MICROMORPHOLOGICAL ANALYSIS AND CHARACTERIZATION
OF 70 BENCHMARK SOILS OF INDIA

A basic reference set

Part IV
MICROMORPHOLOGICAL ANALYSES AND CHARACTERIZATION
OF 70 BENCHMARK SOILS OF INDIA

A basic reference set

Part IV
Soils of the Red and Laterite Soil Region (50-66)
Soils of the Coastal and Deltaic Region (67-70)

M.J. KOOISTRA

Scanned from original by ISRIC – World Soil Information, as ICSU World Data Centre for Soils. The purpose is to make a safe depository for endangered documents and to make the accrued information available for consultation, following Fair Use Guidelines. Every effort is taken to respect Copyright of the materials within the archives where the identification of the Copyright holder is clear and, where feasible, to contact the originators. For questions please contact soil.isric@wur.nl indicating the item reference number concerned.

NETHERLANDS SOIL SURVEY INSTITUTE, WAGENINGEN - 1982
CONTENTS

Part I
Summary 1
Introduction 3
Material 4
Methods 5
Presentation of the micromorphological information 6
Results and conclusion 8
Recommendations 9
Presentation of the reference set 11
  General information 11
  Chapter 4 of the publication "Benchmark Soils of India" 15
  The reference set 39

Part II
Soils of the Kashmir Valley (1-2) 42
Soils of the Himalayan and Northern Mountains (3) 67
Soils of the Indo-Gangetic Plains, the Brahmaputra Valley and the Tarai (4-22) 81

Part III
Soils of the Desert Region (23-27) 309
Soils of the Black Soil Region (28-49) 359

Part IV
Soils of Red and Laterite Soil Region 549
50. Jamkhandi series - Karnataka 551
51. Tyamagondalu series - Karnataka 562
52. Vijaypura series - Karnataka 574
53. Channasandra series - Karnataka 586
54. Kadirabad series - Andhra Pradesh 597
55. Chinnaloni series - Andhra Pradesh 606
56. Kasireddipalli series - Andhra Pradesh 615
57. Thekkadi series - Kerala 622
58. Trivandrum series - Kerala 631
59. Kunnanangalam series - Kerala 643
60. Palathurai series - Tamil Nadu 651
61. Coimbatore series - Tamil Nadu 662
62. Ooty series - Tamil Nadu 675
63. Pusaro series - Bihar 687
64. Hathiapathar series - Bihar 699
65. Mrigindihi series - West Bengal 710
66. Bhubaneswar series - Orissa 724

Soils of the Coastal and Deltaic Region 733
67. Motto series - Orissa 735
68. Dandi series - Gujarat 750
69. Lakhpat series - Gujarat 758
70. Sanes series - Gujarat 770
SOILS OF THE RED AND LATERITE SOIL REGION

1. General Information and Typifying pedon description

Pedon described by core group members consisting of Dr. B.K. Bhide and P.B. Shashankararaya.


The Jambhundi series comprise very deep, moderately well drained reddish brown to dark reddish brown and yellowish red, clayey soils. They have developed on the sediimentary alluvium of sandstones and quartzites. Jambhundi soils occur on very gently sloping to gently sloping fill-ups-in valleys adjoining the sandstone ranges (mesas), varying slopes up to 4 percent. These soils have well developed Alfisol-Horizons. The climate is semi-arid to sub-tropical with mean annual air temperatures of 30-3°C and average annual rainfall of 872.8 mm. The principal associated soils are Margayji series, which are dark brown to dark grey brown-fine sandy loam-skeletal occurring on the flood plains and Jambhundi series which are fine loamy, bish Nphonok Ite, occurring on upper pediments.

Jambhundi series is a member of the clayey, mixed, isohyper-Orthic family of Typic Hapludalfs.
1. General information and typifying pedon description

Pedon described by core group members consisting of Sri N.K. Barde and H.S. Shankaranarayana. S. Subramanyam and C.S. Harindranath associated. Date of study: 20.6.79.

The Jamkhandi series comprise very deep, moderately well drained reddish brown to dark reddish brown and yellowish red, clayey soils. They have developed on the sedimentary alluvium of sandstones and quartzites. Jamkhandi soils occur on very gently sloping to gently sloping filled-in valleys, adjoining the sandstone ranges (cuestas), having slopes up to 5 percent. These soils have well developed argillic horizons. The climate is semi-arid sub tropical with mean annual air temperature of 26.4°C and average annual rainfall of 573.9 mm. The principal associated soils are Marguppi series which are dark brown to dark gray brown fine Vertic Ustorthents occurring on the flood plains and Arakeri series which are fine loamy Udic Rhodustalfs occurring on upper pediments.

Jamkhandi series is a member of the clayey, mixed, isohyperthermic family of Typic Haplustalfs.
Typifying pedon: Jamkhandi coarse sandy clay loam -cultivated.

Ap  0-16 cm: Dark reddish brown (5 YR 3/4 D & M) sandy clay loam; weak, fine sub-angular blocky breaking to fine to very fine granular; loose, friable, sticky, slightly plastic; few coarse to fine exped roots; many very fine discontinuous in ped tubular open random vertical pores; pH 8.2; clear smooth boundary.

B1  16-40 cm: Dark reddish brown (5 YR 2.5/2 D & M) sandy clay loam; moderate medium sub-angular blocky; friable, sticky, plastic; few fine in ped roots; many very fine tubular open vertical continuous and discontinuous in ped pores; few thin random cutans on ped faces; pH 8.5; clear smooth boundary.

B21t 40-61 cm: Dark reddish brown (5 YR 2.5/2 D & M) sandy clay; moderate medium prismatic breaking to angular blocky; firm, sticky and plastic; slightly effervescent at places; few to very few fine in ped roots; many very fine tubular open vertical continuous and discontinuous spouting in ped pores; broken thin clay cutans on both horizontal and vertical ped faces; pH 8.2; clear smooth boundary.

B22t 61-89 cm: Dark reddish brown (5 YR 2.5/2 M) clay; strong medium prismatic breaking to fine prisms; firm, sticky and plastic; continuous strongly effervescent; very few very fine in ped roots; many very fine tubular open vertical continuous and discontinuous spouting in ped pores; continuous moderately thick clay cutans on both vertical and horizontal ped faces; pH 8.3; clear smooth boundary.

B31 89-123 cm: Reddish brown (5 YR 4/4 M) clay loam; dark reddish brown (5 YR 3/4 rubbed); weak medium sub-angular blocky tending to prismatic; friable, slightly sticky and slightly plastic; strongly effervescent; few pseudo lime mycelia; vertical continuous and discontinuous in ped pores; patchy thin clay cutans; pH 8.6; clear smooth boundary.

B32 123-152 cm: Reddish brown (5 YR 5/3 M about 75%) dark red (2.5 YR 3/4 M about 25%) sandy clay, reddish brown (5 YR 4/3 rubbed); weak medium sub-angular blocky; friable, slightly sticky and slightly plastic; violently effervescent; many pseudo lime mycelia; pH 8.5; abrupt smooth boundary.
IIC 152-176 cm: Yellowish red (5 YR 4/6 M about 70%) dark red (2.5 YR 3/4 M about 30%), sandy clay loam; reddish brown (5 YR 4/4 rubbed); weak medium sub-angular blocky; friable; slightly sticky and slightly plastic; strongly effervescent; few pseudo lime mycelia; (25 to 30% by volume 5-10 mm size quartz gravels); pH 8.2.

Range in characteristics: The depth of the solum is more than 150 cm. The minerology of the regolith is mixed. The estimated mean annual soil temperature at 50 cm is 27.4°C. The mean summer soil temperature is 25.9°C and the mean winter soil temperature is 23.6°C. The moisture regime is Ustic. The colour of the Ap horizon ranges from dark brown to dark reddish brown in hues of 7.5 YR and 5 YR, value of 3 to 5 and chroma of 4 to 6, the texture ranges from loamy sand to sandy clay loam. The boundary between A and B is clear and smooth. The epipedon is ochric. The B horizon ranges in thickness from 120 to 150 cm and the colour ranges from dark reddish brown to dark red in hues of 5 YR and 2.5 YR value of 2.5 to 5 and chroma of 2 to 6. The structure of the B horizon ranges from moderate sub-angular blocky to strong prismatic. The sub-surface diagnostic horizon is argillic. The texture in the control section is clayey with clay percentage ranging between 29.1 to 45.5.

Competing series and their differentiae: Tumbermatti series are clayey skeletal very deep Udic Rhodustalfs derived from Hematitic quartzite.

Use and vegetation: Sorghum, pearl millet, Italian millet (Navane) are grown in Kharif and sorghum in rabi as rainfed crops. Under well irrigation cotton, sugarcane and hybrid maize are grown. Natural vegetation consists of babool (Acacia sp.), Tamarind (Tamarindus indica), Neem (Azadirachta indica), Bellary jali (Prosopis sp.).

Drainage and permeability: Moderately well drained with moderate permeability.

Distribution and extent: They occur extensively in Belgaum and Bijaipur districts of Karnataka state. In Ghataprabha left Bank. Command area 10 700 ha has been mapped covering 0.05 percent of the total command.
Type location: Field No. 47. Four km west of Jamkhandi town on Audchi-Jamkhandi road in village Honnur about 200 metres south west of village, 100 metres north of road, left side of a mango tree.

Series proposed: State Soil Survey Organization, Department of Agriculture, Government of Karnataka under, Ghataprabha Irrigation Project.

Interpretation: Jamkhandi soils have good soil moisture air relationship. They will respond to management of all climatically adapted crops. Rainfall variation appears to be the only limitation.

Management interpretation:

a) Inductive (based on physical production potential)
   1. Land capability sub-class : IIIC/IVC (?)
   2. Irrigability sub-class : 1
   3. Fertility management potential : high

b) Quantitative (management potential for crops under farmer's levels and package of practices based on information from Department of Agriculture, Government of Karnataka).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level</th>
<th>Package practices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rainfed irrigation</td>
<td>rainfed irrigation</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Maize</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sorghum (Rabi)</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Italian millet (Navane)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cotton</td>
<td>6</td>
<td>12.5</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Legumes</td>
<td>-</td>
<td>23.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>17.5</td>
<td>-</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Organic carbon (%)</th>
<th>pH (1:2.5)</th>
<th>pH H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-16</td>
<td>1.03</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>16-40</td>
<td>1.17</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>B21t</td>
<td>40-61</td>
<td>1.46</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>B22t</td>
<td>61-89</td>
<td>1.15</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>B31</td>
<td>89-123</td>
<td>0.77</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>B32</td>
<td>123-152</td>
<td>0.51</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>IIC</td>
<td>152-176</td>
<td>0.22</td>
<td>8.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Sand</th>
<th>Coarse (2-0.5)</th>
<th>Coarse (0.5-0.25)</th>
<th>Coarse (0.25-0.1)</th>
<th>Fine (0.1-0.05)</th>
<th>Very fine (&lt;0.05)</th>
<th>Very coarse (2-)</th>
<th>Coarse fragments % by weight of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-16</td>
<td>73.8</td>
<td>6.1</td>
<td>20.1</td>
<td>11.3</td>
<td>25.4</td>
<td>19.7</td>
<td>12.2</td>
<td>4.2</td>
<td>62.2  13.1  4.6  20.1  3</td>
</tr>
<tr>
<td>B1</td>
<td>16-40</td>
<td>65.1</td>
<td>5.8</td>
<td>29.1</td>
<td>8.9</td>
<td>24.7</td>
<td>17.1</td>
<td>10.5</td>
<td>3.9</td>
<td>54.4  13.4  3.1  29.1  1</td>
</tr>
<tr>
<td>B21t</td>
<td>40-61</td>
<td>47.2</td>
<td>14.8</td>
<td>38.0</td>
<td>10.3</td>
<td>13.2</td>
<td>10.5</td>
<td>5.7</td>
<td>2.5</td>
<td>41.1  7.2  13.7  38.0  -</td>
</tr>
<tr>
<td>B22t</td>
<td>61-89</td>
<td>44.0</td>
<td>10.5</td>
<td>45.5</td>
<td>5.4</td>
<td>18.4</td>
<td>11.4</td>
<td>6.4</td>
<td>2.4</td>
<td>37.7  7.3  9.5  45.5  -</td>
</tr>
<tr>
<td>B31</td>
<td>89-123</td>
<td>42.8</td>
<td>16.3</td>
<td>40.9</td>
<td>8.5</td>
<td>17.0</td>
<td>9.9</td>
<td>5.2</td>
<td>2.2</td>
<td>37.3  6.6  15.2  40.9  1</td>
</tr>
<tr>
<td>B32</td>
<td>123-152</td>
<td>51.9</td>
<td>8.9</td>
<td>39.2</td>
<td>8.6</td>
<td>22.2</td>
<td>12.7</td>
<td>6.1</td>
<td>2.3</td>
<td>45.9  6.0  8.9  39.2  5</td>
</tr>
<tr>
<td>IIC</td>
<td>152-176</td>
<td>59.7</td>
<td>9.8</td>
<td>30.5</td>
<td>28.7</td>
<td>12.6</td>
<td>10.0</td>
<td>6.2</td>
<td>2.2</td>
<td>53.6  7.1  8.8  30.5  3</td>
</tr>
</tbody>
</table>

Size class and particle diameter (mm)
3. Micromorphological data

Three thin sections are studied, all derived from the B horizon. Depths: 20-35 cm (1), 62-77 cm (2) and 97-112 cm (3).

1. Depth: 20-35 cm.

Macroscopic characteristics

Dark reddish brown, coarse textured, weak pedal soil material including gravels up to 5 mm diameter.

Micromorphological characteristics

Structure: Weak medium sub-angular blocky structure to which a few elongated voids belong, sometimes intersected. Other voids: Common elongated, irregular voids, widths < 1.5 mm and common equant voids, locally often interconnected, diameters generally < 1 mm. Randomly distributed.

Groundmass: The coarse textured soil material includes grain sizes up to gravels of 5 mm diameter. Size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and includes a few rock fragments. A few coarse organic particles, root fragments, do occur. The fine material is largely clay-sized, contains a few mineral and organic particles up to 10 µm and has a skel-vosepic plasmic/fabric which is often masked by the dark reddish brown colour of the fine material.

Special features:

Associated with voids: Few to common voids partly infilled with mineral aggregates, often excrements.

- : Common, often interconnected voids generally bordered by coarser grains, with locally some aggregates of fine soil material. These voids are formed by disappearance of most of the finer grained material between coarser grains.

In the groundmass

- : Common voids infilled with mineral aggregates, only a part are excrements, diameter < 4 mm.

- : Few to common voids infilled with mainly fine material (< 10 µm).
2. Depth: 62-77 cm.

Macroscopic characteristics

Dark reddish brown, medium textured, pedal soil material, including gravels up to 5 mm diameter.

Micromorphological characteristics

Structure: Strong medium prismatic structure, divided into moderate medium angular blocky peds, to which common, largely regular, intersected elongated voids belong. Other voids: common elongated voids, widths < 1.5 mm and few to common equant voids, diameters generally less than 1 mm. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 5 mm diameter. Size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and includes a few rock fragments. The fine material is largely clay-sized, contains a few particles up to 10 µm and has a skel-voepic plasmic fabric which is often masked by the dark-reddish brown colour of the fine material.

Special features:

Associated with voids: Few to common voids partly infilled with mineral aggregates, often excrements.

: Locally in voids occur small clusters of carbonate crystals.

In the groundmass: Common voids infilled with mineral aggregates, only a part are excrements, diameter < 4 mm.

: Few to common small nearly completely to completely infilled voids with carbonate crystals.

3. Depth: 97-112 cm.

Macroscopic characteristics

Reddish brown, medium textured, weak pedal soil material, including gravels up to 5 mm diameter.

Micromorphological characteristics

Structure: Weak medium sub-angular blocky structure to which a few elongated
voids belong, sometimes intersected. Other voids: Common elongated voids, widths up to 4 mm and common equant voids, locally often interconnected, diameters generally < 1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to gravels of 5 mm. Size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and includes a few rock fragments. The fine material is largely clay-sized, contains a few particles up to 10 µm and has a skel-vosepic plasmic fabric, which is often masked by the reddish brown colour of the fine material.

**Special features:**

Associated with voids: Common voids partly infilled with mineral aggregates, often excrements.

- Common coatings of carbonate particles and/or needles of voidwalls.
- Common in voids occur clusters of carbonate crystals.

In the groundmass: Common voids infilled with mineral aggregates, only a part are excrements, diameter voids up to 14 mm.

- Few to common small nearly completely to completely infilled voids with carbonate crystals including carbonate needles.
- Few to common carbonate nodules, of varying size classes up to 5 mm diameter.
- At 111 cm depth occurs one broken embedded fragment of a red coloured argillan.
- One location with a few red coloured papules at 110 cm depth.

**Short micromorphological description**

Three thin sections are studied, all derived from the B horizon. Depths: 20-35 cm (1), 62-77 cm (2) and 97-112 cm (3).

The soil material is coarse (1) and medium textured (2 and 3) and includes grain sizes up to gravels of 5 mm diameter. The size limit coarse/fine material is 10 µm; the related distribution: porphyric. The fine material is largely clay-sized, contains a few particles up to 10 µm and has a skel-vosepic plasmic fabric, which is often masked.
by the dark colours of the fine material. The coarse material consists of a small variety of minerals, mainly quartz and feldspars and includes a few rock fragments. In (1) a few coarse organic particles, root fragments do occur.

The soil material has a weak medium sub-angular blocky structure in (1) and (3), to which a few elongated voids belong, sometimes interconnected; and a strong medium prismatic structure divided into moderate medium angular blocky peds in (2), to which common, largely regular, intersected elongated voids belong. Other voids: Common elongated voids, widths < 1.5 mm in (1) and (2) and < 4 mm in (3); and common in (1) and (3) and few to common equant voids, diameters in all cases generally < 1 mm. In (1) and (3) the equant voids are often locally interconnected. The voids are randomly distributed.

Associated with voids occur: Few to common in (1) and (2), and common in (3) voids are partly infilled with mineral aggregates, often excrements; Small clusters of carbonate particles occur locally in voids in (2) and are common in (3); Common coatings of carbonate particles and needles in (3); In (1) common interconnected voids, occur, formed as result of disappearance of most of the finer grained material.

In the groundmass occur: Common voids infilled with mineral aggregates, only partly excrements, diameters < 4 mm in (1) and (2) and up to 14 mm in (3); Few to common small, nearly completely to completely infilled, voids with carbonate crystals in (2) and (3) including carbonate needles in (3); In (3) occur few to common carbonate nodules, of varying size classes up to 5 mm diameter; Few to common voids infilled with mainly fine material (< 10 µm) in (1); At 111 cm depth (3) one broken embedded fragment of a red coloured argillan is found and once a location with a few red coloured papules all in (3).
Jamkhandi (1 photograph)

1. Carbonate crystals of different shapes nearly completely filling a void. B horizon (crossed polarizers)
4. Interpretation of the micromorphological data

Three thin sections are studied: all derived from the B horizon. Depths: 20-35 (1), 62-77 cm (2) and 97-112 cm (3).

- The B horizon has a weak medium subangular blocky structure in the upper (1) and lower part (3) and a strong prismatic structure in the middle zone (2). The structure is mainly determined by physical processes, namely swell and shrink, which are strongest in the middle part of the B horizon. The orientation of clay domains in the groundmass near voids and around larger embedded mineral grains, resulting in a skel-vosepic plasmic fabric, is also a result of swell of the clays. The plasmic fabric is often masked by the dark colour of the iron-containing fine material in which the clay domains are present.

- The fauna plays an important role in the B horizon, most pronounced in the upper and lower part. The animals homogenize a large part of the groundmass and produce most of the common voids. Many voids and irregular zones are filled with more or less welded mineral excrements. These voids and zones are often interconnected in the upper and lower part of the B horizon contributing to the subangular blocky structure. The diameters of the voids and varieties of excrements differ in the upper and lower part, consequently other soil animals are responsible for them.

- Carbonates are present from a depth of 62 cm onwards. At first, only a few clusters of carbonate crystals occur locally, which partly or completely fill voids. In the lower part of the B horizon (3), coatings of void walls, complete infillings of voids as well as carbonate nodules up to 5 mm in diameter are common features. Carbonate present in voids as cutans or complete infillings can be needle-shaped as well as composed of small, more equant, crystals. Carbonate precipitation is a current process.

- In the lower part of the B horizon (3), at 112 cm depth, one embedded broken fragment of an argillan and a few other papules are present. These are allochthonous fragments of a clay illuviation, incorporated by soil animals. The fragments are probably derived from a greater depth.

Remark: In the studied pedon occur only deep in the B horizon at 112 cm depth one embedded broken fragment of an argillan and a few other papules. These fragments are probably derived from greater depth. No other evidences of a clay illuviation are observed. Consequently this pedon cannot be classified as an alfisol. This soil can be an alfisol covered with younger deposits.
1. General information and typifying pedon description


Date of study: 30.8.1979

Tyamagondalu series comprises very deep, well drained reddish brown to red and dark red soils occurring on nearly level to gently sloping uplands and are developed on weathered gneissic rocks. The landform in which these soils occur is considered to be very old and stable and is unique in the deep weathering of the regolith that are susceptible to erosion and form deep gullies. In the B horizon there are Fe-Mn concretions of varying sizes from less than 0.5 mm to 20 mm and volume of concretions increase below 80 cm depth. The climate is semi-arid with mean annual temperature of about 24°C and mean annual rainfall of 750-850 mm. The principal associated soils are Channasandra, Nelamangala and Mallapur series.

Tyamagondalu series is a member of the clayey, mixed, isohyperthermic family of oxic Paleustalfs.
Typifying pedon: Tyamagondalu sandy loam-uncultivated

A1  0-13 cm: Dark red (2.5 YR 3/5 M) sandy loam: weak medium sub-angular blocky breaking into weak fine and medium granular; friable, sticky and slightly plastic; plentiful medium inped roots; pH 6.8; clear smooth boundary.

B21t  13-34 cm: Dark red (2.5 YR 3/4 D & M) sandy clay; strong coarse subangular blocky; hard (dry), friable (moist), slightly sticky and plastic (wet); many fine inped roots; patchy thin clay cutans in pores and on ped faces; many very fine tubular inped pores; pH 5.9; clear smooth boundary.

B22t  34-80 cm: Dark red (2.5 YR 3/4 M) clay; strong coarse subangular blocky; firm, sticky and plastic; few iron and manganese concretions of 1 mm size; many fine roots inside peds; patchy thin clay cutans; many fine tubular pores; pH 6.1; clear smooth boundary.

B23t  80-110 cm: Dark red (2.5 YR 3/6 M) clay; strong coarse subangular blocky; firm, sticky and plastic; few soft iron and manganese concretions of 2-5 mm size; few coarse and very fine inped roots; broken thick clay cutans in pores and ped faces; many fine tubular inped pores; pH 6.5; gradual smooth boundary.

B24t  110-160 cm: Dark red (2.5 YR 3/6 M) clay; strong coarse subangular blocky; firm, sticky and plastic; many soft iron and manganese concretions of 2-5 mm size; few coarse and very fine roots inside peds; broken thick clay cutans in pores and on ped faces; many fine tubular inped pores; pH 6.5.

Range in characteristics: The thickness of the solum ranges from 150-250 cm or sometimes more. The thickness of B horizon ranges from 120-160 cm. The content of coarse fragments (quartz and other gravel) range from 0-15 percent in the upper 5 cm. Sometimes coarse fragments occur as a thin stone line. The estimated mean annual soil temperature is about 24.6°C and MWT is 21.5°C and MST is 23.0°C. The colour of the A horizon ranges from reddish yellow to dark red, in hue of 5 YR to 2.5 YR, dry value of 3 to 5 chromas of 4 to 6; texture ranges from loamy sand to sandy loam. The colour of the B horizon ranges from dark red to yellowish red in hue of 2.5 YR to 5 YR. Texture B horizon is clay with some subhorizons of clay loam texture. The clay cutans are patchy thin to broken thick in peds and ped faces throughout.
the solum depth. Texture of the control section is fine clayey with clay percentage of 43.3 to 49.7. The structure of the B horizon is coarse strong subangular blocky. There are few to many soft iron and manganese concretions in B22t horizon. The size of concretions is 1-5 mm and their number and size increases with depth.

Competing series and their differentiae: The competing series are Kanakapura and Shanmangala series. Shanmangala series are very deep, reddish brown soils of fine loamy udic Rhodustalfs. Kanakapura series are very deep, yellowish red soil of clayey Udirc Rhodustalfs.

Drainage and permeability: Well drained with moderate permeability.

Use and vegetation: Mostly cropped land under rainfed conditions; seasonal crops include millets like Ragi (Eleusine Coracana), Navane (Sataria italica); pulses like Avare (Dolichos-Lab-lab), Togari (Cajanus Cajan). The natural vegetation consists of ficus sps. local grasses and weeds.

Distribution and extent: It is quite extensive and occurs in parts of Nelamangala, Bangalore South, Bangalore North, Kanakapura taluks and other taluks of Bangalore district.

Type location: About 2 km from Tyamagondalu cross along T. Begu Niduvanda road towards west of the road.

Series established: Regional Centre, Bangalore, National Bureau of Soil Survey and Land Use Planning in 1972.

Interpretation: Tyamagondalu soils are agriculturally important. They have good soil-air-water relationships. They can retain the moisture of the rainfall with conservation measures to prevent runoff. They are expected to respond to all climatically adapted crops. Under irrigation, a variety of adapted crops can be grown and they will respond to input management.

Management interpretation:

a) Inductive (based on physical productive potential of the series).
   1. Land capability sub-class: IIIs
   2. Irrigability sub-class : 1
   3. Fertility management potential: high
   4. Management potential/productivity: Moderately high
b) Quantitative (Management potential for production of crops under rainfed agriculture).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's Level Unirrigated</th>
<th>Irrigated</th>
<th>Package of practices Unirrigated / Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ragi</td>
<td>6</td>
<td>7.5</td>
<td>15 / 30</td>
</tr>
<tr>
<td>Groundnut</td>
<td>8</td>
<td>-</td>
<td>12.5 / 20</td>
</tr>
<tr>
<td>Redgram (Pigeon pea)</td>
<td>6.25</td>
<td>-</td>
<td>12.5 / 15</td>
</tr>
</tbody>
</table>
### 2. Tentative soil characterisation by NBSS & LUP, Bangalore

#### Size class and particle diameter (mm)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand (0.05)</td>
<td>Sil (0.05-0.002)</td>
<td>Cl (0.002)</td>
<td>Coarse (2-1)</td>
<td>Medium (0.5-0.25)</td>
<td>Fine (0.25-0.1)</td>
<td>Very fine (0.1-0.05)</td>
<td>(0.05-0.02)</td>
<td>(0.02-0.002)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
<td>% of &lt; 2 mm</td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>79.3</td>
<td>7.9</td>
<td>12.3</td>
<td>5.4</td>
<td>10.5</td>
<td>19.8</td>
<td>30.8</td>
<td>12.8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2lt</td>
<td>13-34</td>
<td>50.6</td>
<td>9.3</td>
<td>40.1</td>
<td>2.4</td>
<td>9.5</td>
<td>13.9</td>
<td>17.6</td>
<td>7.2</td>
<td>tr</td>
</tr>
<tr>
<td></td>
<td>B2lt</td>
<td>34-80</td>
<td>40.2</td>
<td>10.5</td>
<td>43.3</td>
<td>3.1</td>
<td>8.0</td>
<td>12.2</td>
<td>16.0</td>
<td>6.9</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B2lt</td>
<td>80-110</td>
<td>42.2</td>
<td>9.8</td>
<td>48.0</td>
<td>3.1</td>
<td>6.5</td>
<td>11.1</td>
<td>14.7</td>
<td>6.8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B2lt</td>
<td>110-160</td>
<td>38.5</td>
<td>11.8</td>
<td>49.7</td>
<td>3.8</td>
<td>5.9</td>
<td>9.2</td>
<td>13.2</td>
<td>6.4</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Extractable bases (5 B/a)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon (1:2)</th>
<th>pH</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Sum</th>
<th>Ext. acidity</th>
<th>Sum Cations</th>
<th>Ext. Acidity</th>
<th>Exchangeable sodium</th>
<th>Sodium absorption ratio</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13</td>
<td>0.50</td>
<td>6.8</td>
<td>2.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-34</td>
<td>0.46</td>
<td>5.9</td>
<td>5.0</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-80</td>
<td>0.50</td>
<td>6.1</td>
<td>6.4</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>6.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80-110</td>
<td>0.49</td>
<td>6.5</td>
<td>6.9</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>7.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110-160+</td>
<td>0.36</td>
<td>6.5</td>
<td>7.3</td>
<td>0.2</td>
<td>0.5</td>
<td>0.1</td>
<td>8.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied: one from the A horizon and three from the B horizon.

Depths: 2-17 cm (1); 21-36 cm (2); 40-55 cm (3) and 99-114 cm (4).

1. Depth: 2-17 cm.

Macroscopic characteristics

Dark red, coarse textured, apedal soil material, which becomes finer-grained with depth.

Micromorphological characteristics

Structure: Apedal soil containing a few elongated voids widths up to 3 mm, lengths up to several cm, generally less than a cm, and few to common equant voids, diameters up to 3 mm, sometimes interconnected. Randomly distributed.

Groundmass: The coarse textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material is 5 µm. The related distribution 2 - 12 cm: gefu-chitonic; 12-17 cm: gefu chitonic to porphyric. The coarse mineral material consists of a small variety of minerals mainly quartz and feldspars and some rockfragments. Other minerals generally are strongly altered. A few coarse root fragments. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a faint sepic plasmic fabric, masked by the red colour.

Special features:

Associated with voids: Common few-argillans in voids

- Few-common voids partly infilled with mineral aggregates, sometimes soil aggregates, sometimes excrements.
- Few voids have a coating of fine-grained soil material.

In the groundmass: Few to common voids completely infilled with laminated red-coloured clay.

- Common papules of ferri-argillans or infilled voids with material of the same composition.
- Common voids almost completely infilled with mineral aggregates, often excrements with some soil aggregates. Some of these infilled voids have a coating of fine-grained soil material.
- Few to common, generally rounded, often strongly
altered, sesquioxidic rock fragments, most diameters < 2 mm.

2. Depth: 21-36 cm.

Macroscopic characteristics

Dark red, fine textured, pedal soil material.

Micromorphological characteristics

Structure: Moderate, coarse subangular blocky, to which common, intersected elongated voids belong. Other voids: Few to common elongated voids, widths up to 3 mm, lengths up to a few cm, sometimes interconnected and common equant voids, diameters up to 3 mm, sometimes interconnected. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material is 5 µm. The related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and some rockfragments. Other minerals generally are strongly altered. A few coarse root segments occur. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a faint sepic plasmic fabric, masked by the red colour.

Special features:

Associated with voids: Few to common ferri-argillans in voids.

: Few to common voids partly infilled with mineral aggregates, soil aggregates as well as excrements.

: Few voids have a coating of fine-grained soil material. Shapes of excrements are sometimes recognizable in these coatings.

In the groundmass: Few voids completely infilled with laminated red-coloured clay.

: Few papules of ferri-argillans or infilled void material of the same composition.

: Common to many voids almost completely infilled with mineral aggregates, soil aggregates as well as excrements. Some of these voids have a coating of fine-grained soil material.

: Few to common, generally rounded, often strongly altered, sesquioxidic rock fragments, most diameters < 2 mm.
3. Depth: 40–55 cm

Macroscopic characteristics

Dark red, fine textured, pedal soil material.

Micromorphological characteristics

Structure: Strong coarse subangular blocky to which common, intersected elongated voids belong. Other voids: Few to common elongated voids, widths up to 3 mm, length up to a few cm, sometimes interconnected and common equant voids, diameters up to 3 mm, sometimes interconnected. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material is 5 µm. The related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and some rock fragments. Other minerals generally are strongly altered. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a faint sepic plasmic fabric, masked by the red colour.

Special features:
Associated with voids: A few ferri-argillans decreasing with depth. Below 45 cm only rarely ferri-argillans occur.

In the groundmass: Rare sample.

: Few to common voids, also structural voids, infilled with mineral aggregates, mainly excrements.


Macroscopic characteristics

Dark red, fine textured soil material.

Micromorphological characteristics

Structure: The structure cannot be identified, only a few large soil fragments diam. between 2–3 cm remained, due to disturbance during transport.
Groundmass: The fine textured soil material includes grain sizes up to gravels of 2.5 mm in diameter. Size limit coarse/fine material is 5 µm. The related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz and feldspars and some rock fragments. Other minerals generally are strongly altered, the fine material is largely clay-sized and includes a few particles up to 5 µm and has a faint sepic plasmic fabric, masked by the red colour.

Special features (present in the 6 large soil fragments):
Associated with voids: A very few ferri-argillans in voids.
Generically excrements.
In the groundmass: A very few voids completely infilled with red-coloured clay.
: A few papules.
: Common voids almost completely infilled with mineral aggregates, generally more or less welded excrements.
: Few to common, generally rounded often strongly altered, sesquioxidic rock fragments, most diameters < 2 mm.

Short micromorphological description

Four thin sections are studied: one from the A horizon and three from the B horizon.

Depths: 2-17 cm (1), 21-36 cm (2), 40-55 cm (3) and 99-114 cm (4).

The soil material is coarse textured in the A horizon (1) and fine textured in the B horizon (2, 3, 4) and includes grain sizes up to gravels of 3 mm in diameter. The size limit coarse/fine material is 5 µm; the related distribution gefu-chitonic to porphyric in the A horizon and porphyric in the B horizon. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a faint sepic plasmic fabric, masked by the red colour. The coarse material consists of a small variety of minerals, mainly quartz and feldspars, and some rock fragments. Other minerals generally are strongly altered. In the A and top of the B horizon (1, 2) also a few coarse root segments occur.

The soil material is apedal in the A horizon (1) and has a moderate (2) and strong (3) coarse subangular blocky structure in the B horizon to which common, intersected elongates belong. The soil structure in (4) is disturbed and cannot be identified. Other voids: A few elongated voids (1) and few to common in (2, 3), widths up to 3 mm, lengths up to a few cm. In the B horizon (2, 3) elongated voids are sometimes interconnected. Few to common equant voids
(1), common in (2, 3) diam. up to 3 mm, sometimes interconnected. The voids are randomly distributed.

- In voids ferri-argillans are found. Their numbers decrease in quantity with depth from common in the A horizon to a few at 45 cm depth. Below that depth they are rare. At 100 cm depth their number increases slightly. Voids completely infilled with material of the same colour and composition occur. The distribution with depth shows the same tendency as the ferri-argillans, but quantities are lower: few to common in the A horizon (1), a few (2), nil (3) and a very few in (4). Papules, fragments of ferri-argillans or infillings of the same material are common in the A horizon, decrease in the B horizon to rare in (3) and increase to a few in (4).

- In all thin sections occur voids partly or almost completely infilled with mineral aggregates, structural voids as well as other elongated or equant voids. Till about 40 cm depth (1, 2) the mineral aggregates are soil aggregates as well as excrements; below that depth (3, 4) they generally are excrements. In structural voids in (3) a higher quantity consists of soil aggregates. Few to common voids are partly infilled in (1, 2, 3) decreasing to a few in (4). Almost completely infilled voids are common over the whole studied depth with exception of a maximum of common to many in the top of the B horizon (2). Some of the partly or almost completely infilled voids have a coating of fine-grained soil material.

- Over the whole studied depth occur few to common, generally rounded, often strongly altered, sesquioxidic rock fragments, diam. generally < 2 mm.
Tyamagondalu (1 photograph)

Gefu-chitonic c/f related distribution. Open packing due to cultivation practices; A horizon (plain light).
Interpretation of the micromorphological data

Four thin sections are studied: one from the A horizon and three from the B horizon. Depths: 2-17 cm (1), 21-36 cm (2), 40-55 cm (3) and 99-114 cm (4).

- In this pedon strong clay-illuviation occurred. Over the whole studied depth clay-illuviation features: ferri-argillans, voids infilled with the same material and papules, fragments of these features, are observed in varying quantities. A large number of these features are disturbed and disappeared especially in the middle part of the B horizon (3). Clay illuviation features are most numerous in the A (1) and top of the B horizon (2). Deeper in the B horizon (4) the quantity increases again.
- The studied pedon is truncated. In the A horizon clay-illuviation features are common.
- The A horizon is coarser-grained than the B horizon. The quantity of fine-grained soil material is relatively low, which can be due to erosion and/or cultivation practices.
- The fauna plays an important role, producing a large number of voids, which are often partly or completely filled with mineral excrements. Over the whole depth a part of the voids are coated with fine-grained soil material. These are a result of the plastering of void walls with excrements by soil fauna. The influence of the fauna is large in the middle part of the B horizon (3), where clay-illuviation features are nearly disappeared due to its activity. The papules present in the groundmass and excrements also are clear indications of animal activity.
- Due to cultivation practices, probably accentuated by disturbance during transport, small soil aggregates occur in structural voids. They decrease in quantity with depth. In infillings in structural voids soil aggregates are most numerous.
- The soil is developed in strongly weathered parent material. Over the whole depth are few to common, generally rounded, often strongly altered, sesquioxidic rock fragments found. Except for quartz and feldspar minerals are strongly altered.
VIJAYAPURA SERIES

1. General information and typifying pedon description

Pedon described by the core group members consisting of N.G. Godse, N.K. Barde and H.S. Shankaranarayana. S.R. Naga Bhushana and C.S. Harindranath associated.

Date of study: 1.9.1979.

Vijayapura series comprises very deep, moderately well drained, clayey yellowish red to occasionally light reddish brown lateritic soils. They have developed on granites and granite gneisses of Archean age. Vijayapura soils occur on very gently to gently sloping pediments with slopes up to 3%. The climate is semi-arid with mean annual air temperature of 23.6°C and average annual rainfall of 750 to 830 mm. The principal associated soils are Hoskote series which are gravelly and light brown to yellowish red clayey soils of Oxic Paleustalfs.

Vijayapura series is tentatively classified as a member of the clayey, mixed, isohyperthermic family of Oxic Rhodustalfs (haplustalfs?)

For climatic data and water balance see data Station Bangalore, given by Channasandra series.

Typifying pedon: Vijayapura fine sandy loam-cultivated

Ap1 0-7 cm: Yellowish red (5 YR 5/6 D) fine sandy loam, yellowish red (5 YR 4/6 M) weak fine sub-angular blocky; hard, friable, slightly sticky, many very fine discontinuous tubular inped pores; pH 5.6; clear smooth boundary.

Ap2 7-21 cm: Yellowish red (5 YR 5/6 D) fine sandy loam, yellowish red (5 YR 4/6 M) moderate, medium to fine sub-angular blocky; hard, friable, slightly sticky and non-plastic; less than 1 percent by volume of very fine quartz and ferro-manganese grains; many very fine discontinuous tubular inped pores; many fine roots; pH 5.2; gradual smooth boundary.

Blt 21-46 cm: Yellowish red (5 YR 5/6 D) sandy clay loam; yellowish red (4 YR 4/6 M) moderate medium sub-angular blocky; slightly hard, friable, sticky and plastic; less than 1 percent by volume of very fine quartz grains and soft ferro-manganese concretions;
few patchy thin cutans on ped faces; many very fine discontinuous tubular inped pores; pH 5.6; gradual smooth boundary.

**B21t** 46-87 cm: Yellowish red (5 YR 5/6 D) sandy clay, yellowish red (4 YR 4/6 M); moderate medium, sub-angular blocky; hard, friable, sticky and plastic; about 2 percent by volume of 1 to 2 mm size quartz grains and ferro-manganese concretions; common thin patchy cutans; many very fine discontinuous tubular inped pores; pH 5.6, clear smooth boundary.

**B22t** 87-104 cm: Dark red (2.5 YR 3/6 D) sandy clay, dark red (2.5 YR 3/4 M); moderate medium sub-angular blocky; hard, friable, sticky and plastic; about 2 percent by volume of 1-2 mm size quartz grains and ferro-manganese concretions; few patchy thin clay skins on ped faces; many very fine discontinuous inped pores; few fine roots; pH 6.1; abrupt smooth boundary.

**B3** 104-135 cm: Dark red (2.5 YR 3/6 M) gravelly sandy clay loam, red (2.5 YR 4/6 rubbed); weak fine sub-angular blocky breaking to coarse granular; very friable, sticky and plastic; about 60 percent by volume of 3 to 75 mm quartz gravel and ferro-manganese concretions; many very fine discontinuous tubular inped pores; pH 6.5; abrupt wavy boundary.

**C** 135-152 cm: Dark red (2.5 YR 3/6 M) sandy clay, red (2.5 YR 4/6 rubbed); structure less; friable, sticky; about 3 percent by volume of 2-3 mm quartz gravels.

**Range in characteristics:** The thickness of the solum ranges from 100 to 180 cm. The estimated mean annual soil temperature is 24.6°C, mean summer soil temperature is 23.0°C and mean winter soil temperature is 20.5°C. The colour of Ap horizon ranges from yellowish red to dark red in 5 YR, 4 YR of 2.5 YR hues, 3-4 value and 4 to 6 chroma. The texture ranges from loamy sand to sandy loam to gravelly sandy loam with 10-15 percent by volume quartz gravels and iron concretions. The colour of B1t horizon ranges from yellowish red in 5 YR and 4 YR hue to 5 to 4 value and 4 to 6 chroma. The texture ranges from sandy clay loam to sandy clay. The colour of B3 horizon is dark red in 2.5 YR hue. The texture ranges from gravelly clay loam to gravelly clay with more than 60% quartz gravel and iron concretions. Texture in the control section is clayey with clay percentage ranging between 29-38.5.
Competing series and their differentiae: The Hoskote soils are light brown to reddish yellow in 7.5 YR hue and clayey.

Drainage and permeability: Moderately well drained with moderate permeability.

Use and vegetation: Mostly under cultivation of rainfed crops. The common crops grown are Ragi, Avare, Linseed as mixed crops, pure crop of Ragi of Ragi with Avare. The natural vegetation consists of Ficus sp. (Banian), Pongamea glabra (Honge), Tamarindus indica (Tamarind), Casuarina.

Distribution and extent: These soils are widely distributed in Bangalore and Kolar districts of Karnataka.

Type location: Plot No. (next of the observatory), G.K.V.K. dry land agriculture farm, Bangalore North Taluk, District Bangalore, Karnataka.

