content of sand ranging from 3.2 to 4.1 per cent.

4.2.2.2 Silt (%): The black soils, generally, showed higher content of silt (except pedon 19) compared to red soils. Pedon 19 had silt content varying from 2.0 to 11.1 per cent. The silt content ranged from 3.7 (pedon 1) to 28.2 per cent (pedon 14) in red soils. In black soil pedons, the silt content ranged from 2 to 40 per cent. The highest value was observed in pedon 7 while the lowest value was noticed in pedon 19. Increasing trend with depth was observed in pedons 7, 12, 15 and 22. Whereas silt content decreased with depth in pedons 9 and 17. Other pedons did not show any particular trend.

4.2.2.3 Clay (%): The clay content in black soil pedons was found high compared to red soils. In red soils, its content ranged from 5.5 (pedon 22) to

55.8 per cent (pedon 20). Among red soil pedons, higher content of clay throughout the profile ranging from 26.6 to 55.8 was observed in pedon 20.

In black soil pedons, the clay content varied from 30.9 (pedon 21) to 78.0 per cent (pedon 17). Highest clay content recorded in pedon 17 ranged from 72.6 to 78.0.

In case of red soil pedons, the clay content increased with depth due to eluviation from upper horizons.

The clay content, in general was found nearly uniform in black soil pedons. But in the deeper horizons, its content decreased to some extent. In pedons 13 and 17 clay content was more whereas in pedons 8, 18 and 19, no specific trend was noticed.

4.2.3 Bulk density (Mg m^{-3})

The values for bulk density ranged from 1.25 to 1.58 Mg m^{-3} in red soils whereas black soils recorded a range between 1.47 to 1.97 Mg m^{-3} . Pedon 6 had the lowest BD values, ranging from 1.47 to 1.52 Mg m^{-3} in black soils. Excluding Jaipur pedon, the lowest value of BD in black soils was 1.64.

4.2.4 Moisture retention (%)

The moisture retention at 33 and 1500 Kpa and available water capacity were more in black soils when compared with red soils. In the studied pedons

the retention of moisture at 33 Kpa was ranging from 4.2 to 28.0 per cent in red soils, where as it varied from 22.9 to 81.6 per cent in black soils. In pedon 6, it was between 14.9 and 23.0 per cent. At 1500 Kpa the retention of moisture in red soils ranged from 2.5 to 20.0, whereas in black soils it was between 15.0 and 46.3 per cent. In pedon 6 the retention of moisture at 1500 Kpa was between 10.7 to 14.8 per cent. Available water capacity in red soils ranged from 1.7 to 12.7 per cent, whereas in black soils it was between 6.9 and 37.1 per cent. The AWC in pedon 6 was between 3.4 and 8.8 per cent.

4.3 CHEMICAL PROPERTIES OF PEDONS AND THEIR NUTRINT STATUS

The data pertaining to chemical properties of pedons and their nutrient status are presented in Table 9.

4.3.1 Soil reaction (pH)

There was a general trend of increasing pH with depth in all the pedons. Higher values of pH 7.2 (pedon 2) to 9.2 (pedon 7) were observed in black soils. The range in pH in red soil pedons was between 4.7 (pedon 14) to 7.8 (pedon 1).

4.3.2 Electrical conductivity (dSm^{-1})

The electrical conductivity was low in most of the soils studied and the values ranged between 0.04 and 0.76 dSm^{-1} indicating that the soils were non-

Table 8: Physical properties of soils

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)			Bulk Density Mg m ⁻³	Water retention		AWC (%)	
				Sand (2-0.05)	Silt (0.05- 0.002)	Clay (<0.002)		33 KPa (%)	1500 KPa (%)		
----- Pct of < 2 mm -----											
1	2	3	4	5	6	7	8	9	10	11	
1	Ap	0-22	10	65.4	3.7	30.9	1.25	15.3	11.2	4.1	
	Bw1	22-52	20	68.7	6.8	24.5	1.31	16.2	12.1	4.1	
	Bw2	52-77	20	70.0	9.3	20.7	1.33	12.0	8.0	4.0	
	BC1	77-98	50	82.5	6.7	10.8	1.40	8.0	4.9	3.1	
	BC2	98-145	50	86.4	5.1	8.5	1.45	4.8	2.5	2.3	
2	Crk	145+	Weathered granite with calcium carbonate accumulation								
	Ap	0-35	5	19.8	11.4	68.8	1.68	37.0	26.5	10.5	
	Bw	35-64	5	22.1	8.8	69.1	1.70	36.8	25.7	11.1	
	Bss	64-105	10	24.5	5.1	70.4	1.75	39.3	28.0	11.3	
	BC	105-154	40	38.0	6.7	55.3	1.72	33.5	23.8	9.7	
3	Crk	154-200	Weathered granite with calcium carbonate accumulation								
	Ap	08	15	85.9	5.4	8.7	1.57	5.4	2.5	2.9	
	Cr	8+	Weathered granite								
4	Ap	0-24	15	65.4	12.2	22.4	1.43	13.7	7.2	6.5	
	Bw1	24-68	15	70.8	10.0	19.2	1.50	9.3	5.7	3.6	
	Bw2	68-120	30	75.0	8.5	16.5	1.52	10.1	6.0	4.1	
	Bw3	120-170	15	76.2	7.4	16.2	1.52	9.3	5.8	3.5	
	Bw4	170-200	60	62.5	10.6	26.9	1.52	18.7	10.9	7.8	

Contid..

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)				Bulk Density Mg m ⁻³	Water retention		AWC (%)
				Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Pct of < 2 mm -----		33 KPa (%)	1500 KPa (%)	
1	2	3	4	5	6	7	8	9	10	11	
5	Ap	0-31	20	26.9	18.9	54.2	1.76	25.4	18.2	7.2	
	Bw1	31-62	10	26.5	17.1	56.4	1.74	29.7	20.3	9.4	
	Bw2	62-97	20	25.8	15.5	58.7	1.80	32.5	21.5	11.0	
	Bss1	97-135	25	26.1	15.8	58.1	1.81	34.7	22.7	12.0	
	Bss2	135-172	40	26.0	16.0	58.0	1.83	37.4	25.1	12.3	
6	Ck	172-200	70	36.5	19.1	44.4	1.86	31.2	20.6	10.6	
	Ap	0-25	15	60.1	15.5	24.4	1.47	14.9	14.9	11.5	
	Bw1	25-54	20	58.2	16.2	25.6	1.50	15.9	10.7	5.2	
	Bw2	54-95	25	56.2	16.0	27.8	1.52	23.0	14.8	8.2	
	Bck	95-132	35	53.5	14.8	31.7	1.50	20.3	11.5	8.8	
7	Crk	132+	40	57.0	13.0	30.0	1.48	20.5	12.5	8.0	
	Ap	0-24	15	32.9	6.8	60.3	1.74	29.1	20.3	8.8	
	Bw	24-43	10	27.8	15.2	57.0	1.72	30.1	21.3	8.8	
	Bss1	43-79	15	23.5	23.8	52.7	1.78	33.7	23.4	10.3	
	Bss2	79-115	20	20.4	28.0	51.6	1.80	38.3	25.3	13.0	
	Bss3	115-152	20	17.7	32.6	49.7	1.85	46.2	28.0	18.2	
	Bss4	152-200	25	15.3	40.0	44.7	1.85	47.7	28.9	18.8	

Contd..

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)			Bulk Density Mg m ³	Water retention		AWC (%)
				Sand (2-0.05)	Silt (0.05- 0.002)	Clay (<0.002)		33 KPa (%)	1500 KPa (%)	
1	2	3	4	5	6	7	8	9	10	11
8	Ap	0-18	5	18.4	34.6	47.0	1.86	35.6	26.0	9.6
	Bw1	18-48	5	20.2	33.4	46.4	1.88	34.2	25.7	8.5
	Bw2	48-90	5	22.5	28.0	49.5	1.85	41.1	28.7	12.4
	Bss1	90-136	5	25.4	24.5	50.1	1.85	43.0	31.6	11.4
	Bss2	136-185	10	27.7	23.8	48.5	1.86	44.3	31.3	13.0
9	Bss3	185-200	20	31.1	25.3	43.6	1.90	44.6	31.7	12.9
	Ap	0-30	10	69.0	14.2	16.8	1.56	14.9	8.3	6.6
	Bw1	30-66	30	64.5	12.5	23.0	1.55	20.5	14.8	5.7
	Bw2	66-90	40	63.5	12.0	24.5	1.57	22.4	14.0	8.4
	Cr	90+	Weathered granite							
10	Ap	0-14	5	19.6	19.4	61.0	1.80	36.4	25.2	11.2
	Bw1	14-48	5	22.1	20.0	57.9	1.84	44.5	30.2	14.3
	Bw2	48-82	5	20.5	20.5	59.0	1.86	52.4	33.3	19.1
	Bss1	82-110	5	26.2	20.5	53.3	1.90	70.8	39.0	31.8
	Bss2	110-144	5	25.5	22.0	52.5	1.92	81.6	44.5	37.1
	Bss3	144-200	10	29.1	20.7	50.2	1.92	72.3	40.2	32.1

Contd.

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)				Bulk Density Mg m ⁻³	Water retention		AWC (%)
				Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Pct of < 2 mm -----		33 KPa (%)	1500 KPa (%)	
1	2	3	4	5	6	7		8	9	10	11
11	Ap	0-6	5	77.5	9.1	13.4		1.57	10.1	6.3	3.8
	Bt1	6-30	5	65.1	9.5	25.4		1.55	23.0	18.1	4.9
	Bt2	30-60	5	67.3	8.5	24.2		1.53	24.0	18.0	6.0
	Bt3	60-90	10	55.8	8.8	35.4		1.56	28.0	18.3	9.7
12	Cr	90+		Weathered granite with calcium carbonate accumulation							
	Ap	0-21	20	37.9	19.9	42.2		1.70	32.5	21.1	11.4
	Bw	21-34	30	39.5	22.0	38.5		1.68	27.1	17.7	9.4
	Bck	34-64	40	42.4	24.1	33.5		1.64	24.3	15.0	9.3
13	Crk	64-104		Weathered hornblende schist with calcium carbonate accumulation							
	Ap	0-20	25	35.9	18.5	45.6		1.76	33.4	20.8	12.6
	Bw1	20-64	20	31.3	20.1	48.6		1.73	33.2	23.0	10.2
	Bw2	64-105	30	28.7	19.8	51.5		1.75	38.4	25.9	12.5
14	Crk	105-162	40	27.3	22.3	50.4		1.77	35.4	24.1	11.3
	Ap	0-21	2	80.2	13.9	5.9		1.52	8.0	4.9	3.1
	Bt1	21-50	-	70.5	18.4	11.1		1.50	13.0	10.4	2.6
	Bt2	50-79	1	48.1	28.2	23.7		1.56	16.2	12.9	3.3
	Bt3	79-123	1	49.2	20.0	30.8		1.54	16.6	13.2	3.4
	Bt4	123-152	5	53.2	18.5	28.3		1.59	14.1	11.4	2.7
	Cr	152-200	60	45.9	18.1	36.0		1.60	15.7	12.7	3.0

Contd..

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)			Bulk Density Mg m ⁻³	Water retention		AWC (%)
				Sand (2-0.05)	Silt (0.05- 0.002)	Clay (<0.002)		33 KPa (%)	1500 KPa (%)	
1	2	3	4	5	6	7	8	9	10	11
	Ap	0-15	10	84.4	5.4	10.2	1.43	7.4	5.0	2.4
	Bt1	15-31	30	70.9	8.3	20.8	1.52	16.6	14.4	2.2
	Bt2	31-50	50	64.3	10.1	25.6	1.58	23.7	18.1	5.6
	Cr	50+	Weathered granite							
16	Ap	0-21	20	73.5	3.7	22.8	1.38	9.5	6.0	3.5
	Bw1	21-40	20	75.8	3.4	20.8	1.35	7.8	5.2	2.6
	Bw2	40-60	20	77.7	4.6	17.7	1.35	4.9	2.8	2.1
	Bw3	60-81	20	78.2	5.8	16.0	1.40	4.2	2.5	1.7
	Bw4	81-95	25	67.4	4.4	28.2	1.55	17.5	12.4	5.1
17	Ap	0-20	15	4.1	23.3	72.6	1.84	51.3	34.2	17.1
	Bw1	20-50	10	4.0	22.6	73.4	1.87	57.9	38.2	19.7
	Bw2	50-80	15	3.8	21.2	75.0	1.90	64.0	41.2	22.8
	Bss1	80-120	15	3.5	20.3	76.2	1.92	66.1	43.0	23.1
	Bss2	120-152	15	3.5	18.8	77.7	1.92	66.4	42.0	24.4
	Bss3	152-185	20	3.2	18.8	78.0	1.95	72.9	46.3	26.6

Contd..

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)				Bulk Density Mg m ⁻³	Water retention		AWC (%)
				Sand (2-0.05)	Silt (0.05- 0.002)	Clay (<0.002)	Pct of < 2 mm -----		33 KPa (%)	1500 KPa (%)	
1	2	3	4	5	6	7	8	9	10	11	
18	Ap	0-26	15	19.0	23.7	57.3	1.81	42.4	29.0	13.4	
	Bw1	26-0	15	20.5	24.7	54.8	1.84	42.7	30.6	12.1	
	Bw2	60-97	10	21.9	25.1	53.0	1.91	44.0	30.4	13.6	
	Bss1	97-136	10	19.8	25.7	54.5	1.92	52.2	35.6	16.6	
	Bss2	136-170	10	22.7	26.0	51.3	1.95	54.2	36.9	17.3	
	Bss3	170-200	10	21.5	25.7	52.8	1.94	53.7	36.5	17.2	
19	Ap	0-20	-	20.5	10.2	69.3	1.90	40.9	27.7	13.2	
	Bw1	20-40	-	19.2	10.0	70.8	1.95	39.0	26.2	12.8	
	Bw2	40-60	-	19.0	11.1	69.9	1.93	41.4	26.5	14.9	
	Bss1	60-80	5	18.5	9.0	72.5	1.96	39.5	26.5	13.0	
	Bss2	80-110	5	18.8	6.2	75.0	1.97	41.8	28.0	13.8	
	Bss3	110-140	5	19.0	6.6	74.4	1.96	45.2	29.6	15.6	
	Bss4	140-165	10	18.6	4.3	77.1	1.95	47.4	30.9	16.5	
	Bss5	165-200	10	21.5	2.0	76.5	1.94	48.9	31.1	17.8	
	Ap	0-14	20	52.7	20.7	26.6	1.35	11.5	7.6	3.9	
	Bw	14-26	20	51.7	16.8	31.5	1.40	12.3	7.8	4.5	
20	Bt1	26-50	40	31.6	13.6	54.8	1.43	18.1	8.8	9.3	
	Bt2	50-69	35	35.2	11.3	53.5	1.47	19.2	9.0	10.2	
	Bt3	69-80	20	30.0	14.2	55.8	1.50	21.5	9.3	12.2	
	Bt4	80-95	40	32.8	12.4	54.8	1.54	22.2	9.5	12.7	
	BC	95-120	55	34.7	13.2	52.1	1.52	18.1	8.6	9.5	

Pedon	Horizon	Depth (cm)	Coarse fragments (>2mm) Pct of whole soil	Size class and particle diameter (mm)				Bulk Density Mg m ⁻³	Water retention			AWC (%)
				Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)			33 KPa (%)	1500 KPa (%)		
1	2	3	4	5	6	7		8	9	10	11	
21	Ap	0-15	20	30.0	14.0	56.0		1.81	27.8	19.8		8.0
	Bw1	15-35	20	28.2	16.1	55.7		1.83	31.5	20.7		10.8
	Bw2	35-52	20	27.0	18.1	54.9		1.83	30.6	22.2		8.4
	Bw3	52-71	25	24.1	22.3	53.6		1.86	32.7	21.3		11.4
	Bw4	71-97	30	28.5	21.3	50.2		1.88	31.4	20.8		10.6
22	BC	97-120	40	30.8	23.4	45.8		1.84	32.5	22.4		10.1
	Ck	120+	60	31.1	38.0	30.9		1.80	22.9	16.0		6.9
	Ap	0-15	25	82.8	11.7	5.5		1.55	8.8	5.3		3.5
	Bt	15-28	30	59.4	18.2	22.4		1.58	11.4	9.1		2.3
	C	28+										
Weathered granite												

tr : traces

saline ($EC < 1 \text{ dSm}^{-1}$) in nature. However, there were exceptions in pedon 10 and pedon 17. In pedon 10, the EC values were between 0.28 to 2.75 dSm^{-1} , increasing with depth. In pedon 17, the value was between 0.35 and 1.11 dSm^{-1} , increased upto the depth of 120 cm and thereafter decreasing trend was noticed. The EC values, in general, had no definite trend of distribution in the profiles except in pedons 9 and 12. The EC content increased with depth in pedon 9, whereas in pedon 12, it decreased.

4.3.3 Organic carbon (%)

Organic carbon content ranged from 0.02 to 1.38 per cent in the pedons under study and was found to decrease with depth in most of the pedons. In pedons 6, 10, 16, 18, 19, 20, 21, it was irregularly distributed through depth. In Pedons 15 and 22, the content increased with depth. Organic carbon content was higher in pedon 14 than other pedons ranging from 0.21 to 1.38 per cent.

4.3.4 Calcium carbonate equivalent (%)

Red soils except pedons 1 and 4 in the study area were noncalcareous. All the black soils were found calcareous. The CaCO_3 content ranged from traces to 24.9 per cent in the studied soils and, in general, the content increased with depth and it was found accumulated in the lower horizons in some of the black soil pedons (Pedons 5, 6, 12, 13 and 21). Nearly uniform distribution of calcium carbonate was found in pedons 8 and 17.

4.3.5 Available phosphorus (kg ha^{-1})

Both red and black soil pedons showed decreasing trend of available phosphorus with depth. In red soil pedons, it varied from 3.9 (pedon 1) to 86.0 kg/ha (pedon 20) while in black soil pedons, it varied from 2.0 (pedon 21) to 54.3 kg/ha (pedon 19).

4.3.6 Available micronutrients

4.3.8.1 Available zinc : In red soil pedons the available zinc content varied from 0.35 (pedon 14) to 1.51 ppm (pedon 20), whereas in black soil pedons, it ranged from 0.22 (pedons 12 and 13) to 2.02 ppm (pedon 19). No definite trends were noticed in both red and black soils in respect of available Zn status.

4.3.6.2. Available copper : No definite trend was noticed with depth in available copper content in both types of soils. In red soil pedons, the variation was from 0.22 (pedon 4) to 1.91 ppm (pedon 15) and in black soil pedons, it was 0.26 to 2.00 ppm (pedon 18).

4.3.6.3. Available iron : Irregular distribution of iron with depth was found in all the pedons studied. In red soil pedons, the available iron content ranged from 2 (pedons 11) to 68 ppm (pedons 16) and in black soil pedons, it ranged from 2 (pedons 13) to 77 ppm (pedon 19).

4.3.6.4 Available manganese : In red soil pedons, the variation of available manganese was from 4 (pedon 11) to 45 ppm (pedon 16) while in black soil pedons, it ranged from 6 (pedon 8) to 72 ppm (pedon 19).

4.3.7 Cation exchange capacity [$\text{cmol}(\text{p}^+)\text{kg}^{-1}$] and its ratio to clay per cent

Cation exchange capacity and extractable bases data are presented in Table 10.

The cation exchange capacity (CEC) values varied from 5.1 to 23.0 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ soil in red soil pedons whereas CEC/clay ratio ranged from 0.26 to 1.78. The CEC values were observed to range from 29.8 to 61.4 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ soil and CEC/clay ratios were found to vary from 0.52 to 1.27 in black soil pedons. In pedon 6, CEC varied from 17.3 to 29.6 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ soil and CEC/clay ratio ranged between 0.71 to 1.06.

4.3.8 Extractable bases [$\text{cmol}(\text{p}^+)\text{kg}^{-1}$]

4.3.8.1 Calcium: The extractable calcium per cent values indicated that the calcium was the dominant cation in the exchange complex of all the pedons. It was more than 50 per cent in most of the pedons except pedons 14, 17 and in the surface layer of pedon 20. Extractable calcium ranged from 2.6 to 16.8 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ soil in the red soil pedons studied. In black soil pedons, the range was between 14.4 and 51.8.

Table 9: Chemical properties and nutrient status of the soils

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Ap	0-22	7.1	6.2	0.15	1.8	0.64	40.3	1.31	1.05	15	33
	Bw1	22-52	7.1	6.2	0.13	8.2	0.25	8.1	0.84	1.09	11	26
	Bw2	52-77	7.2	6.0	0.10	9.0	0.20	5.6	0.53	0.76	6	19
	Bc1	77-98	7.6	6.3	0.15	8.8	0.17	3.9	0.74	0.78	8	15
	BC2	98-145	8.2	6.4	0.16	9.2	0.06					
2	Crk	145+	Weathered granite with calcium carbonate accumulation									
	Ap	0-35	7.2	6.0	0.16	2.4	0.60	13.5	1.09	1.41	11	24
	Bw	35-64	7.7	6.2	0.20	2.2	0.50	6.5	0.98	1.48	15	26
	Bss	64-105	7.8	6.4	0.21	3.5	0.48	4.3	0.70	1.42	14	15
	BC	105-154	7.9	6.5	0.20	8.2	0.45	2.6	0.46	0.78	7	23
	Crk	154-200	Weathered granite with calcium carbonate accumulation									
3	Ap	0-8	6.1	5.8	0.16	-	0.37	42.8	1.02	1.74	24	19
	Cr	8+	Weathered granite									

Contd..

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
4	Ap	0-24	6.6	5.6	0.15	0.2	0.80	20.2	1.24	1.11	21	18
	Bw1	24-68	6.6	5.7	0.12	0.2	0.50	13.2	1.57	0.84	11	18
	Bw2	68-120	6.7	6.0	0.17	0.3	0.22	10.8	1.54	0.46	10	12
	Bw3	120-170	6.9	6.2	0.18	1.5	0.06	6.4	1.06	0.36	8	14
	Bw4	170-200	7.2	6.5	0.20	4.0	0.02	7.2	1.25	0.22	4	13
5	Ap	0-31	7.9	6.5	0.21	2.5	0.45	21.7	1.88	1.19	12	36
	Bw1	31-62	8.2	6.6	0.25	2.6	0.25	18.1	1.28	1.40	19	24
	Bw2	62-97	8.3	6.6	0.36	2.6	0.22	16.8	0.83	1.07	15	33
	Bss1	97-135	8.3	6.6	0.66	4.3	0.21	13.4	0.79	1.09	25	24
	Bss2	135-172	8.1	6.7	0.10	5.1	0.15	11.9	0.62	1.02	14	22
6	Clk	172-200	8.3	6.7	0.65	10.2	0.06	10.6	0.31	0.62	13	14
	Ap	0-25	7.6	6.4	0.22	1.7	0.56	8.6	0.94	1.29	45	42
	Bw1	25-54	7.6	6.4	0.19	2.0	0.60	5.4	0.90	0.73	19	32
	Bw2	54-95	7.7	6.7	0.27	5.5	0.55	5.0	0.76	0.45	12	26
	Bck	95-132	7.8	7.0	0.20	19.8	0.52	3.6	0.69	0.45	17	24
	Crk	132+	7.9	7.0	0.20	24.4	0.45	2.2	0.45	0.30	10	20

Contd.

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
7	Ap	0-24	7.8	6.6	0.21	3.9	0.56	20.2	0.72	1.20	38	39
	Bw	24-43	8.0	6.8	0.24	4.5	0.53	21.6	0.78	1.17	28	31
	Bss1	43-79	8.3	6.8	0.27	10.2	0.46	18.6	0.40	1.28	28	33
	Bss2	79-115	8.6	6.8	0.38	9.7	0.37	5.6	0.68	0.84	19	29
	Bss3	115-152	8.9	6.9	0.56	11.5	0.22	7.7	0.42	0.72	26	24
8	Bss4	152-200	9.2	7.1	0.46	11.5	0.17	4.3	0.52	0.48	23	22
	Ap	0-18	7.7	6.6	0.22	7.5	0.37	14.2	1.22	1.85	18	6
	Bw1	18-48	7.7	6.6	0.20	7.2	0.37	12.4	1.01	1.21	17	12
	Bw2	48-90	7.7	7.1	0.20	7.6	0.25	8.2	0.83	1.36	17	14
	Bss1	90-136	7.8	7.2	0.27	7.5	0.23	7.5	0.78	1.13	16	24
9	Bss2	136-185	7.8	6.7	0.29	7.6	0.14	4.8	0.60	0.90	14	14
	Bss3	185-200	7.8	7.0	0.28	7.3	0.06	4.0	0.61	0.42	13	22
	Ap	0-30	7.1	6.2	0.15	-	0.56	15.1	0.65	0.89	12	35
	Bw1	30-66	7.3	6.2	0.23	-	0.21	8.2	0.43	0.52	7	21
	Bw2	66-90	7.4	6.2	0.28	-	0.17	6.4	0.45	0.62	4	21
Weathered granite												
	Cr	90+										

Contd.

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
10	Ap	0-14	8.1	6.6	0.28	tr	0.53	24.2	1.22	1.21	48	15
	Bw1	14-48	8.4	6.6	0.46	tr	0.41	18.6	1.11	0.58	34	13
	Bw2	48-82	8.7	6.6	0.62	4.6	0.43	10.1	0.70	0.38	44	21
	Bss1	82-110	8.8	6.7	1.07	5.0	0.37	8.6	0.68	0.56	33	21
	Bss2	110-144	8.8	6.8	1.44	4.8	0.10	4.6	0.54	0.67	24	13
11	Bss3	144-200	8.6	6.8	2.75	8.3	0.14	2.1	0.29	0.47	24	13
	Ap	0-6	6.2	5.3	0.14	-	0.80	17.6	1.47	0.70	6	14
	Bt1	6-30	5.9	5.2	0.15	-	0.72	16.6	1.05	1.25	4	9
	Bt2	30-60	6.2	5.2	0.19	-	0.56	15.2	1.02	1.11	3	4
	Bt3	60-90	6.3	5.2	0.16	-	0.56	10.1	1.41	0.67	2	5
Weathered granite												
12	Cr	90+										
	Ap	0-21	7.6	6.5	0.47	12.3	0.88	30.5	0.34	0.82	13	22
	Bw	21-34	8.0	6.6	0.26	16.7	0.14	20.1	0.22	0.56	3	19
	Bck	34-64	8.1	6.7	0.25	24.3	0.06	13.1	0.33	0.26	3	12
	Crk	64-104										
Weathered hornblende schist with calcium carbonate accumulation												

Contd..

