MICROMORPHOLOGICAL ANALYSIS AND CHARACTERIZATION
OF 70 BENCHMARK SOILS OF INDIA

A basic reference set

Part III

NETHERLANDS SOIL SURVEY INSTITUTE, WAGENINGEN - 1982
MICROMORPHOLOGICAL ANALYSES AND CHARACTERIZATION
OF 70 BENCHMARK SOILS OF INDIA

A basic reference set

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

M.J. KOOISTRA

NETHERLANDS SOIL SURVEY INSTITUTE, WAGENINGEN - 1982
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SOILS OF THE DESERT REGION

everal interaction and uplifting of great increments of bedrock. The

soils are characterized by well-drained, very deep, light-colored agglomerated soils of pale brown to yellowish brown color on alluvial plains that are modified under a variety of conditions.

In the arid region of Rajasthan state, there exists a well-developed or pedonal zone of considerable magnitude, generally at 75 cm or lower, which on flat lands with occasional to common farm size and often

available in these areas. The clays are rich with average annual rainfall ranging from 250 to 300 mm. With minimal s

moisture on the surface and most of the field boundaries in the

cropland and pasture land common.

Chiral series is tentatively classified as a member of warm-temperate

hyperthermic family of Fajer accommodation.
1. General information and typifying pedon description


Chirai series comprises well drained, very deep, loamy fine sand, weakly aggregated soils of pale brown to yellowish brown colour developed on old alluvial plains that are modified under subsequent aeolian activity in the arid region of Rajasthan State. These have a weakly to moderately developed zone of lime accumulation, generally at 75 cm or deeper. They occur on flat lands with occasional to common fence line and/or in field hummocks. The climate is arid with average annual air temperature of 26.7°C and mean annual rainfall ranging from 250 to 350 mm. Wind working is conspicuous on the surface and most of the field boundaries in the cultivated lands have sandy fence like hummocks.

Chirai series is tentatively classified as a member of coarse loamy, mixed, hyperthermic family of Typic camborthids.
Typifying pedon: Chirai sandy loam - cultivated.
(Colours are for dry soils unless otherwise indicated).

Ap 0-9 cm: Yellowish brown (10YR 5/4) sandy loam, single grain; slight effervescence with dil acid, many fine roots; clear smooth boundary.

A1 9-36 cm: Brown to pale brown (10YR 5.5/3) sandy loam; very weak fine to medium sub-angular blocky slightly hard (dry), very friable (moist), slightly sticky and non-plastic; strong effervescence; some mycelial lime; many fine roots; many very fine to fine, some medium, vertical discontinuous pores; gradual smooth boundary.

B1 36-76 cm: Brown to pale brown (10YR 5.5/3) sandy loam; very weak fine to medium sub-angular blocky; slightly hard (dry), very friable (moist), slightly sticky and non-plastic (wet); strong effervescence; some mycelial lime; common fine roots; many very fine to fine and some medium vertical discontinuous pores; clear smooth boundary.

B2 76-90 cm: Pale brown to light yellowish brown (10YR 5/3.5) sandy loam; weak medium sub-angular blocky; slightly hard (dry), friable (moist), slightly sticky and non-plastic (wet); violent effervescence; 5-7 percent by volume lime concretions; common fine roots; many very fine to fine and some medium vertical discontinuous pores; clear smooth boundary.

C1Ca 90-140 cm: Pale brown to light yellowish brown (10YR 6/3.5) yellowish brown to dark yellowish brown (10YR 4.5/4 M) sandy loam; weak medium sub-angular blocky; slightly hard (dry), friable (moist), slightly sticky and non-plastic; violent effervescence; about 7-10 percent by volume lime concretions; few fine roots; many very fine to fine vertical discontinuous pores; clear smooth boundary.

C2Ca 140+ cm: Light yellowish brown (10YR 5/4) sandy loam; weak medium sub-angular blocky; slightly hard (dry), friable (moist), slightly sticky and non-plastic (wet); violent effervescence; about 20-25 percent by volume lime concretions; few fine roots; many very fine to fine and some medium vertical discontinuous pores.

Range in characteristics: The thickness of the solum is 60 to 100 cm. Wind sorted surface layer mostly varies between 10 to 30 cm. The solum grades into substrata of loamy sands that are strongly calcareous with lime nodules. The estimated mesh annual soil temperature is 27.7°c,
mean summer temperature 31.0°C and mean winter temperature 21.3°C. The soil moisture control section is aridic.

The A horizon is up to 36 cm deep with dark yellowish brown colour in 10YR hue. The texture ranges from fine sand to loamy fine sand and structure from single grain to very weak fine sub-angular blocky. The epipedon is ochric.

The boundary A and B horizon is gradual and smooth. The colour of the B horizon ranges from pale brown (10YR 6/3 D) to yellowish brown (10YR 5/4 D). The texture is dominantly loamy fine sand with 6 to 10 percent clay. Structure ranges from single grain to very weak sub-angular blocky. The solum is slightly to strongly calcareous with up to 7 percent lime nodules. The substratum is also uniformly loamy fine sand and with lime concretions nodules forming 7 to 10 percent which may increase up to 25 percent or more below 140 cm depth.

C.E.C. between 25 to 100 cm depth is around 8 meq/100g.

Competing series and their differentiae: Thar Series which is a Typic Torripsamment is developed on sandy plains and dunes of aeolian origin.

Drainage and permeability: Excessively drained with moderately rapid to rapid permeability.

Use and vegetation: Bulk of the area falling in 300 mm rainfall zone is under cultivation. Pearl millet, Cluster beans, Moth Beans, Green gram and Sesamum are major crops grown. Prosopis Cineraria is the dominant tree. Zizyphus numalaria, Capparis Decidua, Lycium Barbarum, Indiaplera Tinotoria, Crobleria Burlia and Cenchrus Ciliaris, Eleusine Compressa, Panicum Turgidum, Cenchrus Biflorus are the common grasses under natural vegetation.

Distribution and extent: Very extensive soils in Jodhpur and Bikaner districts.

Type location: About 4 km east of Bhandu village on Bhandu Phinch road. 26°05' N latitude and 72°50' E longitude.

Interpretation: The soils are draughty due to low available moisture capacity and surface sandy layer makes them erodible due to strong winds. Due to sandy nature of the soils rainfall goes as deep as recharge during wet spells of 100-200 mm intensities. Arid condition is the major limiting factor for crop plant growth. On average rainfall conditions adapted smaller millets can be successfully grown in 5 out of 10 years and adapted legumes in 6 out of 10 years.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub-class : IVc
   2. Irrigability sub-class : 2s
   3. Fertility management potential: Low (problem of loss of fertiliser due to leaching)
   4. Management potential/productivity: Low

b) Quantitative (management potential for crops under farmers level and package of practices based on CAZRI data).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Farmers level</th>
<th>Package level</th>
</tr>
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<tbody>
<tr>
<td>Pearl millet</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Green gram</td>
<td>1.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Moth bean</td>
<td>1.4</td>
<td>3.5</td>
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<tr>
<td>Sesamum</td>
<td>1.5</td>
<td>4.5</td>
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2. Tentative soil characterisation by KRSS & ITP, Delhi

<table>
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<tr>
<th>Depth (cm)</th>
<th>Total Sand</th>
<th>Clay (2-0.05)</th>
<th>Silt (0.05-0.002)</th>
<th>Very Fine (0.002)</th>
<th>% of &lt; 2 mm</th>
<th>% of &lt; 45um</th>
<th>% of &lt; 60um</th>
<th>% of &lt; 90um</th>
<th>% of &lt; 140um</th>
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<tr>
<td>0- 9</td>
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<td>18.4</td>
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<td>37- 76</td>
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<td>2.3</td>
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<td>76- 90</td>
<td>70.5</td>
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<td>9.0</td>
<td>3.6</td>
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<td>55.7</td>
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<td>9.3</td>
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<tr>
<td>90-140</td>
<td>75.8</td>
<td>15.2</td>
<td>9.0</td>
<td>3.9</td>
<td>3.3</td>
<td>50.1</td>
<td>15.5</td>
<td>3.9</td>
<td>11.3</td>
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<tr>
<td>140+</td>
<td>72.1</td>
<td>16.3</td>
<td>10.6</td>
<td>1.2</td>
<td>4.1</td>
<td>46.0</td>
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</table>

<table>
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<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>Carbonate as CaCO&lt;sub&gt;3&lt;/sub&gt;</th>
<th>Ext. exchangeable bases</th>
<th>pH E.C.</th>
<th>Bulk density</th>
<th>Water Retention</th>
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<th>Extractable bases</th>
<th>Ext. acidity</th>
<th>E.C.</th>
<th>Exchangeable Sodium</th>
<th>Sodium absorption ratio</th>
<th>Base saturations</th>
<th>Ratios to clay</th>
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<td>0.50</td>
<td>0.47</td>
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<td>3.20</td>
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<td>0.50</td>
<td>6.10</td>
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<td>35- 75</td>
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<td>0.50</td>
<td>0.51</td>
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<td>75- 90</td>
<td>2.25</td>
<td>0.80</td>
<td>0.80</td>
<td>0.98</td>
<td>5.08</td>
<td>5.44</td>
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<td>2.25</td>
<td>0.85</td>
<td>0.85</td>
<td>0.83</td>
<td>4.60</td>
<td>5.44</td>
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<td>140+</td>
<td>2.50</td>
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<td>0.75</td>
<td>5.15</td>
<td>5.87</td>
<td>0.010</td>
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</table>
3. Micromorphological data

Three thin sections are studied: two derived from the B horizon and one from the C horizon.

Depths: 44-59 cm (1); 70-85 cm (2) and 92-107 cm (3)

1. Depth: 44-59 cm.

Macroscopic characteristics
Pale brown, coarse textured apedal (homogeneous) soil material.

Micromorphological characteristics

Structure: The soil material is apedal and contains a few elongated voids, diam. < 1.5 mm, rarely several cm long and few equant voids, most with diameters < 1.5 mm.

Groundmass: The coarse textured soil material includes grain sizes up to and inclusive very coarse sand, bulk part is fine sand sized. Size limit coarse/fine material is 25 µm. Related distribution is gefu-chitonic. The coarse mineral material consists of a variety of minerals, which are fresh or nearly fresh. A few root sections are present. The fine mineral material largely consists of small carbonate particles which form coatings around and bridges between coarse mineral material.

Special features:
Associated with voids: Few to common carbonate needles in voids and in larger pores between mineral grains.
In the groundmass: Common voids (faunal or floral) loosely infilled with mineral grains.

: Few voids infilled with mineral aggregates, often excrements, which can have varying grain size compositions.

: Few carbonate nodules, up to 3 mm diameter, including some other mineral grains. They are largely composed of fine carbonate crystals < 15 µm, and have a sharp boundary.

: Few locations where a limited number of mineral grains are cemented together by small carbonate particles, diameter < 15 µm.
2. Depth: 70-85 cm

Macroscopic characteristics

Pale brown, coarse textured very weak pedal to apedal soil material.

Micromorphological characteristics

Structure: The soil material is very weak medium sub-angular blocky to which a few irregular elongated voids, rarely interconnected and a few large irregular, short elongated voids with diameters of about 5 mm belong. A few equant voids, diameters < 1.5 mm and short elongated voids, diameters < 1.5 mm; random distribution.

Groundmass: The coarse textured soil material includes grain sizes up to and inclusive very coarse sand; the bulk part is composed of fine sand sized material. Size limit coarse/fine material is 25 µm. Related distribution is gefu-chitonic. The coarse mineral material consists of a variety of minerals which are fresh or nearly fresh. A few root sections are present. The fine mineral material consists of some clay-sized material mixed with many small carbonate particles, which form coatings and bridges between coarse mineral material. The quantity of fine material is slightly higher as in the zone 44-50 cm depth and the coatings and bridges are thicker.

Special features:

Associated with voids: Few times some, probably carbonate, needles are present in voids and larger pores between mineral grains.

At some void walls show compression zones as a result of biological action.

A few neacalcans occur.

In the groundmass: Common voids (floral, faunal) loosely infilled with mineral grains. Sometimes coatings of fine grained soil material are present along the walls.

Commonly a few coarse mineral grains are cemented together by carbonate particles < 15 µm in diameter, random distribution.

Few to common zones infilled with mineral aggregates, partly excrements which can be composed of mainly fine material. In these zones also single mineral grains occur.

Common carbonate nodules, diameters up to 9 mm.

Distribution: most occur from 77-85 cm depth. Boundaries of nodules; clear. On the outer edge of the nodules is often a thin brown coloured carbonate rich zone present.
It has the same colour as the coatings and bridges around the coarse mineral material. Locally on the edges small accumulations of cemented mineral grains by carbonate particles are added to the main nodule. The internal part of the nodules consists of mainly small carbonate particles (< 15 µm), with some larger ones which are often present around incorporated other mineral grains.

3. Depth: 92-107 cm

Macroscopic characteristics

Pale brown, coarse textured very weak pedal to apedal soil material.

Micromorphological characteristics

Structure: The soil material is very weak medium sub-angular blocky to which a few elongated voids, rarely interconnected belong. A few equant voids, diameters < 1.5 mm and short elongated voids, diameters < 1.5 mm occur too, random distribution.

Groundmass: The coarse textured soil material includes grain sizes up to and inclusive very coarse sand; the majority is fine sand sized. Size limit coarse/fine material is 25 µm. Related distribution is gefu-chitonic. The coarse mineral material consists of a variety of minerals which are fresh or nearly fresh. The fine mineral material consists of some clay-sized material mixed with many small carbonate particles which form coatings and bridges between coarse mineral material. The quantity of fine material is about equal or slightly higher as in the previous section (2).

Special features:

Associated with voids: Few times some, probably carbonate, needles are present in voids and in larger pores between mineral grains.

: Few to common faunal voidwalls, partly infilled with mineral grains, have coatings of a high quantity of fine grained material.

: Few neocalcans.

In the groundmass : Common zones (mainly faunal) loosely infilled with mineral grains. Common coatings/fragments of coatings of fine grained soil material present along walls.
Few to common zones loosely infilled with mineral aggregates, partly excrements < 80 µm in diameter, often together with some mineral grains, diameter infilled zones < 3 mm. These zones locally can have coatings of mainly fine grained soil material.

Common zones where a limited number of mineral grains are cemented together by carbonate particles < 15 µm in diameter.

Common carbonate nodules, diameters up to 9 mm, more or less random distribution. Part of the nodules have a thin brown coloured carbonate-rich outer zone, identical to the coatings around mineral grains. Locally on the edges small areas in which some mineral grains are cemented by small carbonate particles are added to the main nodule. The internal part of the nodules often consists of small carbonate particles (< 15 µm), which contain only a limited number of larger crystals. A small number of carbonate nodules consists of larger crystals. Often the nodule is composed of several smaller nodules cemented together by small carbonate particles. The carbonate nodules usually have a number of incorporated other coarse mineral grains.

Short micromorphological description

Three thin sections are studied: two derived from the B horizon and one from the C horizon.

Depths: 44-59 cm (1), 70-85 cm (2) and 92-107 cm (3).

- The coarse textured soil material contains grain sizes up to and including very coarse sand. The majority is fine sand-sized. The size limit coarse/fine material is 25 µm; the related distribution: gefu-chitonic. The fine material largely consists of small carbonate particles (<25 µm in diam.) forming coatings around and bridges between coarse mineral material. The coarse mineral material consists of a variety of minerals which are fresh or nearly fresh. In the B horizon a few coarse root fragments occur.

- The soil material is apedal in the upper part of the B horizon (1); in the lower part of the B horizon and the studied C horizon the soil material is very weak medium subangular blocky, to which a few irregular elongated voids belong, rarely interconnected. A few other elongated and equant voids occur. Their widths and diameters are generally less than 1.5 mm, length of elongated voids generally less than one cm, all randomly distributed.
Over the whole studied zone voids are commonly infilled with mineral grains. The quantity of infilled floral voids decreases with depth. Some of the voids have a coating of fine-grained soil material along the walls in the lower part of the B horizon (2) and in the studied C horizon (3). In the C horizon some voids are only partly infilled with mineral grains.

In the whole studied zone voids occur that are mainly filled with shaped mineral elements. The quantity increases slightly with depth from a few, in the upper part of the B horizon (1), to few to common deeper in the profile (2, 3). These infillings often also contain single mineral grains.

Over the whole studied zone carbonates are present in several forms. In voids and larger pores between mineral grains carbonate needles occur. Their quantity decreases with depth from few to common in the upper part of the B horizon (1) to a few deeper in the pedon (2, 3). In contrast, carbonate nodules increase in quantity from a few in the upper part of the B horizon (1), diam. up to 3 mm, to common from 77 cm depth onwards (2, 3), diam. up to 9 mm. In the latter zone, carbonate nodules often have a thin brownish coloured outer zone. Some of the carbonate nodules are small accumulations in which a few coarse mineral grains are cemented together by carbonate particles, <25 µm in diameter.
Chirai (2 photographs)

1. Gefu-chitonic c/f related distribution. The fine material forming the coatings and bridges consists of small carbonate crystals. B horizon (crossed polarizers).

2. Infilling of mineral grains in a faunal void with a coating of fine-grained material. C horizon (plain light).
4. Interpretation of the micromorphological data

Three thin sections are studied, two derived from the B horizon and one from the C horizon.
Depths: 44-59 cm (1), 70-85 cm (2) and 92-107 cm (3).

- The sandy parent material is loosely packed. This packing gives the soil a high porosity and permeability but also induces instability. The quantity of larger pores is low. A few elongated and equant voids are present with widths and diameters which are generally less than 1.5 mm. Most voids are of a biological origin. The number of voids produced by plant roots is low and decreases with depth. The fauna plays a minor role. It produces some of the recent and former voids and causes some homogenization. A few voids are filled with shaped mineral excrements in the upper part of the B horizon, increasing in quantity to few-common from that depth onwards. Animals often plaster void walls with fine-grained soil material to increase stability.

- Due to the regular addition of aeolian sand on the surface and the loose packing of the soil constituents, voids are commonly infilled with mineral grains. Also, in those voids filled with shaped mineral excrements, mineral grains are often present. In the C horizon, this kind of infilling decreases as a number of voids are only partly infilled with mineral grains.

- Carbonates have been accumulated and are accumulating. Carbonate particles form the greatest part of the fine material (<25 µm) and are present as coatings and bridges between coarse mineral grains, increasing the stability. Locally, carbonate particles completely occupy spaces between a small number of coarse mineral grains, forming new small carbonate nodules.
Carbonate nodules increase in quantity from a few in the upper part of the B horizon (1) to common from 77 cm depth onwards. Their diameters increase from 3 to 9 mm with depth. Carbonate needles are present in voids and larger pores between mineral grains, with a maximum occurrence in the upper part of the B horizon (few to common).
PALI SERIES

1. General information and typifying pedon description


Pali series comprises well drained, moderately deep, dark brown to dark grayish brown, loam to clay loam soils. They are developed over unconsolidated, weathered granite material, weathered in association with rhyolitic material in the semi arid region of Rajasthan State. Pali soils occur on nearly level plains of one percent slope. The climate is marginally arid to semi arid with mean annual air temperature of 26.7°C and mean annual rainfall of 350 to 500 mm. The lower stratum which is gravelly, occurring at depth ranging from 20 to 45 cm and gravels are coated with lime. It is hard and compact but still fairly permeable. The soils are well aggregated at the surface.

Pali series is tentatively classified as a member of fine loamy, mixed hyperthermic family of Typic Calciorthids.

Typifying pedon: Pali loam-cultivated. (Colours are for dry soils unless otherwise noted).

Ap 0-10 cm: Brown to dark brown (10 YR 4/3) loam moderate fine to medium granular, partly blocky structure; slightly hard (dry), friable (moist), slightly sticky but plastic (wet); negligible effervesence; many fine to medium roots; many fine to medium horizontal and vertical discontinuous pores; clear smooth boundary.

Al 10-22 cm: Dark brown (10 YR 4/3) loam; moderate fine to medium angular blocky; hard (dry), firm (moist); sticky and slightly plastic (wet); negligible effervesence many fine to medium roots; many fine to medium horizontal and vertical discontinuous pores; clear smooth boundary.
B21 22-34 cm: Dark brown (10 YR 3/3) clay loam; moderate medium angular blocky hard (dry), firm (moist), sticky and plastic (wet); negligible effervescence; many fine to medium roots; many fine to medium horizontal and vertical discontinuous pores; clear smooth boundary.

B3 34-44 cm: Dark brown (10 YR 3/3) to brown (10 YR 4/3) clay loam with gravel of granite rock fragments coated with lime and fine lime concretions weakly tending to be subangular blocky; slightly hard (dry), friable (moist), sticky and non-plastic (wet); slightly calcareous; common fine to medium roots; many medium pores; clear smooth boundary.

IIc 44-100 cm: Weathered granite coated with lime and powdery lime in pockets.