Series proposed by: National Bureau of Soil Survey and Land Use Planning, Bangalore.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub-class: II
   2. Irrigability sub-class : 2s
   3. Fertility management potential : moderately high

b) Quantitative (management potential of crops under farmers level and package of practices based on information from Dry land Research Project, UAS, GKVK Campus, Bangalore).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level unirrigated</th>
<th>Package of practices unirrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ragi</td>
<td>7.5</td>
<td>25</td>
</tr>
<tr>
<td>Groundnut</td>
<td>8.75</td>
<td>15</td>
</tr>
<tr>
<td>Redgram (pigeon pea)</td>
<td>6.25</td>
<td>12.5</td>
</tr>
</tbody>
</table>
2. Tentative soil characterization by NBSS & LUP, Bangalore

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Coarse (% of &lt; 2 mm)</th>
<th>Sand (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (0.002)</th>
<th>Very coarse (1-0.5)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.1)</th>
<th>Very fine (0.1-0.05)</th>
<th>(0.05-0.02)</th>
<th>(0.002-0.001)</th>
<th>&lt;0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap1</td>
<td>0-7</td>
<td>11.0</td>
<td>16.5</td>
<td>1.3</td>
<td>4.4</td>
<td>13.3</td>
<td>37.4</td>
<td>15.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Ap2</td>
<td>7-21</td>
<td>12.5</td>
<td>17.8</td>
<td>1.7</td>
<td>3.3</td>
<td>11.5</td>
<td>38.1</td>
<td>15.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Blt</td>
<td>21-46</td>
<td>13.7</td>
<td>29.5</td>
<td>1.4</td>
<td>3.2</td>
<td>9.5</td>
<td>29.9</td>
<td>13.8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B1t</td>
<td>46-87</td>
<td>13.0</td>
<td>38.5</td>
<td>1.8</td>
<td>3.3</td>
<td>9.4</td>
<td>25.4</td>
<td>12.1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B2t</td>
<td>87-104</td>
<td>12.8</td>
<td>37.6</td>
<td>3.8</td>
<td>2.9</td>
<td>7.8</td>
<td>24.0</td>
<td>11.1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td>104-135</td>
<td>12.0</td>
<td>30.1</td>
<td>14.9</td>
<td>6.1</td>
<td>10.7</td>
<td>17.5</td>
<td>8.7</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>135-152</td>
<td>19.0</td>
<td>37.7</td>
<td>8.1</td>
<td>3.9</td>
<td>7.3</td>
<td>17.1</td>
<td>8.9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon (1:1)</th>
<th>pH</th>
<th>Extractable bases (5 B/a)</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H₂O₂</td>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
</tr>
<tr>
<td>0-7</td>
<td>0.44</td>
<td>5.6</td>
<td>1.72</td>
<td>0.58</td>
<td>0.05</td>
<td>0.19</td>
</tr>
<tr>
<td>7-21</td>
<td>0.42</td>
<td>5.2</td>
<td>1.02</td>
<td>0.70</td>
<td>0.03</td>
<td>0.14</td>
</tr>
<tr>
<td>21-46</td>
<td>0.48</td>
<td>5.5</td>
<td>1.54</td>
<td>1.26</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>46-87</td>
<td>0.44</td>
<td>5.5</td>
<td>1.93</td>
<td>1.43</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>87-104</td>
<td>0.45</td>
<td>5.1</td>
<td>2.90</td>
<td>1.44</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>104-135</td>
<td>0.20</td>
<td>6.5</td>
<td>2.81</td>
<td>1.45</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>135-152</td>
<td>0.18</td>
<td>6.5</td>
<td>3.21</td>
<td>1.42</td>
<td>0.10</td>
<td>0.12</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied: one from the A horizon and three from the B horizon.
Depths: 4-15 cm (1), 23-48 cm (2), 55-70 cm (3) and 87-102 cm (4).

1. Depth: 4-15 cm.

Macroscopic characteristics
Yellowish red, coarse textured, apedal soil material, containing few to common brown and black coloured nodules, diameter up to 2 mm.

Micromorphological characteristics
Structure: The soil material is apedal and contains a few to common elongated voids, lengths less than a few cm, widths <2 mm, and common equant voids, diameter up to 2 mm, randomly distributed.
Groundmass: The coarse textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 10 µm.
Related distribution: porphyric. The coarse material consists of a variety of minerals and rock fragments, of which a part are altered. The fine material is mainly clay-sized, includes a few particles up to 10 µm and is practically isotopic.
Special features:
Associated with voids: Locally common thin ferri-argillans in small voids.
: Few voids partly filled with mineral aggregates, including excrements.
In the groundmass: Locally common small infilled voids with red coloured, often laminated, oriented clay.
: Locally common small red coloured papules.
: Common to many voids and irregular zones filled with mineral aggregates, which are excrements and/or soil fragments and some larger rock fragments.
: Common, larger 1-3 mm in diameter, rock fragments, which can be strongly altered, and, more or less rounded, sesquioxidic nodules, including a few mineral grains, of the same diameters, randomly distributed.
2. Depth: 23-48 cm.

Macroscopic characteristics

Yellowish red, medium textured weak sub-angular blocky soil material, containing a few brown and black-coloured nodules, diameter up to 2 mm and a few black pseudomorphs of organic matter.

Micromorphological characteristics

Structure: The soil material is weak medium sub-angular blocky* and contains a few to common elongated voids, lengths up to a few cm, widths generally less than 2 mm and common equant voids, diameter up to 2 mm, randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 10 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part are altered. The fine material is mainly clay-sized, includes a few particles up to 10 µm and is practically isotropic.

Special features:

Associated with voids: Locally common thin ferri-argillans in small voids.

: Few voids partly filled with mineral aggregates including excrements.

: Few voids have a coating of mainly clay-sized soil material.

In the groundmass: Locally common small infilled voids with red coloured, often laminated, oriented clay.

: Locally common small, red coloured, papules.

: Common to many voids and irregular zones filled with mineral aggregates, which are excrements and/or soil fragments and some larger rock fragments.

: Few to common, larger 1-3 mm in diameter, rock fragments, which can be strongly altered, and more or less rounded sesquioxidic nodules (including a few mineral grains) of the same diameters, randomly distributed.

* The structure visible in the thin section is largely influenced by disturbances during transport (artefact)
Two nearly ellipsoidal zones with black root pseudomorph-fragments, probably of tree roots, diameters 1.5 cm and 0.5 cm.

3. Depth: 55-70 cm.

Macroscopic characteristics

Yellowish red, fine to medium textured weak sub-angular blocky soil material, containing few to common brown and black-coloured nodules, diameter up to 3 mm.

Micromorphological characteristics

Structure: The soil material is weak medium sub-angular blocky to which a few, sometimes intersected, elongated voids belong. Other voids: Few to common elongated voids, lengths up to a few cm, widths generally less than 2 mm and common equant voids, diameter up to 2 mm, randomly distributed.

Groundmass: The fine to medium textured soil material includes grain-sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part are altered. The fine material is mainly clay-sized, includes a few particles up to 10 µm and is practically isotropic.

Special features:

Associated with voids: Few voids partly filled with mineral aggregates, including excrements.

: Common voids have a coating of mainly fine-grained, often clay-sized, soil material.

In the groundmass : Locally a few small papules.

: Abundant voids and irregular zones filled with mineral aggregates, which are mainly excrements, but include also soil fragments and some larger rock fragments and minerals. These infilled zones commonly have coatings of mainly fine-grained soil material.

: Few to common larger, 1-3 mm in diameter, rock fragments, which can be strongly altered and more or less rounded sesquioxidic nodules (including a few mineral grains), of the same diameters, randomly distributed.
4. Depth: 87-102 cm.

Macroscopic characteristics

Red, fine to medium textured, weak sub-angular blocky soil material containing few to common brown and black-coloured nodules, diameters up to 3 mm, mainly present in the lower part of the section.

Micromorphological characteristics

Structure: The soil material is weak medium sub-angular blocky to which a few, sometimes intersected, elongated voids belong. Other voids: Few to common elongated voids, lengths up to a few cm, widths generally less than 2 mm and common equant voids, most diameter less than 2 mm, randomly distributed.

Groundmass: The fine to medium textured soil material includes grain-sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part are altered. The fine material is mainly clay-sized, includes a few particles up to 10 µm and is practically isotropic.

Special features:

Associated with voids: Few voids partly filled with mineral aggregates, including excrements.

- Some rare argillans in small voids.
- Few to common voids have coatings of mainly fine-grained soil material.

In the groundmass:

- Locally a few small papules.
- Abundant voids and irregular zones filled with mineral aggregates, which are mainly excrements but include also soil fragments and some larger rock fragments and minerals. These infilled zones commonly have coatings of mainly fine-grained soil material.
- Few isotubules tending to striotubules and irregular zones of which the infilling has a lower content on fine-grained material than the surrounding groundmass.
- Few to common larger 1-3 mm in diameter rock fragments which can be strongly altered and more or less rounded sesquioxidic nodules, including a few mineral grains, of the same diameters. More larger sizes of nodules than in previous sections. Most of rock fragments and nodules occur in the lower part of the thin section.
Four thin sections are studied: one from the A horizon and three from the B horizon. Depths: 4–15 cm (1), 23–48 cm (2), 55–70 cm (3) and 87–102 cm (4).

- The soil material becomes increasingly finer textured with depth, from coarse texture in the A horizon (1), to fine–medium textured in the B2 (3, 4) and includes grain sizes up to gravels of 3 mm in diameter. The size limit coarse/fine material is 10 μm the related distribution: porphyric. The fine material is mainly clay-sized, includes a few particles up to 10 μm and is practically isotropic. The coarse mineral material consists of a variety of minerals and rock fragments, some of which are altered.

- The soil material is apedal in the A horizon (1) and has a weak medium subangular blocky structure in the B horizon, to which a few, sometimes intersected, voids belong. Over the whole studied zone the other voids occurring are: few to common elongated voids, widths generally less than 2 mm, lengths up to a few cm and common equant voids, most diam. less than 2 mm, randomly distributed.

- Over the whole studied zone, voids and irregular zones occur which are partly or completely filled with mineral aggregates. These are mainly excrements but also include soil fragments and some larger rock fragments and minerals. The quantity of partly filled voids and zones is low (few) and constant with depth. The number of completely filled voids is much higher and increases with depth from common to many in the A (1) and B1 (2) horizons to abundant in the B2 horizon (3, 4). These voids, partly or completely filled, can have coatings of fine-grained soil material along the walls. These coatings only occur in the B horizon and vary in quantity from a few in the B1 (2) to common in the upper part of the B2 (3) to few–common in the lower part of the B2 (4).

- In the lower part of the B2 horizon (4) a few isotubules tending to striotubules and irregular zones with iso or strio type infillings occur. These infillings have a lower content of fine-grained material than the surrounding groundmass.

- In the A (1) and B1 (2) horizons locally common ferri–argillans occur and voids are commonly infilled with red-coloured, often laminated, oriented clay. In the lower part of the B2 (4) horizon only a few argillans are observed. These clay accumulations are found predominantly in the smallest voids. Papules occur in all thin sections. They are locally common in the A (1) and B1 (2) horizons, but in the B2 horizon (3, 4) only a few papules are present.

- In the B1 horizon (2) two almost ellipsoidal zones with black root pseudomorph fragments, diam. 1,5 cm and 0,5 cm occur.

- In the whole studied zone, rock fragments, which can be strongly altered, with colours varying from white to black, and more or less rounded sesquioxidic nodules, including a few mineral grains, with brownish black colours, occur. They are common in the A horizon (1) and few to common in the B horizon (2, 3, 4) and do not exceed 3 mm in diameter. They are randomly distributed, except in the lower part of the B2 horizon (4) where most rock fragments and nodules occur in the lower part of the thin section. Here most fragments and nodules are found with relatively large diameters.
Vijayapura (4 photographs)


Vijayapura (4 photographs)

3. Faunal void with thick coating of fine-grained soil material, infilled with excrements and mineral grains. B horizon (plain light).

4. Sesquioxidic nodule (left) and an altering rock fragment (right) with sharp external boundaries embedded in the groundmass. B horizon (plain light).
4. Interpretation of the micromorphological data

Four thin sections are studied: one from the A horizon and three from the B horizon. Depths: 4-15 cm (1), 23-48 cm (2), 55-70 cm (3) and 87-102 cm (4).

Features related to a former clay-illuviation occur over the whole studied zone. They are most numerous in the A (1) and B (2) horizons and consist of locally common ferri-argillans and common infillings of often-laminated oriented clay. These features are predominantly found in small voids and do not occur in recently formed voids. Papules, embedded fragments of clay-illuviation features, occur in all thin sections. They are locally common in the A (1) and B1 (2) horizons. In the B2 horizon (3, 4) a few papules are present locally. In the lower part of the B2 horizon a few ferri-argillans occur.

In this pedon recent processes are eliminating the inherited features of the former clay-illuviation. In this the fauna plays a major role. Animals cause considerable homogenization of the soil material. Over the whole studied zone voids and irregular zones occur which are partly or completely filled with mineral aggregates, mainly excrements, but also including soil fragments and some larger rock fragments and minerals. These features are most numerous (abundant) in the B2 horizon (3, 4) where, due to this large scale homogenization, only a few papules can be found. Moreover, animals often plaster the walls of voids with a layer of fine-grained soil material. These coatings mainly consist of clay-sized material. They occur in the whole studied B horizon and are most numerous in the B2. These coatings can easily be mistaken for clay illuviation phenomena.

The occurrence of so many features of clay illuviation in the A horizon indicate that this profile is eroded.

In the whole studied zone, in slightly varying quantities, rock fragments occur, which are partly strongly altered, and more or less rounded sesquioxidic nodules. Their diameters reach up to 3 mm. The sesquioxidic nodules and the alteration of the rock fragments are mainly a result of former processes. The sesquioxidic nodules are rounded off due to local dislocations as a result of faunal activity.

Remark: In the studied Vijayapura pedon the number of features due to former clay illuviation are reduced as consequence of high animal activity resulting in homogenization of the groundmass. The present clay illuviation is marginal for classification as an alfisol.
1. General information and typifying pedon description


Channasandra series comprises well developed, deep to very deep, reddish brown soils occurring on undulating pediments developed on weathered gneiss. Typically the soils have dark reddish brown gravelly sandy loam A horizons and dark red Bt horizons. The B horizon is well developed with moderately thick cutans. Occurrence of coarse fragments of quartz and weathered gneiss exceeds 35 percent in the solum. They are susceptible to erosion and available water capacity of the soil is about 9 cm. The climate is semi-arid with mean annual temperature of about 24°C and mean annual rainfall of 750-850 mm. Mean summer and winter temperature differ less than 5°C. The principal associated soils are Dyavapatna and Tyamagondalu series.

Channasandra series is a member of clayey skeletal, mixed, hyperthermic family of Oxic Rhodustalfs.
Typifying pedon: Channasandra sandy loam—cultivated.

**Ap**
0-17 cm: Dark reddish brown (5 YR 3/3 M) gravelly sandy loam; weak fine granular; very friable, non sticky; common fine roots inside peds; common very fine and fine tubular inped pores; 25 percent by volume of angular blocky cobbles and gravel of 5-20 mm size; pH 6.7; clear smooth boundary.

**B21t**
17-52 cm: Dark red (2.5 YR 3/6 M) gravelly clay; moderate fine and medium sub-angular blocky; firm, sticky and plastic many fine roots; common fine tubular pores; few thin clay cutans on vertical and horizontal ped faces and thick clay cutans in pores; 35 to 40% by volume of angular quartz gravel of 10 to 40 mm size; pH 6.5; clear smooth boundary.

**B22t**
52-87 cm: Dark red (2.5 YR 3/6 M) gravelly sandy clay; moderate medium and fine sub-angular blocky; firm, sticky and plastic; many fine roots; common fine tubular pores; few thin clay cutans on vertical and horizontal ped faces and moderately thick clay cutans in pores; 30 to 35 percent by volume of quartz gravel of 5 to 10 mm size; pH 6.7; clear wavy boundary.

**B23**
87-106 cm: Dark (2.5 YR 3/6 M) clay; moderate medium sub-angular blocky; firm, very sticky and very plastic; few very fine inped roots; many very fine discontinuous tubular pores; common thin patchy cutans on ped faces; few fine quartz gravel; pH 6.7; clear smooth boundary.

**B3t**
106-146 cm: Dark red (2.5 YR 3/6 M) and yellowish red (5 YR 5/6 M) gravelly sandy loam; weak fine sub-angular blocky breaking into granular; friable, non sticky; many discontinuous random tubular pores; very few thin patchy cutans on ped faces; 80 to 90 percent quartz gravel (quartz vein); pH 6.7; abrupt smooth boundary.

**C**
146-163+ cm: Weathered soft granite gneiss.

Range in characteristics: The thickness of the solum ranges from 90-150 cm. Coarse fragments consisting of quartz and gneissic fragments range from 30 to 40 percent by volume. Occurrence of uniform size of quartz gravel is very common in the "B" horizon. The estimated mean annual soil temperature is 24.6°C. The mean summer soil temperature is 23.0°C and mean winter soil temperature is 21.5°C. The moisture regime is ustic. The Ap horizon is
dark reddish brown gravelly sandy loam to gravelly loamy sand. The texture of Bt horizon is gravelly clay with dark red colour of 2.5 YR hue value of 3-4 and chroma of 4-6. The Bt horizon is very hard and firm. The clay percentage in the control section varies from 50 to 39.

Competing series and their differentiae: The competing soils are Dyavapatna and Koppali series. Dyavapatna series are very gravelly colluvial soils with solum depth not exceeding 120 cm. Koppali series are loamy skeletal Udic Ustochrepts occurring on rolling lands and steeply sloping hills.

Drainage and permeability: Well drained with moderately rapid permeability.

Use and vegetation: Cultivated to rainfed crops like Ragi, Horsegram and Pulses like Avare, Togari. The natural vegetation consists of Kavanj (Pongemea glabra) Banian (Ficus bengalensis).

Distribution and extent: It is in parts of Bangalore South, Kanakapura, Ramanagara and Channapatna taluks of Bangalore District.

Type location: 16.5 km from Bangalore on Bangalore-Kanakapura road in village Talaghattapura. About 150 m, north of Government Silk Farm and east of main road.

Series proposed: Regional Centre, National Bureau of Soil Survey and Land Use Planning, Bangalore.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub class : III
   2. Land irrigability sub class : 3t
   3. Fertility management potential : moderately low to low

b) Quantitative (management potential for production of crops).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmers level</th>
<th>Package of practices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>unirrigated</td>
<td>irrigated</td>
</tr>
<tr>
<td>Ragi</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Mulberry (green leaves)</td>
<td>5.0</td>
<td>200</td>
</tr>
</tbody>
</table>
### 2. Tentative soil characterisation by Dr. P. Krishnan & Sri S.L. Budihal

#### Size class and particle diameter (mm)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Sand (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (0.002)</th>
<th>Coarse Very Coarse (2-1)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.1)</th>
<th>Very Fine (0.1-0.05)</th>
<th>INT I (2.0-0.2)</th>
<th>INT II (0.2-0.02)</th>
<th>INT III (0.02-0.002)</th>
<th>INT IV (&lt;0.002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-17</td>
<td>78.1</td>
<td>13.4</td>
<td>8.5</td>
<td>9.1</td>
<td>9.5</td>
<td>14.6</td>
<td>28.2</td>
<td>16.7</td>
<td>40.7</td>
<td>45.5</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>17-52</td>
<td>41.0</td>
<td>8.7</td>
<td>50.3</td>
<td>7.6</td>
<td>5.4</td>
<td>7.2</td>
<td>13.2</td>
<td>7.6</td>
<td>23.7</td>
<td>20.2</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>52-87</td>
<td>50.8</td>
<td>10.1</td>
<td>39.1</td>
<td>12.8</td>
<td>10.1</td>
<td>9.1</td>
<td>11.7</td>
<td>7.1</td>
<td>35.4</td>
<td>18.1</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>87-106</td>
<td>41.2</td>
<td>17.6</td>
<td>41.2</td>
<td>4.8</td>
<td>4.4</td>
<td>6.9</td>
<td>14.5</td>
<td>10.6</td>
<td>19.8</td>
<td>26.9</td>
<td>12.1</td>
</tr>
<tr>
<td>B3</td>
<td>106-146</td>
<td>57.9</td>
<td>21.9</td>
<td>20.2</td>
<td>12.4</td>
<td>12.7</td>
<td>10.5</td>
<td>12.6</td>
<td>9.7</td>
<td>39.3</td>
<td>26.6</td>
<td>13.9</td>
</tr>
<tr>
<td>C</td>
<td>146-163</td>
<td>78.6</td>
<td>18.0</td>
<td>3.4</td>
<td>1.1</td>
<td>6.2</td>
<td>18.7</td>
<td>35.3</td>
<td>17.3</td>
<td>35.7</td>
<td>50.2</td>
<td>10.7</td>
</tr>
</tbody>
</table>

#### Extractable bases

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon (1:2.5) %</th>
<th>pH</th>
<th>Ca (H₂O₂)</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Sum (H₂O₂)</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Sum Cations</th>
<th>NH₄Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-17</td>
<td>0.53</td>
<td>6.7</td>
<td>3.5</td>
<td>0.8</td>
<td>0.3</td>
<td>0.2</td>
<td>4.8</td>
<td>0.05</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-52</td>
<td>0.88</td>
<td>6.5</td>
<td>9.1</td>
<td>1.0</td>
<td>0.4</td>
<td>0.2</td>
<td>10.1</td>
<td>0.05</td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52-87</td>
<td>0.39</td>
<td>6.7</td>
<td>7.2</td>
<td>1.0</td>
<td>0.3</td>
<td>0.1</td>
<td>8.6</td>
<td>0.05</td>
<td>8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87-106</td>
<td>0.46</td>
<td>6.7</td>
<td>8.7</td>
<td>1.0</td>
<td>0.2</td>
<td>0.1</td>
<td>10.0</td>
<td>0.05</td>
<td>10.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>106-146</td>
<td>0.14</td>
<td>6.7</td>
<td>5.4</td>
<td>1.0</td>
<td>0.2</td>
<td>0.1</td>
<td>6.7</td>
<td>0.05</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>146-163</td>
<td>0.08</td>
<td>7.2</td>
<td>4.0</td>
<td>0.5</td>
<td>0.2</td>
<td>0.05</td>
<td>4.75</td>
<td>0.05</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied: one from the A horizon, two from the B horizon and one from the C horizon. Depths: 0-15 cm (1); 34-49 cm (2); 53-68 cm (3) and 150-165 cm (4).

1. Depth: 0-15 cm.

Macroscopic characteristics

Dark reddish brown, gravelly coarse textured, apedal, soil material, containing common light-coloured gravels up to 10 mm in diameter.

Micromorphological characteristics

Structure: The soil material is apedal. Other voids: few to common elongated voids, widths up to 2 mm, length several cm long and few to common equant, often irregular, voids, diam. up to 2 mm, randomly distributed.

Groundmass: The gravelly coarse textured soil material includes grain sizes up to 10 mm in diameter. The size limit coarse/fine material is 10 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, mainly quartz, and rock fragments, which partly are strongly altered. A few coarse root fragments are present. The fine material is largely clay sized, contains common fine particles up to 10 µm, which for a minor part are organic, and has an asepic plasmic fabric.

Special features:

Associated with voids: A few voids are partly infilled with some mineral grains and soil aggregates.

In the groundmass: A few voids are almost completely infilled with mineral grains and soil aggregates.

: A few voids are almost completely infilled with wealded, mainly fine-grained shaped mineral excrements.

: Common charcoal fragments.

2. Depth: 34-49 cm.

Macroscopic characteristics

Dark red, gravelly fine textured, moderate sub-angular blocky soil material containing many light-coloured gravels up to 22 mm in diameter.
Micromorphological characteristics

Structure: The soil material is moderate medium sub-angular blocky to which common, often intersected elongated voids belong. Other voids: common elongated voids, widths up to 2 mm, lengths a few cm, and common often irregular equant voids, diam. up to 2 mm.

Groundmass: The gravelly fine textured soil material includes grain sizes up to gravels of 22 mm in diameter. The size limit coarse/fine material is: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals and rock fragments, mainly quartz. The rock fragments are partly strongly altered. The fine material is predominantly clay-sized, contains a very few particles up to 10 µm and has a moderate omniseptic plasmic fabric.

Special features:

Associated with voids: Many ferri-argillans.

: Few voids partly infilled with soil aggregates, mineral grains and sometimes also some excrements.

In the groundmass

: Many complete infillings composed of clay

: Common papules in the groundmass.

: Few to common voids, nearly completely infilled with soil aggregates, minerals, fragments of argillans, excrements etc.

: A very few zones/fragments with a higher content on sesquioxides, predominantly of iron compounds.

: Few zones with a high content of quartz grains, due to desintegration of quartzitic gneiss.

3. Depths: 53-68 cm.

Macroscopic characteristics

Dark red, gravelly fine textured, moderate sub-angular blocky soil material, containing, common light coloured gravels up to 18 mm in diameter.

Micromorphological characteristics

Structure: The soil material has a moderate fine and medium sub-angular blocky structure, to which common, often intersected elongated voids, belong. Other voids: Common elongated voids, widths up to 2 mm, lengths generally less than 1 cm and common, often irregular, equant voids, diam. up to 2 mm.
Groundmass: The gravelly fine textured soil material includes grain sizes up to gravels of 18 mm in diameter. The size limit coarse/fine material is 10 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals and rock fragments, mainly quartz. Other minerals are often strongly altered (rock fragments). The fine material is predominantly clay-sized, contains a very few particles up to 10 µm and has a moderate omnisepic plasmic fabric.

Special features:
Associated with voids: Many ferri-argillans (also a few in rock fragments).
: Few voids partly infilled with mineral grains, soil aggregates and/or mineral excrements.
In the groundmass: Many complete infillings composed of clay.
: Common papules.
: Few to common voids almost completely infilled with soil aggregates, minerals and mineral excrements.
: Few zones with a high content of quartz grains, due to desintegration of quartzitic gneiss.

4. Depth: 150–165 cm.

Macroscopic characteristics
Yellowish red, gravelly coarse textured, weathered soft rock.

Micromorphological characteristics

Structure: The weathered soft rock contains a few elongated voids, widths up to 2 mm, lengths several cm long and a few equant voids, diam. up to 2 mm. Randomly distributed.
Groundmass: The groundmass consists of desintegrating altering granite gneiss.

Special features:
Associated with voids: A few zones contain few-common ferri-argillans.
: Few to common voids are partly infilled with mineral grains, soil aggregates and mineral excrements.
: Faunal voids commonly have a plastering along the wall of mainly clay-sized material from the B horizon.
In the altering rock: In a few zones occur a few voids completely infilled with clay.
Commonly voids are almost completely infilled with mineral excrements or a mixture of these excrements, minerals and rock fragments. These infilled voids commonly have a plastered void wall, composed of mainly clay-sized material. In the excrements material of the B horizon is present including papules.

Micas are desintegrating and altering.

Few striotubules, infilled with B horizon material.

Short micromorphological description

Four thin sections are studied: one from the A horizon, two from the B horizon and one from the C horizon.

Depths: 0-15 (1), 34-49 cm (2), 53-68 (3) and 150-165 (4).

The soil material is gravelly coarse textured in the A horizon (1), gravelly fine textured in the B horizon (2, 3) and consists of weathered soft rock in the C horizon (4). It includes grain sizes up to gravels of 19 mm in diam. in the A horizon and up to 22 mm in diam. in the B horizon. In the A and B horizon is the size limit coarse/fine material 10 µm and the related distribution porphyric. The fine material is largely clay sized, contains common fine particles up to 10 µm, which for a minor part are organic in the A horizon and a very few fine mineral particles up to 10 µm in the B horizon. The fine material is asepic in (1) and has a moderate omnisepic plasmic fabric in (2, 3). The coarse mineral material consists of a small variety of minerals and rock fragments, mainly quartz. The rock fragments are partly strongly altered. In the A horizon also a few coarse organic, root, fragments are present. The groundmass in the C horizon consists of desintergrating altering granite gneiss.

The soil material is apedal in the A horizon and has a moderate medium (2) and fine to medium (3) sub-angular blocky structure in the B horizon, to which common, often intersected, elongated voids belong. Other voids:

Few to common (1) and common (2, 3) elongated voids, widths up to 2 mm, lengths reducing with depth from several cm (1) to less than 1 cm (3); few to common (1) and common (2, 3) often irregular equant voids, diam. up to 2 mm. All voids are randomly distributed. The weathered soft rock in the C horizon contains a few elongated and equant voids of the same dimensions, lengths of elongated voids up to several cm.
In all thin sections voids occur partly infilled with aggregates and minerals. The infillings consist of minerals and soil aggregates in the A horizon and of a mixture of minerals, soil aggregates and mineral excrements in the B and C horizon; abundance few in A and B horizon, few to common in the C horizon. Voids also are almost completely infilled with material from the same horizon. Except for the mentioned kinds of infillings in the A horizon also infillings composed of only mineral excrements occur; in the B horizon often fragments of ferri-argillans are present in the infilling and in the C horizon mineral excrements and rock fragments form the main part of infillings. Quantities increase from a few in the A horizon to few–common in the B horizon to common in the C horizon.

In the C horizon voids, whether or not infilled, commonly have a coating of fine-grained material derived from the B horizon. In the same horizon also a few strictotubules infilled with material from the B horizon occur.

In the B horizon (2, 3) many ferri-argillans occur, many small voids are infilled with alluviated clay and commonly papules, fragments of ferri-argillans and infillings of clay, occur embedded in the groundmass. In the C horizon (4) occur in a few zones few–common ferri-argillans and a few infilled voids with clay.

In the C horizon (4) micas are desintegrating and altering.

In the B horizon occur a few zones with a high content of quartz grains, due to desintegration of quartzitic gneiss and a very few zones with a higher content on sesquioxides, predominantly iron compounds.

In the A horizon commonly charcoal fragments are present.
Channasandra (2 photographs)

1. Ferri-argillans, often laminated, in small voids. B horizon (plain light)

2. Argillans in intermineral voids of a disintegrating rock fragment. B horizon (plain light)
4. Interpretation of the micromorphological data

Four thin sections are studied: one from the A horizon, two from the B horizon and one from the C horizon.

Depths: 0-15 cm (1), 34-49 cm (2), 53-68 cm (3) and 150-165 cm (4).

- In this pedon strong clay illuviation has occurred. Many ferri-argillans and complete infillings with red-coloured clay occur in the studied zone of the B horizon (2, 3). In the C horizon (3) few to common ferri-argillans and a few infillings of clay are observed in a few small zones.

- The moderate, mainly medium, subangular blocky structure is an old void system, largely determined by physical processes and influenced by former fauna. Some of the voids with clay illuviation features are old faunal voids.

- The present fauna plays a minor role in the A and B horizons, producing a small number of new voids, which are often partly or completely filled with shaped mineral excrements. Papules, fragments of argillans and clay infillings, are commonly present in excrements. Besides these infilled voids, infillings composed of soil aggregates and minerals, sometimes including a few excrements, also occur. Some of these infillings are recent and mainly a result of physical processes, but most were formed long ago. In the C horizon, the influence of the present fauna is more pronounced. The quantity of more or less filled voids with excrements is higher than in the upper studied horizons. These voids often have a thick coating of fine-grained soil material along the walls. These are due to soil animals plastering the walls with excrements. A few striotubules also occur. Coatings and excrements consist of material derived from the B horizon.

- The C horizon consists of disintegrated granitic gneiss, the micas of which are altering. Faunal features, together with a small amount of clay illuviation features, mainly argillans, are present in this disintegrated rock.

- Slightly rounded quartz gravels, and a few rounded sesquioxicid nodules, both indications of a colluvium are present in the A horizon (1) and upper part of the B horizon (2). Deeper in the B horizon, the gravels present are derived from a quartz vein of the autochthonic rock.

- The A horizon is apedal, contains voids which are mainly partly or completely filled with mineral grains and soil fragments, and randomly distributed charcoal fragments, all a result of management practices.
KADIRABAD SERIES

1. General information and typifying pedon description

Pedon examined by core group members N.G. Godse, N.K. Barde, M.A. Mirajkar, H.S. Shankaranarayana. C.S. Harindranath, C. Ramaiah associated. Date of study: 3.2.1980

Kadirabad series comprises very deep, moderately well drained, dark grayish brown to very dark grayish brown clayey cracking soils. They have developed from weathered material derived from granodiorite. Kadirabad soils occur on gently sloping plains on slopes up to 5 percent. The climate is semi-arid with mean annual air temperature of 25.9°C and average annual rainfall of 730.6 mm. The cracks remain open for more than 90 cumulative days and are closed for at least 60 consecutive days in most years.

The principal associated soils are Dabbavagu which are very deep soils on mixed alluvium. Nagalpalli and Palvatla are moderately deep black soils.

Kadirabad soils is a member of the fine, montmorillonitic Isohyperthermic family of Typic Chromusterts.

For climatical data and water balance Station Hyderabad, see Chinnaloni series.

Typifying pedon: Kadirabad clay - cultivated.

Ap 0-2 cm: Dark grayish brown (10 YR 4/2 D & M) clay loam; weak fine sub-angular blocky breaking to weak fine granular; loose, friable, sticky and plastic; about 3% by volume of irregularly shaped 2-5 mm size lime nodules and 2% of irregularly shaped 2 to 10 mm size quartz gravel; slightly effervescent; many fine roots; pH 8.0; abrupt smooth boundary.

Ap2 2-19 cm: Very dark grayish brown (10 YR 4/2 M) clay; moderate medium sub-angular blocky; firm, sticky and plastic; about 3% by volume of irregularly shaped 2-5 mm size lime nodules and 2% by volume of irregularly shaped 2-5 mm size quartz gravel; slightly effervescent; few fine inped roots; cracks more than 1 cm wide; common fine to very fine micro pores; pH 8.1; clear smooth boundary.
A12 19-38 cm: Very dark grayish brown (2.5 Y 3/2 M) clay; moderate medium sub-angular blocky; firm, sticky and plastic; about 5% by volume of irregularly shaped 2 to 5 mm size lime nodules and 2% by volume of irregularly shaped 2-5 mm quartz and felspar gravels; slightly effervescent; few fine inped roots; cracks more than 1 cm wide; common fine to very fine micro pores; pH 8.1; clear smooth boundary.

A13 38-66 cm: Very dark grayish brown (2.5 Y 3/2 M) clay; moderate medium angular blocky with sphenoids and slickensides intersecting at 45°; firm, sticky and plastic; 5% by volume of irregularly shaped 2-5 mm size lime nodules and 2% by volume of irregularly shaped 2.5 mm quartz and felspar gravels; slightly effervescent; few cracks less than 1 cm wide; few very fine exped roots; common fine to very fine and micro pores; pH 8.1.; gradual smooth boundary.

A14 66-86 cm: Very dark grayish brown (2.5 Y 3/2 M) clay; moderate medium angular blocky with sphenoids and prominent slickensides close enough to intersect at 45°; firm, sticky and plastic; about 5% by volume irregularly shaped 2-5 mm size lime nodules and 2% by volume of irregularly shaped 2-5 mm size quartz and felspar gravels; slightly effervescent; very few cracks; very few very fine exped roots; common fine to very fine and micro pores; pH 8.2; clear smooth boundary.

ACca 86-103 cm: Very dark grayish brown (10 YR 3/2 M), gravelly clay; moderate medium sub-angular blocky; friable, slightly sticky and slightly plastic; 10-15% by volume irregularly shaped 10-20 mm size quartz gravel and 10-20% by volume irregularly shaped lime nodules and soft powdery lime; strongly effervescent; common very fine discontinuous pores; pH 8.3; clear smooth boundary.

Cca 103-115 cm: Weathered grano diorite; violently effervescent.

Range in characteristics: Thickness of the solum ranges from 100 to 225 cm, colour of the solum ranges from very dark gray and very dark grayish brown to dark grayish brown in hues of 10 YR and 2.5 YR values of 3 to 4 and chroma of 2 to 3. The estimated mean annual soil temperature is 26.9°C and mean summer soil temperature is 25.6°C and mean winter soil temperature is 23.1°C. The thickness of the Ap horizon ranges from 13 to 20 cm with a thin (about 2 to 3 cm) mulch layer due to cultivation practices. Structure
of the Ap horizon ranges from weak fine granular to moderate medium sub-angular blocky. The thickness of the A horizon below Ap ranges in thickness from 80 to 180 cm with well developed angular blocky structure and sphenoids tilting from the horizontal by 10 to 45°. Cracks reach up to a depth of more than a meter. The cracks are 1-3 cm wide. The texture in the control section is clayey with clay percentage between 42.9 to 48.8.

Competing series and their differentiae: Dabbavagu series is very deep developed on alluvium. Nagalpalli and Palvatla series are moderately deep black soils.

Drainage and permeability: Moderately well drained, slowly permeable in moist condition. Deep and fairly wide cracks develop on drying; intake of water is rapid till the cracks are sealed off. After saturation these soils are unworkable for some time.

Use and vegetation: Cultivated for Jowar, Wheat, Safflower, Cotton, Coriander and Gram. Natural vegetation consists of Acacia sp (Babool), Azadiracta indica (Neem), Magnifera indica (mango), Tamarindus indica (Tamarind).

Distribution and extent: Very extensive in Medak district of A.P. covers about 50% of the total area, in Nh1 and Nh1b and Nh1c sub-watersheds of Nizamsagar.

Type location: Field no.56. 1 km north east of village Kadirabad, 200 m east of Jogipet-Kadirabad road in Andol taluk, Medak district A.P.

Series proposed: All India soil and Land Use Survey, Bangalore Centre.

Interpretation: Kadirabad soils have the problem due to heavy texture. The intake of water during initial rainfall will be good but after the soil is saturated the water intake and permeability will be very slow. Due to the heavy texture and nature of the clay they will present problems for management. Loss of ammonia nitrogen due to volatilisation and fixation of added phosphorous are the likely problems of fertility management.
Management interpretation:

a) 1. Land capability sub-class : III
2. Land capability sub-class : 3
3. Fertility management potential : moderate

b) Quantitative: (Management potential for crop production under Farmer's level).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield Q/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmer's level</td>
</tr>
<tr>
<td>Jowar</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>not grown</td>
</tr>
<tr>
<td>Gram</td>
<td>6-8</td>
</tr>
<tr>
<td>Others (Wheat)</td>
<td>6-8</td>
</tr>
<tr>
<td>Safflower</td>
<td>4-5</td>
</tr>
<tr>
<td>Coriander</td>
<td>5-7</td>
</tr>
<tr>
<td>Cotton</td>
<td>3-5</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Sand</th>
<th>Coarse (2-0.05)</th>
<th>Medium (0.25-0.1)</th>
<th>Fine (0.05-0.002)</th>
<th>Very fine (&lt;0.002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap1</td>
<td>0- 2</td>
<td>40.6</td>
<td>22.7</td>
<td>36.7</td>
<td>9.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Ap2</td>
<td>2- 19</td>
<td>39.1</td>
<td>20.6</td>
<td>40.3</td>
<td>8.5</td>
<td>7.4</td>
</tr>
<tr>
<td>A12</td>
<td>19- 38</td>
<td>35.0</td>
<td>20.5</td>
<td>44.5</td>
<td>8.1</td>
<td>7.2</td>
</tr>
<tr>
<td>A13</td>
<td>38- 66</td>
<td>30.3</td>
<td>22.3</td>
<td>47.4</td>
<td>7.9</td>
<td>5.7</td>
</tr>
<tr>
<td>A14</td>
<td>66- 86</td>
<td>29.1</td>
<td>22.1</td>
<td>48.8</td>
<td>8.6</td>
<td>5.4</td>
</tr>
<tr>
<td>ACca</td>
<td>86-103</td>
<td>37.2</td>
<td>19.9</td>
<td>42.9</td>
<td>15.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Cca</td>
<td>103-115</td>
<td>53.0</td>
<td>15.0</td>
<td>32.0</td>
<td>22.8</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>Carbonate as CaCO3</th>
<th>Ext. Iron as Fe</th>
<th>pH (1:1)</th>
<th>pH H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>0- 2</td>
<td>0.71</td>
<td>2.22</td>
<td>1.47</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>2- 19</td>
<td>0.59</td>
<td>3.04</td>
<td>1.16</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>19- 38</td>
<td>0.48</td>
<td>3.31</td>
<td>1.16</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>38- 66</td>
<td>0.47</td>
<td>3.75</td>
<td>1.50</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>66- 86</td>
<td>0.47</td>
<td>4.35</td>
<td>2.00</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>86-103</td>
<td>0.40</td>
<td>7.89</td>
<td>1.98</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>103-115</td>
<td>0.30</td>
<td>9.50</td>
<td>1.96</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: one from the A horizon and one from the transition of AC to C horizon. Depths: 62-77 cm (1) and 96-111 cm (2).

1. Depth: 62-77 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, angular blocky soil material containing nodules and gravels, max. diam. nodules 12 mm.

Micromorphological characteristics

Structure: The soil material has a moderate medium angular blocky structure, to which common, intersected, elongated voids belong with a few enlarged intersection notes. Other voids: few to common elongated voids, widths up to 2 mm, length less than a few cm and few to common equant voids, diam. up to 2 mm, randomly distributed.

Groundmass: The fine textured soil material contains grain sizes including gravels of 5 mm diam. Size limit coarse/fine material is 15 µm; related distribution: porphyric. The coarse mineral material consists of a small variety of minerals and rock fragments, mainly quartz and feldspar, which are rather fresh, locally desintegrating. The fine material is largely clay-sized, includes common fine particles up to 15 µm, and has a strong vo-skelsepic plasmic fabric.

Special features:
Associated with voids: Few voids partly filled with soil fragments and shaped, mineral, excrements. In the groundmass: Few voids/zones completely filled with soil fragments and mineral grains and/or excrements. Few to common, often elongated, zones in the groundmass with a high concentration of large mineral grains. Common carbonate nodules, often composed of coarse crystals. The large carbonate nodules often contain sesquioxides in the outer zone. Carbonate accumulations are also present in former voids in the groundmass, as well as in desintegrating rock fragments and along larger gravels.
Common to many small, generally < 1 mm in diameter sesquioxidic accumulations in the groundmass, mainly composed of manganese, with clear, diffuse boundaries.
2. Depth: 96-111 cm.

Macroscopic characteristics

Very dark grayish brown, gravelly fine material, angular to sub-angular blocky soil material containing many gravels and nodules, increasing in quantity with depth.

Micromorphological characteristics

Structure: The soil material has a moderate medium angular to sub-angular blocky structure, to which common, intersected, elongated, voids belong. 
Other voids: few elongated voids, widths up to 2 mm, length less than a few cm and few equant voids, diam. up to 2 mm, randomly distributed.
Groundmass: The gravelly fine textured soil material contains grain sizes including gravels of 8 mm diam. Size limit coarse/fine material is 15 µm; related distribution: porphyric. The coarse mineral material in the upper 10 cm consists of a small variety of minerals and rock fragments, mainly quartz, feldspar and minor quantities of micas, which are rather fresh. Locally desintegrating micas have varying grades of alteration. Below that depth altering, desintegrating granodiorite rock is present. The fine material is largely clay-sized, includes common fine particles up to 15 µm and has a strong/moderate vo-skelsepic plasmic fabric.