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
13	Ap	0-20	8.0	6.7	0.32	7.0	0.72	16.7	0.46	1.28	4	22
	Bw1	20-64	8.0	6.7	0.30	8.4	0.41	13.5	0.52	1.24	4	19
	Bw2	64-105	8.0	6.8	0.38	13.8	0.37	10.1	0.36	1.12	4	16
	Ck	105-162	7.9	6.8	0.57	24.9	0.21	6.6	0.22	0.94	2	11
14	Ap	0-21	6.2	5.7	0.09	-	1.38	18.1	0.85	0.86	27	28
	Bt1	21-50	5.9	5.6	0.11	-	0.99	11.6	0.64	0.63	34	35
	Bt2	50-79	4.7	4.1	0.12	-	0.82	10.2	0.82	0.56	20	24
	Bt3	79-123	4.7	4.1	0.10	-	0.60	12.3	0.88	0.96	22	32
	Bt4	123-152	4.9	4.1	0.11	-	0.53	10.8	0.84	0.85	32	24
	Cr	152-200	4.6	4.1	0.18	-	0.21					
15	Ap	0-15	5.0	3.8	0.04	-	0.26	18.4	0.66	1.91	46	31
	Bt1	15-31	5.3	4.0	0.06	-	0.46	15.5	0.67	1.81	22	27
	Bt2	31-50	6.3	4.7	0.05	-	0.49	10.3	0.81	1.39	14	9
	Cr	50+										
Weathered granite												
16	Ap	0-21	7.2	6.3	0.14	-	0.58	15.5	0.46	0.65	53	44
	Bw1	21-40	7.3	6.2	0.09	-	0.10	9.2	0.42	0.66	49	45
	Bw2	40-60	7.6	6.5	0.08	-	0.17	6.9	0.44	0.63	49	34
	Bw3	60-81	7.6	6.8	0.05	-	0.02	7.2	0.36	0.32	38	36
	Bw4	81-95	7.4	6.7	0.06	-	0.22	4.8	0.38	0.40	68	35

Contd.

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equi- valent (%)	Organic carbon (%)	Available phos- phorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
17	Ap	0-20	8.1	6.7	0.35	6.7	1.14	13.0	0.68	1.97	39	48
	Bw1	20-50	8.6	6.6	0.44	6.5	0.58	12.3	0.64	1.80	15	39
	Bw2	50-80	8.7	6.6	0.53	6.0	0.56	10.9	0.42	1.51	29	38
	Bss1	80-120	8.6	6.7	1.11	6.4	0.53	4.3	0.40	0.56	29	46
	Bss2	120-152	8.7	6.9	1.04	6.8	0.34	4.4	0.50	0.50	30	26
18	Bss3	152-185	8.7	6.9	0.82	6.4	0.24	2.1	0.40	0.48	25	25
	Ap	0-26	7.4	5.9	0.18	tr	0.95	19.6	0.52	1.51	4	22
	Bw1	26-0	7.6	6.1	0.16	tr	0.64	16.1	0.48	1.28	3	19
	Bw2	60-97	7.8	6.1	0.18	3.2	0.64	12.6	0.42	1.54	3	14
	Bss1	97-136	7.8	6.2	0.23	3.4	0.70	6.6	0.42	2.00	5	16
19	Bss2	136-170	8.0	6.3	0.27	3.2	0.76	5.2	0.36	1.68	4	11
	Bss3	170-200	8.1	6.4	0.28	5.1	0.68	3.3	0.25	1.19	3	15
	Ap	0-20	7.9	6.6	0.76	3.8	0.82	54.3	2.02	1.15	77	72
	Bw1	20-40	8.1	6.7	0.70	4.1	0.34	38.9	1.96	1.05	72	64
	Bw2	40-60	8.2	6.7	0.59	4.3	0.37	33.1	1.56	0.86	67	66
	Bss1	60-80	8.2	6.7	0.66	4.3	0.34	21.4	1.44	0.80	69	64
	Bss2	80-110	8.2	6.6	0.65	4.2	0.37	11.8	1.25	0.63	59	54
	Bss3	110-140	8.2	6.7	0.53	4.5	0.22	12.9	1.18	0.83	47	58
	Bss4	140-165	8.3	6.7	0.61	4.6	0.35	8.2	1.14	0.50	48	43
	Bss5	165-200	8.2	6.7	0.61	5.2	0.41	4.5	1.10	0.61	36	43

Contd.

Pedon	Horizon	Depth (cm)	pH (1:2.5)		EC (1:2.5) dSm ⁻¹	CaCO ₃ equivalent (%)	Organic carbon (%)	Available phosphorus (kg/ha)	Available micronutrients (Mg Kg ⁻¹)			
			H ₂ O	1N KCl					Zn	Cu	Fe	Mn
1	2	3	4	5	6	7	8	9	10	11	12	13
20	Ap	0-14	6.6	5.5	0.09	-	1.14	86.0	1.51	1.17	30	34
	Bw	14-26	6.1	5.2	0.08	-	0.90	29.3	1.45	1.57	24	17
	Bt1	26-50	6.4	5.2	0.06	-	0.60	14.3	0.73	1.43	25	14
	Bt2	50-69	6.3	5.2	0.07	-	0.46	11.3	0.77	1.38	26	13
	Bt3	69-80	6.3	5.1	0.06	-	0.53	13.5	0.67	0.97	16	16
	Bt4	80-95	6.1	5.1	0.08	-	0.54	11.7	0.61	0.90	14	18
	BC	95-120	6.1	5.0	0.07	-	0.30	8.4	0.62	0.94	19	13
21	Ap	0-15	7.7	6.2	0.19	tr	0.82	15.3	0.81	1.04	59	57
	Bw1	15-35	8.0	6.4	0.20	tr	0.46	10.1	0.72	1.08	62	43
	Bw2	35-52	8.0	6.5	0.19	3.9	0.56	8.7	0.66	0.79	60	45
	Bw3	52-71	8.0	6.5	0.21	4.7	0.46	6.8	0.63	0.71	45	32
	Bw4	71-97	8.0	6.6	0.20	5.6	0.53	5.4	0.63	0.72	44	32
	BC	97-120	8.1	6.8	0.22	14.5	0.42	3.2	0.71	0.43	40	34
	Ck	120+	8.1	7.2	0.21	24.1	0.18	2.0	0.66	0.45	35	25
22	Ap	0-15	7.2	5.9	0.10	-	0.30	10.9	0.53	1.71	6	16
	Bt	15-28	7.5	6.0	0.08	-	0.42	10.4	0.65	1.75	7	10
	C	28+										
Weathered granite												

tr : traces

4.3.8.2 Magnesium: The data on magnesium content indicated that it was the second dominant cation in the exchange complex of all the pedons. It varied from 0.6 to 5.0 $\text{cmol(p}^+\text{)kg}^{-1}$ soil in the red soil pedons, whereas in black soil pedons, it ranged from 1.1 to 27.4. Lower values of ex.Ca/ex.Mg (ranging from 0.7 to 1.8) were found in pedon 17 and except surface layer in pedon 7, which indicated the increase in extractable magnesium content in soils.

4.3.8.3 Sodium: The extractable sodium in black soils was higher than red soils. In black soils extractable sodium content varied from traces to 20.2 $\text{cmol(p}^+\text{)kg}^{-1}$ while in red soils, it ranged from traces to 0.8 $\text{cmol(p}^+\text{)kg}^{-1}$. In general, in black soils there was an increasing trend with depth, whereas red soil pedons did not show any trend. In pedon 10, exchangeable sodium per cent (ESP) increased with depth, ranging from 4 to 36. It was found that sodicity also increased with depth in pedon 17 where ESP ranged from 2 to 18.

4.3.8.4 Potassium: In studied soils, this value varied from 0.1 to 1.1 $\text{cmol(p}^+\text{)kg}^{-1}$. In general, there was decreasing trend with depth in all the pedons, except in pedons 10, 15 and 22, where increasing trend was found. Nearly uniform distribution was observed in pedons 11, 18 and 21. No trend was found in pedons 7, 13 and 19.

4.3.9 Base saturation (BS)

The BS was nearer to 100 per cent in most of the pedons except surface layers in pedons 4, 11 and 15. The per cent base saturation was lowest in pedon 14.

Table 10: Ion exchange data of soils

Pedon	Horizon	Depth (cm)	Extractable bases						CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum						
								-----cmol(p ⁺) kg ⁻¹ -----					
1	2	3	4	5	6	7	8	9	10	11	12	13	
1	Ap	0-22	13.4	2.5	tr	0.3	16.2	16.1	tr	0.52	5.4	100	
	Bw1	22-52	13.6	2.7	tr	0.2	16.5	16.1	tr	0.66	5.0	100	
	Bw2	52-77	13.8	3.0	tr	0.2	17.0	16.6	tr	0.80	4.6	100	
	BC1	77-98	14.1	3.1	0.2	0.2	17.6	17.0	1	1.57	4.5	100	
	BC2	98-145	13.1	2.7	0.1	0.2	16.1	15.1	1	1.78	4.8	100	
Weathered granite with calcium carbonate accumulation													
2	Crk	145+											
	Ap	0-35	46.3	7.8	tr	0.4	54.5	53.2	tr	0.77	5.9	100	
	Bw	35-64	48.2	7.8	tr	0.4	56.4	55.2	tr	0.80	6.2	100	
	Bss	64-105	51.8	8.0	tr	0.4	60.2	58.9	tr	0.84	6.5	100	
	Bc	105-154	35.1	4.2	tr	0.3	39.6	37.8	tr	0.68	8.4	100	
Weathered granite with calcium carbonate accumulation													
3	Crk	154-200											
	Ap	0-8	5.0	1.1	0.5	0.1	6.7	6.9	7	0.79	4.4	97	
Weathered granite													
	Cr	8+											

Contd.

Pedon	Horizon	Depth (cm)	Extractable bases					CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum					
			-----cmol(p ⁺) kg ⁻¹ -----									
1	2	3	4	5	6	7	8	9	10	11	12	13
	Ap	0-24	9.1	3.7	tr	0.3	13.1	14.9	tr	0.66	2.5	88
	Bw1	24-68	9.2	2.9	tr	0.1	12.2	14.2	tr	0.74	3.2	86
	Bw2	68-120	10.0	3.1	0.1	0.1	13.3	14.6	1	0.88	3.2	91
	Bw3	120-170	11.2	3.3	0.1	0.1	14.7	14.8	1	0.91	3.4	99
4	Bw4	170-200	14.4	3.6	0.3	0.1	18.4	17.6	2	1.04	4.0	100
	Ap	0-31	26.3	9.6	0.4	0.3	36.6	36.5	1	0.67	2.7	100
	Bw1	31-62	31.0	9.3	1.9	0.1	42.3	42.0	4	0.74	3.3	100
	Bw2	62-97	35.0	10.2	2.1	0.1	47.4	46.8	5	0.80	3.4	100
	Bss1	97-135	32.0	11.5	2.9	0.1	46.5	46.5	6	0.80	2.8	100
5	Bss2	135-172	28.0	12.3	5.0	0.2	47.3	43.5	11	0.75	2.3	100
	Ck	172-200	20.3	9.6	4.8	0.1	34.8	31.8	15	0.72	2.1	100
	Ap	0-25	15.6	1.1	tr	0.3	17.0	17.3	tr	0.71	14.2	98
	Bw1	25-54	16.2	1.5	tr	0.3	18.0	18.2	tr	0.71	10.8	99
	Bw2	54-95	26.6	2.8	tr	0.3	29.7	29.6	tr	1.06	9.5	100
6	Bck	95-132	22.0	2.9	tr	0.3	25.2	25.0	tr	0.79	7.6	100
	Crk	132+	21.6	3.1	0.3	0.1	25.1	24.6	1	0.82	7.0	100

Contd.

Pedon	Horizon	Depth (cm)	Extractable bases					CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)	
			Ca	Mg	Na	K	Sum						
													-----cmol(p ⁺) kg ⁻¹ -----
1	2	3	5	6	7	8	9	10	11	12	13	14	
7	Ap	0-24	32.4	9.2	tr	0.4	42.0	42.0	tr	0.70	3.5	100	
	Bw	24-43	25.3	14.3	0.4	0.1	40.1	40.9	1	0.72	1.8	98	
	Bss1	43-79	22.3	17.0	1.4	0.2	40.9	40.6	3	0.77	1.3	100	
	Bss2	79-115	20.5	18.3	2.3	0.2	41.3	41.0	6	0.79	1.1	100	
	Bss3	115-152	16.0	19.1	5.4	0.2	40.7	40.4	13	0.81	0.8	100	
8	Bss4	152-200	14.4	20.0	6.1	0.2	40.7	40.2	15	0.90	0.7	100	
	Ap	0-18	41.1	7.9	0.1	0.3	49.4	49.6	tr	1.05	5.2	100	
	Bw1	18-48	42.6	7.4	0.3	0.2	50.5	50.6	1	1.09	5.8	100	
	Bw2	48-90	42.0	9.5	0.1	0.2	51.8	52.0	tr	1.05	4.4	100	
	Bss1	90-136	38.5	12.4	0.4	0.2	51.5	51.5	1	1.03	3.1	100	
9	Bss2	136-185	39.2	17.1	0.3	0.2	56.8	56.6	1	1.17	2.3	100	
	Bss3	185-200	36.5	18.0	0.6	0.1	55.2	55.2	1	1.27	2.0	100	
	Ap	0-30	9.4	3.7	tr	0.3	13.4	13.5	tr	0.80	2.5	99	
	Bw1	30-66	11.0	3.1	tr	0.3	14.4	14.6	tr	0.63	3.5	99	
	Bw2	66-90	10.5	3.5	0.3	0.4	14.7	14.9	2	0.61	3.0	99	
	Cr	90+	Weathered granite										

Contd

Pedon	Horizon	Depth (cm)	Extractable bases					CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum					
1	2	3	4	5	6	7	8	9	10	11	12	13
10	Ap	0-14	33.5	12.5	2.2	0.2	48.4	48.5	4	0.79	2.7	100
	Bw1	14-48	31.0	14.4	5.4	0.2	51.0	50.9	11	0.88	2.1	100
	Bw2	48-82	31.5	15.2	9.7	0.2	56.6	56.3	17	0.95	2.1	100
	Bss1	82-110	25.0	17.2	15.0	0.2	57.4	56.6	26	1.06	1.4	100
	Bss2	110-144	23.5	17.9	19.9	0.3	61.6	61.4	32	1.17	1.3	100
11	Bss3	144-200	20.1	18.3	20.2	0.3	58.9	55.8	36	1.11	1.1	100
	Ap	0-6	4.5	1.9	tr	0.2	6.6	7.7	tr	0.57	2.4	86
	Bt1	6-30	10.5	2.1	0.1	0.2	12.9	14.5	1	0.57	5.0	89
	Bt2	30-60	10.6	4.6	0.4	0.2	15.8	16.2	2	0.67	2.3	97
	Bt3	60-90	11.3	4.5	0.6	0.2	16.6	17.7	3	0.50	2.5	94
12	Cr	90+	12.8	4.8	0.8	0.2	18.6	19.5	4	0.52	2.7	95
	Ap	0-21	24.2	13.2	0.3	0.2	37.9	37.6	1	0.89	1.8	100
	Bw	21-34	24.8	10.2	0.9	0.2	36.1	36.0	2	0.93	2.4	100
	Bck	34-64	22.0	7.6	0.5	0.1	30.2	29.8	2	0.89	2.9	100
	Crk	64-104										
Weathered hornblende schist with calcium carbonate accumulation												

Contd..

Pedon	Horizon	Depth (cm)	Extractable bases						CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum						
	2	3	4	5	6	7	8	9	10	11	12	13	
13	Ap	0-20	40.8	4.5	0.5	0.3	46.1	45.1	1	0.99	9.1	100	
	Bw1	20-64	38.2	5.2	0.7	1.1	45.2	44.6	2	0.92	7.3	100	
	Bw2	64-105	44.0	7.2	0.8	0.2	52.2	51.3	2	1.00	6.1	100	
	Ck	105-162	39.7	8.2	0.8	0.1	48.8	48.6	2	0.96	4.8	100	
14	Ap	0-21	5.1	1.0	0.3	0.2	6.6	10.2	3	1.73	5.1	65	
	Bt1	21-50	4.2	1.5	tr	0.2	5.9	8.4	tr	0.76	2.8	70	
	Bt2	50-79	2.6	1.6	tr	0.1	4.3	10.3	tr	0.43	1.6	42	
	Bt3	79-123	3.0	1.5	0.1	0.2	4.8	11.1	1	0.36	2.0	43	
	Bt4	123-152	3.4	1.4	tr	0.1	4.9	7.7	tr	0.27	2.4	64	
	Cr	152-200	3.8	2.0	tr	0.1	5.9	9.4	tr	0.26	1.9	63	
15	Ap	0-15	2.8	0.9	tr	0.2	3.9	5.1	tr	0.50	3.1	76	
	Bt1	15-31	10.6	2.6	0.2	0.2	13.6	18.2	1	0.87	4.1	75	
	Bt2	31-50	14.8	4.8	0.7	0.3	20.6	23.0	3	0.90	3.1	90	
	Cr	50+	Weathered granite										

Contd.

Pedon	Horizon	Depth (cm)	Extractable bases					CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum					
1	2	3	4	5	6	7	8	9	10	11	12	13
16	Ap	0-21	6.6	1.9	tr	0.3	8.8	9.1	tr	0.40	3.5	97
	Bw1	21-40	6.8	1.4	tr	0.3	8.5	8.7	tr	0.42	4.8	98
	Bw2	40-60	7.0	1.0	tr	0.2	8.2	8.2	tr	0.46	7.0	100
	Bw3	60-81	6.7	0.6	0.1	0.2	7.6	7.6	1	0.47	11.2	100
	Bw4	81-95	10.4	0.8	tr	0.2	11.4	11.5	tr	0.41	13.0	99
17	Ap	0-20	38.0	21.6	1.1	0.6	61.3	61.0	2	0.84	1.8	100
	Bw1	20-50	30.2	25.3	3.7	0.5	59.7	59.5	6	0.81	1.2	100
	Bw2	50-80	26.5	26.1	5.2	0.5	58.3	58.2	9	0.78	1.0	100
	Bss1	80-120	21.7	27.4	10.0	0.4	59.5	59.3	17	0.78	0.8	100
	Bss2	120-152	21.2	26.0	9.4	0.4	57.0	56.8	17	0.73	0.8	100
18	Bss3	152-185	21.4	2.8	10.2	0.3	57.7	57.6	18	0.74	0.8	100
	Ap	0-26	42.8	12.5	tr	0.2	55.5	55.7	tr	0.97	3.4	100
	Bw1	26-0	39.3	13.7	0.2	0.2	53.4	53.5	tr	0.98	2.9	100
	Bw2	60-97	35.2	15.9	0.7	0.2	52.0	52.3	1	0.99	2.2	99
	Bss1	97-136	38.2	16.3	0.8	0.2	55.5	55.6	1	1.02	2.3	100
	Bss2	136-170	38.0	18.4	0.9	0.2	57.5	57.4	2	1.12	2.1	100
	Bss3	170-200	38.3	18.6	0.9	0.2	58.0	58.0	2	1.10	2.1	100

Contd..

Pedon	Horizon	Depth (cm)	Extractable bases						CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			-----cmol(p ⁺) kg ⁻¹ -----										
			Ca	Mg	Na	K	Sum						
1	2	3	4	5	6	7	8	9	10	11	12	13	
19	Ap	0-20	21.8	11.7	2.1	0.8	36.4	36.4	6	0.52	1.9	100	
	Bw1	20-40	21.8	15.9	2.1	0.6	40.4	40.2	5	0.57	1.4	100	
	Bw2	40-60	23.3	16.3	2.2	0.5	42.3	42.3	5	0.60	1.4	100	
	Bss1	60-80	23.8	17.6	2.3	0.4	44.1	44.1	5	0.61	1.3	100	
	Bss2	80-110	20.0	18.0	2.4	0.4	40.8	40.6	6	0.54	1.1	100	
	Bss3	110-140	20.8	18.2	2.2	0.4	41.6	41.6	5	0.56	1.1	100	
	Bss4	140-165	20.0	18.6	2.1	0.5	41.2	40.9	5	0.53	1.1	100	
	Bss5	165-200	22.1	19.4	1.5	0.6	43.6	43.5	3	0.57	1.1	100	
20	Ap	0-14	3.8	1.9	0	0.3	6.0	9.0	0	0.34	2.0	67	
	Bw	14-26	8.8	2.2	0.1	0.2	11.3	11.6	1	0.37	4.0	97	
	Bt1	26-50	14.3	4.6	0.4	0.3	19.6	20.0	2	0.36	3.1	98	
	Bt2	50-69	13.0	5.0	0.6	0.3	18.9	19.1	3	0.36	2.6	99	
	Bt3	69-80	13.1	4.5	0.7	0.3	18.6	18.9	4	0.34	2.9	98	
	Bt4	80-95	13.2	4.1	0.4	0.3	18.0	18.3	2	0.33	3.2	98	
	BC	95-120	11.7	3.8	0.4	0.3	16.2	16.5	2	0.32	3.1	98	

Contd.

Pedon	Horizon	Depth (cm)	Extractable bases					CEC	Exchan- geable sodium (%)	CEC ----- Clay	Exch. Ca/Mg	Base satura- tion (%)
			Ca	Mg	Na	K	Sum					
			-----cmol(p) kg ⁻¹ -----									
1	2	3	4	5	6	7	8	9	10	11	12	13
21	Ap	0-15	36.8	5.0	0.2	0.3	42.3	42.3	tr	0.75	7.4	100
	Bw1	15-35	36.8	5.7	0.2	0.3	43.0	42.8	tr	0.77	6.5	100
	Bw2	35-52	39.2	6.5	0.5	0.3	46.5	46.4	1	0.84	6.0	100
	Bw3	52-71	37.0	8.6	0.3	0.3	46.2	46.0	1	0.86	4.3	100
	Bw4	71-97	33.0	8.8	0.3	0.3	42.4	42.1	1	0.84	3.7	100
	Bc	97-120	29.3	10.5	0.2	0.3	40.3	39.8	1	0.87	2.8	100
22	Ck	120-	22.2	8.4	0.2	0.3	31.1	30.4	1	0.98	2.6	100
	Ap	0-15	6.9	1.2	tr	0.2	8.3	8.4	tr	1.53	5.7	99
	Bt	15-28	16.8	2.1	tr	0.3	19.2	19.3	tr	0.86	8.0	99
	c	28-	Weathered granite									

tr : traces

4.4 MINERALOGICAL CHARACTERISTICS

Mineralogical data are prerequisite for classification of soils at lower category levels and for predicting the physico-chemical behaviour of the soils. The minerals from sand fractions of the soils help to understand about the parent material, environment of deposition and weathering processes involved in their formation and the stage of soil evolution.

4.4.1 Sand mineralogy

The relative per cent of light and heavy minerals in sand fraction of the selected horizons of the studied profiles is presented in Tables 11a and 11b.

4.4.1.1 Light minerals: Light minerals quartz, orthoclase, plagioclase and mica (muscovite and biotite) were observed in the sand fractions of these soils. Quartz was the dominant mineral, followed by feldspars (orthoclase, plagioclase) and mica. Microcline occurs in traces in Tandur pedon (pedon 18). From traces to small amounts of biotite and muscovite were also found in these soils.

Except pedon 12, which had only 63.3 per cent light minerals in the Ck horizon and 85.1 per cent in the surface soil, remaining pedons had 93.9 to 99.9 per cent of light minerals.

4.4.1.2 Heavy minerals: The Ck horizon of Wyrā pedon (pedon 12) recorded highest values of heavy minerals (36.7 per cent), followed by 14.9 per cent in

the surface soil of the same pedon. In the remaining samples, the content ranged between 0.1 to 7.2 per cent.

Epidote, garnet, zircon, hornblende, pyroxenes and opaque minerals were the heavy minerals found in these soils. Opaque minerals consisted mostly of iron ore minerals like ilmenite, limonite, magnetite and haematite.

The abundance of pyroxenes and hornblende was more in black soils when compared with red soils. In the surface layers of red soils (Pedons 11, 14, 22), zircon constituted more than 50 per cent of the heavy minerals. Among opaque minerals, ilmenite was the dominant mineral in the soils. Sand samples of red soils constituted more percentage of opaque minerals than that of black soils. Magnetite content was found more in pedons 1, 2, 15, 18 and 21 than in other soils.

4.4.2 Clay mineralogy

The data on semi-quantitative estimation of minerals in clay fraction (per cent) are presented in Table 12.

4.4.2.1 Clays of shallow (<50 cm) red soils: Karimnagar pedon (pedon 3) was studied to represent <50 cm deep red soils in the study area. X-ray diffraction patterns were obtained for clay samples from Ap and Cr horizons. The results are represented in Figs.8a and 8b. The diffraction pattern of clay

Table 11a: Light mineral assemblages (%) in the sand fraction

Pedon	Horizon	Depth (cm)	Percentage light minerals	Quartz	Orthoclase	Plagioclase	Biotite	Muscovite
1	Ap	0-22	92.8	52.8	21.6	tr	9.8	15.8
2	Ap	0-35	96.0	41.5	33.2	5.6	8.6	11.1
3	Ap	0-8	98.7	59.2	38.4	tr	tr	2.4
	Cr	35-72	98.9	68.5	30.6	-	tr	0.9
4	Ap	0-24	99.5	60.1	39.9	tr	-	tr
5	Ap	0-31	99.7	59.5	32.2	8.3	tr	-
6	Ap	0-25	99.5	58.0	42.0	tr	-	tr
7	Ap	0-24	99.1	53.0	37.8	9.2	tr	tr
	Bss1	43-79	99.6	50.7	38.8	10.5	-	tr
	Bss4	452-200	99.8	42.8	40.2	17.0	-	tr
8	Ap	0-18	99.8	75.2	22.5	tr	2.3	-
9	Ap	0-30	99.8	52.3	39.3	-	tr	8.4
10	Ap	0-14	99.6	62.6	28.0	9.4	-	-
11	Ap	0-6	99.8	51.5	28.0	tr	tr	20.5
12	Ap	0-21	85.1	55.6	35.4	9.0	tr	-
	Crk	64-104	63.3	67.3	22.2	8.5	tr	2.0
13	Ap	0-20	99.9	55.8	23.5	9.2	tr	11.5

Contd..

Pedon	Horizon	Depth (cm)	Percentage light minerals	Quartz	Orthoclase	Plagioclase	Biotite	Muscovite
14	Ap	0-21	99.0	85.4	9.8	-	tr	4.8
	Bt2	50-79	98.9	92.4	5.0	-	tr	2.6
	Cr	152-200	98.3	95.8	4.2	tr	-	tr
15	Ap	0-15	99.8	52.1	45.8	-	-	2.1
16	Ap	0-21	99.0	93.5	36.5	-	tr	tr
17	Ap	0-20	99.5	58.2	38.0	3.8	tr	-
18	Ap	0-26	93.9	91.8	8.2	-	tr	-
19	Ap	0-20	99.2	62.8	31.2	-	6.0	tr
20	Ap	0-14	99.0	55.4	43.8	-	-	0.8
	Bt1	26-50	99.2	55.8	42.7	-	tr	1.5
	BC	95-120	99.7	60.8	39.2	tr	-	tr
21	Ap	0-15	99.8	48.4	32.8	tr	7.2	11.6
	Bw3	52-71	99.6	51.5	31.5	tr	6.8	10.2
	Ck	120+	99.0	57.8	33.0	tr	tr	9.2
22	Ap	0-15	99.8	60.8	34.5	-	-	4.7

Table 11b: Heavy mineral assemblages (%) in the sand fraction

Pedon	Horizon	Depth (cm)	Percentage heavy minerals	Epidote	Garnet	Zircon	Pyroxene	Hornblende	Opaque minerals
1	Ap	0-22	7.2	18.2	15.4	tr	tr	tr	66.4
2	Ap	0-35	4.0	45.4	tr	tr	3.3	9.0	42.3
3	Ap	0-8	1.3	25.6	25.4	15.3	tr	tr	33.7
	Cr	35-72	1.1	32.3	45.0	-	-	-	22.7
4	Ap	0-24	0.5	47.8	tr	31.4	-	-	20.8
5	Ap	0-31	0.3	18.8	tr	-	30.3	25.3	25.6
6	Ap	0-25	0.5	20.2	33.2	-	10.2	14.6	21.8
7	Ap	0-24	0.9	19.6	tr	11.9	16.2	27.8	24.5
	Bss1	43-79	0.4	28.7	tr	-	29.7	29.3	12.3
	Bss4	152-200	0.2	26.5	tr	-	15.5	39.6	18.4
8	Ap	0-18	0.2	10.0	tr	-	17.6	31.6	40.8
9	Ap	0-30	0.2	25.2	31.0	tr	12.4	9.8	21.6
10	Ap	0-14	0.4	16.3	26.3	tr	18.4	20.1	18.9
11	Ap	0-6	0.2	tr	16.1	50.2	-	8.2	25.5
12	Ap	0-21	14.9	35.4	tr	-	-	27.0	37.6
	Crk	64-104	36.7	31.5	8.2	-	-	30.0	30.3
13	Ap	0-20	0.1	16.9	6.6	-	13.8	37.1	25.6

Contd..