Range in characteristics: The thickness of the solum is 20 to 65 cm. The solum is underlain by weathered granitic and quartzite material coated with lime. The mineralogy of the regolith is mixed. The estimated mean annual temperature of the soil is 27.7°C, mean summer temperature 31.0°C and mean winter temperature 21.3°C. The soil moisture control section is never moist more than half the time cumulative and never moist in some or all parts for as long as 90 consecutive days. The A horizon consists of an upper ploughed layer and its depth is 14 to 22 cm. The colour of the A horizon is brown to dark brown in 10 YR and 7.5 YR hues. The dry colour values are 3 to 4 and moist colour values are 2 to 3. The texture of the A horizon ranges from fine sandy loam to clay loam and structure from granular to medium sub-angular blocky. The epipedon is ochric. The boundary between A and B horizon is clear and smooth. B horizon is 12 to 23 cm thick. The colour of the B horizon is brown to dark brown in 10 YR and 7.5 YR hues and moist values 3 to 4. The texture is mostly clay loam and structure moderate sub-angular blocky to angular blocky. The B horizon is slightly to strongly calcareous and calcium carbonate content is highly variable and it may be negligible at certain places. The C horizon is massive with weathered granitic, rhyolitic and quartzitic material. C.E.C. of the solum depth is 20 to 26 meq/100 g.
Drainage and permeability: Well drained with moderately rapid permeability.

Use and vegetation: Largely cultivated to rainfed pearl millet, bajra, green gram, cluster beans quar and moth beans. Jowar is taken at places. Natural vegetation consists of Prosopis Cineraria, Acacia Nilotica and Selvadora Oleoides amongst trees; Zizyphus Numularia, Cappris Decidua, Acacia Gacquemonti, Cenchrus Cilliaris, Elusine Compressa and Cyperus Spp.

Distribution and extent: Extensive areas in Pali district and part of Jalore district in Rajasthan state.

Type location: CAZRI Farm Pali at the south and in the Agrostology Block, approximately 25°45' N latitude and 73°15' E longitude.

Series proposed by: Central Arid Zone Research Institute, 1968.

Interpretation: The soils are good in available moisture capacity with moderate permeability. Due to gently sloping surface, 15-20% of the rainfall is estimated to be lost as run-off. They are low in organic matter and available phosphorus. Available potash is high. Low rainfall is the major constraint for growing crop plants during kharif, rabi crops are irrigated. With improved seeds and moderate doses of N and P fertilisers yields are increased by 100 to 150 percent.

Management interpretation:

a) Inductive (Based on physical productive potential of the series)
   1. Land capability sub-class : IVC
   2. Irrigability sub-class : 2s
   3. Fertility management potential : Moderate
   4. Management potential/productivity: Moderate

b) Quantitative: (Management potential for crops under farmer's level and package of practices based on CAZRI data)
<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmer's level</th>
<th>Yield Q/ha</th>
<th>Package level</th>
<th>Remarks</th>
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<tr>
<td>Pearl millet</td>
<td>5</td>
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<tr>
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<td>6.8</td>
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<tr>
<td>Sesamum</td>
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<tr>
<td>Maize</td>
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<td>5.6</td>
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<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>2.3</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>10-12</td>
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<td></td>
</tr>
<tr>
<td>Barley</td>
<td>10-12</td>
<td>20-25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roya (Mustard)</td>
<td>3-5</td>
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### Tentative soil characterisation by NBSS & LUP, DELHI

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Depth Organic carbon</th>
<th>Extractable bases</th>
<th>CEC</th>
<th>Base saturations %</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Organic carbon %</td>
<td>Extractable bases</td>
<td>CEC</td>
<td>NH4OAc iron water</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>&lt;2 mm &lt;0.002 Fe (1:1)</td>
<td>%</td>
<td>cm</td>
<td>%</td>
<td>meq/100g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>KCl</td>
<td>15-bar</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/3-</td>
<td>g/cc</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15-</td>
<td>mmhos/cm</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

| Ap      | 0-10       | 0.37 | 6.60 | 3.28 | 0.52 | 7.8 | 7.8 | 0.50 | 1.36 | 18.7 | 0.13 |
| A12     | 10-22      | 0.37 | 6.36 | 2.90 | 0.49 | 7.9 | 7.9 | 0.40 | 1.39 | 17.2 | 0.14 |
| B21     | 22-34      | 0.46 | 6.47 | 7.8  | 7.8  | 7.8  | 7.8  | 0.40 | 1.36 | 19.7 | 0.10 |
| B3      | 34-44      | 0.47 | 6.47 | 7.8  | 7.8  | 7.8  | 7.8  | 0.40 | 1.36 | 19.7 | 0.10 |

<table>
<thead>
<tr>
<th>Size class and particle diameter (mm), % of &lt;2 mm</th>
<th>Total</th>
<th>Sand</th>
<th>Silt (0.05-0.002)</th>
<th>Clay (&lt;0.002)</th>
<th>Very coarse (2-1)</th>
<th>Coarse (0.5-0.25)</th>
<th>Medium (0.25-0.1)</th>
<th>Fine (0.05-0.02)</th>
<th>Very fine (&lt;0.002)</th>
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<td>35.8</td>
<td>17.9</td>
<td>1.7</td>
<td>9.9</td>
<td>5.0</td>
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<td>8.8</td>
<td>4.6</td>
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</tr>
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<td>38.1</td>
<td>33.9</td>
<td>28.0</td>
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<td>11.9</td>
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<table>
<thead>
<tr>
<th>Organic Carbonate</th>
<th>Extractable bases</th>
<th>CEC</th>
<th>Base saturations %</th>
<th>Ratios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Sum NH4OAc</td>
<td>%</td>
<td>NH4OAc iron water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NH4OAc iron water</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>15-bar</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>1/3-</td>
<td>g/cc</td>
<td>cm</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>15-</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>mmhos/cm</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic Carbonate</th>
<th>Extractable bases</th>
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<tr>
<td></td>
<td>Sum NH4OAc</td>
<td>%</td>
<td>NH4OAc iron water</td>
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<tr>
<td></td>
<td>15-bar</td>
<td>%</td>
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<td>%</td>
</tr>
<tr>
<td></td>
<td>1/3-</td>
<td>g/cc</td>
<td>cm</td>
<td>%</td>
<td>%</td>
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<tr>
<td></td>
<td>15-</td>
<td>%</td>
<td>%</td>
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<td>%</td>
</tr>
<tr>
<td></td>
<td>mmhos/cm</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>
1. Faunal void nearly completely filled with shaped mineral excrements. B horizon (crossed polarizers)
3. Micromorphological data

One thin section is studied: derived from the B horizon.

Depth: 22-37 cm (1)

1. Depth: 22-37 cm

Macromorphological characteristics:

Dark brown medium textured weak pedal soil material containing many light coloured mineral gravels up to 7 mm Ø.

Micromorphological characteristics

Structure: The weak medium angular blocky soil material contains few irregular long elongated voids, sometimes interconnected belonging to the structure. Few elongated voids, <2 cm long, widths <1 mm and many equant voids up to 5 mm in Ø. Groups of large equant voids <2 mm Ø are often interconnected.

Groundmass: The medium textured soil material includes grain sizes up to gravels Ø 7 mm. Size limit coarse/fine material is 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, mainly feldspars and quartz which are fresh to nearly fresh. The fine material is mainly composed of clay-sized matter with a weak skelsepic plasmic fabric.

Special features

Associated with voids: very few discontinuous thin calcans and neocalcans.

: Common voids partly filled with mineral aggregates, often excrements of different sizes and shapes.

In the groundmass : Few small <500 µm carbonate nodules including other mineral grains.

: Common zones infilled with mineral aggregates, largely excrements of different shapes and sizes.

: Few isotubules.

: Few striotubules.
4. Interpretation of the micromorphological data

One thin section is studied: derived from the B horizon.
Depth: 22-37 cm.

- The features present in the studied thin section are mainly due to faunal activity.
  Voids and zones are commonly partly or completely filled with shaped mineral excrements and a few isotubules and striotubules occur. The influence of the fauna largely results in homogenization.
- Some swell and shrink occurs as the soil material has a weak angular blocky structure and a weak skelsepic plasmic fabric.
- Almost no carbonate is present in the studied zone. A few carbonate nodules and, associated with voids, a very few calcitans and neocalcitans occur in the groundmass.

Remark: According to the micromorphological information this pedon need not to be a calciorthid and can be classified as a camborthid.
THAR SERIES

1. General information and typifying pedon description


Thar series comprises very deep, well drained light coloured, calcareous, soils of fine sand to loamy fine sand. They occur on undulating sandy plains and established dunes of aeolian sandy material in the arid and semi-arid region of Rajasthan state. Lime nodules upto 15-20% by volume may be present below 120 cm forming a layer by itself which may be 10-25 cm thick. The climate is semi-arid with mean annual air temperature of 25.9°C and mean annual rainfall of 100 to 287 mm. The area is characterised by strong south westerly winds during summer which cause frequent sand and dust storms.

Thar series is tentatively classified as a member of mixed, hyperthermic family of Typic Torripsamments.

![Climatic Data and Soil Water Balance](image)
Typifying pedon: Thar fine sand-uncultivated.

C1 0-38 cm: Pale brown (10 YR 6/3 D) loamy sand, single grain loose (dry), very friable (moist), non-sticky and non-plastic (wet); strong effervescence; plentiful roots; gradual smooth boundary.

C2 38-92 cm: Pale brown (10 YR 6/3 D) loamy sand; single grain, loose (dry), very friable (moist), non-sticky and non-plastic (wet); strong effervescence; somewhat soft, lime concretions 1-5 mm size constitute about 3 percent by volume; medium plentiful roots; gradual smooth boundary.

C3 92-108 cm: Pale brown (10 YR 6/3 D) loamy sand, single grain, slightly hard (dry), friable (moist), non-sticky and non-plastic (wet); strong effervescence; few lime concretions as in above; many medium roots; gradual smooth boundary.

C4 108-138 cm: Pale brown (10 YR 6/3 D) loamy sand; single grain; slightly hard (dry), friable (moist) non-sticky and non-plastic (wet); strong effervescence; many fine to medium roots; sporadic occurrence of 5-20 mm size calcium carbonate splotches trending to form concretions; diffuse smooth boundary.

C5 138-160 cm: Pale brown (10 YR 6/3 D) loamy sand; single grain; slightly hard (dry), friable (moist), non-sticky and non-plastic (wet); strong effervescence; few fine roots.

Range in characteristics: The regolith is very deep. It is of mixed mineralogy and of uniform texture. There may be over burden sand on the surface from 15 to 45 cm. The estimated M.A.S.T. is 26.9°C. Mean summer soil temperature is 33.4°C and mean winter soil temperature 15.4°C. The moisture control section is usually dry and not moist for 90 consecutive days. The colour of the regolith is uniformly pale brown to light yellowish brown when dry. The texture ranges from fine sand to loamy fine sand. The structure is generally non coherent single grain. Lime is in dispersed but not too well formed lime nodules upto 3 percent by volume are often present below 100 cm depth. Tendency of cementation may be seen due to lime. Lime content ranges from 3.8 to 11 percent.

Competing series and their differentiae: Competing series are Bikaner, Kanasar and Shakhi. Bikaner and Kanasar series have a calcic horizon in the control section and Shakhi soils are developed on Chaggar flood plains which may have fine sandy loam texture in some part of the control section.
Drainage and permeability: Well drained with very rapid permeability.

Use and vegetation: Used for grazing under natural conditions, Grasses include Eleusine compressa (ganthil), Cenchrus biflorus (Bhurat), Lasisurus suichus (seven), shrubs: Aerva-tomentosa (bui), Calitropis procera (aak), Capparis-decidua (Kee), Heloxylo- spp (whitelana) trees are dominantly of Prosopis cinerala (Khejri). Cultivated crops are bajra (millet) and moth (legume).

Distribution and extent: Extensive in Western Rajasthan; likely to occur in southern Punjab and Haryana.

Type location: Rajasthan canal project, approximately 27°30' N. latitude and 71°41'E. longitude.

Series proposed: Rajasthan State Soil Survey Organisation, Department of Agriculture.

Remarks: The pedon meets the requirement of Torripsamments. Apparently there is some structural formation. Brittle characteristics in dry condition suggests tendency for cementation. Land use consists of grazing. The lands are overgrazed. Grass is also cut and fed to cattle.

Interpretation: The soils pore problems due to climatic limitation of aridity. Where irrigation is possible a variety of crops can be grown. The land poses problems due to levelling requirement. Under irrigation, excessive permeability will be a problem. Selection of crops for complementary use of fertilizers and irrigation water should be made. The potential to yield food crops under irrigation is moderate.

Management interpretation: (Based on physical productive potential of the series):

a) Inductive
   1. Land capability sub-class
   2. Irrigability sub-class
   3. Fertility Management potential Low, due to loss of leached applied fertilisers
   4. Management potential/productivity: low
b) Quantitative: (Management, potential under irrigation based on yield of crops by extension Department Programme on farmers level and package of practices)

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<tr>
<th>Crop</th>
<th>Yield Q/ha</th>
<th>Farmers level</th>
<th>Package level</th>
</tr>
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<tr>
<td>Wheat</td>
<td>19</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Gram</td>
<td>12</td>
<td>16.5</td>
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<tr>
<td>Mustard</td>
<td>10.5</td>
<td>15</td>
<td></td>
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</tbody>
</table>
2. Tentative soil characterisation by NBSS & LUP, DELHI

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

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Total</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
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</table>

### Depth (cm) | Organic Carbonate | Ext. pH | E.C. | Bulk Water Retention |
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</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Fe (1:1)</td>
<td>(1:1)</td>
<td>Density cm/cm</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>KCl</td>
<td>H2O</td>
<td>cm</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>g/cc</td>
<td>bar</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>cm</td>
<td></td>
<td>cm/cm</td>
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<tr>
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### Depth (cm) | Extractable bases | CEC | Exchangeable Sodium Base saturations | Ratios to clay |
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<tr>
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<td>0.80</td>
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<tr>
<td>108-138</td>
<td>0.95</td>
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<td>0.44</td>
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<td>138-160</td>
<td>0.95</td>
<td>0.60</td>
<td>0.54</td>
<td>0.37</td>
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</tbody>
</table>
3. Micromorphological data

One thin section is studied: derived from the C horizon.
Depths: 55-70 cm.

Macroscopic characteristics
Pale brown homogeneous, coarse textured, apedal soil material.

Micromorphological characteristics

Structure: The soil material is apedal and contains a few elongated voids < 1 mm wide, rarely several cm long and a few equant voids, most with diameters < 0.5 mm.

Groundmass: The coarse textured soil material includes grain sizes up to and inclusive coarse sand; the majority is fine sand sized. Size limit coarse/fine material is 15 µm. Related distribution is gefu-chitonic. The coarse mineral material consists of a variety of rather rounded minerals including carbonate grains, which are fresh or nearly fresh. A few root sections are present. The fine mineral material largely consists of small carbonate particles which form coatings around and bridges between coarse mineral material.

Special features:

In the groundmass: Some shell or snail fragments.

: Few to common carbonate nodules, Ø up to 2 mm, which include some other coarse mineral grains and are composed of fine (< 15 µm) and/or coarse (up to 80 µm) carbonate crystals, with clear boundaries.

: Common locations where a few coarse mineral grains are cemented together by carbonate particles < 15 µm Ø.

: Few to common voids (faunal or floral) loosely infilled with mineral grains. Sometimes discontinuous coatings of finer-grained soil material occur along walls.
Thar (1 photograph)

1. Weak gefu-chitonic c/f related distribution.

The fine material forming the coatings and bridges consist of small carbonate crystals.

C horizon (crossed polarizers)
4. Interpretation of the micromorphological data

One thin section is studied: derived from the C horizon. Depth: 55-70 cm.

- In the studied zone nearly all soil material consists of very fine and fine sand. This zone is rich in carbonates, most of which are present in small particles \(<15 \, \mu m\), which form coatings and bridges around and between the sand grains. Locally, a limited number of sand grains are cemented together by small carbonate particles. Besides these fine carbonate particles few to common carbonate nodules also occur, diameters up to 2 mm.

- A few voids, caused by fauna or flora, are present in this soil material. Due to the low coherence of the sandy soil material and the frequent sand dust storms, once formed the voids are soon infilled with mineral grains in an open packing.
MASITAWALI SERIES

1. General information and typifying pedon description


The Masitawali series consists of very deep, well drained, sandy loam to loam (coarse loamy), calcareous soils of yellowish brown and dark yellowish brown colour. They may have over burden sands. They have developed on alluvium derived from the Siwaliks on old flood plains of Ghaggar in North Western, Rajasthan. The climate is arid with mean annual air temperature of 24.9°C and mean annual rainfall of 267 mm. Strong south westerly winds cause frequent sand and dust storms.

Principal associated soil is Shakhi which is sandy in control section.

Masitawali Series is tentatively classified as a member of coarse-loamy, mixed (Calcareous), hyperthermic family of Typic Torrifluvents.
Typifying pedon: Masitawali loamy fine sand-cultivated

**Ap** 0-15 cm: Brown to dark brown (10 YR 4/3 M) loamy fine sand; moderate medium granular structure; slightly hard (dry), friable (moist), slightly sticky and slightly plastic (wet); slight effervescence: many fine to medium roots; clear smooth boundary.

**Cl** 15-29 cm: Dark yellowish brown (10 YR 4/4 M) fine sandy loam; moderate medium subangular blocky; slightly hard (dry), very friable (moist), slight sticky and slightly plastic (wet); effervescence; sand pockets; fine to medium common roots; many very fine to fine vertical and oblique discontinuous pores; diffuse smooth boundary.

**C2** 29-45 cm: Dark yellowish brown (10 YR 4/4 M) fine sandy loam; weak to moderate medium subangular blocky to locally granular; slightly hard (dry), friable (moist), slightly sticky and plastic (wet); strong effervescence; very few fine lime concretions; about 1 cm size sand pockets; few fine to medium roots; many very fine to fine vertical and oblique discontinuous pores; diffuse smooth boundary.

**C3** 45-84 cm: Dark yellowish brown (10 YR 4/4 M) loam, weak to moderate fine to medium subangular blocky; hard (dry), friable (moist), sticky and plastic (wet); strong effervescence; few, 0.5 cm size, soft lime concretions; few fine roots; many very fine to fine vertical and oblique discontinuous pores; diffuse smooth boundary.

**C4** 84-124 cm: Dark yellowish brown (10 YR 4/4 M) loam; weak fine to medium subangular blocky; hard (dry) friable (moist), sticky and plastic (wet); strong effervescence; irregular distribution of soft lime nodules 1-2% by volume of 5-10 mm size; few fine roots; many very fine pores; clear wavy boundary.

**C5** 124-150+ cm: Dark yellowish brown (10 YR 4/4 M) fine sandy loam; very weak fine subangular blocky; slightly hard (dry), friable (moist), slightly sticky and plastic (wet); strong effervescence; irregular distribution of soft lime nodules 1-2% by volume of 5-10 mm size; many very fine pores.
Range in characteristics: The regolith is of mixed mineralogy and of uniform texture to more than 150 cm. There may be overburden sandy material on the surface from 15 to 45 cm thickness. The estimated mean annual soil temperature at 50 cm depth is 25.9°C. Mean summer soil temperature is 31.2°C and mean winter soil temperature 16.7°C. The moisture control section is usually dry and not moist for 90 consecutive days.

Generally there is an Ap horizon. The colour of the Ap horizon ranges from pale brown to brown in 10 YR hues when dry and yellowish brown to dark brown in 10 YR hues when moist. The texture of the Ap ranges from fine sand to silt loam, structure ranges from single grain to granular. The epipedon is ohric.

The colour of the C-horizon varies from yellowish brown to dark yellowish brown. Texture varies from fine sandy loam to silt loam and structure from weak fine granular to sub-angular blocky. Clay within 25 to 100 cm of control section is less than 18 percent. There are sand pockets and structure is apparent in about 50 percent of the horizon area. The soils are calcareous with lime generally in dispersed form and nodular concretions occupying up to 2 percent by volume. Lime percentage varies from 3-15% percent within the control section. The soils may be variably saline.

Competing series and differentiae: Competing series is Shakhi which is sandy.

Drainage and permeability: Well drained with moderately rapid permeability.

Use and vegetation: With irrigation these soils are cropped to cotton, cluster beans, sugarcane, wheat and gram. Under natural condition grasses like Eleusine-compressa (Ganthil), Shrubs, like Aerva-tomentosa (Bui), Capparis-decidua (Ker), Calotropis-Procera (aak) and Haloxylon-sp (Lana) and Trees of Prosopis specipera (Khejri) grown.
Distribution and extent: Flood plains of North Western Rajasthan and in the adjoining terrid parts of Punjab and Haryana States. Occupies a significant part of phase I area of Rajasthan canal project.