Special features:

Associated with voids: Few voids are partly filled with soil fragments, minerals and shaped mineral, excrements.
In the groundmass: Few voids almost completely filled with soil fragments, mineral grains and/or excrements. 
: Common to many carbonate nodules. These are pure carbonate nodules, and nodules formed in and around rock fragments. 
: Common small generally < 1 mm in diameter sesquioxidic accumulations in the groundmass, often near micas, with clear, diffuse external boundaries.
Kadirabad (2 photographs)

1. Carbonate nodule (right side of vertical white void) with a black accumulation of manganese in the outer zone, containing a disintegrating rock fragment (white). A horizon (plain light).

2. Disintegrating rock with altering micas (black). AC to C horizon (plain light).
4. Interpretation of the micromorphological data

Two thin sections are studied: one from the A horizon and one from the transition of AC to C horizon.
Depths: 62-77 cm (1) and 96-111 cm (2).

- The structure, moderate medium angular blocky (1) and moderate medium angular to sub-angular blocky (2), is determined by physical processes. In the A horizon (1) the horizontal axes are inclined. The tendency in the AC-C horizon (2) to a subangular blocky type is due to the high quantity of gravels, which are close to ped faces at edges which are more likely to split off during shrinkage. Strong swell and shrink caused orientation of clay domains in zones most exposed to pressure, namely near voids and along coarse mineral grains and nodules, resulting in a strong vo-skelsepic plasmic fabric. Angular soil fragments and mineral grains or small rock fragments are present in a few voids. After repeated swell and shrink, voids infilled with these materials are only recognizable by higher contents of mineral grains occurring in elongated zones, a few of which are present in the A horizon.

- The influence of the fauna is low. Animals produce a few voids, some of which are more or less infilled with excrements, often also including a few mineral grains and soil fragments.

- Rock fragments are disintegrating, but individual grains are rather fresh, except for micas which are partly strongly altered.

- Carbonate accumulation is a current process. Carbonate nodules increase in quantity with depth from common (1) to common-many (2). Carbonate accumulates in the groundmass; along large mineral grains or rock fragments; in voids of disintegrating rock fragments (increasing the fragmentation by crystal growth) and in combinations of the last two. In the A horizon (1) some of the carbonate nodules have accumulations of sesquioxides, mainly manganese, in the outer zone.

- Sesquioxides are accumulating in small, generally less than 1 mm in diameter, nodules in the groundmass. They have clear or diffuse external boundaries and occur in and just above the weathering rock (2), also in combination with altering micas.
CHINNALONI SERIES

1. General information and typifying pedon description


Chinnaloni series comprise moderately deep, moderately well drained, cracking clayey soils of very dark grayish brown colours. They have developed on mixed colluvium derived from grano diorite and basalts. Chinnaloni soils occur on gently sloping middle pediment along the higher portion of the interfluve, with slope up to 5%. The climate is semi arid with mean annual air temperature of 25.8°C and average annual rainfall of 734.4 mm.

The principal associated soils are Babulgaon and Taklapalli series which are deep Chromusterts.

Chinnaloni soils is a member of the fine, montmorillonitic, isohyperthermic family of Vertic Ustropepts.
Typifying pedon: Chinnaloni clay-cultivated, fallow.

Ap1 0-2 cm: very dark grayish brown (10YR 3/2 D & M) clay; weak fine granular; loose, friable, sticky and plastic; about 5% by volume of 2-5 mm size rounded line nodules and quartz gravels; slightly effervescent; many fine roots; pH 7.9; abrupt smooth boundary.

Ap2 2-13 cm: Very dark grayish brown (10 YR 3/2 D & M) clay, moderate medium sub-angular blocky; hard, firm, sticky and plastic; 3-8% by volume rounded lime nodules and quartz gravels; slightly effervescent; more than 1 cm wide cracks; many very fine exped roots; many very fine vertical tubular discontinuous pores; pH 7.9; clear and smooth boundary.

A12 13-47 cm: Very dark grayish brown (10YR 3/2 M) clay; moderate fine to medium angular blocky with lenticular sphenoids; firm, sticky and plastic; 3-8% by volume 2-5 mm size rounded lime nodules and quartz gravels; slightly effervescent; 0.5-0.7 cm wide cracks up to 30 cm depth; few coarse, many fine exped roots; many very fine vertical tubular discontinuous pores; pH 7.9; clear smooth boundary.

Cca 47-65 cm: Yellowish brown (10YR 5/4 M) about 40%, dark grayish brown (10YR 3/3 M) about 30%, white (10YR 8/1 M) about 30%, weathered zone with 60-70% by volume quartz, felspar gravels, 3-8 mm size cobbles and weathered rounded grano-diorite up to 25 cm size and soft powdery lime violently effervescent; pH 8.2.

Range in characteristics: The thickness of the solum ranges from 25-50 cm. The estimated soil temperature at 50 cm depth is 26.8°C, the mean summer soil temperature is 26.3°C and the mean winter temperature is 23.0°C. The colour of the Ap horizon ranges from dark grayish brown to very dark grayish brown in hue of 10YR, value of 3 to 4 and chroma of 2 to 3. The thickness of the Ap horizon ranges from 10 to 15 cm with a thin layer of 5 cm thick granular structure. The colour of the A horizon below the Ap ranges from dark grayish brown to very dark grayish brown in hues of 10YR and 2.5 Y value of 3 to 4 and chromas of 2 to 3. The texture ranges from clay to gravelly clay in the sub soil. The lime concretions of 2 to 5 mm size are present up to 3 to 8% by volume. The cracks are seen up to 50 cm depth. The sub soil structure is sub-angular blocky with sphenoids between 25 and 50 cm. Texture in the control section is clayey with clay percentage of 55%.
Competing series and their differentiae: Taklapalli and Babulgaon are deep Typic Chromusterts.

Drainage and permeability: Moderately well drained with moderate permeability.

Use and vegetation: Cultivated for jowar, chillies, safflower, under rainfed conditions. Natural vegetation consists of acacia, neem, palms, ber, tamarind, mango.

Distribution and extent: Occurs extensively in the Medak district of A.P.

Type location: 200 m south of vill. Chinnahilmedo in Sadashivpet taluk of Medak district A.P.

Series proposed: AIS & LUS Bangalore Centre.

Management interpretation: Chinnaloni soils present problem due to shallow depth and heavy texture. Their cracking nature helps in initial intake of rain water. They are susceptible to erosion due to heavy nature and long slopes. They are adapted to jowar, chillies and safflower under rainfed conditions.

Management interpretations:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub-class: III’s and IIe
   2. Land irrigability class: 3e
   3. Fertility management potential: Moderately high
   4. Management potential/productivity: Moderately high

b) Quantitative (Management potential for crop production at different levels of farming under rainfed and irrigation agriculture).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer’s level:</th>
<th>Unirrigated</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jowar</td>
<td>8-1</td>
<td>15-20</td>
<td></td>
</tr>
<tr>
<td>Chillies</td>
<td>3-5</td>
<td>6-8</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>Not grown</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>Carbonate as CaCO$_3$ &lt; 0.02 mm %</th>
<th>Ext. iron as Fe (1:2.5) %</th>
<th>pH</th>
<th>E.C. H$_2$O mmhos/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap1</td>
<td>0-2</td>
<td>0.91</td>
<td>6.19</td>
<td>3.00</td>
<td>7.9</td>
<td>0.09</td>
</tr>
<tr>
<td>Ap2</td>
<td>2-13</td>
<td>0.90</td>
<td>6.22</td>
<td>2.98</td>
<td>7.9</td>
<td>0.09</td>
</tr>
<tr>
<td>A12</td>
<td>13-47</td>
<td>0.69</td>
<td>9.53</td>
<td>3.67</td>
<td>7.9</td>
<td>0.09</td>
</tr>
<tr>
<td>Cca</td>
<td>47-65</td>
<td>0.29</td>
<td>12.79</td>
<td>2.28</td>
<td>8.2</td>
<td>0.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Sand (2-0.05) %</th>
<th>Silt (0.05-0.002) %</th>
<th>Clay (&gt;0.002) %</th>
<th>Very coarse (2-1) %</th>
<th>Coarse (1-0.5) %</th>
<th>Medium (0.5-0.25) %</th>
<th>Fine (0.25-0.1) %</th>
<th>Very fine (0.1-0.05) %</th>
<th>Silt (2.0-0.2) %</th>
<th>Silt (0.2-0.02) %</th>
<th>Clay (0.02-0.002) %</th>
<th>Coarse fragments &gt; 2 mm % by weight of whole soil %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap1</td>
<td>0-2</td>
<td>18.0</td>
<td>26.8</td>
<td>55.2</td>
<td>2.9</td>
<td>2.6</td>
<td>3.7</td>
<td>5.7</td>
<td>3.7</td>
<td>10.9</td>
<td>13.0</td>
<td>20.9</td>
<td>55.2</td>
</tr>
<tr>
<td>Ap2</td>
<td>2-13</td>
<td>19.1</td>
<td>25.9</td>
<td>55.0</td>
<td>6.1</td>
<td>2.7</td>
<td>3.4</td>
<td>4.1</td>
<td>2.8</td>
<td>13.6</td>
<td>10.7</td>
<td>20.7</td>
<td>55.0</td>
</tr>
<tr>
<td>A12</td>
<td>13-47</td>
<td>22.1</td>
<td>22.8</td>
<td>55.1</td>
<td>7.7</td>
<td>4.7</td>
<td>4.2</td>
<td>3.3</td>
<td>2.2</td>
<td>17.8</td>
<td>8.0</td>
<td>19.1</td>
<td>55.1</td>
</tr>
<tr>
<td>Cca</td>
<td>47-65</td>
<td>45.9</td>
<td>24.2</td>
<td>29.9</td>
<td>19.5</td>
<td>9.7</td>
<td>7.1</td>
<td>6.1</td>
<td>3.5</td>
<td>38.6</td>
<td>13.2</td>
<td>18.3</td>
<td>29.9</td>
</tr>
</tbody>
</table>

Size class and particle diameter (mm)
3. Micromorphological data

Two thin sections are studied: one from the A horizon and one from the C horizon.
Depths: 16-31 cm (1) and 52-67 cm (2).

1. Depth: 16-31 cm

Macroscopic characteristics

Dark brown, fine textured, pedal soil material, containing common mainly light coloured nodules/rock fragments, diam. up to 6 mm.

Micromorphological characteristics

Structure: Moderate medium sub-angular blocky and some porous spheroids diam. 1-3 cm, to which common, intersected, elongated voids belong. Other voids: Few to common elongated voids, widths generally less than 3 mm, lengths up to a few cm and common equant voids, most diam. < 3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3.5 mm Ø. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying degrees of alteration, but mainly are rather fresh. A few coarse organic fragments occur, in voids as well all embedded in the groundmass. The fine material is predominantly clay sized, includes a few particles up to 5 µm and has a moderate skel-vosepic plasmic fabric.

Special features:

Associated with voids: Few to common voids partly filled with mineral aggregates, excrements as well as, most angular, soil aggregates.

In the groundmass : Common voids/zones nearly completely filled with mineral aggregates, mainly more or less wealded excrements, diam. up to 10 mm.

: Few isotubules, diam. about 2 mm.

: Common carbonate nodules, diam. up to 6 mm, clear external boundaries. A part of the carbonate nodules contain accumulations of sesquioxides.
2. Depth: 52-67 cm.

Macroscopic characteristics

Dark brown and yellowish brown coloured parent material, containing abundant light coloured nodules/rock fragments, diam. up to 15 mm.

Micromorphological characteristics

Structure: Apedal parent material with few to common elongated voids, sometimes intersected, widths generally less than 3 mm, lengths up to a few cm and few to common equant voids, diameters generally less than 3 mm randomly distributed.

Groundmass: The parent material includes grain sizes from clay sized to gravels of 15 mm in diameter. More than half of the parent material consists of gravels. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration. The fine material is predominantly clay sized, includes a few particles up to 5 µm and has a moderate skel-sepic plasmic fabric. Special features:

Associated with voids: Few to common voids partly filled with mineral aggregates, excrements as well as soil aggregates.

In the groundmass: Common voids/zones between gravels nearly completely filled with mineral aggregates, mainly more or less wealed excrements.

: Many carbonate nodules, diam. up to 15 mm. A part of the carbonate nodules are desintegrating in smaller nodules and single crystals. Some carbonate nodules contain accumulations of sesquioxides.

: Rock fragments show varying degrees of alteration. They can be strongly altered.
Short micromorphological description

Two thin sections are studied; one from the A horizon and one from the C horizon.
Depths: 16-31 cm (1) and 52-67 cm (2).

The soil material is fine textured in the A horizon (1) and consists more than half of the parent material of gravels in the C horizon (2) and includes grain sizes up to gravels of 3.5 mm in diam. (1) and 15 mm in diam. (2). Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a moderate skel-vosepic plasmic fabric (1) and a moderate skel-sepic plasmic fabric (2). The coarse material consists of a variety of minerals and rock fragments, which show varying degrees of alteration and in the A horizon (1) a few organic fragments occur in voids as well as embedded in the groundmass.

The soil material has a moderate medium sub-angular blocky structure and includes porous spheroids in (1), to which common intersected elongated voids belong, and is apedal in (2). Other voids: Few to common elongated voids, widths generally less than 3 mm, lengths up to a few cm and common (1), few to common (2) equant voids, most diameters < 3 mm, randomly distributed.

Few to common voids are partly filled with mineral aggregates, excrements as well as soil aggregates. Commonly are voids/zones in the C horizon (2) between the gravels, nearly completely filled with mineral aggregates, mainly more or less wealded excrements.

Few isotubules are found in the A horizon (1), diam. about 2 mm.
Carbonate nodules are common in the A horizon (1) and increase to many in the C horizon (2). The diameters increase from up to 6 mm in (1) to 15 mm in (2). A part of the carbonate nodules contain accumulations of sesquioxides. In the C horizon (2) a part of the carbonate nodules are desintegrating into smaller nodules and single crystals.

Rock fragments in the C horizon (2) show varying degrees of alteration. Some are strongly altered.
Chinnaloni (2 photographs)

1. Disintegrating carbonate nodule. C horizon (crossed polarisers)

2. Carbonate precipitation in a disintegrating rock fragment. C horizon (crossed polarisers)
4. Interpretation of the micromorphological data

Two thin sections are studied: one from the A horizon and one from the C horizon. Depths: 16-31 cm (1) and 52-67 cm (2).

- The structure in the A horizon (1) is primarily a result of strong swell and shrink. The few angular soil aggregates present in voids are split off during shrinkage in upper horizons. The orientation of clay domains near voids and around larger nodules and rock fragments resulting in a skel-vosepic plasmic fabric in (1) and a skelsepic plasmic fabric in (2) is also due to the same processes.

- The soil fauna plays an important role. Structural voids are modified by soil animals, resulting in a moderate subangular blocky structure in (1). The fauna produces most of the voids not belonging to the structure and homogenizes large parts of the groundmass. The number of open voids decreases slightly with depth from common (1) to few-common (2). The few-common partly filled and common almost completely filled voids with more or less welded shaped mineral excrements occurring in both studied zones and the few striotubules present in the A horizon (1) are all forms of homogenization. In the studied C horizon (2) most of the groundmass between the gravels is homogenized by the soil fauna.

- Most of the gravels >2 mm in diameter, which are common in the A horizon (1) and abundant in the studied part of the C horizon (2) are carbonate nodules. These nodules, diameters up to 6 mm in (1) and 15 mm in (2), form part of the colluvium in which the pedon is developed. In (2) carbonate nodules occupy half the studied area and some of them are disintegrating into smaller nodules and single crystals. In some of the carbonate nodules sesquioxides are accumulated.

- In the studied zones, rock fragments form a minor part of the gravels. These fragments are still altering.

Remarks: The pedon is developed in a colluvium containing gravels which mainly are carbonate nodules. Only a minor part are rock fragments. This material is not identical to the colluvium of grano-diorite and basalts mentioned in the pedon description.
KASIREDDIPALLI SERIES

1. General information and typifying pedon description

Location: Plot No. BW 7, ICRISAT Farm, Patancheru 17°30' N 78°16' E.
Elevation: 540 m above MSL.
Climate: Semiarid tropical with 835 mm rainfall, mild winters and warm summers.
Vegetation: Currently fallow.
Landform: Nearly level lower pediment
Parent Material: Basaltic alluvium over weathered gneiss.
Slope: 1 to 2 per cent.
Drainage: Imperfectly drained, slow to very slow permeability.
Land Use: Sorghum, pigeonpea, maize, groundnut, pearl millet, and bengal gram.

Typifying pedon: Kasiraddipalli clay - cultivated

Ap

0-20 cm: Very dark gray to very dark grayish brown (10 YR 3/1.5 M) clay; moderate medium subangular blocky structure breaking to weak medium granular; friable, sticky and plastic; common fine and medium roots; common fine subrounded segregated lime concretions and powdery lime mixed; strongly effervescent; many fine to medium tubular inped pores; strongly alkaline; clear smooth boundary.

Al2

20-40 cm: Very dark gray (10 YR 3/1 M) clay; strong coarse prismatic structure breaking to medium subangular blocky peds with shiny pressure faces; firm, sticky and plastic; common fine and medium roots; common subrounded fine to medium lime concretions and few quartz gravels; strongly effervescent; few fine inped and exped pores; very strongly alkaline; gradual smooth boundary.
A13  40–60 cm: Very dark gray to black (10 YR 2.5/1 M) clay; intersecting slickensides forming coarse parallelepips breaking to strong coarse angular blocky peds with shiny pressure faces; very firm, very sticky and plastic; very few medium roots; few coarse to medium lime concretions; strongly effervescent; few fine to very fine oblique inped and exped pores; very strongly alkaline; gradual smooth boundary.

A14  60–90 cm: Very dark gray to black (10 YR 2.5/1 M) clay; intersecting slickensides forming coarse parallelepips breaking to strong coarse angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; very few fine roots; common fine to medium lime concretions; strongly effervescent; very fine irregular exped pores; very strongly alkaline; clear wavy boundary.
### 2. Analytical Data of Kasireddipalli Profile

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Sand (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&lt;0.002)</th>
<th>Very coarse (2-1)</th>
<th>Coarse (1-0.5)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.1)</th>
<th>Very fine (&lt;0.1-0.05)</th>
<th>% of &lt;2 mm</th>
<th>Coarse fragments &lt;2 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-20</td>
<td>23.5</td>
<td>22.8</td>
<td>53.7</td>
<td>4.0</td>
<td>2.2</td>
<td>4.3</td>
<td>8.6</td>
<td>4.4</td>
<td>6</td>
<td>31.2</td>
<td>13.4</td>
</tr>
<tr>
<td>A12</td>
<td>20-40</td>
<td>21.7</td>
<td>21.6</td>
<td>56.7</td>
<td>3.6</td>
<td>2.2</td>
<td>3.9</td>
<td>7.6</td>
<td>4.4</td>
<td>6</td>
<td>32.6</td>
<td>14.2</td>
</tr>
<tr>
<td>A13</td>
<td>40-60</td>
<td>19.5</td>
<td>22.1</td>
<td>58.4</td>
<td>4.4</td>
<td>2.0</td>
<td>3.1</td>
<td>6.2</td>
<td>3.8</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A14</td>
<td>60-90</td>
<td>16.2</td>
<td>23.7</td>
<td>60.1</td>
<td>1.5</td>
<td>1.9</td>
<td>3.0</td>
<td>5.9</td>
<td>3.9</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AC</td>
<td>90-130</td>
<td>11.6</td>
<td>21.0</td>
<td>67.4</td>
<td>1.0</td>
<td>1.1</td>
<td>2.1</td>
<td>4.3</td>
<td>3.1</td>
<td>7</td>
<td>34.6</td>
<td>17.2</td>
</tr>
<tr>
<td>C</td>
<td>130-180</td>
<td>12.9</td>
<td>20.4</td>
<td>66.7</td>
<td>1.2</td>
<td>1.5</td>
<td>2.1</td>
<td>3.9</td>
<td>3.2</td>
<td>9</td>
<td>34.2</td>
<td>16.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Organic carbon %</th>
<th>CaCO₃ equiv. %</th>
<th>pH (1:2.5) H₂O</th>
<th>Extractable bases Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Sum</th>
<th>CEC me/100 g</th>
<th>ESP (NH₄Ac) mmhos/cm</th>
<th>EC (1:2.5) mmhos/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0.73</td>
<td>5.3</td>
<td>8.8</td>
<td>41.7</td>
<td>10.9</td>
<td>0.9</td>
<td>0.7</td>
<td>54.2</td>
<td>57.2</td>
<td>2.09</td>
<td>0.09</td>
</tr>
<tr>
<td>A12</td>
<td>0.54</td>
<td>7.4</td>
<td>9.2</td>
<td>37.5</td>
<td>14.7</td>
<td>5.3</td>
<td>0.6</td>
<td>58.1</td>
<td>58.5</td>
<td>0.99</td>
<td>0.09</td>
</tr>
<tr>
<td>A13</td>
<td>0.47</td>
<td>7.0</td>
<td>9.4</td>
<td>38.4</td>
<td>13.0</td>
<td>2.9</td>
<td>0.6</td>
<td>54.9</td>
<td>56.1</td>
<td>0.19</td>
<td>0.09</td>
</tr>
<tr>
<td>A14</td>
<td>0.39</td>
<td>6.3</td>
<td>9.4</td>
<td>34.1</td>
<td>16.4</td>
<td>7.8</td>
<td>0.6</td>
<td>58.9</td>
<td>60.1</td>
<td>1.31</td>
<td>0.18</td>
</tr>
<tr>
<td>AC</td>
<td>0.28</td>
<td>6.2</td>
<td>9.4</td>
<td>30.2</td>
<td>18.4</td>
<td>12.8</td>
<td>0.6</td>
<td>62.0</td>
<td>62.9</td>
<td>0.45</td>
<td>0.20</td>
</tr>
<tr>
<td>C</td>
<td>0.25</td>
<td>7.5</td>
<td>9.4</td>
<td>26.2</td>
<td>19.1</td>
<td>14.2</td>
<td>0.6</td>
<td>60.9</td>
<td>61.5</td>
<td>0.34</td>
<td>0.23</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied both from a deep A horizon. Depth: 15-30 cm (1) and 60-75 cm (2).

1. Depth: 15-30 cm

Macroscopic characteristics

Very dark gray, fine textured, pedal soil material, containing common light coloured carbonate nodules, diam. up to 4 mm.

Micromorphological characteristics

Structure: Strong medium subangular blocky structure to which common, intersected often irregular elongated voids belong. Other voids: Common often irregular elongated voids, widths up to 6 mm, lengths a few cm and common equant voids most <2 mm, sometimes interconnected. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which for a part are altering. A few coarse root fragments occur. The fine material is largely clay-sized and includes a few particles up to 10 µm and has a weak-moderate ma-skelsepic plasmic fabric.

Special features

Associated with voids: Common voids partly infilled with mineral aggregates, mainly shaped excrements.

: In a few voids and in a few root fragments occur some shaped organic excrements.

In the groundmass: Many voids almost completely infilled with mineral aggregates, predominantly shaped, more or less welded excrements. A part of these voids are interconnected.

: Common, rounded, carbonate nodules, diam. up to 4 mm with at random distribution. A few of these carbonate nodules have an accumulation of sesquioxides in the outer zone.

: Locally in the groundmass occur higher concentrations of coarse grains and rock fragments.
2. Depth: 60-75 cm

Macroscopic characteristics

Very dark gray, fine textured, pedal soil material, containing common light colored carbonate nodules, diam. up to 6 mm.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure to which common, intersected, elongated voids belong. Other voids: few-common elongated, sometimes irregular voids, widths up to 5 mm, length a few cm and few-common equant voids most <2 mm. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which for a part are altering. The fine material is largely clay-sized and includes a few particles up to 10 µm and has a moderate vo-skelsepic plasmic fabric, vosepic along inclined horizontal axes.

Special features:

Associated with voids: A few voids partly infilled with mineral aggregates, shaped excrements or/and soil fragments.

: Along a few voids occur locally coatings of soil material.

In the groundmass: Common voids almost completely infilled with more or less shaped, strongly welded mineral excrements.

: Common rounded carbonate nodules diam. up to 4 mm with at random distribution. A few of these carbonate nodules have an accumulation of sesquioxides in the outer zone.

: In the groundmass occur common small, irregular, accumulations of sesquioxides, predominantly of manganese.

: Locally in the groundmass occur higher concentrations of coarse grains and rock fragments.
1. Zone composed of shaped, more or less welded, fine-grained mineral excrements; A horizon.

(plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied, both from a deep A horizon
Depths: 15-30 cm (1) and 60-75 cm (2).

- The strong developed structure is due to strong swell and shrink of
  montmorillonitic clays. In the upper section (1) occur in a few voids
  angular soil fragments, split off during shrinkage in the soil. In (2)
  these infilled fragments are locally present as coatings along voids,
  after swell and shrink. In both studied sections occur locally accumula-
  tions of embedded coarse grains and rock fragments in the groundmass,
  which are the result of swell after infilling of a void. The roundness
  of carbonate nodules and the orientation of clay domains in the fine
  material resulting in a weak-moderate ma-skelsepic plasmic fabric in
  (1) and a moderate vo-skelsepic plasmic fabric in (2) are all
  consequences of vertic properties of the soil.

- The soil fauna plays an important role. In the upper section (1) the
  structure is largely influenced by faunal activities. Structural voids
  are locally enlarged and many voids are infilled with shaped, more or
  less welded, mineral excrements. In coarse organic fragments often small,
  shaped organic excrements occur. Deeper in the A horizon (2) the impact
  of the soil fauna is still evident. Local enlargements of voids are
  present and commonly voids are infilled with more or less shaped,
  strongly welded mineral excrements. The high degree of welding is partly
  due to the vertic properties of the soil.

- Carbonate nodules are common in the A horizon. The sizes reach up to
  4 mm in diameter in (1) and to 6 mm in (2). A part of these nodules are
  small ones, <1 mm, apparently formed in situ. A few of the larger
  carbonate nodules have accumulations of sesquioxides in the outer zone.

- Deeper in the A horizon small irregular accumulations of predominantly
  manganese are common in the groundmass.

Remark: Compared with other vertisols of the peninsula this pedon has
a high animal activity, positively influencing the structure and porosity.
THEKKADI SERIES

1. General information and typifying pedon description

Pedon examined by Dr. N.G. Godse, N.K. Barde and H.S. Shankaranarayana Associates: Haridas C.R. Shiva Prasad. Date of study: 16.3.79.

Thekkadi series comprises very deep, well drained, clay to sandy clay soils of dark reddish brown to dark red colours. They have developed on gneisses in the sub-tropical mixed evergreen and wet deciduous forest area of western Ghat of Kerala state. Thekkadi soils occur on moderately sloping hill slopes of 5 to 10 percent slopes. The climate is humid tropical with mean annual air temperature of 27.1°C and a mean annual rainfall of 3996 mm.

Principal associated soils are Kumali series which are moderately deep bouldary and fine loamy Typic Udorthents occurring on foot hill slopes.

Thekkadi series is a member of fine loamy, isohyperthermic mixed acid family of Typic Hapludolls.

Climatic Data and Soil Water Balance

SERIES THEKKADI

--- PE --- Precip ---- Temp. ---
Typifying pedon: Thekkadi clay-forest.

O  
+5-10 cm: Partially decomposed forest litter and twigs with very little soil mixed with decomposed organic matter.

A1  
0-27 cm: Dark reddish brown (5 YR 2/2 M) clay; weak fine sub-angular blocky breaking to weak medium granular; friable, sticky and plastic; about 3 per cent quartz fragments of 2-5 mm size; many fine, medium, coarse roots; common fine tubular pores; pH 6.0; clear smooth boundary.

B1  
27-58 cm: Dusk red (2.5 YR 3/2 M) sandy clay; weak fine to moderate medium subangular blocky; friable, sticky and plastic; about 3 to 5 per cent quartz fragments; of 3-5 mm size common medium and coarse roots; common fine tubular pores; pH 5.6; abrupt wavy boundary.

B21  
58-85 cm: Dark reddish brown (2.5 YR 3/4 M) sandy clay; weak, fine to medium sub-angular blocky; very friable, sticky and plastic; about 5-10 percent quartz fragments of 2 to 15 mm size; few medium and coarse roots; common fine tubular pores; pH 5.3; clear smooth boundary.

B22  
85-113 cm: Dark red (2.5 YR 3/6 M) sandy clay; weak fine to medium subangular blocky; very friable, sticky and plastic; about 5-10 percent quartz fragments of 2 to 15 mm size; few medium to coarse roots; common fine tubular pores; pH 5.0; clear smooth boundary.

B31  
113-143; Dark red (2.5 YR 3/6 M) sandy clay; weak fine to medium subangular blocky; very friable, sticky and plastic; about 10-15 percent quartz fragments of 2 to 15 mm size; common fine tubular pores; pH 5.0; clear smooth boundary.

C  
143-190 cm: Dark red (2.5 YR 3/6 M) gravelly sandy clay; coarse granular; very friable, sticky and plastic; about 50-60 percent quartz fragments of 2 to 20 mm size, pH 4.9.

Range in characteristics: The thickness of solum ranges from 60 to 150 cm. The thickness of the A horizon ranges from 15-30 cm. The colour ranges from very dusky red to dark reddish brown in 5 YR and 2.5 YR hues, 2 to 3 value and 2 to 3 chroma. However dark reddish brown is the dominant colour. The texture ranges from loam to clay loam. The thickness of B horizon ranges from 45-120 cm and the colour from red to dark red, dark reddish brown.
and reddish yellow in 2.5 YR to 7.5 YR hues, 3 to 5 value and 2 to 6 chroma. The texture of the B horizon ranges from sandy clay to clay. Some subhorizon may have clay loam texture. Coarse fragment of gneissic material of 5 to 30 mm size ranges from 10 to 15 percent by volume. The structure ranges from fine to medium subangular blocky. Texture in the C horizon is sandy clay. Gravelly material occupy 60 to 80 percent by volume.

Competing series and their differentiae: Kumali series occurring on foothill slopes are moderately deep to deep bouldery fine loamy soils of Typic Udothents.

Drainage and permeability These soils are well drained with moderate permeability.

Use and vegetation: Under forest natural vegetation consists of Teak (Tectona grandis) Jack (Artocarpus indicus) Rose wood (Dalbergia sp) shrubs and grasses.

Distribution and extent: Occurs extensively in the forests of western Ghats in Idikki district of Kerala.

Type location: Thekkadi reserve forest area 1.5 km from Periyar lake.

Series proposed by: State Soil Survey Organisation Kerala.
2. Tentative soil characterisation by Dr. P. KRISHNAN

<table>
<thead>
<tr>
<th>Size class and particle diameter (mm), % of &lt;2 mm</th>
<th>Total</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Coarse fragments &gt; 2 mm % by weight of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horiz- Depth</td>
<td>Sand (2- (0.05) 0.02)</td>
<td>Silt (0.05) 0.02)</td>
<td>Clay (2- (0.5) 0.25)</td>
<td>Very coarse (1- 0.5)</td>
<td>Medium Fine (0.25- 0.1)</td>
</tr>
<tr>
<td>A1 0-27</td>
<td>42.6</td>
<td>16.2</td>
<td>41.2</td>
<td>9.2</td>
<td>9.0</td>
</tr>
<tr>
<td>B1 27-58</td>
<td>41.8</td>
<td>15.7</td>
<td>42.5</td>
<td>13.3</td>
<td>7.2</td>
</tr>
<tr>
<td>B21 58-85</td>
<td>40.9</td>
<td>12.5</td>
<td>46.6</td>
<td>16.7</td>
<td>5.9</td>
</tr>
<tr>
<td>B22 85-113</td>
<td>38.6</td>
<td>16.2</td>
<td>45.2</td>
<td>14.1</td>
<td>5.9</td>
</tr>
<tr>
<td>B3 113-143</td>
<td>38.3</td>
<td>18.0</td>
<td>43.7</td>
<td>13.6</td>
<td>5.7</td>
</tr>
<tr>
<td>BC 143-190</td>
<td>48.8</td>
<td>11.0</td>
<td>40.2</td>
<td>29.7</td>
<td>4.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>pH</th>
<th>E.C.</th>
<th>Water Retention pH</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1:2.5)</td>
<td>H2O</td>
<td>(1:2.5)</td>
<td>1/3-bar</td>
<td>15-bar</td>
<td>(1:5)</td>
</tr>
<tr>
<td></td>
<td>KCl</td>
<td>K2O</td>
<td>mmhos/cm</td>
<td>%</td>
<td>%</td>
<td>CaCl2</td>
</tr>
<tr>
<td>0-27</td>
<td>3.29</td>
<td>5.5</td>
<td>6.0</td>
<td>-</td>
<td>31.8</td>
<td>12.7</td>
</tr>
<tr>
<td>27-58</td>
<td>1.43</td>
<td>5.2</td>
<td>5.6</td>
<td>0.09</td>
<td>31.9</td>
<td>12.8</td>
</tr>
<tr>
<td>58-85</td>
<td>1.00</td>
<td>4.4</td>
<td>5.3</td>
<td>0.09</td>
<td>32.7</td>
<td>12.7</td>
</tr>
<tr>
<td>85-113</td>
<td>0.87</td>
<td>4.1</td>
<td>5.0</td>
<td>-</td>
<td>31.6</td>
<td>12.6</td>
</tr>
<tr>
<td>113-143</td>
<td>0.81</td>
<td>4.2</td>
<td>5.0</td>
<td>-</td>
<td>31.1</td>
<td>12.5</td>
</tr>
<tr>
<td>143-190</td>
<td>0.69</td>
<td>4.3</td>
<td>4.9</td>
<td>-</td>
<td>30.3</td>
<td>12.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>sum cations</th>
<th>NH4Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
<td>Sum</td>
</tr>
<tr>
<td>meq/100 g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-27</td>
<td>10.58</td>
<td>2.60</td>
<td>0.14</td>
<td>0.72</td>
<td>14.00</td>
</tr>
<tr>
<td>27-58</td>
<td>5.35</td>
<td>3.07</td>
<td>0.12</td>
<td>0.56</td>
<td>9.10</td>
</tr>
<tr>
<td>58-85</td>
<td>1.41</td>
<td>3.53</td>
<td>0.10</td>
<td>0.48</td>
<td>5.52</td>
</tr>
<tr>
<td>85-113</td>
<td>1.30</td>
<td>2.18</td>
<td>0.10</td>
<td>0.52</td>
<td>4.10</td>
</tr>
<tr>
<td>113-143</td>
<td>0.95</td>
<td>1.23</td>
<td>0.10</td>
<td>0.42</td>
<td>2.72</td>
</tr>
<tr>
<td>143-190</td>
<td>1.29</td>
<td>0.72</td>
<td>0.10</td>
<td>0.40</td>
<td>2.51</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: both derived from the B horizon. Depths: 32-47 cm (1) and 79-94 cm (2).

Macroscopic characteristics

Dark reddish brown, fine textured, weak pedal soil material, including common light coloured gravels up to 5 mm ø.

Micromorphological characteristics

Structure: Weak medium subangular blocky structure, to which a few irregular elongated, sometimes intersected, voids belong. Other voids: few to common elongated voids, widths up to 10 mm length, several cm long and common equant voids, ø up to 10 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 5 mm in diameter. Size limit coarse/fine material is 25 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rockfragments, which show varying stages of alteration. The coarse organic matter consists of few to common root fragments. The fine material is largely clay-sized and includes common particles up to 25 µm. Most of these particles are black and a number are remnants of organic matter. The plasmic fabric, if any, is not detectable, due to the red colour of the fine material.

Special features:

Associated with voids: Common voids partly filled with mineral aggregates, mainly excrements but also soil aggregates. Diameters up to 10 mm, randomly distributed.

: Locally common thin, often laminated, red coloured, argillans in small voids.

In the groundmass: Common voids nearly completely filled with mineral aggregates, mainly excrements but also soil aggregates. A number of these voids are interconnected. They generally have clear external boundaries and are randomly distributed. The colour of the excrements is sometimes darker red brown or lighter red than the groundmass.
Few to common red, sometimes laminated papules, embedded in the groundmass and in excrements.

Few to common small voids completely filled with clay, red coloured and often laminated.

Common strongly altered rockfragments, randomly distributed.

Few to common small organic fragments embedded in the groundmass and in excrements.

Common dark coloured, angular or subangular small fragments in the groundmass and in excrements.

2 Depth: 79-94 cm

Macroscopic characteristics

Dark red, fine textured, weak pedal soil material, including common light coloured gravels up to 10 mm ø.

Micromorphological characteristics

Structure: Very weak medium subangular blocky structure, to which a few irregular elongated, sometimes intersected voids belong. Other voids: few to common elongated voids, widths up to 10 mm, length a few cm and common equant voids, ø up to 10 mm, most < 2 mm, randomly distributed.

Groundmass: The fine textured groundmass includes grain sizes up to gravels of 10 mm in diameter. Size limit coarse/fine material is 25 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rockfragments, which show varying stages of alteration. The coarse organic matter consists of a few root fragments. The fine material is largely clay-sized and includes few to particles up to 25 µm. The plasmic fabric, if any is not detectable, due to the red colour of the fine material.

Special features

Associated with voids: Common voids partly filled with mineral aggregates, mainly excrements, but also soil aggregates. Diameters up to 10 mm, randomly distributed.

Few thin, often laminated, red coloured, argillans in small voids.
In the groundmass: Common voids, nearly completely filled with mineral aggregates, mainly excrements. A large number of these voids are interconnected. They generally have clear external boundaries and are randomly distributed. Some of these filled voids have a thick coating of predominantly fine material.

: Common red, sometimes laminated, papules embedded in the groundmass and in excrements.

: Few small voids completely filled with clay, red coloured and often laminated.

: Common strongly altered rock fragments, randomly distributed.

: Few small organic fragments mainly present in excrements.
Thekkadi (2 photographs)


Interpretation of the micromorphological data

Two thin sections are studied: both derived from the B horizon.
Depths: 32-47 cm (1) and 79-94 cm (2).

The influence of the fauna is strong in the studied zone and mainly results in homogenization. Soil animals produce varying void systems, many of which are partly or completely filled with, predominantly, shaped mineral excrements. These void systems are often interconnected, largely determining the subangular blocky structure of this B horizon. Along the walls of a few voids deeper in the B horizon (2) thick coatings of mainly fine-grain material occur. These are caused by animals plastering the walls with excrements.

Roots have also produced, and are still producing a number of voids. Root fragments decrease in quantity with depth in the B horizon from few to common in (1) to few in (2).

In the upper part of the B horizon (1) a large number of small black particles up to 25 µm are present in the fine material. Most of them are charcoal particles and not decomposing fragments of organic matter. The charcoal was probably formed during a forest fire and, due to animal activity, incorporated in the soil material. The incorporation of black charcoal fragments resulted in a darker colour of the upper horizons, but is not related to a mollic epipedon.

Some clay illuviation occurred in this pedon. Red coloured argillans and clay infillings, both often laminated, are present. They are locally common in the upper part of the B horizon (1) and decrease to few in the middle part (2). The soil fauna has homogenized some of the clay illuviation features. Their remnants occur as papules in excrements. No features indicating current clay illuviation are observed.

Strong weathering has occurred in this soil material. Minerals and rock fragments show varying stages of alteration. Many rock fragments are strongly weathered. Some alteration still occurs.

Conclusion: This Benchmark soil is tentatively classified as a Typic Hapludoll. Micromorphological observations indicate that the colour of the A horizon is due to charcoal fragments. Based on the studied thin sections it is unlikely to expect a mull humusform in the A horizon. In the B horizon clay illuviation features occur. Strong weathering has occurred, but weatherable minerals are still present. Based on this, limited, data the soil can either be classified as an Ultisol or an Inceptisol.
TRIVANDRUM SERIES

1. General information and typifying pedon description


Trivandrum series comprises well drained, deep, gravelly soils of light yellowish brown to yellowish red colours. They are underlain by massive soft laterite. Trivandrum soils occur on laterite mound cuts and levelled plots having slopes of less than 1%. The climate is humid tropical with mean annual air temperature of 27.1°C and average annual rainfall of 1484.4 mm. The lands in the farm have been buldozed and terraced to divide them into level plots, as such the natural depth of the solum is reduced and surface texture changed. The principal associated soils are Pangabara series which are shallow gravelly soils.

Trivandrum series is a member of the clayey skeletal, kaolinitic, isohyperthermic family of Oxic Dystropepts.
Typifying pedon: Trivandrum gravelly clay-cultivated.

Ap  
0-9 cm: Light reddish brown (5 YR 6/4 D) gravelly clay, yellowish red (5 YR 4/6 M); weak fine granular; loose, friable, sticky and plastic; about 30% by volume irregular 2-15 mm size iron gravels and quartz; few fine fibrous roots; pH 4.5; clear smooth boundary.

A12  
9-25 cm: Reddish yellow (5 YR 6/6 D) gravelly sandy clay, yellowish red (5 YR 4/6 M) moderate medium subangular blocky breaking into fine granular; slightly hard, friable, sticky and plastic; about 30% by volume irregular 2-15 mm size iron gravels and quartz; many fine to medium fibrous roots, many horizontal and oblique tubular macropores; pH 4.5; clear smooth boundary.

B  
25-52 cm: Yellowish brown (10 YR 5/6 M about 50%) dark red (2.5 YR 3/6 M, about 25%) light yellowish brown (10 YR 6/4 M about 10%) gravelly clay; massive; firm sticky and plastic about 60% by volume iron gravels and quartz; very few fine fibrous roots; few tubular discontinuous pores; about 60% soft laterite, diffuse boundary. pH 5.0.

C  
52-84 cm: Variegated colours of blue, white, yellow and dark red massive soft laterite.

Range in characteristics: The thickness of the solum ranges from 45 to 80 cm. The estimated mean annual soil temperature is 28.1°C. MSST is 25.7°C and MWST is 27.9°C. The thickness of the A horizon ranges from 10-20 cm. The colour of A horizon ranges from brown to light reddish brown and reddish brown, hue from 7.5 YR to 5 YR and value 4 to 6. The thickness of the B horizon ranges from 25 to 60 cm. Colour ranges from yellowish red to reddish brown in hue of 5 YR, value from 4 to 5 and chroma from 4 to 8. Texture of A horizon ranges from sandy clay to gravelly clay. The proportion of iron and quartz gravels ranges from 25 to 40 percent. The size of gravel ranges from 5 to 40 mm diameter. The texture of the B horizon is generally gravelly clay with 35 to 60 percent quartz and iron stone gravel of 5 to 50 mm size. Texture in the control section is clayey skeletal with clay percentage ranging between 51.4 and 53.0. The structure ranges from weak fine granular to moderate medium subangular blocky. The C horizon comprises of gravelly clay soils mixed with saprolitic laterite material ranging from 50-80% which is generally of quarrying type.
Competing series and their differentiae: Soils of Pangapara series which are shallow; Vizhinjam series have thicker A horizons.