Pedon	Horizon	Depth (cm)	Percentage light minerals	Quartz	Orthoclase	Plagioclase	Biotite	Muscovite	
14	Ap	0-21	1.0	5.8	9.1	63.5	-	-	21.6
	Bt2	50-79	1.1	18.3	19.7	36.5	-	tr	25.5
	Cr	152-200	1.7	14.5	22.3	29.4	-	tr	33.8
15	Ap	0-15	0.2	20.1	13.4	21.9	-	tr	44.6
16	Ap	0-21	1.0	31.4	19.9	tr	-	tr	48.7
17	Ap	0-20	0.5	28.8	tr	18.7	15.6	14.6	22.3
18	Ap	0-26	6.1	13.0	-	-	32.8	18.6	35.6
19	Ap	0-20	0.8	22.8	-	20.8	12.1	26.1	18.2
20	Ap	0-14	1.0	17.4	23.8	tr	-	tr	58.8
	Bt1	26-50	0.8	26.4	13.5	tr	tr	tr	60.1
	BC	95-120	0.3	28.7	tr	11.0	tr	tr	60.3
21	Ap	0-15	0.2	18.3	tr	-	28.8	19.7	33.2
	Bw3	52-71	0.4	17.8	tr	-	23.7	22.6	35.9
	Ck	120+	1.0	22.8	tr	-	29.7	25.4	22.1
22	Ap	0-15	0.2	30.2	10.7	50.7	tr	tr	8.4

Table 12: Semi quantitative estimation of minerals (per cent) in clay fraction

S. No.	Location	Horizon	Depth (cm)	Kaolinite	Mica	Vermiculite	Smectite	Chlorite	Quartz	Feldspars
3	Karimnagar	Ap Cr	0-8 35-72	23 42	15 12	4 Tr	14 18	- -	35 28	9 -
7	Adilabad	Ap Bss1 Bss4	0-24 43-79 152-200	6 5 4	2 2 3	5 Tr Tr	73 71 66	- 9 14	14 13 11	- - 2
12	Wyra	Ap Crk	0-21 64-104	2 2.5	1 1.5	Tr Tr	65 80	20 -	12 16	- -
14	Aswaraopet	Ap Bt2 Cr	0-21 50-79 152-200	72 65 76	18 14 12	Tr - -	- - -	- - -	10 21 12	- - -
20	Sangareddi (red)	Ap Bt1 BC	0-14 26-50 95-120	57 59 70	14 14 10	1 3 Tr	7 4 1	- - -	20 20 19	1 - -
21	Sangareddi (black)	Ap Bw3 Ck	0-15 52-71 125+	4 5 8	2 2 1	Tr Tr Tr	73 69 77	- 8 5	21 16 9	- - Tr

samples from Ap horizon (Fig.8a) indicated the presence of kaolinite, mica, vermiculite and smectite.

The presence of kaolinite was established by the basal reflection around $7\text{\AA}$. The position of the basal reflection was not affected by both glycol treatment or K saturation at room temperature (25°C). However, these peaks disappeared upon heating to 550°C .

The presence of mica was established by the basal reflection around $10\text{\AA}$ and a second order reflection around $5\text{\AA}$. The basal reflection around $10\text{\AA}$ was not affected by either glycol treatment or heating after K saturation.

The presence of vermiculite was suspected by the presence of peak around $14\text{\AA}$ of Ca-saturated and glycolated sample. On K saturation, $10\text{\AA}$ peak was intensified and its intensity got further reinforced with progressive heating from 110°C to 550°C establishing the presence of vermiculite. However, some shoulders appeared at the low angle side of $10\text{\AA}$ peak. This noncollapsibility of $10\text{\AA}$ indicated that the vermiculites were chloritised.

The presence of smectite was established by the basal reflection of the Ca-saturated clay sample around $14\text{\AA}$ which expands to around $17\text{\AA}$ on glycolation. These basal reflections collapsed to about $12\text{\AA}$ upon K saturation and $10\text{\AA}$ after heating to 550°C .

Apart from these clay minerals, non-clay minerals like quartz and feldspars were also present. The presence of quartz was established by the peak at $3.35\text{\AA}$, and feldspars by the peak around $3.2\text{\AA}$.

The above criteria were followed in the identification of clay minerals in the other samples also.

A study of the diffraction pattern of the clay sample from Cr horizon of Karimnagar pedon established the presence of same clay minerals as observed in A horizon viz., kaolinite, mica, vermiculite and smectite (Fig.8b). Traces of vermiculite were present in the C horizon. From the intensities of the peaks, the dominance of clay minerals was inferred and could be listed as kaolinite > smectite > mica > vermiculite. From the intensity of peaks, it could also be inferred that the amount of kaolinite and smectite increased with depth, whereas the quantity of mica and vermiculite decreased with depth.

4.4.2.2 Clays of medium deep (50-100 cm) red soils: Sangareddi red soil (pedon 20) was studied to represent 50-100 cm deep red soils in the study area. The clay samples from Ap, Bt1 and BC horizons of this pedon were subjected to X-ray analysis.

In this pedon, the X-ray diffraction pattern and the intensity of peaks of these horizons indicated the presence of kaolinite, mica, smectite and vermiculite in that order of dominance. Kaolinite was dominating in the horizons with highest

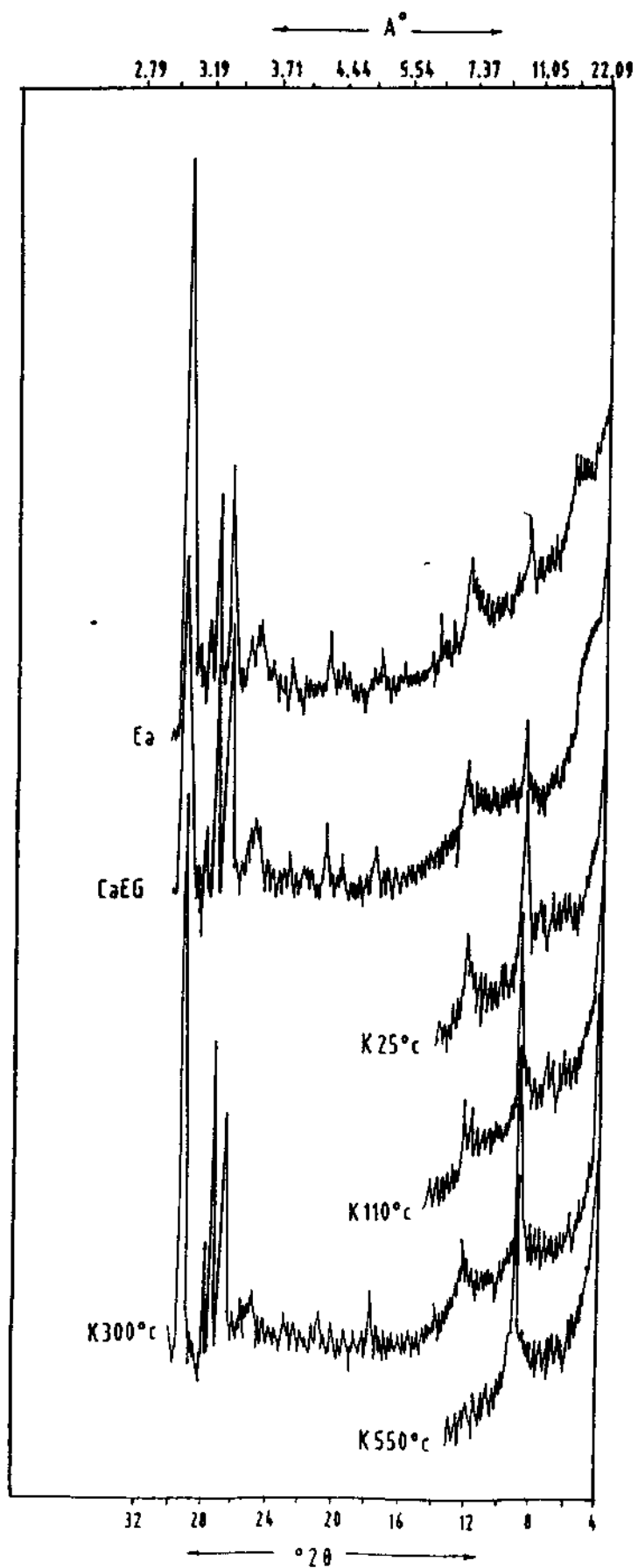


Fig 8a: X-ray diffractograms of clay fraction ($< 2 \mu\text{m}$) from the Ap horizon of pedon 3

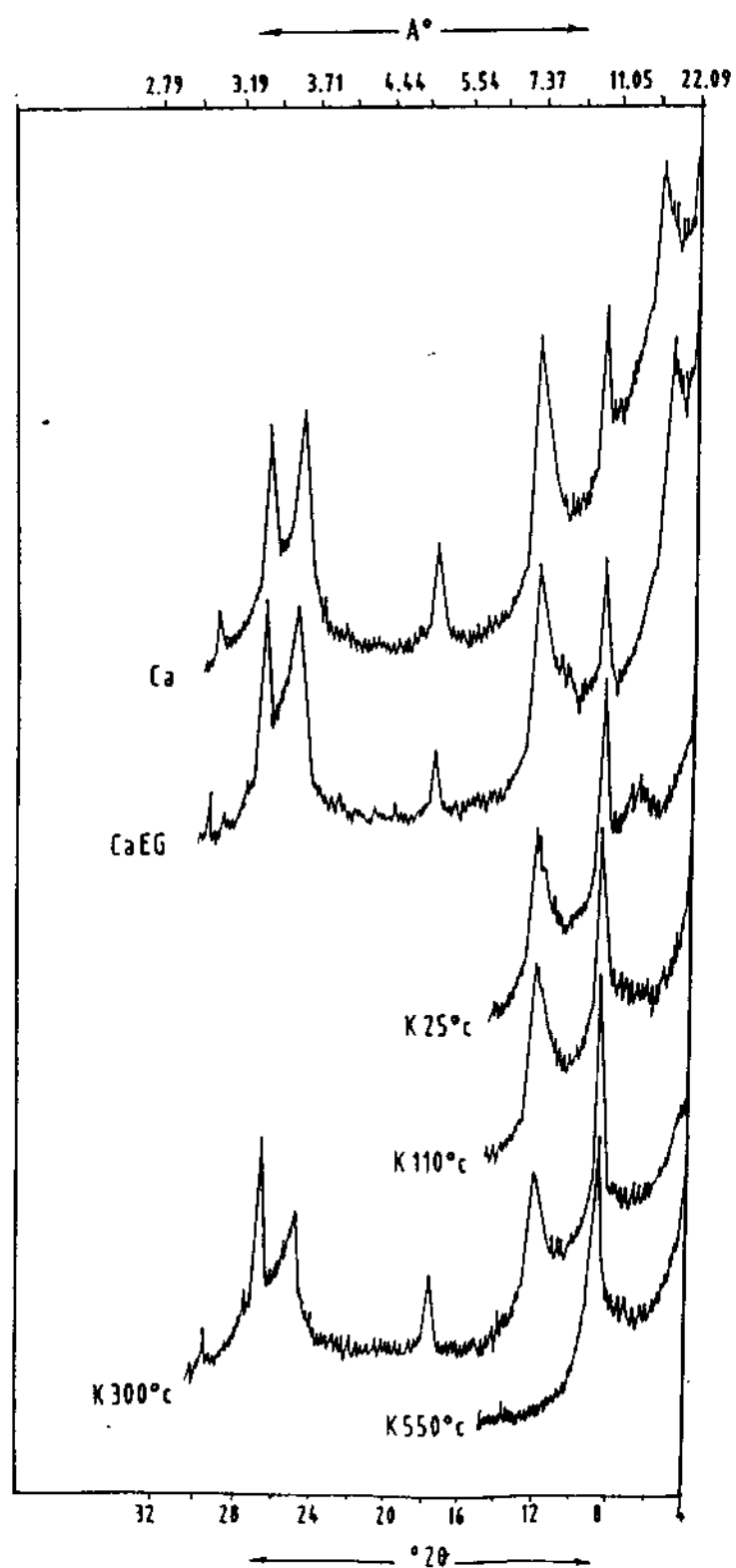


Fig. 8b: X-ray diffractograms of clay fraction (< 2 μm) from the Cr horizon of pedon 3.

quantity in BC horizon (Figs.9a, 9b and 9c). Smectite content decreased with depth. Mica content was uniform in Ap and Bt1 horizons and decreased in BC horizon. Non clay minerals like quartz and feldspars were also present in the pedon (Table 11).

4.4.2.3 Clays of deep (> 100 cm) red soils: Aswaraopet pedon (pedon 14) was studied to represent deep red soils in the study area. The clay samples from Ap, Bt2 and Cr horizons of this pedon were subjected to x-ray analysis (Figs.10a to 10c) and the results are presented below.

The X-ray diffraction analysis indicated the presence of kaolinite, mica and vermiculite in order of dominance. Vermiculite was present in the surface horizon in traces. Non clay mineral like quartz was also observed in this pedon. Feldspars were absent.

4.4.2.4 Clays of shallow (<50 cm) black soils: Wyra (pedon 12) was selected to represent the shallow black soils of study area for the x-ray diffraction analysis. The samples from Ap and Crk horizons of Wyra pedon were subjected to X-ray analysis. The X-ray diffraction pattern and the intensity of peaks of Ap horizon indicated that the smectite content was dominating followed by chlorite. The remaining clay minerals identified in this horizon were kaolinite, mica and vermiculite in order of dominance. Traces of vermiculite were observed. Non clay mineral, quartz was also present. The diffraction pattern of Crk horizon established the presence of smectite, kaolinite, mica and vermiculite in order

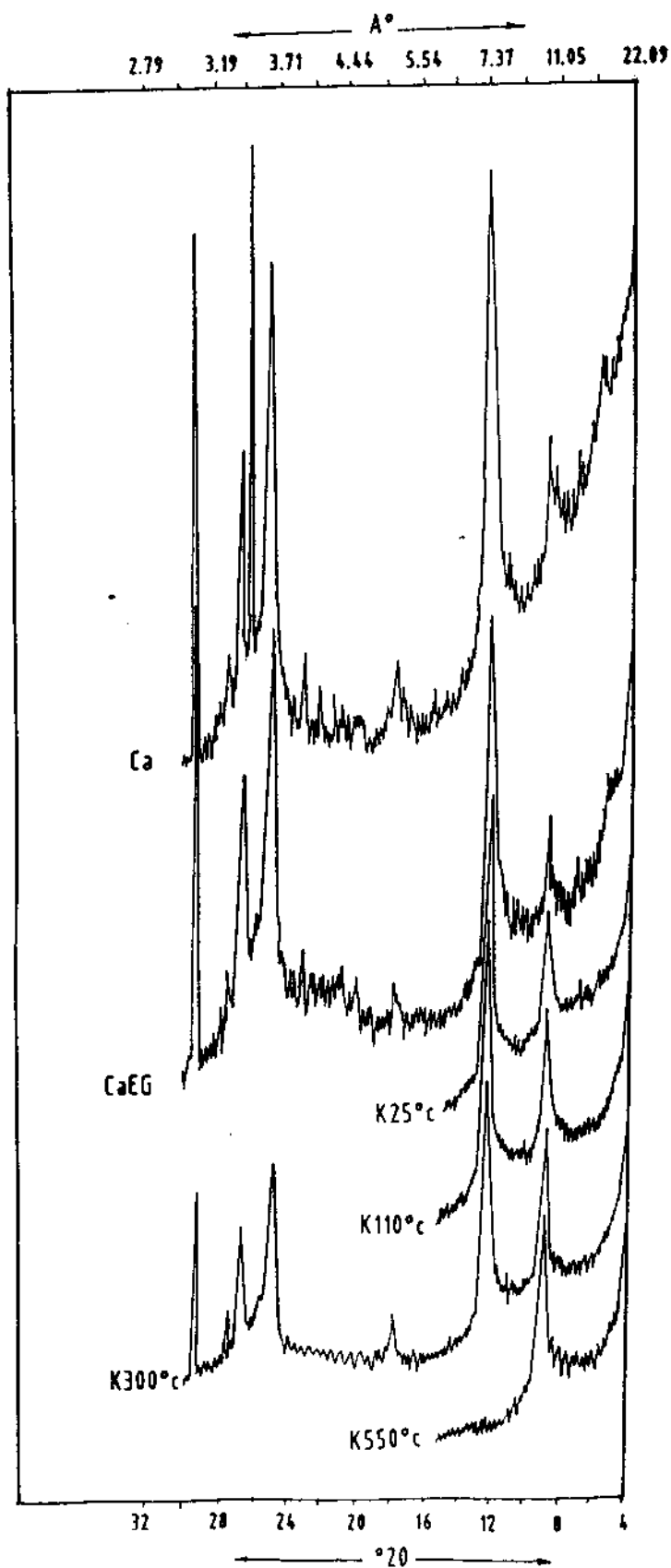


Fig. 9a. X-ray diffractograms of clay fraction (< 2 μm) from the Ap horizon of pedon 20.

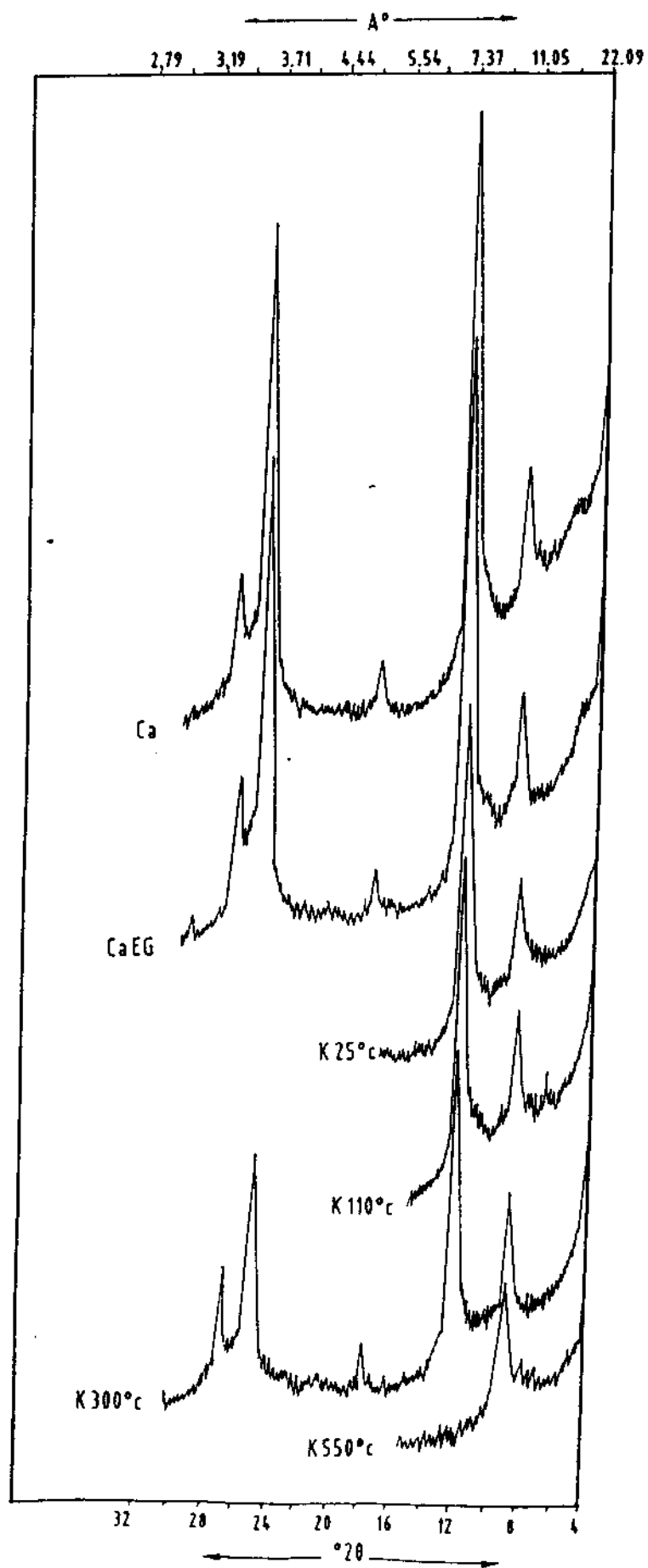


Fig. 9b. X-ray diffractograms of clay fraction (< 2 μm) from the Bt₁ horizon of pedon 20

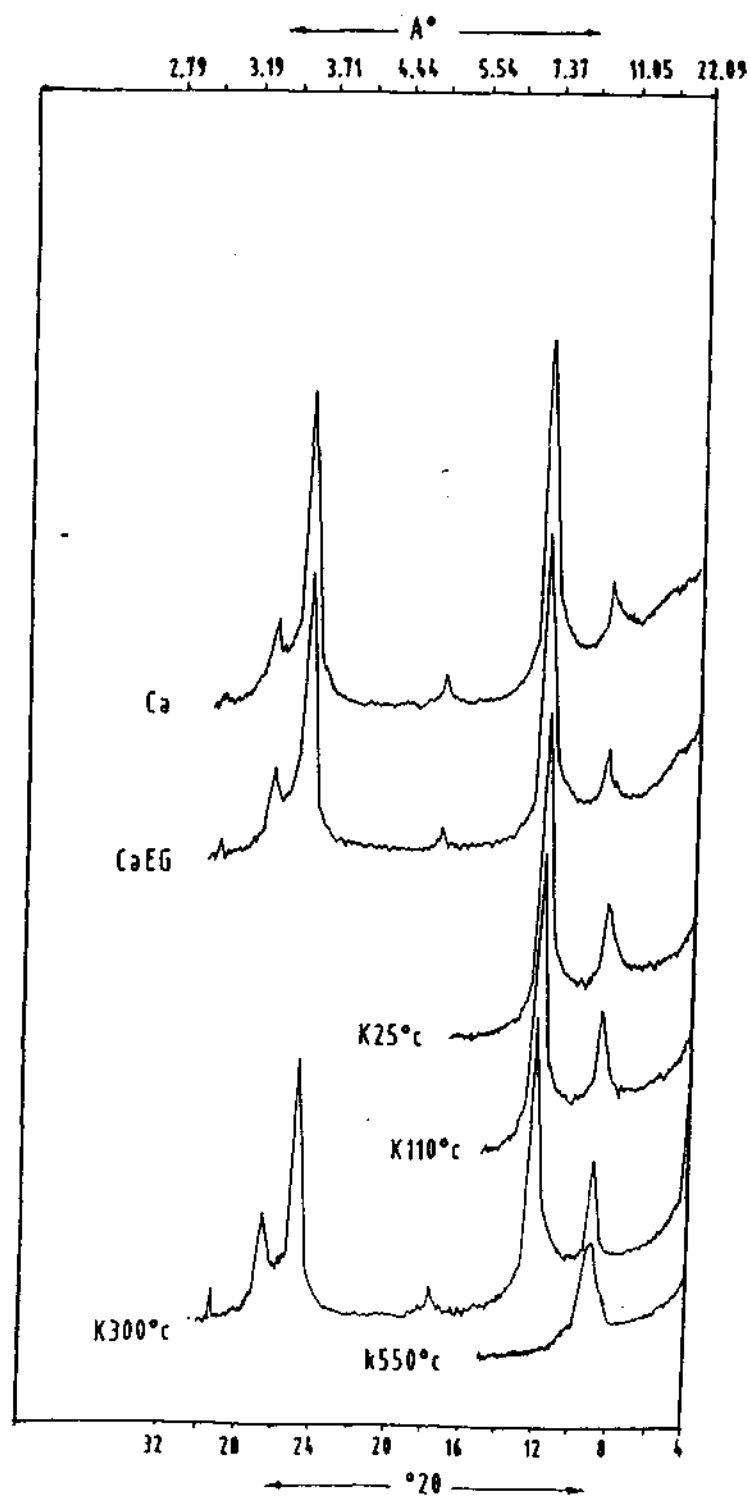


Fig. 9c: X-ray diffractograms of clay fraction (< 2 μm) from the BC horizon of pedon 20.

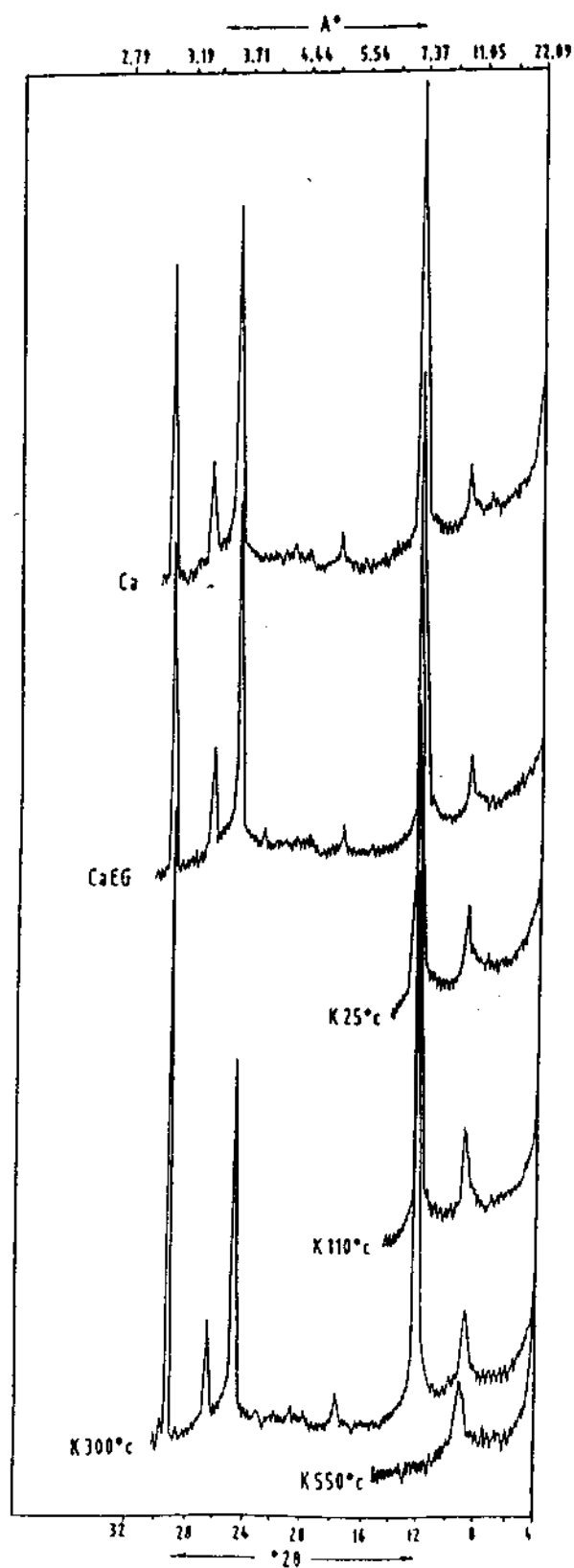


Fig. 10a. X-ray diffractograms of clay fraction (< 2 μm) from the Ap horizon of pedon 14.