Series proposed: Rajasthan State Soil Survey Organisation of the Department of Agriculture.

Type location: Eastern Block ara of Rajasthan Canal Project near Rawatsar, about 75 m north of stone No. 153 E/4035, approximately 29°15' N latitude and 74°20' E longitude.

Remarks: Structure indicates that the soils are developed, even though fluventic characteristics are apparent due to sand pockets indicating that pedoturbation is actively in progress. Micromorphological data may throw better evidence.

Interpretation: The soils pose problems due to climatic limitation due to aridity. Under irrigation the soils support a variety of crops that are climatically adapted. Response to management is fairly high. Under package treatment yield of wheat crop is 4-8 Q/ha over farmers level of management of application of 25-40 kg/N per ha.

Management interpretation: (Based on physical productive potential of the series)
a) Inductive
1. Land capability sub-class IVc
2. Irrigability sub-class 2c
3. Fertility Management potential Good. May present problem (problem of fixing a loss of applied fertiliser) due to free lime and sandy surface soils.
b) Quantitative

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield Q/ha</th>
<th>farmers' level</th>
<th>package level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>21</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Mustard</td>
<td>10</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Gram</td>
<td>12</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>
### Tentative soil characterisation by NBSS & LUP, DELHI

#### 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>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>&lt;2 mm</th>
<th>&lt;0.002</th>
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</thead>
<tbody>
<tr>
<td>Ap 0-15</td>
<td>68.1</td>
<td>16.6</td>
<td>15.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.9</td>
<td>24.8</td>
<td>42.0</td>
<td>7.7</td>
<td>8.9</td>
</tr>
<tr>
<td>C1 15-29</td>
<td>65.9</td>
<td>15.6</td>
<td>18.5</td>
<td>-</td>
<td>0.2</td>
<td>0.5</td>
<td>28.7</td>
<td>36.5</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>C2 29-45</td>
<td>62.0</td>
<td>21.9</td>
<td>16.1</td>
<td>0.2</td>
<td>0.5</td>
<td>1.1</td>
<td>26.6</td>
<td>33.6</td>
<td>6.9</td>
<td>15.0</td>
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<tr>
<td>C3 45-84</td>
<td>60.1</td>
<td>21.0</td>
<td>18.9</td>
<td>0.2</td>
<td>0.9</td>
<td>0.9</td>
<td>27.0</td>
<td>31.1</td>
<td>7.0</td>
<td>14.0</td>
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<tr>
<td>C4 84-124</td>
<td>70.6</td>
<td>16.2</td>
<td>13.2</td>
<td>-</td>
<td>0.5</td>
<td>0.7</td>
<td>33.5</td>
<td>35.9</td>
<td>4.8</td>
<td>11.4</td>
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<td>C5 124-150+</td>
<td>70.6</td>
<td>19.2</td>
<td>10.2</td>
<td>0.8</td>
<td>0.3</td>
<td>0.7</td>
<td>23.5</td>
<td>45.1</td>
<td>8.2</td>
<td>11.0</td>
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</tbody>
</table>

#### Depth (cm)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>Carbonate Fe (1:1) KCl (1:1) Nh4Ac H2O</th>
<th>Ext. pH</th>
<th>E.C. Bulk density 1/3-bar 15-bar 15-bar</th>
<th>Water Retention</th>
<th>COLE cm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>0.16</td>
<td>1.65 1.64</td>
<td>0.40 7.0</td>
<td>8.0 0.50 1.37 10.4 5.3 0.06</td>
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</tr>
<tr>
<td>15-29</td>
<td>0.12</td>
<td>1.10 1.64</td>
<td>0.45 7.2</td>
<td>8.0 0.45 1.37 11.8 5.9 0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-45</td>
<td>0.12</td>
<td>2.10 1.51</td>
<td>0.48 7.2</td>
<td>8.0 0.36 1.35 12.4 6.0 0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-84</td>
<td>0.12</td>
<td>2.19 1.64</td>
<td>0.48 7.2</td>
<td>8.2 0.41 1.37 14.2 6.6 0.10</td>
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</tr>
<tr>
<td>84-124</td>
<td>0.09</td>
<td>7.15 1.64</td>
<td>0.57 7.3</td>
<td>8.2 0.35 1.33 10.9 4.7 0.08</td>
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<tr>
<td>124-150+</td>
<td>0.07</td>
<td>7.15 0.76</td>
<td>0.42 7.3</td>
<td>8.1 0.40 1.29 9.7 4.3 0.07</td>
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</tr>
</tbody>
</table>

#### Extractable bases

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Extractable bases</th>
<th>CEC Base saturations</th>
<th>Rotios to clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>2.75 0.43 0.22 0.16</td>
<td>3.56 3.64 97</td>
<td>0.31 0.03 0.46</td>
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<tr>
<td>15-29</td>
<td>2.75 0.75 0.10 0.13</td>
<td>3.73 4.04 92</td>
<td>0.21 0.02 0.32</td>
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<tr>
<td>29-45</td>
<td>3.60 0.55 0.22 0.19</td>
<td>4.36 4.46 100</td>
<td>0.29 0.03 0.39</td>
</tr>
<tr>
<td>45-84</td>
<td>3.25 0.60 0.10 0.13</td>
<td>4.08 4.34 94</td>
<td>0.23 0.03 0.36</td>
</tr>
<tr>
<td>84-124</td>
<td>2.75 0.55 0.10 0.13</td>
<td>3.53 3.68 96</td>
<td>0.26 0.04 0.35</td>
</tr>
<tr>
<td>124-150+</td>
<td>2.25 0.50 0.10 0.13</td>
<td>2.93 3.40 87</td>
<td>0.29 0.04 0.43</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: both of the C-horizon
Depths: 29-44 cm (1); 42-57 cm (2)

1. Depth: 29-44 cm

Macroscopic characteristics: Dark yellowish brown coarse to medium textured apedal soil material.

Microscopic characteristics:

Structure: The soil material is apedal. Voids: Common elongated voids of all sizes up to 2 cm long and 1.5 mm in diameter. Abundant equant voids often interconnected, with diam. up to 2 mm. Bulk part smaller than 0.5 mm. Random distribution.

Groundmass: The coarse to medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/ fine material is 35 µm. Related distribution; porphyric - but due to abundant equant, often interconnected and elongated mesovoids, the areas with porphyric related distribution can be limited.

The coarse mineral material consists of a variety of minerals which mainly are fresh or nearly fresh. The fine mineral material consists of clay-sized matter containing fine mineral particles < 35 µm. It has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Commonly occur a few single mineral aggregates in mesovoids.

: A few root-remains in voids.

In the groundmass : Common carbonate nodules up to 2 mm Ø, including some mineral grains and open spaces. Nodules are composed of larger carbonate crystals up to 150 µm and/or of small particles < 10 µm. Random distribution.

: In the groundmass, as part of the fine material, locally single isotroph, transparent to white coloured crystals up to 30 µm are present in varying quantities. In some small mesovoids these crystals occur too.
Few to common infilled voids with mineral grains of 35-135 µm Ø, sometimes including a few mineral aggregates.

Many voids loosely infilled with mineral aggregates - often excrements, which can be desintegrating - Diam. up to 2 mm.

A few striotubulic zones present with slightly varying composition compared with groundmass.

2. Depth: 42-57 cm

Macroscopic characteristics: Dark yellowish brown medium textured pedal soil material.

Microscopic characteristics

Structure: The soil material has a weak medium to coarse subangular blocky structure, to which a few long elongated, irregular, intersected voids belong. Other voids: common elongated voids up to 2 cm long and 2 mm in diameter. Abundant equant voids, often interconnected, with diameters up to 2 mm. Bulk part smaller than 0.5 mm.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material is 35 µm. Related distribution: generally porphyric. The coarse mineral material consists of a variety of minerals which mainly are fresh or nearly fresh. The fine mineral material consists of clay-sized matter containing fine mineral particles up to 35 µm. It has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: Commonly occur a few single mineral aggregates in voids.

A few well developed not continuous neaocalcans/calcans.

In the groundmass: Common carbonate nodules up to 4 mm Ø including some other mineral grains and open spaces. Nodules are composed of larger carbonate crystals up to 150 µm and/or of small particles < 10 µm. Some nodules are infilled voids. Random distribution.
In the groundmass as part of the fine material locally single, isotroph, transparent to white crystals up to 35 µm are present in varying quantities.

Many voids loosely infilled with mineral aggregates, often excrements, which can be desintegrating. Zones up to 24 mm in diameter. Locally plastering of walls with soil material containing a higher content of clay-sized matter.

Few striotubules with slightly varying composition compared with groundmass. Along the walls pressure-affected zones can be present.
4. Interpretation of the micromorphological data

Two thin sections are studied: both of the C-horizon. Depths: 29-44 cm (1) and 42-57 cm (2).

- The influence of the fauna is strong in the studied zone and mainly results in homogenization. Soil animals have produced, and are still producing many voids that are generally partly to completely filled with mineral excrements, often including mineral grains and some soil aggregates. These more or less infilled zones are often interconnected locally giving the soil a weak subangular blocky-like structure. Animals have commonly plastered their void-walls with fine-grained soil material. The few striotubulic zones present are also a result of faunal activity.

- Carbonate are mainly present as nodules. A minor part of the nodules are completely infilled voids with carbonates. The number of nodules increase slightly with depth, but the size increases from 2 mm in diameter in (1) to 4 mm in (2). The size of the individual carbonate crystals in the nodules varies from less than 10 µm to 150 µm in diameter. Due to current processes, a few neocalcitans and calcitans occur below a depth of 42 cm.

- To 40 cm depth, a number of voids are infilled with mineral grains varying in size from about 35 to 135 µm in diameter. Below that depth they are rare. The same mineral material often occurs as admixture in voids more or less filled with excrements. This material is derived from the topsoil due to management practices and is also due to the addition of windblown sand and silt to the surface.

Remark: The composition of the single, isotroph, transparant to white coloured crystals up to 30 µm in diameter, could not be detected with SEM-EDXRA in impregnated samples. There habit indicate that they can be salt crystals.
1. General information and typifying pedon description

Pedon described by the core group members consisting of H.S. Shankaranarayana, A.S. Gowaikar, D.S. Nathawat, S.C. Saxena and P.N. Singh associated.

Chomu series comprises very deep, well drained, loamy fine sand soils of strong brown to dark brown colour. They have been developed on aeolian alluvial material in the semi-arid region of Rajasthan State. Chomu soils occur on nearly level to very gently sloping lands up to 3 percent slopes. The mean annual air temperature is 25°C and mean annual rainfall 710 mm. The climate is semi-arid. Texture is loamy fine sand in the solum with horizons having variable colours indicating coating of oxides of iron and manganese on the grains and peds. Clay movement is not apparent in B2 horizon. Krotovinas are present throughout the profile.

Chomu series is tentatively classified as a member of mixed, hyper-thermic family of Udic Ustochrepts/Typic Ustipsamments.
Typifying pedon: Chomu fine sand-cultivated.

**Ap**
0-11 cm: Light yellowish brown (10YR 6/4 D) fine sand yellowish brown (10YR 5/6 M) single grain; slightly hard (dry), very friable (moist), non-sticky and non-plastic (wet); many very fine to fine fibrous roots; clear smooth boundary.

**A1**
11-26 cm: Light yellowish brown (10YR 6/4 M); brown to dark brown (7.5 YR 4/4 M & R) loamy fine sand; weak very fine granular; slightly hard (dry), very friable (moist), non-sticky and non-plastic (wet); very few, 0.5 mm size soft ferro-manganese concretions; common very fine to fine fibrous roots; many fine tubular and vertical pores; gradual smooth boundary.

**B21**
26-55 cm: Brown to dark brown (7.5 YR 4/4 M & R) loamy fine sand; weak fine sub-angular blocky to granular; friable (moist), non-sticky and non-plastic (wet) very few 0.5 mm size very soft ferro-manganese concretions; coating on grains and peds is prominent; very fine to fine common fibrous roots; many fine tubular and vertical pores; diffuse smooth boundary.

**B22**
55-87 cm: Brown to dark brown (7.5 YR 4/4 M) loamy fine sand; very weak fine sub-angular blocky to granular structure; friable (moist), non-sticky and non-plastic (wet); few 0.5 mm size very soft ferro-manganese concretions; coatings on grains and peds is prominent; few very fine to fine fibrous roots; many fine tubular and vertical pores; diffuse smooth boundary.

**B3**
87-110 cm: Strong brown (7.5 YR 6/4 M & R) loamy fine sand; single grain; friable (moist), non-sticky and non-plastic (wet); few 0.5 mm size very soft ferro-manganese concretions; coatings on grains; very fine few fibrous root; diffuse smooth boundary.

**C1**
119-155 cm: Strong brown (7.5 YR 5/6 M & R) loamy fine sand; single grain; very friable (moist), non-sticky and non-plastic (wet); few very soft ferro-manganese concretions; few very fine fibrous roots; gradual smooth boundary.

**C2**
155+ cm: Strong brown (7.5 YR 5/6) loamy fine sand; single grain; very friable (moist), non-sticky and non-plastic (wet).

Range in characteristics: The thickness of the solum is 100 to 125 cm. The solum grades into very friable single grain loamy sand sub-stratum. The mineralogy of the regolith is mixed. The estimated mean annual soil temper-
Temperature is 27°C. Mean summer soil temperature is 30.6°C and mean winter soil temperature 16.7°C. Moisture control section is dry for more than 90 cumulative days but moisture control section is moist in some part for at least 90 consecutive days during the period July to October.

The A horizon consists of an upper ploughed layer generally, with a total thickness up to 30 cm. The colour of the A horizon is in 10YR hue when dry and moist with values 4 to 6. Under moist condition 7.5 YR hue colours may also be present. In A1 horizon soft ferro-manganese concretions are present. The texture of the A horizon varies from fine sand to loamy fine sand and structure from single grain to fine granular. The epipedon is ochric. The boundary between A and B horizon is gradual and smooth. The colour of the B horizon is brown to dark brown in 7.5 YR and ______ hues. The rubbed colour is generally the same as unrubbed though apparent colour variation is observed. The texture of the B horizon is loamy fine sand and structure in the B2 is fine sub-angular blocky to granular. B3 is single grain. The depth of the B horizon is 90 to 100 cm. The BC horizon is strong brown.

The texture is loamy sand single grain. Soft ferro-manganese concretions are present in the whole of B and C1 horizons.

**Competing series and their differentiae:** Rajan series which is sandy of alluvial origin modified by aeolian sand. Chomu soils are sandy over aeolian deposits.

**Use and vegetation:** Large area is under cultivation. Irrigation available to grow wheat, vegetables and barley. Under dry land forming bajra, groundnut and til are grown. The natural vegetation consists of mainly *Prosopis spicigera* (Khajri), *Acacia-spp* (Babool), *Ficus-religiosa* (Pipal), *Azadirachta-indica* (Neem) trees; *Zizyphus-numelaria* (Jher beri), *Cynodon-dactilon* (Doob), *Argimone-maxicana* (Kateli), *Erianthus-revanae* (Moonj) are some herbs, shrubs and grasses.

**Distribution and extent:** Extensive in Jaipur district and surrounding areas in Rajasthan.

**Type location:** Udaipur University Farm at Durgapura, Jaipur in Plot No. 8, approximately 26°50' N latitude and 75°45' longitude.
Series proposed: Soil Survey Organisation, Rajasthan.

Interpretation: Chomu series have fairly good available moisture capacity due to the presence of nearly 30% very fine sand, more than 50% fine sand in the B horizon. The uncertain rain during kharif season is the problem for crop plants on these soils. These are adapted to a variety of farm crops, vegetables and orchards.

Management interpretation:

a) Inductive (based as physical productive potential of the series)
   1. Land capability sub-class : IIIc
   2. Irrigability sub-class : 2s
   3. Fertility management potential : moderate (problem due to leaching of nutrients due to texture)

b) Quantitative (based on data from the Dept. of Agriculture, Rajasthan).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Ordinary management</th>
<th>Improved management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bajra</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Wheat</td>
<td>26</td>
<td>38</td>
</tr>
</tbody>
</table>
2. Tentative soil characterisation by NRSS & IUP, Delhi

### Size class and particle diameter (mm)

| Horizon | Depth (cm) | Total | Sand (2-0.05) | Silt (0.05-0.002) | Clay (≤0.002) | Coarse (2-1) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very Fine (0.1-0.05) | Very Fine (0.05-0.02) | Very Fine (0.02-0.002) | Organic Carbonate as CaCO₃ | pH (1:1) | E.C. (1:1) | Bulk density (g/cc) | Water Retention (15-bar) | Water Retention (1/3-bar) | Coarse Fragments > 2 mm % of < 2 mm |
|---------|------------|-------|--------------|----------------|---------------|--------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|---------|----------|----------------|----------------|----------------|-----------------------------|
| Ap      | 0-11       | 0.18  | 0.11         | 0.20          | 8.3           | 0.30         | 1.55           | 3.9            | 1.9            | 0.03           |                 |                 | 3.00             | 87      | 0.11     | 0.38          |                 |                 |                             |
| A1      | 11-26      | 0.07  | 0.28         | 0.28          | 8.1           | 0.23         | 1.50           | 5.4            | 3.0            | 0.03           |                 |                 | 3.10             | 100     | 0.04     | 0.40          |                 |                 |                             |
| B21     | 26-55      | 0.06  | -            | 0.31          | 7.8           | 0.26         | 1.40           | 5.1            | 3.0            | 0.03           |                 |                 | 2.00             | 100     | 0.04     | 0.50          |                 |                 |                             |
| B22     | 55-87      | 0.04  | -            | 0.31          | 7.7           | 0.26         | 1.37           | 5.3            | 3.0            | 0.03           |                 |                 | 2.00             | 95      | 0.04     | 0.40          |                 |                 |                             |
| B3      | 87-119     | 0.02  | -            | 0.31          | 7.8           | 0.31         | 1.42           | 4.3            | 2.6            | 0.02           |                 |                 | 2.00             | 90      | 0.04     | 0.40          |                 |                 |                             |
| C1      | 119-155    | 0.03  | -            | 0.25          | 7.9           | 0.28         | 1.42           | 5.5            | 2.9            | 0.03           |                 |                 | 2.00             | 85      | 0.04     | 0.39          |                 |                 |                             |
| C2      | 155-       |       |              |               |               |             |                |                |                |                |                 |                 |                  |         |          |               |                 |                 |                             |

### Extractable bases

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Sum</th>
<th>Exchangeable sodium</th>
<th>Sodium absorption ratio</th>
<th>NH₄OAc</th>
<th>CEC</th>
<th>Ext. iron as Fe</th>
<th>NH₄OAc CEC Ext. iron as Fe</th>
<th>NH₄OAc CEC Ext. iron as Fe</th>
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3. Micromorphological data

Three thin sections are studied: one from the A horizon and two from the B horizon.
Depths: 13-28 cm (1); 31-46 cm (2) and 56-71 cm (3)

1. Depth: 13-28 cm.

Macroscopic characteristics
Yellowish brown and brown, coarse textured, apedal, soil material.

Micromorphological characteristics
Structure: The soil material is apedal and contains only a few elongated voids of maximal several cm long, diam. < 2 mm. Common to many equant voids, up to 2 mm in diam.; most < 0.05 mm, locally interconnected.
Groundmass: The coarse textured soil material includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material is 25 µm. Related distribution: gefu-chitonic. The coarse mineral material consists of a variety of minerals of which a very minor quantity is strongly altered. The fine mineral material consists mainly of clay-sized matter and contains a few fine mineral particles up to 25 µm. It has a moderate skelsepic plasmic fabric. The groundmass shows remnants of a geogenetic lamination in which laminae with higher contents of fine material alternate with laminae practically without fine material.
Special features:
Associated with voids: In voids a few times some mineral aggregates are observed.

In the groundmass: A few root remains present in voids.
Commonly infilled voids with mineral aggregates.
In zones with higher contents of clay-sized material commonly thin, often continuous, ferri-argillans occur around mineral grains and small mineral clusters.

2. Depth: 31-46 cm.

Macroscopic characteristics
Yellowish brown and locally brown coarse textured apedal soil material.
Micromorphological characteristics

Structure: In the apedal soil material only a few elongated voids up to several cm long, diam. < 3 mm, are present. Common to many equant voids up to 3 mm in diam., most < 0.5 mm, locally interconnected.

Groundmass: The coarse textured soil material includes grain-sizes up to inclusive coarse sand. Size limit coarse/fine material is 25 µm. Related distribution: gefu-chitonic, due to very low quantities of fine material below 35 cm depth locally tending to manic. The coarse mineral material consists of a variety of minerals of which a very minor quantity is strongly altered. The fine mineral material consists mainly of clay-sized matter and contains a few fine mineral particles up to 25 µm. It has a moderate skelsepic plasmic fabric. The groundmass locally shows till 35 cm depth faint remnants of a geogenetic lamination in which laminae with higher contents on fine material alternate with laminae practically without fine material.