Drainage and permeability: Well drained, moderate to excessively permeable.

Use and vegetation: Cultivated to Tapioca, Ginger, Coconut, Pepper and cashew. Natural vegetation consists of Eupatorium and grasses.

Distribution and extent: Occurs extensively in Trivandrum, taluk in Kerala.

Type location: Plot No. 9, 1st Block in the Central Tuber Crops Research Institute, Sreekariyam, Trivandrum taluk, Kerala.


Interpretation: The regolith is moderately thick. Trivandrum soils are gravelly and characteristically porous in nature. Their capacity for water intake is good but their available moisture capacity is affected due to their gravelly nature. Garden crops may suffer due to drought during March-May if the premonsoon showers are delayed. Short spells of delayed rain during monsoon may also affect the field crops adversely. They will respond to management but they will pose the problem of phosphate fixation. They will respond to potassic fertilisers.

Management interpretation:

a) Inductive (Based on physical productive potential of the soil)
   1. Land capability sub-class : IIs
   2. Land irrigability sub-class : 3s
   3. Fertility Management potential : Moderately high
   4. Management potential/productivity: Moderately high

b) Quantitative: (Management potential to grow crops based on the information from Soil Survey Officer, Directorate of Agriculture, Trivandrum)
<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level of management</th>
<th>Package of practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut</td>
<td>Unirri./irrig. 7000 hectares</td>
<td>10,000 14,000</td>
</tr>
<tr>
<td>Tapioca</td>
<td>5 metric tons</td>
<td>12 metric tons</td>
</tr>
<tr>
<td>Cashew</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pepper</td>
<td>400 kg/ha -</td>
<td>650 kg/ha -</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by Dr. P. Krishman

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Size class and particle diameter (mm), % of &lt;2 mm</th>
<th>Coarse fragments &gt;2 mm weight of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Sand (2-0.05)</td>
</tr>
<tr>
<td>Ap</td>
<td>0-9</td>
<td>38.5</td>
<td>9.9</td>
</tr>
<tr>
<td>Al2</td>
<td>9-25</td>
<td>39.9</td>
<td>8.7</td>
</tr>
<tr>
<td>B</td>
<td>25-52</td>
<td>37.9</td>
<td>9.1</td>
</tr>
<tr>
<td>C</td>
<td>52-84</td>
<td>34.1</td>
<td>13.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>pH (1:2.5) KCl</th>
<th>pH (1:2.5) H2O</th>
<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>CEC sum cations</th>
<th>N40Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>1.39</td>
<td>3.8</td>
<td>4.5</td>
<td>1.65</td>
<td>0.41</td>
<td>0.04</td>
<td>0.21</td>
</tr>
<tr>
<td>9-25</td>
<td>1.11</td>
<td>3.8</td>
<td>4.5</td>
<td>0.99</td>
<td>0.16</td>
<td>0.03</td>
<td>0.15</td>
</tr>
<tr>
<td>25-52</td>
<td>0.41</td>
<td>3.9</td>
<td>4.8</td>
<td>0.47</td>
<td>0.19</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>52-84</td>
<td>0.27</td>
<td>4.0</td>
<td>5.0</td>
<td>0.19</td>
<td>0.13</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied: two from the A horizon, one from the B horizon and one from the C horizon.

Depths: 0-15 cm (1), 10-25 cm (2), 30-45 cm (3) and 60-75 cm (4)

1. Depth: 0-15 cm

Macroscopic characteristics

Yellowish red, gravelly fine textured, weak granular soil material containing many gravels.

Micromorphological characteristics

**Structure**: The soil material is weak, mainly fine, granular to which a few, sometimes intersected elongated voids belong. Other voids: common often irregular short elongated voids, widths up to 1.5 mm most < 0.5 µm lengths generally less than 1 cm and common equant voids, diam. up to 1.5 mm most < 0.5 µm, randomly distributed.

**Groundmass**: The gravelly fine textured soil material includes gravels up to 18 mm in diameter. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, rock fragments and sesquioxidic nodules, which show varying stages of alteration. A large part is strongly altered.

A few coarse organic root fragments are present. The fine material is mainly clay-sized, includes a few particles up to 5 µm and has a weak skel-masepic plasmic fabric.

**Special features**

Associated with voids: Few voids are partly filled with mineral aggregates, consisting of excrements and/or rounded soil fragments.

In the groundmass: Few voids are nearly completely filled with mineral aggregates, consisting of excrements and/or rounded soil fragments.

: The mainly fine granular peds have slight different granular compositions and colours.

: A few papules, remnants of former clay illuviation features, are present.
2. Depth: 10-25 cm

Macroscopic characteristics

Reddish yellow, gravelly fine textured, moderate subangular, soil material containing many gravels.

Micromorphological characteristics

**Structure:** The soil material is moderate medium subangular blocky to which common, often intersected elongated voids belong. Other voids: Common elongated voids, widths up to 1.5 mm, lengths generally less than 1 cm and common equant voids, diam. up to 1.5 mm, randomly distributed.

**Groundmass:** The gravelly fine textured soil material includes gravels up to 18 mm in diameter. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, rockfragments and sesquioxidic nodules, which show varying stages of alteration. A large part is strongly altered. The fine material is mainly clay-sized, includes a few particles up to 5 µm and has a very weak lattisepic plasmic fabric.

**Special features**

Associated with voids: Locally common, well developed argillans sometimes laminated. A part are red coloured. These argillans also sometimes continue in voids in the altered rock fragments.

Ferrans, mangans and argillans are common features in voids in the strongly altered rock fragments.

A few to common voids are partly filled with mineral aggregates, excrements and/or soil fragments.

In the groundmass: Few to common voids are filled with mineral aggregates, mainly excrements.

Locally a few voids are completely filled with pure clay.

A few papules are present.
3. Depth: 30-45 cm.

Macroscopic characteristics

Yellowish red to light reddish brown gravelly fine textured, apedal soil material, containing many gravels.

Micromorphological characteristics

Structure: The soil material is apedal. Other voids can not be determined, the soil material is disturbed during transport.

Groundmass: The gravelly fine textured soil material includes gravels up to 25 mm in diameter. Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration. A large part is strongly altered. The fine material is mainly clay-sized, includes a few particles up to 5 µm and has a very weak laticepic plasmic fabric.

Special features:

Associated with voids: Common well developed argillans, sometimes laminated.

: In voids present in the strongly altered rock fragments often argillans, ferrans and mangans occur.

(More features can not be observed, due to disturbance of the soil during transport)

4. Depth: 60-75 cm

Macroscopic characteristics

Reddish yellow, gravelly fine textured apedal soil material, containing many gravels.

Micromorphological characteristics

Structure: The soil material is apedal and contains few to common elongated and equant voids, widths and diameters reach up to 1.5 m, lengths elongated voids up to a few cm, randomly distributed.

Groundmass: The gravelly, fine textured, soil material includes gravels up to 25 mm in diameter. Size limit coarse/fine material is 5 µm, related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments which show varying stages of alteration. A
large part is strongly altered. The fine material is mainly clay-sized, includes a few particles up to 5 \( \mu m \) and has a very weak lattisepic plasmic fabric.

**Special features:**

*Associated with voids:* Common well developed argillans, sometimes laminated. The colour of the argillans varies from nearly white, via yellow to red. In the fine-grained groundmass they are mainly white to yellow coloured. In the altered rock fragments also red argillans are found.

*In voids:* In voids often in association with argillans, also ferrans and mangans occur. Most are found in the altered rock fragments.

*In the groundmass:* A few voids are partly filled with mineral aggregates, soil fragments and/or excrements. Few voids nearly completely filled with mineral aggregates, excrements and/or soil fragments.

*Few voids filled with pure clay.*
Short micromorphological description

Four thin sections are studied: two from the A horizon, one from the B horizon and one from the C horizon. Depths: 0-15 cm (1), 10-25 cm (2), 30-45 cm (3) and 60-75 cm (4).

- The gravelly fine textured soil material includes grain sizes up to 18 mm in the A horizon (1, 2) and up to 25 mm in the deeper horizons (3, 4). The size limit coarse/fine material is 5 µm; the related distribution: porphyric. The fine material is mainly clay sized, includes a few particles up to 5 µm and has a weak skel-masepic plasmic fabric in the first 15 cm and a very weak lattisepic plasmic fabric deeper in the pedon. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration. A large part is strongly altered. In the A horizon, large sesquioxidic nodules are also present and a few coarse organic root fragments.

- The soil material is weak fine granular in the top part of the A horizon (1), moderate medium subangular blocky in the rest of the A horizon (2) and apedal deeper in the pedon (3, 4). To the structure in the A horizon belong a few (1) and common (2) elongated, often interconnected voids. Other voids present are common elongated and equant voids, widths and diameters up to 1.5 mm, lengths of elongated voids generally less than 1 cm in the A and B horizons, decreasing to few common voids of the same measurements in the studied C horizon, all randomly distributed.

- In the whole studied zone voids are partly or completely filled with mineral aggregates, excrements as well as soil fragments. In the first 15 cm, a few of these voids occur; in the lower part of the A horizon and the top of the B horizon, there is a maximum of few to common. Deeper in the B horizon only a few are present.

- Argillans are present from a depth of 15 cm onwards. They occur in the groundmass as well as in voids in the strongly altered rock fragments. Their colour varies from nearly white and yellow to red. In the lower part of the A horizon (2) they are locally common, deeper they are common and well-developed. Below the A horizon, they are often associated with thin ferrans or mangans. In the same zone, from 15 cm depth onwards, a few voids completely filled with pure clay occur. A few papules are present in the A horizon (1, 2).

- The fine granular peds present in the first 15 cm have slightly different granular compositions and colours.
1. Well-developed argillans with a dark coloured thin neosesquai in small voids (white) near a strongly altered rock fragment. A horizon (plain light).

Interpretation of the micromorphological data

Trivandrum

Four thin sections are studied: two from the A horizon, one from the B horizon and one from the C horizon.

Depths: 0-15 cm (1), 10-25 cm (2), 30-45 cm (3) and 60-75 cm (4).

Many features present in the studied pedon are inherited from former soil forming processes. A strong weathering of rock has occurred. Clay is formed and illuviated, iron is released and mainly accumulated in rock fragments and nodules. Clay illuviation features are present in the whole studied pedon. In the first 15 cm only papules occur. From that depth onwards argillans are present. They occur in the groundmass as well as in voids in the strongly altered rock fragments and contain varying quantities of iron, which is reflected in their colours. The colours vary from nearly white and yellow to red. In the studied B and C horizons, argillans are common and also a few voids filled with pure clay.

Iron accumulations are present in the A horizon as large sesquioxidic nodules. In this zone and deeper, iron is also present in large, strongly altered rock fragments and as ferrans in voids, often alternating with argillans.

Current processes are restricted. Some of the voids are formed by physical processes. The flora and fauna play a minor role. They produce the majority of the current voids. Some of the voids are partly or completely filled with excrements and/or soil aggregates, with a maximum (few to common) in the lower part of the A (2) and upper part of the B horizon (3). The papules present in the A horizon are fragmented and incorporated mainly as a result of faunal activity.

Due to levelling, the top layer (0-15 cm) has a heterogeneous character. The peds are derived from different horizons and have slightly different granular compositions and colours. The weak granular structure in this zone is due to management practices.

Remark: In micromorphology no rules are set to make a distinction between a saprolite, a laterite and argillic horizons. In this case no statement can be given.
KUNNAMANGALAM SERIES

1. General information and typifying pedon description


Date of study: 13.3.79.

Kunnamangalam series comprises well drained, very deep, gravelly sandy loam to clayey soils of reddish brown to red and dark red colours. They have developed on laterites in the humid tropical parts of Kerala. Kunnamangalam soils occur on very gently to gently sloping dissected laterite plateau with 2 to 5 percent slopes. The climate is humid tropical with mean annual air temperature of 27.3°C and mean annual rainfall of 3282.7 mm. Principal associated soils are Kalarikunnu series which are iron rich soils occurring on undulating upper pediment and Morrikara series occurring on buried pediments and having thick gravelly B3 horizon.

Kunnamangalam series is a member of clayey skeletal kaolinitic, isohyperthermic, family of Ustoxic Dystropepts.
Typifying pedon: Kunnamangalam gravelly clay loam - cultivated.

A1 9-13 cm: Yellowish red (5 YR 4/6 D) and red (2.5 YR 4/6 moist) gravelly sandy clay loam; weak fine granular; hard, friable, non sticky non plastic; iron stones and quartz about 50% by volume; many medium roots; many fine vertical discontinuous pores; pH 5.4; clear smooth boundary.

A12 13-43 cm: Yellowish red (5 YR 4/6 D) gravelly clay and dark red (2.5 YR 3/6 M); weak fine sub-angular blocky breaking to weak fine granular; hard, firm, sticky and plastic; iron and manganese concretions of more than 2 mm size about 5% by volume; iron stone, quartz and feldspar gravels about 50% by volume; common fine roots; many fine simple tubular vertical discontinuous pores; krotovinas about 1 to 4 cm in diameter; pH 5.4; clear wavy boundary.

B11 43-84 cm: Red (2.5 YR 4/6 D) and dark red (2.5 YR 3/6 M) gravelly clay; moderate medium sub-angular blocky; hard, firm, sticky and plastic; iron and manganese concretions of more than 2 mm size about 5% by volume; iron stones, quartz and feldspar gravels of 5 to 25 mm about 30-40% by volume; many fine vertical discontinuous pores; krotovinas about 1 to 4 cm diameter; pH 5.6; clear wavy boundary.

B12 84-116 cm: Red (2.5 YR 5/6 D) and red (2.5 YR 4/6 M) gravelly clay; weak medium sub-angular blocky breaking to fine granular; hard, firm, sticky and plastic; iron stones and quartz gravel of 5-20 mm about 50 to 65% by volume; vesicular holes of medium size; pH 5.8; clear smooth boundary.

B13 116-154 cm: Red (2.5 YR 5/8 D) and red (2.5 YR 4/8 M) gravelly clay; weak medium sub-angular blocky breaking to fine granular; very hard, firm, sticky and plastic; iron stones quartz gravel of 3 to 30 mm about 40% by volume; vesicular holes; pH 5.6; gradual smooth boundary.

C 154-172 cm: Red (2.5 YR 5/8 D) gravelly clay mixed with saprolitic material red (2.5 YR 4/8 moist); moderate medium sub-angular blocky; slightly hard, firm, sticky and plastic; iron stones and quartz gravel of 5 to 30 mm about 25% by volume; laterised saprolitic material about 50-55% by volume; pH 5.7.
Range in characteristics: The depth of solum ranges from 90-180 cm. The estimated mean annual soil temperature at 50 cm depth is 28.3°C, the mean summer soil temperature is 25.5°C and mean winter soil temperature is 27.1°C. The thickness of A horizon ranges from 10 to 20 cm. The colour of A horizon ranges from reddish brown to yellowish red and dark red in 5 YR and 2.5 YR 4 to 5 value and 4 to 6 chroma. The thickness of B horizon ranges from 70 to 120 cm. Colour ranges from red to dark red to yellowish red and strong brown in 2.5 YR to 7.5 YR hue 4 to 5 value and 6 to 8 chroma. The texture of A horizon ranges from gravelly loam to gravelly clay loam. The proportion of iron and manganese concretions range from 2 to 5 percent while the quartz, feldspar and iron stones range from 50 to 70%. The size of gravel ranges from 5 to 50 mm diameter.

The texture of B horizon is gravelly clay with 40 to 50% quartz, feldspar and iron stone gravel of 5 to 30 mm size and iron and manganese concretions of 2 to 5 mm size from 2 to 10%.

The structure ranges from weak to moderate medium sub-angular blocky. Common to many discontinuous vertical pores are observed throughout B horizon.

C horizon comprises of gravelly clay soils mixed with saprolitic lateritic material ranging from 50-80 percent. Laterite of varying composition, strength and varigated colour is met with at more than two meter depth in most cases. It is found to occur at 180 cm depth at lower slopes. The texture in the control section is clayey with clay percentage between 44 to 46.

Competing series and their differentiae: Nenmanda series are darker in colour, coarse loamy in control section with bouldery to cobly grades of coarse fragments in the sub soil.

Drainage and permeability: These soils are well drained with moderate permeability.

Use and vegetation: Under coconut cultivation with inter crops of tapioca. Natural vegetation consists of Teak (Tectona grandis), Vata (Macarange indica) as trees and Euphoratorium and Cynodon as grasses.
Distribution and extent: Occurs in the districts of Calicut, Kerala.

Type location: Field no. Village Kunnamangalam, Tehsil and District, Calicut, Kerala.


Interpretation: The Kunnamangalam soils are extensive and are important garden land soils. Due to the physiographic position they have run off losses of rain water. They are good in the water intake capacity but their available moisture capacity is affected due to their gravelly nature. These soils suffer to drought when there is considerable gap during successive rainy seasons. They are dry during the dry season before monsoon rains start. Garden crops suffer due to delays in pre-monsoon showers during March-May. Checking run off to help conserve moisture and recharging the ground water is necessary to avoid moisture stress on garden crops on these soils.

Management interpretation:

a) Inductive (Based on physical productive potential of the soil)
   1. Land capability sub-class : IIIIs
   2. Land irrigability sub-class : 3s
   3. Fertility management potential : moderately high

b) Quantitative: (Management potential for growing crops under farmer's level and package of practices).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level unirrigated</th>
<th>Farmer's level irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nuts/ha</td>
<td>M.tons/ha</td>
</tr>
<tr>
<td>Coconut</td>
<td>8000</td>
<td>12000</td>
</tr>
<tr>
<td>Tapioca</td>
<td>4. M.tons./ha</td>
<td>-</td>
</tr>
<tr>
<td>Pepper</td>
<td>500 kg/ha</td>
<td>-</td>
</tr>
<tr>
<td>Rubber</td>
<td>600 kg/ha</td>
<td>-</td>
</tr>
<tr>
<td>Cashew</td>
<td>1.5 to 2 Q/ha</td>
<td>-</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>pH (1:1 KCl)</th>
<th>pH (1:1 H₂O)</th>
<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>meq/100 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>1.63</td>
<td>4.4</td>
<td>5.4</td>
<td>0.56</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12</td>
<td>13-43</td>
<td>0.70</td>
<td>4.3</td>
<td>5.4</td>
<td>0.82</td>
<td>0.32</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B11</td>
<td>43-84</td>
<td>0.66</td>
<td>4.7</td>
<td>5.6</td>
<td>1.58</td>
<td>0.48</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B12</td>
<td>84-116</td>
<td>0.41</td>
<td>5.0</td>
<td>5.8</td>
<td>1.27</td>
<td>0.41</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A13</td>
<td>116-154</td>
<td>0.28</td>
<td>5.1</td>
<td>5.6</td>
<td>1.13</td>
<td>0.62</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>154-172</td>
<td>0.19</td>
<td>5.6</td>
<td>5.7</td>
<td>0.96</td>
<td>0.51</td>
<td>0.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>pH (1:1 KCl)</th>
<th>pH (1:1 H₂O)</th>
<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Coarse fragments</th>
<th>&gt; 2 nm % by weight of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>1.63</td>
<td>4.4</td>
<td>5.4</td>
<td>27.6</td>
<td>18.0</td>
<td>9.5</td>
<td>13.9</td>
<td>17.2</td>
</tr>
<tr>
<td>A12</td>
<td>13-43</td>
<td>0.70</td>
<td>4.3</td>
<td>5.4</td>
<td>46.2</td>
<td>19.3</td>
<td>7.4</td>
<td>8.1</td>
<td>5.7</td>
</tr>
<tr>
<td>B11</td>
<td>43-84</td>
<td>0.66</td>
<td>4.7</td>
<td>5.6</td>
<td>46.1</td>
<td>16.6</td>
<td>7.7</td>
<td>7.9</td>
<td>7.2</td>
</tr>
<tr>
<td>B12</td>
<td>84-116</td>
<td>0.41</td>
<td>5.0</td>
<td>5.8</td>
<td>46.0</td>
<td>14.3</td>
<td>9.3</td>
<td>7.8</td>
<td>6.7</td>
</tr>
<tr>
<td>B13</td>
<td>116-154</td>
<td>0.28</td>
<td>5.1</td>
<td>5.6</td>
<td>45.4</td>
<td>15.1</td>
<td>6.7</td>
<td>7.3</td>
<td>6.4</td>
</tr>
<tr>
<td>C</td>
<td>154-172</td>
<td>0.19</td>
<td>5.6</td>
<td>5.7</td>
<td>42.6</td>
<td>8.1</td>
<td>8.2</td>
<td>9.5</td>
<td>7.3</td>
</tr>
</tbody>
</table>
3. Micromorphological data

One thin section from the transition of the A and B horizon is studied. Depth: 38-51 cm.

1. Depth 38-51 cm.

Macroscopic characteristics

Red, fine textured, pedal soil material containing many dark red nodules, diameters up to 11 mm.

Micromorphological characteristics

Structure: Weak medium sub-angular blocky structure, to which a few, sometimes interconnected, elongated voids belong. Other voids: Few elongated voids, widths up to 3 mm, less than a few cm long and common equant voids, diam. up to 3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 11 mm. Size limit coarse/fine material: 15 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration. Few coarse organic fragments of roots. The fine material is largely clay-sized and includes a few particles up to 15 µm. The fine material is almost isotropic.

Special features:

Associated with voids: Common voids partly filled with mineral aggregates, mainly excrements but also soil aggregates, nodules, rock fragments, etc. These voids are often interconnected.

: In some voids with root remnants occur organic and mineral excrements, partly filling the voids.

: Locally common red coloured argillans.

In the groundmass:

: Common voids, nearly completely filled with mineral, aggregates, mainly excrements, but also soil aggregates, nodules, rock fragments, etc. These voids are often interconnected.

: Locally common red coloured papules mainly present in excrements.

: Common sesquioxidic nodules, containing some mineral grains and/or rock fragments and/or clay-rich material. These nodules are rather rounded and have dark red colours, diam up to 11 mm, randomly distributed.

: Few rather rounded strongly altered rock fragments, randomly distributed.
Kunnamangalam (2 photographs)

1. Laminated infilling of pure clay (centre).
   B horizon (plain light)

2. Ellipsoidal organic excrements in root remains.
   B horizon (plain light)
4. Interpretation of the micromorphological data

One thin section from the transition of the A and B horizon is studied.
Depth: 38-51 cm.

- The soil material, a gravelly clay, present in the studied zone is a colluvium. The gravels are common sesquioxidic nodules including mineral grains, clay-rich materials as well as rock fragments and a number of single strongly altered rock fragments, up to 11 mm in diameter. They are rounded off fragments of laterites, which are transported and deposited in clay-rich material.

- In this soil material rather strong clay illuviation has occurred of which locally argillans and clay infillings are common present. No evidence of current clay illuviation is traced in the studied zone.

- Of the voids present, a few are caused by physical processes and form part of the structure. The common voids are due to flora and fauna.

- The soil fauna has homogenized the largest part of the groundmass between the gravels, including clay-illuviation features. Remnants of argillans and clay infillings occur as papules in excrements which partly or almost completely fill interconnected void systems.

- Weathering of minerals and rock fragments is still occurring.

Conclusion: The Kunnamangalam pedon studied, is a real alfisol in which clay-illuviation features currently are disappearing due to animal activity resulting in homogenization. As only one thin section is studied the extent of homogenization in the B horizon cannot be given. The present number of clay-illuviation features in the transition of A to B horizon is sufficient for classification as an alfisol.

Remark: The soil temperature data given are not correct.
1. General information and typifying pedon description

Pedon described by the core group members consisting of N.K. Barde, M. Jayaraman and H.S. Shankaranarayana. P.S. Anjaneya Reddy and Kandakumar associated. Date of study: 12.7.79.

Palathurai series comprises deep, well drained, reddish brown to dark reddish brown, calcareous soils developed on gneisses. They occur on very gently sloping to undulating upper and middle pediments with slope gradient of 1 to 3 percent. The climate is semi-arid sub tropical with mean annual air temperature of 26.5°C and average annual rainfall of 574 mm in 42.9 rainy days with about 50 percent distributed during Kharif and Rabi season each. The principal associated soils are Coimbatore which are Vertic Ustochrepts and Salem series which are Udic Haplustalfs respectively.

Palathurai series is a member of the fine loamy, mixed isohyperthermic family of Typic Haplustalfs.
Typifying pedon: Palathurai sandy loam – cultivated.

Ap 0-12 cm: Reddish brown (5 YR 4/3 D) sandy loam, dark reddish brown (5 YR 3/3 M); weak fine granular; loose, very friable, slightly sticky; few fine inped roots; strongly effervescent; pH 8.4; clear smooth boundary.

B2lt 12-39 cm: Dark reddish brown (5 YR 3/2 M) sandy clay loam; moderate medium sub-angular blocky breaking to medium weak granular; friable, slightly sticky and slightly plastic; few thin patchy discontinuous cutans; many, fine to very fine tubular dendritic and open inped pores; many very fine inped roots; slightly effervescent; pH 8.3; gradual smooth boundary.

B22t 39-57 cm: Dark reddish brown (5 YR 3/2 M) sandy clay loam, dark reddish brown (5 YR 3/3r); moderate coarse sub-angular blocky breaking to medium moderate granular; firm, sticky and plastic; common thin patchy discontinuous cutans; few 5-10 mm size irregular lime nodules; about 7-10 by volume 2-10 mm size weathered parent material fragments; many fine to very fine tubular dendritic open inped pores; few very fine inped roots; slightly effervescent; pH 8.6; clear and smooth boundary.

Caca 57-68 cm: Weathered parent material mixed with lime nodules and very small proportion of sandy clay loam soil some weathered parent material pieces coated with lime; violently effervescent; very few very fine inped roots.

C2 68-136 cm: Weathered parent rock.

Range in characteristics: The depth of solum ranges from 60 to 80 cm.

The estimated mean annual soil temperature is 27.4°C. The mean summer and winter soil temperature are 25.4°C and 25.9°C respectively. The moisture regime is ustic.

The thickness of the Ap horizon ranges from 10-15 cm. The colour ranges from reddish brown to yellowish red in 5 YR hue, 4 to 5 value and 3 to 6 chroma. The texture ranges from loamy sand to sandy loam and gravelly sandy loam. Structure ranges from weak fine granular to weak fine sub-angular blocky breaking to weak fine granular, The surface horizon may be non calcareous to very slightly calcareous.
The thickness of B21t horizon ranges from 25 to 35 cm. The colour ranges from dark reddish brown to reddish brown in 5 YR and 2.5 YR hue 3 to 4 value and 2 to 4 chroma. The texture ranges from sandy clay loam to loam. Structure is moderate medium sub-angular blocky to weak medium sub-angular blocky breaking into medium weak granular.

The thickness of B22t horizon ranges from 18 to 30 cm. The colour ranges from dark reddish brown to very dark reddish brown in 5 YR and 2.5 YR hue. Texture ranges from sandy clay to gravelly clay. The proportion of lime nodules varies from 5 to 15%. Small fragments of weathered parent material coated with lime are encountered in this horizon.

The content of clay percentage in the control section ranges from 20.9 to 22.9.

Competing series and their differentiae: Chikarasam soils are clay loam to clay in the control section but dark brown to brown in 10 YR hue.

Drainage and permeability: Well drained with moderate permeability.

Natural vegetation and land use: Neem (Azadirachta indica); Tamarind (Tamarindus indica); Jali (Acacia arabica); Bellary Jali (Prosopis juliflora) and Toddy Palm (Borassus flabellifer); cultivated to Horsegram (Dolichos biflorus) and Sorghum (Sorghum bicolor).

Distribution and extent: Very extensive in Coimbatore, Salem and Dharmpuri districts of Tamil Nadu.

Type location: 100 m north-west of Kumarpalyam village Palathurai-Kumarpalyam road (3 km from Palathurai).

Series proposed: All India Soil and Land Use Survey, Bangalore.

Interpretation:

a) Inductive (based on physical productive potential).

1. Land capability sub-class : IVs
2. Land irrigability sub-class : 3
3. Fertility management potential : moderately low
2. Tentative soil characterisation by Dr. P. Krishnan

| Horizon | Depth (cm) | Total | Coarse fragments
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>INT I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>INT (2-0.05)</td>
<td>INT (0.05-0.002)</td>
</tr>
<tr>
<td>Ap</td>
<td>0-12</td>
<td>75.9</td>
<td>10.6</td>
</tr>
<tr>
<td>B21t</td>
<td>12-39</td>
<td>67.0</td>
<td>12.1</td>
</tr>
<tr>
<td>B22t</td>
<td>30-57</td>
<td>66.4</td>
<td>12.7</td>
</tr>
<tr>
<td>Clca</td>
<td>57-68</td>
<td>66.4</td>
<td>14.1</td>
</tr>
<tr>
<td>C2ca</td>
<td>68-136+</td>
<td>66.7</td>
<td>18.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon as Caco₃</th>
<th>Carbonate as Caco₃</th>
<th>Ext. carbonate as Caco₃</th>
<th>pH (1:2.5)</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-12</td>
<td>0.66</td>
<td>&lt;2 mm</td>
<td>&lt;0.002 mm</td>
<td>2.06</td>
<td>8.4</td>
</tr>
<tr>
<td>12-39</td>
<td>0.74</td>
<td>1.61</td>
<td>8.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39-57</td>
<td>0.81</td>
<td>2.14</td>
<td>8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57-68</td>
<td>0.73</td>
<td>12.43</td>
<td>8.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>68-136+</td>
<td>0.33</td>
<td>12.74</td>
<td>8.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied covering the A, B and Cca horizons. Depths: 2-17 cm (1), 20-35 cm (2), 40-55 cm (3) and 57-72 cm (4).

1. Depth: 2-17 cm.

Macroscopic characteristics

Reddish brown/dark reddish (last 4 cm) coarse textured, weak pedal soil material containing a few light coloured gravels up to 4 mm in diameter.

Micromorphological characteristics

Structure: Weak medium sub-angular blocky, to which a few, sometimes interconnected, elongated voids belong. Other voids: A very few elongated voids, most less than 1 mm wide, less than 5 mm long and a very few equant voids most less than 1 mm in diameter, randomly distributed.

Groundmass: The coarse textured soil material includes grain sizes up to gravels of 4 mm in diameter. Size limit coarse/fine material: 10 µm.

Related distribution: mainly gefu-chitonic. The coarse material consists of a variety of minerals and rock fragments, of which a part show varying stages of alteration. The fine material is largely clay sized, includes a few particles up to 10 µm and has a weak skelsepic plasmic fabric.

Special features:

Associated with voids: A very few voids contain some mineral material, which are fragments of the groundmass.

In the groundmass: A few voids are nearly completely infilled with mineral aggregates, derived from the groundmass.

: A few voids are partly infilled with mainly mineral excrements.

: In a few packing voids carbonate particles are present. Also a few carbonate nodules occur.

2. Depth: 20-35 cm.

Macroscopic characteristics

Dark reddish brown, medium textured, weak pedal soil material containing a few light coloured gravels up to 4 mm in diameter.
Micromorphological characteristics

Structure: Weak medium sub-angular blocky, to which a few, sometimes interconnected elongated voids belong. Other voids: A few elongated voids, most less than 4 mm wide, less than a few cm long and a few equant voids, most diameters less than 4 mm, randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 4 mm in diameter. Size limit coarse/fine material: 10 \( \mu \text{m} \). Related distribution: mainly porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 10 \( \mu \text{m} \) and has a weak skelsepic plasmic fabric.

Special features:

Associated with voids: A few voids contain some mineral aggregates, which can be either fragments of the groundmass or excrements.

Associated with voids: A few voids, whether or not infilled with mineral aggregates, have, often layered, coatings of mainly fine-grained mineral material.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, which mainly are shaped excrements. Excrements of a few different sizes, shapes and compositions occur.

In the groundmass: A few striotubules, diameter 2 à 3 mm.

In the groundmass: A few accumulations of calcium carbonate particles.

3. Depth: 40-55 cm.

Macroscopic characteristics

Dark reddish brown, medium textured, weak pedal soil material containing few to common light coloured gravels up to 4 mm in diameter.

Micromorphological characteristics

Structure: Weak coarse sub-angular blocky structure, to which a few, sometimes interconnected, elongated voids belong. Other voids: Few to common elongated and equant voids, diameters up to 4 mm; lengths of elongated voids up to a few cm; randomly distributed.
Groundmass: The medium textured soil material includes grain sizes up to gravels of 4 mm in diameter. Size limit coarse/fine material: 10 μm.
Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 10 μm and has a very weak skelsepic plasmic fabric.

Special features:
Associated with voids: A few voids contain some mineral aggregates, which mainly are shaped excrements.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, which mainly are shaped excrements. These voids are often irregular and interconnected. Excrements of a few different sizes, shapes and compositions occur.

: A very few striotubules, diameter 2 à 3 mm occur.

4. Depth: 57-72 cm.

Macroscopic characteristics

Reddish brown, coarse textured, apedal soil material containing many light coloured gravels and large rock fragments up to 2 cm in diameter.

Micromorphological characteristics

Structure: Apedal soil material. Voids: A few elongated and equant voids, diameters up to 9 mm, most less than 4 mm; length of elongated voids less than a few cm. Randomly distributed.

Groundmass: The coarse textured soil material includes grain sizes up to gravels of 20 mm in diameter. Size limit coarse/fine material: 10 μm.
Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, including carbonates, of which a part show varying stages of alteration. The fine material is largely clay-sized, includes common particles up to 10 μm of which a part are carbonates.

Special features:
Associated with voids: A few voids contain some mineral aggregates which mainly are shaped excrements.

: Commonly in voids, also between shaped excrements, coatings of small carbonate crystals, often needle-shaped, occur.
In the groundmass: Common voids, nearly completely infilled with mineral aggregates, which mainly are shaped excrements. These voids are often irregular, occur between larger rock fragments and are often interconnected. Excrements are of a few different sizes, shapes and compositions.

: Common carbonate nodules composed of small $< 10 \mu m$ or larger up to $200 \mu m$ carbonate crystals. Also in voids between individual minerals in rock fragments carbonates can be present. Around large rock fragments sometimes coatings of carbonate particles, including some clay-sized soil material, are present.

Short micromorphological description

Four thin sections are studied covering the A, B and C horizons. Depths: 2-17 cm (1), 20-35 cm (2) 40-55 cm (3) and 57-72 cm (4).

The soil material is coarse (1, 4) and medium (2, 3) textured and includes grain sizes up to gravels of 4 mm in the A and B horizon (1, 2, 3) and weathering rock fragments containing carbonates up to 2 cm in the Cca horizon (4). The size limit coarse/fine material is $10 \mu m$; the related distribution mainly gefu-chitonic in the Ap horizon (1) and porphyric in the other horizons (2, 3, 4). The fine material is largely clay sized and contains a few fine particles up to $10 \mu m$ in the A and B horizons (1, 2, 3) and common particles of which a part are carbonates in the Cca horizon (4). The fine material has a weak skelsepic plasmic fabric in the Ap (1) and B21 (2) horizon and a very weak skelsepic plasmic fabric in the B22 (3) horizon. The coarse material consists of a variety of minerals and rock fragments of which a part show varying stages of alteration. In the Cca horizon (4) also carbonates occur.

The soil material has a weak medium sub-angular blocky structure in the Ap (1) and B21 (2) horizon, a weak coarse sub-angular blocky structure in the B22 (3) horizon and is apedal in the Cca (4) horizon. To the structure belong, in all cases, a few, sometimes interconnected, elongated voids. Other voids present increase in quantity from a very few elongated and equant voids in the Ap horizon (1) to few to common in the B22 horizon (3), diameters generally less than 4 mm, lengths of elongated voids up to a few cm. In the Cca horizon a few elongated and equant voids occur, diameters up to 9 mm, most less than 4 mm, length of elongated voids up to a
few cm. All other voids are randomly distributed.

Over the whole studied depth, voids occur which are partly or nearly completely filled with mineral aggregates. In the Ap horizon (1) these mineral aggregates are nearly all fragments of the groundmass; in the B21 horizon (2) fragments of the groundmass, as well as excrements occur, while in the deeper studied horizons (3, 4) nearly only excrements are present. Excrements are of a few different sizes, shapes and compositions. The number of partly infilled voids is low: a very few in the Ap (1) horizon and a few in the other zones (2, 3, 4). The number of nearly completely infilled voids is higher and increases from a few in the Ap (1) horizon to common in the B and Cca horizon (2, 3, 4). The nearly completely infilled voids become more irregular and interconnected with depth. In the B horizon a few voids, whether or not infilled with mineral aggregates, have, often layered, coatings of mainly fine-grained mineral material. In the B horizon also a few striotubules with diameters between 2-3 mm are found.

In the Ap horizon (1) and upper part of the B horizon (2) a few accumulations of carbonates are observed. In the Cca horizon carbonate nodules are common. Carbonates are also present in voids between individual minerals in rock fragments, as coatings around rock fragments, as coatings of needle-shaped carbonates in voids, and as individual small crystals in the groundmass.

1. Gefu-chitonic c/f related distribution. Open packing due to cultivation practices; A horizon (plain light).
(3 photographs)

2. Void infilled with shaped, welded mineral excrements; B horizon (plain light).

3. Void (black) partly infilled with shaped mineral excrements. In and along the void wall carbonate precipitations; C horizon (crossed polarizers).
4. Interpretation of the micromorphological data

Four thin sections are studied: covering the A, B and Cca horizons. Depths: 2-17 cm (1), 20-35 cm (2), 40-55 cm (3) and 57-72 cm (4).

- In the B horizon (2, 3) the quantity of fine-grained soil material is higher than in the A horizon (1), which is due to exogenic processes or land use and not a result of clay illuviation. Not any feature due to clay illuviation is observed and no indications of a former or current clay illuviation are present.

- Physical processes do not have a large influence. The B horizon has a weak developed sub-angular blocky structure and around larger mineral grains and rock fragments in the A and B horizon some orientation of clay domains is present, resulting in a weak (1, 2) to very weak (3) developed skelsepic plasmic fabric.

- The fauna plays an important role in the B and Cca horizons, which results in an increase of porosity and homogenization of soil material. Most voids present are produced by the fauna. A large number of voids in the B and Cca horizons are more or less infilled with shaped mineral excrements, of a few different species. The few striotubules present in the B horizon are of faunal origin, as well as the coatings of fine-grained soil material occurring in some voids. These coatings can easily be mistaken for argillans in the field. In the Ap horizon hardly any evidence of faunal activity is present.

- The packing of the soil material in the topsoil (1), a gefu-chitonic coarse/fine related distribution, and the few infillings of mineral aggregates derived from the groundmass, present in the Ap (1) and B21 (2) horizons are due to cultivation practises.

- In the Ap and B21 horizons some small carbonate accumulations occur as infilling in packing voids or as nodules. These accumulations are formed in dry periods, when evaporation is high. In the Cca horizon carbonate is present in nodules, as coatings along voidwalls, as individual crystals in the groundmass and in - and around rock fragments. Evidence of solution as well as of precipitation is visible. Precipitation forms dominate.

Conclusion: In the studied pedon of the Palathurai series not any feature due to former or current clay illuviation occurs. Consequently this pedon cannot be classified as an alfisol. On of the results of faunal activity is the coating of voidwalls with fine-grained soil material, which in the field easily can be mistaken for clay-illuviation cutans.
COIMBATORE SERIES

1. General information and typifying pedon description

Pedon described by the core group members consisting of N.K. Barde, M. Jayaraman and H.S. Shankaranarayana. P.S. Anjaneya Reddy and Kandakumar associated. Date of Study: 14-7-79.

Coimbatore series comprises deep, moderately well drained, very dark gray brown to pale brown, calcareous soils developed on clayey alluvium of calcic gneisses origin. The occur on very gently sloping to level interfluve plains with slope gradient 0-2 percent. The soils crack during summer. The climate of the area is semi-arid sub-tropical with mean annual air temperature of 26.5°C and average annual rainfall of 574 mm received in 42.9 rainy days with about 50% distribution during Kharif and Rabi season each. Principal associated soils comprises of Palathurai and Salem series which are member of the Typic Haplustalfs and Udic Haplustalfs, respectively. Coimbatore series is a member of the clayey, montmorillonitic, isohyperthermic, family of Vertic Utropepts.
Typifying pedon: Coimbatore clay-cultivated.

**Ap 0-15 cm:** Dark gray brown (10YR 4/2 D) clay, gray brown (10YR 5/2 M) moderate fine to coarse granular; loose, friable, sticky and plastic; very few irregular lime nodules of 2 to 5 mm size; slightly effervescent; very few fine inped roots; pH 8.7; clear smooth boundary.

**B2 15-42 cm:** Very dark gray brown (10YR 3/2 D & M) clay; strong coarse prismatic breaking into angular blocky; very hard, firm, very sticky and plastic; few (about 2%) coarse fragments and few (about 3%) spherical and sub-rounded lime nodules of 2 to 10 mm size; prominent pressure faces; strongly effervescent; few fine inped roots; many discontinuous micro exped pores; pH 8.8; clear smooth boundary.

**B3 42-75 cm:** Yellowish brown (10YR 5/4 D) clay; dark yellowish brown (10YR 4/4 M) 80% and very dark grayish brown (10YR 3/2 M) moderate coarse prismatic and sub-angular blocky; slightly hard, friable, sticky and plastic; few coarse fragments (1-2%) of 1 to 2 mm size and spherical and sub-rounded lime nodules of 2-10 mm size; violently effervescent; common medium and coarse inped and exped roots; many discontinuous micro exped and inped pores; pH 8.5; clear wavy boundary.

**Cca 75-124+ cm:** Very pale brown (10YR 6/4), dark yellowish brown (10YR 4/4), very pale brown (10YR 7/3) brown (10YR 5/3 D), very dark gray brown (10YR 3/2 M) white (10YR 8/1 M) and brown 10YR 5/3 (moist rubbed). Clayey; moderate coarse prismatic and sub-angular blocky; slightly hard friable, sticky and plastic; few (10%) spherical and sub-rounded lime nodules of 2-10 mm size; violently effervescent; many fine inped roots; pH 8.5.