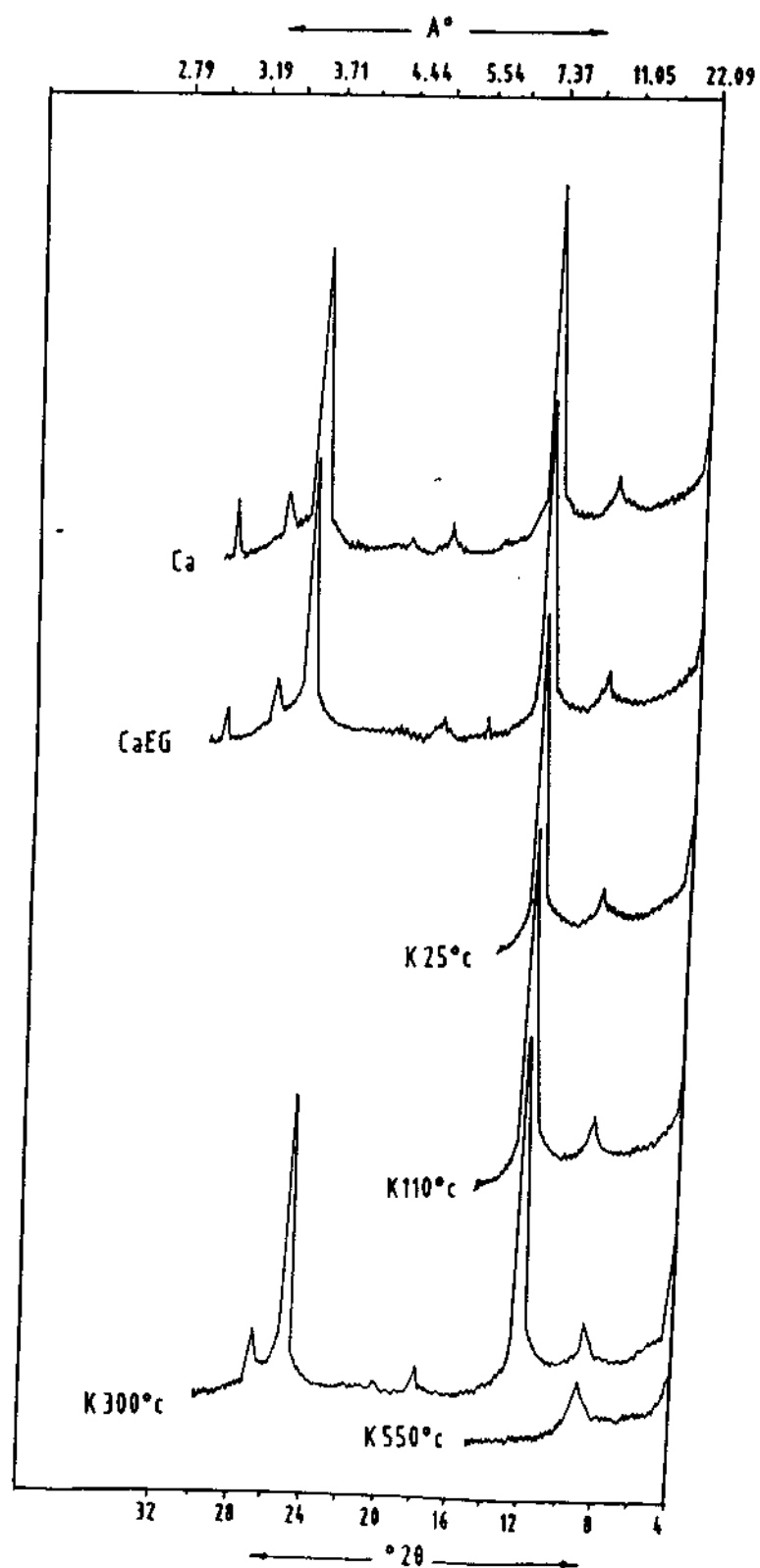


Fig. 10b: X-ray diffractograms of clay fraction (< 2 μm) from the Bt2 horizon of pedon 14.

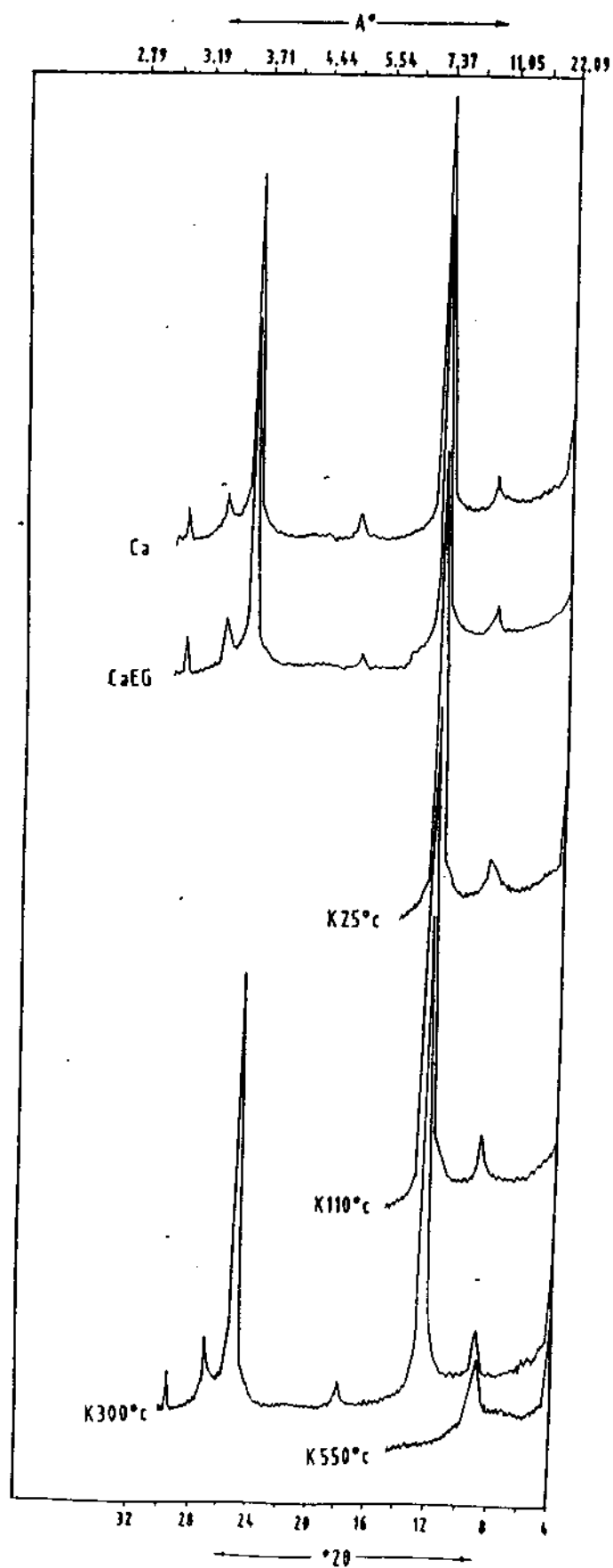


Fig. 10C: X-ray diffractograms of clay fraction (< 2 μm) from the Cr horizon of pedon 14.

of dominance. From the intensity of different peaks, it could also be inferred that the amount of smectite increased with depth (Fig.11a & b).

4.4.2.5 Clays of medium (50-100 cm) black soils: To represent the medium black soils in the study area, pedon 21 (Sangareddi black) has been selected. Clay samples from Ap (Fig.12a), Bw3 (Fig.12b) and Ck (Fig.12c) horizons of this pedon were subjected to X-ray analysis and the results are presented below. The diffraction patterns of all the three samples were similar showing the presence of smectite, kaolinite, chlorite and mica in order of dominance. Vermiculite was found in traces. Non-clay minerals like quartz and feldspars were also present.

4.4.2.6 Clays of deep (>100 cm) black soils: Adilabad (pedon 7) was selected to represent deep black soils in the study area. Clay samples from Ap (Fig.13a), Bss1 (Fig.13b) and Bss4 (Fig.13c) horizons of this pedon were subjected to X-ray analysis. The X-ray diffraction pattern of all three horizons of this pedon was similar. It indicated the presence of smectite, kaolinite, mica and vermiculite in order of dominance. Other than smectite, the three other minerals were present in very small amounts. Chlorite was present in the subsurface horizons. Non clay minerals like quartz and feldspars were also present.

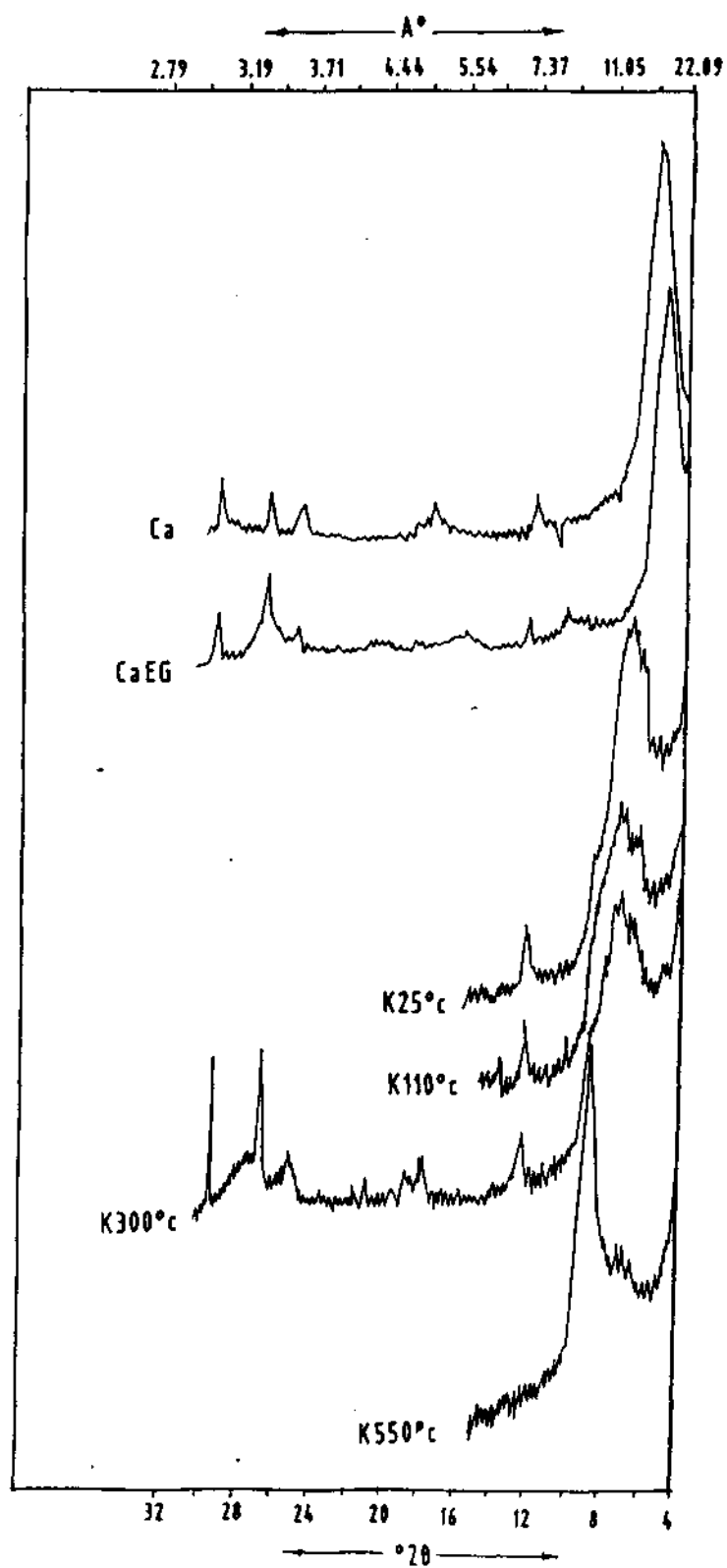


Fig. 10. X-ray diffractograms of clay fraction (< 2 μm) from the Ap horizon of pedon 12.

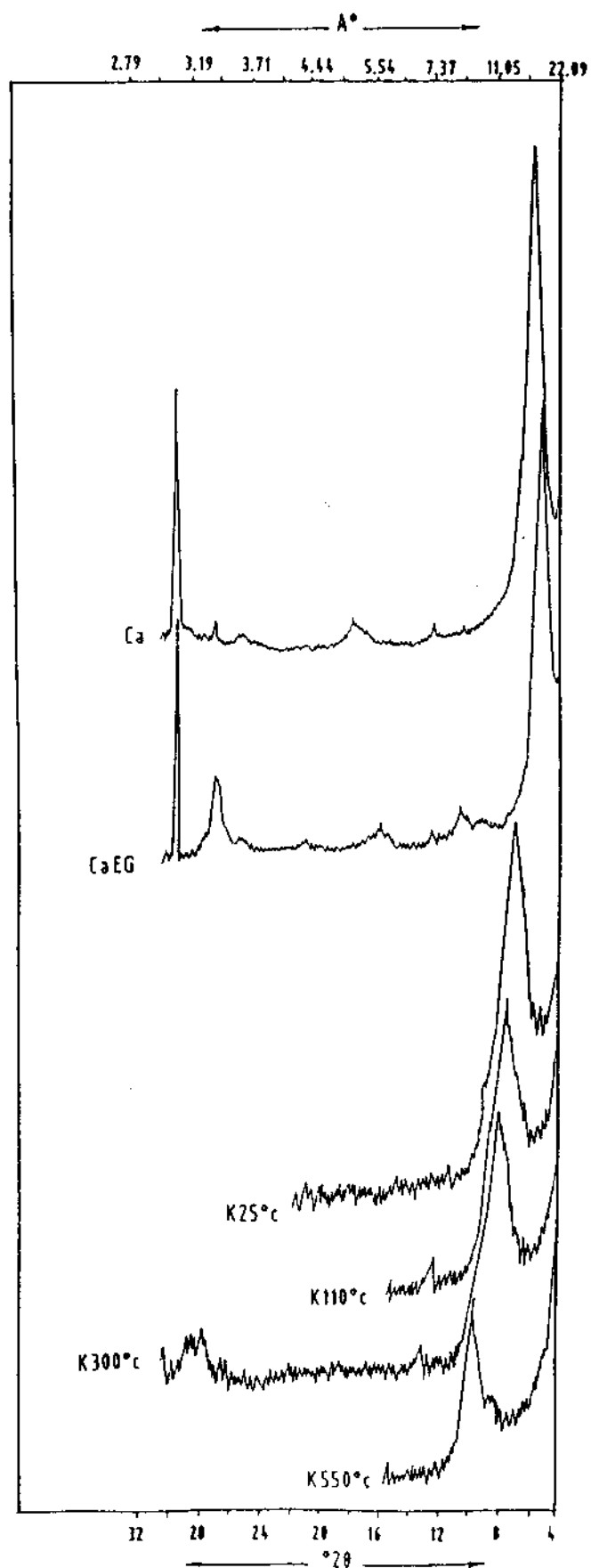


Fig. 11b: X-ray diffractograms of clay fraction (< 2 μm) from the Ck horizon of pedon 12.

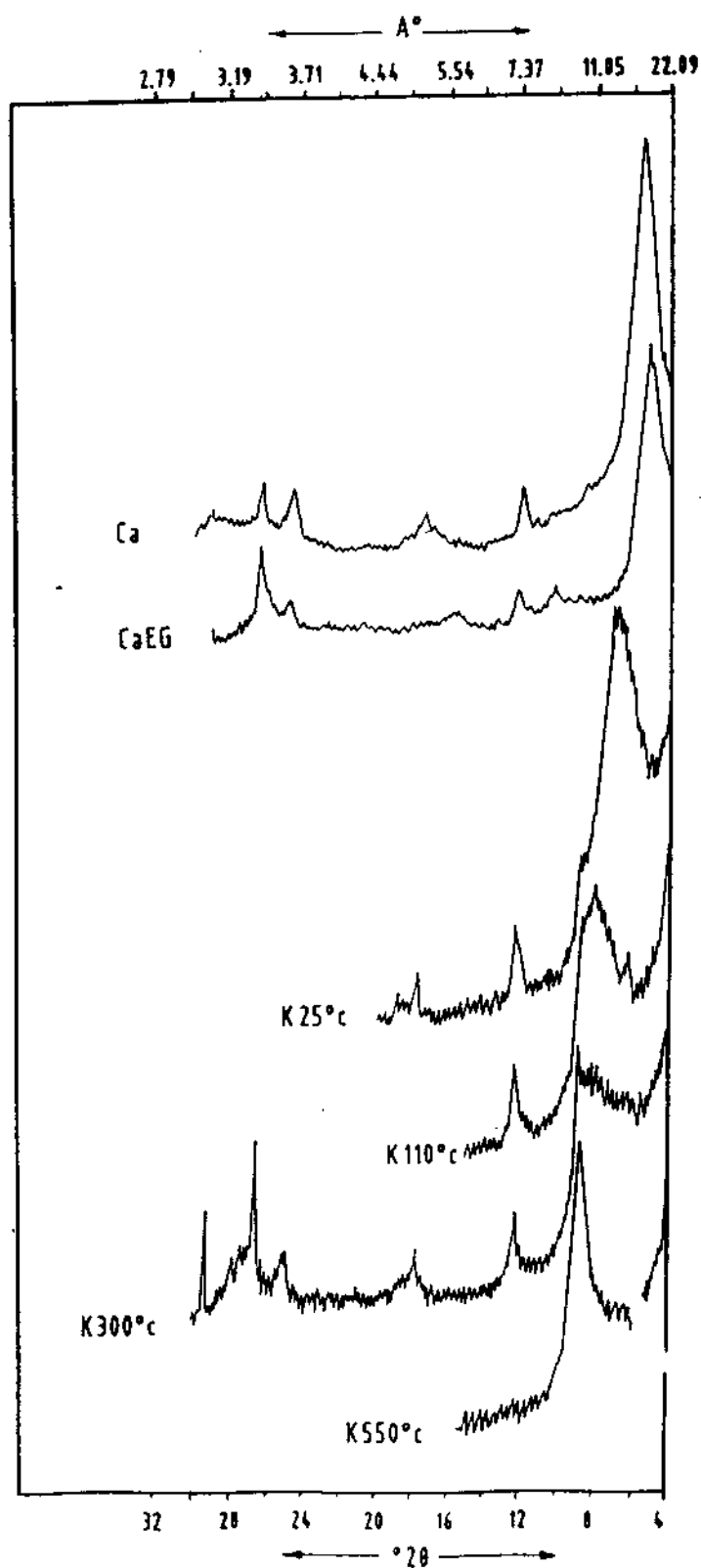


Fig. 120. X-ray diffractograms of clay fraction ($< 2 \mu\text{m}$) from the Ap horizon of pedon 21.

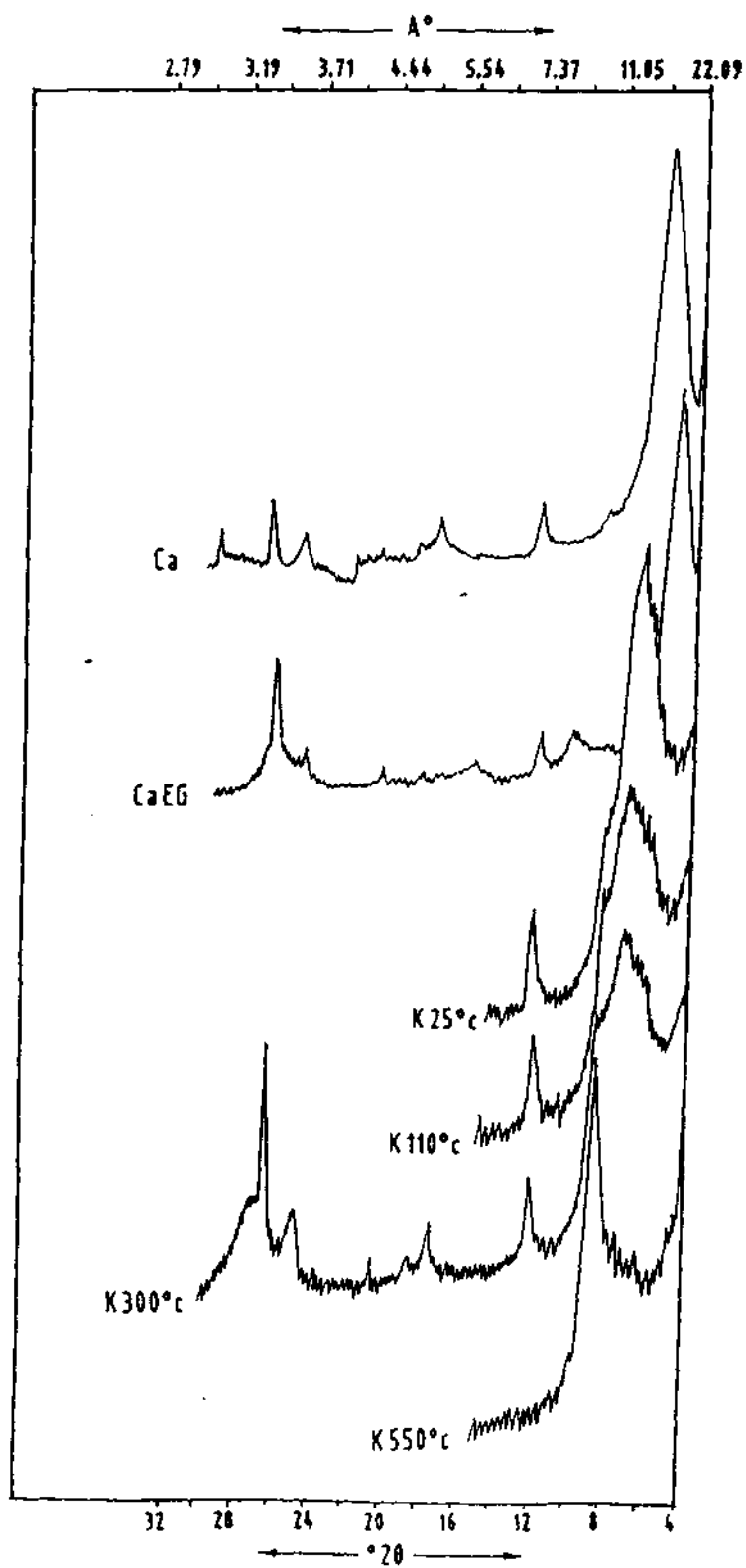


Fig. 12b: X-ray diffractograms of clay fraction (< 2 μm) from the Bw₃ horizon of pedon 2i.

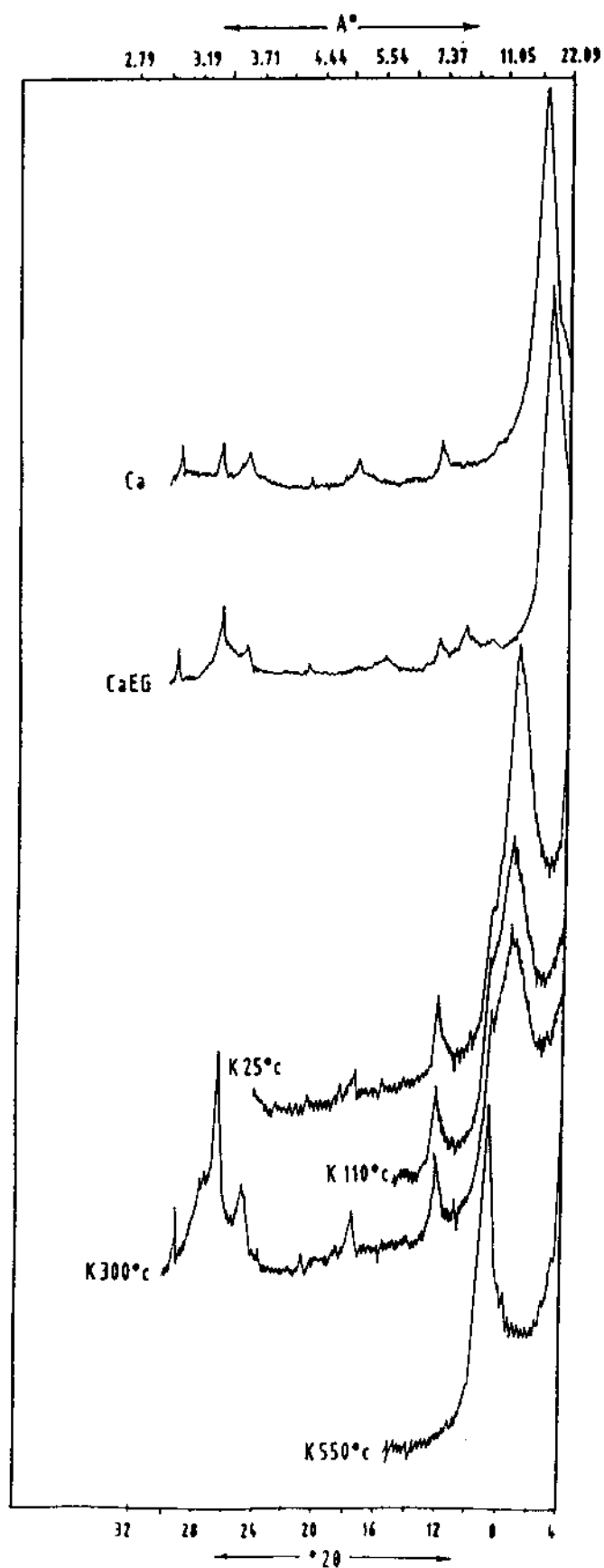


Fig. 2C: X-ray diffractograms of clay fraction ($< 2 \mu\text{m}$) from the Ck horizon of pedon 21.