Special features:

Associated with voids: A few times some mineral aggregates are observed in voids.

In the groundmass: A few times root remains are present in voids.

- Common infilled voids with mineral aggregates and single grains. Sometimes small ellipsoidal excrements, diam. ~ 60 µm, composed of only clay-sized matter are present too. Along voids compacted zones with a more or less porphyric groundmass occur.

- Common zones with thin often continuous ferriargillans, occurring in equant sometimes interconnected voids, around grains and small mineral clusters. The colour of the ferri-argillans is less red than in the previous thin section (13-28 cm). The quantity of ferri-argillans decreases with depth.

3. Depth: 56-71 cm.

Macroscopic characteristics

Yellowish brown coarse textured apedal soil material, crossed by one large, 35 mm in diameter, channel partly infilled with a few large rounded mineral aggregates.
Micromorphological characteristics

Structure: In the apedal soil material a few elongated voids up to several cm long, diam. < 3 mm, are present. Common to many equant voids up to 3 mm in diam., most < 0.5 mm, locally interconnected. A few very large voids in a channel of 35 mm diam. partly infilled with large rounded mineral aggregates.

Groundmass: The coarse textured soil material includes grain-sizes up to and inclusive coarse sand. Size limit coarse/fine material is 25 µm. Related distribution: gefu-chitonic, due to very low quantities of fine material locally tending to monic. The coarse mineral material consists of a variety of minerals, a minor quantity of which is strongly altered. The fine material is mainly clay-sized, includes a few fine particles up to 25 µm and has a moderate skelsepic plasmic fabric.

Special features:

Associated with voids: In a few voids are some mineral aggregates present, as in the large channel 35 mm Ø.

In the groundmass: Common infilled voids with mineral aggregates and single grains. Along voids compacted pressure-affected zones occur.

: Local common very thin, argillans, present in the smallest equant, voids which are interconnected. The colour of the argillans is comparable or less red than in the thin section from 31-46 cm depth.

Short micromorphological description

Three thin sections are studied: one from the A horizon and two from the B horizon. Depths: 13-28 cm (1), 31-46 cm (2) and 56-71 cm (3).

- The soil material is coarse textured and contains grain sizes up to and including coarse sand. The size limit coarse/fine material is 25 µm; related distribution: gefu-chitonic. Due to the low quantities of fine material below 35 cm depth, locally tending to monic. The fine material consists mainly of clay-sized matter, includes a few fine particles up to 25 µm and has a moderate skelsepic plasmic fabric. The coarse mineral material consists of a variety of minerals, a minor quantity of which is strongly altered. A few coarse root fragments are present above 46 cm depth. To 35 cm depth remnants of alternating fine and coarse grained laminae occur.
- The soil material is apedal in the studied zone. Besides the packing voids only a few elongated and equant voids are present, widths and diameters reach up to 3 mm, lengths of elongated voids up to a few cm, randomly distributed.
- Over the whole studied zone voids are partly or completely infilled with mineral aggregates and some mineral grains. Their occurrence does not change with depth; voids are commonly completely infilled, only a few voids are partly infilled. Only a minor part of the mineral aggregates is made up of excrements. Some of the voids have zones with compacted soil material along the walls.

- In the studied part of the A and B horizons thin argillans are commonly present. They occur around mineral grains and in packing voids. To 35 cm depth they are red coloured. With increasing depth they become yellower and are less well-developed.

1. The coatings of the mineral grains and those around the black voids are argillans.
   B horizon (crossed polarizers).

2. Infilling of mineral grains in a faunal void with a coating of fine-grained material.
   B horizon (plain light).
4. Interpretation of the micromorphological data

Three thin sections are studied: one from the A horizon and two from the B horizon. Depths: 13-28 cm (1), 31-46 cm (2) and 56-71 cm (3).

- In the coarse textured groundmass are remnants of a geogenetic lamination, visible as alternating laminae with slight variations in content of clay-sized material. They are found to 35 cm depth. Below 35 cm depth the content of clay-sized material is lower than in the upper zones.

- The soil material has loose packing with a gefu-chitonic, locally, tending to monic related distribution of the coarse/fine material, resulting in a high porosity. Other voids are nearly all due to flora and fauna. Both types can be surrounded by pressure-affected zones where the packing is more compact. The majority of the voids once formed by flora or fauna is partly but more often completely infilled with mineral aggregates and mineral grains. Only a minor part is made up of excrements. Most material is derived from the groundmass that due to the loose packing has an unstable character.

- In all thin sections, argillans are commonly found occurring around mineral grains and in packing voids. They are best developed and most numerous above 35 cm depth where more clay-sized material is present. Below 35 cm depth the argillans have a more yellow colour and are very thin. The argillans are a result of weathering in situ.
1. Lifting of mineral grains in a fluvial bed with a coating of fine-grained material.

A horizon (clay film).
SOILS OF THE BLACK SOIL REGION

1. General information and typifying pedon description


Areal series is a member of fine, montmorillonitic argillans in the family of Typic Chromusterts. Areal soils have dark grayish brown to very dark brown, moderately alkaline, clayey, A horizons grading into B horizons and are developed in bosaltic horizons.

Typifying pedon: Saras clay - cultivated. (Colours are for dry soil unless otherwise noted).

Ap

0-8 cm: Dark grayish brown (2.5 Y 4/2) clay, very dark grayish brown to dark grayish brown (2.5 Y 4/2 M), moderate medium subangular blocky, dry hard, moist firm, wet sticky and plastic; many clay, imped roots; medium tubular pores; pH 8.0; clear subsoil boundary.

A1b

11-25 cm: Dark grayish brown (2.5 Y 4/2) clay, very dark grayish brown (2.5 Y 1/2), moderate medium subangular blocky, dry hard, moist firm, wet sticky and plastic, many fine roots; fine and medium tubular pores; pH 8.0; clear subsoil boundary.

A1c

29-54 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3/2) clay, very dark grayish brown (2.5 Y 3/2 M), medium alkali montmorillinite that break into moderate medium angular blocky pods with shiny presence facets; dry hard, nodose firm, wet sticky and plastic; few fine imped and arrested roots; fine irregular pores; slightly effervescent; pH 8.1; diffuse smooth boundary.

A1d

54-93 cm: Very dark grayish brown to dark grayish-brown (2.5 Y 3/2 M & 4/2 clay; coarse intermixed alkali montmorillinite, forming...
1. General information and typifying pedon description


Sarol series is a member of fine, montmorillonitic; hyperthermic family of Typic chromusterts. Sarol soils have dark grayish brown to very dark brown, moderately alkaline, clayey A horizons grading to AC horizons and are developed in basaltic outwash.

Typifying pedon: Sarol clay – cultivated. (Colours are for dry soils unless otherwise noted).

Ap 0-11 cm: Dark grayish brown (2.5 Y 4/2) clay, very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 M); moderate medium subangular blocky; dry hard moist firm, wet sticky and plastic; many fine, inped roots; medium tubular pores; pH 8.0; clear smooth boundary.

A12 11-29 cm: Dark grayish brown (2.5 Y 4/2) clay, very dark grayish brown (2.5 Y 3.5/2 M) moderate medium subangular blocky; dry hard, moist firm, wet sticky and plastic, many fine inped roots; fine and medium tubular pores; pH 8.0; clear smooth boundary.

A13 29-54 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2) clay, very dark grayish brown (2.5 Y 3/2 M); medium slickensides that break into moderate medium angular blocky peds with shiny pressure faces; dry hard, moist firm, wet sticky and plastic; few fine inped and exped roots; fine irregular pores; slightly effervescent; pH 8.1; diffuse smooth boundary.

A14 54-95 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 D & M) clay; coarse intersecting slickensides forming
wet very sticky and very plastic; few fine inped and exped roots; slightly effervescent; fine irregular pores; pH 8.7; gradual smooth boundary.

A15 95-119 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 D & M) clay; coarse intersecting slickensides forming parallelepipeds with long axes 10 to 15 cm tilted at 30° from horizontal that break into strong coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic; few fine inped and exped roots; slightly effervescent; pH 8.1; gradual smooth boundary.

A16 119-147 cm: Dark grayish brown (2.5 Y 4/2) clay; very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 M) coarse intersecting slickensides forming parallelepipeds with long axes 25 to 30 cm tilted at 35° from horizontal that break into strong coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic; few fine inped and exped roots; slightly effervescent; fine few irregular pores; pH 8.2; clear smooth boundary.

AC 147-160 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 D & M) clay; the matrix is mottled with white (2.5 Y 8/2) interdigitating material constituting 10% (Vol) medium intersecting slickensides forming parallelepipeds tilted at 35° from horizontal that break to strong coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic; strongly effervescent; fine irregular pores; pH 8.2.

Type location: Indore Tehsil and district Madhya-Pradesh, Binjalai village.

Range in characteristics: Thickness of the solum varies from 1.3 to 1.5 m. Within the depth 15 to 100 cm of the surface the content of coarse fragments larger than 2 mm, mostly lithorelicts with lime accretion, ranges from 2 to 7% and are distributed irregularly. The content of total clay within this depth varies from 56 to 58% while content of organic
carbon and calcium carbonate varies from 0.4 to 0.3% and 1.9 to 2.7% respectively. The CEC varies from 80 to 99 me/100 g clay indicating, soils are montmorillonitic. Predominantly colours are dark grayish brown to very dark grayish brown in hue of 2.5 Y with chroma 2 and values 3.5 and 4. AC horizon shows interdigitation material of white (2.5 Y 8/2) colour in the ped interiors and matrix. The pedality varies from moderate subangular blocky to angular blocky with shiny pressure faces upto 50 to 60 cm of the surface while in the deeper layers of the solum intersecting slickensides form the parallelepipeds tilted at 30 to 45 degrees from horizontal. Open cracks 2-3 cm wide on the surface extend by tapering through depth upto 119 cm of the surface.

Competing series and differentiae: Baloda soils which are deep, moderately well drained clayey calcareous with colours of 10 YR and classified als Typic Chromusters.

Setting: Sarol series occur in nearly level to very gently sloping (slope gradient 1 to 3%) piedmont plains. The climate is dry subhumid.

Principal associated soils: Baloda series which is very deep, calcareous, clayey, moderately well drained and Kamalaikheri series which is moderately deep, moderately well drained, clayey and non-calcareous. Baloda and Kamalaikheri series are classified as Typic Chromusterts and Vertic Ustochrepts.

Drainage and permeability: Moderately well drained with moderate permeability.

Use and vegetation: Cultivated for Sorghum, red gram in kharif and for wheat, gram and linseed in Rabi. Accacia arabica, zyzphyus jujuba are common vegetation.

Distribution and extent: Extensive in Malwa plateau of Madhya Pradesh.

Interpretation: Sarol soils are clayey heavy textured soils with moderate alkalinity. These soils have high water retention and nutrient retention capacity. Due to their high cation exchange capacity these soils despond well for fertilization. As such these soils are cultivation for millets and pulses in Kharif and for cereals in Rabi. As these soils are deep these can be cultivated for cotton also. Continuous irrigation without proper internal drainage may cause sodium hazard.

Management interpretation:

a) Inductive: Based on physical potential of the series.
   1. Land capability classification: II
   2. Land suitability classification: 2d

b) Quantitative: (Based on crop production at different levels of management).

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<th>Package of practice</th>
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<td>Red gram</td>
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<td>Gram</td>
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<td>Linseed</td>
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2. Tentative soil characterisation by NBSS & LUP, NAGPUR

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<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 (0.1-0.05)</th>
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<th>E.C. (1:2 H2O) mmhos/cm</th>
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3. Micromorphological data

Two thin sections are studied: both derived from a deep A horizon. Depths: 60-75 cm (1) and 120-135 cm (2)

1. Depth 60-75 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, strong angular blocky soil material, containing common mainly white nodules up to 6 mm in diameter.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common intersected voids belong. Other voids: few to common elongated voids, widths up to 2 mm, length less than a few; few to common equant voids, diam. up to 2 mm; randomly distributed.

Groundmass: The fine textured groundmass includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 10 µm; related distribution: porphyric. The coarse mineral material consists of a variety of minerals which show varying stages of altering. The fine material is largely clay-sized, includes common particles up to 10 µm and has a moderate ma-vo-sepic plasmic fabric.

Special features:

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

In the groundmass: Common voids/zones almost completely filled with mineral aggregates: shaped, more or less welded excrements.

: Common carbonate nodules, diam. up to 6 mm. Composing carbonate crystals of varying sizes up to 100 µm with clear or sharp external boundaries; randomly distributed. Also some fragments of carb. nodules are embedded. In a part of the carb. nodules occur sesquioxidic accumulations, mainly manganese.

: Few to common small sesquioxidic nodules, up to 1.5 mm diameter, most <0.5 mm, mainly with clear external boundaries. Randomly distributed.
2. Depth: 120-135 cm

Macroscopic characteristics

Very dark grayish brown, fine textured, strong angular blocky soil material containing common white nodules up to 6 mm in diameter.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common intersected voids belong. Other voids: few to common elongated voids, widths up to 2 mm, length less than a few cm; few to common equant voids, diam. up to 2 mm; randomly distributed but few elongated/equant voids.

Groundmass: The fine textured groundmass includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 10 µm; related distribution: porphyric. The coarse mineral material consists of a variety of minerals which show varying stages of altering. The fine material is largely clay-sized, includes common particles up to 10 µm and has a moderate ma-vosepic plasmic fabric which is locally strongly developed.

Special features

Associated with voids: Very few voids partly filled with mineral aggregates: angular soil fragments as well as excrements.

In the groundmass: Few voids almost completely filled with mineral aggregates which are shaped more or less welded excrements.

: Common carbonate nodules, diam. up to 6 mm.

Composing carbonate crystals are coarse and fine grained with clear or sharp external boundaries, randomly distributed. Some more carbonate present as in previous section, mainly as small carbonate nodules. In a part of the carbonate nodules occur sesquioxidic accumulations, mainly manganese.

: Few to common small sesquioxidic nodules up to 1.5 mm in diameter, most <0.5 mm, mainly with clear external boundaries. Randomly distributed.
1. Part of a zone in the groundmass almost completely filled with more or less welded, shaped, mineral excrements. A horizon (plain light).
4. Interpretation of the micromorphological data

Two thin sections are studied: both derived from a deep A horizon. Depths: 60-75 cm (1) and 120-135 cm (2).

- The strong coarse angular blocky structure with inclined horizontal axis is due to strong swell and shrink of montmorillonitic clays. The few angular soil fragments present in some voids are split off during shrinkage and accumulated deeper in voids. The roundness of the large carbonate nodules and the orientation of clay domains resulting in a moderate ma-vosepic plasmic fabric which, locally, is strongly developed deep in the A horizon (2), are also consequences of the vertic properties of the soil.
- For a vertisol the fauna plays a relatively important role. The influence decreases with depth in the A horizon. Soil animals produce most of the present voids few to common in (1) decreasing to few in (2). They homogenize a large part of the groundmass in (1) where common zones are almost completely filled by more or less welded, shaped, mineral excrements, decreasing to a few zones deep in the A horizon (2).
- In both thin sections carbonate nodules, diameters up to 6 mm, are common. The quantity and sizes are slightly higher and larger deep in the A horizon. The nodules are composed of carbonate crystals with varying diameters up to 100 μm and have sharp or clear external boundaries. Some of the carbonate nodules contain accumulations of sesquioxides, mainly of manganese.
- Few to common small sesquioxidic nodules occur in both thin sections. Diameters reach up to 1.5 mm, but most are less than 0.5 mm in diameter and have clear external boundaries. They are randomly distributed.
SINGPURA SERIES

1. General information and typifying pedon description


Singpura series includes moderately well drained, very deep, soils developed on fine alluvium occurring on nearly level to very gently sloping flood plain of Chambal river system. The soil pedon exhibits a brown to yellowish brown fine sandy loam to sandy clay loam A horizon grading to dark yellowish brown to dark brown coarse prismatic loam to sandy clay loam compact B horizon with patchy clay skins on the peds faces, underlain by the C horizon of calcareous sandy loam to sandy clay loam material. In India these soils have been classified as Regosols.

The climate of the area is tropical subhumid. The mean annual temperature is 25.7°C rising to 35.5°C in May and falling to 15.6° in January. The mean annual rainfall is 90 cm of which about 80.6% is received during July to September in most of the years. The principal associated soils are those of Piperghan and Sumera series which are deep Alfisols and Vertisols respectively.

Singpura series comprises members of fine loamy, mixed, hyperthermic, deep family of Udic Paleustalfs.

Typifying pedon: Singpura loam - cultivated. (Colours are for dry soils unless otherwise noted).

Ap 0-20 cm: Yellowish brown (10 YR 5/4) fine sandy loam, dark yellowish brown (10 YR 4/4 M); fine weak subangular blocky; dry slightly hard, moist friable, wet nonsticky and nonplastic; many fine to medium vertical pores; abundant fine roots; moderately rapid permeability, pH 7.7; clear and smooth boundary.

Bl 20-32 cm: Dark yellowish brown (10 YR 4/4 D & M) loam; medium weak subangular blocky; dry slightly hard, moist friable, wet slightly sticky and plastic; many fine discontinuous tabular
inped and exped pores; many fine roots; moderate permeability; pH 7.6; gradual and smooth boundary.

B21t 32-63 cm: Dark yellowish brown (10 YR 4/4) sandy clay loam, dark yellowish brown (10 YR 3.5/4) when moist; coarse moderate prismatic breaking into medium moderate angular blocky peds coated with thin patchy clay skins; dry hard, moist slightly firm, wet slightly sticky and plastic; many fine oblique discontinuous inped and exped pores; many fine roots; moderate permeability; pH 7.5; gradual and smooth boundary.

B22t 63-96 cm: Dark yellowish brown (10 YR 3/4) sandy clay loam, brown to dark brown (10 YR 3.5/3) when moist; coarse strong prismatic breaking into medium moderate prismatic peds coated with thin patchy horizontal clay skin; dry hard, moist firm, wet sticky and plastic; few fine to very fine oblique inped and exped pores; many medium to coarse lithorelicts in the matrix with lime accretion; few fine roots; moderate permeability; pH 7.7; gradual and smooth boundary.

B23t 96-116 cm: Brown to dark brown (10 YR 3.5/3) sandy clay loam, dark brown (10 YR 3/3) when moist; coarse strong prismatic, breaking into medium moderate prismatic peds coated with thin patchy clay skins; dry hard, moist firm, wet sticky and plastic; very few discontinuous inped and exped oblique pores; many medium accretionary lithorelict in the matrix; moderate permeability; pH 8.4; diffuse and smooth boundary.

3t 116-155 cm: Dark yellowish brown (10 YR 4/4) sandy clay loam, dark brown (10 YR 3/3) when moist; coarse strong prismatic breaking into medium moderate prismatic peds coated with thin patchy clay films; dry hard, moist firm, wet sticky and plastic; very few fine micropores; moderate permeability; pH 8.1; diffuse and smooth boundary.

C 155-190 cm: Dark yellowish brown (10 YR 4/6 D & M) sandy clay loam, when moist; coarse strong prismatic breaking into same peds; dry hard, moist firm, wet sticky and plastic; very fine micro pores; moderate permeability; upper part calcareous and effervesces violently; pH 8.1.
Range in characteristics: The average thickness of the solum ranges from 1.10 to 1.35 metre. Within the depth of 15 cm to 100 cm of the surface the content of the coarse fragments larger than 2 mm are negligible while the content of the clay progressively increases through depth. The soil reaction is mildly to moderately alkaline with pH ranging from 7.7 to 8.1 through depth. The conductivity through the depth is <3 mhos/cm. The texture of the fine earth of the soil material through depth of the solum is sandy loam to sandy clay loam. The colour of the soil in A horizon is in the hue of 10 YR with dry value 5 and moist value 4 while the chroma is 4 both for dry and moist soils. The thickness of Bt horizon ranges from 95 to 115 cm. The structure development in the A horizon is fine weak subangular blocky with slightly hard consistency. The pedality in B21t is coarse moderate prismatic breaking into medium moderate angular blocky peds while in B22t, B23t and B3t pedality is coarse moderate prismatic breaking into medium moderate prismatic peds coated with thin patchy clay cutans. Consistency in B2t to B3t horizon is very hard when dry and very firm when moist. The depth of the groundwater table ranges from 8 to 10 metre of the surface. About 3/4th of the pedon remains dry for more than 180 days during the dry period for most of the years retaining moisture at or below wilting point.

Competing series and their differentiae: The competing soils are those of Piperghan series which are also very deep having the colour dominantly in the hue of 10 YR. Singpura soils are non-calcareous through the depth while Piperghan series are calcareous in the subsoil layer and has the presence of Cca horizon.