**Range in characteristics:** The depth of solum ranges from 70 to 90 cm. The estimated mean annual soil temperature is 27.4°C. The mean summer soil temperature is 25.4°C and the mean winter temperature is 25.9°C. Moisture regime is ustic. The thickness of Ap horizon ranges from 10 to 25 cm depending upon the surface sheet erosion. The colour of Ap horizon is in shades of 10YR hue value 3 to 5 and chroma 2 to 4. The texture ranges from clay loam to clay, lime nodules 2 to 5 mm size occur in Ap horizon. In eroded areas, however, the proportion of the nodules on the surface is more. The structure is always coarse to fine granular.
The thickness of B2 horizon ranges from 25 to 40 cm. The colour ranges from very dark gray brown to dark grayish brown and in 10YR hue, 3-4 value and 2 to 3 chroma. The texture is invariably clay. The structure is strong, coarse to medium angular blocky to prismatic. There are prominent pressure faces below 40 cm depth. Lime nodules range from 1 to 5 percent.

The thickness of B3 horizon ranges from 25 to 35 cm. The colour of B3 horizon ranges from dark yellowish brown to yellowish brown and dark grayish brown in 10YR hue, 4 to 5 value and 2 to 4 chroma. Texture ranges from silty clay to clay. Pressure faces are prominent. The structure is dominantly sub-angular blocky when moist and grades to prismatic when semi dry.

The depth of Cca horizon ranges from 40 to 60 cm. The colours are variegated due to changing proportion of lime nodules and other weathered fragments. The colours are generally in 10YR hue with 8 to 5 value and 1 to 4 chroma. The texture is generally clay but occasionally clay loam. Structure is coarse sub-angular blocky in major portion and at places prismatic. The sub-soil is generally moist. The texture of the control section is clayey with clay percent ranging from 40 to 50 percent.

Competing series and their differentiae: Dasarapatti soils are very deep dark gray brown fine Chromusterts with gypsum in control section. Chikkarasam soils are deep yellowish brown, clay loam calcareous Ustochrepts and Peelamedu soils are very deep fine Chromusterts with Petrocalcic horizon.

Drainage and permeability: Imperfectly drained with moderately slow to slow permeability.

Use and vegetation: Cultivated to Jowar, Cotton, Pigeon Pea under rainfed condition and Paddy and Sugarcane under irrigation. Natural vegetation comprises of Acacia and Prosopis species.

Distribution and extent: Very extensive in Coimbatore, Salem and Dharmapuri districts in Tamil Nadu and occupies 2% area in Coimbatore district.

Type location: T.N.A.U. Farm, Coimbatore, T.N.
Series proposed by: All India Soil and Land Use Survey, Bangalore.

Interpretation:

a) Inductive (based on physical productive potential)
   1. Land capability sub-class: IIIIs
   2. Land irrigability sub-class: 2d
   3. Fertility management potential: moderate
   4. Management potential/productivity: moderately low

b) Quantitative (management potential under different levels of management)

Crops: Sorghum, Cotton, Sugarcane.
2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Sand (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&gt;0.002)</th>
<th>Coarse (2-1)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.1)</th>
<th>Very fine (0.1-0.05)</th>
<th>(0.02-0.002)</th>
<th>&lt;0.002</th>
<th>Coarse fragments % of &lt;2 mm % by weight of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-15</td>
<td>40.7</td>
<td>16.3</td>
<td>43.0</td>
<td>1.8</td>
<td>4.4</td>
<td>10.9</td>
<td>17.0</td>
<td>6.6</td>
<td>23.2</td>
<td>22.5</td>
</tr>
<tr>
<td></td>
<td>15-42</td>
<td>32.7</td>
<td>16.2</td>
<td>51.1</td>
<td>1.0</td>
<td>3.0</td>
<td>8.3</td>
<td>14.1</td>
<td>6.3</td>
<td>17.4</td>
<td>17.5</td>
</tr>
<tr>
<td>B3</td>
<td>42-75</td>
<td>23.6</td>
<td>21.7</td>
<td>54.7</td>
<td>0.8</td>
<td>2.2</td>
<td>5.7</td>
<td>9.6</td>
<td>5.3</td>
<td>11.7</td>
<td>15.6</td>
</tr>
<tr>
<td>Cca</td>
<td>75-124</td>
<td>23.1</td>
<td>21.9</td>
<td>55.0</td>
<td>1.1</td>
<td>1.7</td>
<td>5.3</td>
<td>9.3</td>
<td>5.7</td>
<td>11.1</td>
<td>15.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic Carbon %</th>
<th>Carbonate as CaCO₃ %</th>
<th>Ext. iron as Fe %</th>
<th>pH (1:2.5)</th>
<th>H₂O₂ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>0.35</td>
<td>6.91</td>
<td>3.65</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>15-42</td>
<td>0.40</td>
<td>9.14</td>
<td>6.00</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>42-75</td>
<td>0.41</td>
<td>11.71</td>
<td>6.37</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>75-124</td>
<td>0.31</td>
<td>13.76</td>
<td>8.04</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Four thin sections are studied: one derived from the A horizon, two from the B horizon and one from the C horizon.

Depths: 2-17 cm (1), 25-40 cm (2), 50-65 cm (3) and 88-103 cm (4).

1. Depth: 2-17 cm.

Macroscopic characteristics

Greyish brown, fine textured, granular soil material.

Micromorphological characteristics

Structure: The soil material is moderate fine to coarse granular to which common short elongated, intersected voids belong, with locally large intersection nodes. Other voids: few elongated voids, widths up to 1.5 mm, length less than a few cm and a few equant voids, diam. up to 1.5 mm; randomly distributed.

Groundmass: The fine textured soil material includes grain-sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals mainly quartz, which are fresh or slightly altered. The coarse organic matter consists of a few root sections. The fine material is largely clay-sized contains common fine particles up to 5 µm, mainly carbonate and has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Common voids partly filled with mineral aggregates, excrements as well as soil fragments, often including some larger mineral grains.

In the groundmass: Common to many voids and irregular zones completely filled with mineral aggregates, often largely excrements, but include also soil fragments and some mineral grains.

: Few to common, voids mainly filled with mineral grains. The external boundaries are not always clearly to distinguished.

: Common carbonate nodules, diam. up to 3 mm, randomly distributed. A part of these nodules have an accumulation of sesquioxides in the outer zone, mainly manganese.
2. Depth: 25-40 cm.

Macroscopic characteristics

Very dark greyish brown, fine textured, angular blocky, soil material.

Micromorphological characteristics

Structure: The soil material is moderate medium to coarse angular blocky, to which common elongated, intersected, voids belong with locally enlarged intersection nodes. The blocky elements often have an inclined horizontal axis. Other voids: few elongated voids, widths up to 2 mm, length less than a few cm and a few equant voids, diam. up to 2 mm; randomly distributed. Groundmass: The fine textured soil material includes grain-sizes up to gravels of 3 mm in diam. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz, which are fresh or slightly altered. The fine material is largely clay-sized contains common fine particles up to 5 µm, mainly carbonates and has a weak vo-skelsepic plasmic fabric.

Special features:

Associated with voids: Common voids including some large intersection nodes are partly filled with mineral aggregates, excrements as well as soil fragments and include often mineral grains.

In the groundmass: Common voids and irregular zones are completely filled with mineral aggregates, often largely excrements, but include also soil fragments and mineral grains.

: Few to common voids, including some large intersection nodes, diam. up to 10 mm are nearly completely filled with mineral grains. The external boundaries of the voids are not always clearly to distinguish.

: Common carbonate nodules, diam. up to 3 mm, randomly distributed. A part of these nodules have an accumulation of sesquioxides, mainly manganese, in the outer zone.

3. Depth: 50-65 cm.

Macroscopic characteristics

Brown, fine textured, sub-angular blocky soil material.
Micromorphological characteristics

During transport some disturbance of the soil material occurred, resulting in a higher content in small soil fragments, which are also present in the infillings of voids.

Structure: The soil material is moderate medium to coarse sub-angular blocky to which common intersected elongated voids belong. Other voids: Common elongated voids, widths up to 2 mm, most < 0.5 mm, length less than a few cm and common equant voids, up to 2 mm diam. but most are <0.5 mm in diam.; randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz, which are fresh or slightly altered. The fine material consists of clay-sized material which contains many-abundant fine particles up to 5 µm in diam., mainly carbonates and has an asepic plasmic fabric.

Special features:
Associated with voids: Common voids are partly filled with mineral aggregates; excrements as well as soil fragments and include often some mineral grains, carbonate nodules, etc.

: Few voids have thin, often discontinuous neomangans and/or mangans.

In the groundmass: Abundant voids and irregular, often interconnected, zones filled with mineral aggregates, often largely excrements, but includes also soil fragments and mineral grains, carbonate nodules, etc.

: Many carbonate nodules, diam. up to 3 mm; randomly distributed. Most of these nodules are accumulations in the groundmass, with diffuse external boundaries in which the fine grained material only consists of small carbonate particles. The quantity of carbonate nodules with clear/sharp external boundaries is low.

4. Depth: 88-103 cm.

Macroscopic characteristics

Dark yellowish brown, fine textured, sub-angular blocky soil material.
Micromorphological characteristics

Structure: The soil material is moderate medium to coarse sub-angular blocky to which common intersected, elongated voids belong. Other voids: Common elongated voids, widths up to 2 mm, most < 0.5 mm, length less than a few cm and common equant voids up to 2 mm diam., but most < 0.5 mm in diam.; randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz, which are fresh or slightly altered. The fine material consists of clay-sized material which contains abundant fine particles up to 5 µm in diam. mainly carbonates and has an asepicplasmic fabric.

Special features:

Associated with voids: Common voids are partly filled with mineral aggregates, mainly excrements, but include also soil fragments, some mineral grains and carbonate nodules.

- A few voids have a thin, often discontinuous neomangan and/or mangan.

In the groundmass: Abundant voids and irregular, often interconnected, zones filled with mineral aggregates, mainly excrements.

- Abundant carbonate nodules, diam. up to 3 mm, randomly distributed. Most of these nodules are accumulations in the groundmass, with diffuse external boundaries in which the fine grained material only consists of small carbonate particles. The quantity of carbonate nodules with clear/sharp external boundaries is low.

- Few voids are locally filled with gypsum crystals of different diameters.

Short micromorphological description

Four thin sections are studied: one derived from the A horizon, two from the B horizon and one from the C horizon.

 Depths: 2-17 cm (1), 25-40 cm (2), 50-65 cm (3) and 88-103 cm (4)

- The fine-textured soil material includes grain sizes up to gravels of 3 mm in diameter. The size limit coarse/fine material is 5 µm; the related distribution: porphyric. The fine material is largely clay-sized and contains an increasing quantity of fine particles up to 5 µm from common in the A (1) and upper part of the B (2) horizon, via
many in the lower part of the B horizon (3) to abundant in the C horizon (4). The plasmic fabric is moderate skelsepic in the A horizon (1), weak vo-skelsepic in the upper part of the B horizon (2) and apparently asepic deeper in the profile (3,4). The high quantity of carbonate particles hamper proper observations in the latter case. The coarse mineral material consists of a small variety of minerals, mainly quartz, which are fresh or slightly altered. In the A horizon (1) a few coarse organic root fragments are present.

- The soil material is pedal and varies from moderate fine to coarse granular in the A horizon (1), via moderate medium to coarse angular blocky in the upper part of the B horizon (2), to moderate medium to coarse subangular blocky deeper in the pedon (3, 4). In all cases, common elongated, intersected voids with locally large intersection nodes in the A and upper part of the B horizon belong to the structure. A few other elongated and equant voids occur in the A and upper part of the B horizon; common elongated and equant voids occur deeper in the pedon (3, 4). Their widths and diameters reach up to 2 mm, lengths less than a few cm, randomly distributed. In the lower part of the B horizon (3) and in the studied zone of the C horizon (4) most widths and diameters are less than 0.5 mm.

- In the whole studied zone voids and irregular zones occur which are partly or completely filled with soil aggregates; excrements, soil fragments and often some mineral grains. Over the whole studied zone voids commonly are partly infilled. The quantity of completely filled voids varies from common to many in the A horizon (1), via common in the upper part of the B horizon (2) to abundant in the deeper studied zones (3, 4). In the C horizon the mineral aggregates are mainly excrements.

- In the A horizon (1) and upper part of the B horizon (2) few to common voids, in (2) including some large intersection nodes, are almost completely filled with mineral grains. The external boundaries of the voids are not always easily distinguishable.

- In the lower part of the B horizon (3) and in the C horizon (4) a thin, often discontinuous, neomangan and/or mangan occurs along a few voids.

- Carbonate nodules occur over the whole depth and increase from common in the A horizon to abundant in the C horizon. In all cases, diameters reach up to 3 mm. In the first two thin sections some of the nodules have an accumulation of sesquioxides, mainly manganese, in the outer zone. In the two deepest thin sections most nodules are accumulations of small carbonate particles in the groundmass, with diffuse external boundaries.

- In the C horizon a few voids are locally filled with gypsum crystals of varying diameters.
Coimbatore (3 photographs)

1. Thin, discontinuous neomangan (black) along a structural void (white). B horizon (plain light).

2. Large round mineral excrements, mainly composed of fine-grained soil material. C horizon (plain light).
3. Structural void (black) with an accumulation of gypsum crystals (white). The groundmass is rich in single small carbonate particles and contains a few carbonate nodules. C horizon (crossed polarizers).
4. Interpretation of the micromorphological data

Four thin sections are studied: one derived from the A horizon, two from the B horizon and one from the C horizon.

Depths: 2-17 cm (1), 25-40 cm (2), 50-65 cm (3) and 88-103 cm (4).

- The moderately developed structure changes in type with depth. The granular structure in the Ap is a result of management practices. The structure in the studied B and C horizons is determined by physical processes and largely influenced by animal activity. The angular blocky structure present in the upper part of the B horizon (2) changes into subangular deeper in the pedon (3, 4), influenced by the soil animals. The influence of the fauna mainly results in homogenization. In the whole studied zone voids and irregular zones, often interconnected, are partly or completely filled with soil aggregates; mainly excrements but also soil fragments and often some mineral grains. In the lower part of the B horizon (3) and in the C horizon (4) these features are abundant and have changed the type of structure. The quantity of soil fragments, mainly formed by swell and shrink of the soil material decreases with depth. In the C horizon (4) it is mainly only excrements that are present in the infillings.

- In the pedon sesquioxides, mainly manganese is accumulating to a slight extent. To a depth of 40 cm (1, 2) accumulations are found in the outer zones of carbonate nodules, deeper in the pedon a few thin cutans and/or neocutans of manganese occur.

- The whole profile is rich in carbonate, increasing in quantity with depth. The carbonate is partly present as nodules, diameters up to 3 mm and partly as small carbonate particles up to 5 µm in the fine-grained soil material. Carbonate nodules are common in the A horizon (1) and increase in quantity to abundant in the C horizon (4). The content of carbonate particles in the fine-grained soil material also increases from common in (1) to abundant in (4). In the C horizon most of the nodules consist of these fine particles, which with diffuse external boundaries merge into the groundmass where the fine particles are not joined together.

- In the C horizon occur a few voids locally filled with gypsum crystals of different diameters. The presence of gypsum may be due to natural processes or to management practices.

- Mainly restricted to the upper 40 cm (1, 2), a number of voids (few to common) occur which are almost completely filled with mineral grains. These mineral grains are not autochthonous and their presence is probably due to exogenic processes such as flooding of a river. Due to swell and shrink of the soil material the external boundaries of the infilled voids are not always easily distinguishable.
OOTY SERIES

1. General information and typifying pedon description


Ooty series comprises, well to excessively drained, very deep, very dark gray to reddish brown and yellowish red, loam to clay loam, acid soils. They have been developed from charnockites of the Nilgiri ranges. Ooty soils occur along steep sloping hills of 20 to 30% slopes. The area has humid temperate climate with annual rainfall of 1500 to 2750 mm and mean annual air temperature of 14.6°C. The principal associated soils are Nanjanad series which are brown to dark brown, loam to clay loam on the surface grading to red, clayey in the sub-surface.

Ooty series is a member of fine isothermic mixed family of: (classification not given, probably a humitropept).
Typifying pedon: Ooty loam-forest.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0-16 cm: Black to very dark gray (5 YR 2.5/1 M) clay; moderate fine granular; friable, slightly sticky non plastic; many fine to coarse inped roots; many very fine to fine discontinuous tubular vertical inped open pores; pH 4.9; diffuse boundary.</td>
</tr>
<tr>
<td>A2</td>
<td>16-36 cm: Black to very dark gray (5 YR 2.5/1 M) gravelly clay loam; moderate fine granular; very friable, slightly sticky and slightly plastic, many fine to coarse inped roots; many very fine to fine discontinuous tubular vertical inped open pores; rapid permeability; pH 5.2; clear smooth boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>36-59 cm: Dark reddish brown (5 YR 2.5/2 M) gravelly loam; weak very fine to fine granular; friable (moist), slightly sticky: coarse fragments of quartz, felspar and iron concretions of 3 to 2.5 mm, about 20-25% by volume; thin patchy clay cutans on ped faces and coatings on gravel; many fine to coarse inped roots; many very fine to fine discontinuous vertical inped open pores; rapid permeability; pH 5.5; clear wavy boundary.</td>
</tr>
<tr>
<td>B2</td>
<td>59-75 cm: Reddish brown to yellowish red (5 YR 4/6 M) sandy loam; weak fine subangular blocky breaking to granular; friable, slightly sticky and slightly plastic; thin patchy clay cutans on ped faces; many medium to coarse inped roots; many very fine to fine discontinuous tubular vertical inped pores; pH 5.7; clear smooth boundary.</td>
</tr>
<tr>
<td>C1</td>
<td>74-100 cm: Yellowish red (5 YR 5/8 M) 70% and red to dark red (2.5 YR 3.5/6 M) 30% coarse sandy loam; weak fine subangular blocky breaking to granular; very friable slightly sticky and slightly plastic; few coarse inped roots; few fine discontinuous micro pores and many macro pores; pH 5.8; gradual smooth boundary.</td>
</tr>
<tr>
<td>C2</td>
<td>100-160 cm: Weathered material with many macro pores.</td>
</tr>
</tbody>
</table>
Range in characteristics: The solum depth ranges from 100 to 150 cm. The texture in the texture control section is fine loamy with clay percentage ranging between 18 to 34. The estimated mean annual soil temperature at 50 cm depth is 15.6°C, mean summer soil temperature is 13.4°C and mean winter soil temperature is 12.9°C. The colour of the A horizon ranges from very dark gray to reddish brown in the hue of 7.5 YR with values from 2 to 3 and chromas from 1 to 3. The above colour is in soils under forest vegetation, soils under cultivation have higher value and chroma wherein these soils are put under cultivation mostly for tea plantations and potato cultivation. The epipedon is mollic which ranges in thickness from 25 to 35 cm. The texture of the A horizon ranges from loam to clay. The structure of the A horizon ranges from weak crumb to weak granular. The colour of the B horizon ranges from strong brown to yellowish red in hues of 7.5 YR and 5 YR with values from 4 to 5 and chromas from 4 to 6. The texture of the B horizon ranges from loam to clay loam with structure ranging from granular to weak subangular blocky breaking into granular. Occasionally the epipedon and the cambic horizon are separated by a thin gravelly horizon with gravels of quartz, feldspar and iron concretions which is generally observed along the steep slopes of high hills, nearer to summit. The B-horizon grades to soft variegated C horizon with fine weatherable minerals of feldspar and mica. Macro pores are common in the C-horizon.

Competing series and their differentiae: Soils of Nanjanad series are brown to dark brown loam to clay loam soils on the surface grading to red clayey in the subsurface.

Drainage and permeability: These soils are well to excessively drained with rapid to moderate permeability.

Use and vegetation: These soils are largely under cultivation to plantation crops like tea and coffee and occasionally for potato and vegetables. Bluegum, Eucalyptus are also planted in a few reserve
forest areas. The vegetation comprises of grasses, shrubs, pines and sub-tropical types.

Distribution and extent: Widely distributed in the Ootacamud area of Nilgiris district of Tamil Nadu.

Series established: Regional Centre, Bangalore, National Bureau of Soil Survey and Land Use Planning (ICAR).

Type location: 8 km East of Ooty settlement (town) along Ootacamund, Doddabetta road.

Interpretation: Ooty soils under forest maintain the characteristics of the series. When put to cultivation they lose organic matter due to decomposition and erosion. The lands are susceptible to erosion due to slope.

Management interpretation:
Inductive (Based on physical productivity potential of the soil)
1. Land capability sub-class - IIs
2. Land irrigability sub-class 6 ts.
3. Fertility management - Moderate Potential
4. Management potential/productivity - Moderate

Quantitative (Management potential for growing crops under farmers level and package of practices).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield Q/ha</th>
<th>Farmers level</th>
<th>Package of practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>289.76</td>
<td>336.8</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>-</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Grasses (Cynodon sp)</td>
<td>210 Tons/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digitaris sp</td>
<td>200</td>
<td>&quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>Hybrid Napier</td>
<td>200</td>
<td>&quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>Clover-Triflium sp.</td>
<td>10-20</td>
<td>&quot;&quot;</td>
<td></td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation: No information provided.

3. Micromorphological data

Four thin sections are studied: one from the A horizon, two from the B horizon and one from the C horizon.
Depths: 0-15 cm (1), 33-47 cm (2); 59-74 cm (3); 90-105 cm (4).

1. Depth: 0-15 cm

Macroscopic characteristics: Very dark gray, fine textured, pedonal soil material, containing a few nodules/gravels up to 5 mm in diameter.

Micromorphological characteristics:

Structure: Mainly moderate fine subangular blocky structure to which common irregular, elongated, intersected voids belong. Other voids: Few to common elongated voids, widths up to 3 mm, less than a few cm long and common equant voids diam. up to 3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration. Common coarse organic-matter fragments occur in voids as well as embedded in the fine material. The fine material is largely clay sized and includes a few particles up to 5 µm. The fine material is isotropic.

Special features:

Associated with voids: Common voids partly filled with mineral aggregates, mainly excrements, but also some soil aggregates, coarse minerals, nodules etc. A number of these voids are interconnected. Diameters up to 5 mm, randomly distributed.
In the groundmass: Many voids nearly completely filled with mineral aggregates, mainly excrements of several shapes and sizes, but also soil aggregates, coarse minerals, nodules etc. These voids are often interconnected, diameters up to 15 mm, randomly distributed.

Few to common nodules, which can be altered rock fragments or sesquioxidic-clay accumulations. These nodules are rounded off, have generally sharp external boundaries, different colours from yellowish, red to black, have diameters up to 5 mm and are randomly distributed.

2. Depth: 33-48 cm

Macroscopic characteristics: Dark reddish brown, medium textured, apedal soil material, containing abundant nodules varying from yellowish - to red to black colours, diameters up to 10 mm.

Micromorphological characteristics

Structure: Apedal soil material containing few to common elongated voids, widths up to 3 mm, length generally less than 1 cm and common equant voids, diam. up to 3 mm, randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 10 mm Ø. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consist of a variety of minerals and rock fragments, which show varying stages of alteration. Few coarse organic matter fragments. The fine material is largely clay sized and includes a few particles up to 5 um. The fine material is isotropic.

Special features: Few voids partly filled with mineral aggregates, excrements as well as soil aggregates, diameters up to 3 mm.

In the groundmass: Common voids nearly completely filled with mineral aggregates, mainly excrements but contains also soil aggregates, mineral grains, rock fragments etc. These voids are sometimes interconnected.
Abundant nodules, which mainly are rather rounded sesquioxidic clay accumulations, containing a few mineral grains. A number are strongly altered rock fragments. Both kinds have sharp external boundaries, different colours from yellowish, red to black, have diameters up to 10 mm and are randomly distributed.

3. Depth: 59-74 cm – undisturbed part from 64-68 cm depth is described

Macroscopic characteristics: Reddish brown to yellowish red medium textured, weak pedal soil material.

Micromorphological characteristics

Structure: Weak medium subangular blocky structure to which a few, sometimes interconnected elongated voids belong. Other voids: few to common elongated voids, widths generally less than 3 mm, length up to 1 cm, and common equant voids, \( \phi < 3 \) mm, randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 5 mm in diameter. Size limit coarse/fine material 25 \( \mu \)m. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which except for quartz mainly all are strongly to completely altered. The fine material is largely clay sized, includes a few particles up to 25 \( \mu \)m and has an argilasepic plasmic fabric.

Special features

Associated with voids: Many, often thick yellowish, argillans, which are often laminated.

In the groundmass: Many voids filled with yellowish clay – often laminated. The clay-sized laminae are locally alternating with fine silt sized laminae.

: Few voids mainly filled with fine silt-sized laminated soil material.

: Many strongly and completely altered rock fragments, diam. up to 5 mm, randomly distributed.
4. Depth: 90-105 cm

Macroscopic characteristics: yellowish red and red, coarse textured, apedal soil material of different horizons, with an abrupt smooth boundary at 100 cm depth.

Micromorphological characteristics

Structure: Apedal soil material containing few to common elongated voids, widths up to 3 mm, sometimes interconnected, lengths generally less than 1 cm and common equant voids, diam. up to 3 mm. Most voids occur from 90-100 cm depth.
Groundmass: The course textured material includes grain sizes up to 8 mm. Size limit coarse/fine material: 25 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which except for quarts mainly are strongly to completely altered. The fine material is largely clay sized, includes a few particles up to 25 µm and has an argilasepic plasmic fabric. Below 100 cm depth nearly no fine material is present.

Special features
Associated with voids: Few voids partly filled with mineral aggregates, mainly soil aggregates, rock fragments, and mineral grains.

: Common, yellowish and red argillans, which often are laminated. Most red argillans occur > 100 cm depth.

In the groundmass: Common voids nearly completely filled with mineral aggregates, soil aggregates and rock fragments, and coarse mineral grains. The majority of these voids occur from 90-100 cm depth.

: Common voids completely filled with clay, often laminated, yellowish or red coloured. They occur over the whole studied depth.

: Few voids, often with argillans, are completely filled with fine silt-sized material. These voids occur above 100 cm depth.

: Many strongly and completely altered rock fragments up to 8 mm diameter. Below 100 cm depth nearly all material consists of desintegrating, more or less strongly altered rock (except for quartz).
Short micromorphological description

Four thin sections are studied, one from the A horizon, two from the B horizon and one from the C horizon.

Depths: 0-15 cm (1); 33-47 cm (2); 59-74 cm (3); 90-105 cm (4).

The soil material is fine textured (1), medium textured in (2) and (3) and coarse textured in (4), and includes grain sizes up to and inclusive very coarse sand in (1), and gravels up to 10 mm diameter in (2), of 5 mm diameter in (3) and 8 mm in (4). The size limit coarse/fine material is 5 μm in (1) and (2); 25 μm in (3) and (4). Related distribution porphyric in all cases. The fine material is largely clay sized and includes a few particles up to 5 μm in (1) and (2), and up to 25 μm in (3) and (4). Below 100 cm depth no fine material occurs. The fine material is isotropic in (1) and (2) and has an argilosepic plasmic fabric in (3) and (4). The coarse mineral material consists of a variety of minerals and rock fragments, which show varying stages of alteration in (1) and (2), and which are, except for quartzs mainly strongly to completely altered in (3) and (4). Common coarse organic matter fragments occur in voids and embedded in the groundmass in (1) and a few fragments in (2).

The soil material in mainly moderate fine subangular blocky in (1) to which common irregular elongated intersected voids belong, is apedal in (2) and (4) and has a weak medium subangular blocky structure, to which a few, sometimes interconnected, elongated voids belong in (3). Other voids: Few to common elongated voids, widths up to 3 mm, less than a few cm long in (1), in other section generally less than 1 cm long and common equant voids, diameter up to 3 mm, randomly distributed. Special features:

Over the whole studied depth occur voids partly or almost completely infilled with mineral aggregates. These kinds of voids are most numerous in the A horizon (1). Partly infilled voids are common here and a few occur deeper in the pedon. Many voids are almost completely infilled in the A horizon, in the deeper horizons they are common. The mineral aggregates consist of excrements, soil aggregates and rock fragments. In the A horizon (1) the mineral aggregates mainly consist of excrements, diameter up to 5 mm; in (2) of excrements and soil aggregates; in (3) mainly soil aggregates and in (4) of soil aggregates, rock fragments and some
coarse mineral grains. The voids almost completely infilled with mineral aggregates are often interconnected.

From 59 cm onwards clay illuviation features, argillans as well as completely infilled voids with oriented clay, occur. These quantities decrease from many to common from (3) to (4). The clay illuviation features are laminated. Fine silt-sized laminae are locally incorporated in the complete infilled voids in (3). A few voids are completely filled with fine silt-sized soil material in (3) and (4). In (4) these voids often have argillans. Till 100 cm depth the colour of the clay-illuviation features is predominantly yellowish; below 100 cm depth they are mainly red coloured.

In the upper part of the pedon nodules occur, which consist of sesquioxideic clay fragments or altered rock fragments. Few to common nodules occur in (1); they are abundant in (2). These nodules are rounded off, have sharp external boundaries, different colours from yellowish, red to black, have diameters up to 5 mm in (1) up to 10 mm in (2) and are randomly distributed. Area occupied by nodules in (2) about 45% of the thin section.

Deeper in the pedon, in (3) and (4) occur many strongly and completely altered rock fragments, including garnets, diameter up to 5 mm (3) and up to 8 mm in (4). Below 100 cm depth nearly all material consists of desintegrating, more or less strongly altered rock.
Interpretation of the micromorphological data

From thin section are studied: one from the A horizon, two from the B horizon and one from the C horizon.
Depth: 0-15 cm (1); 33-47 cm (2); 59-74 cm; 90-105 cm (4).

- The soil material is not autochthonous. The soil material studied from the upper part of the pedon (1, 2) is a colluvium which rests on the truncated original pedon developed on weathered charnockite rock. The colluvium contains a high number of rounded sesquioxidic-rich clay nodules and altered rockfragments (charnockite), both derived from pedons developed in the same parent material as the original truncated pedon.

In this heterogeneous parent material the following processes occur or occurred:

- The voids forming the structure are largely the result of physical processes, swell and shrink of days. The other voids are of biological origin. In the upper part of the pedon (1, 2) floral voids dominate and are common, deeper in the pedon (3, 4) faunal voids dominate. Soil fauna is responsible for fragmentation and incorporation of organic matter in mineral material, mainly in excrements in the A horizon and to a minor extent in the upper part of the B horizon.

- Voids of biological origin are often partly or almost completely infilled with mineral aggregates. In the A horizon (1) the infilling consists mainly of excrements; in the upper part of the B horizon (2) of the excrements and soil aggregates and in the deepest sample (4) of soil aggregates, rockfragments and coarse mineral grains. Except for the excrements, soil aggregates and mineral grains are accumulated in voids due to gravity. The material is worked loose by animals or shrinkage.

In the deeper part of the pedon (3, 4), clay illuviation has occurred on a large scale. The number of clay illuviation features decreases with depth from many to common. In the section 64-68 cm depth the area covered by clay illuviation features is almost the same as the area covered with fine material (<25 µm). The clay illuviation features generally have a yellowish colour, but in the desintregating weathered rock, below 100 cm depth, they are predominantly red. The A horizon and upper part
of the argillic B horizon of the original pedon are eroded. Besides clay illuviation, also fine silt is illuviated and occurs as local fine silt-sized laminae in clay illuviation features or forms complete infillings in voids. These are indications of unstable conditions in upper horizons under wet circumstances.

In the pedon strong weathering has occurred and weathering still continuous. Rockfragments show varying stages of alteration, sesquioxides are released and clays formed. Below 100 cm depth desintegrating weathered rock occurs.

Remark: The given mean summer soil temperature and mean winter soil temperature can not be correct.

The base saturation of the epipedon can be < 50 percent (by NH40Ac), in which case this epipedon is umbric instead of millic. Based on the probable presence of an umbric epipedon the soils is tentatively classified as a humitropept.
1. General information and typifying pedon description

Pedon described by the core group members consisting of H.S. Shankaranarayana, R.R. Biswas, P. Chakraborty, H. Prodhan, B.P. Sahi and S. Digar. S. Maji and A.C. Gayan associated.

The Pusaro series is a member of the fine loamy, mixed, hyperthermic family of Ultic Paleustalfs. These soils have strong brown to yellowish red loamy sand to loam strongly acid, A horizons and strong brown to yellowish red, clay loam slightly acid Bt horizons. They have developed over convex upland of peneplained plateau in the sub humid tract of Santhal Parganas, Bihar. These soils occur on gently sloping upland with less than five percent slopes. The climate is sub humid tropical monsoonic with mean annual air temperature of 26°C and mean annual rainfall of 1096 mm. Principal associated soils are Dumka series and Hathiapathar series. Dumka series occurs on the back slope and Hathiapathar over the toe slope of peneplained plateau. Dumka series belongs to lithic Ustochrepts and Hathiapathar to Aeric Ochraqualfs.

Climatic Data and Soil Water Balance
SERIES PUSARO

<table>
<thead>
<tr>
<th>Month</th>
<th>Precip</th>
<th>Temp</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mar</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Apr</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aug</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sep</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oct</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nov</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dec</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

---

PE - Precip

---
Typifying pedon: Pusaro sandy loam-native vegetation.

A1 0-9 cm: Strong brown (7.5 YR 4.5/6 D) to yellowish red (5 YR 4/6 M), sandy loam; massive; very hard, friable, and slightly sticky; few fine roots; few very fine pores; pH 5.1; clear and smooth boundary.

A3 0-30 cm: Yellowish red (5 YR 5/6 D) loam; reddish brown (5 YR 4/4 M), moderate medium subangular blocky; hard, friable, and sticky; very few fine ferruginous concretions; few very fine pores; few fine roots; pH 5.5; gradual and smooth boundary.

B1 30-48 cm: Yellowish red (5 YR 5.5/8 D) and (5 YR 4/6 M), clay loam; moderate fine and medium subangular blocky; hard, friable, and sticky; few medium ferromanganese concretions; few very fine pores; few fine roots; pH 6.3; gradual smooth boundary.

B2lt 48-73 cm: Yellowish red (5 YR 5.5/8 D) and (5 YR 5/6 M) clay loam; strong coarse subangular blocky; hard, friable, and sticky and plastic; few medium ferromanganese concretions; few very fine pores; patchy, thick cutans; pH 6.3; gradual and smooth boundary.

B22t 73-91 cm: Yellowish red (5 YR 4.5/6 D) and (5 YR 4/6 M) clay loam; strong coarse subangular blocky; hard, friable, sticky and plastic; few medium ferromanganese concretions; few very fine pores; patchy moderately thick cutans; pH 6.5; gradual and smooth boundary.

B23t 91-114 cm: Reddish yellow (5 YR 6/8 D) to yellowish red (5 YR 4/6 M) clay loam; strong coarse subangular blocky; very hard, friable, sticky and plastic; few medium ferromanganese concretions; few very fine pores; patchy moderately thick cutans; pH 6.5; gradual and smooth boundary.

B24t 114-141 cm: Reddish yellow (5 YR 6/8 D) to yellowish red (5 YR 4/6 M), clay loam; strong coarse prismatic, breaking to angular blocky; very hard, friable, sticky and plastic; distinct mottles of red colour (2.5 YR 4/8); few medium to coarse ferromanganese concretions; few very fine pores;
patchy moderately thick cutans; pH 6.5; gradual and smooth boundary.

B3 141-186 cm: Red (2.5 YR 4.5/6 M) clay loam; moderate medium subangular blocky; very hard friable, very sticky and very plastic; few fine and medium few ferromanganese concretions; few very fine pores; patchy moderately thick cutans, pH 6.3.

Range in characteristics: The thickness of solum is more than 150 cm. The mineralogy of the regolith is mixed. The estimated HAST in the temperature control section is 26°C. Mean summer temperature is 28.5°C to 29.2°C and the mean winter soil temperature is 20°C. Moisture regime is ustic and moisture control section dry for more than 90 cumulative days but it is moist during monsoon months from June to October. The A horizon ranges in thickness from 25 to 40 cm. The colour of the A horizon is 7.5 YR or redder hue with chroma 4 or more. The texture of the A horizon varies from loamy sand to clay loam. The structure of the A horizon ranges from massive to subangular blocky; the boundary between A and B is gradual and smooth. The colour of the B horizon varies from strong brown to yellowish red in 7.5 YR or redder hue with moist value 4 or more, chroma 4 or more and distinct mottles of red colours are present in the lower part of Bt horizon. In the Bt horizon clay coatings are present on the ped faces. The structure of the Bt horizon is strong medium and coarse subangular blocky to prismatic. Ferromanganese concretions ranging from 1 to 5 percent by volume are present in the sub-surface horizons. The sub-surface diagnostic horizon is argillic, clay in the profile does not decrease by 20 percent from the maximum in the control section. Mineralogy of the clay is kaolinitic.

Competing series and their differentiae: Competing soil series is Balia series which differs in having 2.5 YR hue, value less than 4 in major part of the Bt horizon. Balia series is a member of the fine loamy mixed hyperthermic family of Udic Rhodustalfs.

Drainage and permeability: Well drained with moderate permeability.
Use and vegetation: Pusaro soils are used for upland crop cultivation during Kharif season. Natural vegetation consists of: Trees: Shorea robusta (Sal), Tectona grandis (Teak), Jambulana indica (Black berry), Artocarpus integrifolia (Jackfruit), Mangifera indica (Mango) and Borassus flabellifer (Date); Grasses: Cynodon dactylon (Dub), Perricum frumentascum (Shama), Saccharum sporiterium (Kans) and Cypress rotundus (Nutgrass).

Distribution and extent: Very extensive, covering about 17 percent of the Mayurakshi catchment mostly as the upland slopes. They may occur in Ranchi and adjoining districts.

Type location: Village (Pusaro) Hathiapathar, Tola Phansiadangal Tahsil-Dumka, Santal Pargana, Bihar, 87°14'E & 24°17'30"N about 3 km N-NW of Dumka & 0.5 km east of Dumka-Bhagalpur road.

Series proposed by: A.I.S. & L.U.S. Calcutta Centre.

Interpretation: Pusaro soils have good soil-moisture-air relationship. Initial water intake during early rains may be affected due to massive nature of the surface soil and the sloping lands may induce runoff losses. With proper moisture and soil conservation measures these soils may support a variety of climatically adapted crops.

Management Interpretation:

a) Inductive (based on physical productive potential of the series).
   1. Land capability sub-class : IIIe
   2. Irrigability sub-class : 2s
   3. Fertility management potential : Moderately high

b) Quantitative: (Management potential under farmer's level of management and package of practices).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield Q/ha Farmer's level (Rainfed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Maize</td>
<td>50-55</td>
</tr>
<tr>
<td>2 Kodo</td>
<td>12-15</td>
</tr>
<tr>
<td>3 Kuthi</td>
<td>20-25</td>
</tr>
<tr>
<td>4 Sorguza</td>
<td>2-3</td>
</tr>
</tbody>
</table>
### Tentative soil characterisation by NBSS & LUP, CALCUTTA

#### Size class and particle diameter (mm), % of <2 mm

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Total Sand (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&lt;0.002)</th>
<th>Coarse Very (1-0.5)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.02)</th>
<th>Very (0.02-&lt;0.002)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>A1 0-9</td>
<td>51.68</td>
<td>28.43</td>
<td>19.89</td>
<td>1.46</td>
<td>6.34</td>
<td>14.64</td>
<td>20.51</td>
</tr>
<tr>
<td>A3 9-30</td>
<td>43.69</td>
<td>29.74</td>
<td>26.57</td>
<td>1.09</td>
<td>6.31</td>
<td>19.37</td>
<td>16.21</td>
</tr>
<tr>
<td>B1 30-48</td>
<td>40.16</td>
<td>29.00</td>
<td>31.84</td>
<td>1.20</td>
<td>5.41</td>
<td>10.59</td>
<td>16.19</td>
</tr>
<tr>
<td>B2lt 48-73</td>
<td>40.75</td>
<td>26.71</td>
<td>32.54</td>
<td>2.28</td>
<td>5.48</td>
<td>10.76</td>
<td>15.38</td>
</tr>
<tr>
<td>B2tt 73-91</td>
<td>40.31</td>
<td>25.98</td>
<td>33.71</td>
<td>2.19</td>
<td>7.18</td>
<td>10.27</td>
<td>14.40</td>
</tr>
<tr>
<td>B3t 91-114</td>
<td>42.15</td>
<td>23.95</td>
<td>33.90</td>
<td>2.56</td>
<td>8.04</td>
<td>11.48</td>
<td>15.35</td>
</tr>
<tr>
<td>B4t 114-141</td>
<td>36.65</td>
<td>25.75</td>
<td>37.60</td>
<td>1.41</td>
<td>3.29</td>
<td>9.76</td>
<td>15.03</td>
</tr>
<tr>
<td>B5 141-186</td>
<td>32.77</td>
<td>30.61</td>
<td>34.61</td>
<td>1.34</td>
<td>3.41</td>
<td>10.97</td>
<td>16.48</td>
</tr>
</tbody>
</table>

#### Depth | Organic Carbonate & Ext. pH | Bulk Density | Water retention

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic Carbonate as CaCO₃</th>
<th>Ext. as CaCO₃</th>
<th>pH</th>
<th>Bulk density g/cc</th>
<th>Water retention %</th>
<th>% cm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>0.26</td>
<td>Trace</td>
<td>1.16</td>
<td>4.35</td>
<td>5.1</td>
<td>1.81</td>
</tr>
<tr>
<td>9-30</td>
<td>0.23</td>
<td>&quot;</td>
<td>1.44</td>
<td>5.05</td>
<td>5.5</td>
<td>1.65</td>
</tr>
<tr>
<td>30-48</td>
<td>0.13</td>
<td>&quot;</td>
<td>2.06</td>
<td>5.75</td>
<td>6.3</td>
<td>-</td>
</tr>
<tr>
<td>48-73</td>
<td>0.10</td>
<td>&quot;</td>
<td>2.12</td>
<td>5.95</td>
<td>6.3</td>
<td>-</td>
</tr>
<tr>
<td>73-91</td>
<td>0.10</td>
<td>&quot;</td>
<td>2.18</td>
<td>5.65</td>
<td>6.3</td>
<td>1.62</td>
</tr>
<tr>
<td>91-114</td>
<td>0.08</td>
<td>&quot;</td>
<td>2.18</td>
<td>5.75</td>
<td>6.5</td>
<td>-</td>
</tr>
<tr>
<td>114-141</td>
<td>0.07</td>
<td>&quot;</td>
<td>2.44</td>
<td>5.65</td>
<td>6.3</td>
<td>-</td>
</tr>
<tr>
<td>141-186</td>
<td>0.05</td>
<td>&quot;</td>
<td>2.66</td>
<td>5.55</td>
<td>6.3</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Depth (cm) | Extractable bases (5 Bla) | Ext. acidity CEC | Exchangeable sodium | Base saturations | Ratios to clay

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases (5 Bla)</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Exchangeable sodium</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca  Mg  Na  K  Sum</td>
<td>Ext. acidity</td>
<td>CEC</td>
<td>Exchangeable sodium</td>
<td>Base saturations</td>
<td>Ratios to clay</td>
<td></td>
</tr>
<tr>
<td>0-9 2.4 16 0.15 0.46 4.64 5.94</td>
<td>10.58</td>
<td>8.48</td>
<td>2.12</td>
<td>43.86</td>
<td>54.72</td>
<td>0.43</td>
</tr>
<tr>
<td>9-30 3.6 2.0 0.11 0.42 6.93 4.62</td>
<td>11.55</td>
<td>9.12</td>
<td>1.21</td>
<td>60.00</td>
<td>75.49</td>
<td>0.29</td>
</tr>
<tr>
<td>30-48 5.6 2.4 0.18 0.35 8.57 4.40</td>
<td>12.97</td>
<td>9.60</td>
<td>1.87</td>
<td>66.08</td>
<td>89.27</td>
<td>0.30</td>
</tr>
<tr>
<td>48-73 6.0 2.4 0.11 0.39 8.90 3.96</td>
<td>12.86</td>
<td>10.40</td>
<td>1.06</td>
<td>69.20</td>
<td>85.56</td>
<td>0.31</td>
</tr>
<tr>
<td>73-91 6.0 2.8 0.07 0.46 9.33 3.96</td>
<td>12.97</td>
<td>11.36</td>
<td>0.61</td>
<td>70.20</td>
<td>82.13</td>
<td>0.31</td>
</tr>
<tr>
<td>91-114 7.2 2.8 0.07 0.50 10.57 3.30</td>
<td>13.87</td>
<td>13.28</td>
<td>0.52</td>
<td>76.20</td>
<td>79.59</td>
<td>0.35</td>
</tr>
<tr>
<td>114-141 6.8 4.0 0.35 0.66 11.81 3.96</td>
<td>15.77</td>
<td>14.28</td>
<td>2.45</td>
<td>77.89</td>
<td>82.70</td>
<td>0.35</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Three thin sections are studied: all derived from the B horizon.
Depths: 32-47 cm (1), 74-89 cm (2) and 149-164 cm (3).