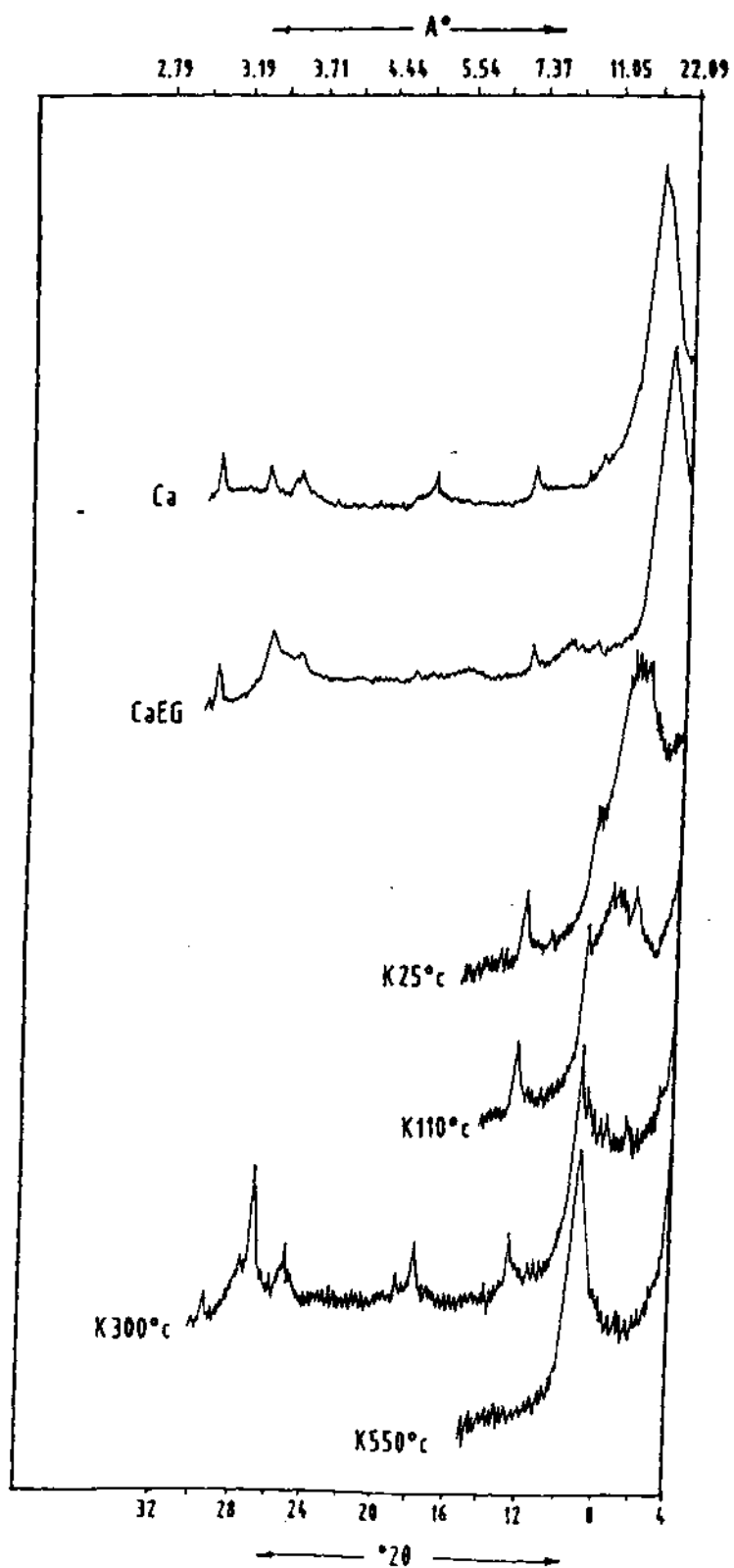


Fig. 13a X-ray diffractograms of clay fraction (< 2 μm) from the Ap horizon of pedon 7.

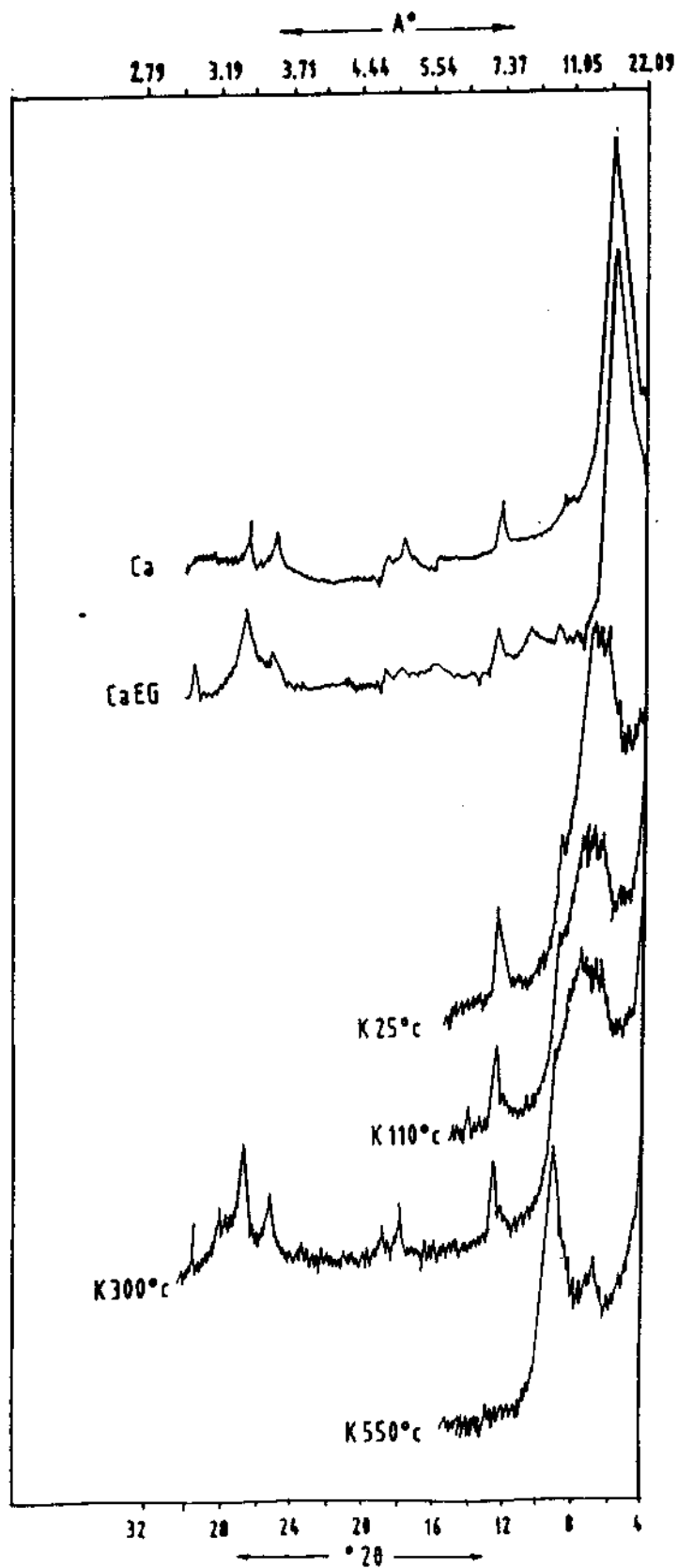


Fig. 136 X-ray diffractograms of clay fraction (< 2 μm) from the Bss1 horizon of pedon 7.

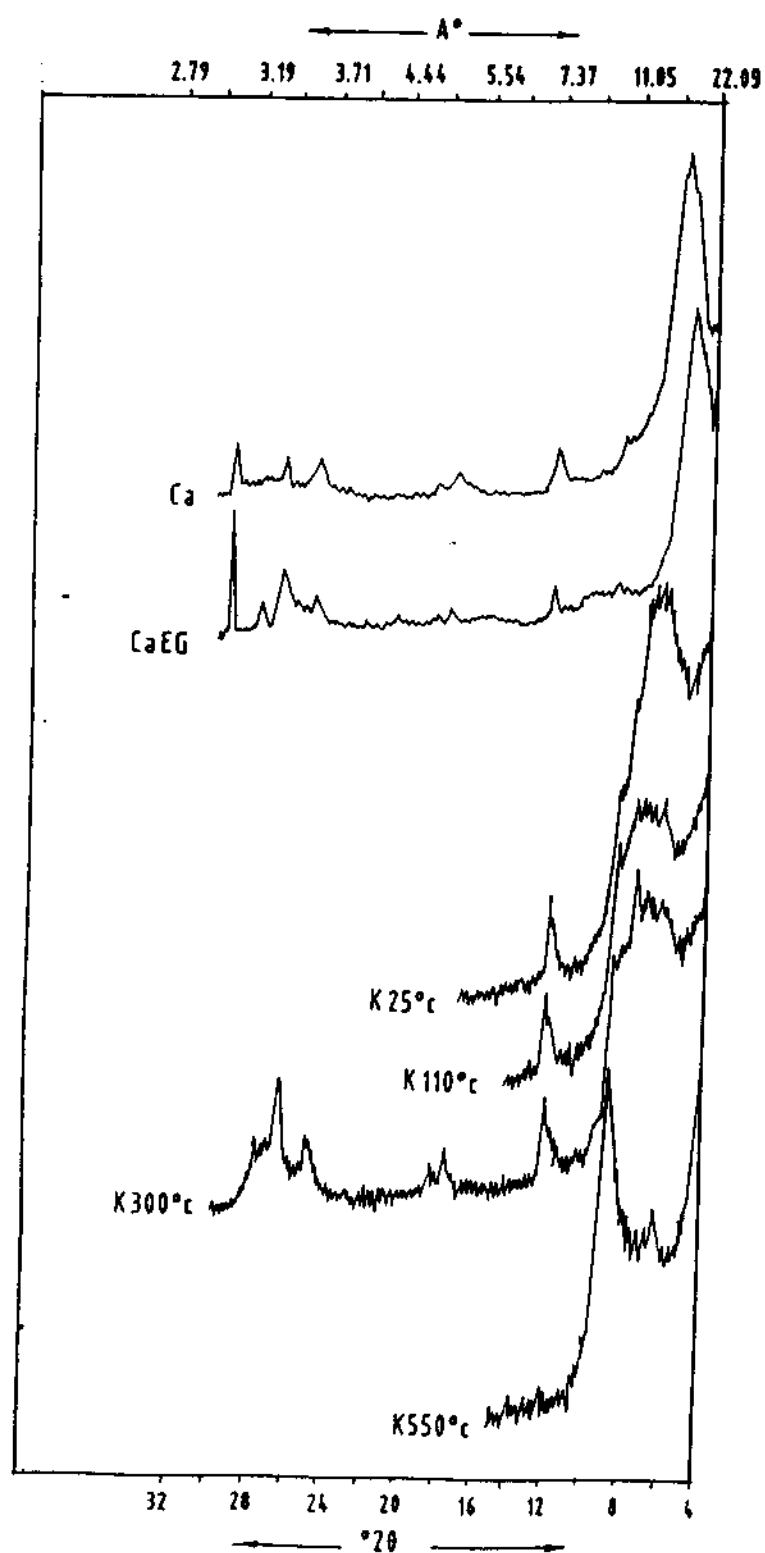


Fig.13C: X-ray diffractograms of clay fraction (< 2 μm) from the Bss₄ horizon of pedon 7.

4.5 SOIL CLASSIFICATION

Soil classification is grouping of objects into defined classes based on their morphology and other inherent properties.

Classification of the studied soils has been done according to Soil Taxonomy (Soil Survey Staff, 1999) upto family level and is presented in Table 13.

In classifying a specific soil to the sub group level of the soil Taxonomy, one begins by checking through the key to soil orders to determine the name of the order which according to the criteria listed, includes the soil in question. The next step is to systematically go through the key to suborders of that particular order, i.e., the first in the list for which it meets all the criteria. The same procedure is used to find the great group in the key to great groups of the identified suborder. Likewise, going through the key to subgroups of that great group, one selects the subgroup name for the classified soil, the name of the first taxon for which it meets all the criteria.

4.6 USE POTENTIAL

Land evaluation was done according to method suggested by Riquier *et al.* (1970). Calculated productivity index, productivity class and the potentiality of the studied soils are given in Table 14.

Table 13: Classification of the soils

Order	Suborder	Great group	Sub group	Family	Pedon
Alfisol	Ustalf	Haplustalf	Typic Haplustalf	Fine-loamy, mixed, isohyperthermic	11
				Loamy-skeletal, mixed, isohyperthermic	15
				Loamy, mixed, isohyperthermic	22
				Fine-loamy, mixed, isohyperthermic	14
				Clayey-skeletal, kaolinitic, isohyperthermic	20
Entisol	Psamment	Rhodustalf	Typic Rhodustalf	Mixed, isohyperthermic	3
Inceptisol	Ustept	Haplustept	Typic Ustipsamment	Fine-loamy, mixed, isohyperthermic	9
			Typic Haplustept	Fine-loamy, mixed, calcareous, isohyperthermic	1
				Coarse-loamy, mixed, calcareous, isohyperthermic	4
				Fine-loamy, mixed, calcareous, isohyperthermic	6
			Vertic Haplustept	Fine, smectitic calcareous, isohyperthermic	13, 21
			Fluventic Haplustept	Fine-loamy, mixed, isohyperthermic	16
		Calcistept	Vertic Calcistept	Loamy-skeletal, smectitic, calcareous, isohyperthermic	12
Vertisol	Ustert	Haplustert	Typic Haplustert	Fine, smectitic, calcareous, isohyperthermic	5, 7
				Very fine, smectitic, calcareous, isohyperthermic	2, 17
			Chromic Haplustert	Fine, smectitic, calcareous, isohyperthermic	8, 18
				Very fine, smectitic, calcareous, isohyperthermic	19
			Sodic Haplustert	Fine, smectitic, calcareous, isohyperthermic	10

Table 14: Productivity and potentiality of the soils

Pedon	Location	Moisture		Drainage		Effective depth (P)		Texture ¹ structure (T)		Base saturation (N)		Organic matter content (O)		Mineral exchange capacity (A)		Mineral reserve (M)		Productivity index	Productivity class	Potentiality
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2			
1	Jagti (red)	H3b	60	D3a	80	P4	80	T4b	50	N5	100	O1	85	A2	95	M2b	90	13.95	Poor	IV
2	Jagti (black)	H4a	80	D3a	80	P6	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	43.52	good	II
3	Karinnagar	H3a	50	D4	100	P2	20	T4a	30	N5	100	O1	85	A2	95	M2b	90	2.18	Extremely poor to nil	V
4	Rudnur (red)	H3b	60	D4	100	P6	100	T4b	50	N5	100	O1	85	A2	95	M2b	90	21.80	average	III
5	Rudnur (black)	H4b	90	D3b	90	P6	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	55.08	good	II
6	Jaipur	H3a	50	D4	100	P4	80	T7	100	N5	100	O1	85	A2	95	M2a	85	27.45	average	III
7	Adilabad	H4b	100	D3b	90	P6	100	T5b	80	N5	100	O1	85	A3	100	M2c	100	61.20	good	II
8	Mudhol	H5	100	D3a	80	P6	100	T5b	80	N5	100	O1	85	A3	100	M3c	100	54.40	good	II
9	Warangal (red)	H3a	50	D4	100	P3	50	T7	100	N5	100	O1	85	A2	95	M2b	90	18.17	Poor	IV
10	Warangal (black)	H5	100	D2a	40	P6	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	27.20	average	III
11	Malyal	H3a	50	D4	100	P4	80	T7	100	N5	100	O1	85	A2	95	M2b	90	29.07	average	III
12	Wyra	H5	100	D3b	90	P3	50	T5b	80	N5	100	O1	85	A3	100	M3b	100	30.60	average	III
13	Madhira	H5	100	D2b	60	P5	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	40.80	good	II
14	Aswaraopet	H3a	50	D4	100	P6	100	T4b	50	N4	80	O2	90	A1	90	M1	85	13.77	poor	IV
15	Palem	H3a	50	D4	100	P3	50	T7	100	N5	100	O1	85	A2	95	M2b	90	18.17	poor	IV
16	Rajendranagar (red)	H3a	50	D4	100	P4	80	T7	100	N5	100	O1	85	A2	95	M2b	90	29.07	average	III
17	Rajendranagar (black)	H4a	80	D2b	60	P6	100	T5b	80	N5	100	O2	90	A3	100	M3b	100	34.56	average	III
18	Tandur	H5	100	D3a	80	P6	100	T5b	80	N5	100	O1	85	A3	100	M3c	100	54.40	good	II
19	Ambipet	H5	100	D3a	80	P6	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	54.40	good	II
20	Sangareddi (red)	H3a	50	D4	100	P5	100	T7	100	N5	100	O2	90	A2	95	M2b	90	38.47	good	II
21	Sangareddi (black)	H4a	80	D3b	90	P5	100	T5b	80	N5	100	O1	85	A3	100	M3b	100	48.96	good	II
22	Mallepalli	H3a	50	D4	100	P2	20	T4b	50	N5	100	O1	85	A2	95	M2b	90	3.63	extremely poor to nil	V

1 - Factor/characteristic

2 - Tentative rating

According to Riquier *et al.* rating, soils of pedons 2, 5, 7, 8, 13, 18, 19, 20 and 21 were grouped under potentiality grade II (good) as the productivity index of these soils was between 35 and 64, while soils of pedons 4, 6, 10, 11, 12, 16 and 17 qualify for grade III (average). The productivity index of average grade soils was between 20 and 34. Pedons 1, 9, 14 and 15 fall under grade IV (poor) soils as per Riquier rating whereas soils of pedons 3 and 22 were grouped under grade V (extremely poor to nil). The productivity index of poor grade soils was between 8 and 19, and for grade V soils, it was between 0 to 7.

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Discussion

CHAPTER V

DISCUSSION

The morphological, physical, chemical and mineralogical characteristics of the pedons studied are discussed in this chapter. Attempts have been made in this study to interpret the results on the genesis of studied soils.

Red and black soils of various depths were found in the Talangana region on various geological set ups.

5.1 MORPHOMETRIC CHARACTERISTICS

5.1.1 Soil Colour

As the black soil pedons are situated at the lowest position of the landform, they remained under waterlogged condition for such a long time to have attained 10YR colours. Coventry *et al.* (1983) opined that saturation for lengthy periods resulted in grey colours.

The light shades in the bottom horizons were due to the presence of lime mixed with soil or well weathered parent material charged with lime and mixed with the soil. Krishnamurthy (1969) made similar observations. The colour of the black soils did not appear to be due to the presence of organic matter alone. It may be due to the combined effect of clay-humus complex and the

type of clay (smectite). Additional factors which might induce dark colour were due to the presence of iron sulphides and manganese oxides.

Colour of the red soils varies from brown to dark reddish brown with hues of 2.5YR, 5YR and 7.5YR (Chakrabarty and Sarkar, 1968). The free iron oxides played an important role in imparting red colour to soil. It is reasonable to believe that 5YR colours may be due to the presence of both lepidocrocite and ferrihydrite (Schwertmann and Taylor, 1977). Childs and Wilson (1983) proved that haematite was associated with 2.5YR and 5YR colours while goethite with 7.5YR and 10YR colours.

The 5YR colours in the B horizon indicate that this horizon is highly weathered and would have had good drainage. The wetter moisture regime and accumulation of silt through irrigation in the A horizon would have caused the 10YR colours in the AP horizon.

5.1.2 Soil structure

The surface horizons of red soils had weak to moderate, fine to medium and granular to sub-angular blocky structure, whereas black soils had moderate medium subangular blocky structure and sub horizons had moderate to strong, medium to very coarse angular blocky structures. Similar findings regarding structure of red and black soils were made by previous workers (Subbaiah, 1984; Kaistha and Gupta, 1994).

5.1.3 Consistence

Hard consistence under dry condition and sticky and plastic nature under wet condition were the characteristic features of black soils with smectite as dominant mineral (Coulombe *et al.*, 1996a). Low clay content and type of clay mineral are responsible for the consistence in red soils.

5.1.4 Cracks

Cracks are the characteristic phenomena in Vertisols (Subbaiah, 1984; Shrikant *et al.*, 1993; Venkateswarlu *et al.*, 1995).

The variation in the volume of cracks might be attributed to the variation in contents of cementing materials and exchangeable Na^+ . If the cementing materials like humic acid, iron and aluminium hydroxides were more, the extent of cracks will be less due to reduction in swelling property. If the soil is having more exchangeable Na, more will be the swelling and development of wider cracks (Nimkar *et al.*, 1992).

5.1.5 Calcium carbonate concretions

The leaching environment which could cause the movement of clay would also have caused the leaching of calcium bicarbonate from the upper horizons. The leached calcium bicarbonate gets precipitated due to high pH in the lower horizons as powdery lime. Therefore, the leaching and subsequent

precipitation would increase the content of concretionary and powdery lime in the lower horizons. Similar reports of enrichment of lower horizons with powdery and concretionary lime were made by Sharma and Bhargava (1973).

5.2 PHYSICAL PROPERTIES

5.2.1 Soil texture

5.2.1.1 Sand: All the red soil profiles showed higher contents of sand in the surface horizon. The surface enrichment of sand fraction was due to the removal of finer particles by clay eluviation and surface run off in tune with the results of Torrent *et al.* (1980) and Klich *et al.* (1990).

5.2.1.2 Silt: The surface horizons of all the studied pedons showed higher values of silt content. Most of the pedons showed decreasing trend in silt content with depth. This was recorded earlier by Bhaskar and Subbaiah (1995).

5.2.1.3 Clay: There was not much variation in texture with depth in black soil pedons. This may be due to the process of haploidization in the Vertisol pedons. The process of haploidization leads to homogenization as reported by Buol *et al.* (1998).

In red soils, the increase in clay content with depth could be attributed to vertical migration of clay and translocation of clay from the surface to lower horizons (Torrent *et al.*, 1980; Klich *et al.*, 1990). The clay particles after mechanical eluviation have accumulated in lower horizons.

5.2.2 Bulk density

The results revealed that bulk density was showing increasing trend with depth for the studied pedons due to compaction of finer particles in deeper layers caused by overburden weight (Landey *et al.*, 1982; Brar, 1991; Prasuna Rani *et al.*, 1992).

5.2.3 Moisture retention

Among the pedons studied, black soil pedons have higher values at both 1/3 and 15 bars and available water capacity which may be due to high clay content, more CEC and more exchangeable Ca^{2+} and Mg^{2+} . The results further indicated that most of the pedons showed low moisture retention in surface layers. It may be attributed to the relatively less clay content, more sand fraction, less CEC and less exchangeable Mg and Na on the exchange complex. Moisture retention properties are governed by the amount and type of clay mineral present in the soils (Singh *et al.*, 1988; Gajbhiye, 1990; Hirekurubar *et al.*, 1991).

5.3 CHEMICAL PROPERTIES

5.3.1 Soil Reaction (pH)

The lower pH values in pedon 14 and 15 indicate the increase in age and degree of development of the soil (Shrikant *et al.*, 1993). Higher values of pH (7.3 to 9.0) in Vertisols of Andhra Pradesh were also reported by Subbaiah and Manickam (1992).

5.3.2 Organic carbon

In general, the organic carbon values were low in all the pedons and the values were found to decrease with depth. Similar trend was noticed by Gawande and Biswas (1967) and Raychaudhuri *et al.* (1963).

As reported by Thyagarajan (1998) in some red soil profiles, sub surface horizons had more organic carbon content than the surface horizons, which might be due to translocation of humus along with clay. The irregular distribution of organic carbon in pedon 16 may be attributed to the sedimentary layering of the soils.

5.3.3 Calcium carbonate

Increase in calcium carbonate content with depth was noticed by Biswas *et al.* (1966), Krishnamurthy and Govindarajan (1977) and Bhatia and Vardani (1982).

Bicarbonate leaches down from the upper layers in rainy season and subsequently precipitates as carbonate in the lower layers during hot periods. In pedon 17, leaching of bicarbonates was restricted because of poor drainage and therefore, precipitation of carbonates occurs throughout pedon depth as was evident from almost uniform distribution of carbonates and strong effervescence throughout pedon depth.

5.3.4 Available phosphorus

In all the soils in the surface layers, available phosphorus content was high due to yearly application of phosphatic fertilizers and consequent accumulation of phosphorus in surface layers.

5.3.5 Available micronutrients

The studied soils are well supplied with respect to available copper and manganese. Lower contents of zinc in black soils is due to its fixation by clay (Manohar, 1974). Availability of iron in black soils decreased due to excessive amounts of calcium carbonate (Brown *et al.*, 1959).

5.3.6 Cation exchange capacity

Increasing trend in CEC with depth was due to increased clay content in the deeper layers and also due to relative accumulation of fine clay in the deeper layers. Bhattacharjee *et al.* (1977) found that CEC varied with clay and OM content. In general, the CEC of various soils studied was dependent upon the clay content and type of clay. The CEC values of red soil pedons were lower than that of black soil pedons (Subbaiah and Manickam, 1992).

Low CECs are correlated with disappearance or absence of primary weatherable minerals and accumulation of secondary clay minerals of low CEC as a result of weathering process. High CECs tend to be associated with the

less weathered soils with weatherable primary minerals as a plant nutrient reserve (Buol *et al.*, 1998).

The higher CEC/clay values in the BC horizons of pedon 1 would have been due to the less weathered nature of the soils with weatherable primary minerals (Buol *et al.*, 1998). Similarly, though the pedons 2 and 8 recorded similar CEC values, the CEC/clay ratio values were higher (>1.0) in all horizons of pedon 8. It may be attributed to the presence of weatherable primary minerals.

Pedon 17 recorded higher CEC values and fairly lower CEC/clay ratio. This can be attributed to the fairly lower content of primary minerals and presence of more amount of clays with high CEC.

However, lower CEC values and CEC/clay ratios in pedons 14 and 20 indicate low content of primary weatherable minerals and accumulation of secondary clay minerals of low CEC as a result of weathering process. The high CEC values and CEC/clay ratios of pedon 19 indicate the sedimentary layering of less weathered materials.

5.3.7 Exchangeable cations

In all the pedons, exchangeable complex was mostly saturated with Ca^{2+} followed by Mg^{2+} , Na^+ and K^+ . Karale *et al.* (1969) and Daji (1970) also reported that Ca^{+2} dominates the exchange complex. This order of abundance was in accordance with Jenny's (1941) view that the leaching caused preferential losses

of Na^+ and K^+ . In black soil pedons 10 and 17 the exchangeable Na^+ increased with depth. In general, the ESP values for black soils were higher than red soils. The higher values of ESP (>15) in the subsoil horizons of these two pedons can be attributed to the presence of poor drainage conditions in pedon 17 and also as a result of raised ground water table in case of pedon 10.

Increase in ESP with depth indicates that sodicity is developing in these two soils. This is a general observation for the black and associated soils in the semi arid regions of the Peninsular India (Murthy *et al.*, 1982; Dubey *et al.*, 1983; Nimkar *et al.*, 1992). It is also observed that decrease in the Ca/Mg ratio of sub soils of pedons 10 and 17 causes increase in the sodicity of these soils. Decrease in Ca/Mg ratio with depth in pedon 7 indicates that there is a tendency to develop sodicity in this soil.

The high amounts of exchangeable Ca and Mg would have helped in the formation of smectites when other conditions remained favourable as reported by Barshad (1964).

5.3.8 Base saturation

Per cent base saturation nearer to 100 is an indication that the soils were not much weathered. Accordingly, black soil pedons were low to medium in weathering. Pedon 14 with a base saturation of 42 to 70 in the profile was highly weathered.

5.4 MINERALOGICAL CHARACTERISTICS

5.4.1 Mineralogy of the sand fraction

5.4.1.1 Light minerals: The results indicated the abundance of light minerals. Among the light minerals, quartz was found to be dominant fraction followed by feldspars and micas (Muscovite and/or biotite). Rao and Krishna Murti (1984) and Subbaiah and Manickam (1986) also reported similar findings from their research work. These soils have developed from granite, granite-gneiss and sandstone which are reportedly rich in quartz, except pedons 7, 8 and 18, which were derived from basalt. Though soils were developed from wide ranging parent material, the direction of change is the same leading to the predominance of quartz (Surekha *et al.*, 1997). The abundance of quartz in the sand fraction is ascribed to selective accumulation due to its relative resistance to weathering.