Drainage and permeability: Moderately well drained with moderate to moderately slow permeability.

Vegetation and land use: These are mostly cultivated for Pearl Millet (Bajra), Red gram, Wheat and Mustard. Natural vegetation includes, Neem, Bar and Acacia species.

Distribution and extent: Extensive in Gwalior and Morena districts, Madhya Pradesh.
Type location: Gwalior, tehsil and district Gwalior, M.P.; Plot No. Cl, Agricultural College Farm JNKVV. Series proposed: Jawaharlal Nehro Krishi Vishwa Vidhyalaya, Jabalpur.

Interpretation: Singpura soils have good soil-moisture-air relationship and the crops respond to management. A variety of crops can be grown under rainfed and irrigated conditions:

a) Interpretative groups:
   (i) Land capability subclass: IIe
   (ii) Irrigability subclass : 1
   (iii) Productivity potential : High

b) Yields based on data from farmer's fields:

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<thead>
<tr>
<th>Crops</th>
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<tr>
<td>Rice</td>
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<tr>
<td>Wheat</td>
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<td>Sorghum</td>
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<tr>
<td>Maize</td>
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<td>Pigeonpea</td>
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<td>Peas</td>
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<td>Groundnut</td>
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### Tentative soil characterisation by NBSS & LUP, NAGPUR

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<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Sand (2-0.05) %</th>
<th>Total Silt (0.05-0.002) %</th>
<th>Total Clay (&lt;0.002) %</th>
<th>Very coarse (2-1) %</th>
<th>Coarse (1-0.5) %</th>
<th>Medium Coarse (0.5-0.25) %</th>
<th>Fine (0.25-0.1) %</th>
<th>Very fine (0.1-0.02) %</th>
<th>Clay (&lt;0.002) %</th>
<th>Coarse fragments % of Total</th>
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<table>
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<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>pH (1:1)</th>
<th>E.C. (1:1)</th>
<th>Bulk density H20 g/cc</th>
<th>Water Retention 1/3-bar %</th>
<th>15-bar %</th>
<th>1/3-to-15 bar %</th>
<th>CEC</th>
<th>NH4OAc CEC</th>
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3. Micromorphological data

Three thin sections are studied: all derived from the B horizon. Depths: 41-56 cm (1), 66-81 cm (2) and 143-158 cm (3).

1. Depth: 41-56 cm.

Macroscopic characteristics

Dark yellowish brown, medium textured, moderate angular blocky soil material.

Micromorphological characteristics

**Structure:** Coarse prismatic, breaking into moderate coarse angular blocky peds, to which a few, rather regular, intersected, elongated voids belong. Other voids: Common elongated voids, widths up to 4 mm, lengths up to 15 mm and common equant voids, diam. up to 4 mm, most <1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material 5 µm. Related distribution: porphyric. The coarse material consists of a variety of minerals of which a part show varying stages of altering. A few coarse organic fragments, root fragments, are present. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a moderate ma-skelsepic plasmic fabric, accentuated by altering micas.

**Special features**

Associated with voids: Few to common thin cutans of mainly clay-sized material, not argillans, in elongated and equant voids. These cutans are specked with black dots.

In common voids: Common voids partly infilled with mineral aggregates, mainly excrements often including also soil aggregates.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, mainly excrements which are single and/or wealed together.

A few striotubules and/or isotubules. These kinds of tubules merge into each other.
Few to common infillings of voids with selections of soil material. A part are completely infilled with mainly finer-grained material (<50 µm), sometimes laminated, others are infilled with mainly coarser grains (>50 µm).

A few embedded fragments of fine-grained infillings. A few large mineral grains and rock-fragments up to 1 mm Ø.

2. Depth: 66-81 cm.

Macroscopic characteristics

Dark yellowish brown, medium textured, strong angular blocky soil material.

Micromorphological characteristics

**Structure:** Coarse prismatic breaking into moderate to strong coarse angular blocky peds, to which common rather regular intersected, elongated voids belong. Other voids: Common elongated voids, widths up to 4 mm, lengths up to 30 mm and common equant voids, diam. up to 4 mm, most <1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material 5 µm. Related distribution: porphyric. The coarse material consists of a variety of minerals of which a part show varying stages of altering. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a moderate ma-skelsepic plasmic fabric, accentuated by altering micas.

**Special features**

Associated with voids: Common voids partly infilled with mineral aggregates, mainly excrements. Elongated particles near the void walls in the groundmass are often oriented parallel to the void. The walls of the voids belonging to the structure generally are uneven. They show cavities and locally mineral excrements are added to the walls.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, mainly excrements which are single and/or wealded together. Elongated particles near the void walls in the groundmass are often oriented parallel to the void.

Few to common isotubules and/or striotubules. These kinds of tubules merge into each other.
3. Depth: 143-158 cm

Macroscopic characteristics

Dark yellowish brown, medium textured, moderate angular blocky soil material.

Micromorphological characteristics

**Structure:** Coarse prismatic breaking into weak to moderate coarse angular blocky peds, to which a few, rather regular, intersected, elongated voids belong. Other voids: Common elongated voids, widths up to 4 mm, most <1 mm, lengths up to 15 mm, and common equant voids, diam. up to 4 mm, most <1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals of which a part show varying stages of altering. The fine material is largely clay-sized, includes a few particles up to 5 µm and has a moderate ma-skelsepic plasmic fabric, accentuated by altering micas.

**Special features**

**Associated with voids:** Few voids with thin to moderately thick cutans of mainly clay-sized material, not argillans, in elongated and equant voids. These cutans are specked with black dots.

**In the groundmass**

- Common voids partly infilled with mineral aggregates, mainly excrements.
- Common voids nearly completely infilled with mineral aggregates, mainly excrements which are single and/or wealded together.
- Few to common isotubules and/or striotubules. These kinds of tubules merge into each other.
- Common pressure-affected zones in the groundmass, with oriented elongated particles.
- A few sesquioxidic nodules, with clear or sharp external boundaries, diam. up to 2 mm, randomly distributed.
- 2 carbonate nodules, clear external boundaries, including some other mineral grains, diam. 6 and 7 mm.
Short micromorphological description

Three thin sections are studied, all derived from the B horizon. Depths: 41-56 cm (1); 66-81 cm (2) and 143-158 cm (3).

The soil material is medium textured and includes grain sizes up to and inclusive medium sand. 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 moderate ma-skelseptic plasmic fabric, accentuated by altering micas. The coarse mineral material consists of a variety of minerals of which a part show varying stages of altering. In (1) a few coarse organic fragments, root fragments, are present.

The soils material is coarse prismatic breaking into coarse angular peds, which are best developed in the middle part of the B horizon: moderate (1), moderate to strong (2) and weak to moderate (3). To the structure belong a few in (1) and (3) and common in (2), rather regular intersected, elongated voids. Other, elongated and equant, voids are common over the whole studied depth. Diameters up to 4 mm, in (3) most <1 mm, length of the elongated voids up to a few cm, all randomly distributed. Special features: In the whole B horizon voids are commonly partly or completely filled with mineral aggregates, mainly excrements which are single and/or wealded together. In the middle part of the B horizon (2) elongated particles in the groundmass near the voidwalls are often oriented parallel to the void.

: Increasing from few in the upper part (1) to few to common in the middle part and onwards (2, 3) striotubules and/or isotubules are present. These kind of tubules merge into each other.

: In the middle part of the B horizon (2) the void walls belonging to the structure generally are uneven. They show cavities and locally mineral excrements are added to the walls.

: In the lower part of the B horizon (3) pressure-affected zones with oriented elongated particles are common in the groundmass.

: In the upper part of the B horizon (1) occur few to common cutans of mainly clay-sized material, decreasing to a few in the lower part of the B horizon. These cutans are not argillans, they are specked with black dots and occur in elongated and equant voids.
In the upper part of the B horizon (1) few to common voids are completely filled with selections of soil material. These infillings can either be mainly finer grained material (<50 µm), sometimes laminated, or mainly coarser grained (>50 µm). A few fragments of finer grained infills occur embedded in the groundmass.

In the lower part of the B horizon are a few sesquioxidic nodules with clear or sharp external boundaries present, diameters up to 2 mm, randomly distributed.

In the same zone also 2 carbonate nodules with clear external boundaries occur, diameters about 6 mm.
1. Zones almost completely filled with shaped mineral excrements; B2 horizon (plain light).

2. Cutan composed of clay-sized material, not an argillan, in a void (white) in the B3 horizon (plain light).
4. Interpretation of the micromorphological data

Three thin sections are studied; all derived from the B horizon. Depths: 41-56 cm (1), 66-81 cm (2) and 143-158 cm (3).

- The coarse prismatic structure, breaking into angular blocky peds is mainly due to physical processes. The structure is best developed in the middle part of the B horizon. The fauna is mainly responsible for the other, over the whole depth common, elongated and equant voids. Many of these voids are not primary voids, but smaller ones situated between the walls of the primary void and infilled mineral aggregates. They are, in the main, shaped excrements which commonly, partly or completely, fills the larger voids. Apart from these common, more or less filled voids, few to common striotubules and isotubules are also present in the B horizon. In the middle and lower part of this horizon, elongated particles in the groundmass, near faunal voids, are often oriented parallel to the walls. This is due to pressure exerted by animal under wet soil conditions. Consequently, the fauna plays an important role in the B horizon, which results more in homogenization of soil materials than in the production of voids.

- Micas are altering in the whole B horizon. This results in an accentuation of the ma-skelsepic plasmic fabric of the groundmass.

- In the lower part of the B horizon, sesquioxides are accumulating to a minor extent an some accumulation of carbonate has taken place.

- Soil material in the topsoil is periodically saturated with water and flows in existing voids, whereby sorting occurs. Only in the upper part of the B horizon (1) are few to common voids completely infilled with varying grain-size compositions. Over the whole B horizon, from few to common in the upper part (1) to a few in the lower part (3), cutans of clay-sized material, not argillans, are found due to this process. This illuviation is identical to the one which leads to the development of an agric horizon, but is less extensive. The periodical saturation with water can have a natural cause (monsoon rains) and/or may be due to management practices.

Conclusion: This Benchmark pedon is tentatively classified as an Udic Haplustalf (S.T.). The cutans visible in thin sections however, are due to the inflow of fine-grained, wet soil material from the topsoil. The quantity decreases with depth and cutans become finer grained. This process leads to the development of an agric horizon. Consequently this pedon cannot be classified as an alfisol, and most probably is an Udic Ustochrept.
1. General description and typifying pedon description

Pedon described and sampled by the core group members consisting J.C. Bhattacharjee, R.J. Landey, H.P. Chowdhary, S.G. Pandey, G.V. Patel and B.R. Tembhare.

Kheri series include imperfectly drained, very deep, soils occurring on level to very gently sloping lower piedmont plain. These are developed on fine basaltic alluvium laid by Narmada and its tributaries. The soil pedons have AC profiles with thick dark grayish brown to very dark grayish brown clayey A horizons grading to very dark grayish brown clayey, C horizons through an intermediary AC horizon. Fine to medium, hard and irregularly rounded basaltic lithorelicts are disseminated through the profile. During dry periods these soils develop gilgai micro relief on the surface and soil cracks 3 to 4 cm wide extending 55 to 60 cm and more deep in the soil. The ground water table is very deep. The soils are locally called as "Kabar Soils" and have been classified as "Deep Black Soils" in India.

The climate of the area belongs to tropical sub-humid type. The mean annual air temperature is 25°C rising to maximum 41.9°C during May and falling to minimum 9°C in December. The mean annual rainfall is 130-140 cm of which about 77 to 80% is received during July to September in most of the years. The associated soils are those of Adhartal series which are deep Inceptisols.

Kheri series comprises fine, montmorillonitic, hyperthermic deep family of Typic Chromusterts.

Typifying pedon: Kheri clay - cultivated.

(Colours are for dry soil unless otherwise noted).

Ap 0-15 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 D & M) clay; weak medium prismatic breaking to moderate medium sub-angular blocky; hard, firm, sticky, plastic; few fine to medium basaltic lithorelicts and fine lime nodules; strongly effervescent; abundant fine to medium inped roots; fine tubular pores; moderate permeability; gradual smooth boundary; pH 7.1; 15-20 cm thick.
A12 15–37 cm: Very dark grayish brown (10 YR 3/2 M) clay; moderate coarse prismatic breaking to moderate medium angular blocky; very hard, very firm, very sticky, plastic; few fine to medium basaltic lithorelicts and lime nodules; strongly effervescent; common fine roots inside peds and outside peds; very fine tubular and irregular pores; moderately slow permeability; diffuse smooth boundary; pH 7.3; 20 to 25 cm thick.

A13 37–60 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse intersecting slickensides breaking to strong coarse angular blocky with shiny pressure faces; very hard, very firm, very sticky, plastic; few fine to medium basaltic lithorelicts and lime nodules; strongly effervescent; few fine roots inside peds and outside peds; slow permeability; diffuse smooth boundary; pH 7.4; 20 to 25 cm thick.

A14 60–84 cm: Very dark grayish brown (10 YR 3/2 M) clay with dark grayish brown (10 YR 4/2 M) interdigitating colour constituting 10% in the matrix; coarse intersecting slickensides breaking to strong coarse angular blocky with shiny pressure faces; very hard, very firm, very sticky, plastic; few fine to medium basaltic lithorelicts and lime nodules; strongly effervescent; few fine roots; slow permeability; diffuse smooth boundary; pH 7.3; 20 to 25 cm thick.

A15 84–129 cm: Very dark grayish brown (10 YR 3/2 M) clay with dark grayish brown (10 YR 4/2 M) interdigitating colour constituting 10% in the matrix; coarse intersecting slickensides forming parallelepipeds with longitudinal axes tilted 40 to 45° from the horizontal and breaking to strong coarse angular blocky; shiny pressure faces; very hard, very firm, very sticky, plastic; few fine to medium basaltic lithorelicts and few lime nodules; strongly effervescent; few fine roots; slow permeability; wavy boundary; pH 7.3; 40 to 45 cm thick.

AC 129–150 cm: Very dark grayish brown (10 YR 3/2 M) clay with dark grayish brown (10 YR 4/2 M) colour constituting 20% in the matrix; coarse intersecting slickensides forming parallelepipeds with longitudinal axes tilted 30 to 35° from the horizontal breaking to strong coarse angular blocky; shiny pressure faces; very hard, very firm, very sticky; few fine to medium basaltic lithorelicts and lime nodules; strongly effervescent; fine roots; slow permeability; gradual wavy boundary; pH 7.5; 20 to 25 cm thick.
C 150-175 cm+: Dark grayish brown (10 YR 4/2 M) clay; coarse intersecting slickensides forming parallelepipeds with longitudinal axes tilted 30 to 35° from the horizontal breaking to coarse angular blocky with shiny pressure faces; very hard, very firm, very sticky; few fine roots; fine to medium size accretionary lime nodules strongly effervescent; slow permeability; pH 7.7.

Range in characteristics: The thickness of solum ranges from 115 to 140 cm. The content of particles coarser than 2 mm ranges from 5 to 10 percent and CaCO₃ ranges from 1 to 2.5% between the depth of 15 cm to 1 m of the surface. The content of clay within this depth varies from 50 to 56 percent (with high cation exchange capacity indicating the dominance of montmorillonitic mineralogy in exchange complex). The common soil type is clay but at places silty clay is also met with.

The colour of the A horizon ranges from dark grayish brown to very dark grayish brown mostly in the hue of 10 YR and 2.5 Y with value 4 and 3 and chroma 2 both for dry and moist soils. The colour of the AC and C horizon remains the same as that in A horizon. The colour is mostly in the hue of 10 YR with value 3 and 4 and chroma 2 for both dry and moist soils. The pedality in A13, A14 horizons exhibits coarse intersecting slickensides breaking into coarse strong angular blocky peds with shiny pressure faces while A15, AC and C horizon exhibit the parallelepipeds with their long axes ranging from 77 to 81 cm tilting 30-45° from the horizontal. (The AC horizon also contains about 20% volume of upward intruded core material of C horizon). The soil reaction is neutral to mildly alkaline with pH ranging from 7.1 to 7.7. The effective rooting depth extends up to 100 cm of the surface. The soil moisture between the depth of 15 to 25 cm of the surface remain dry and moisture remains at or below wilting point during dry period in most of the years. The frequency of linear distance between micro high and micro low is of 110-115 cm indicating medium size pedon.

Competing series and their differentiae: Deori and Karmeta are the competing series. These are very deep clayey soils with high shrink-swell potential. The cracks (2-3 cm) are wide and separate soil surface into several polyhedron of different sizes. The colour of soils in Deori series is dominantly in hue of 10 YR while that in Karmeta soils is in hue of 2.5 Y (while values were 4 and 3 for dry and moist soils respectively and chroma 2 both for dry and moist soils).
Drainage and permeability: Imperfectly drained with slow permeability.

Use and vegetation: The soils are mostly cultivated. The important Kharif and rabi crops are paddy, wheat, gram, linseed, pea, lentil, etc. Natural vegetations are Sawan (Setaria glauca L.), Kans (Sachharum spontanium L.), Dub (Cynodon dactylon L.), Goikhroo (Xanthium strumarium L.), Cassiabora (Argimone maxicana), Danmurai (Tridex procumbans L.), Agare (Steriga lutea L.) etc. Palas (Butea monosperma), Ber (Ziziphus jujuba L.), Sitaphal (Annana squamosa L.) and Babool (Acacia arabica L.).

Distribution and extent: The Kheri Series occupies considerable areas in lower piedmont plain in the upper catchment of Narmada river system. These are found in parts of Jabalpur and Narsingpur districts.

Series established and type location: Soil pedon no. 15, located about 500 metres to the west of Adhartal railway station at Kheri Research Farm of J.N.K.V.V., Jabalpur Campus, Madhya Pradesh.

N.B.: 1. The weighted values of properties are subject to changes, additions and alteration.

2. Soil survey interpretation chapter would be appended after the completion of analytical work.
2. Tentative soil characterisation by NBSS & LUP, Nagpur

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Size class and particle diameter (mm)</th>
<th>Coarse fragments  &gt; 2 mm % of whole soil</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>Silt (0.02-0.002)</td>
<td>Clay (2-0.05)</td>
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<tr>
<td>AC</td>
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<tr>
<th>Depth (cm)</th>
<th>Organic carbon &lt;2 mm &lt;0.002 mm</th>
<th>Carbonate as CaCO₃</th>
<th>pH</th>
<th>E.C. (1:1)</th>
<th>Bulk density</th>
<th>water Retention 1/3-bar</th>
<th>15-bar</th>
<th>1/3-to-15 bar cm/cm</th>
<th>15-bar cm/cm</th>
<th>NH₄OAc</th>
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3. Micromorphological data

Two thin sections are studied: both from a deep A horizon. Depths: 94-109 cm (1) and 129-144 cm (2).

1. Depth: 94-109 cm.

Macroscopic characteristics:

Very dark grayish brown, fine textured, pedal soil material, containing few to common dark colored nodules, diam. up to 4 mm.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. Other voids: Few elongated voids, widths < 3 mm, lengths up to 15 mm and common equant voids, Ø up to 3 mm, most < 1 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 10 μm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, which show varying stages of alteration. A few coarse organic fragments, root fragments, occur. The fine material is largely clay-sized includes a few particles up to 10 μm and has a moderate vo-masepic plasmic fabric.

Special features:

Associated with voids: Few voids partly filled with mineral aggregates, mainly angular soil aggregates. They occur mainly in structural voids. Along structural voids, a few times thick coatings of soil material occur.

In the groundmass: A few infillings of soil material. Some of these infillings have a higher content on coarse particles than the groundmass. Few to common voids, nearly completely filled with mineral aggregates, mainly wealded excrements.

: Few to common rounded off, altered dark colored rock fragments and/or sesquioxide nodules with sharp external boundaries, diam. up to 4 mm, randomly distributed.
2. Depth: 129-144 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, pedal, soil material, containing a few dark coloured nodules, diam. up to 4 mm.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. Other voids: Few elongated voids, widths <3 mm, lengths up to 15 mm and few to 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 medium sand. Size limit coarse/fine material: 10 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, which show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderate vo-masepic plasmic fabric.

Special features:

Associated with voids: Few voids partly infilled with mineral aggregates, mainly angular soil aggregates. They occur mainly in structural voids.

: Along structural voids a few times thick coatings of soil material occur.

In the groundmass: Few voids, nearly completely infilled with mineral aggregates, mainly wealded excrements.

: Few rounded off dark coloured nodules which are mainly sesquioxidic accumulations, sometimes including altered rock fragments, with sharp external boundaries and often concentric internal fabric, diam. up to 4 mm, randomly distributed.

: Common small sesquioxidic accumulations, with diffuse boundaries, diameters generally less than 250 µm, randomly distributed.
1. Rounded nodule composed of iron and manganese.

A horizon (plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied: both from a deep A horizon. Depths: 94-109 cm (1) and 129-144 cm (2).