1. Depth: 32-47 cm.

Macroscopic characteristics:
Yellowish red, medium textured, weak subangular blocky soil material, containing common red and/or black coloured nodules up to 4 mm in diameter.

Micromorphological characteristics

Structure: Weak medium subangular blocky structure, to which a few elongated voids belong which are sometimes intersected. Other voids:
Common to many elongated voids, widths up to 2 mm, lengths less than 15 mm and many equant voids, often interconnected, diameters up to 2 mm, most <1 mm. Randomly distributed.

Groundmass: The medium textured groundmass includes grain sizes up to gravels of 2.5 mm. Size limit coarse/fine material 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals of which a part shows varying stages of alteration, and a few rock fragments. The fine material is predominantly clay-sized, contains a few particles up to 5 µm and has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Common voids partly infilled with mineral aggregates, mainly excrements of several shapes and sizes. These voids have regular and irregular shapes and diameters up to 4 mm.

In the groundmass: Common voids/zones nearly completely infilled with mineral aggregates, often excrements of several shapes and sizes. These voids/zones often have irregular shapes, diameters up to 15 mm, and are usually interconnected. Besides excrements, soil aggregates and mineral grains are present.
Common sesquioxidic nodules, black and red coloured, with diameters up to 4 mm, but usually smaller than 2 mm. The nodules sometimes include weathered rock fragments and generally have clear external boundaries.

2. Depth: 74-89 cm

Macroscopic characteristics

Yellowish red, medium textured, weak subangular blocky soil material, containing common red and/or black nodules up to 4 mm in diameter.

Micromorphological characteristics

Structure: Weak, medium, subangular structure, associated with a few elongated voids, which are sometimes intersected. Other voids: Common to many elongated voids, widths up to 2 mm, lengths less than 15 mm and many equant voids often interconnected, diameters up to 2 mm, most <1 mm. Randomly distributed.

Groundmass: The medium textured groundmass includes grain sizes up to gravels of 2.5 mm. Size limit coarse/fine material: 5 mm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and a few rock fragments of which a part show varying stages of alteration. The fine material is predominantly clay-sized, contains a few particles up to 5 µm and has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Common voids, partly infilled with mineral aggregates, mainly excrements of several shapes and sizes. These voids have regular and irregular shapes and have diameters up to 4 mm.

Locally a few usually thin red and/or yellow argillans in small voids.

In the groundmass: Common voids/zones nearly completely infilled with mineral aggregates, which are often excrements of several shapes and sizes. These voids/zone often have irregular shapes, because of interconnection of infilled voids; diameters up to 15 mm. Besides excrements, soil aggregates and mineral grains are present.
few small voids are infilled with clay, red and/or yellow coloured.

few papules are locally found.

few weathered rock fragments.

common sesquioxic nodules, black and red coloured, diameters up to 4 mm. The nodules sometimes include weathered rock fragments and generally have clear external boundaries.

few red nodules, often irregular with diffuse boundaries, diameters up to 4 mm.

3. Depth: 149-164 cm

Macroscopic characteristics

Red, medium textured, weak subangular blocky soil material, containing common red and/or black nodules up to 8 mm in diameter.

Micromorphological characteristics

Structure: Weak, medium, subangular blocky structure which is associated with a few elongated voids, which are sometimes intersected. Other voids: Common elongated voids, widths up to 4 mm, lengths less than 30 mm and common equant voids, diameters up to 4 mm. Randomly distributed.

Groundmass: The medium textured groundmass includes grain sizes up to gravels of 2.5 mm. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, including a few rock fragments, of which a part shows varying stages of alteration. The fine material is predominantly clay-sized, contains a few particles up to 5 µm and has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Few to common voids partly infilled with mineral aggregates, mainly excrements, diameters up to 4 mm.

In the groundmass: Few to common voids nearly completely infilled with mineral aggregates, often excrements. Soil aggregates and mineral grains are also included, diameters up to 4 mm.
Common small voids infilled with red and/or yellow coloured clay.

: few weathered rock fragments.

: Common sesquioxidic nodules, black and red coloured, diameters up to 8 mm. The nodules sometimes include weathered rock fragments, have diffuse external boundaries. The black and red colours in the nodules also generally show diffuse transitions.

: Few red nodules, irregular shaped with diffuse boundaries, diameters up to 8 mm.

Short micromorphological description

Three thin sections are studied, all derived from the B horizon. Depths: 32-47 cm (1), 74-89 cm (2) and 149-164 cm (3).

- The soil material is in the B horizon medium textured and includes grain sizes up to gravel of 2.5 mm diameter. The size limit coarse/fine material is 5 µm; the related distribution: porphyric. The fine material is largely clay-sized, contains a few particles up to 5 µm and has a moderate skewsepic plasmic fabric. The coarse mineral material consists of a variety of minerals, including a few rock fragments, of which a part shows varying stages of alteration. The soil material has in all sections a weak medium subangular blocky structure, which is associated with a few elongated, sometimes intersected voids. Other elongated and equant, voids slightly decrease in quantity with depth from common to many (1, 2) to common (3). Diameters of the voids reach up to 2 mm in (1) and (2), up to 4 mm in (3); length of the elongated voids up to 15 mm in (1) and (2), up to 3 cm in (3); all randomly distributed.

- In the B horizon studied occur voids partly or nearly completely infilled with mineral aggregates, which often are excrements. In the nearly completely infilled voids also soil aggregates and mineral grains are included. The quantities of all types of infilled voids slightly decrease with depth from common in the upper part of the B horizon (1, 2) to few-common deep in the B horizon (3). Diameters of the partly infilled voids reach up to 4 mm over
the whole depth. In the upper part of the B horizon nearly completely infilled voids are often interconnected, forming irregular shaped zones with infilled material up to 15 mm wide. Deep in the B horizon these voids reach up to 4 mm in diameters.

- In the two deepest samples (2, 3) of the B horizon occur argillans and completely infilled small voids with pure oriented clay. Locally a few argillans are present in (2), they are common in (3). A few voids are completely infilled in (2), increasing to common in (3). In the middle part of the B horizon (2) occur also locally a few papules, embedded fragments of argillans or infilled voids. The colours of the clay accumulations vary from yellow to red.

- Black and red coloured sesquioxidic nodules are common over the whole B horizon. Their diameters increase from maximal 4 mm in (1) to 8 mm deeper in the B horizon (2, 3). The nodules sometimes include weathered rock fragments and have clear external boundaries in (1, 2) and diffuse ones in (3).

- In the two deepest samples (2, 3) occur a few red nodules, irregular shaped, with diffuse external boundaries. Diameters increase with depth from 4 mm (2) to 8 mm (3).

- In the same part of the B horizon (2, 3) occur a few weathered rock fragments.
Pusaro (2 photographs)


2. Fossil argillans and a laminated clay-infilling (left). B3 horizon (plain light).
4. Interpretation of the micromorphological data

Three thin sections are studied: all derived from the B horizon. Depths: 32-47 cm (1), 74-89 cm (2) and 149-164 cm (3).

- The weak subangular blocky structure present in the whole B horizon is largely determined by the fauna. Animals produce varying void systems, the majority of which being partly or almost completely filled with shaped mineral excrements, mixed with a few soil fragments and some large mineral grains. These void systems are often interconnected and contribute to the subangular blocky structure. Due to these activities, the groundmass becomes homogenized and the soil achieves a good porosity. The influence of the fauna decreases with depth in the B horizon. In the upper part of this horizon (1, 2) most of the groundmass is homogenized; deep in the B horizon (3) only a minor part.

- In this soil material features of a former clay illuviation occur from a depth of 75 cm onwards. In the upper part of the zone with clay illuviation features (2) only a few argillans, clay infillings and papules occur. Deep in the B horizon (3) argillans and clay infillings are common, papules do not occur. The papules present in the top of this zone are the result of faunal homogenization.

- Sesquioxidic nodules are common over the whole studied zone and are mainly due to former processes. In the upper part of the B horizon (1, 2) the nodules (diameters up to 4 mm) have clear external boundaries as a result of high animal activity. There is no evidence of current accumulation of sesquioxides. Deep in the B horizon (3) the influence of the fauna is less, the external boundaries of the nodules are diffuse and diameters reach up to 8 mm.

- In this soil, strong alteration of minerals and rock fragments has occurred. This alteration is largely responsible for the origin of the illuviated clay and accumulated sesquioxides. Some alteration is still taking place.
HATHIAPATHAR SERIES

1. General information and typifying pedon description

Pedon described by the core group members consisting of H.S. Shankaranarayana, R.R. Biswas, P. Chakraborty, H. Prodhan, B.P. Sahi and Digar, S. Maji and A.C. Gayen associated.

The Hathiapathar series is a member of the fine, mixed, hyperthermic family of Aeric Ochraqualfs. They have a grayish brown, sandy loam strongly acid, A horizons and light brownish gray to light gray, clay loam to clay, strongly acid Bthorizons with distinct yellowish red mottles. They have developed over toe slopes of peneplaned plateau in the sub-humid tract of Santal Parganas, Bihar. These soils occur on very gently sloping lands with less than three percent slope. The climate is sub-humid tropical monsoon with mean annual air temperature of 26°C and mean annual rainfall of 1096 mm. The soils remain under water during Kharif season. Principal associated soils are Pusaro series and Sarua series. Pusaro soils occur on the gently sloping upland and Sarua series on valley bottom. Pusaro soils are Udic Paleustalfs and Sarua soils Aeric Ochraqualfs.
Typifying pedon: Hathiapathar sandy loam-cultivated.

Ap 0-13 cm: Dark grayish brown to grayish brown (2.5 Y 4-5/2 M) sandy loam; massive; hard, friable and slightly sticky, many fine roots with yellowish red colour (5 YR 4/6) stain; pH 5.3; clear and smooth boundary.

A3 13-24 cm: Grayish brown (2.5 Y 5/2 M) sandy loam; massive; hard, friable and sticky; few fine ferro-manganese concretions; common coarse and medium prominent reddish brown (5 YR 4/4) and reddish yellow (7.5 YR 1/6) mottles; few fine roots; many very fine pores; pH 5.4; clear and smooth boundary.

B1 24-47 cm: Light brownish gray (10 YR 6/2 M) clay loam; moderate medium sub-angular blocky; very hard, friable, sticky and plastic; few fine ferro-manganese concretions; few coarse faint yellowish brown (10 YR 5/4) mottles; patchy thin cutans on ped faces; few fine roots; many very fine pores; pH 5.5; gradual and smooth boundary.

B21t 47-71 cm: Light brownish gray to light gray (2.5 Y 6-5/2 M) clay loam; weak fine and medium angular blocky; very hard, friable, sticky and plastic; plentiful medium and coarse prominent yellowish red (5 YR 4/6) mottles; patchy moderately thick cutans on ped faces; many fine pores; pH 5.5; gradual and smooth boundary.

B22t 71-101 cm: Light gray (2.5 Y 7/2 M); clay loam; moderate medium angular blocky; very hard, firm, sticky and plastic; plentiful medium and coarse prominent yellowish red (5 YR 5/6) mottles; continuous moderately thick cutans on ped faces; many fine pores; pH 5.5; gradual smooth boundary.

B23t 101-127 cm: Light gray (5 Y 7/2 M) clay loam; moderate medium angular blocky; very hard, firm, sticky and plastic; few fine medium ferro-manganese concretions; common coarse prominent yellowish red (5 YR 5/6) mottles; patchy moderately thick cutans on ped faces; many fine pores; pH 5.3.

Range in characteristics: The thickness of solum is 125 cm to 150 cm which grades into loam to clay loam substrata. The minerology of the regolith is mixed. The estimated MAST in the temperature control section is 26.8°C, MSST is 28.5°C and MWST is 20.0°C. Moisture regime is aquic.
During monsoon (July to October) the lands are under wet conditions.

The A horizon ranges from 15 to 25 cm of depth with puddled surface layer up to 15 cm. The colour of the A horizon is of 10 YR or yellower hues with chroma of 2 or less. The texture of the A horizon ranges from sandy loam to clay loam. The structure of the A horizon is massive to sub-angular blocky. The boundary between A & B horizon is clear and smooth. The colour of the B horizon which includes B1 and Bt varies from light brownish gray to light gray in 10 YR or yellower hue with moist chroma of 2 or less. Distinct mottles of yellowish brown to yellowish red are present from or below the surface of Ap up to the Bt horizon. The texture of the Bt horizon varies from clay loam to clay with depth. In the Bt horizon clay coatings are present on the ped faces. The structure of the Bt horizon is moderate to strong, medium to coarse, sub-angular to angular blocky.

Ferro-manganese concretions ranging from 5 to 15 percent by volume are present in the sub-surface soil horizons. Sub-surface diagnostic horizon is argillic. Clay percent in the control section is between 18 and 35. Clay minerology is kaolinitic.

Competing series and their differentiae: Kachanpur series which has gravels and pebbles in the underlying horizon.

Drainage and permeability: Imperfectly to poorly drained with slow to very slow permeability.

Use and vegetation: Natural vegetation consists of: Trees: Shorea robusta (Sal), Tectona grandis (Teak), Jambulana indica (Black berry), Artocarpus integrifolia (Jackfruit), Mangifera indica (Mango) and Borassus flabellifer (Date); Grasses: Cynodon dactylon (Dub), Pterium frumentascum (Shama), Saccharum sporiterium (Kans) and Cyperus rotundus (Nutgrass).

Distribution and extent: Covering about 17 percent of the Mayurakshi catchment mostly along the lower slope of the uplands. They may occur in other districts of the state also.
Type location: Vill. Hathiapathar, Tahasil Dumka, Bihar 87°14'23"E and 24°17'45"N about 3.5 km NW of Dumka and about 1 km east of Dumka-Bhagalpur.

Series proposed by: All India soil and Land use Survey, Calcutta Centre.

Interpretation: Hathiapathar soils are aquic and so they have the inherent problem of soil moisture-air relationship. They are subject to surface flooding during rainy season due to their position in the landscape. Hence they are adapted to Paddy crop only during Kharif season. They may support climatically adopted crops like Mustard and Gram on conserved soil moisture and with supplemental irrigation, wheat during rabi.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub-class: IIIw
   2. Land irrigability sub-class: 3d
   3. Fertility management potential: 3d moderate (loss of nitrogen from nitrogenous fertilizers due to volatilization and heavy texture; and Zn deficiency)

b) Quantitative: (management potential under farmer's level and package of practices)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainfed</td>
</tr>
<tr>
<td>Paddy</td>
<td>25-27</td>
</tr>
</tbody>
</table>
1. Tentative soil characterization by NABSS & CUP, Calcutta

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Size class and particle diameter (μm)</th>
<th>Total</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Very</th>
<th>Course</th>
<th>Medium</th>
<th>Fine</th>
<th>Very fine</th>
<th>Clay</th>
<th>Course</th>
<th>Fragments</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2-0.05)</td>
<td>(0.05-0.002)</td>
<td>(0.002-0.004)</td>
<td>(0.004-0.008)</td>
<td>(0.008-0.1)</td>
<td>% of &lt; 2 μm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-13</td>
<td></td>
<td>31.56</td>
<td>35.26</td>
<td>0.55</td>
<td>2.32</td>
<td>6.10</td>
<td>13.07</td>
<td>9.91</td>
<td>24.55</td>
<td>28.04</td>
<td>15.56</td>
<td>2.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>13-24</td>
<td></td>
<td>27.78</td>
<td>39.11</td>
<td>0.35</td>
<td>2.19</td>
<td>5.03</td>
<td>11.02</td>
<td>7.27</td>
<td>22.71</td>
<td>27.32</td>
<td>39.11</td>
<td>1.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt</td>
<td>24-47</td>
<td></td>
<td>34.53</td>
<td>39.73</td>
<td>0.85</td>
<td>2.55</td>
<td>3.38</td>
<td>7.24</td>
<td>5.68</td>
<td>27.39</td>
<td>13.14</td>
<td>36.72</td>
<td>3.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btlt</td>
<td>47-71</td>
<td></td>
<td>40.92</td>
<td>39.70</td>
<td>0.85</td>
<td>2.55</td>
<td>3.38</td>
<td>7.24</td>
<td>5.68</td>
<td>27.39</td>
<td>13.14</td>
<td>36.72</td>
<td>3.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btlt</td>
<td>71-101</td>
<td></td>
<td>44.25</td>
<td>30.75</td>
<td>0.67</td>
<td>2.20</td>
<td>4.61</td>
<td>9.68</td>
<td>7.00</td>
<td>24.11</td>
<td>20.18</td>
<td>39.75</td>
<td>2.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btlt</td>
<td>101-127</td>
<td></td>
<td>20.97</td>
<td>51.19</td>
<td>28.74</td>
<td>1.09</td>
<td>1.65</td>
<td>2.75</td>
<td>6.37</td>
<td>4.05</td>
<td>25.15</td>
<td>26.04</td>
<td>28.74</td>
<td>4.20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic Carbonate as CaCO₃</th>
<th>Carbons as Fe</th>
<th>pH (1:1)</th>
<th>E.C. (1:1)</th>
<th>Bulk density</th>
<th>Water Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 2 μm</td>
<td>&lt; 0.002 μm</td>
<td>H₂O</td>
<td>g/cc</td>
<td>1/3-bar</td>
<td>15-bar</td>
</tr>
<tr>
<td>0-13</td>
<td>0.59</td>
<td>traces</td>
<td>3.70</td>
<td>5.3</td>
<td>1.74</td>
<td>16.88</td>
</tr>
<tr>
<td>13-24</td>
<td>0.40</td>
<td></td>
<td>0.61</td>
<td>5.4</td>
<td>-</td>
<td>17.10</td>
</tr>
<tr>
<td>24-47</td>
<td>0.13</td>
<td></td>
<td>0.53</td>
<td>5.5</td>
<td>-</td>
<td>26.84</td>
</tr>
<tr>
<td>47-71</td>
<td>0.31</td>
<td></td>
<td>0.67</td>
<td>5.5</td>
<td>1.71</td>
<td>27.35</td>
</tr>
<tr>
<td>71-101</td>
<td>0.10</td>
<td></td>
<td>1.24</td>
<td>5.5</td>
<td>1.68</td>
<td>22.50</td>
</tr>
<tr>
<td>101-127</td>
<td>0.10</td>
<td></td>
<td>1.18</td>
<td>5.3</td>
<td>-</td>
<td>21.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases (5% H₂O)</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Exchangeable sodium absorption ratio</th>
<th>Exchangeable sodium absorption %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
<td>Sum Cations</td>
</tr>
<tr>
<td>0-13</td>
<td>4.40</td>
<td>1.60</td>
<td>0.64</td>
<td>0.19</td>
<td>6.93</td>
</tr>
<tr>
<td>13-24</td>
<td>4.80</td>
<td>1.60</td>
<td>0.14</td>
<td>0.19</td>
<td>7.23</td>
</tr>
<tr>
<td>24-47</td>
<td>5.20</td>
<td>2.00</td>
<td>0.16</td>
<td>0.39</td>
<td>8.45</td>
</tr>
<tr>
<td>47-71</td>
<td>5.50</td>
<td>2.40</td>
<td>0.98</td>
<td>0.47</td>
<td>8.93</td>
</tr>
<tr>
<td>71-101</td>
<td>5.60</td>
<td>3.20</td>
<td>0.50</td>
<td>0.47</td>
<td>9.57</td>
</tr>
<tr>
<td>101-127</td>
<td>5.80</td>
<td>4.40</td>
<td>0.64</td>
<td>0.57</td>
<td>12.01</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Three thin section are studied: one from the transition of the A and B horizon and two of the B horizon. Depths: 16-31 cm (1), 52-67 cm (2) and 108-123 cm (3).

1. Depth: 16-31 cm.

Macroscopic characteristics

Greyish brown and yellowish brown, medium to fine textured, apedal, soil material, containing a few dark coloured nodules in the lower half of the section, diam. up to 2 mm.

Micromorphological characteristics

Structure: The soil material is apedal and contains common elongated, sometimes interconnected voids, widths up to 2 mm, lengths up to a few cm and common equant voids, diam. up to 2 mm, randomly distributed.

Groundmass: The medium to fine textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material: 5 µm. Related distribution: porphyrif. The coarse material consists of a rather large variety of minerals and some rock fragments, which show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a weak vo-skelsepic plasmic fabric.

Special features:

Associated with voids: Few voids partly filled with mineral aggregates, mainly excrements. : Few to common, thin neosquans and/or sesquans mainly composed of manganese compounds, occurring mainly in the upper 8 cm. : Few thin argillans, mainly in the lower half of the section, often laminated. : Few cutans, often laminated and well developed only at the lower side of the voids, are composed of mainly silt-sized soil material.

In the groundmass: Few voids nearly completely filled with mineral aggregates, mainly excrements. : Few voids completely or nearly completely filled with mainly silt-sized soil material, often laminated, including some laminae of clay-sized material. : Few to common, weak developed, sesquioxidic accumulations with diffuse external boundaries, diam. up to about 6 mm, becoming better developed with increasing depth. : Few brownish-black charcoal fragments, sharp external boundaries, diam. up to 3 mm.
2. Depth: 52-67 cm.

Macroscopic characteristics

Light brownish gray, fine textured weak angular blocky soil material, containing common yellowish-red mottles, diam. up to 7 mm.

Micromorphological characteristics

Structure: The soil material is weak medium angular blocky, to which a few elongated, sometimes intersected, voids belong. Other voids: Common elongated voids, widths up to 2 mm, lengths up to a few cm and common equant voids diam. up to 2 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a rather large variety of minerals and some rock fragments, which show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a weak vo-skelsepic plasmic fabric.

Special features:

Associated with voids: Few voids partly filled with mineral aggregates, mainly excrements.

- Common yellowish argillans, most not in structural voids, often laminated.
- In the groundmass: Few voids nearly completely filled with mineral aggregates, mainly excrements.
- Few small voids, nearly completely or completely filled with yellowish clay.
- Common yellowish red nodules composed of sesquioxides, clear and diffuse external boundaries, diam. up to 7 mm. Voids in these nodules often have argillans or are completely filled with clay, both generally laminated and of a red colour.
- A very few rounded dark coloured sesquioxidic nodules, sharp boundaries, diam. up to 2 mm.

3. Depth: 108-123 cm.

Macroscopic characteristics

Light gray, fine textured, moderate angular blocky soil material, containing many yellowish-red mottles, diam. up to 8 mm and few to common brownish-black nodules, diam. up to 3 mm.

Micromorphological characteristics:

Structure: The soil material is moderate medium angular blocky to which few to common, intersected, elongated voids belong. Other voids: few elongated voids, widths up to 2 mm, length up to a few cm and a few equant voids, diam. up to 2 mm, randomly distributed.
**Groundmass**: The fine textured soil material includes grain sizes up to gravels of 8 mm diameter. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The coarse mineral material consists of a rather large variety of minerals and some rock fragments, which show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a weak vo-skelsepic plasmic fabric.

**Special features:**
- Associated with voids: Few voids partly filled with mineral aggregates, mainly excrements.
  - Common yellowish argillans, in structural voids as in other voids, often laminated.
  - Common cutans of laminated sorted soil material: silt-sized, clay-sized and only clay, mainly present in structural voids. Most material is silt-sized.
  - A few thin sesquans and/or neosesquans.
- In the groundmass: Few voids nearly completely or completely filled with yellowish clay.
  - Common voids nearly completely or completely filled with laminated sorted soil material, silt-sized, clay-sized and only clay. Most material is silt-sized. Structural voids as well as other voids are filled.
  - Many yellowish-red sesquioxidic accumulations, with diffuse external boundaries, diam. up to 8 mm. In voids in these accumulations red argillans are sometimes present, neosesquans and/or sesquans occur as well as complete or partly filled voids with laminated sorted soil material.
  - Few to common rounded brownish-black nodules, composed of sesquioxides, enclosing sometimes altered rock fragments, with sharp external boundaries, diam. up to 3 mm, random distribution.
Short micromorphological description

Three thin sections are studied: One from the transition of the A and B horizon and two of the B horizon.
Depths: 16-31 cm (1); 52-67 cm (2); 108-123 cm (3).

The soil material becomes slightly finer textured from medium to fine (1) to fine textured in the B horizon and includes grain sizes up to and inclusive very coarse sand (1), (2) or gravels up to 8 mm in (3). The size limit coarse/fine material is 5 µm; the related distribution: porphyric. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a weak vo-skelsepic plasmic fabric. The coarse mineral material consists of a rather large variety of minerals and some rock fragments, which show varying stages of alteration.

The soil material is apedal at the transition of the A and B horizon (1) and has with increasing depth a better developed structure, from weak to moderate medium angular blocky, to which intersected elongated voids belong. Other, elongated and equant, voids are common in (1) and (2) and decrease with increasing depth to a few. Diameters of the voids up to 2 mm, length of elongated voids up to a few cm, all randomly distributed.

Special features: In both the A and B horizon occur a few voids partly filled with mineral aggregates, mainly excrements; above 70 cm depth also a few voids are nearly completely filled with the same material. In the B horizon yellowish argillans, often laminated, are common starting with a few in the transition of the A and B horizon. They occur in structural voids as well as in other elongated and equant voids. A few voids in the B horizon are nearly completely or completely filled with laminated yellowish clay.

In the transition of the A and B horizon occur a few laminated cutans and a few completely or nearly completely filled voids, both mainly composed of silt-sized soil material. In the thin section of the upper part of the B horizon (2) these features are rare but in the lower part of the B horizon (3) they are common. Here the laminated cutans and fillings are composed of soil material which is silt-sized, clay sized or consist of pure clay. Most material is silt-sized.

In the lower part of the A horizon occur few to common neosesquans and/or sesquans mainly composed of manganese compounds. Sesquioxidic accumulations in the groundmass are found in all thin sections. They increase in quantity with depth from few to common at the transition of the A and B horizon (1) to many in the lower part of the B horizon (3), become more pronounced with depth and the diameters of the nodules slightly increase with depth from maximal 6 mm (1), 7 mm (2) to 8 mm (3). These accumulations are mainly composed of iron compounds and have diffuse external boundaries. In (3) also a few sesquans and/or neosesquans occur. The colour of the groundmass is grayer with increasing depth.

In the B horizon occur a very few (2) and few to common (3) rounded brownish-black sesquioxidic nodules, enclosing in (3) sometimes altered rock fragments. These nodules have sharp external boundaries, diameters up to 2 mm (2) and 3 mm in (3) and are randomly distributed.

In the transition of the A and B horizon occur a few brownish-black charcoal fragments, diam. up to 3 mm.
Hathiapathar (2 photographs)

1. Argillans and infilling of pure clay. At the right side, part of a sesquioxide nodule. B horizon (plain light)

2. Hydromorphic features, sesquioxide mottles with diffuse external boundaries due to current processes and inherited rounded sesquioxide nodules. B horizon (plain light)
4. Interpretation of the micromorphological data

Three thin sections are studied: one from the transition of the A and B horizons and two of the B horizon. Depths: 16-31 cm (1), 52-67 cm (2) and 108-123 cm (3).

- The structure, only present in the B horizon where it becomes increasingly more developed with depth, from weak to moderate angular blocky, is a result of physical processes. All other voids (diameters up to 2 mm) are due to fauna and flora. They reduce in quantity with depth from common to few. Homogenization of soil material by soil fauna is restricted; Varying quantities of mineral excrements only occur in a few faunal voids.

- Clay illuviation is common in the B horizon and leads to laminated cutans and complete infillings of voids. A few argillans are present in the transition from the A to the B horizon.

- In the A and B horizons, periodical illuviation of wet soil material takes place. This material flows into voids, structural as well as biological ones, is sorted and forms cutans to complete infillings of voids. They are laminated and composed of silt-sized and clay-sized material. Most material is silt-sized. Deeper in the B horizon pure clay laminae are incorporated in these cutans and infillings. The illuviation of wet soil material can be ascribed to the physiographic position of the site and to management practices. The absence of a structure in the A horizon is an indication of instability of the top soil. The few charcoal fragments observed in the transition of the A to the B horizon were, added to the soil and incorporated due to cultivation practices.

- A number of hydromorphic features are present. In the lower part of the A horizon, few to common neocutans and cutans of (mainly) manganese compounds occur. Also from this zone, and becoming more numerous and more developed with increasing depth, sesquioxidic accumulations, mainly composed of iron compounds, are present in the groundmass, maximum diameters 8 mm. These accumulations have diffuse external boundaries indicating formation in situ. Depletion and accumulation of ferric iron compounds in the groundmass occurs with increasing intensity with depth. The colour of the groundmass is greyer with depth and the sesquioxidic accumulations are redder and more numerous.

- In the B horizon a varying number of brownish-black sesquioxidic nodules with sharp external boundaries are also found. These nodules, sometimes enclosing altered rock fragments, are rounded due to transport and are probably pedorelicts which form part of the parent material.
MRIGINDIHI SERIES

1. General information and typifying pedon description


The Mrigindihi series is a member of fine loamy, mixed, hyperthermic family of Ultic Paleustalfs. They have yellowish red, sandy loam, very strongly acid, A horizons and yellowish red to red, sandy clay loam, strongly, to very strongly acid Bt horizons. They have developed on old alluvium in the undulating western part of West Bengal. These soils normally occur in upper pediment with slopes between 1.57 to 3%. The climate of the area is subtropical monsoonic; more than 60% rainfall is received during monsoon months of June to September. The mean annual air temperature is 27°C. Principal associated soil series are Sagpara and Bhulanpur. In topographical sequence Mrigindihi soils normally occur between Sagpara in the upper situation and Bhulanpur in the lower. Sagpara soils are shallow and Bhulanpur have laterite layer within series control section.
Typifying pedon: Mrigindihī sandy loam-degraded forest

Ap  0-15 cm: Reddish yellow to yellowish red (5YR 5/8 D) sandy loam, yellowish red (5 YR 4/8 M); moderate to weak medium subangular blocky breaking to granular; slightly hard, friable, non sticky and non plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal and mostly continuous simple tubular pores; pH 4.9; gradual smooth boundary.

A3  15-33 cm: Yellowish red (5 YR 5/8 D) sandy loam, yellowish red (5 YR 4/6 M); moderate to weak medium subangular blocky breaking to granular; slightly hard, friable, slightly sticky and non plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal tubular pores; pH 4.9; gradual smooth boundary.

Blt  33-59 cm: Yellowish red (5 YR 4.5/6 D) (5 YR 4/6 M) sandy loam; moderate to weak medium subangular blocky breaking to granular; slightly hard, friable, slightly sticky and non plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal tubular pores; thin patchy cutans; pH 5.2; diffuse smooth boundary.

B2lt  59-87 cm: Yellowish red (5 YR 4.5/6 D) (5 YR 4/6 M) sandy clay loam; moderate to weak medium subangular blocky breaking to granular; slightly hard, friable, slightly sticky and slightly plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal tubular pores; thin patchy cutans; pH 5.1; diffuse smooth boundary.

B22t  87-114 cm: Yellowish red (5 YR 4.5/6 D) (5 YR 4/6 M), sandy clay loam; moderate to weak medium sub-angular blocky breaking to granular; slightly hard, friable, sticky and plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal tubular pores; medium (2-5 mm) 1% ferromanganese semi hard to hard concretions; moderately thick patchy cutans on ped faces; pH 5.1 clear smooth boundary.
B31t 114-141 cm: Red (2.5 YR 4/6 D) sandy clay loam, dark red (2.5 YR 3.5/6 M); moderate medium subangular blocky hard, friable, sticky and plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal tubular pores; medium to coarse 3-5% concretions of semi hard to hard nature; patchy cutans on peds; pH 5.0; gradual smooth boundary.

B32t 141-165 cm: Red (2.5 YR 4.5/6 D) sandy clay loam, dark red (2.5 YR 3.5/6 M) moderate medium subangular blocky; hard, friable, sticky and plastic; common very fine to fine inped roots; common very fine to fine vertical and horizontal continuous simple tubular pores; 3-5% medium to coarse semi hard to hard ferromanganese concretions; patchy cutans in pores and forming sand bridges; 2-4 mm quartz gravels present; pH 4.5.

Range in characteristics: The thickness of the solum ranges from 140-185 cm which grades into gravelly sandy loam to sandy clay loam with ferromanganese concretions. The mineralogy of the regolith is mixed. The mean annual soil temperature is 27.8°C. The estimated mean summer soil temperature is 28.2°C and mean winter soil temperature is 21.9°C. The moisture regime is Ustic.

The colour of the Al horizon is light red (2.5 YR 6/8) to reddish yellow (7.5 YR 6/6). The most common colour is reddish yellow (5 YR 6/8). Texture of Al is loamy sand and sandy loam. The A horizon is strongly to very strongly acid. Few ferromanganese concretions may be present in the Bl and B2t horizon. Texture of argillic horizon varies from sandy clay loam to clay loam. The colour of Bt horizon varies from red (2.5 YR 4/6 M) to yellowish red (5 YR 4/8 M). Percentage of ferro-manganese concretions by volume in Bt horizon varies from 3 to 10 percent. Clay percentage in the control section varies from 19-24%. The B horizon is strongly to very strongly acid.

Competing series and their differentiae: Bhulanpore is the competing series. Bhulanpore soils are gravelly in the control section.
Drainage and permeability: Excessively drained with moderate permeability.

Use and vegetation: Under rainfed condition vegetable like sweet gourd and bitter gourd are cultivated. Direct sown paddy is practised with irrigation. These soils are cropped to wheat, potato and winter vegetables under irrigation. Under natural condition, Grass like Euphorbea laxil, Heteropogon contortus, Dicanthium annulatum, Cyperus rotundus (common sedge); shrubs like Croton spiceriflorum (Ban-tulasi) Lantana camera (Chotra) Vitex negundo (Nishinda); and tress of Bombax malabaricum (silk cotton tree) Ziziphus jujuba (kul), Aegle marmelos (Sirish), syzygium cumini and forest sp. like Acacia auriculiformis (Acacia) and Shorea robusta (Sal) are grown.

Distribution and extent: Undulating tract of Western part of Midnapore district and Southern part of Bankura district of West Bengal. These soils are very extensive covering about 15 to 18 percent of the undulating area of Western part of Midnapore and Southern part of Bankura districts.

Series proposed: West Bengal State Soil Survey Organisation of the Department of Agriculture.

Type location: Mouja-Jharia, P.S. Bishnupur District, Bankura, State West Bengal. About ¼ km south-west of Bishnupur Railway Station, approximately 23°03' N latitude and 87°15' E longitude.

Interpretation: Mrigindihi soils are important agriculturally and their soil characteristics indicate fairly good soil moisture air relationship and their response to management is expected to be good. But they need measures to check run-off losses and conserve moisture. There may be some loss of applied nitrogen due to leaching. They are expected to respond to phosphorus but there may be problem of fixation of applied phosphorus. They will respond to intensive input crops like vegetables under irrigation.
Management interpretation:

a. Inductive (based on physical productive potential of the series)
   1. Land capability sub-class: IIb.
   2. Irrigability sub-class: 2s

b. Quantitative (Management potential for crops under farmer's level and package of practices).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield Q/ha</th>
<th>farmers's level</th>
<th>package practices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rainfed</td>
<td>irrigated</td>
<td>rainfed</td>
</tr>
<tr>
<td>Aman Paddy</td>
<td>12.50</td>
<td>-</td>
<td>12.50</td>
</tr>
<tr>
<td>Aus Paddy</td>
<td>-</td>
<td>-</td>
<td>12.50</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>-</td>
<td>12.50</td>
</tr>
<tr>
<td>Vegetables:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brinjal</td>
<td>-</td>
<td>-</td>
<td>250.00</td>
</tr>
<tr>
<td>Tomato</td>
<td>-</td>
<td>-</td>
<td>120.00</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>125-00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweet Gourd</td>
<td>250-00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by NBSS & LUP, Calcutta

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Total Sand</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (% of &lt;2 mm)</th>
<th>Coarse fragments % of whole soil</th>
<th>Moisture %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>(2-0.05)</td>
<td>(0.05-&lt;0.002)</td>
<td>Silt Coarse (1-0.5) Medium (0.5-0.25) Fine (0.25-0.02) Very fine (&lt;0.02)</td>
<td></td>
</tr>
<tr>
<td>Al 0-15</td>
<td>69.90</td>
<td>15.99</td>
<td>14.11</td>
<td>2.34</td>
<td>10.93</td>
</tr>
<tr>
<td>A3 15-33</td>
<td>67.92</td>
<td>14.68</td>
<td>17.40</td>
<td>3.03</td>
<td>13.22</td>
</tr>
<tr>
<td>B1 33-59</td>
<td>64.84</td>
<td>15.16</td>
<td>20.00</td>
<td>3.55</td>
<td>15.84</td>
</tr>
<tr>
<td>B2lt 59-87</td>
<td>60.06</td>
<td>16.83</td>
<td>23.11</td>
<td>2.83</td>
<td>15.28</td>
</tr>
<tr>
<td>B31 114-141</td>
<td>60.53</td>
<td>16.49</td>
<td>22.98</td>
<td>8.23</td>
<td>17.27</td>
</tr>
<tr>
<td>B32 141-165+</td>
<td>57.38</td>
<td>17.43</td>
<td>25.19</td>
<td>11.49</td>
<td>13.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>&lt;0.002 mm Fe %</th>
<th>pH</th>
<th>Bulk iron</th>
<th>ECP</th>
<th>H2O</th>
<th>g/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>0.274</td>
<td>Trace</td>
<td>0.72</td>
<td>4.35</td>
<td>4.90</td>
<td>1.63</td>
<td></td>
</tr>
<tr>
<td>15-33</td>
<td>0.235</td>
<td></td>
<td>0.81</td>
<td>4.25</td>
<td>4.83</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>33-59</td>
<td>0.131</td>
<td></td>
<td>1.07</td>
<td>4.50</td>
<td>5.20</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>59-87</td>
<td>0.118</td>
<td></td>
<td>2.06</td>
<td>4.25</td>
<td>5.06</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>87-114</td>
<td>0.118</td>
<td></td>
<td>2.21</td>
<td>4.25</td>
<td>5.10</td>
<td>1.66</td>
<td></td>
</tr>
<tr>
<td>114-141</td>
<td>0.105</td>
<td></td>
<td>1.44</td>
<td>4.20</td>
<td>4.95</td>
<td>1.73</td>
<td></td>
</tr>
<tr>
<td>141-165+</td>
<td>0.091</td>
<td></td>
<td>1.14</td>
<td>4.50</td>
<td>4.45</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases</th>
<th>CEC</th>
<th>Exchangeable Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca Mg Na K Sum sum NH4OAc sodium %</td>
<td>sum</td>
<td>cations</td>
<td>CEC Ext. NH4OAc Iron</td>
</tr>
<tr>
<td></td>
<td>meq/100g</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>0-15</td>
<td>2.04 0.82 0.26 0.23 3.35 9.55 5.80</td>
<td>4.48</td>
<td>35.01</td>
<td>0.41</td>
</tr>
<tr>
<td>15-33</td>
<td>2.45 0.82 0.23 0.19 3.69 9.85 6.20</td>
<td>3.70</td>
<td>37.46</td>
<td>0.36</td>
</tr>
<tr>
<td>33-59</td>
<td>2.86 1.22 0.25 0.23 4.52 10.24 7.60</td>
<td>3.29</td>
<td>44.14</td>
<td>0.38</td>
</tr>
<tr>
<td>59-87</td>
<td>2.26 1.22 0.21 0.23 4.92 10.64 8.00</td>
<td>2.63</td>
<td>46.24</td>
<td>0.35</td>
</tr>
<tr>
<td>87-114</td>
<td>3.26 1.22 0.26 0.26 5.00 11.16 8.80</td>
<td>2.95</td>
<td>44.80</td>
<td>0.37</td>
</tr>
<tr>
<td>114-141</td>
<td>3.66 1.63 0.25 0.33 5.85 11.79 9.20</td>
<td>2.72</td>
<td>49.61</td>
<td>0.40</td>
</tr>
<tr>
<td>141-165+</td>
<td>4.48 2.04 0.26 0.44 7.22 12.28 9.60</td>
<td>2.71</td>
<td>58.79</td>
<td>0.38</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: one from the A horizon and three from the B horizon.

Depths: 0.5-15.5 cm (1), 39-54 cm (2), 93-108 cm (3) and 122-137 cm (4)

1. Depth: 0.5-15.5 cm

Macroscopic characteristics

Reddish brown, coarse textured, apedal soil material.

Micromorphological characteristics

Structure: Apedal soil material with a few, mainly irregular elongated voids, diam. up to 2 mm, less than 15 mm long and abundant interconnected equant voids, diameters up to 2 mm, most <1 mm. Randomly distributed.

Groundmass: The coarse textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material: 35 µm. Related distribution: enau-chitonic, locally porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz. A few organic fragments, mainly root fragments, are present. The fine material is largely clay-sized, includes common particles up to 35 µm and has a skel-masepic plasmic fabric masked by the red colour of the fine material.