Seshagiri Rao and Chatterjee (1990) also noticed quartz and feldspars as the principal primary minerals in all the pedons developed on the granite rock. The abundance of orthoclase feldspars with subordinate amount of plagioclase feldspars was attributed to minor variations in parent rock.

Higher amount of feldspars in pedons 7, 8, 18 indicates a low degree of weathering as reported by Al-Kanani *et al.* (1984) and Krishnamurthy and Govindarajan (1977).

5.4.1.2 Heavy minerals: Zircon constituted more than 50 per cent of the heavy minerals in the soils of the pedon14, thereby indicating prolonged weathering of the pedon.

The sand fractions of pedons 7, 8 and 18 were rich in pyroxenes and hornblende thereby indicating that these pedons were comparatively less weathered. The depth functions of heavy minerals in pedon 18 are erratic and indicated depositional origin.

The high amount of opaque minerals (>60%) in pedons 14 and 22 indicate high degree of weathering.

Absence of pyroxenes and hornblende in some soils is indicative of the advanced stage of weathering (Subbaiah and Manickam, 1986).

Presence of readily weatherable minerals like feldspars, hornblende, pyroxenes and micas indicate the nutrient reserves as they can undergo weathering and release ions like Ca, Mg and K.

5.4.2 Mineralogy of the clay fraction

The interpretation of diffraction peaks as presented in the previous chapter indicated that the clay fraction constituted of kaolinite, smectite, mica, vermiculite and chlorite in the pedons. The primary minerals commonly occurred were quartz and feldspars in traces. In red soils, the dominant clay mineral was kaolinite followed by mica, whereas in black soils the dominant clay mineral was smectite followed by kaolinite (Rao and Krishna Murti, 1984; Seshagiri Rao and Chatterjee, 1990). Chlorite was found to occur only in black soil pedons.

5.4.3 Genesis of clay minerals

Quartz and feldspars constitute an appreciable amount of the light mineral fraction. It was observed that most of the primary minerals from sand fraction of the different pedons are not phyllosilicates but belong to tectosilicates, which are very stable. The formation of clay minerals involves release of cations, silica and alumina followed by their recombination into phyllosilicates. The necessary cationic environment for these secondary formations is provided by the constant recharge of the surrounding solution by the cations released during the weathering of minerals present in silt and sand fractions.

Mica appears to have originated from weathering of feldspars on partial hydrolysis. Hydration of micas and their transformation into vermiculite might have occurred.

Smectite might have been formed in the soils through transformation from weathering sequence of mica-vermiculite-smectite. Vermiculite is an intermediate stage of weathering sequence.

The kaolinite clay mineral should have been formed in the past as the present conditions are not favourable for the synthesis of kaolinite from smectite. According to Satyanarayana and Biswas (1970), kaolinite could be formed by loss of bases and iron from montmorillonite under intensive leaching conditions prevailing over long periods.

Presence of residual laterite in Deccan trap basalt in Shankarapalli area confirms the pre-existing humid climatic conditions, which are active atleast from the upper cretaceous era in the Indian peninsula (Subramanian and Mani, 1981). Di- and Tri-octahedral smectites in saprolites, developed on precambrian sediments in southern peninsular India, indicate the climatic change from tropical humid to semi-arid during Pli-Pleistocene transition period (Pal *et al.*, 1989). Smectite might have been formed as the first weathering product of gneissic rock during humid climatic conditions. Pal and Deshpande (1987a) also suggested while working on the genesis of clay minerals in black and red soil complex, that kaolinite in red soil has possibly developed at the expense of smectite with progressive weathering.

Tardy *et al.* (1973) and Kantor and Schwertmann (1974) also suggested that smectite is the first weathering product of all rocks and resists decomposition under poor drainage conditions but can decompose to kaolinite in high leaching conditions. Because of that reason, kaolinite was found in soils of higher elevation.

Chlorite has been transformed from mica as suggested by Pal *et al.* (1989) and Seshagiri Rao and Chatterjee (1990) in the following way.

Mica → Vermiculite → Montmorillonite → Chlorite

From the studies on genesis of clay minerals in red and black soils complex on precambrian granite-gneiss, in ICRISAT farm, Patancheru, Pal and

Deshpande (1987a) reported that less than 2 micron fractions contained smectite, vermiculite (Ap horizon), mica, 10-14 Å mixed layer minerals and kaolinite with minor amounts of quartz and feldspars. In Kasireddipalli soil (black soil), presence of smectite, vermiculite, chlorite, mica, 10-14 Å mixed layer minerals and kaolinite in coarse clay fraction, were noticed with smectite as the dominant mineral. The smectite was observed to be of dioctahedral type, iron rich and also partially chloritised.

5.5 SOIL GENESIS

An examination of soil profile shows with distinctive horizontal layers, some of which are highly visible. Significant changes are made as soils develop from relatively unconsolidated parent materials. A study of soil formation (genesis) gives some notion as to how these changes occur and why they can stimulate the development of so many different kinds of soils. Soil genesis is brought about by a series of processes, the most significant of which are: (1) Weathering and organic matter breakdown by which some soil constituents are modified or destroyed and others are synthesized. (2) Translocation of inorganic and organic materials up and down the soil profile, the materials being moved mostly by water but also by soil organisms and (3) accumulation of soil materials in horizontal layers (horizons) in the soil profile, either as they are formed in place or translocated from above or below the zone of accumulation (Brady, 1995).

Simonson (1959) outlined the processes of soil formation include (a) additions of organic and mineral materials to the soil as solids, liquids and gases,

(b) losses of these from the soil (c) translocations of materials from one point to another within the soil and (d) transformation of mineral and organic substances within the soil.

In the present study, as per outlines given by Simonson (1959), the addition of organic matter was noticed due to accumulation of the organic matter and humus on the surface of the soils (Pedon 14 and 20) and to a certain depth of the subsoil. In the remaining pedons also the influence of this process was noticed but relatively to a small degree.

The soil forming process which was covered by the losses from the soils was leaching (depletion) and erosion. Leaching is analogous to eluviation by solution but connotes removal from the entire solum. The leaching process appeared in red soils as there was no accumulation of calcium carbonate in pedons 3, 9, 11, 14, 15, 16, 20 and 22. Black soil pedons showed insignificant effect of the leaching by accumulating calcium carbonate due to their occurrence in low lying areas. Here topography played an important role. Aridity caused the formation of CaCO_3 . The presence of powdery lime on ped faces is of pedogenic origin resulted during the semi-arid climatic conditions (Pal *et al.*, 1999).

Next to the soil formation was translocation of materials from one point to another within the soil. In this category, eluviation and illuviation were of

importance. The development of B horizons in the studied soils was a result of the eluviation and illuviation. Due to these processes, the cambic and argillic horizons were formed. The eluviation and illuviation processes were in lesser degree giving rise to cambic horizon in black soils.

The next category of the soil forming processes were transformation of minerals and organic substances within the soil.

Smectites have been formed in these soils through transformation from weathering sequence of mica-vermiculite-smectite. Chlorite has been transformed from smectite.

For the formation of swell-shrink soils, huge amount of smectite clay is required and such an amount cannot be produced in semi-arid climatic conditions. Climatic and geomorphic history of the central peninsular India (Pal and Deshpande, 1987b; Pal *et al.*, 1989; Bhattacharyya *et al.*, 1993) suggest that the smectitic clay of Vertisols which formed in an earlier humid climate must have been detached from the weathering and transported downstream and deposited covering the lower piedmont areas or valleys (Pal and Deshpande, 1987b). Thus, the Vertisols occur in the lower piedmont plain or valleys or microdepressions, and the dominance of smectitic clay is due to the mechanical deposition in an earlier humid climate (Pal and Deshpande, 1987b; Bhattacharyya *et al.*, 1993).

Preservation of smectite crystallinity in black soils was achieved due to aggradation process that took place in the non-leaching environment of semi-arid climate.

Under intensive leaching conditions prevailing over long periods, kaolinite could be formed from montmorillonite by loss of alkalies and iron.

The study area have semiarid climate with high summer temperatures and low to medium rainfall, which is essentially monsoonic type. The natural vegetation consists of short to medium grasses. The general topography is undulating to gently sloping plain in the red soil areas and gently to nearly level plains in black soil areas. The red soils are well drained but the black soils are imperfectly drained.

The genesis of red and black soils occurring in close proximity in the study area under similar conditions of climate in detail has been given below.

5.5.1 Pedogenesis of Black soils

The black soils were categorised under the orders Vertisols and Inceptisols, commonly known as shrinking and swelling dark clay soils. The black soil pedons have developed on granite/granite-gneiss (pedons 2, 5, 10, 13, 17, 19), basalt (pedons 7, 8 and 18) and hornblende schist (pedon 12). The rocks from which the above soils were derived have been classified under igneous (basalt and granite) metamorphic (granite-gneiss and hornblende schist) and

clayey material of sedimentary origin (basaltic alluvium of pedon 18 and granitic alluvium of pedon 19). These different types of rocks have given rise to black soils under semi-arid climate.

Even though the soils were formed from different types of parent materials, topography played major role in the development of these soils. It might be due to the accumulation of bases under restricted drainage conditions and formation of clay rich in smectite type of minerals.

The physical properties of the black soils were not influenced by the variation in the parent materials. Parent material appears to be a passive factor of soil formation in the study area. The black soils are heavy textured and are clayey throughout the profiles. Changes in soil moisture content seemed to be essential for the genesis of Vertisols. In arid and semi-arid regions, Vertisols or soils with vertic properties commonly develop in closed depressions. The predominant process in the formation of black soils was haploidization by argilopedoturbation.

The soil reaction was towards alkaline side as the drainage was restricted. All the black soils were rich in bases, inspite of the variations in their parent materials. It might be due to low rainfall and impeded drainage since they were formed on lower pediments. Increased Ca/Mg ratio in black soils revealed that these soils have undergone less weathering. High exchangeable sodium content was observed in pedons 10 and 17, especially in the lower layers,

indicating the development of sodicity in the pedons. All the black soils were having calcium carbonate in different proportions (from traces to 24.9 per cent). It was found to be higher in the lower layers.

The black soils were less weathered and young as they contained more quantities of weatherable light and heavy minerals than red soils. Smectite was the predominant mineral in black soils.

5.5.2 Pedogenesis of red soils

Red soils have developed over igneous (grey/pink granite), metamorphic (granite-gneiss) and sedimentary (sandstone) rocks. They have coarser texture. Topography seems to have played a major role in the development of these soils.

Clay content was lower in the surface horizons either due to eluviation or erosion of finer particles.

The colour of the soils was red which might be due to rubifaction and ferrugination wherein ferric oxide coupled with low organic matter imparted red colour (Gawande and Biswas, 1967). Argillans were identified as they are redder, darker coloured than the interior of the ped (Buol *et al.*, 1998).

The soil reaction was acidic in pedon 14 developed on sandstone, mainly due to higher rainfall (>1000 mm) in Aswaraopet region. Organic carbon content

was also high in this pedon and kaolinite was the dominant mineral in these red soils. Remaining pedons are relatively more basic. The per cent base saturation was also low in pedon 14. No significant difference was noticed with regard to electrical conductivity, organic carbon and exchangeable cations in the remaining pedons.

Pedons 11, 14, 15, 20 and 22 were classified under the order Alfisols. These Alfisols showing well drained conditions, were developed from sandstone (pedon 14) and granite/granite-gneiss (pedons 11, 15, 20 and 22). Pedon 14 was a deep soil while pedons 11, 20 were moderately deep and pedon 15 and 22 were shallow soils with well marked horizonisation. Leaching of these soils, as evidenced by eluviation was observed in these pedons. In general, organic carbon content decreased with depth and in pedons 15 and 22, it increased with depth. Thin clay cutans/argillans were observed in Bt3 horizon in pedon 11 and 20 and from Bt2 horizon in pedon 14. The structure at the surface was granular to sub-angular blocky and sub-angular blocky at the sub-surface. The red colour might have developed by rubifaction and ferrugination. The sand mineralogy revealed the presence of more contents of resistant minerals which is indicative of the highly weathered nature of these soils.

Among red soils, pedons 1, 4, 9 and 16 were classified under the order Inceptisols. These were developed on granite-gneiss and were moderately deep soils. No argillans were noticed in these pedons. These pedons were well drained. The structure of these pedons was granular or subangular blocky at

the surface and sub-angular blocky at the sub-surface. The red colour of the soils might be due to rubification and ferrugination. The sand mineralogy of these pedons revealed that these soils were highly weathered, since they contained more contents of resistant minerals.

Red soil pedon 3 was classified under Entisols, wherein there was no horizonisation. It developed from pink granite under semi-arid climate. This soil was shallow, some what excessively drained and subjected to wind erosion. Red colour of the soil was due to ferrugination in which the presence of ferric oxide influenced the red colour formation. It is a coarse textured soil. This soil was having paralithic contact. It was having higher contents of resistant minerals indicating that this soil was highly weathered.

5.6 SOIL CLASSIFICATION

The classification of the soils of the study area has been done according to Soil Taxonomy (Soil Survey Staff, 1999) and keys to soil Taxonomy (Soil Survey Staff, 1998) and is presented in Table 13.

Based on this systematic approach, the studied soils keyed out to be Vertisols, Alfisols, Inceptisols and Entisols.

The pedons 2, 5, 7, 8, 10, 17, 18 and 19, which were keyed out to be Vertisols had

- (1) a layer of 25 cm or more thickness, with an upper boundary within 100 cm of the mineral soil surface, that has either slickensides or wedge shaped peds that have their long axes tilted 10 to 60 degrees from the horizontal; and
- (2) A weighted average of 30 per cent or more clay in the fine-earth fraction either between the mineral soil surface and a depth of 18 cm or in an Ap horizon whichever is thicker, and 30 per cent or more clay in the fine-earth fraction of all horizons between a depth of 18 cm and either a depth of 50 cm or a densic, lithic or paralithic contact, a duripan, or a petrocalcic horizon if shallower; and
- (3) Cracks that open and close periodically.

Each order is subdivided into "suborders" primarily on the basis of the characteristics that seem to produce classes with the greatest genetic homogeneity. The properties selected are dynamic, such as the moisture regimes; others may relate to materials or processes that retard horizon differentiation. In case of the Vertisol order the characteristics selected for the suborders are the moisture regime and the temperature regime. The suborders framed are in all six, viz., Aquerts, Cryerts, Xererts, Torrerts, Usterts and Uderts. The studied soils key out as Usterts because these Vertisols, if not irrigated during the year, have cracks in normal years that are 5 mm or more wide, through a thickness of 25 cm or more within 50 cm of the mineral soil surface, for 90 or more cumulative days per year.

Each great group is defined, within its respective suborder largely on the presence or absence of diagnostic horizons and the arrangement of those horizons. Within the Usterts suborder, five great groups have been identified in Soil Taxonomy. The placement of the studied soils at the great group level is discussed below:

These soils do not have a pH value of 4.5 or less in 0.01 M CaCl_2 and, hence, are not Dystrusterts. They are neither Salusterts as they do not have a salic horizon nor Gypsiusterts as there is no gypsic horizon. They are not Calciusterts because of absence of calcic or petrocalcic horizons. Hence, these soils are Haplusterts, the remaining great group of the Ustert suborder.

Subgroups are subdivisions of the great group and are defined only in terms of reference to the great group indicating as to whether they represent the central concept of the great group or are transitional to other orders, suborders or great groups. In soil Taxonomy, 16 subgroups are defined within the Haplustert great group.

The pedon 10 keys out to be sodic Haplusterts, as these soils have, within 100 cm of the mineral soil surface, an exchangeable sodium percentage of 15 or more.

Pedons 8, 18 and 19 key out to be Chromic Haplusterts, as these soils have, in one or more horizons within 30 cm of the mineral soil surface, 50 per cent or more colours as follows:

- (1) A colour value, moist of 4 or more; or
- (2) A colour value, dry, of 6 or more; or
- (3) Chroma of 3 or more.

Pedons 2, 5, 7 and 17 could not meet the requirements of the other subgroups listed in the key to subgroups. Hence, these are Typic Haplusterts, the remaining subgroup of the Haplustert great group.

Families are differentiated within a subgroup primarily on the basis of properties important to the growth of plants. Properties used to differentiate families are particle size, mineralogy, reaction, soil temperature and a few others. The particle size class and the mineralogy class are applied to certain horizons, or to the soil materials within specific depth limits, designated as particle size control section. For these soils, it is between the lower boundary of an Ap horizon or a depth of 25 cm below the mineral soil surface, whichever is deeper and the shallower of the following: (1) a depth of 100 cm below the mineral soil surface or (b) a root-limiting layer. For pedon 2, the particle size control section is between the depths of 35 cm and 100cm from the mineral soil surface. For the remaining Haplusterts, it is between a depth of 25 cm below the mineral soil surface and a depth of 100 cm.

The particle size class of pedons 5, 7, 8, 18 and 10 is fine because the weighted average of clay content is less than 60 per cent in the fine-earth

fraction. The particle size class of pedons 2, 17 and 19 is very fine as they have 60 per cent or more clay (by weight) in the fine-earth fraction.

The control section for mineralogy classes is the same as that was defined for the particle size classes. The mineralogy classes are based on the less than 0.002 mm fraction, which is smectitic for these Haplusterts. The smectitic mineralogy class includes soils with more smectite, by weight, than any other single kind of clay mineral.

The soil temperature class is 'isohyperthermic' for all the soils as based on the climatological data of Rudrur, Rajendranagar and Warangal.

The isohyperthermic soil temperature class includes soil families that have a difference of less than 5°C between mean summer and mean winter temperatures at a depth of 50 cm and a mean annual soil temperature of 22°C or higher.

Pedons 11, 14, 15, 20 and 22 have an argillic horizon and hence, were keyed out to be Alfisols as per key to soil orders (Soil Survey Staff, 1998). The Alfisol order is subdivided into 'suborders' primarily on the basis of moisture and temperature regimes. The suborders framed are in all five viz., Aqualfs, Cryalfs, Ustalfs, Xeralfs and Udalfs. These soils get keyed out as Ustalfs because they have an ustic soil moisture regime. Within the Ustalfs suborder, eight great groups had been identified in Soil Taxonomy. Pedon 20 keyed out to be Rhodustalfs

which had throughout the entire argillic horizon, more than 50 per cent colors that have hue of 2.5 YR or redder, value moist, of 3 or less and dry value not more than 1 unit higher than the moist value. Pedons 11, 15 and 22 get keyed out as Haplustalfs as they could not meet the requirements of the other great groups listed in the key to great groups.

At the subgroup level, the soils had been keyed out as Typic Rhodustalfs and Typic Haplustalfs. At family level, the particle size classes are fine (Pedon 20), fine-loamy (pedons 11, 15 and 14) and loamy (pedon 22). Mineralogy classes are kaolinitic (pedons 14) and mixed (pedons 11, 15, 20 and 22). The soil temperature class is isohyperthermic.

Some of the studied soils get keyed out as Inceptisols as per key to soil orders. The Inceptisol order is subdivided into 'suborders' primarily on the basis of diagnostic horizons, moisture regime and the temperature regime. The suborders framed are in all six viz., Aquepts, Anthrepts, Cryepts, Ustepts, Xerepts and Udepts. Since the studied soils have ustic soil moisture regime, they keyed out as Ustepts.

Pedon 12 get keyed out as Calciustept as it has a calcic horizon with its upper boundary within 100 cm of the mineral soil surface and is calcareous. Pedons 1, 4, 6, 9, 13, 16 and 21 get keyed out as Haplustepts great group. At subgroup level the studied soils qualified for Typic Haplustepts (pedons 9, 1 and 4), Calcic Haplustepts (pedon 6), Vertic Haplustepts (pedons 13 and 21),

Fluventic Haplustepts (Pedon 16) and Vertic Calciustepts (pedon 12). The particle size class of Inceptisol pedons is fine loamy (pedons 1, 6, 9 and 16), where weighted average clay is in the range of 18 to 35 per cent, coarse-loamy (pedon 4), where weighted average clay is less than 18 per cent and fine (pedons 12, 13 and 21) where weighted average clay is more than 35 per cent in the fine-earth fraction. The mineralogy class of pedons 1, 4, 6, 9 and 16 is mixed and of pedons 12, 13 and 21 is smectitic. The soil temperature class is isohyperthermic.

Pedon 3 get keyed out as Entisol as per key to soil orders. Suborders of Entisols were not defined by moisture or temperature regime. The Entisol suborders were designed to differentiate the conditions under which subsurface horizon development was found impeded. The five Entisol suborders are Orthents, Psamments, Fluvents, Aquents and Arents. The studied pedon keyed out as Psamments, because they have less than 35 per cent rock fragments and a texture of loamy sand in the particle size control section. Within Psamments suborder, six great groups had been identified in Soil Taxonomy. The studied soils keyed out to be Ustipsamments great group because they have an ustic moisture regime.

At subgroup level, the soils had been keyed out as Typic Ustipsamments. At family level, the mineralogy class is mixed. The soil temperature class is isohyperthermic.

The classification of the studied soils is also given in Appendix.

5.7 USE POTENTIAL

Telangana zone contains some of the best potential agricultural lands having under utilized natural resources which are yet to be exploited. The major rivers of the state, Godavari, Manjira, Sabari, Palar, Manier, Wyra and Krishna pass through this zone. Besides the major irrigation projects Sriram Sagar and Nagarjuna Sagar which provide irrigation to larger area, projects like Nizam Sagar, Kadem, lower and upper Manier dam and lakes like Pakala, Ramappa and several tanks and open borewells also provide irrigation water to a considerable area.

The temperature is not a limiting factor in this area. On the basis of the computation of soil-water balance data of the region, the length of growing period (LGP) was found to be between 150 to 165 days.

Soils in Telangana region have great agricultural importance as annual field crops like rice, *jowar*, maize, pulses and commercial crops like sunflower, chillies, cotton, sugarcane and turmeric, horticultural crops like mango along with cashew, oranges and citrus thrive well on these soils.

Broadly, the soils in the studied area can be divided into two groups viz., black and red soils. Black soils are important group of soils in this semi-arid dryland agriculture area because in this environment, they are among the most productive soils. The major factor contributing to the productivity of these

soils in semi-arid environments is their high water holding capacity and favourable water release characteristics over a wide suction range. These two properties of soils are very important in an agricultural system, where the annual rains are erratic (Venkateswarlu, 1987).

The Vertisols and vertic intergrades of the studied area have high moisture storage capacity due to the presence of high percentage of smectitic clay. The high moisture storage capacity ensures much safer and more productive cropping; it can assist crops to survive and perhaps even to grow during prolonged dry spells. This high moisture storage capacity will also allow crops to continue to grow for several weeks after the rainy season.

Despite the fact that these soils are potentially productive and the thermal regime of the region is conducive to cropping throughout the year, there are certain soil-related constraints to the agricultural potential. The soil related factors which limit the productivity of various crops are given below:

As per Riquier rating, the actual productivity of black soils in the studied area is from average to good.

5.7.1.1 Limitations :

- * Imperfect drainage due to swelling and shrinkage of soil clays.
- * Low infiltration rate
- * Shrinkage cracks

- * Run off
- * Soil erosion
- * Development of sodicity

Sodicity has been developed in pedons 10 and 17. There is a tendency to develop sodicity in pedon 7.

- * The calcium carbonate in black soils adversely influences the availability of micronutrients, particularly of zinc and iron.
- * The higher contents of calcium carbonate lead to greater fixation of phosphorus and zinc to limit crop production.
- * These soils are low to medium in nitrogen. All the pedons have low contents of organic carbon.

5.7.1.2 Management practices recommended to increase the productivity of black soils:

- * Enrich and maintain the organic matter content by applying organic manures and/or *in-situ* incorporation of green manure
- * Organic manures supply micronutrients to soil, increase the efficiency of applied fertilizers and improve the physical condition of soil
- * Judicious applications of fertilizers is necessary
- * *In-situ* soil and water conservation through watershed management approach
- * To eliminate sodium salts, gypsum application is essential

Actual productivity of red soils in the study area is between poor to average as per Riquier rating.

5.7.2.1 Limitations:

- * Shallow to medium in depth. Pedons 3 and 22 are very shallow soils, with a depth of less than 30 cm.
- * These soils in general were formed on higher elevations, as a result, are subjected to wind/water erosion resulting in loss of valuable soil nutrients.
- * Somewhat excessive drained soils. Pedon 3 is excessively drained soil.
- * Available water capacity is low.
- * Low in micronutrient status, particularly zinc.
- * Low in available phosphorus.
- * Development of acidity was noticed in pedons 14 and 15. A decrease in CEC and increase in the concentration of H^+ , Al^{+3} and Mg^{+2} by replacing exchangeable Ca^{+2} indicates that chemical degradation had occurred in these two soils (Ahmed, 1985).

5.7.2.2 Management practices recommended to increase the potential productivity of red soils:

- * Application of bulky organic manures or green leafy manuring improves the physical condition and nutrient status of the soil

- * Application of zinc sulphate would prove beneficial
- * Liming the acid soils
- * Application of fertilizers as per soil test
- * Measures to control wind and water erosions(wind breaks, mulching, construction of terraces etc.)
- * *In-situ* soil and water conservation through watershed management approach

The soil characteristics can be improved by the above management practices. By doing so, potential productivity will be increased.

CONCLUSIONS

1. In Telangana region the soils were formed on various geological formations like igneous (granite, basalt), metamorphic (gneiss, hornblende schist) and sedimentary (sandstone, limestone) rocks.
2. Physiographically the study area comprised of north-western plateau (between altitudes 620 m and 700 m) and interior rugged plains. The north-western plateau is geologically the Deccan trap terrain, consisting of terraced plateaus. The interior rugged plain is formed predominantly of granite-gneiss complex.
3. From shallow (<50 cm) to deep (>100 cm) red and black soils are occurring in juxtaposition in this area. The red soils had colours in the hue of 7.5YR to 2.5 YR, whereas black soils had colours in the hue of

10 YR. The values ranged between 3 to 6 and chromas between 3 to 8.

4. The surface horizons of black soils had moderate medium subangular blocky structure and hard to very hard (dry) and friable to very firm (moist) consistence. The surface horizons of red soils had weak to moderate, fine to medium and granular to sub-angular blocky structure with soft to slightly hard (dry) and loose to friable (moist) in consistence.
5. The texture of the soils varied from sandy to clayey in red soils and in black soils it is from gravelly sandy clay loam to clayey.
6. The black soil pedons were characterised by cracks, slickensides and calcium carbonate concretions. Red soil pedons were characterised by development of colour/structure and/or presence of thin clay cutans.
7. Bulk density increased with depth due to compaction by overburden pressure. Amount and type of clay are the main factors deciding the amount of moisture retained in soils. Hence, the black soils retain more moisture at 33 and 1500 Kpa and have more available water capacity than red soils.
8. The pH of black soils ranged from neutral to alkaline and for red soils it varied from acidic to neutral and pH values showed increase with depth. The EC values were low indicating non-saline nature of the soils.