- The strong coarse angular blocky structure with an inclination of about 35-40° with the horizontal axis is due to strong swell and shrink of the montmorillonitic clays. Locally, a few angular soil aggregates which have split off during shrinkage in upper parts of the A horizon, accumulate in structural voids. The thick coatings of soil material occurring locally along structural voids are remnants of these accumulations after a period of swell. More features are influenced by the vertic properties of the soil. A few elongated zones with a higher content of coarse particles than the surrounding groundmass are infilled former voids, closed after swell of the soil material. Larger altered rock fragments and sesquioxidic nodules are rounded off and have sharp external boundaries due to dislocations in the A horizon. Strong swell and shrink caused orientation of clay domains resulting in a moderate vo-masepic plasmic fabric.

- The fauna plays a minor role. Their effects are restricted to the production of few to common in (1) decreasing to a few in (2) voids, which are nearly always completely filled with welded mineral excrements.

- In the soil, minerals and rock fragments are still altering.

- Deep in the A horizon (2) common small sesquioxidic accumulations with diffuse boundaries, diameters less than 250 µm, are found. They are formed by current processes related to slow permeability in wet periods.

Remark: No solid carbonates are observed, not in nodules, in or around voids, nor in small particles in the fine material of the groundmass. This is in contradiction with the pedon description.
MARHA SERIES

1. General information and typifying pedon description

Pedon described by:

Marha series is a member of fine, montmorillonitic, hyperthermic family of Entic chromusterts. The soils have dark grayish brown to grayish brown clay loam A horizons grading to dark grayish brown silty clay loam AC horizons developed on basaltic alluvium. They occur on nearly level to gently sloping old flood plains. The climate is tropical semiarid to warm subhumid with hot summer. Principal associated soils are Jamra series which are very deep calcareous Inceptisols.

Typifying pedon: Marha clay loam - cultivated (Colours are for dry soils unless otherwise mentioned)

Ap 0-12 cm: Dark grayish brown to grayish brown (2.5 Y 4.5/2) clay loam, dark grayish brown (2.5 Y 4/2) when moist; medium moderate subangular blocky structure; dry soft, moist friable, wet slightly sticky and plastic; common fine inped roots; very few fine interstitial pores; moderate permeability; pH 8.0; clear wavy boundary.

A12 12-44 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2) clay loam, very dark grayish brown (2.5 Y 3/2) when moist; strong coarse angular blocky structure; dry slightly hard, moist friable, wet slightly sticky and plastic; abundant fine inped roots; very few fine interstitial and common tubular inped pores; moderate permeability; pH 8.0; gradual wavy boundary.

A13 44-70 cm: Very dark grayish brown to dark grayish brown (2.5 Y 3.5/2 D & M) clay; coarse prismatic breaking into strong coarse angular blocky peds with prominent pressure faces; dry hard, moist firm, wet sticky and plastic; few
fine inped roots; many fine tubular pores; moderately slow permeability; pH 8.0; gradual smooth boundary.

A14 70-105 cm: Dark grayish brown (2.5 Y 4/2 D & M) clay; coarse prismatic breaking into strong coarse angular blocky peds with prominent shiny pressure faces; dry hard, moist firm, wet sticky and plastic; very few fine inped roots; very few fine interstitial and tubular pores; moderately slow permeability; pH 8.0; diffuse smooth boundary.

A15 105-137 cm: Dark grayish brown to dark brown (2.5 Y 4.5/2) clay, dark grayish brown (2.5 Y 5/2) when moist; coarse prismatic breaking into strong coarse angular blocky peds with slickensides close enough to intersect; dry very hard, moist very firm, wet very sticky and plastic; very few, fine inped roots; very few fine interstitial and tubular pores; slow permeability; pH 8.0; diffuse smooth boundary.

AC 137-180 cm: Dark grayish brown (2.5 Y 4/2 D & M) clay; coarse prismatic breaking into strong coarse angular blocky peds with slickensides close enough to intersect; dry very hard, moist very firm, wet very sticky and plastic; slightly effervescent, with 2.0 % calcium carbonate very few fine exped pores; pH 8.1.

Range in characteristics: The thickness of the solum is more than 125 cm. The estimated MAST is 26.2°C. MSST is 30.2°C and MWST is 20.2°C. Moisture regime is ustic and the moisture control section is dry for more than 90 cumulative days. The A horizon is more than 125 cm thick. Its colour is in hue 2.5 Y and 10 YR, value 3 to 5 and chroma 2 to 3. Texture is silty clay loam to silty clay with clay content varying from 44 to 52 per cent. Cracks 2 to 4 cm wide at the surface that taper and extend into the AC horizon are observed. The effective rooting depth extends upto 115 cm.
Competing series and their differentiae: Jamra series (Vertic Ustochrept) is the competing series which includes very deep, moderately well drained clayey and calcareous soils. 1 to 2 cm wide cracks pressure faces and shining powdery mass of lime is present. Colours are in 10 YR hue and texture silty clay loam to clay through depth.

**Drainage and permeability:** Moderately well drained moderately slow permeability.

**Use and vegetation:** Soils are mostly cultivated under rainfed conditions and the important crops grown are jowar, arhar, wheat and gram.

**Distribution and extent:** Occurs extensively in Bundelkhand Region of Madhya Pradesh.

**Type location and series established:** Village Marha: Tehsil Lauri: District Chattarpur (M.P.)

**Interpretation:** Marha soils have high water retentive capacity. They are productive and respond to a variety of crops. If irrigated these soil can be cultivated in both the seasons. As these soils are of montmorillonitic mineralogy, they may pose problems for intercultivation during the rainy season.

**Management interpretation:**

a) Inductive: (Based on physical productive potential of the series)

1. Land Capability subclass : IIa
2. Irrigability class : 2d
3. Fertility management potential : High
4. Management potential productivity: High
## Tentative soil characterisation by NBSS & LUP, NAGPUR

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

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</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 (0.1-0.005)</th>
<th>(0.005-0.002)</th>
<th>&lt;0.001 % of whole soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap 0-12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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### Depth Organic Carbonate pH E.C. Bulk CEC Ratios to clay % (cm) Carbonate as CaCO3 % <2 mm (1:1) H2O density % H2O cm

<table>
<thead>
<tr>
<th>Horizon Depth (cm)</th>
<th>Organic Carbonate as CaCO3 %</th>
<th>&lt;2 mm %</th>
<th>pH</th>
<th>E.C. (1:1) density H2O</th>
<th>Bulk NH4Ac</th>
<th>CEC NH4Ac</th>
<th>Ratios to clay</th>
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<td>2.01</td>
<td>47.5</td>
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3. Micromorphological data

Two thin sections are studied: both from the A-horizon. Depths: 44-59 cm (1) and 70-85 cm (2)

1. Depth: 44-59 cm

Macroscopic characteristics
Dark grayish brown, fine textured, pedal soil material, containing common mainly light coloured modules, diam. up to 8 mm.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. Other voids: Few elongated voids, widths < 3 mm, lengths up to a few cm and common equant voids, Ø up to 3 mm, most < 1 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: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments which show varying stages of alteration, but mainly are rather fresh. A few coarse organic fragments occur. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderate vo-masepic plasmic fabric.

**Special features**

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

In the groundmass: Few to common voids nearly completely filled with mineral aggregates, mainly more or less welded excrements.

: Locally in the groundmass zones occur with higher contents on coarse grains than present in the surrounding groundmass.
Common carbonate nodules. A part are distinctly rounded, often with clear external boundaries, diameters up to 8 mm, randomly distributed. Many of the carbonate nodules have accumulations of sesquioxides, predominantly of manganese, often restricted to the outer zone. Many carbonate nodules show internal structures of several growing phases.

A few small irregular accumulations of sesquioxides occur.

2. Depth: 70–85 cm

Macroscopic characteristics
Dark grayish brown, fine textured, pedal soil material, containing common mainly light coloured nodules, diam. up to 8 mm.

Micromorphological characteristics
Structure: Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. Some intersection nodes are enlarged. Other voids: Few elongated voids, widths up to 3 mm, lengths up to a few cm and few to common equant voids, ø up to 3 mm, most < 1 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 3 mm ø. Size limit coarse/fine material: 10 µm. related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments which show varying stages of alteration, but mainly are rather fresh. A few coarse organic fragments occur. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderate vo-masepic plasmic fabric.

Special features:
Associated with voids: Few voids partly filled with mineral aggregates, excrements as well as, often angular, soil aggregates.
In the groundmass: Few to common voids nearly completely filled with mineral aggregates, mainly more or less wealded excrements.
Common carbonate nodules, a part are distinctly rounded, often with clear external boundaries, diameters up to 8 mm, randomly distributed. Compared to the previous section there are more small carbonate nodules present, composed of small carbonate particles, with clear and diffuse external boundaries. Many of the carbonate nodules have accumulations of sesquioxides, often restricted to the outer zone. Some carbonate nodules show internal structures of several growing phases.

Few to common small, often irregular, accumulations of sesquioxides occur.
Short micromorphological description

Two thin sections are studied: both from the A horizon.
Depths: 44-59 cm (1) and 70-85 cm (2).

- The soil material is fine textured and includes grain sizes up to gravels of 3.5 mm in diameter. The size limit coarse/fine material is 10 µm; the related distribution is porphyric. The fine material is largely clay-sized, includes a few particles up to 10 µm and has a moderate vo-masepic plasmic fabric. The coarse material consists of a variety of minerals and rock fragments which show varying stages of alteration, but are mainly rather fresh, and of a few coarse organic fragments.

- The soil material has a strong coarse angular blocky structure to which common, intersected, elongated voids belong. Other voids: Few elongated voids, widths up to 3 mm, lengths up to a few cm and common (1), few to common (2) equant voids, diam. up to 3 mm, most <1 mm, randomly distributed.

- In the A horizon a few voids are partly filled and few to common voids completely filled with mineral aggregates, which are usually more or less wealded excrescences. The voids partly filled with mineral aggregates also often contain angular soil aggregates. Zones are locally present in the groundmass of the A13 horizon (1) which have a higher content of coarse mineral grains than the surrounding groundmass.

- Carbonate nodules are common in both thin sections. They usually have clear external boundaries, diam. up to 8 mm and are randomly distributed. In the middle part of the A horizon (2) more small carbonate nodules occur. They are composed of carbonate particles <20 µm, with clear and diffuse external boundaries. Many nodules in (1) and some in (2) show internal structures of several growing phases.

- The majority of the carbonate nodules have accumulations of sesquioxides, often predominantly manganese, usually mainly present in the outer zones of the nodules. In the studied part of the A horizon small, often irregular, accumulations of sesquioxides occur. Their quantity slightly increases with depth from a few (1) to few to common (2).
Marha (2 photographs)

1. Planar void (white) partly filled with mineral excrements, 50 cm depth (plain light).

2. Carbonate nodule with a dark coloured accumulation of manganese in the outer zone, about 80 cm depth (plain light).
Interpretation of the micromorphological data

Two thin sections are studied: both derived from the A horizon. Depths: 44-59 cm (1) and 70-85 cm (2).

- The strong coarse angular blocky structure of the A horizon is a result of swell and shrink of the montmorillonitic clay. In structural voids, small accumulations of angular soil fragments are present locally. They are split off during shrinkage and accumulated deeper in voids. The few zones in the A13 horizon (1), containing a higher content of coarse grains than the surroundings groundmass, the rounded-off carbonate nodules with clear external boundaries occurring in the studied zone, as well as the moderately vo-masepic plasmic fabric of the fine material, are all consequences of the vertic properties of the soil.

- The fauna plays a minor role. Its effect is restricted to local modifications of structural voids, the production of most of the common elongated and equant voids, and the few to common voids, partly or completely filled with mainly shaped mineral excrements.

- Carbonates are accumulating or have been accumulated in the A horizon. In the middle part of the A horizon, small carbonate accumulations are formed in the groundmass. Due to the vertic properties of the soil, the larger carbonate nodules are often rounded off and can be dislocated. Some of these carbonate nodules are formed in several more or less concentric growing phases.

- In the A horizon, accumulation of sesquioxides takes place. Many carbonate nodules have accumulations of sesquioxides, predominantly manganese, in the outer zone. In the studied part of the A horizon, sesquioxides are accumulating in small nodules. Their quantities increase slightly with depth from a few (1) to few to common (2). Sesquioxides are released by the alteration of minerals and rock fragments present.
JAMBHA SERIES

1. General information and typifying pedon description


Jambha series includes somewhat poorly drained, very deep soils developed on basaltic alluvial material occurring on very gently to gently sloping flood plain in Godavari river system. The soil pedons are with AC profiles having dark grayish brown to very dark grayish brown A horizon grading to dark yellowish brown to yellowish brown AC horizon overlying yellowish brown, massive unconsolidated calcareous C horizon. The soils have high shrink-swell potential and they develop open cracks of 2-4 cm width on the surface separating the soil into several polyhedrons of different dimensions and tapers along with the depth extending up to 90 cm. The subsoil develops coarse intersecting slickensides that form coarse parallelepipeds in the deep layers. These have been classified in India as Deep Black Soils. The common soil associates are soils of Mahitapur series which are deep vertisols developed over Basalt.

The climate of the area is tropical subhumid. The mean annual air temperature ranges between 26 and 27°C while the mean annual precipitation varies from 90 to 95 cm of which about 70% is received during monsoon season (July-September) in most of the years.

Jambha series comprises members of fine, montmorillonitic, hyperthermic, deep family of Typic Chromusterts.

Typifying pedon: Jambha clay – cultivated.

(Colours are for dry soil unless otherwise noted).

Ap

0-20 cm: Dark grayish brown (10YR 4/2) clay, very dark grayish brown (10 YR 3/2) when moist; medium moderate sub-angular blocky; dry very hard, moist friable, wet very sticky and very plastic; slightly effervescent; cracks 2 cm wide extending up to 20 cm; 2-2.5 cm thick very dark gray pulverised layer covering open cracks as surface mulch; slow permeability; few fine fibrous roots; fine
inped and exped pores; diffuse smooth boundary; strongly alkaline (pH 8.6). (18-22 cm thick).

A12 20-45 cm: Dark grayish brown (10 YR 3.5/2) clay, very dark grayish brown (10 YR 3/2) when moist; coarse prismatic breaking into angular blocky peds with shiny pressure faces; cracks 1-2 cm wide extends up to 25 cm dry very hard, moist firm, wet sticky and very plastic; slightly effervescent; very few fibrous roots; few fine irregular pores, low permeability; diffuse and smooth boundary; moderately alkaline (pH 8.4). (20-30 cm thick).

A13 45-65 cm: Very dark grayish brown (10 YR 3/2 D & M) clay; coarse prismatic breaking into coarse angular blocky peds with shiny pressure faces; few 1 cm wide cracks extends up to 20 cm dry very hard, moist very firm, wet very sticky and very plastic; slightly effervescent; very slow permeability; diffuse and smooth boundary; moderately alkaline (pH 8.3). (20-25 cm thick).

A14 65-105 cm: Very dark grayish brown (10 YR 3/2 D & M) clay; coarse intersecting slickensides forming parallelepipeds with longitudinal axis tilted at an angle 30 to 35° from horizontal breaking into coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic; slightly effervescent; very slow permeability; diffuse and smooth boundary; moderately alkaline (pH 8.3). (35-45 cm thick).

A15 105-145 cm: Very dark grayish brown (10 YR 3/2 D & M) clay; coarse intersecting slickensides forming parallelepipeds with longitudinal axes 30 to 35 and 20 to 25 cm respectively and tilted at an angle 30 to 35° from horizontal breaking into coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and plastic, slightly effervescent; very slow permeability, diffuse and smooth boundary; moderately alkaline (pH 8.4). (40 to 45 cm thick).

AC 145-190 cm: Dark grayish brown to yellowish brown (10 YR 4/2 to 5/3) clay; brown to pale brown (10 YR 4/3; 5/3) when moist; coarse intersecting slickensides forming parallelepipeds with longitudinal axes 28 to 30 cm tilted at angle 30 to 35° from horizontal breaking into strong medium angular blocky peds with shiny pressure faces; coarse inter-digitating cores of C and A horizon of (10 YR 5/4 & 10 YR 4/2) respectively; in the matrix dry very hard, moist firm, wet very sticky
and very plastic; strong effervescence; wavy and smooth boundary; strongly alkaline (pH 8.5).

C 190-240 cm+: Yellowish brown (10 YR 5/4) clay, dark yellowish brown (10 YR 4/4) when moist; angular blocky peds with shiny pressure faces; matrix shallow 20% (vol) of interdigital cores, materials of A horizon having colour of 10 YR 3.5/2; dry very hard, moist firm, wet very sticky and very plastic; violently effervencent; strongly alkaline (pH 8.8).

Range in characteristics: The average thickness of the solum ranges from 1.25 to 1.5 metre of the surface. The soil reaction is strongly alkaline with pH ranging from 8.5 to 8.9 through depth. The E.C. ranges below 0.2 mmhos/cm through depth. The content of coarse fragments larger than 2 mm are negligible in the normal cases in the soil pedon but it increases in the lower depth and in eroded phases it ranges from 15 to 21%. The texture of the fine earth of the soil material through depth of the solum is silty clay to clay. The soil type varies from silty clay to clay. The mineralogy of the soil is montmorillonitic. The colour of the soil in A horizon is in the hue of 10 YR with dry value 3 to 5 and chroma 2 to 3. The pedality may vary from weak fine sub-angular blocky to medium moderate sub-angular blocky peds having unevenly distributed lime nodules and basaltic lithorelicts.

The pedality in sub-soil horizons varies from coarse intersecting slickensides breaking to coarse strong angular blocky peds with shiny pressure faces forming parallelepipsds tilting at an angle 30-35° to the horizontal axes. The dominant colour of the subsoil is in the hue of 10 YR with dry value 4 and moist value 3 while the chroma is 4 for dry and 2 in moist soils respectively. The effective rooting depth extends up to 45 to 55 cm of the surface. The depth of 20 to 25 cm of the surface remains dry for 180 or more cumulative days in most of the years.

Competing series and their differentiae: Soils of Kalunna series are the competing series. Kalunna soils are with very deep solum developed over basaltic alluvium and are mottled in subsoil horizon.

Drainage and permeability: Somewhat poorly drained with moderate to moderately slow permeability.
Vegetation and land use: Almost entirely under cultivation for important crops like cotton, jowar, tur under kharif season while gram, wheat, linseed and other crops under rabi season. At places it is under irrigation wherever it is available. Natural vegetation consists of Acacia arabica, Prosopis juliflora, thorny shrubs, Terminalia, Chebula, etc.

Distribution and extent: Soils of Jambha series occurs extensively in parts of Amaravati, Wardha and Akola districts of Maharashtra State. Type location and series established: Profile is located in village Palasheda, taluka Chandur Rly., District Amravati, Maharashtra.
2. Tentative soil characterisation by NBSS & LUP, Delhi

<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>
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<th>Depth (cm)</th>
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<th>Ext. iron as Fe</th>
<th>pH</th>
<th>E.C.</th>
<th>Bulk density</th>
<th>water Retention</th>
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<td>1.90</td>
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<tr>
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<td>8.6</td>
<td>0.23</td>
<td>1.93</td>
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</table>
3. Micromorphological data

Two thin sections are studied: both from a deep A horizon.
Depths: 75-90 cm (1) and 160-175 cm (2).

1. Depth: 75-90 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured pedal soil material, containing common mainly white nodules, diam. up to 5 mm, randomly distributed.

Micromorphological characteristics

Structure: Strong, coarse angular blocky structure, to which rather wide intersected voids belong. Other voids: few to common elongated voids, widths < 3 mm, lengths less than 15 mm and few to 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: 10 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, inclusive a few rock fragments, which show varying stages of altering. The fine material is largely clay sized and includes common particles up to 10 µm and has a moderate ma-vosepic plasmic fabric.

Special features:

Associated with voids: Few large voids partly infilled with mineral aggregates, mainly angular soil aggregates.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, often wealed excrements.

: Few to common weathering minerals and rock fragments surrounded by sesquioxidic accumulations with diffuse or clear boundaries, diam. < 1 mm, randomly distributed.

: Common carbonate nodules composed of coarse and/or fine particles with clear or sharp external boundaries. Most carbonate nodules include accumulation of sesquioxides. Diameters up to 5 mm, randomly distributed.
2. Depth: 160-175 cm.

Macroscopic characteristics

Dark greyish brown, fine textured, pedal soil material, containing common largely white coloured nodules, diam. up to 7 mm, randomly distributed.

Micromorphological characteristics

Structure: Strong medium to coarse angular blocky structure, to which common intersected voids belong. Other voids: few elongated voids, widths < 2 mm, lengths less than 10 mm and a few equant voids, diam. up to 2 mm, most < 1 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 10 µm

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, inclusive a few rock fragments, which show varying stages of altering. The fine material is largely clay sized and includes common particles up to 10 µm and has a moderate and locally strong ma-vosepic plasmic fabric.