Special features:

Associated with voids: Locally a few thin argillans, occasionally specked with black dots, in interconnected equant voids, most <1 mm.

: Common partly infilled voids with mineral aggregates, excrements as well as soil aggregates, including some mineral grains.

In the groundmass: Many nearly completely infilled voids, with mineral aggregates, excrements as well as soil aggregates, including some mineral grains. Around a part of these voids coatings of mainly fine-grained soil material occur.
2. Depth: 39-54 cm

Macroscopic characteristics

Yellowish red, medium textured, weak pedal soil material.

Micromorphological characteristics

Structure: Weak medium subangular blocky structure to which a few, intersected, voids belong. Other voids: a few, mainly irregular elongated voids, diam. up to 2 mm, less than 15 mm long and many interconnected equant voids, diameters up to 2 mm, most <1 mm. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive very coarse sand. Size limit coarse/fine material: 35 μm. Related distribution: porphyric/enau-chitonic. The coarse mineral material consists of a small variety of minerals, mainly quartz. The fine material is largely clay-sized and includes common particles up to 35 μm. The plasmic fabric cannot be determined. It is masked by the colour of the fine material.

Special features:

Associated with voids: Few to common thin argillans in interconnected equant voids, most <1 mm.

Common partly infilled voids with mineral aggregates, excrements as well as soil aggregates, including some mineral grains.

In the groundmass: Many nearly completely infilled voids, with mineral aggregates, excrements as well as soil aggregates, including some mineral grains.

Few infilled voids with clay-minerals, diam. voids <0.5 mm.

Few embedded charcoal fragments.

Few irregular sesquioxidic accumulations, mainly diffuse boundaries, diam. to 2 mm.
3. Depth: 93-108 cm

Macroscopic characteristics:

Yellowish red, medium textured, weak pedal soil material.

Micromorphological characteristics

Structure: Weak medium subangular blocky structure to which a few, intersected, voids belong. Other voids: a few, mainly irregular elongated voids, diam. up to 2 mm, less than 15 mm long and many interconnected equant voids, diameters up to 2 mm, most <1 mm. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 2.5 mm. Size limit coarse/fine material: 35 µm. Related distribution: porphyric/enau-chitonic. The coarse mineral material consists of a small variety of minerals, mainly quartz. The fine material is largely clay-sized and includes common particles up to 35 µm. The plasmic fabric is masked by the red colour of the fine material.

Special features:

Associated with voids: A few thin, often discontinuous, argillans in interconnected equant voids, most <1 mm.

: Common partly infilled voids, with mineral aggregates, excrements as well as soil aggregates, including some mineral grains.

In the groundmass: Many nearly completely infilled voids, with mineral aggregates, excrements as well as soil aggregates including some mineral grains.

: Few sesquioxide accumulations, clear boundaries, diam. up to 2 mm.

: Few remnants of a more or less horizontal lamination.
4. Depth: 122-137 cm

Macroscopic characteristics:

Red, medium textured, apedal soil material containing a few dark red and black mottles, diameters up to 8 mm.

Micromorphological characteristics

**Structure:** Apedal soil material with a few to common, mainly irregular elongated voids, diam up to 2 mm, less than 15 mm long and many interconnected equant voids, diameters up to 2 mm, most <1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to gravels of 2.5 mm. Size limit coarse/fine material 35 µm. Related distribution: porphyric, locally enau-chitonic. The coarse mineral material consists of a small variety of minerals, mainly quartz. The fine material is largely clay-sized and includes common particles up to 35 µm. The plasmic fabric is masked by the red colour of the fine material.

**Special features**

Associated with voids: Common partly infilled voids, with mineral aggregates, excrements as well as soil aggregates, including some mineral grains.

In the groundmass: Common nearly completely infilled voids with mineral aggregates, excrements as well as soil aggregates, including mineral grains.

: Few to common irregular shaped, sesquioxidic nodules, including argillans and complete infillings of clay minerals in internal small voids <0.5 mm, with clear and sharp external boundaries, diameters up to 8 mm; randomly distributed.

: Few remnants of a more or less horizontal lamination.
Short micromorphological description

Four thin sections are studied, one from the A horizon and three from the B horizon.
Depths: 0.5-15.5 cm (1); 39-54 cm (2); 93-108 cm (3) and 122-137 cm (4).

- The soil material is coarse textured in (1) and medium textured in (2), (3) and (4) and includes grain sizes up to and inclusive very coarse sand in (1) and (2) and includes gravels up to 2.5 mm in (3) and (4). The size limit coarse/fine material is 35 µm; the related distribution: in (1) enau-chitonic, locally porphyric; in (2) and (3): porphyric/enau-chitonic and in (4): porphyric, locally enau-chitonic.

The fine materials is largely clay-sized and includes common particles up to 35 µm. The plasmic fabric is masked by the red colour of the fine material, in (1) a skel-masepic plasmic fabric is detectable. The coarse mineral material consists of a small variety of minerals, mainly quartz. In (1) a few coarse organic fragments, mainly root-fragments, are present.

- The soil material is apedal in (1) and (4) and has a weak medium subangular blocky structure in (2) and (3) to which a few intersected voids belong. Other voids: a few in (1), (2) and (3) and a few to common in (4), mainly irregular, elongated voids, diam. up to 2 mm, less than 15 mm long, and abundant in (1) and many in (2), (3) and (4) interconnected equant voids, diameters up to 2 mm, most <1 mm. All randomly distributed.

- In the A horizon (1) and a large part of the B horizon (2, 3) occur thin argillans in small interconnected equant voids, diam. <1 mm. The quantities vary from locally a few in the A horizon (1), few to common in the top of the B horizon (2) to a few, often discontinuous argillans, in the middle part of the B horizon (3)

- Over the whole studied depths voids are partly or nearly completely infilled with mineral aggregates, excrements as well as soil aggregates and often include also some mineral grains. Partly infilled voids are common in the A and B horizon. Many voids are nearly
completely infilled with this material in the A and upper and middle part of the B horizon (1, 2, 3) decreasing to common deeper in the B horizon (4).

- A few embedded charcoal fragments are found in the upper part of the B horizon (2).

- Accumulations of sesquioxides occur in the whole B horizon. In the upper and middle part of the B horizon a few sesquioxidic accumulations are present, diam. up to 2 mm. The external boundaries of the accumulations are diffuse in the upper part of the B horizon (2) and clear in the middle part (3). Deeper in the B horizon (4) few to common sesquioxidic accumulations occur, irregular shaped, diam. up to 8 mm, with sharp external boundaries. In voids, diam. <0.5 mm, in these accumulations argillans are found and some voids are completely infilled with pure clay.

- A few remnants of a more or less horizontal lamination are present in the middle and deeper part of the B horizon (3, 4).
Mrigindih (2 photographs)

1. Remnants of ferri-argillans in small voids. B horizon (plain light)

2. Shaped mineral excrements partly filling an irregular void. B horizon (plain light)
Interpretation of the micromorphological data

Four thin sections are studied: one from the A horizon and three from the B horizon. Depths: 0.5-15.5 cm (1), 39-54 cm (2), 93-108 cm (3) and 122-137 cm (4).

- A number of features related to a former clay illuviation are present in the A and B horizons. They are most numerous in the top of the B horizon (2) and consist of few to common ferri-argillans. In the A horizon (1) and middle part of the B horizon (3) only a few ferri-argillans are present. These features are predominantly found in small voids, and do not occur in recently formed voids, which are present in small zones where the groundmass is not disturbed by faunal activity.

- The fauna causes considerable homogenization of the soil material. Over the whole studied zone, voids and irregular zones occur which are partly or completely filled with mainly mineral excrements. Partly infilled voids are common and many voids are almost completely infilled over the whole studied zone. Animals occasionally plaster the walls of voids, sometimes with quite a thick layer of fine-grained soil material. These coatings occur in the A as well as in the B horizon and can easily be mistaken for clay illuviation features.

- Sesquioxidic nodules occur, but are mainly restricted to the lower part of the B horizon (4). They generally have irregular shapes, sharp external boundaries and, in internal voids include argillans and completely infilled voids with clay. Diameters reach up to eight mm. These nodules are also a relict of former processes. The irregular and sharp external boundaries are due to animal activity.

**Conclusion:** In the studied pedon a real argillic B horizon was developed. The clay illuviation features are currently disappearing due to animal activity resulting in homogenisation. The present quantity of clay illuviation features is not sufficient for classification as an alfisol.
BHUBANESWAR SERIES

1. General information and typifying pedon description


The Bhubaneswar series is a member of the fine loamy, mixed, isohyperthermic family of Ultic Haplustalfs. They have reddish yellow to strong brown, loamy sand, very strongly acid A horizons and reddish brown to red, sandy clay loam to clay loam, very strongly acid B horizons over very hard Vesicular laterite C horizons.

They have developed on weathered ferruginous sandstone of Athgarh sandstone series of Gondwana system. These occur on upper pediments of 1 to 3 percent slope. The climate is sub-tropical monsoonic hot and humid with mean annual air temperature of 26.9°C and mean annual rainfall of 1517 mm. Principal associated soils are Andharua series, occur on flat ridges and belongs to fine loamy, mixed, hyperthermic family of Udic Paleustalfs. Aiginia series occur on slope breaks and belong to fine loamy, mixed, hyperthermic family of Plinthustalfs. Mendhasal series are fine loamy, mixed, hyperthermic family of Udic Haplustalfs.
Typifying pedon: Bhubaneswar loamy sand - cultivated.

Ap 0-13 cm: Yellowish red (5 YR 5/8 D) loamy sand, dark-red (2.5 YR 3/6 M); moderate medium sub-angular blocky; slightly hard, very friable, non-sticky and non-plastic; many fine to medium random simple tubular imped pores; many fine to medium fibrous roots; pH 4.7; gradual smooth boundary.

B1 13-27 cm: Yellowish red (5 YR 5/8 D) sandy loam, dark-red (2.5 YR 3.5/6 M); moderate medium sub-angular blocky; slightly hard, friable, slightly sticky and non-plastic; many fine to medium random simple tubular imped pores; many fine to medium fibrous roots; pH 4.8; gradual smooth boundary.

B2t 27-50 cm: Yellowish red (5 YR 5/6 D) sandy clay loam, red (2.5 YR 3.5/6 M); moderate medium, sub-angular blocky; slightly hard, friable, slightly plastic; many fine to medium random simple tubular imped pores; many fine to medium fibrous roots; few krotovinas of ants and termites; thin patchy clay coatings on ped faces; pH 4.9; gradual smooth boundary.

B22t 50-78 cm: Red (2.5 YR 5/8 D) sandy clay loam; (2.5 YR 4.5/6 M); moderate medium sub-angular blocky; hard, friable, sticky and slightly plastic; few ferro-manganese concretions of 2 to 5 mm size; coarse fragments of ferruginous nodules about 1 to 2% by volume; many fine to medium fibrous roots; few krotovinas of ants and termites; few medium thick patchy clay coatings on ped faces; pH 4.8; clear smooth boundary.

B23t 78-88 cm: Red (2.5 YR 5/8 D) gravelly loam; red (2.5 YR 4.5/6 M); massive; hard, friable sticky and plastic; ferro-manganese concretions of 2 to 5 mm size and coarse fragments of ferruginous nodules about 30% by volume; many fine interstitial and few vesicular medium pores; few thin patchy clay coatings on ped faces; pH 4.7; abrupt smooth boundary.

Ccn 88-165 cm: Vesicular gravelly hard laterite.

Range in characteristics: The thickness of the solum ranges from 65 cm to 1 m. If cultivated the A horizon is 12 cm thick. On eroded phase, it may reduce to 9 cm and left virgin, protected under forest, it may be 25 cm thick. There is a B1 horizon underlying A, whose thickness may range from 14 to
35 cm. B2t horizon may range in thickness from 20 to 40 cm which is characterised by thin patchy clay films, filling the decayed root channels or bridging the sand grains. There is a gravelly "murram" layer, consisting of ferruginous concretions and ferruginous nodules, underlain by Vesicular gravelly hard laterite. The estimated MAST in the temperature control section is 28.0°C, MSST is 28.4°C and MWST is 24.1°C. The moisture control section remains dry consecutively for more than 180 days, but is moist consecutively for more than 90 days. The moisture regime is ustic.

The colour of the surface soil ranges from reddish yellow to strong brown of hue 5 YR to 7.5 YR. The texture of A horizon ranges from loamy sand to sandy loam and structure is weak fine sub-angular blocky.

The colour of B2t horizon ranges from brown through reddish brown to red in hue 5 YR and 2.5 YR and value moist is 3 to 5 and chroma moist is 4 to 6. The structure is moderate medium sub-angular blocky and the texture ranges from sandy clay loam to clay loam. Very strongly to strongly acidic (pH 4.7 to 5.5). Percentages base saturation in the control section ranges from 45 to 60%.

Competing series and their differentiae: Competing soil series is Bermunda series situated on convex ridges on slope breaks which is moderately deep member of Dystrochrepts.

Drainage and permeability: Well drained with rapid permeability.

Use and vegetation: Under rainfed farming these soils are cropped to rice-fallow, rice-horse gram, or Groundnut Arhar or Ragi-Arhar or Mesta. With irrigation these soils are cropped to rice-greengram/blackgram/Sesamum/groundnut/maize. Under natural condition Argimone maxicana (Agara), Calotropis-Procera (Arakh) and Trees of C.Siamea (Chakunda), Madhuca latifolia (Mahua), Shorea robusta (Sal) and Bureai monos (Palas) are common.

Distribution and extent: Central Table land region of Orissa and in the adjoining humid parts of West Bengal and Bihar.

Series proposed: Department of Soils and Agricultural Chemistry, Orissa University of Agriculture and Technology.
Type location: Dryland Research Stn. at Bhubaneswar, of O.U.A.T.

Remarks: The hue of the dry soil colour actually is intermediate between 5 YR and 2.5 YR. Clay coatings on ped faces which are observed in the field need confirmation for argillans from micromorphology studies. Whether there is a lithologic discontinuity between B23t and Ccn needs confirmation from optical mineralogy studies.

These soils have a problem of crusting of the surface after a heavy rain and crusts are destroyed by cultural practices. Available moisture capacity of the soil is low and short duration of drought may subject, the crops under moisture stress. The soils subject to run-off loss of rains due to their nature of crusting. Research gaps exist for physico-chemical improvement of these soils. Phosphate fixation is a problem because of the presence of free-oxide of iron. Soils respond to liming for maize and fertilization in general. Under fertilization of 60 kg P₂O₅ and 40 kg K₂O/ha high yielding varieties of rice yield 300/grain of rice/ha.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
1. Land capability sub-class : IIIe
2. Irrigability sub-class : 2s
3. Fertility Management Potential: Low to medium
   (leaching losses of applied nitrogen is possible).

b) Quantitative (Management potential for crops under farmer's level and package of practices).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level (non-irrigated)</th>
<th>Package practices (non-irrigated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>Ragi</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Maize</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Mesta (fibre)</td>
<td>--</td>
<td>12</td>
</tr>
<tr>
<td>Sesamum</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Sunflower</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Groundnut</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Greengram</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Blackgram</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Horsegram</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Arhar</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>
## Tentative soil characterisation by NBSS & IUP, Calcutta

### Size class and particle diameter (mm)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Sand (&gt;0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&lt;0.002)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>% of &lt;2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>77.26</td>
<td>33.44</td>
<td>23.63</td>
<td>5.71</td>
</tr>
<tr>
<td></td>
<td>13-27</td>
<td>56.03</td>
<td>25.80</td>
<td>19.44</td>
<td>6.48</td>
</tr>
<tr>
<td>Blt</td>
<td>27-50</td>
<td>59.92</td>
<td>21.15</td>
<td>18.64</td>
<td>6.48</td>
</tr>
<tr>
<td>Bltt</td>
<td>50-78</td>
<td>54.22</td>
<td>16.45</td>
<td>14.03</td>
<td>5.65</td>
</tr>
<tr>
<td>Bltt</td>
<td>78-98</td>
<td>43.32</td>
<td>14.06</td>
<td>11.12</td>
<td>6.95</td>
</tr>
<tr>
<td>C</td>
<td>88-106</td>
<td>4.32</td>
<td>1.38</td>
<td>1.47</td>
<td>2.47</td>
</tr>
</tbody>
</table>

### Organic Carbonate as Caco3 and Bulk density

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>Carbonate as Calc %</th>
<th>Ext. as Fe %</th>
<th>Bulk density g/cc</th>
<th>Water Retention cm/cm</th>
<th>Cole cm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13</td>
<td>0.59</td>
<td>1.00</td>
<td>0.29</td>
<td>1.57</td>
<td>3.74</td>
<td>5.56</td>
</tr>
<tr>
<td>13-27</td>
<td>0.54</td>
<td>0.14</td>
<td>0.77</td>
<td>1.80</td>
<td>11.69</td>
<td>5.47</td>
</tr>
<tr>
<td>27-50</td>
<td>0.41</td>
<td>0.10</td>
<td>0.27</td>
<td>1.30</td>
<td>13.90</td>
<td>7.66</td>
</tr>
<tr>
<td>50-78</td>
<td>0.39</td>
<td>0.10</td>
<td>0.16</td>
<td>1.16</td>
<td>13.06</td>
<td>8.77</td>
</tr>
<tr>
<td>78-98</td>
<td>0.39</td>
<td>-</td>
<td>0.26</td>
<td>1.26</td>
<td>12.78</td>
<td>7.90</td>
</tr>
<tr>
<td>88-106</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Extractable bases

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Cations</th>
<th>Combined Cations</th>
<th>CEC</th>
<th>Ext. acidity</th>
<th>Exchangeable sodium ratio</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13</td>
<td>7.40</td>
<td>0.30</td>
<td>0.26</td>
<td>0.16</td>
<td>3.62</td>
<td>9.78</td>
<td>6.20</td>
</tr>
<tr>
<td>13-27</td>
<td>7.80</td>
<td>0.30</td>
<td>0.25</td>
<td>0.12</td>
<td>4.07</td>
<td>7.04</td>
<td>11.11</td>
</tr>
<tr>
<td>27-50</td>
<td>7.40</td>
<td>1.00</td>
<td>0.25</td>
<td>0.16</td>
<td>4.11</td>
<td>7.48</td>
<td>11.59</td>
</tr>
<tr>
<td>50-75</td>
<td>7.00</td>
<td>0.30</td>
<td>0.29</td>
<td>0.20</td>
<td>3.25</td>
<td>8.40</td>
<td>11.01</td>
</tr>
<tr>
<td>75-88</td>
<td>7.40</td>
<td>0.40</td>
<td>0.28</td>
<td>0.16</td>
<td>3.25</td>
<td>8.80</td>
<td>12.05</td>
</tr>
</tbody>
</table>

### Moisture %

- 7.15
- 11.19
- 12.02
- 9.09
- 0.77
- 0.65
- 0.50
- 0.32
3. Micromorphological data

One thin section is studied: derived from the B horizon.
Depth: 55-70 cm.

Macroscopic characteristics
Red, medium textured, pedal soil material.

Micromorphological characteristics

Structure: Weak medium sub-angular blocky structure to which a few irregular elongated, sometimes intersected, voids belong. Other voids: few to common elongated voids, widths up to 5 mm, lengths several cm and common equant voids, diam. up to 5 mm; randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to gravels of 3 mm in diameter. Size limit coarse/fine material is 25 µm.
Related distribution: mainly porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz. The coarse organic material consists of a few root fragments. The fine material is largely clay-sized and includes a few particles up to 25 µm. The plasmic fabric cannot be determined; it is masked by the red colour of the fine material.

Special features:

Associated with voids: Common voids partly filled with mineral aggregates, excrements as well as soil aggregates, and mineral grains. A few of these voids have diameters of several cm, most are less than 1 cm in diameter, randomly distributed.

In the groundmass: Common to many nearly completely filled voids with mineral aggregates, excrements as well as soil aggregates, and mineral grains. The largest part consists of excrements. These voids are often interconnected and have diffuse or clear external boundaries.

Few rounded off dark coloured nodules, consisting of sesquioxides, including mineral grains, mainly quartz and some rare ferriargillans or clay infillings, diam. up to 4 mm; randomly distributed.
Short micromorphological description

One thin section is studied: derived from the B horizon.

Depth: 55-70 cm.

- The soil material is medium-textured and includes grain sizes up to gravels of 3 mm in diameter. The size limit coarse/fine material is 25 µm; the related distribution: mainly porphyric. The fine material is largely clay-sized and includes a few particles up to 25 µm. The plasmic fabric is practically isotropic, due to the red colour of the fine material. The coarse mineral material consists of a small variety of minerals, mainly quartz. The coarse organic material consists of a few root fragments.

- The soil material has a weak medium subangular blocky structure to which a few irregular, elongated, sometimes intersected, voids belong. Other voids: few to common elongated voids, widths up to 5 mm, lengths several cm and common equant voids, diam. up to 5 mm; randomly distributed.

- Common to many voids are completely filled with mineral aggregates, which are mainly excrements, but also include soil fragments and some mineral grains. Common voids are only partly filled with the same materials. The voids are often interconnected and have diffuse or clear external boundaries. The diameters of these voids can be several cm. Some of the voids have, sometimes thick, coatings of mainly fine-grained soil materials along the walls.

- Few to common papules occur embedded in the groundmass or in excrements.

- In the groundmass a few rounded off dark coloured nodules are present, mainly consisting of sesquioxides. They include some mineral grains, mainly quartz and have, in internal voids, some rare ferriargillans or complete infillings of clay. Diameters of these nodules up to 4 mm, randomly distributed.
1. Thick plastering of a faunal void wall with fine-grained material. B horizon (plain light).

2. Two biological voids: (1) longitudinal section with root-remnants and infilling of mineral and organic excrements, including some mineral grains, and (2) a cross-section with some mineral grains and excrements. B horizon (plain light).
4. Interpretation of the micromorphological data

One thin section is studied: derived from the B horizon.
Depth: 55-70 cm.

- In this part of the B horizon the influence of soil animals is dominant. Most of the groundmass is homogenized as a result of deposit-feeding. Animals consume soil material, except for large mineral grains and nodules, and produce varying void systems. Most of these voids are partly or completely filled with, in the main, shaped mineral excrements and also contain soil fragments and some larger mineral grains. These voids are often interconnected, thus largely determining the weak subangular blocky structure. Some of the voids have, often thick, coatings of fine-grained soil material along the walls. These coatings are the result of the plastering of the walls by animals and resemble argillans in the field.

- Remnants of a former clay illuviation occur. Due to the homogenization of the fauna only few to common papules, embedded fragments of clay-illuviation features, are observed in the groundmass and in excrements. Some rare, undisturbed ferriargillans and infillings of clay occur in small voids in the sesquioxidic nodules. The few sesquioxidic nodules occurring are inherited features of former processes. They are rounded off due to local dislocations as a result of faunal activity.

Conclusion: The studied Bhubaneswar pedon is tentatively classified as an Ultic Haplustalf. In the studied thin section few to common remnants of clay illuviation features (papules) are present. No clay illuviation features are present in situ. This is due to high animal activity resulting in homogenization of the groundmass. The present quantity of clay illuviation features is too low for classification as an alfisol. As only one thin section of the B horizon is studied the extent of the homogenization cannot be given. The clay coatings mentioned in the pedon description are most probably coatings formed as result of animal activity.
SOILS OF THE COASTAL AND DELTAIC REGION

1. General information and identifying group description

The soils described in the New York Geochemistry Program are from the

Coastal and Deltaic Region. They are

brown to dark brown, silty clay loam to loamy sand, and have
different soil profiles characterized by distinct

textural and chemical differences. These soils are

associated with coastal and estuarine environments,

and are subject to frequent flooding and

exposure to saltwater intrusion. The climate is subtropical

and humid, with high temperatures and significant

rainfall. These soils are important for agriculture

and wetland ecosystems.

2. Soil description

The coastal and deltaic region soils are

characterized by a well-drained strata of

sandy loam to sandy clay loam, with

occasional clayey layers. The topsoil is

brown to dark brown, with a distinct

subsoil layer of gray to dark gray

clay loam. The subsoil and

subsoil layers are well stratified,

with distinct horizons indicating

different soil development stages.

3. Soil fertility

The coastal and deltaic region soils

are generally well-drained and

fertile, with high organic matter

content. The high rainfall and

temperature contribute to

considerable leaching of nutrients,

thereby maintaining a high

nutrient status. The soils are

important for agriculture and

wetland ecosystems, providing

a suitable environment for

plant growth and biodiversity.

4. Soil management

The coastal and deltaic region soils

require careful management to

maintain their fertility and

productivity. Practices include

 proper drainage, soil

amendments, and

rotation of crops to

improve soil health. The

high nutrient status and

fertility make these soils

suitable for intensive

agricultural use.

5. Conclusion

The coastal and deltaic region soils

are characterized by distinct

textural and chemical differences,

and are subject to frequent

flooding and saltwater intrusion.

Their high fertility and nutrient

status make them suitable for

agriculture and wetland

ecosystems. Proper management

is necessary to maintain their

productivity and health.
MOTTO SERIES

1. General information and typifying pedon description


The Motto series is a member of fine, mixed, hyperthermic family of Vertic Haplaquepts. They have yellowish brown to dark brown, silty clay loam A horizons and grayish brown to dark gray, silty clay loam to silty clay B horizons which have distinct brownish yellow mottles over gray to dark gray silt loam C horizons. These are developed on deltaic and coastal alluvium, subjected to inundation by brackish water located on flat bottom land of concave relief. The climate is sub-tropical, sub humid. The mean annual air temperature is 26.9°C and the mean annual rainfall is 1626 mm. These soils are extensive on a narrow strip of land (2 to 15 km wide) along coastal belt of Northern Orissa and adjoining portions of West Bengal. Principal associated soil series are Nalgunda series, Permanandapur series and Nuanai series. Nalgunda series does not exhibit cracks, is fine silty in the textural control section and belongs to the fine silty, mixed hyperthermic family of Typic Haplaquepts. Permanandapur series lack aquic moisture regime, is of lighter texture in the textural control section and belongs to Fluventic Ustochrepts. Nuanai series exhibits aeric properties and belongs to vertic Aeric Halaquepts.

---

Climatic Data and Soil Water Balance
SERIES MOTTO

- PE  Precip  Temp.

---
Typifying pedon: Motto clay loam-cultivated

Ap 0-14 cm: Dark grayish brown (10 YR 4/2 M) silty clay loam; massive; hard, firm, sticky and plastic; very few (1%) ferro manganese concretions of size greater than 2 mm; cracks of width 1-2.5 cm; many fine vertical tubular inped pores; abundant very fine to fine and frequent medium roots; abrupt smooth boundary;

B21 14-28 cm: Grayish brown (2.5 Y 5/2 M) silty clay loam; strong coarse angular blocky; extremely hard, very firm, very sticky and very plastic; few (2%) fine to medium soft to moderately hard ferromanganese concretions; cracks of width 1-2.5 cm; shining pressure faces, possibly due to stress; many fine vertical tubular pores; abundant fine pores and frequent medium roots; silicate clay cutans observed on vertical and horizontal ped faces; gradual smooth boundary;

B22g 28-54 cm: Grayish brown (2.5 Y 5/2 M) silty clay; strong coarse angular blocky; extremely hard, very firm, very sticky and very plastic; few (2%) fine to medium, soft to moderately hard ferro-manganese concretions; cracks of width 1-2.5 cm; common, fine faint olive yellow (2.5 Y 6/6) mottles; shining pressure faces, possibly due to stress; many fine vertical, tubular pores; frequent very fine to fine roots; clay cutans observed on vertical and horizontal ped faces; pH 7.5; gradual smooth boundary.

B23g 54-73 cm: Dark gray (2.5 Y 4/0 M) silty clay; moderately strong coarse angular blocky; hard, friable, sticky and slightly plastic; very few (1%) fine ferromanganese concretions and stray (1%) fine to medium calcareous nodules; cracks of width 1 cm, upto 73 cm depth; common fine faint light olive brown (2.5 Y 5/6) mottles; shining pressure faces, possibly due to stress; many fine continuous vertical, tubular pores; frequent very fine to fine roots; clay cutans observed on vertical and horizontal ped faces; pH 7.8; gradual smooth boundary.
Clg 73-98 cm: Gray to dark gray (2.5 Y 4.5/0) silty clay loam; moderately strong coarse angular blocky; hard, sticky and slightly plastic; stray (1%) fine to medium soft ferromanganese concretions; common medium distinct yellowish brown (10 YR 5/6) mottles; many fine continuous vertical tubular pores; few very fine to fine roots; pH 7.9; diffuse smooth boundary.

II C2g 98-129 cm: Dark gray (2.5 4/0 M) silt loam; stratified slightly hard, friable, slightly sticky and slightly plastic; stray fine to medium soft ferromanganese concretions; common, medium distinct yellowish brown (10 YR 5/8) mottles; many, fine continuous vertical tubular pores; pH 8.0.

Range in characteristics: The thickness of the solum is 62 to 115 cm which is underlain by stratified alluvium of varying texture ranging from sandy loam to clay. The mineralogy of the regolith is mixed. The estimated mean annual soil temperature at a depth of 50 cm from the soil surface is 24.4°C to 27.7°C and that of mean summer and mean winter temperature is 28.8°C and 21.4°C respectively. The moisture regime is aquic. During monsoon (July to October) the lands are submerged under water and subjected to inundation with brackish water that comes from the Bay of Bengal through rivulets and cracks during high tides.

The A horizon consists of a ploughed surface layer and its depth is upto 15 cm. The colour of the A horizon is of 10 YR hue and ranges from yellowish brown to dark brown, with chroma of 3 to 4. The texture of the A horizon is clay loam and structure, weak medium sub-angular blocky.

The subsurface diagnostic horizon is cambic and the colour of the B horizon is of 10 YR to 2.5 Y hue with value ranging from 3 to 5 chroma ranging from 2 to 0, grayish brown to dark gray. The lower layer of cambic horizon and the underlying C horizon often exhibit gleying. Distinct mottles of brownish yellow to yellowish brown (10 YR 5/6) are present on the ped faces. The texture of the B horizon ranges from silty clay loam to silty clay.
and structure is of coarse prismatic breaking to strong coarse angular blocky. The structure of the stratified alluvium is moderate coarse platy to moderate coarse angular blocky. Occassionally few fine to medium, soft to moderately hard ferromanganese concretions and stray fine to medium calcareous nodules are met with within the subsurface horizons. Pressure faces, originated due to stress cutans are sometimes observed on horizontal and vertical ped faces in clayey layers; cracks of width ranging from 1 to 5 cm and of depth ranging from 50 cm to 152 cm are the characteristic features of these soils.

Competing series and their differentiae: Competing soil series is Nuanai series, which is also one of the associated soil series.

Drainage and permeability: Poorly drained with slow permeability.

Use and vegetation: The Motto soil series is under rice cultivation during khariff season. During rabi season green gram, barley, wheat and arum are grown. Natural vegetation consists of Azadirachta indica (Neem), Mangifera indica (Mango), Tamarindus indica (Tamarind), Pandanus fascicularis (Keya), Acacia arabica (babul) and Ficus curea (Fig).

Distribution and extent: Extensively distributed in flood plain, alluvial Deltaic and coastal tracts in Balasore district of Orissa.

Series Proposed: Department of Soils and Agricultural Chemistry, Orissa University of Agriculture and Technology.

Type location: Agricultural Farm, Motto village, P.S. Chandbali, Bhadrak subdivision of Balasore district, Orissa.

Remarks: These soils are saline with conductivity of the saturation extract during summer going as high as 27.5 mmho/cm in the
subsurface horizon that decreases with depth in the profile. Soils are neutral to moderately alkaline with E.S.P. exceeding 15 and SAR greater than 13.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability subclass - IIw
   2. Irrigability subclass - 2d (Salinity problem and drainage limitation)
   3. Fertility management potential: Medium
   4. Management potential/productivity: Medium

b) Quantitative: (Management potential of crops under Farmer's level and package of practices)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmers practice</th>
<th>Package of practice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unirrigated</td>
<td>Unirrigated</td>
</tr>
<tr>
<td>Rice (Kharif)</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Green Gram</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Barley</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>
2. Tentative soil characterization by NBSS & LUP, CALCUTTA

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Size class and particle diameter (μm) % of &lt;2 mm</th>
<th>Coarse fragments (μm)</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total (2-0.05)</td>
<td>Sand (0.05-&lt;0.002)</td>
<td>Silt (0.05-&lt;0.002)</td>
</tr>
<tr>
<td>Ap</td>
<td>0-14</td>
<td>10.68</td>
<td>51.48</td>
<td>37.84</td>
</tr>
<tr>
<td></td>
<td>14-28</td>
<td>8.15</td>
<td>52.62</td>
<td>39.23</td>
</tr>
<tr>
<td></td>
<td>28-54</td>
<td>5.93</td>
<td>50.63</td>
<td>43.44</td>
</tr>
<tr>
<td></td>
<td>54-73</td>
<td>5.74</td>
<td>46.47</td>
<td>45.97</td>
</tr>
<tr>
<td>Clg</td>
<td>73-98</td>
<td>6.79</td>
<td>54.21</td>
<td>39.00</td>
</tr>
<tr>
<td>Ilc2g</td>
<td>98-129+</td>
<td>8.79</td>
<td>65.00</td>
<td>26.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>Organic carbon</th>
<th>Carbonate &lt;0.002</th>
<th>Ext. pH Fe (1:1)</th>
<th>Bulk density KCl H2O g/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14</td>
<td>0.96</td>
<td>tr</td>
<td>0.64</td>
<td>5.6</td>
</tr>
<tr>
<td>14-28</td>
<td>0.40</td>
<td>&quot;</td>
<td>0.63</td>
<td>6.3</td>
</tr>
<tr>
<td>28-54</td>
<td>0.26</td>
<td>&quot;</td>
<td>0.53</td>
<td>6.4</td>
</tr>
<tr>
<td>54-73</td>
<td>0.19</td>
<td>&quot;</td>
<td>0.72</td>
<td>6.9</td>
</tr>
<tr>
<td>73-98</td>
<td>0.08</td>
<td>&quot;</td>
<td>0.37</td>
<td>7.0</td>
</tr>
<tr>
<td>98-129+</td>
<td>0.05</td>
<td>&quot;</td>
<td>0.22</td>
<td>7.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>Extractable bases (2Bla)</th>
<th>CEC</th>
<th>Exchangeable sodium %</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
<td>Sum</td>
</tr>
<tr>
<td>0-14</td>
<td>8.40</td>
<td>7.20</td>
<td>5.64</td>
<td>1.84</td>
<td>23.08</td>
</tr>
<tr>
<td>14-28</td>
<td>8.80</td>
<td>11.60</td>
<td>4.68</td>
<td>1.53</td>
<td>26.61</td>
</tr>
<tr>
<td>28-54</td>
<td>8.40</td>
<td>11.20</td>
<td>3.44</td>
<td>1.28</td>
<td>24.62</td>
</tr>
<tr>
<td>54-73</td>
<td>8.40</td>
<td>10.00</td>
<td>4.68</td>
<td>1.58</td>
<td>25.46</td>
</tr>
<tr>
<td>73-98</td>
<td>8.00</td>
<td>8.80</td>
<td>5.10</td>
<td>2.04</td>
<td>23.94</td>
</tr>
<tr>
<td>98-129+</td>
<td>8.00</td>
<td>8.00</td>
<td>4.52</td>
<td>1.02</td>
<td>21.54</td>
</tr>
</tbody>
</table>

---

This site was extensively distributed in flood plains of the Ganges.Briefly, the soil texture is a balance of district, Orissa.
3. Micromorphological data

Two thin sections are studied: one from the B-horizon and one from the C-horizon
Depths: 50-65 cm (1) and 79-94 cm (2)

1. Depth: 50-65 cm

Macroscopic characteristics: Dark grayish brown, heterogeneous, fine textured pedal soil material, containing a few dark coloured sesquioxidic nodules up to 3 mm in diameter.

Micromorphological characteristics

Structure: Moderately coarse angular blocky structure, to which a few, intersected, elongated voids belong. Other voids. Common elongated voids up to 3 mm wide, most < 1 mm, less than a few centimeters long and common equant voids, diameters up to 3 mm, most < 1 mm. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive fine sand. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The distances between coarse grains in the fine mass vary considerable from one area to another in the groundmass. The coarse mineral material consists of a variety of minerals, which mainly are fresh or slightly altered. The fine material is largely clay-sized, contains a few particles up to 5 µm and has a strong vo-masepic plasmic fabric.

Special features:

Associated with voids: Common cutans of mainly fine material (< 5 µm) in equant and elongated voids. A few cutans are composed of only clay minerals.

: A few voids partly infilled with mineral aggregates, which are excrements.

In the groundmass : Many voids infilled with soil material, which consist of only fine grained or mixtures of varying quantities of coarse and fine material which can be laminated. In some voids argillans were present before complete infilling. Many of the
infilled voids show deformations of the original shapes.

: Few sesquioxidic nodules, generally rounded and with clear external boundaries, diameters up to 3 mm. Randomly distributed.

: Common small, irregular shaped iron accumulations with diffuse external boundaries. Diameters up to 3 mm, Randomly distributed.

: One carbonate nodule, with radial internal structure, diameter 3 mm.

2. Depth: 79-94 cm

Macroscopic characteristics: Dark gray, heterogeneous, medium textured, weak pedal soil material, locally finely laminated, containing a few sesquioxidic accumulations up to 3 mm in diameter.

Micromorphological characteristics

Structure: Weak coarse angular blocky structure, to which a few, intersected, elongated voids belong. Other voids: few to common elongated voids up to 3 mm wide, most < 1 mm, less than a few cm long and common equant voids, diameters up to 3 mm, most < 1 mm. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive fine sand. Size limit coarse/fine material: 5 µm. Related distribution: porphyric. The distances between coarse grains in the fine mass vary considerable from one area to another especially in the laminated zones. The coarse mineral material consists of a variety of minerals, which mainly are fresh or slightly altered. The fine material is largely clay-sized, contains a few particles up to 5 µm and has a strong wo-masepic plasmic fabric.

Special features:

Associated with voids: Common cutans of mainly fine material (< 5 µm) in equant and elongated voids.

: Few neosesquans around equant or elongated voids.
In the groundmass: Common infilled voids with soil material, which can be only fine grained or mixtures of varying quantities of coarse and fine material which can be laminated. Some infilled voids had a neosesquan before infilling.

- Common passage features containing several different shapes and sizes of excrements.
  - Few striotubules, diam. < 3 mm.
  - Locally zones with fine sedimentary lamination.
  - Few sesquioxidic and iron accumulations with clear or diffuse external boundaries, diameters up to 3 mm. Randomly distributed.
Motto (2 photographs)

1. Passage features in intertidal deposits.
   Coarse-grained, ellipsoidal excrements with a fine-grained wall. Sesquioxides have accumulated in a few excrements. C horizon (plain light)

2. Infilling of coarse-grained material in a faunal channel. C horizon (plain light)
Interpretation of the micromorphological data

Two thin sections are studied: one from the B horizon and one from the C horizon. Depths: 50-65 cm (1) and 79-94 cm (2).

- The studied zone is a sediment that became finer-grained and less laminated with continuing accretion. It forms part of a former intertidal-flat deposit. Besides geogenetic lamination features characteristic of pedogenesis in unripened intertidal deposits are also found. Marine macro-fauna causes; the common passage features and the few striotubules present in the C horizon (2), and a number of voids in all studied zones. Neosesquans are formed along some of these voids. They are the result of redox reactions due to aeration of the ripening sediment. Many of the voids formed shortly after sedimentation are infilled with soil material, which may be either only fine-grained or mixtures of different granular compositions. The infillings are sometimes laminated. These infillings are also due to pedogenesis in unripened sediment and are formed when semi-fluid soil material from the surface flows into voids. These infillings often show deformations of original shape.

- The present structure, moderate (1) and weak (2) coarse angular blocky is mainly due to ripening of the sediment. The other more recent voids are produced by flora and fauna. In these voids cutans of fine-grained material (<5 μm) are commonly found. The cutans can be due to periodical wet conditions, whereby soil material on the surface becomes water saturated and flows into voids, or can be due to floodings or inundations with sediment-loaded water.

- Iron and sesquioxidic nodules are common in the studied zone. They are small, diameters reach up to 3 mm, and have diffuse external boundaries and irregular shapes.

Remark: The soil is developed in coastal alluvium. The structure present is primary determined by physical ripening and need not to be vertic.
1. General information and typifying pedon description


Dandi series includes moderately drained, deep, dark grayish brown to very dark grayish brown soils formed in marine alluvium. These soils usually occur on slightly concave basins in deltas along the sea shore. The topography is level to nearly level with gradients ranging from 1 to 2%. The soil pedons have ABC profiles with very dark grayish brown clayey A horizons grading to dark brown to dark grayish brown clayey and prismatic B horizons underlain by dark brown to dark yellowish brown clay loam C horizons. A thin pulvarised layer of about 2 cm thickness is observed usually on the surface. Coarse columnar structure followed by dark prismatic to massive in subsoil layers. These soils have been classified in India as "Saline alkali soils". The climate is tropical subhumid with mean annual temperature 27 to 28°C rising to Max. 36°C in May and falling to 15°C in January in most of the years. The mean annual rainfall is 120 cm of which about 94% is received during summer rain period (June-Sept.). The principal soil associates are Lalitpur (Chinam) series which are mod. deep to deep Inceptisols formed in recent alluvium.

Dandi series comprises members of fine, montmorillonitic, hyperthermic, deep, family of Vertic Halaquepts.

**Typifying pedon**: Dandi clay loam - waste land (Khar land)

*All*  
0-2 cm: Dark greyish brown (10 YR 4/2 M) clay with salt efflorescence; many medium oblique tubular pores; pH 7.6; abrupt smooth boundary.

*All2sa*  
2-17 cm: Very dark greyish brown (10 YR 3/2 M) clay, light brownish grey (10 YR 6/2 D); moderate very coarse
columnar structure breaking into strong coarse angular blocky; salt encrustations on ped faces; hard, firm, very sticky and very plastic; strongly effervescent; many fine discontinuous oblique and horizontal pores; pH 8.0; clear smooth boundary.

B21sa  17-53: Dark brown (10 YR 3/3 M) clay, very pale brown (10 YR 7/3 D); moderate coarse prismatic structure breaking to strong coarse angular blocky with pressure faces; hard, firm, very sticky and very plastic; strongly effervescent; white salt patches on dry peds; few very fine oblique inped pores; pH 8.0; diffuse smooth boundary.

B22sa  53-75 cm: Dark brown (10 YR 3/3 M) clay; yellowish brown (10 YR 5/4) mottles; coarse prismatic structure breaking to strong coarse angular blocky with pressure faces; firm, very sticky and very plastic; strongly effervescent; few very fine discontinuous oblique inped and exped pores; pH 8.2; diffuse smooth boundary.