9. The organic carbon content ranged from low to medium. Soils were well supplied with available phosphorus and micronutrients copper and manganese. Availability of zinc was low in black soils due to its fixation by clay and excess amounts of calcium carbonate is the reason for low availability of iron in black soils.
10. The CEC was dependent upon the amount and type of clay. Exchangeable complex was saturated with Ca^{+2} followed by Mg^{+2} , Na^{+} and K^{+} . The hazard of development of sodicity was noticed in few black soil pedons. The lower pH values and low base saturation in a few red soil pedons indicate the increase in age and degree of development of the soils.
11. Light minerals (quartz, feldspars and mica) constituted more than 90 per cent of the sand fraction and heavy minerals (epidote, garnet, zircon, amphibole, pyroxenes and opaque minerals) consisted of the remaining fraction.
12. In black soils the dominant clay mineral was smectite followed by kaolinite, whereas in red soils, the dominant clay mineral was kaolinite followed by mica. Smectite was formed in the past humid climate through transformation from weathering sequence of mica-vermiculite-smectite. Under intensive leaching conditions which prevailed over long periods, kaolinite was formed by loss of alkalies and iron from montmorillonite.

13. The genesis of the soils appears to have been mostly influenced by topography while the parent material and climate played passive roles. Hydrolysis, leaching, eluviation and illuviation, translocation and transformation of minerals were some of the important processes in the soils.
14. As per USDA Soil Taxonomy black soils qualified for Vertisols and Inceptisols and red soils for Entisols, Inceptisols and Alfisols.
15. The actual productivity of black soils was from average to good, whereas for red soils it was between poor to average. Imperfect drainage, low infiltration rate, development of sodicity were the important limitations in black soils. In red soils, soil erosion, shallow depth, severe leaching leading to chemical degradation were the important limitations. The potential productivity in both red and black soils of Northern and Southern Telangana agroclimatic zones can be substantially increased through efficient management practices for sustainable crop production.

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Summary

CHAPTER VI

SUMMARY

The present study was initiated to understand the pedogenic processes that might be responsible for the genesis of soils of Telangana region. The major focus of the present study was to provide appropriate and detailed characterisation of soils of the study area. Genesis, classification and land use potential of these soils with a view that this would ultimately help in making rational planning for efficient management of these soils towards sustainable agriculture.

Northern and Southern Telangana zones (NTZ and STZ) among the seven agro-climatic zones occurring in Andhra Pradesh come under semi-arid (moist) tropics and semi-arid (dry) tropics, respectively. The major difference between these two zones is the difference between the quantum of rainfall. Physiographically the study area comprised of north-western plateau (between altitudes 620 m and 700 m) and interior rugged plains. Here, the soils were formed on various geological formations; on igneous (granite, basalt), metamorphic (granite-gneiss, hornblende schist) and sedimentary (sandstone, limestone) rocks.

Red sandy soils (*Dubba* and *Chalka*), red earths with loamy sub-soils (*chalka*), lateritic soils and black cotton soils (shallow, moderately deep and deep)

are found largely in this area. Broadly, these are two groups of soils viz., red and black occurring in close proximity.

Representative pedon sites were selected in Agricultural Research Stations of Acharya N.G. Ranga Agricultural University. Soil samples were collected from 14 profiles from NTZ and 8 profiles in STZ.

Pedons were studied morphometrically and soil samples were collected horizonwise. These samples were analysed for physical, chemical and mineralogical properties.

The studied area comprised shallow, moderately, deep and deep red and black soils. The soils varied in colour ranging from a hue of 10 YR to 2.5 YR with different values and chromas. The surface horizons of black soils had moderate medium subangular blocky structure and hard to very hard (dry) and friable to very firm (moist) consistence. The sub-soil horizons had moderate to strong, medium to very coarse angular blocky structure and hard to extremely hard (dry) and firm to extremely firm (moist) consistence.

The surface horizons of red soils generally had weak to moderate, fine to medium and granular to sub-angular blocky structure with soft to slightly hard (dry) and loose to friable (moist) in consistence. The sub-soil horizons of red soil pedons generally fall under weak to moderate, fine to medium sub angular

blocky structure and soft to hard (dry) and friable to firm (moist) in consistence. The black soil pedons were characterised by cracks, slickensides and calcium carbonate concretions. The texture of the studied pedons was varying from sandy to clayey. Bulk density was found to increase with depth. The moisture retention at 33 and 1500 Kpa and available water capacity were more in black soils than in red soils. The pH of black soils was ranging from neutral to alkaline and for red soils, it was varying from acidic to neutral and pH values showed increase with depth. The EC values were low indicating non-saline nature of the soils. In general, the organic carbon values were low. The black soils have high cation exchange capacity values than the red soils indicating less weathered nature of these soils than red soils. Calcium was the dominant cation in the exchange complex followed by magnesium. The hazard of development of sodicity was noticed in few black soil pedons. Decrease in Ca/Mg ratio in some of the sub soils is an indicative of the increase in sodicity. Per cent base saturation nearer to 100 is an indication of low to medium weathered nature of black soils. The lower pH values and low base saturation in a few red soil pedons indicate the increase in age and degree of development of the soil.

Petrographic studies of sand fraction constituted light minerals >90% of the sand fraction. Among light minerals, quartz was the dominant mineral followed by feldspars and micas (muscovite and biotite). Zircon, garnet, hornblende, epidote, pyroxens and opaque minerals (limonite, ilmenite, magnetite

and haematite) are the heavy minerals found. Selected clay samples of both red and black soils were subjected to x-ray diffraction analyses. Study of the diffraction patterns in general established the presence of kaolinite, smectite, mica and vermiculite in all the studied soils. The primary minerals commonly occurred were quartz and feldspars in traces. In red soils, the dominant clay mineral was kaolinite followed by mica, whereas in black soils the dominant clay mineral was smectite followed by kaolinite. Smectite was formed in the past humid climate through transformation from weathering sequence of mica-vermiculite-smectite. Under intensive leaching conditions prevailed over long periods, kaolinite was formed by loss of bases and iron from montmorillonite.

The genesis of the soils appears to have been mostly influenced by topography while the parent material and climate played passive roles. Hydrolysis, leaching, eluviation and illuviation, translocation and transformation of minerals were some of the important processes in these soils.

Based on the systematic approach of soil taxonomy, red soils of the study area were keyed out to be Entisols, Inceptisols and Alfisols. The pedons 11 and 15 were classified as fine-loamy, mixed isohyperthermic family of Leptic Haplusterts. Pedon 22 and 14 were classified as loamy, mixed, isohyperthermic family and fine-loamy, kaolinitic, isophyperthermic family of Typic Haplustalf, respectively. The pedon 20 is a member of fine, mixed, isohyperthermic family

of Typic Rhodustalf. Pedon 3 is a sandy, mixed, isohyperthermic family of Typic Ustipsamment. Pedons 1, 4 and 9 are Typic Haplustepts belonging to fine-loamy/coarse loamy, mixed (calcareous), isohyperthermic family. Pedon 16 is a member of fine-loamy, mixed, isohyperthermic family of Fluventic Haplustepts.

Black soils of the study area were qualified for Vertisols and Inceptisols. Pedon 6 was classified as fine-loamy, mixed (calcareous), isohyperthermic family of Calcic Haplustepts. The pedons 13 and 21 were classified as fine, smectitic (calcareous), isohyperthermic family of Vertic Haplustepts. The pedon 12 is a member of fine, smectitic (calcareous), isohyperthermic family of vertic calciustepts.

Pedons 2, 5, 7, 8, 10, 17, 18 and 19 classified as members of fine/very fine, smectitic (calcareous), isohyperthermic family of Typic Haplusterts (pedons 5,7,2 and 17), Chromic Haplusterts (pedons 8,18 and 19) and Sodic Haplusterts (pedon 10).

Land evaluation was done according to method suggested by Riquier *et al.* (1970). The actual productivity of black soils was found from average to good, whereas for red soils, it was between poor to average. Imperfect drainage, low infiltration rate, development of sodicity were some of the important limitations in black soils. In red soils, soil erosion, shallow depth, severe leaching leading to chemical degradation were some of limitations. Suitable management practices

were suggested to improve the potential productivity. The length of growing period (LGP) was about 150 days in this area, the *kharif* crops during monsoon can be taken up successfully with supplemental irrigations during dry spell if occurred. The black soils being smectitic were quite capable of holding a high amount of moisture.

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* Originals not seen

Note: References were given as per ANGRAU guidelines for thesis presentation, 1997

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Appendices

APPENDIX

DESCRIPTION OF PEDONS

Pedon 1

Classification	: Fine-loamy, mixed, calcareous, isohyperthermic, Typic Haplustepts
Location	: Jagtial; Mandal: Jagtial District: Karimnagar, Andhra Pradesh 18°49'30"N, 78°58'02" E
Elevation	: About 300 m above MSL
Landform	: Upper sectors of Valley-side slopes
Drainage class	: Well drained
Depth to water table	: 1.0 - 2.0 m
Land use	: Crop land - Maize, Sesamum, groundnut, redgram, greengram, blackgram
Natural vegetation	: Neem, Palms
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 22 cm; brown (7.5YR 4/4) sandy clay loam, strong brown (7.5YR 4/6) moist, moderate fine granular structure; slightly hard, friable, slightly sticky and nonplastic; many medium roots inside peds; common fine pores; slightly effervescent; neutral (pH 7.0); 10 per cent fine pebbles; clear smooth boundary.
Bw1	22 to 52 cm; brown (7.5YR 4/4) gravelly sandy clay loam, strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; many medium roots inside peds; common fine pores; few medium carbonate

- concretions; common fine distinct reddish yellow (7.5 YR 7/6) mottles; strongly effervescent; neutral (pH 7.1); 20 per cent fine pebbles; diffused smooth boundary.
- Bw2 52 to 77 cm; brown (7.5YR 4/4) gravelly sandy clay loam, strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; common fine pores; few medium carbonate concretions; common fine distinct reddish yellow (7.5YR 7/6) mottles; strongly effervescent; neutral (pH 7.2); 20 per cent fine pebbles; gradual smooth boundary.
- BC1 77 to 98 cm; brown (7.5YR 4/4) very gravelly loamy sand and weathered bed rock; strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; common medium pores; common medium carbonate concretions; strongly effervescent; slightly alkaline (pH 7.6); 50 per cent pebbles; clear smooth boundary.
- BC2 98 to 145 cm; brown (7.5YR 4/4) gravelly loamy sand and weathered bed rock with calcium carbonate accumulation; strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; many medium pores; many medium carbonate concretions; strongly effervescent; moderately alkaline (pH 8.2); 50 per cent pebbles; abrupt smooth boundary
- Crk 145 cm*; weathered granite with calcium carbonate accumulation; moderately alkaline (pH 8.2).

Classification	: Very fine, smectitic, calcareous, isohyperthermic, Typic Haplusterts
Location	: Jagtial; Mandal: Jagtial District: Karimnagar, Andhra Pradesh 18°49'30"N, 78°58'02" E
Elevation	: About 300 m above MSL
Landform	: Upper sectors of valley-side slopes
Drainage class	: Moderately well drained
Depth to water table	: >10 metres
Land use	: Agroforestry - Teak, Neem, Subabul
Natural vegetation	: Neem, Tamarind
Parent material	: Weathered granite/granite gneiss
Ap	0 to 35 cm; very dark gray (10YR 3/1) clay, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; very hard, very firm, sticky and slightly plastic; common medium roots inside peds; common fine and very fine pores; 1-2 cm wide cracks; few fine carbonate concretions; slightly effervescent; neutral (pH 7.2); 5 per cent fine pebbles; clear smooth boundary.
Bw3	5 to 64 cm; very dark gray (10YR 3/1) clay, very dark grayish brown (10YR 3/2) moist, moderate medium subangular blocky structure; very hard, very firm, sticky and slightly plastic; few fine roots throughout; common fine pores; 0.5-1 cm wide cracks; shiny

pressure faces, few fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.7); 5 per cent fine pebbles; clear smooth boundary.

- Bss 64 to 105 cm; very dark gray (10YR 3/1) with strong brown (7.5YR 5/8) clay, very dark grayish brown (10YR 3/2) with strong brown (7.5YR 5/8) moist; moderate medium angular blocky structure; very hard, very firm; sticky and slightly plastic; few fine roots throughout; few fine pores; shiny pressure faces and slickensides close enough to intersect; common fine carbonate concretions; slightly effervescent, slightly alkaline (pH 7.8); 10 per cent fine pebbles; diffused smooth boundary.
- BC 105 to 154 cm; strong brown (7.5YR 5/8) with dark gray (10YR 4/1) clay and weathered bed rock with lime concretions; strong brown (7.5YR 5/8) with dark grayish brown (10YR 4/2) moist; moderate medium angular blocky structure, very hard, very firm, sticky and slightly plastic; many fine carbonate concretions; strongly effervescent, slightly alkaline (pH 7.8); 40 per cent fine pebbles; clear smooth boundary.
- Crk 154 to 200 cm; weathered granite with calcium carbonate accumulation. slightly alkaline (pH 7.8).

Classification	: Mixed, isohyperthermic, Typic Ustipsamments
Location	: Karimnagar; Mandal: Karimnagar District: Karimnagar, Andhra Pradesh 18°26'35"N, 79°04'45" E
Elevation	: About 280 m above MSL
Landform	: Footslopes of granite spur
Drainage class	: Somewhat excessively drained
Depth to water table	: >10 metres
Land use	: Crop land - Redgram, maize, greengram
Natural vegetation	: Neem, Palm, Babool
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 8 cm; reddish yellow (7.5YR 7/6) gravelly loamy sand, strong brown (7.5YR 5/6) moist; single grain; loose; common fine and medium roots; slightly acid (pH 6.1); 15 per cent fine igneous pebbles; abrupt smooth boundary.
Cr	8 cm; Weathered granite, slightly acid (pH 6.1)

Pedon 4

Classification	: Coarse-loamy, mixed, calcareous, isohyperthermic, Typic Haplustepts
Location	: Rudrur; Mandal: Varni District: Nizamabad, Andhra Pradesh 18°33'45"N, 77°52'25" E
Elevation	: About 380 m above MSL
Landform	: Inter-hill valley
Drainage class	: Somewhat excessive
Depth to water table	: > 10 metres
Land use	: Crop land - Pulses, Chillies
Natural vegetation	: Neem, babool, Eucalyptus
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 24 cm; brown (10YR 4/3) gravelly sandy clay loam, dark brown (10YR 3/3) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine and many fine roots throughout; common fine pores; few fine carbonate concretions; slightly effervescent, neutral (pH 6.6); 15 per cent fine pebbles, abrupt smooth boundary.
Bw1	24 to 68 cm; strong brown (7.5YR 5/6) gravelly sandy loam, strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure; soft, friable, nonsticky and nonplastic; many fine roots; few fine carbonate concretions; slightly effervescent; neutral (pH 6.6); 15 per cent fine pebbles; diffused smooth boundary.
Bw2	68 to 120 cm; strong brown (7.5YR 5/6) gravelly sandy loam, strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure, soft, friable, nonsticky and nonplastic; few fine roots; few

fine carbonate concretions; slightly effervescent; neutral (pH 6.7); 20 per cent fine gravels and 10 per cent coarse pebbles; gradual smooth boundary.

Bw3 120 to 170 cm; strong brown (7.5YR 5/6) gravelly sandy loam, strong brown (7.5YR 4/6) moist; weak fine subangular blocky structure, soft, friable, nonsticky and nonplastic; few fine carbonate concretions; slightly effervescent; neutral (pH 6.9); 15 per cent fine pebbles; abrupt smooth boundary.

Bw4 170 to 200 cm; yellowish brown (10YR 5/6) gravelly sandy loam with weathered bedrock, very pale brown (10YR 7/4) moist; weak fine subangular blocky structure, soft, friable, nonsticky and nonplastic; common medium carbonate concretions; slightly effervescent; slightly alkaline (pH 7.8); 40 per cent fine and medium gravels and 20 per cent coarse pebbles.

Classification	: Fine, smectitic, calcareous, isohyperthermic, Typic Haplusterts
Location	: Rudrur; Mandal: Varni District: Nizamabad, Andhra Pradesh 18°33'45"N, 77°52'25" E
Elevation	: About 380 m above MSL
Landform	: Inter-hill valley
Drainage class	: Moderately well drained
Depth to water table	: > 10 metres
Land use	: Crop land - Sugarcane
Natural vegetation	: Neem, Tamarind, babool
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 31 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium subangular blocky structure; hard, friable, sticky and plastic; many medium roots inside peds; common fine and very fine pores; 3-4 cm wide cracks; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 7.9); 20 per cent fine and medium pebbles; clear smooth boundary.
Bw1	31 to 62 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium subangular blocky structure; hard, friable, sticky and plastic; few fine roots; common fine and very fine pores; 2-3 cm wide cracks; few fine carbonate concretions, slightly effervescent; moderately alkaline (pH 8.2); 10 per cent fine and medium pebbles; clear smooth boundary.
Bw2	62 to 97 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium subangular blocky structure; very hard, firm,

sticky and plastic; few fine roots; common very fine pores; shiny pressure faces; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.3); 20 per cent fine and medium pebbles; clear smooth boundary.

Bss1 97 to 135 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium angular blocky structure; very hard, very firm, sticky and plastic; few very fine roots; slickensides close enough to intersect; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.3), 25 per cent fine pebbles; clear broken boundary.

Bss2 135 to 172 cm; yellowish brown (10YR 5/4 D&M) with very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium angular blocky structure; very hard, very firm, sticky and plastic; slickensides close enough to intersect; common fine and medium carbonate concretions; strongly effervescent; moderately alkaline (pH 8.1); 40 per cent fine pebbles; clear smooth boundary.

Ck 172 to 200 cm; yellowish brown (10YR 5/4 D&M) gravelly clay and weathered bed rock with lime concretions; many fine and medium carbonate concretions; moderately alkaline (pH 8.3); 50 per cent coarse pebbles and 20 per cent cobbles.

Pedon 6

Classification	: Fine-loamy, mixed, calcareous, isohyperthermic, Calcic Haplustepts
Location	: Jaipur; Mandal: Jaipur District: Adilabad, Andhra Pradesh 18°50'56"N, 79°35'28" E
Elevation	: About 160 m above MSL
Landform	: Foot slopes of Kundaram (sandstone) ridge
Drainage class	: Some what excessive
Depth to water table	: > 10m
Land use	: Rangeland (grazed) - Teak, Neem, palm, local grasses
Parent material	: Sandstone

Ap 0 to 25 cm; brownish yellow (10YR 6/6) gravelly sandy clay loam, yellowish brown (10YR 5/6) moist; weak medium granular structure; soft, friable, nonsticky and nonplastic; many fine and medium roots inside peds; common fine and medium pores; few fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.6); 10 per cent fine and medium pebbles and 5 per cent coarse pebbles; clear wavy boundary.

Bw1 25 to 54 cm; brownish yellow (10YR 6/6) gravelly sandy clay loam, yellowish brown (10YR 5/8) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; few fine roots, common fine and medium pores; common fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.6); 20 per cent fine pebbles; clear smooth boundary.

- Bw2 54 to 95 cm; brownish yellow (10YR 6/6) gravelly sandy clay loam with lime, brownish yellow (10YR 6/8) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic, few fine roots; common fine and medium pores; many coarse carbonate concretions; strongly effervescent; slightly alkaline (pH 7.7), 25 per cent fine pebbles; clear smooth boundary.
- Bck 95 to 132 cm; yellowish brown (10YR 5/8) gravelly sandy clay loam and weathered bedrock with calcium carbonate accumulation, yellowish brown (10YR 5/6) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; violently effervescent; slightly alkaline (pH 7.8); 35 per cent medium and coarse pebbles; clear smooth boundary.
- Crk 132 cm* weathered material with abundant quantities of calcium carbonate accumulation; moderately alkaline (pH 7.9).

Pedon 7

Classification	: Fine, smectitic, calcareous, isohyperthermic, Typic Haplusterts.
Location	: Adilabad; Mandal: Adilabad District: Adilabad, Andhra Pradesh 19°39'10" N, 78°30'40" E
Elevation	: About 280 m above MSL
Landform	: Undulating, denuded plateau spur (lower level)
Drainage class	: Moderately well drained
Depth to water table	: > 10 m
Land use	: Crop land - Cotton, <i>jowar</i>
Natural vegetation	: Neem, Tamarind
Parent material	: Weathered basalt
Ap	0 to 24 cm; very dark grayish brown (10YR 3/2 D&M) gravelly clay; moderate coarse subangular blocky ; hard, firm, slightly sticky and slightly plastic; many fine roots inside peds; many fine pores; 1-2 cm wide cracks, few fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.8); 15 per cent fine pebbles; clear smooth boundary.
Bw	24 to 43 cm; very dark grayish brown (10YR 3/2 D&M) clay, moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; few fine roots; common fine pores; 0.5-1 cm wide cracks; common fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.0); 10 per cent fine pebbles; clear smooth boundary.

- Bss1 43 to 79 cm; very dark grayish brown (10YR 3/2 D&M) gravelly clay, moderate medium subangular blocky structure; slightly hard, firm, sticky and plastic; common fine pores; shiny pressure faces, slickensides close enough to intersect at 50 cm depth; common fine carbonate concretions; strongly effervescent; moderately alkaline (pH 8.3); 15 per cent fine pebbles; clear smooth boundary.
- Bss2 79 to 115 cm; very dark gray (10YR 3/1) gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure, slightly hard, firm, sticky and plastic; common fine pores; shiny pressure faces, slickensides close enough to intersect; common fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.6); 20 per cent fine pebbles; gradual smooth boundary.
- Bss3 115 to 152 cm; yellowish brown (10YR 5/4 D&M) with very dark gray (10YR 3/1) gravelly clay; moderate medium angular blocky structure; slightly hard, firm, sticky and plastic; common fine pores; shiny pressure faces, slickensides close enough to intersect; common fine carbonate concretions; few medium distinct gray (10YR 5/1) mottles; strongly effervescent; strongly alkaline (pH 8.9); 20 per cent fine pebbles; clear smooth boundary.
- Bss4 152 to 200 cm; yellowish brown (10YR 5/4 D&M) gravelly silty clay; moderate medium angular blocky structure; slightly hard, firm, sticky and plastic; common fine and medium pores; shiny pressure faces, slickensides close enough to intersect; many medium carbonate concretions; common medium distinct gray (10YR 5/1) mottles; violently effervescent; very strongly alkaline (pH 9.2); 25 per cent fine pebbles.

Pedon 8

Classification	: Fine, smectitic, calcareous, isohyperthermic, Chromic Haplusterts
Location	: Mudhol; Mandal: Mudhol District: Adilabad, Andhra Pradesh 18°58'N, 77°55' E
Elevation	: About 350 m above MSL
Landform	: Main valley-side slopes
Drainage class	: Moderately well drained
Depth to water table	: > 10 m
Land use	: Crop land - Maize, pulses, cotton
Natural vegetation	: Neem, babool, bamboo, wild badam
Parent material	: Weathered basalt
Ap	0 to 18 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; very few fine roots inside peds; many very fine and fine pores; 8-10 cm wide cracks; few fine carbonate concretions and few fine rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.7); 5 per cent medium and coarse pebbles; clear smooth boundary.
Bw1	18 to 48 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure; slightly hard, firm, sticky and plastic; few fine roots; many fine pores; 5-8 cm wide cracks; few fine carbonate concretions and few fine and medium rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.7); 5 per cent medium and coarse pebbles; clear smooth boundary.

- Bw2 48 to 90 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium sub-angular blocky structure; slightly hard, firm, sticky and plastic; very few medium roots; many fine pores; shiny pressure faces; few fine carbonate concretions and few medium rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.7); 5 per cent medium and coarse pebbles; clear smooth boundary.
- Bss1 90 to 136 cm; very dark grayish brown (10YR 3/2) clay, yellowish brown (10YR 5/4) moist; moderate medium angular blocky structure; slightly hard, very firm, very sticky and very plastic; very few medium roots; many fine pores; common continuous distinct intersecting slickensides on horizontal faces of peds; few fine carbonate concretions and common medium and coarse rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.8); 5 per cent medium and coarse pebbles; clear smooth boundary.
- Bss2 136 to 185 cm; very dark grayish brown (10YR 3/2) clay, yellowish brown (10YR 5/4) moist; moderate medium angular blocky structure; slightly hard, very firm, very sticky and very plastic; very few medium roots; many fine pores; common continuous distinct intersecting slickensides on horizontal faces of peds; common medium carbonate concretions and common medium and coarse rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.8); 10 per cent medium and coarse pebbles; clear smooth boundary.
- Bss3 185 to 200 cm; very dark grayish brown (10YR 3/2) gravelly clay, yellowish brown (10YR 5/4) moist; moderate medium angular blocky structure; slightly hard, very firm, very sticky and very plastic; common continuous distinct intersecting slickensides on horizontal faces of peds; common medium carbonate concretions and common medium and coarse rounded dark concretions; strongly effervescent; slightly alkaline (pH 7.8); 20 per cent medium and coarse pebbles.

Pedon 9

Classification	: Fine-loamy, mixed, isohyperthermic, Typic Haplustepts
Location	: Warangal; Mandal: Warangal District: Warangal, Andhra Pradesh 18°03'N, 79°22' E
Elevation	: About 270 m above MSL
Landform	: Gently sloping plains
Drainage class	: Well drained
Depth to water table	: 1-2 metres
Land use	: Crop land - Orange, mango
Natural vegetation	: Neem, local grasses
Parent material	: Weathered granite/granite-gneiss

Ap 0 to 30 cm: Pale brown (10YR 6/3) sandy clay loam, brown (10YR 5/3) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; few fine roots, many medium pores; neutral (pH 7.1); 10 per cent fine pebbles; gradual wavy boundary.

Bw1 30 to 66 cm: Pale brown (10YR 6/3) and strong brown (7.5YR 5/8 D&M) gravelly sandy clay loam and weathered bed rock; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; neutral (pH 7.3); 30 per cent fine pebbles; clear smooth boundary.

Bw2	66 to 90 cm; strong brown (7.5YR 5/8) with pale brown (10YR 6/3) gravelly sandy clay loam and weathered rock; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; slightly alkaline (pH 7.4); 40 per cent fine pebbles; clear smooth boundary.	251
Cr	90 cm+: strong brown (7.5YR 5/8); weathered bed rock (granite); slightly alkaline (pH 7.6).	

Pedon 10

Classification	: Fine, smectitic, (calcareous), isohyperthermic, Sodic Haplusterts
Location	: Warangal; Mandal: Warangal District: Warangal, Andhra Pradesh 18°03'N, 79°22' E
Elevation	: About 270 m above MSL
Landform	: Gently sloping plains
Drainage class	: Imperfectly drained
Depth to water table	: 5-10 metres
Land use	: Crop land - Cotton, pulses
Natural vegetation	: Neem, babool
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 14 cm, very dark gray (10YR 3/1 D&M) clay, moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; few fine roots; many fine pores; 0.5-1 cm wide cracks; moderately alkaline (pH 8.1); 5 per cent fine pebbles; clear smooth boundary.
Bw1	14 to 48 cm, very dark gray (10YR 3/1 D&M) clay; moderate medium sub-angular blocky structure; slightly hard, firm sticky and plastic; many fine pores; 5-6 mm wide cracks; moderately alkaline (pH 8.4); 5 per cent fine pebbles; clear smooth boundary.
Bw2	48 to 82 cm; very dark gray (10YR 3/1 D&M) clay; moderate medium subangular blocky structure; hard, firm, very sticky and very plastic; many fine pores; shiny pressure faces; strongly alkaline (pH 8.7); 5 per cent fine pebbles; clear smooth boundary.