Special features:

Associated with voids: Few voids, partly infilled with mineral aggregates, mainly angular soil aggregates.

In the groundmass: Few voids nearly completely infilled with mineral aggregates, often wealded excrements.

: Common weathering minerals and rock fragments surrounded by sesquioxidic, and pure sesquioxidic accumulations with diffuse or clear boundaries, diam. < 1 mm, randomly distributed.

: Common carbonate nodules composed of coarse and/or fine particles with clear or sharp external boundaries. Many carbonate nodules include accumulations of sesquioxides. Diameters up to 7 mm, including many small nodules < 2 mm, randomly distributed.
Tamboha (1 photograph)

1. Rounded carbonate nodule in a zone almost completely filled with more or less welded, shaped, mineral excrements. A horizon (plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied: both from a deep A horizon.
Depths: 75-90 cm (1) and 160-175 cm (2).

- The strong coarse angular blocky structure with an inclination of about 30° with the horizontal axis is due to strong swell and shrink of the montmorillonitic clays. The few angular soil aggregates present in, sometimes enlarged, intersection nodes are split off during shrinkage in upper parts of the A horizon. The roundness of some of the large carbonate nodules and the orientation of clay domains resulting in a moderate ma-vo-sepic plasmic fabric which, locally, is strongly developed in (2), are also consequences of the vertic properties of the soil.
- The fauna plays a minor role. Their effects are restricted to the production of few to common voids in (1) decreasing to a few in (2); which are mainly almost completely filled with welded shaped mineral excrements.
- Carbonate nodules are common in both studied zones. They are composed of coarse and/or fine carbonate particles and have clear or sharp external boundaries. The diameters of the nodules increase with depth from 5 mm (1) to 7 mm maximum (2). Deep in the A horizon (2) the carbonate is predominantly present in small carbonate nodules, diameters <2 mm, with clear or diffuse external boundaries. They are commonly joined together forming larger irregular shaped nodules, indicating current accumulation of carbonates in this zone.
- Minerals and rock fragments are altering in the soil material. The quantity of altering particles increases slightly with depth. Around these particles accumulations of sesquioxides commonly occur. Deep in the A horizon (2) pure sesquioxidic accumulations, with diffuse or clear external boundaries, diameters up to 1 mm, are also present indicating current accumulation. In many of the larger carbonate nodules accumulations of sesquioxides occur.
LINGA SERIES

1. General information and typifying pedon description


Linga series includes poorly drained, very deep, dark grayish brown clayey soils having wide and deep cracks and intersecting slickensides. Lime nodules gradually decrease along depth. They are found to occur on nearly level to very gently sloping (0-3%) alluvial plains and have been formed from fine basaltic alluvium. The soil pedon exhibits AC profile with thick very dark grayish brown clayey A horizon showing coarse intersecting slickensides forming coarse parallelepipeds in the lower parts and grading to yellowish brown clayey C horizon through the dark grayish brown clayey intermediary AC horizon expressing coarse parallelepipeds. These soils have been classified in India as "Deep Black Soils". The climate of the area is tropical sub-humid. The mean annual rainfall is 110 cm of which 80% is received during monsoon season (July-September) while the mean average annual air temperature is 27°C. The principal soil associates are those of Karla, Panjra and Wadhona series.

Linga series comprises the members of fine, montmorillonitic, hyperthermic family of Udic Chromusterts.

Typifying pedon: Linga clay - Orange garden
(Colours are for dry soils unless otherwise noted).

Ap 0-17 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse strong sub-angular blocky; dry hard, moist firm, wet sticky and plastic; many fine oblique and vertical pores; few fine roots; coarse fragments of lithorelicts 2-10 mm size 2-3% (vol); slow permeability; clear and smooth boundary; moderately alkaline; pH 8.3; 15-20 cm thick.

A12 17-47 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse intersecting slickensides forming parallelepipeds with 32 cm long axes tilting at angle 30° from horizontal and breaking into strong coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet sticky and very plastic; coarse lithorelicts 2-10 mm
size 2-3% (vol); few strongly cemented accretionary lime nodules; many fine oblique and vertical pores; few fine roots, slow permeability; clear and smooth boundary; moderately alkaline; pH 8.1; 25-30 cm thick.

A13  47-84 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse intersecting slickensides forming parallelepipeds with 42 cm long axes tilting at angle 30° from horizontal and breaking into coarse strong angular blocky peds with shiny pressure faces; dry hard, moist firm, wet sticky and plastic; many fine oblique pores; few fine roots; coarse accretionary lithorelicts 3% (vol); slow permeability; clear and smooth boundary; moderately alkaline; pH 8.1; 30-35 cm thick.

A14  84-117 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse intersecting slickensides forming parallelepipeds; with 65 cm long axes tilting at angle of 45° from horizontal that break into strong coarse angular blocky peds with shiny pressure faces; interdigitating cores of 10 YR 5/2 colours comprising less than 40% of matrix; dry very hard, moist very firm, wet very sticky and very plastic; very few very fine, shallow pores on slickensides; coarse fragments of accretionary lithorelicts 2-10 mm size up to 3% (vol); very slow permeability; clear and wavy boundary; moderately alkaline; pH 8.05; 30-35 cm thick.

AC  117-140 cm: Dark grayish brown (2.5 Y 4/2 M) to grayish brown (2.5 Y 4.5/2) clay; coarse intersecting slickensides forming parallelepipeds breaking into coarse strong angular blocky peds with shiny pressure faces; interdigitating cores of A14 with 10 YR 3/2 colour mixing up in the upper part of AC horizon; dry hard, moist firm, wet sticky and plastic; very slow permeability; coarse fragments of accretionary lithorelicts 2-10 mm size up to 20% (vol) in pockets; moderately alkaline; pH 8.1.

Range in characteristics: The average thickness of the solum is very deep and it ranges normally between 1.0 m and 1.5 m of the surface in the thick regolith. The soil colour of the solum varies from very dark brown to very dark grayish brown in hue of 10 YR with values 2 and 3 and chroma 2 both for dry and moist soils. The clay content in the fine earth fraction of
the soil material increases with depth and the texture ranges from clay to silty clay. During dry period there appear gilgai microrelief on the surface with the linear interval of microknoll and micro depression ranging from 1.0 m to 1.5 m. The open cracks 3-5 cm wide separate the soil into several polyhedrons of different sizes during the dry period in most of the years. The wide open cracks taper and extend upto 90-100 cm of the surface. The pedality of the surface layer varies from medium moderate to coarse strong subangular blocky peds while that in the subsoil layers coarse intersecting slickensides form parallelepips with long axes ranging from 30 to 65 cm tilting at angles 30 to 45 degrees from horizontal that break into coarses strong angular blocky peds with shiny pressure faces. The intermediary AC horizon ranges 20 to 30 cm in thickness followed by C horizon. The colour of the soil is in hue of 2.5 Y with values 4 and 4.5 having chroma 2 for both moist and dry soils. The ped interior and patches in the matrix these would be colours of interdigitating cores from adjacent and subjacent horizons which are in hue of 10 YR with values 3 and 4 having chromas 2 and 4. During dry periods about 25 to 30 cm gets dry in most of the years while subsoil remains moist. The soil temperature ranges between 28 to 29°C while the difference of mean summer and mean winter soil temperature at the depth 50 cm of the surface exceeds 5°C in most of the years.

Competing series and their differentiae: Panjra and Malegaon are the competing series. Closely associated Panjra series is well to moderately well drained while Malegaon soils are deep, well drained, dark brown occurring on plateau tops.

Drainage and permeability: Poorly drained with very slow permeability.

Use and vegetation: These soils are mostly under cultivation and are used for double crops wherever irrigation facilities are available. Climatically adapted all the crops of the region are grown over these soils. Cotton, jowar, wheat, tuar, gram are the main crops besides oranges, vegetables and flowers where irrigation facilities exist.

Distribution and extent: Linga series are widely distributed in Nagpur district and the adjoining areas.

Type location: Regional Fruit Research Station Farm, Wandli, Tahsil Katol, District: Nagpur.
2. Tentative soil characterisation by NBSS & LUP, Nagpur

<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>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>
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<th>Total % of &lt; 2 mm</th>
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<td></td>
<td></td>
<td>Sand</td>
<td>Silt</td>
<td>Clay</td>
<td>Coarse</td>
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<td>Fine</td>
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<th>pH</th>
<th>E.C. (1:1)</th>
<th>E.C. (1:1)</th>
<th>Cole</th>
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<td>%</td>
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<td>Mg</td>
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3. Micromorphological data

Two thin sections are studied: both from a deep A horizon. Depths: 40-55 cm (1) and 94-109 cm (2).

1. Depth: 40-55 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, pedal soil material, containing common black nodules $\phi < 2$ mm and common white coloured nodules $\phi < 6$ mm, randomly distributed.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common intersected, partly regular, partly irregular elongated voids belong. A part of the intersecting nodes are enlarged. Other voids: few to common elongated voids, widths $< 3$ mm, lenghts less than 15 mm and few to 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 very coarse sand. Size limit coarse/fine material: 10 $\mu$m. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, inclusive a few rock fragments, which show varying stages of altering. A few coarse organic fragments, root fragments, are present. The fine material is largely clay sized and includes common particles up to 10 $\mu$m and has a moderate vo-masepic plasmic fabric.

Special features:

Associated with voids: Locally along structural voids, irregular enlargements of the original void occur.

- Few voids partly infilled with mineral aggregates, mainly angular soil aggregates.

In the groundmass:

- Few voids nearly completely infilled with mineral aggregates, often welded excrements.

- Common weathering minerals and rockfragments surrounded by sesquioxidic accumulations, with diffuse clear boundaries, diam. up to 2 mm, randomly distributed.

- Common carbonate nodules, often built up of concentric rings of coarse crystals, sometimes sesquioxidic accumulations are incorporated, sharp external boundaries, diameters up to 6 mm, most $> 2$ mm. Randomly distributed.
2. Depth: 94-109 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, pedal soil material, containing common black nodules, \( \varnothing < 2 \text{ mm} \). and common white coloured nodules, \( \varnothing < 6 \text{ mm} \), randomly distributed.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure, to which common intersected, partly regular, partly irregular elongated voids belong. A part of the intersecting nodes are enlarged. Other voids: few to common elongated voids, widths < 3 mm, lengths less than 15 mm, and few to common equant voids, diameter up to 3 mm, most < 1 mm. Randomly distributed.

**Groundmass:** The fine textured groundmass includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 10 \( \mu \text{m} \). Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, inclusive a few rock fragments, which show varying stages of altering. The fine material is largely clay sized and includes common particles up to 10 \( \mu \text{m} \) and has a moderate ma-vosepic plasmic fabric, locally skelsepic around large carbonate nodules.

**Special features:**

Associated with voids: Locally along structural voids irregular enlargements of the original voids occur.

: Few voids partly infilled with mineral aggregates, mainly angular soil aggregates.

In the groundmass: some rare voids nearly completely infilled with mineral aggregates, often welded excrements.

: Common weathering minerals and rock fragments surrounded by sesquioxidic accumulations, with diffuse or clear boundaries, diam. up to 2 mm, randomly distributed.

: Common to many carbonate nodules, composed of coarse or fine particles with clear or sharp external boundaries, sometimes including sesquioxidic accumulations, diameters up to 6 mm, most < 2 mm. Randomly distributed.
1. Accumulations of iron and manganese in the groundmass (black). A horizon (plain light)

2. Embedded, rounded, basaltic rock fragment (centre). A horizon (plain light)
Interpretation of the micromorphological data

Two thin sections are studied: both from a deep A horizon. Depths: 40-55 cm (1) and 94-109 cm (2).

- The strong coarse angular blocky structure with an inclination of about 30° with the horizontal axis is due to strong swell and shrink of the montmorillonitic clays. At intersection nodes some angular soil fragments are often present. These are split off during shrinkages in upper parts of the A horizon. The roundness of the carbonate nodules and the orientation of clay domains in the fine material resulting in a vo-masepic plasmic fabric in (1) and a ma-vosepic plasmic fabric in (2) are all consequences of the vertic properties of the soil.

- The fauna plays a minor role. Their effects are restricted to the production of local enlargements of structural voids, a few open voids and some voids almost completely filled with welded mineral excrements.

- Carbonate accumulations are common and occur in nodules of up to 6 mm diameter. Deep in the A horizon the quantity of carbonate is higher. In contrast to the studied zone higher in the A horizon, most diameters of the carbonate nodules are less than 2 mm, mainly consisting of fine carbonate particles, indicating current accumulation.

- In the soil material minerals and rock fragments are altering. Around these particles accumulations of sesquioxides are commonly found, diameters up to 2 mm, with diffuse or clear external boundaries. Accumulations of sesquioxides also occur in carbonate nodules.
BAGBORI SERIES

1. General information and typifying pedon description

Classification: Fine, montmorillonitic, hyperthermic, deep, calcareous family of Vertic Ustochrepts (7th Approx.) Verto Calcaric Cambisol (FAO/UNESCO)

Location: Telinkhedi farm, Nagpur, Maharashtra, lying between 21°8' to 21°9'N Lat. and 79°1' to 79°3' E. Long.

Physiographic unit: Valley bottom.

Vegetation: Cultivated area with occasional stand of species like Terminalia arjuna (Arjun); Tectona grandis (Teak) etc.

Climate: Subtropical Monsoonic

Parent material: Weathered basaltic outwash

Remarks: There are 1-2 m wide cracks extending up to 50 cm through depth. Groundwater 6 to 8 m of the surface during summer.

Typifying pedon: Bagbori clay.

Ap1 0-2.5 cm: Dark gray to very dark gray (10 YR 3.5/1) clay, dark grayish brown to very dark grayish brown (10 YR 3.5/2) when moist; several disseminated medium lime nodules (10 YR 8/1) and (10 YR 6/3) constituting 5-10% (Vol); fine pulverised crumbs; dry soft, moist friable, wet sticky and plastic; violent effervescence; clear smooth boundary;

Ap2 2.5-12 cm: Very dark gray to very dark grayish brown (10 YR 3/1.5) clay, very dark grayish brown (10 YR 3/2) when moist; moderate coarse prismatic structure breaking into moderate medium angular blocky peds showing weak pressure faces; dry hard, moist friable, wet sticky and plastic; few coarse to medium tubular and many fine continuous tubular pores; many fine roots; medium to fine disseminated lime nodules and calcinated lithorelicts in the matrix 10% (Vol); violently effervescent; moderately slow permeability clear and smooth boundary.
B21 12-26 cm: Very dark gray to very dark grayish brown (10 YR 3/1.5) clay, very dark grayish brown (10 YR 3/2) when moist; moderate coarse prismatic structure breaking into moderate coarse angular blocky peds with weak pressure faces; dry hard, moist friable, wet sticky and plastic; few discontinuous tubular and many fine oblique inped pores; few fine roots; coarse lithorelicts with lime accretion and many fine semi-soft lime concretions in the matrix 15% (Vol); violent effervescence; slow permeability; clear and smooth boundary.

B22 26-52 cm: Very dark to very dark grayish brown (10 YR 3/1.5) clay, very dark grayish brown (10 YR 3/2) when moist; coarse slickensides breaking into strong coarse angular blocky peds with moderate pressure faces; coarse lithorelicts with lime accretion and secondary lime in powdery and nodular form constituting about 20% vol. in the matrix; dry hard, moist firm, wet sticky and plastic; few fine discontinuous oblique inped pores; very few roots; violent effervescence; slow permeability; clear and smooth boundary.

B3 52-80 cm: Very dark grayish brown to dark brown (10 YR 3/2.5) clay, dark brown (10 YR 3/3) when moist; weak medium angular blocky; dry hard, moist friable, wet sticky and plastic; lime in the form of soft powdery and semihard nodules 50% (Vol) in the matrix; very few exped and inped discontinuous pores; very few exped roots; slow permeability; clear and smooth boundary.

Cca 80-129 cm: Dark grayish brown (10 YR 4/2) clay (Gritty), dark grayish brown to brown (10 YR 4/2.5) when moist; weak medium subangular blocky; dry slightly hard, moist friable, wet slightly sticky; many coarse lithorelicts with lime accretion and secondary lime in soft powdery and semihard nodular form constitute 60% (Vol) of the matrix; violently effervescent; many discontinuous medium and fine pores.
### 2. Tentative soil characterisation by NBSS & LUP, NAGPUR

<table>
<thead>
<tr>
<th>Depth</th>
<th>Horizon</th>
<th>Particle Size Distribution (&lt;2 mm)</th>
<th>Bulk density</th>
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3. Micromorphological data

Two thin sections are studied, from the A and B horizon. Depths: 6-21 cm (1) and 46-61 cm (2).

1. Depth: 6-21 cm

Macroscopic characteristics

Very dark gray, fine textured, pedal soil material containing common carbonate nodules up to 6 mm in diameter.

Micromorphological characteristics

Structure: The soil material has a strong medium to coarse angular blocky structure to which common elongated, intersected, voids belong. Other voids: common elongated voids, widths up to 3 mm, lengths up to a few cm, and common equant voids, Ø up to 3 mm.

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 basaltic minerals and rock fragments which partly are altering. A few coarse root fragments occur. The fine material is largely clay-sized, contains common fine particles up to 5 µm and has a weak ma-skelsepic plasmic fabric.

Special features

Associated with voids: Few to common voids partly infilled with mineral aggregates, mainly soil aggregates and some mineral grains and rock fragments.

: A few structural voids locally show irregular enlargements.

In the groundmass : Common voids infilled with mineral aggregates which are soil aggregates or excrements, often welded shaped ones.

: Common carbonate nodules, diam. up to 6 mm, generally sharp external boundaries, randomly distributed. Carbonate nodules generally are composed of small carbonate particles.
2. Depth: 46-61 cm

Macroscopic characteristics

Very dark grayish brown, fine textured, pedal soil material containing many carbonate nodules up to 8 mm in diameter.

Micromorphological characteristics

**Structure:** The soil material has a medium angular blocky structure which is strongly developed in the upper 6 cm and moderate in the lower 9 cm, to which common intersected elongated voids belong. Other voids: common elongated voids, widths up to 3 mm, lengths up to a few cm and common equant voids, Ø up to 3 mm.

**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 basaltic minerals and rock fragments which partly are altering. The fine material is largely clay-sized, contains common fine particles up to 5 µm and has a weak vo-skelsepic plasmic fabric.

**Special features:**

Associated with voids: Few voids partly infilled with mineral aggregates, mainly soil aggregates and some mineral grains and rock fragments; rarely only excrements.

In the groundmass: Common voids infilled with mineral aggregates, which are soil aggregates or excrements often welded shaped ones.

Many carbonate nodules, diam. up to 8 mm. The larger nodules generally have sharp external boundaries. The smaller ones, the largest number, have diffuse to clear external boundaries. The nodules generally are composed of small carbonate particles. A small part of the carbonate nodules contain some accumulations of iron and/or manganese.

: In a few zone accumulations of embedded nodules, carbonate nodules as well as rounded rock fragments, occur.

: In outer zones of rock fragments accumulations of sesquioxides can be found.

: Few to common small irregular accumulations of manganese and/or iron in the groundmass.
1. Weathering basaltic rock fragment; B horizon.

(plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied from the A and B horizon. Depths: 6-21 cm (1) and 46-61 cm (2).

- The well developed angular blocky structure is due to swell and shrink of the clay. In voids belonging to the structure some soil fragments, minerals or rock fragments can be present (1, 2). These are split off during shrinkage in upper parts of the pedon. The few zones with accumulations of embedded nodules (2) are formed in the same way and embedded after swell of the soil. Other features due to vertic properties are the roundness of large carbonate nodules and the orientation of clay domains in the fine material resulting in a weak ma-skelsepic plasmic fabric (1) and a weak vo-skelsepic plasmic fabric (2).

- Soil fauna is responsible for the local enlargements of structural voids in (1) and the common voids almost completely infilled with shaped welded mineral excrements.

- The soil material is rich on carbonates. In the B horizon (2) carbonate precipitation is an actual process, many small accumulations with diffuse or clear external boundaries occur.

- Weathering of minerals and rockfragments occurs, most pronounced in the B horizon (2). Rockfragments can have accumulations of sesquioxides in the outer zone and few to common small irregular accumulations of manganese and/or iron occur in the groundmass. Also a part of the carbonate nodules contain some accumulation of iron and/or manganese.
1. General information and typifying pedon description

Classification: Fine loamy, mixed, hyperthermic, shallow family of Vertic Ustochrepts (7th Approx.). Fine loamy, lepto Vertic Cambisol (FAO/UNESCO).

Location: Between 21°8' to 21°9' N lat. and 79°1' to 29°3' long. Telinkhedi Farm, Nagpur, Maharashtra, India.