B3sa  75-96 cm: Dark greyish brown to very dark greyish brown (10 YR 3.5/2 M) clay; few prominent dusky red (2.5 YR 3/2) mottles; moderate coarse angular blocky structure with pressure faces; firm, very sticky and very plastic; few brown (10 YR 5/3) sand streaks; few iron-manganese concretions; strongly effervescent; very fine irregular pores; pH 8.3; abrupt smooth boundary.

Csa  96-155+ cm: Dark brown to dark yellowish brown (10 YR 3/3, 4/4 M) clay; moderate medium subangular blocky structure with prominent pressure faces; firm, very sticky and very plastic; white salt encrustations on dry peds; violently effervescent; pH 8.7.

Range in characteristics: The thickness of the solum ranges from 87 to 108 cm. The texture of the fine earth in the A horizon ranges from clay loam to clay and colour varies from dark grayish brown to very dark grayish brown in hue of 10 YR. The colour of the B horizon is in hue of 10 YR having moist value 3 and 3.5 with chroma 3 and 2 for moist soils. The matrix in the B horizon shows distinct mottled
patches. The ped interior shows streaks of red mottles in hue of 2.5 YR with value 2.5 and chroma 2. Fine salt coating in the colour notation of 10 YR 8/1 and 10 YR 8/2 is observed when the matrix is dried. The pedality of the A horizon is columnar in the upper part followed by coarse prismatic in the lower subsoil layers. The soil reaction is mildly to mod. alkaline and EC varies from 0.57 to 10.3 mmhos/cm through the pedon. The ground water table is pretty high with high capillary fringe. The moisture regime in the upper few centimeters of the control section ranges at or below wilting point while the remaining part remains at or above field capacity and lowest layers remain saturated at least for 3 months in most of the years.

**Competing series and their differentiae:** Competing soils are those of Att series. Att soils are moderately deep and solum extends up to 80 cm with a cambic horizon transitional to C horizon. E.S.P. decreases along with depth and there is no salic horizon that remain saturated for 1 month or more.

**Drainage and permeability:** Imperfectly to poorly drained with very slow permeability.

**Ground water table:** The ground water table fluctuates between one and two metre of the surface with high capillary fringe.

**Vegetation:** Xerophytes and halophytes, cultivated crop-paddy.

**Distribution and extent:** These soils extend along the coastal parts of Bulsar district.

**Type location and series established:** Dandi clay loam, village Dandi, about 1 Km. east of village Dandi, Taluka Navsari, Distt. Bulsar, Gujarat State.
2. Tentative soil characterisation by NBSS & LUP, NAGPUR

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Sand (0.05-0.002)</th>
<th>Silt (&lt;0.002)</th>
<th>Clay (&lt;2 mm)</th>
<th>Coarse (&gt;0.002)</th>
<th>Medium (0.05-0.25)</th>
<th>Fine (0.25-0.002)</th>
<th>Whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Size class and particle diameter (mm), % of &lt;2 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>A12</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>B22</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>HIC</td>
<td>27.8</td>
<td>31.0</td>
<td>40.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>28.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>Carbonate</th>
<th>pH</th>
<th>E.C.</th>
<th>Bulk density/cm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% &lt;2 mm (1:1)</td>
<td>(1:1)</td>
<td>(1:2)</td>
<td>g/cc</td>
<td>cm/cm</td>
</tr>
<tr>
<td>0-2</td>
<td>6.5</td>
<td>1.4</td>
<td>6.9</td>
<td>7.6</td>
<td>&gt;15</td>
</tr>
<tr>
<td>2-17</td>
<td>5.4</td>
<td>1.4</td>
<td>7.1</td>
<td>8.0</td>
<td>&gt;15</td>
</tr>
<tr>
<td>17-53</td>
<td>4.9</td>
<td>2.9</td>
<td>7.1</td>
<td>8.0</td>
<td>&gt;15</td>
</tr>
<tr>
<td>53-75</td>
<td>4.7</td>
<td>5.3</td>
<td>7.2</td>
<td>8.2</td>
<td>&gt;15</td>
</tr>
<tr>
<td>75-96</td>
<td>4.9</td>
<td>6.2</td>
<td>7.1</td>
<td>8.3</td>
<td>&gt;15</td>
</tr>
<tr>
<td>96-155+</td>
<td>4.13</td>
<td>21.1</td>
<td>7.2</td>
<td>8.7</td>
<td>&gt;15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases</th>
<th>CEC</th>
<th>Exchangeable sodium</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
<td>Sum</td>
</tr>
<tr>
<td></td>
<td>meq/100g</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2</td>
<td>16.0</td>
<td>16.0</td>
<td>23.2</td>
<td>2.5</td>
<td>69.7</td>
</tr>
<tr>
<td>2-17</td>
<td>15.0</td>
<td>16.0</td>
<td>20.2</td>
<td>3.0</td>
<td>57.2</td>
</tr>
<tr>
<td>17-53</td>
<td>16.0</td>
<td>14.0</td>
<td>26.7</td>
<td>3.5</td>
<td>56.2</td>
</tr>
<tr>
<td>53-75</td>
<td>12.0</td>
<td>10.0</td>
<td>22.8</td>
<td>3.5</td>
<td>48.3</td>
</tr>
<tr>
<td>75-96</td>
<td>11.0</td>
<td>13.0</td>
<td>20.6</td>
<td>3.5</td>
<td>48.1</td>
</tr>
<tr>
<td>96-155+</td>
<td>8.0</td>
<td>6.0</td>
<td>14.6</td>
<td>2.8</td>
<td>31.4</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: both derived from the B horizon. Depths: 53-68 cm (1) and 76-91 cm (2)

1. Depth: 53-68 cm

Macroscopic characteristics

Dark brown, fine textured, pedal like, fine laminated soil material.

Micromorphological characteristics

Structure*: The soil material looks coarse prismatic subdivided into moderate coarse angular blocky peds, to which few to common elongated voids, commonly intersected, belong. Other voids: few elongated voids, widths up to about 3 mm, lengths a few centimeters, and equant voids, \( \phi \) up to about 3 mm. Randomly distributed.

Groundmass: The fine grained soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 15 \( \mu \)m. Related distribution: mainly porphyric; in sand laminae: monic. The coarse material consists of a variety of minerals which are fresh or nearly fresh. The fine material is largely clay-sized, contains a few particles up to 15 \( \mu \)m and has an aseptic plasmic fabric. The laminae are composed either of fine material, coarse and fine material or only coarse material, including fine sand laminae. The majority of the laminae are composed of fine material and of mixtures of coarse and fine material.

Special features

Associated with voids: Few coatings of fine material around voids.

: Few manganese neocutans.

: Locally along the walls of some voids occur salt crystals.

* Structure: The structure visible is due to drying of unripened soil material (artefact). The real structure is not detectable.
- 755 -

: Around a few voids in fine-grained laminae pressure affected zones, with orientation of clay domains are present.

In the groundmass:

: Common passage features, of several faunal species.

: Few infillings of mainly fine material.

: Few manganese accumulations, with diffuse boundaries.

: Few bio-geogenetic laminae, composed of excrements.

: Common small snails

: Common small carbonate nodules, composed of mainly small carbonate particles.

2. Depth: 76-91 cm

Macroscopic characteristics

Dark brown, fine textured, pedal-like, fine laminated soil material.

Micromorphological characteristics

Structure*: The soil material looks coarse prismatic, subdivided into moderate coarse angular blocky peds to which few to common elongated voids, commonly intersected belong. Other voids: few elongated voids, widths about 2 mm, length up to a few cm and a few equant voids, Ø up to about 2 mm. Randomly distributed.

Groundmass: The fine grained soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 15 µm. Related distribution: mainly porphyric; in sand laminae: monic. The coarse material consists of a variety of minerals which are fresh or nearly fresh. The fine material is largely clay-sized, contains a few particles up to 15 µm and has in asepic plasmic fabric. The present laminae are composed ether of fine material, fine and coarse material and only coarse material including fine sand laminae.

* Structure: The structure visible is due to the drying of unripened soil material (artefact). The real structure is not detectable.
1. Passage features in intertidal deposits. The dark coloured ellipsoidal features are fine-grained mineral excrements. B horizon (plain light)

2. Sedimentary lamination. B horizon (plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied: both derived from the B horizon. Depths: 53-63 cm and 76-91 cm.

- The B horizon studied is a buried intertidal flat deposit. Except for the geogenetic characteristics such as tidal lamination and marine snails, features due to a marine macrofauna, characteristic of pedogenesis in unripened intertidal flat deposits, are also found. These are common passage features and biogeogenetic laminae. The fauna present in current intertidal-flat deposits is also responsible for the few coatings of voids with fine-grained material and the pressure-affected zones around voids in clay-rich laminae. The few voids filled with fine and/or coarse-grained soil material present over the whole depth are due to inflow of wet unripened sediment in voids and are characteristic of intertidal-zone deposits.

- With increasing accumulation of the sediment chemical processes occurred, resulting in 1) redistribution of carbonates and 2) accumulation of sesquioxides, mainly manganese. The carbonates are present as nodules. They are common and increase in quantity with depth, where diameters reach up to 2 mm. The few accumulations of sesquioxides, mainly composed of manganese, are present as neocutans around voids and occur to a depth of 80 cm.

- Due to the high initial water content of the soil material, artificial cracking occurred during drying of the samples. The real structure cannot be determined with certainty, but ripening cracks, forming part of a prismatic structure, are present.

- Additional information: SEM-EDXRA information indicate the presence of halite (NaCl) and gypsum in the studied thin sections. Halite occurs along void walls and in coarse-grained laminae. Gypsum is rather rare and occurs locally in voids and in clay-rich soil material near voids. The type of gypsum occurring has rather circular shapes, diam. varying between 200-500 µm and a diffuse extinction pattern.
1. General information and typifying pedon description


Lakhpat series comprises very deep, moderately well drained, clayey soils of light olive brown to light yellowish brown colours. They have developed over shales and occur on nearly level to very gently sloping dissected coastal plains. The climate is tropical semi-arid with mean annual air temperature of 26°C and mean annual rainfall of 300 to 348 mm. The principal associated soils are Adesar, Vajapur and Chad series which are Aridisols. They were previously classified as coastal alluvium.

Lakhpat series is a member of fine, mixed, hyperthermic, very, deep family of Haplic Natrargids.

**Typifying pedon:** Lakhpat sandy clay loam-uncultivated (Colours are for dry soils unless otherwise noted).

**A1** 0-10 cm: Light olive brown (2.5 Y 5/4) sandy clay loam, olive brown (2.5 Y 4/4 M) medium moderate subangular blocky; (dry) slightly hard, (moist) friable, (wet) sticky and plastic; fine lime nodules; slight effervescent; very few medium and many fine pores; few fine roots; moderately slow permeability; clear smooth boundary.

**B2lt** 10-45 cm: Light olive brown (2.5 Y 5/4) clay, olive brown (2.5 Y 4/4 M) coarse strong prismatic breaking into strong medium subangular blocky with discontinuous thin clay skins on the ped faces; (dry) hard, (moist) firm, (wet) sticky and very plastic; few lime nodules; slight effervescent; few fine pores; few fine roots; moderately slow permeability; diffuse smooth boundary.

**B22t** 45-83 cm: Olive brown (2.5 Y 4/4 D & M), clay; coarse strong prismatic breaking into coarse strong angular blocky with continuous clay skins on ped faces and also coatings of white salt material; (dry) very hard, (moist) firm, (wet) sticky and very plastic; few fine indurated lime nodules and common fine gypsum.
crystals of 2-3 mm size; slight effervescence; few fine pores; slow permeability; clear smooth boundary.

**B2t** 83-117 cm: Light olive brown (2.5 Y 5/4 M) clay; coarse strong prismatic breaking into strong medium angular blocky with continuous clay skins on the ped faces, coated with powdery lime; (moist) very firm, (wet) very sticky and plastic; fine lime nodules and common fine gypsum crystals of 2-3 mm size; violently effervescent; few very fine pores; slow permeability; clear smooth boundary.

**B3t** 117-150 cm: Dark yellowish brown (10 YR 4/4 M) clay; strong coarse prismatic breaking into strong medium angular blocky with continuous clay skins and also lime coatings on the ped faces; ped interior mottled with many prominent dark reddish brown (2.5 YR 3/4) and yellowish brown (10 YR 5/8) colours; (moist) very firm, (wet) very sticky and plastic; fine lime nodules; violent effervescence; few very fine pores; slow permeability; clear smooth boundary.

**C** 150 cm+: Light olive brown (2.5 YR 5/4 M) altered shales.

**Range in characteristics:** The average thickness of the solum ranges from 128 to 160 cm underlain by altered olive brown shales. The content of diffused lime material increases through depth in the matrix. Within 15 to 100 cm depth of the surface the content of the gravel is irregularly distributed and normally negligible. The soil reaction is moderately to strongly alkaline. The salt content as expressed by EC ranges normally from 8.5 to 11 mmhos/cm. The texture of fine earth of the soil material within the control section varies from clay loam to sandy clay loam and at places silty clay is also met with. The thickness of the surface soil ranges from 8-15 cm and has a moderate subangular blocky structure that does not become hard when dry. The colour of the surface soil is in the hue of 2.5 Y with the dry value 5 and moist value 4 having chroma 4 for both dry and moist soils. Thickness of the B horizon is more than 100 cm, the pedality of which is coarse strong prismatic breaking into coarse strong subangular blocky to angular blocky peds with thin continuous clay skins engulfed partly by thin coatings of lime. The texture is dominantly silty clay to clay. The colour is in hue of 2.5 Y with dry value 5 and moist value 4 having chroma 4 for both dry and moist soils. The clay content increases through depth. The consistency gets very hard and very firm under dry and moist condition respectively. The effective rooting
depth extends up to 70 cm of the surface. The depth of groundwater table ranges from 8 to 10 m of the surface. More than 3/4th part of the pedon remains dry with the moisture remaining below wilting point during the 9 months dry period in most of the years.

**Competing series and their differentiae:*** Competing soils are those of Jangi and Motchhirai series. Both of these are of the similar depth. The colour in Jangi is in the hue of 10 YR and 7.5 YR with dry and moist values 4 and 3 respectively having higher chroma while hue in Motchhirai is in 10 YR with similar values and chroma as that in Jangi soils. Soils of Jangi series are situated on the intermediary situation between Lakhpat and Motchhirai soils.

**Drainage in permeability:** Moderately well drained with moderately slow to slow permeability.

**Vegetation and Land Use:** Partly cultivated for rainfed crops like cotton, and bajra. While the major part is uncultivated, severely eroded and gullied waste lands are under groves of halophytic and xerophytic species.

**Series established and type location:** Profile No. 12, about 3/4 km in the north west of 26th km stone from Santalpur-Gandhidhan road, near Lakhpat railway station; Taluks: Repar; district: Kachcha in Gujarat State.

**Interpretation:** Lakhpat soils have problem due to salinity, heavy subsoil and some sodic hazard. The soils are slowly permeable, the rainfall is low with very high evapotranspiration throughout the year. The soils have gypsum in their profiles which might help in reclaiming the soils and improving their permeability. They are adapted to salt and drought resistant crops of the region like bajra but major part of these soils are not put to cultivation. Eroded lands need to be reclaimed. If good quality irrigation water is available the soils of these lands can be easily reclaimed.
Management interpretation: (Based on physical productive potential of the series)

a) Inductive
   1. Land capability subclass-IVs
   2. Irrigability sub-class-3d
   3. Management potential/Productivity: Low.

Review note: Classification of these soils may become firm after we get data on micromorphology. If the soils are from Narmada area the data from the survey can be used to mention ranges with respect to clay percentage range in the control section and to show the increase in clay. The data on SAR (ESP) have to be used to classify at subgroup level.
2. Tentative soil characterisation by NBSS & LUP, DELHI, NAGPUR

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Size class and particle diameter (mm), % of &lt;2 mm</th>
<th>Coarse fragments % of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>0-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>40.2</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>B21t</td>
<td>10-45</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td>B22t</td>
<td>45-83</td>
<td>36.8</td>
</tr>
<tr>
<td></td>
<td>B23t</td>
<td>83-117</td>
<td>36.6</td>
</tr>
<tr>
<td></td>
<td>B3t</td>
<td>117-150+</td>
<td>32.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>Carbonate</th>
<th>pH</th>
<th>E.C. Bulk density (1:1) H20</th>
<th>CEC NH40Ac meq/100g</th>
<th>Exchangeable sodium %</th>
<th>Ratios to clay CEC NH40Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0.29</td>
<td>1.3</td>
<td>8.7</td>
<td>0.20 1.74</td>
<td>27.0</td>
<td>13</td>
<td>0.66</td>
</tr>
<tr>
<td>10-45</td>
<td>0.18</td>
<td>2.3</td>
<td>8.6</td>
<td>1.70 1.79</td>
<td>27.0</td>
<td>22</td>
<td>0.52</td>
</tr>
<tr>
<td>45-83</td>
<td>0.20</td>
<td>3.7</td>
<td>8.4</td>
<td>4.50 1.93</td>
<td>28.8</td>
<td>26</td>
<td>0.59</td>
</tr>
<tr>
<td>83-117</td>
<td>0.18</td>
<td>1.8</td>
<td>8.2</td>
<td>6.50 1.97</td>
<td>27.8</td>
<td>29</td>
<td>0.59</td>
</tr>
<tr>
<td>117-150+</td>
<td>0.10</td>
<td>2.1</td>
<td>8.3</td>
<td>5.50 1.90</td>
<td>24.7</td>
<td>35</td>
<td>0.59</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Three thin sections are studied: all derived from the B horizon. Depths: 10-25 cm (1), 55-70 cm (2) and 93-108 cm (3)

1. Depth: 10-25 cm

Macroscopic characteristics

Light olive brown, fine textured, pedal locally fine laminated soil material, containing a few dark coloured nodules, Ø < 3 mm.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. A few large irregular voids, occurring as local enlargements of structural voids or on intersection nodes, Ø up to 20 mm. Other voids: few to common elongated voids, widths < 3 mm, length less than 10 mm, and common equant voids, Ø up to 3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm Ø. The size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals of which a few show varying stages of alteration. The fine material is largely clay sized, includes a few particles up to 10 µm and has a moderately ma-skelsepic plasmic fabric. The locally occurring fine lamination is due to different quantities of coarse material in successive laminae. Some laminae containing a higher quantity of fine-grained material are built up of small single excrements of different shapes and sizes.

Special features:

Associated with voids: Few to common voids partly infilled with mineral aggregates, partly angular soil aggregates, partly excrements.

In the groundmass : Common passage features, containing excrements of different shapes and sizes.

: Common complete infilling of voids with soil material which can be composed of mainly fine-grained material (< 10 µm) or coarse-grained material or mixtures, that sometimes show lamination. Many of these infillings show deformations of original shape.
: Common carbonate nodules, sharp or clear boundaries diameters up to 3 mm. Many of the carbonate nodules contain sesquioxidic accumulations, often mainly manganese accumulated in the outer zone.

: Few sesquioxidic nodules, sharp external boundaries diam. up to 3 mm.

2. Depth: 55-70 cm

Macroscopic characteristics

Olive brown, fine textured, pedal soil material, containing some dark coloured nodules, Ø 2 mm.

Micromorphological characteristics

**Structure**: Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. A few large irregular voids, occurring as local enlargements of structural voids or on intersection nodes, Ø up to 12 mm. Other voids: Few elongated voids, widths < 3 mm, lengths less than 10 mm, and few equant voids, Ø up to 3 mm, randomly distributed.

**Groundmass**: The fine textured soil material includes grain sizes up to gravels of 3 mm Ø. The size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals of which a few show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderately maskelsepetic plasmic fabric, locally vosepic.

**Special features**

Associated with voids: Few voids partly infilled with mineral aggregates partly angular soil aggregates, partly excrements.

In the groundmass: Parts of the groundmass consist of more or less welded single excrements, composed of mainly fine material.

: Few passage features, containing excrements of different shapes and sizes.

: Common complete infillings of voids with soil material, which can be composed of mainly fine-grained material (< 10 µm), or coarse-grained material or mixtures, that sometimes show lamination. A part of these infillings show deformations of the original shape.

: Common carbonate nodules, sharp or clear boundaries, diameters up to 3 mm. Many of the carbonate nodules contain sesquioxidic accumulations, often mainly manganese accumulated in the outer zone.
accumulations, often mainly manganese, accumulated in the outer zone.

- Few sesquioxidic nodules, sharp external boundaries, diam. up to 2 mm.
- Some voids contain gypsum crystals.
- A few snail fragments.

3. Depth: 93-108 cm

Macroscopic characteristics

Olive brown, fine textured, pedal soil material containing a few dark coloured nodules, ø < 2 mm.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. A few large irregular voids, occurring as local enlargements of structural voids or on intersection nodes, ø up to 20 mm. Other voids: few elongated voids, widths < 3 mm, lengths less than 10 mm, and a few equant voids, ø up to 3 mm, randomly distributed.

**Groundmass:** The fine textured soil material includes grain sizes up to gravels of 3 mm ø. The size limit coarse/fine material: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals of which a few show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderately ma-skelsepic plasmic fabric, locally vosepic.

**Special features**

Associated with voids: Few voids partly infilled with mineral aggregates, partly angular soil aggregates, partly excrements.

In the groundmass: Few to common complete infillings of voids with soil material, mainly coarser grained than the groundmass.

- Common carbonate nodules with sharp or clear boundaries, diameter up to 3 mm. Only a few small clusters of carbonate particles with diffuse boundaries are observed. Many of the carbonate nodules contain sesquioxidic accumulations, often mainly manganese, accumulated in the outer zone.
  - Few sesquioxidic nodules, sharp external boundaries, diam. up to 2 mm.
  - A few voids contain gypsum crystals.
Short micromorphological description

Three thin sections are studied, all derived from the B horizon. Depths: 10-25 cm (1), 55-70 cm (2) and 93-108 cm (3).

- The soil material is fine textured and includes grain sizes up to gravels of 3 mm ø. The size limit coarse/fine material is 10 µm; the related distribution: porphyric. The fine material is largely clay-sized and includes a few particles up to 10 µm and has a moderately ma-skelsepic plasmic fabric, locally also vosepic in (2) and (3). The coarse mineral material consists of a variety of minerals of which a few show varying stages of alteration. In (1) a locally occurring fine lamination is due to different quantities of coarse material in successive laminae. Some fine-grained laminae are built up of small single excrements of different shapes and sizes.

- The soil material has a strong coarse angular blocky structure, to which common, intersected, elongated voids belong. A few large irregular voids, occurring as local enlargements of structural voids or on intersection nodes, are found up to 20 mm width in (1) and (3) and up to 12 mm width in (2). Other voids: Few to common in (1) and a few in (2) and (3) elongated voids, widths < 3 mm, lengths less than 10 mm, and common in (1), a few in (2) and (3) equant voids, Ø up to 3 mm, randomly distributed.

- In the B horizon occur voids, partly infilled with mineral aggregates; angular soil aggregates as well as excrements. These features slightly decrease in quantity with depth from few to common (1) to few (2, 3).

- Passage features containing excrements of different shapes and sizes are found in the upper and middle part of the B horizon decreasing in quantity from common in (1) to a few in (2).

- A part of the groundmass in (2) consists of more or less welded single excrements, composed of mainly fine-material.

- Infillings of voids with soil material occur over the whole studied depth. The infilled material is composed of mainly fine-grained (< 10 µm) material, or coarser-grained material or mixtures that sometimes show lamination, in (1) and (2) and is mainly coarser grained in (3).
These infilled voids are deformed in the upper and middle part in decreasing number. The quantity of infilled voids slightly decreases with depth from common (1, 2) to few to common (3).

Carbonate nodules are common over the whole studied depth. They have sharp or clear external boundaries and diameters up to 3 mm. Many of the carbonate nodules contain sesquioxide accumulations, often mainly manganese, accumulated in the outer zone.

In the B horizon (1, 2, 3) occur a few sesquioxide nodules, with sharp external boundaries and diameters up to 3 mm in (1) and 2 mm in (2, 3).

A few voids contain gypsum crystals in the middle and lower part of the B horizon (2, 3).

A few snail fragments occur in the middle part (2).
1. Remnants of a tidal lamination. B horizon (plain light)

2. Passage features in an intertidal deposit. The dark-coloured ellipsoidal features are fine-grained mineral excrements. B horizon (plain light)
4. Interpretation of the micromorphological data

Three thin sections are studied: all derived from the B horizon.
Depths: 10–25 cm (1), 55–70 cm (2) and 93–108 cm (3).

The studied B horizon is a former intertidal flat deposit. Besides the geogenetic lamina tion, of remnants which are present in (1), features characteristic of pedogenesis in unripened intertidal deposits are also found. Most of these features are due to the marine macro-fauna. These are passage features and biogeogenetic laminae composed of excrements. Passage features, formed shortly after deposition of the sediment by mobile soil fauna, are common in the upper part of the B horizon (1) and decrease with depth to a few in the middle part of the B2 horizon (2). In the top of the B horizon biogeogenetic laminae occur as thin laminae composed of small single excrements of different shapes and sizes; deeper in the B horizon (2) thick zones of the groundmass consist of more or less welded shaped excrements of different kinds. The complete infillings of voids with soil material, composed either of mainly fine-grained material (<10 µm), coarse-grained material or mixtures, that sometimes show lamination, are also due to pedogenesis in unripened sediment. They are formed when unripened semi-fluid soil material from the surface flows in existing voids, nearly all of which are faunal voids. In the upper and middle part of the studied B horizon (1, 2) these infillings are common and many of them show deformations of the original shape. In the lower part of the studied B horizon (3) only a few of these infillings, mainly coarse grained, occur, which are hardly deformed.

Chemical processes occurred with increasing accretion of the sediment, resulting in accumulations of sesquioxides and carbonates. Over the whole B2 horizon a few sesquioxidic nodules occur, with diameters reaching 3 mm. Carbonate nodules are common in the same zone, have diameters of up to 3 mm and sharp or clear external boundaries. Many of the carbonate nodules contain sesquioxides, often mainly manganese, accumulated predominantly in the outer zone.

The strong coarse angular blocky structure is a result of physical processes; ripening, swell and shrinkage. The current fauna have formed the enlargements of structural voids and intersection nodes. In these voids some mineral aggregates, excrements and angular soil fragments occur. The angular soil fragments are split off from adjoining soil material. The few voids present in the peds are mainly produced by plant roots or fauna.

Locally, from a depth of 55 cm onwards, some gypsum crystals are present in voids.

In the lower part of the B2 horizon (3) a few small clusters of carbonate particles with diffuse external boundaries occur. These accumulations are due to current carbonate precipitation.
SANES SERIES

1. General information and typifying pedon description


Sanes series includes poorly drained, very deep saline alkali soils developed on tidal deposits. These are found to occur on nearly level to very gently sloping mudflats along the sea coast. The soil pedon exhibits an ABC profile with a grayish brown to dark brown clay loam to silty clay loam A horizon grading to dark brown to very dark grayish brown clayey B horizon underlain by yellowish brown to light yellowish brown massive tidal deposits containing coarse and medium gypsum crystals. About 3/4th of the soil pedon remains saturated for most of the year and the matrix exhibits abundant mottles. The surface cracks 2 to 4 cm wide extending up to 20 to 25 cm deep, separating the soil into polyhedrons of different sizes. Salt encrustation and efflorescence are observed on the surface at several places during the dry period. These soils have been classified in India as "Saline Alkali Soils". Associated soils are Velavadar and Piparia series which are deep to very deep Inceptisols and Dholera series which are very deep Aridisols.

The climate of the area is tropical semiarid. The mean annual temperature is 26°C rising to Max. 31°C in May and June and falling to Min. 14°C in January in most of the years. The mean annual rainfall is 70 cm of which about 64% is received in July and August with 19.2 percent in June as pre-monsoonic and 14.8 in Sept. to Nov. as post monsoonic shower in most of the years.

Sanes series comprises fine, montmorillonitic, hyperthermic, deep family of Vertic Halaquepts.
Typifying pedon: Sanes clay loam-uncultivated (Colours are for dry soils unless otherwise noted).

Ap
0-15 cm: Grayish brown (10 YR 5/2) clay loam, very dark grayish brown (10 YR 3/2) when moist; coarse strong prismatic breaking into medium moderate subangular blocky peds; dry very hard, moist firm, wet sticky and plastic; fine powdery lime in the matrix when dry; violently effervescent, few fine discontinuous inped oblique pores; many fine roots; slow permeability; pH 8.4; clear and smooth boundary.

B21
15-51 cm: Grayish brown (10 YR 4.5/2) clay, vary dark grayish brown (10 YR 3/2) when moist; strong coarse prismatic breaking into medium moderate subangular blocky peds with shiny pressure faces; many faint gray (10 YR 4.5/1) mottles in the ped interiors; dry very hard, moist very firm, wet very sticky and plastic; soft powdery lime in sporadic spots all over the matrix; violently effervescent; few fine oblique discontinuous inped pores; very few fine roots; very slow permeability; pH 7.9; gradual smooth boundary.

B22
51-70 cm: Dark grayish brown (10 YR 3.5/2 M) clay; coarse stong prismatic peds with prominent shiny pressure faces; blotches of light gray (10 YR 7/2) in the matrix; dry very hard, moist very firm, wet very sticky and plastic; abundant powdery lime in the matrix when dry; violently effervescent; few very fine discontinuous horizontal pores; very slow permeability; pH 8.0; clear and smooth boundary.

B3
70-100 cm: Dark brown (10 YR 3.5/3 M) clay; strong coarse prismatic with shiny pressure faces; dry very hard, moist very firm, wet very sticky and plastic; abundant powdery lime in the matrix when dry; violently effervescent; very few very fine discontinuous horizontal pores; very slow permeability; pH 7.7; diffuse smooth boundary.

Cl
100-135 cm: Dark brown (10 YR 3.5/3 M) clay; strong coarse prismatic breaking into strong coarse angular blocky peds with shiny pressure faces; vertically downward mottles with many faint yellowish brown (10 YR 5/6) colours; common irregular worm holes 2-10 mm diam.; dry, very hard, moist very firm, wet very sticky and plastic; matrix is coated with powdery lime when dry; violently effervescent; very
few fine discontinuous horizontal pores; very slow permeability; pH 7.8; clear and smooth boundary.

C2 133-160 cm: Dark brown (10 YR 3.5/3 M) clay; strong coarse prismatic breaking into strong coarse angular blocky peds with shiny pressure faces mottled with many distinct yellowish brown (10 YR 5/8) and dark grayish brown (2.5 Y 4/2) colours; dry hard, moist very firm, wet very sticky and plastic; matrix is coated with powdery lime when dry; violently effervescent; very slow permeability; pH 7.9.

Range in characteristics: The thickness of the solum ranges from 97 to 128 cm. The content of CaCO3, within the depth of 18 cm to 1 metre of the surface, ranges from 14 to 20%. The content of the salt expressed as EC ranges from 14 to 44 mmhos/cm through depth. The soil reaction is moderately to mildly alkaline through depth with pH ranging from 8.4 to 7.8 and at places it may be strongly alkaline in subsoil with pH ranging between 8.9 and 9.0. The colour of the soil is in the hue of 10 YR with medium value and chroma of 2 for dry and moist soil. The subsoil portion within 75 cm of the surface is abundantly mottled with chroma 2 and less. The effective rooting depth extends up to 20-25 cm of the surface. Subsoil up to the depth of 20 cm of the surface remains saturated with groundwater for more than 4 months in most of the years while in the dry period 6 to 8 cm of the surface gets dry in the dry period.

Competing series and their differentiae: Competing soils are those of Valavadar series. The soluble salt expressed as EC varies from 1.2 to 11.2 mmhos/cm through depth. Thickness of B horizon ranges from 65 to 85 cm and depth within 75 cm of the surface remains saturated by groundwater for more than three months period in most of the years. Water starts oozing out from the profile wall at the depth below 90 cm of the surface. About 2-3 cm wide shallow cracks covered by salt efflorescence and salt encrustation on the surface appear during the dry period in most of the years.

Drainage and permeability: Poorly drained with slow to very slow permeability.
Water table: The depth of groundwater table is between 2 to 3 metre of the surface in dry period, fluctuating near to the surface during rainy period and subsequent months.

Vegetation and land use: Mostly uncultivated and left as barren salt waste with salt encrustation and efflorescence on the surface at places cultivated mostly for jowar and cotton.

Distribution and extent: Soils of Sanes series occur extensively in the level coastal areas in South Western part of Saurashtra, Gujarat State.

Type location and series established: Profile no. 97 about 4 km to the south-west of village Sanes in Bhavnagar taluka, Bhavnagar district, Gujarat State.
### 2. Tentative soil characterisation by NBSS & LUP, NAGPUR

#### Size class and particle diameter (mm), % of <l mm

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Total (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&lt;0.002)</th>
<th>Very coarse (2-1)</th>
<th>Coarse (1-0.5)</th>
<th>Medium (0.5-0.25)</th>
<th>Fine (0.25-0.1)</th>
<th>Very fine (0.1-0.02)</th>
<th>Coarse fragment % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 0-15</td>
<td>22.2</td>
<td>28.7</td>
<td>48.4</td>
<td>0.6</td>
<td>0.3</td>
<td>0.7</td>
<td>0.5</td>
<td>20.3</td>
<td>28.7</td>
</tr>
<tr>
<td>B21 15-51</td>
<td>24.6</td>
<td>24.2</td>
<td>48.8</td>
<td>0.5</td>
<td>1.2</td>
<td>0.6</td>
<td>0.6</td>
<td>21.7</td>
<td>24.2</td>
</tr>
<tr>
<td>B22 51-70</td>
<td>35.0</td>
<td>23.6</td>
<td>41.6</td>
<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
<td>0.4</td>
<td>33.7</td>
<td>23.6</td>
</tr>
<tr>
<td>B3 70-100</td>
<td>38.8</td>
<td>16.2</td>
<td>44.6</td>
<td>nil</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>37.0</td>
<td>16.2</td>
</tr>
<tr>
<td>C1 100-135</td>
<td>29.2</td>
<td>21.0</td>
<td>49.7</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.2</td>
<td>27.3</td>
<td>21.0</td>
</tr>
<tr>
<td>C2 135-160</td>
<td>12.1</td>
<td>36.8</td>
<td>52.0</td>
<td>0.6</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>11.1</td>
<td>36.8</td>
</tr>
</tbody>
</table>

#### Depth (cm) Organic Carbonate pH E.C. Bulk density

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Organic carbon as CaCO3 (1:2) %</th>
<th>&lt;2 mm H2O</th>
<th>pH (1:2)</th>
<th>E.C. mmhos/cm</th>
<th>Bulk density g/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>0.62</td>
<td>9.6</td>
<td>8.7</td>
<td>2.30</td>
<td>1.57</td>
</tr>
<tr>
<td>15-51</td>
<td>0.35</td>
<td>21.6</td>
<td>8.3</td>
<td>7.90</td>
<td>1.76</td>
</tr>
<tr>
<td>51-70</td>
<td>0.24</td>
<td>18.3</td>
<td>8.2</td>
<td>8.10</td>
<td>1.64</td>
</tr>
<tr>
<td>70-100</td>
<td>0.22</td>
<td>18.3</td>
<td>8.3</td>
<td>11.20</td>
<td>1.70</td>
</tr>
<tr>
<td>100-135</td>
<td>0.20</td>
<td>19.4</td>
<td>8.2</td>
<td>7.80</td>
<td>1.75</td>
</tr>
<tr>
<td>135-160</td>
<td>0.18</td>
<td>27.5</td>
<td>8.2</td>
<td>2.70</td>
<td>1.55</td>
</tr>
</tbody>
</table>

#### Depth (cm) Extractable bases Ext. acidity CEC Sodium absorbtion ratio Base saturation

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>CEC</th>
<th>Sodium absorbtion ratio</th>
<th>Base saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>Mg</td>
<td>Na</td>
<td>K</td>
<td>Sum</td>
<td>corrected</td>
</tr>
<tr>
<td>NaCl</td>
<td>NH4Ac</td>
<td></td>
<td></td>
<td></td>
<td>sum cations</td>
</tr>
<tr>
<td>0-15</td>
<td>11.0</td>
<td>9.0</td>
<td>9.8</td>
<td>1.3</td>
<td>31.1</td>
</tr>
<tr>
<td>15-51</td>
<td>12.0</td>
<td>7.0</td>
<td>13.9</td>
<td>1.2</td>
<td>34.1</td>
</tr>
<tr>
<td>51-70</td>
<td>11.0</td>
<td>3.0</td>
<td>16.3</td>
<td>1.2</td>
<td>31.5</td>
</tr>
<tr>
<td>70-100</td>
<td>5.0</td>
<td>14.0</td>
<td>15.4</td>
<td>1.5</td>
<td>35.9</td>
</tr>
<tr>
<td>100-135</td>
<td>8.0</td>
<td>9.0</td>
<td>18.2</td>
<td>1.5</td>
<td>36.8</td>
</tr>
<tr>
<td>135-160</td>
<td>11.0</td>
<td>9.0</td>
<td>16.5</td>
<td>1.8</td>
<td>38.3</td>
</tr>
</tbody>
</table>

#### Depth (cm) Water at saturation Water extract saturation paste

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Water at saturation %</th>
<th>Water extract saturation paste</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>CO3</th>
<th>HCO3</th>
<th>Cl</th>
<th>SO4</th>
<th>E.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>51.3</td>
<td>29.6</td>
<td>10.4</td>
<td>36.5</td>
<td>0.5</td>
<td>N11</td>
<td>25.2</td>
<td>69.0</td>
<td>7.4</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>15-51</td>
<td>48.8</td>
<td>40.7</td>
<td>33.0</td>
<td>78.2</td>
<td>1.2</td>
<td>N11</td>
<td>25.1</td>
<td>358.9</td>
<td>13.1</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>51-70</td>
<td>49.6</td>
<td>39.5</td>
<td>41.6</td>
<td>91.5</td>
<td>1.8</td>
<td>N11</td>
<td>23.7</td>
<td>415.8</td>
<td>13.3</td>
<td>35.0</td>
<td></td>
</tr>
<tr>
<td>70-100</td>
<td>59.1</td>
<td>36.0</td>
<td>36.6</td>
<td>96.6</td>
<td>1.9</td>
<td>N11</td>
<td>30.6</td>
<td>434.4</td>
<td>13.3</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>100-135</td>
<td>57.6</td>
<td>46.0</td>
<td>50.7</td>
<td>108.7</td>
<td>2.3</td>
<td>N11</td>
<td>21.9</td>
<td>567.5</td>
<td>12.5</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>135-160</td>
<td>70.6</td>
<td>51.3</td>
<td>46.1</td>
<td>109.8</td>
<td>2.5</td>
<td>N11</td>
<td>21.0</td>
<td>510.5</td>
<td>19.2</td>
<td>42.5</td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: one from the B horizon and one from the C horizon.

Depths: 24-39 cm (1) and 109-124 cm (2)

1. Depth: 24-39 cm.

Macroscopic characteristics

Grayish brown, fine textured, coarse prismatic soil material.

Micromorphological characteristics

Structure: Coarse prismatic, subdivided into moderate medium angular blocky peds, to which common, intersected, elongated voids belong. Other voids: few to common elongated and equant voids, widths up to 3 mm, most <1 mm. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive fine sand. Size limit coarse/fine material: 15 µm. Related distribution: porphyric. The coarse material consists of a variety of minerals including gypsum crystals, which are fresh or nearly fresh and probably organic fragments. The fine material is largely clay-sized, contains a few particles up to 15 µm and a varying quantity of carbonate particles which locally constitute the majority of the fine material. The plasmic fabric of the clay-sized part is asepic.

Special features

Associated with voids: Few voids partly infilled with mineral aggregates of identical composition of the groundmass.

In the groundmass: Common to many carbonate accumulations with sharp or diffuse boundaries, diameters up to 4 mm.

: Few voids filled with gypsum crystals.

: Locally occur the groundmass gypsum crystals.

: Few voids infilled with mineral aggregates, partly excrements.

: Common small, up to about 200 µm in diameter, sesquioxidic nodules with diffuse external boundaries.

: Common snail and shell fragments.
2. Depth: 109-124 cm

Macroscopic characteristics

Dark brown, fine textured, coarse prismatic fine laminated, soil material

Micromorphological characteristics

Structure: The soil material is coarse prismatic to which a few long elongated voids belong. Other voids: a few elongated and equant voids, length up to a few cm, diameters up to 3 mm. Randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive very fine sand. Size limit coarse/fine material 15 µm.

Related distribution: porphyric. The coarse material consists of a variety of minerals which are fresh or nearly fresh and probably some organic fragments. The fine material is largely clay-sized, contains many carbonate particles and few other particles up to 15 µm with homogeneous distribution. The plasmic fabric of the clay-sized part is asepic. The fine lamination is due to varying quantities of coarse material in the successive laminae; laminae composed of only coarse material do not occur.

Special features

Associated with voids: Some voids are partly infilled with mineral aggregates, which include excrements.

: A few coatings of mainly fine-grained material.

: Few neoferrans.

In the groundmass: Few voids nearly completely infilled with mineral aggregates, mainly excrements.

: Few to common infilled voids with: only fine material or coarse material, and mixtures of these including also pure clay accumulations in laminated infillings.

: Few striotubules and isotubules.

: Few to common passage features.

: Few to common small accumulations of oxidizing microctic pyrite spheres, Ø to 20 µm.
Sanes  (2 photographs)

1. Gypsum crystals nearly filling a void (centre, voids are black); B horizon (crossed polarizers).

2. Oxidizing pyrite spheres (black) near voids; C horizon (plain light).
4. Interpretation of the micromorphological data

Two thin sections are studied: one from the B horizon and one from the C horizon.

Depths: 24-39 cm (1) and 109-124 cm (2).

- The thin section of the B horizon, 24-39 cm, represents a ripened high silted up, tidal deposit with a developed structure. In this zone carbonates and sulphates are accumulated, due to a fluctuating groundwater level and evaporation in a tropical semi-arid climate. The influence of fauna is low.

- The thin section of the C horizon is derived from a high intertidal flat deposit. The few neoferrians, the majority of the infillings of fine and/or coarse soil material, the passage features, the iso- and striotrebutules and the microlitic pyrite spheres are all features due to pedogeneses during continuing sedimentation in unripened sediment under influence of the tides. The majority of the coatings of fine-grained material, the laminated infillings including laminae of pure clay, the oxidation of pyrite spheres and occurrence of gypsum are phenomena due to actual processes. The coatings and infillings are a consequence of the salinity and alkalinity of the soil, causing instability and shifting of the soil constituents in wet periods. In dry periods oxidation of pyrite occurs.
Price of the basic reference set:

ISBN 90 327 0164 9