- Bss1 82 to 110 cm; very dark gray (10YR 3/1 D&M) clay; moderate medium angular blocky structure; hard, firm, very sticky and very plastic; common fine pores, slickensides close enough to intersect; strongly alkaline (pH 8.8); 5 per cent fine pebbles; clear smooth boundary.
- Bss2 110 to 144 cm; very dark gray (10YR 3/1 D&M) clay; moderate medium angular blocky structure; very hard, firm, very sticky and very plastic; common fine pores; slickensides close enough to intersect; strongly alkaline (pH 8.8); 5 per cent fine pebbles; abrupt smooth boundary.
- Bss3 144 to 200 cm; dark grayish brown (10YR 4/2) with very dark gray (10YR 3/1) clay, brown (10YR 4/3) moist; moderate medium angular blocky structure; very hard, firm, very sticky and very plastic; slickensides close enough to intersect; few fine carbonate concretions; slightly effervescent; strongly alkaline (pH 8.6); 10 per cent fine pebbles.

Pedon 11

Classification	: Fine-loamy, mixed, isohyperthermic, Typic Haplustalfs
Location	: Malyal; Mandal: Mahaboobabad District: Warangal, Andhra Pradesh 17°33'15"N, 79°58'10" E
Elevation	: About 200 m above MSL
Landform	: Narrow valley fringes
Drainage class	: Well drained
Depth to water table	: > 10 m
Land use	: Crop land (Horticulture) - Mango, chillies
Natural vegetation	: Neem, babool, Eucalyptus
Parent material	: Weathered granite/granite-gneiss

Ap	0 to 6 cm; yellowish red (5YR 5/8) loamy sand, yellowish red (5YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; many fine roots; many fine and medium pores; slightly acid (pH 6.2); 5 per cent fine pebbles; abrupt smooth boundary.
Bt1	6 to 30 cm; red (2.5YR 5/6) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; many fine and medium pores; moderately acid (pH 5.9); clear smooth boundary.
Bt2	30 to 60 cm; red (2.5YR 5/6) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; many fine and medium pores; slightly acid (pH 6.2); 5 per cent fine pebbles; clear smooth boundary.

- Bt3 60 to 90 cm; red (2.5YR 5/6) sandy clay, red (2.5YR 4/6) moist, moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; common fine and medium pores, few thin clay films on faces of peds and in pores; slightly acid (pH 6.3); 10 per cent fine and medium pebbles; clear smooth boundary.
- Cr 90 cm+; red (2.5YR 4/6) gravelly sandy clay and weathered granite, red (2.5YR 4/8) moist; slightly acid (pH 6.2).

Classification	: Clayey-skeletal, smectitic calcareous, isohyperthermic, Vertic Calciustepts
Location	: Wyra; Mandal: Wyra District: Khammam, Andhra Pradesh 17°10'45" N, 80°22'30" E
Elevation	: About 85 m above MSL
Landform	: Flood plain of Wyra river
Drainage class	: Moderately well drained
Depth to water table	: < 10 m
Land use	: Crop land - Paddy, blackgram
Natural vegetation	: Palm, babool, neem, <i>Ficus carica</i>
Parent material	: Hornblende schist
Ap	0 to 21 cm; very dark gray (10YR 3/1) gravelly clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic, many fine roots inside peds; many fine pores; 4 to 5 cm wide cracks; common fine and medium carbonate concretions; slightly alkaline (pH 7.6); 20 per cent fine pebbles; clear smooth boundary.
Bw	21 to 34 cm; dark grayish brown (10YR 4/2 D&M) gravelly clay loam, moderate medium subangular blocky structure; very hard, firm, sticky and slightly plastic; many fine pores; 1-2 cm wide cracks, many fine and medium carbonate concretions; strongly effervescent; moderately alkaline (pH 8.0); 25 per cent fine and 5 per cent medium pebbles; clear smooth boundary.

- Bck 34 to 64 cm; weathered bed rock and dark grayish brown (10YR 4/2) gravelly clay loam with lime; moderate medium subangular blocky structure; very hard, firm, sticky and slightly plastic; many medium and coarse carbonate concretions; moderately alkaline (pH 8.0); 25 per cent fine and 15 per cent medium pebbles; clear smooth boundary.
- Crk 64 to 104 cm; weathered hornblende schist with abundant quantities of calcium carbonate; moderately alkaline (pH 8.3).

Pedon 13

Classification	: Fine, smectitic, calcareous, isohyperthermic, Vertic Haplustepts
Location	: Madhira; Mandal: Madhira District: Khammam, Andhra Pradesh 16°55'40N, 80°21'48" E
Elevation	: About 60 m above MSL
Landform	: Gently sloping deltaic plain
Drainage class	: Moderately well drained
Depth to water table	: 1-2 metres
Land use	: Crop land - Greengram, blackgram, redgram, <i>jowar</i>
Natural vegetation	: Neem, pipal, babool
Parent material	: Granite/granite-gneiss

Ap	0 to 20 cm; grayish brown (10YR 5/2) gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; common fine roots; many fine pores; 6-8 cm wide cracks; few very fine carbonate concretions; strongly effervescent; moderately alkaline (pH 8.0); 15 per cent fine pebbles; clear smooth boundary.
Bw1	20 to 64 cm; grayish brown (10YR 5/2) gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; many fine pores; 2-4 cm wide cracks; few very fine carbonate concretions; strongly effervescent; moderately alkaline (pH 8.0); 15 per cent fine pebbles; clear smooth boundary.

- Bw2 64 to 105 cm; grayish brown (10YR 5/2) gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; hard, firm, sticky and plastic; common fine pores; shiny pressure faces; common fine and very fine carbonate concretions; strongly effervescent; moderately alkaline (pH 8.0); 20 per cent fine pebbles; abrupt smooth boundary.
- Ck 105 to 162 cm; Very dark grayish brown (10YR 3/2) moist; weathered bed rock with calcium carbonate; moderately alkaline (pH 7.9).

Pedon 14

Classification	: Fine-loamy, mixed, isohyperthermic, Typic Haplustalfs
Location	: Aswaraopet; Mandal: Aswaraopet District: Khammam, Andhra Pradesh 17°14'58"N, 81°05'25" E
Elevation	: About 160 m above MSL
Landform	: Gently sloping interfluvium
Drainage class	: Somewhat excessively drained
Depth to water table	: > 10 m
Land use	: Crop land - Horticulture crops (mango, citrus, oil palm, <i>Anacardium occidentale</i> , <i>Achras sapota</i>) vegetable crops (beans, ladies finger, tapioca, <i>Memordia dioica</i>)
Natural vegetation	: Neem, <i>Brassica nigra</i> and local grasses
Parent material	: Fine grained ferruginous sandstone
Ap	0 to 21 cm; brown (7.5YR 5/4) loamy sand, dark brown (7.5YR 3/4) moist; weak fine granular structure; soft, friable, nonsticky and nonplastic; many fine and medium roots; many fine and medium pores; slightly acid (pH 6.2); 2 per cent fine pebbles; abrupt smooth boundary.
Bt1	21 to 50 cm; red (2.5YR 5/8) sandy loam, red (2.5YR 4/6) moist; weak fine subangular blocky structure; hard, very friable, nonsticky and nonplastic; few fine roots; common fine pores; common fine rounded iron-manganese concretions; moderately acid (pH 5.9); clear wavy boundary.

- Bt2 50 to 79 cm; red (2.5YR 4/8) loam, red (2.5YR 4/6) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; few fine roots; common fine and medium pores; few thin clay films on faces of peds and in pores; common fine rounded iron manganese concretions; very strongly acid (pH 4.7); 1 per cent fine pebbles; gradual smooth boundary.
- Bt3 79 to 123 cm; red (2.5YR 4/8) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few fine roots; common fine and medium pores; few thin clay films on faces of peds and in pores; common fine rounded iron-manganese concretions; very strongly acid (pH 4.7); 1 per cent fine pebbles; gradual smooth boundary.
- Bt4 123 to 152 cm; red (2.5YR 4/8) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; few fine roots; common fine pores; few medium rounded iron-manganese concretions; very strongly acid (pH 4.9); 5 per cent fine pebbles; abrupt smooth boundary.
- Cr 152 to 200 cm; weathered ferruginous sand stone; very strongly acid (pH 4.6).

Classification	: Loamy-skeletal, mixed, isohyperthermic, Typic Haplustalfs
Location	: Palem; Mandal: Biginapally District: Mahbubnagar, Andhra Pradesh 16°30'N, 78°18' E
Elevation	: About 500 m above MSL
Landform	: gently sloping plains
Drainage class	: Somewhat excessively drained
Depth to water table	: >10 metres
Land use	: Crop land - Redgram, horsegram, <i>jowar</i> , <i>bajra</i> , castor, groundnut, <i>ragi</i>
Natural vegetation	: <i>Eucalyptus</i> , <i>Annona squamosa</i> , <i>Zizyphus jujuba</i>
Parent material	: Weathered granite/granite-gneiss
Ap	0 to 15 cm; reddish yellow (5YR 7/8) loamy sand, reddish yellow (5YR 6/6) moist; weak fine granular structure; soft, friable, nonsticky and nonplastic; few fine roots; many medium pores; very strongly acid (pH 5.0); 10 per cent fine pebbles; abrupt smooth boundary.
Bt1	15 to 31 cm; light red (2.5YR 6/8) gravelly sandy clay loam, red (2.5YR 4/8) moist; weak medium subangular blocky structure; soft, friable, nonsticky and nonplastic; many medium pores; strongly acid (pH 5.3); 30 per cent fine pebbles; abrupt smooth boundary.
Bt2	31 to 50 cm; red (2.5YR 5/8) gravelly sandy clay loam, red (2.5YR 5/6) moist; weak medium subangular blocky structure; soft, friable, nonsticky and nonplastic; many medium pores; slightly acid (pH 6.3); 50 per cent fine pebbles; abrupt smooth boundary.
Cr	50 cm+; weathered granite

Pedon 16**263**

Classification	: Fine-loamy, mixed, isohyperthermic, Fluventic Haplustepts
Location	: Rajendranagar; Mandal: Rajendranagar District: Ranga Reddy, Andhra Pradesh 17°19'30"N, 78°23'30" E
Elevation	: About 520 m above MSL
Landform	: Flood plain of Usa river
Drainage class	: Well drained
Depth to water table	: >10 metres
Land use	: Crop land - Redgram, castor, groundnut
Natural vegetation	: Neem, Gileria
Parent material	: Granitic alluvium

Ap	0 to 21 cm; brown (10YR 4/3) gravelly sandy clay loam, dark brown (10YR 3/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots; many fine and medium pores; neutral (pH 7.2); 20 per cent fine pebbles; abrupt smooth boundary.
Bw1	21 to 40 cm; light brown (7.5YR 6/4) gravelly sandy clay loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few very fine roots; many fine and medium pores; few fine rounded iron-manganese concretions; neutral (pH 7.3); 20 per cent fine pebbles; abrupt smooth boundary.
Bw2	40 to 60 cm; light brown (7.5YR 6/4) gravelly sandy loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure;

slightly hard, friable, nonsticky and nonplastic; many fine and medium pores; few fine rounded iron-manganese concretions; slightly alkaline (pH 7.6); 20 per cent fine pebbles; gradual wavy boundary.

Bw3 60 to 81 cm; light brown (7.5YR 6/4) gravelly sandy loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; many fine and medium pores; few fine rounded iron-manganese concretions; slightly alkaline (pH 7.6); 20 per cent fine pebbles; abrupt smooth boundary.

Bw4 81 to 95 cm; Yellowish red (5YR 5/6) gravelly sandy clay loam and weathered bed rock, yellowish red (5YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, firm, nonsticky and nonplastic; many fine and medium pores; slightly alkaline (pH 7.4); 25 per cent fine pebbles.

Pedon 17

Classification	: Very fine, smectitic, calcareous, isohyperthermic, Typic Haplusterts
Location	: Rajendranagar; Mandal: Rajendranagar District: Ranga Reddy, Andhra Pradesh 17°19'30"N, 78°23'30" E
Elevation	: About 520 m above MSL
Landform	: Flood plain of Usa river
Drainage class	: Imperfectly drained
Depth to water table	: > 10 m
Land use	: Crop land - Jowar, Redgram, sunflower
Natural vegetation	: Babool, Tamarind
Parent material	: Granitic alluvium

Ap	0 to 20 cm; dark gray (10YR 4/1) gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; hard, firm, very sticky and very plastic; common fine and very fine roots inside peds; many fine pores; 10-12 cm wide cracks; many fine carbonate concretions and few medium rounded dark concretions; strongly effervescent; moderately alkaline (pH 8.1); 15 per cent fine pebbles; clear smooth boundary.
Bw1	20 to 50 cm; dark gray (10YR 4/1) clay; very dark grayish brown (10YR 3/2) moist; strong coarse subangular blocky structure; very hard, very firm, very sticky and very plastic; few fine and very fine roots between peds; many fine pores; 6-8 cm wide cracks; many fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.6); 10 per cent fine pebbles; clear smooth boundary.

- Bw2 50 to 80 cm; dark gray (10YR 4/1) gravelly clay; very dark grayish brown (10YR 3/2) moist; strong coarse subangular blocky structure; extremely hard, very firm, very sticky and very plastic; common fine pores; 3-4 cm wide cracks; shiny pressure faces; many fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.7); 15 per cent fine pebbles; clear smooth boundary.
- Bss1 80 to 120 cm; dark gray (10YR 4/1) gravelly clay, very dark grayish brown (10YR 3/2) moist; strong very coarse angular blocky structure; extremely hard, extremely firm, very sticky and very plastic; few fine pores; shiny pressure faces and slickensides close enough to intersect; many fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.6); 15 per cent fine pebbles; clear smooth boundary.
- Bss2 120 to 152 cm; dark gray (10YR 4/1) gravelly clay, very dark grayish brown (10YR 3/2) moist; strong very coarse angular blocky structure; extremely hard, extremely firm, very sticky and very plastic; few fine pores; common continuous distinct intersecting slickensides on horizontal faces of peds; many fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.7); 15 per cent fine pebbles; gradual smooth boundary.
- Bss3 152 to 185 cm; dark brown (10YR 3/3) gravelly clay, dark brown (10YR 3/3) moist; strong very coarse angular blocky structure; extremely hard, extremely firm, very sticky and very plastic; few fine pores; many fine carbonate concretions; strongly effervescent; strongly alkaline (pH 8.7); 20 per cent fine pebbles.

Pedon 18

Classification	: Fine, smectitic, (calcareous), isohyperthermic, Chromic Haplusterts
Location	: Tandur; Mandal: Tandur District: Ranga Reddy , Andhra Pradesh 17°13'56"N, 77°35'25" E
Elevation	: About 530 m above MSL
Landform	: Valley fringe of Kagna river
Drainage class	: Moderately well drained
Depth to water table	: > 10 m
Land use	: Crop land - Pulses, safflower, sorghum
Natural vegetation	: Babool, <i>Glyricidia</i> , <i>Croton taxiflora</i>
Parent material	: Basaltic alluvium

Ap	0 to 26 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure, hard, firm, sticky and plastic; many medium and fine roots between peds; many fine pores; 8-10 cm wide cracks; slightly alkaline (pH 7.4); 10 per cent medium and coarse pebbles; clear smooth boundary.
Bw1	26 to 60 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine roots between peds; many fine pores; 5-6 cm wide cracks; few fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.6); 5 per cent medium and coarse pebbles; clear smooth boundary.
Bw2	60-97 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure;

hard, firm, sticky and plastic; few very fine roots between peds; many fine pores; 3-4 cm wide cracks; shiny pressure faces; few fine carbonate concretions; slightly effervescent; slightly alkaline (pH 7.8); 10 per cent medium and coarse pebbles; clear smooth boundary.

- Bss1 97 to 136 cm; dark grayish brown (10YR 4/2) clay, brown (10 YR 4/3) moist; moderate medium angular blocky structure; hard, very firm, sticky and plastic; few very fine roots between peds; common fine pores; common continuous distinct intersecting slickensides on horizontal faces of peds; few fine carbonate concretions and few fine rounded dark concretions; slightly effervescent; slightly alkaline (pH 7.8); 10 per cent medium and coarse pebbles; clear smooth boundary.
- Bss2 136 to 170 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium angular blocky structure; hard, very firm, sticky and plastic; very few very fine roots between peds; few fine pores; common continuous distinct intersecting slickensides on horizontal faces of peds; few fine carbonate concretions and few fine rounded dark concretions; few fine distinct reddish mottles; slightly effervescent; moderately alkaline (pH 8.0); 10 per cent medium and coarse pebbles; gradual smooth boundary.
- Bss3 170 to 200 cm; dark grayish brown (10YR 4/2) clay, brown (10YR 4/3) moist; moderate medium angular blocky structure; hard, very firm, sticky and plastic; few fine pores; common medium carbonate concretions and few fine rounded dark concretions; few fine distinct reddish mottles; strongly effervescent; moderately alkaline (pH 8.1); 10 per cent medium and coarse pebbles.

Classification	: Very-fine, smectitic, calcareous, isohyperthermic, Chromic Haplusterts
Location	: Amberpet; District: Hyderabad, Andhra Pradesh 17°22'42"N, 78°31'36" E
Elevation	: About 500 m above MSL
Landform	: Food plain of Musi river
Drainage class	: Moderately well drained
Depth to water table	: >10 metres
Land use	: Crop land - Maize
Natural vegetation	: Neem, subabul, <i>Parthenium</i> and local grasses
Parent material	: Granitic alluvium
Ap	0 to 20 cm; gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium granular structure; very hard, very firm, very sticky and very plastic; many medium and fine roots between peds, many fine pores; 8-10 cm wide cracks; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 7.9); clear smooth boundary.
Bw1	20 to 40 cm; gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; very hard, very firm, very sticky and very plastic; many fine pores; 3-4 cm wide cracks; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.1); clear smooth boundary.

- Bw2 40 to 60 cm; gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; very hard, very firm, very sticky and very plastic; many fine pores; 1-2 cm wide cracks; shiny pressure faces; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.2); clear smooth boundary.
- Bss1 60 to 80 cm gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; extremely hard, extremely firm, very sticky and very plastic; common fine pores; slickensides close enough to intersect; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.2); 5 per cent fine pebbles; gradual wavy boundary.
- Bss2 80 to 110 cm; gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; extremely hard, extremely firm, very sticky and very plastic; common fine pores; slickensides close enough to intersect; few fine carbonate concretions; slightly effervescent; moderately alkaline (pH 8.2); 5 per cent fine pebbles; gradual wavy boundary; clear smooth boundary.
- Bss3 110 to 140 cm; gray (10YR 6/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; extremely hard, extremely firm, very sticky and very plastic; common fine pores; slickensides close enough to intersect; few fine carbonate concretions and few fine rounded dark concretions; few fine distinct reddish mottles; slightly effervescent; moderately alkaline (pH 8.2); 5 per cent fine pebbles; gradual smooth boundary.
- Bss4 140 to 165 cm; gray (10YR 5/1) clay, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; extremely hard, extremely firm, very sticky and very plastic; few fine pores; few

fine carbonate concretions and few fine rounded dark concretions;
few fine distinct reddish mottles; slightly effervescent; moderately
alkaline (pH 8.3); 10 per cent fine pebbles; abrupt wavy boundary.

Bss5 165 to 200 cm; dark gray (10YR 4/1) clay, very dark gray (10YR
3/1) moist; moderate medium subangular blocky structure; hard,
very firm, very sticky and very plastic; few fine pores; few fine
carbonate concretions and few fine rounded dark concretions;
slightly effervescent; moderately alkaline (pH 8.2); 10 per cent fine
pebbles.

Classification	: Clayey-skeletal, kaolinitic, isohyperthermic, Typic Rhodustalfs
Location	: Sangareddi, Mandal: Sangareddi District: Medak, Andhra Pradesh 17°37'45"N, 78°05'35" E
Elevation	: About 500 m above MSL
Landform	: Gently undulating plain adjoining the fringes of Manjira flood plain
Drainage class	: Somewhat excessively drained
Depth to water table	: >10 metres
Land use	: Horticulture crops - Mango
Natural vegetation	: Neem, local grasses
Parent material	: Granite/granite-gneiss

Ap	0 to 14 cm; yellowish red (5YR 5/6) gravelly sandy clay loam, yellowish red (5YR 4/6) moist; weak fine granular structure; soft, friable, slightly sticky and slightly plastic; many fine and medium roots; many fine and medium pores; neutral (pH 6.6); 20 per cent fine pebbles; abrupt smooth boundary.
Bw	14 to 26 cm; red (2.5YR 5/8) gravelly sandy clay loam, red (2.5YR 4/6) moist; weak medium subangular blocky structure; soft, firm, sticky and plastic; common fine roots; many fine and medium pores; slightly acid (pH 6.1), 20 per cent fine pebbles; abrupt smooth boundary.
Bt1	26 to 50 cm; red (2.5YR 4/8) gravelly clay, dark red (2.5YR 3/6) moist; moderate medium subangular blocky structure; slightly hard,

firm, sticky and plastic; few fine and very fine roots; many fine and medium pores; slightly acid (pH 6.4); 40 per cent fine and medium pebbles; clear smooth boundary.

- Bt2 50 to 69 cm; red (2.5YR 4/8) gravelly clay, dark red (2.5YR 3/6) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; few fine and very fine roots; many fine and medium pores; slightly acid (pH 6.3); 35 per cent fine and medium pebbles; abrupt smooth boundary.
- Bt3 69 to 80 cm; red (2.5YR 4/8) gravelly clay, dark red (2.5YR 3/6) moist; moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; few fine and very fine roots; many fine and medium pores; few thin clay films on faces of peds and in pores; slightly acid (pH 6.3); 20 per cent fine pebbles; abrupt smooth boundary.
- Bt4 80 to 95 cm; red (2.5YR 4/8) gravelly clay, red (2.5YR 3/6) moist; moderate medium subangular blocky structure; hard, very firm, sticky and plastic; many medium and coarse pores; slightly acid (pH 6.1); 40 per cent fine, medium and coarse pebbles; gradual smooth boundary.
- BC 95 to 120 cm; light red (2.5YR 6/8) gravelly clay and weathered parent material, red (2.5YR 5/6) moist; moderate medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; slightly acid (pH 6.1); 55 per cent fine, medium and coarse pebbles.

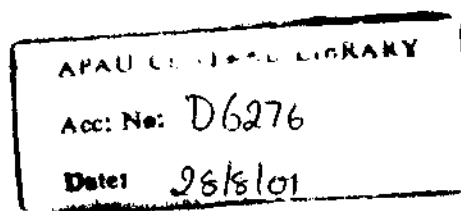
Pedon 21

Classification	: Fine, smectitic, calcareous, isohyperthermic, Vertic Haplustepts
Location	: Sangareddi, Mandal: Sangareddi District: Medak, Andhra Pradesh 17°37'45"N, 78°05'35" E
Elevation	: About 500 m above MSL
Landform	: Gently undulating plain adjoining the fringes of Majra flood plain
Drainage class	: Moderately well drained
Depth to water table	: >10 m
Land use	: Horticulture crops - Mango
Natural vegetation	: Subabul, local grasses
Parent material	: Granite/granite-gneiss

Ap 0 to 15 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium subangular blocky structure; slightly hard, firm, sticky and very plastic; common fine and few medium roots; many fine pores; 1-2 mm wide cracks; common medium carbonate nodules; slightly effervescent; slightly alkaline (pH 7.7); 20 per cent fine and medium pebbles; clear smooth boundary.

Bw1 15 to 35 cm; very dark gray (10YR 3/1 D&M) gravelly clay; moderate medium subangular blocky structure; hard, firm, sticky and very plastic; few fine and common medium roots; many fine pores; 0.3-0.5 cm wide cracks; common medium carbonate nodules; strongly effervescent; moderately alkaline (pH 8.0); 20 per cent fine and medium pebbles; gradual smooth boundary.

- Bw2 35 to 52 cm; very dark gray (10YR 3/1 D&M) gravelly clay; 275
moderate medium subangular blocky structure; very hard, very firm,
sticky and plastic; few fine and common medium roots; common
fine pores; common medium carbonate nodules; strongly
effervescent; moderately alkaline (pH 8.0); 20 per cent fine and
medium pebbles; gradual smooth boundary.
- Bw3 52 to 71 cm; dark gray (10YR 4/1 D&M) gravelly clay; moderate
medium subangular blocky structure; very hard, very firm, sticky
and plastic; very few medium roots; common fine pores; shiny
pressure faces; common medium carbonate nodules; strongly
effervescent; moderately alkaline (pH 8.0); 25 per cent medium
and coarse pebbles; gradual smooth boundary.
- Bw4 71 to 97 cm; dark gray (10YR 4/1 D&M) gravelly clay; moderate
medium subangular blocky structure; very hard, very firm, very
sticky and very plastic; few fine pores; shiny pressure faces;
common medium carbonate nodules; strongly effervescent;
moderately alkaline (pH 8.0); 30 per cent medium and coarse
pebbles; abrupt smooth boundary.
- BC 97 to 120 cm; dark gray (10YR 4/1 D&M) gravelly clay; moderate
medium subangular blocky structure; hard, firm, sticky and plastic;
many coarse carbonate nodules; violently effervescent; moderately
alkaline (pH 8.1); 40 per cent medium and coarse pebbles; abrupt
smooth boundary.
- Ck 120 cm+; dark gray (10YR 4/1) weathered parent material with
abundant quantities of calcium carbonate; moderately alkaline (pH
8.1).



Pedon 22

Classification	: Loamy, mixed, isohyperthermic, Typic Haplustalfs
Location	: Mallepalli; Mandal: Devarakonda District: Nalgonda, Andhra Pradesh 16°42'48"N, 78°59'15" E
Elevation	: About 260 m above MSL
Landform	: Undulating plain (interfluvial)
Drainage class	: Somewhat excessively drained
Depth to water table	: >10 m
Land use	: Horticulture crops - Mango, Jasmine, guava, amla, orange, soapnut
Natural vegetation	: Local grasses, Neem, Subabul, Custard apple
Parent material	: Weathered granite/granite-gneiss

Ap	0 to 15 cm: reddish yellow (5YR 6/6) gravelly loamy sand, yellowish red (5YR 5/6) moist; weak medium granular structure; soft, friable, nonsticky and nonplastic; common fine and very fine roots; many medium and coarse pores; neutral (pH 7.2); 15 per cent fine, medium and 10 per cent coarse pebbles, clear smooth boundary.
Bt	15 to 28 cm; red (2.5YR 5/8) gravelly sandy clay loam, dark red (2.5YR 3/6) moist; weak medium subangular blocky structure; soft, firm, slightly sticky and slightly plastic; common medium and coarse pores; slightly alkaline (pH 7.5); 10 per cent fine, medium and 20 per cent coarse pebbles; abrupt smooth boundary.
Cr	28 cm*, Red (2.5YR 5/8); weathered granite; massive; moderately alkaline (pH 8.0).