Physiographic Unit: Erosional landscape, Pediment slope.

Vegetation: Mostly cultivated while some areas are under mixed deciduous forest of species like Terminalia arjuna (Arjun); Tectona grandis (Teak); Zizyphus jujuba (Ber) etc.

Climate: Subtropical Monsoonic

Parent materials: Weathered basalt

Remarks: The open cracks 0.5-1 cm appear on the surface during dry periods extending 25 to 30 cm through depth.

Typifying pedon: Futala clay loam.

Ap 0-9 cm: Dark brown (7.5 YR 3/2 D & M) clay loam, moderate medium subangular blocky; dry slightly hard, moist friable, wet sticky and plastic; many fine roots, many fine oblique pores; moderately permeable; clear and smooth boundary.

B2 9-30 cm: Dark brown (7.5 YR 3/2 D & M) clay; moderate coarse prismatic structure breaking into moderate medium angular blocky peds with weakly developed pressure faces; dry hard, moist firm, wet sticky and plastic; few fine roots; few fine oblique pores; moderately slow permeability; few calcinated basalt gravel in the matrix, slightly effervescent; moderately slow permeability; gradual and smooth boundary.
B3 30-42 cm: Dark brown (7.5 YR 3/2 D & M) gravelly clay loam; weak medium angular blocky; many saprolite coated with dark reddish brown (2.5 YR 2.5/2) material while matrix is light brownish gray (2.5 Y 6/2); few medium hard calcinated basalt gravels in the matrix showing slight effervescence; irregular and tonging boundary.

C1 42-62 cm: Weathered basalt having matrix colour light brownish gray (2.5 Y 6/2) coated with dark reddish brown (2.5 YR 2.5/2) material; joints are weathered to dark brown (7.5 YR 3/2) loamy material.
### 2. Tentative soil characterisation by NBSS & LUP, NAGPUR

<table>
<thead>
<tr>
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<th>Particle Size Distribution (&lt;2 mm)</th>
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3. Micromorphological data

Two thin sections are studied derived from the B and C horizon. Depths: 20-35 cm (1) and 37-52 cm (2)

1. Depth 20-35 cm

Macroscopic characteristics

Dark brown, fine textured pedal soil material occurring together with basalt gravels which constitute about half of the area, increasing in quantity with depth.

Micromorphological characteristics

Structure: Moderate medium angular blocky structure to which common irregular, intersected, elongated voids belong. Other voids: Few to common elongated voids, widths up to 4 mm, lengths less than a few cm and common equant voids, diam. up to 4 mm. Randomly distributed in the fine textured material.

Groundmass: The fine textured soil material includes gravels up to several cm in diameter. Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The coarse mineral material consists of basalt minerals and rock fragments which partly are strongly altered. Rock fragments are disintegrating. A few coarse root fragments occur. The fine material is largely clay sized and contains common fine particles up to 5 µm and is asepic.

Special features:

Associated with voids: A few voids show local enlargements.

- Common to many coatings in voids in the groundmass around gravels and in voids in basalt gravels of oriented clay including few-common fine impurities.

- Few voids are partly infilled with mineral aggregates. Soil fragments as well as excrements.

In the groundmass: Common voids, almost completely infilled with shaped mineral excrements, more or less welded, including often some coarse mineral grains and rock fragments.
Many disintegrating basaltic rock fragments in fine-grained soil material.

In basaltic gravel minerals are altering and voids formed.

2. Depth: 37-52 cm

Macroscopic characteristics

Dark brown fine textured soil material occurring locally in fragmented basalt which occupies about 75% of the area.

Micromorphological characteristics

Structure: No structure can be given in this mixture of soil material and fragmenting basaltic rock. Other voids: Common, irregular elongated voids, sometimes interconnected, widths up to 4 mm, length up to about 7 cm and common equant voids, diam. up to 4 mm.

Groundmass: The fine textured material includes gravels up to several cm in diameter. Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The coarse mineral material in the fine textured material consists of basalt minerals and rock fragments which partly are strongly altered and disintegrating. The fine material is largely clay sized and contains common fine particles up to 5 µm and is asepic. The fine textured material is locally present in zones in the fragmented basalt, which contains a vein of different material.

Special features:

Associated with voids: Common to many coatings in voids in the fine textured groundmass and in basalt fragments more or less oriented clay including few-common fine impurities.

Few voids are partly infilled with mineral aggregates, soil and rock fragments and/or excrements. Often coatings of clay, as mentioned above, occur around these aggregates.

In the groundmass: Common voids almost completely infilled with shaped mineral excrements, more or less welded, including also often some coarse mineral grains and rock fragments.

In basalt fragments minerals are altering and voids formed.
Futala (1 photograph)

1. Coatings of fine-grained, clay rich soil material due to weathering in voids; C horizon. (plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied derived from the B and C horizon. Depths: 20-35 cm (1) and 37-52 cm (2).

- The material in the studied part of the B and C horizon consists of soil material with saprolitic basalt. With depth the quantity of soil material strongly decreases.

- In the soil material of the B horizon (1) the structure is largely determined by swell and shrink.

- The saprolitic basalt is fractured and minerals are altering, intensifying disintegration of the rock fragments. Due to the alteration clay is formed, which is present as common coatings in voids in the fine textured soil material as well as in basalt fragments. The clay is partly oriented and includes few-common fine impurities. The minerals and small rock fragments occurring in some voids are due to disintegration and physical processes.

- In the B and C horizon studied soil fauna is active. A large part of the voids not belonging to the structure are formed by animals. Most of them are filled with mineral excrements, more or less welded, including also some mineral grains and rock fragments. The mineral material of the excrements especially in the C horizon is largely derived from upper horizons.
NIMONE SERIES

1. General information and typifying pedon description

Pedon described and sampled by the core group members consisting of J.C. Bhattacharjee, R.J. Landey, H.P. Chowdhary, S.G. Pandey, B.R. Tambhare, G.V. Patel, V.K. Misra, G.K. Zende.

Nimone series comprises deep to very deep, moderately well drained, calcareous, cracking clayey soils of dark brown to very dark grayish brown colours. They have developed in basaltic outwash and occur on nearly level to very gently sloping lower piedmont plains. These have gilgai micro-relief on the surface and intersecting slickensides and parallelepiped structural aggregates in the subsoil. The climate is tropical, semiarid with mean annual air temperature of 25°C and mean annual rainfall of 500 to 600 mm. The principal associated soils are Sawargaon, Annapur and Dholwad series which are deep Inceptisols and Umbraj series which is a member of Vertisols. These soils were earlier classified as deep black soils.

Nimone series is a member of fine, montmorillonitic, isohyperthermic, family of Typic Chromusterts.

Typifying pedon: Nimone clay-cultivated. (Colours are for dry soils unless otherwise noted).

Ap 0-19 cm: Dark brown (10 YR 3/2.5) clay; very dark brown grayish brown (10 YR 3/2 M); medium moderate subangular blocky; hard (dry) firm (moist), sticky and plastic (wet); few basaltic lithorelicts; strong effervescence; many fine discontinuous oblique pores and few continuous vertical exped pores; many fine inped roots; moderately slow permeability; pH 8.2; clear smooth boundary.

A12 19-47 cm: Very dark grayish brown (10 YR 3/2 M) clay; coarse slickensides breaking into medium moderate angular blocky peds with shiny pressure faces; firm (moist) very
sticky and very plastic (wet); many basaltic lithorelicts; strong effervescence; few oblique exped and many fine inped pores; many fine inped and few exped roots; slow permeability; gradual smooth boundary.

**A13** 47-84 cm: Dark brown to very dark grayish brown (10 YR 3/2.5 M) clay; coarse intersecting slickensides forming parallelepipses with longitudinal axes of 50 cm tilting at an angle of 40° from the horizontal and breaking into strong coarse angular blocky peds with shiny pressure faces; many dark yellowish brown (10 YR 4/4) material in the matrix; very firm, (moist) very sticky and very plastic (wet); violent effervescence; few, very fine discontinuous oblique pores; very fine inped an exped roots; slow permeability; pH 8.3; clear and wavy boundary.

**AC** 84-107 cm: Dark yellowish brown (10 YR 4/4 M) and dark brown (10 YR 3/3 M) clay; coarse intersecting slickensides forming parallelepipses with longitudinal axes of 55 cm, tilting of 45° from horizontal and breaking into coarse strong angular blocky peds with shiny pressure faces; very firm (moist), very sticky and plastic (wet); dark yellowish brown (10 YR 4/4) core material of C horizon intruding into the matrix of AC; violent effervescence; weathered basaltic materials and accretionary lime nodules 5 to 10% (by volume); slow permeability; pH 8.6; gradual wavy boundary.

**Cca** 107-155 cm: Dark brown (10 YR 4/3 M) and dark yellowish brown (10 YR 4/4 M) gravelly clay; medium moderate subangular blocky; friable (moist), sticky (wet), violent effervescence; pH 8.8.

Range in characteristics: The thickness of the solum ranges from 90 to 120 cm grading with gravelly clay calcareous substrata. The regolith is clayey basaltic alluvium. The estimated annual soil temperature at 50 cm depth ranges from 26°C to 29°C. The soils are dry for more than 150 cumulative days between 10 to 30 cm from the surface. But lower part remains moist, cracks of 3 to 4 cm extend
up to 60 cm. Gilgai relief appear during dry period with frequencies of linear distance of 50 to 75 cm between micro high and micro low. The A horizon is 71-92 cm deep grading into the C horizon with an intermediary 20-30 cm thick AC horizon. The colour of the A horizon is in 10 YR hue with value 3 and chroma 2.5 and 2 for dry and moist soil. In AC horizon the colour is in 10 YR hue with 60 percent of the matrix value 4 and 40 per cent value 3 and chroma 3 and 4 for moist soils. The soils are calcareous and coarser fraction of more than 2 mm size may range from 5 to 25 per cent by volume within 18 to 100 cm depth. Mineralogy in the control section is montmorillonitic. CEC ranges from 95 to 115 meq for 100 g clay.

**Drainage and permeability:** These soils are moderately well drained soils with slow to very slow permeability.

**Use and Vegetation:** These soils are mostly cultivated for Jowar and Bajra. Most of the areas are under sugarcane cultivation with Parvara and Godavari Canal irrigation system. At places there may be patches of cultural waste lands with isolated stands of Accacia arabica and needle grasses (Botanical and English names may kindly be given.

**Type location:** Field No. 97 in M.P.K.V. Farm, Rahuri; about 3 km in the north west of village Kadamba in Rahuri taluka of Ahmednagar district.

**Distribution and extent:** Soils of Nimone series occur extensively in parts of the districts of Ahmednagar, Pune and Aurangabad in Maharashtra State.

**Series established:** Village: Nimone; pit No. 10; Tahsil: Sirur; District: Pune in Maharashtra State.

**Interpretation:** Soils of Nimone series are agriculturally important. They are cracking soils of montmorillonitic clays with high available moisture capacity. These soils with cracks take in all the moisture from the premonsoon rains and this may help to conserve
July-September rainfall for crop plant growth if management problems due to high clay content is taken care of through proper anti-erosion and moisture conservation measures and timely tillage. Under canal irrigation these soils respond well and due to their setting on piedmont plains groundwater hazards may not be a problem.

Management Interpretation: (Based on physical potential of the series).

a) Inductive

1. Land capability sub-class: IIIs
2. Irrigability sub class: 3s
3. Fertility Management: Good, may present problems due to heavy textures and calcareous nature of the soils
4. Management potential/productivity: Medium
2. Tentative soil characterisation by NBSS & LUP, NAGPUR

<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 (0.001)</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>Coarse fragments % of whole soil</th>
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<tbody>
<tr>
<td>Ap</td>
<td>0-19</td>
<td>22.0</td>
<td>22.1</td>
<td>56.1</td>
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<td>1.3</td>
<td>1.1</td>
<td>1.8</td>
<td>16.5</td>
<td>22.1</td>
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<tr>
<td>A12</td>
<td>19-47</td>
<td>25.1</td>
<td>32.7</td>
<td>42.1</td>
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<td>52.3</td>
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<th>Depth (cm)</th>
<th>Organic carbon as CaCO$_3$ %</th>
<th>Carbonate as CaCO$_3$ %</th>
<th>pH (1:1)</th>
<th>E.C. (1:1)</th>
<th>Bulk density H$_2$O g/cc</th>
<th>Water retention 1/3-bar cm</th>
<th>15-bar %</th>
<th>1/3-to 15-bar %</th>
<th>COLE NH$_4$Ac</th>
<th>CEC NH$_4$Ac</th>
<th>Ratios to clay NH$_4$Ac</th>
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<td>0.80</td>
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3. Micromorphological data

Short micromorphological description

One thin section is studied derived from the A horizon.
Depth: 66-81 cm.

- The fine-textured soil material includes grain sizes up to gravels of 3 mm diameter. The size limit coarse/fine material is 15 µm; the related distribution: porphyric. The fine material is largely clay-sized and contains many fine particles up to 15 µm mainly carbonates. The coarse material consists of a variety of basaltic minerals and rock fragments, which partly show varying stages of alteration.
- The soil material has a strong coarse angular blocky structure to which a few elongated, sometimes intersected, voids belong. The longitudinal ped faces have an inclination of about 40° of the horizontal axis. Other, elongated and equant, voids are common. Their diameters and widths reach up to 5 mm, most are <1 mm, length of elongated voids up to a few cm, all randomly distributed.
- In this A horizon are a few voids partly filled with mineral aggregates, excrements or soil fragments and common zones, up to 6 mm wide, are completely filled with mineral aggregates which contain not only excrements or soil fragments but also include mineral grains, rock fragments and nodules.
- The rounded basaltic rock fragments present in the groundmass, showing varying stages of alteration are common. Diameters reach up to 3 mm, randomly distributed.
- Many carbonate nodules, composed of carbonate particles <20 µm in diameter occur. They generally contain a few other mineral grains, have clear external boundaries and diameters up to 3 mm.
1. Altering, rounded off, basaltic rock fragment (centre) and a carbonate nodule (left); A horizon (plain light).

2. Carbonate accumulation around an altering basaltic rock fragment (left) and a sesquioxide nodule (right); A horizon (plain light).
4. Interpretation of the micromorphological data

One thin section is studied derived from the A horizon.
Depth: 66-81 cm.

- In this part of the A horizon the strong coarse angular blocky structure with an inclination of about 40° with the horizontal axis is due to strong swell and shrink of the montmorillonitic clays resulting in slickensides. At this depth, other voids present are mainly due to the fauna, which produces common voids with diameters generally less than 1 mm. A few of these voids are partly or completely filled with shaped mineral excrements. Infilled larger faunal voids (diam. up to 5 mm) contain, as well as mineral excrements, soil fragments, mineral grains, rock fragments and nodules. These materials are released in dry periods when the soil cracks, and accumulate deeper in existing voids. The influence of the fauna is restricted.

- In the groundmass, carbonates have been accumulated and are still accumulating. They form many carbonate nodules, composed of small carbonate particles (<20 μm), have clear external boundaries and diameters up to 3 mm. The fine-grained groundmass is rich in carbonates, occurring as many small single carbonate crystals.

- The coarse minerals and rock fragments (up to 3 mm in diameter) present, show evidence of fresh alteration.
SHENDWADA SERIES

1. General information and typifying pedon description


Shendwada series is a member of fine, montmorillonitic, hyperthermic deep family of Typic Chromusterts. Shendwada soils have dark brown to very dark grayish brown moderately to strongly alkaline silty clay to clay, A horizons followed by dark yellowish brown moderately to strongly alkaline gravelly clay loam C horizons underlain by weathered basalt.

Typifying pedon: Shendwada silty clay - cultivated. (Colours are for moist soils unless otherwise noted).

Ap1 0-10 cm: Dark brown (10 YR 3/3 M) silty clay; prismatic breaking into moderate medium subangular blocky peds; dry hard moist friable, wet sticky and plastic; violently effervescent, common lithorelicts with accretionary lime; many fine inped roots; many fine and medium pores; pH 8.6; clear smooth boundary.

Ap2 10-25 cm: Very dark grayish brown to dark brown (10 YR 3/2.5 M) silty clay; prismatic breaking into moderate medium sub-angular blocky peds; dry hard; moist friable, wet sticky and plastic; violently effervescent; common lithorelicts with accretionary lime; fine inped and exped roots; common slanting tubular pores; vertical cracks of width 2-3 cm; pH 8.6; clear smooth boundary.

A12 25-50 cm: Very dark grayish brown to dark brown (10 YR 3/2.5) silty clay; strong coarse angular blocky peds with shiny pressure faces; dry hard, moist firm, wet sticky and plastic; violently effervescent, few lithorelicts with accretionary lime, very few coarse inped roots and fine exped roots; irregular metavoids with dried roots aligned along pressure planes; vertical cracks of width 1-2 cm; pH 8.4; clear smooth boundary.

A13 50-75 cm: Dark grayish brown to dark brown (10 YR 3/2.5 M) silty clay; coarse intersecting slickensides forming parallelepipeds
with longitudinal axes tilted 45° from horizontal that separate into strong coarse angular blocky peds with prominent pressure faces; dry very hard, moist very firm, wet sticky and plastic; violently effervescent, few accretionary lime nodules; dark yellowish brown intermittent cores of C horizon constitute less than 20% (vol.) of the matrix; few fine inped roots; many fine pores; vertical cracks 0.5-1 cm wide; pH 8.4; clear wavy boundary.

A14 75-110 cm: Very dark grayish brown to dark brown (10 YR 3/2.5 M) clay; coarse intersecting slickensides forming parallelepips with long axes tilted 40° from horizontal that separates into strong coarse angular blocky peds with prominent shiny pressure faces, dry very hard, moist very firm, wet very sticky and very plastic; violently effervescent; dark yellowish brown intermittent cores of C horizon constitute about 30% (vol.) of the matrix; few fine inped roots; many irregular fine pores; vertical cracks 0.5-1 cm wide; pH 8.5; clear wavy boundary.

AC 110-150 cm: Brown (10 YR 4/3) clay; about 30% of the matrix mottled with dark brown (10 YR 3/3); medium intersecting slickensides breaking into coarse strong angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and plastic; violent effervescence; few, fine, inped roots; many irregular metavoids with fine tubular pores; very slow permeability; pH 8.5; clear and wavy boundary.

C 150-175 cm: Dark yellowish brown (10 YR 4/4 M) gravelly clay loam with dark brown (10 YR 3/3) mottles constitute about 10% (vol) of the matrix; moderate, medium subangular blocky; dry hard, moist firm, wet sticky and plastic; violently effervescent; many accretionary lime nodules with light yellowish brown (10 YR 6/4) colour; pH 8.5.
Type location: Sindkheda Tehsil, Dhulia district Maharashtra. About 0.2 km south east of village Towkheda.

Range in characteristics: The thickness of the solum ranges from 90 cm to 115 cm. Within the depth 15 to 100 cm of the surface, the content of CaCO3 ranges from 3 to 5% while content of clay in fine earth fraction ranges from 40 to 50%. The soil mineralogy is dominantly montmorillonitic with high shrink and swell potential. The A horizon is predominantly in hue of 10 YR with moist value 3 and chroma 3 and 2.5 for moist soils while hue in C horizon is 10 YR with moist value 4 and chroma 4. Surface layers (Ap1 + Ap2) exhibit prismatic structure breaking into subangular blocky peds while in A12 horizon peds are angular blocky with shiny pressure faces. The pedality of A13, A14 exhibits intersecting slickenslides forming parallelepipseds that separate into strong angular blocky peds with shiny pressure faces followed by subangular blocky peds in the C horizon. The bulk density ranges from 1.57 to 1.98 respectively while the soil is moderate to strongly alkaline.

Competing series and their differentiae: Jotwada series have a calcareous horizon below one metre depth from surface.

Setting: Shendwada series occur on nearly level to gently sloping alluvial plain (with slope gradient 1 to 3 percent) of the Tapti river system. The climate is tropical semiarid.

Drainage and permeability: Moderately well drained with slow to very slow permeability.

Use and vegetation: Cultivated for cotton, sorghum and red gram in rainfed condition. Under irrigation sugarcane, plantain and orchards are grown. Natural vegetation is *Zyzyphus jujuba, Acacia arabica* and thorny bushes.

Distribution and extent: Extensive in alluvial plains of the river Tapti, Dhulia district, Maharashtra.

Remarks: Earlier classified as deep black soils.

Interpretation: Shendwada soils are clayey with high shrink and swell potential. These have high water retention capacity. These soils have high cation exchange capacity so they respond well for fertilization. As these soils are strongly alkaline, under continuous irrigated conditions without proper drainage, may be prone to alkalinity problem.

Management and interpretation:
a) Inductive (Based on physical potential of the series)
   1. Land capability classification : IIIIs
   2. Soil irrigability classification : 3d
   3. Fertility management : Low
   4. Management potential/productivity: Low

b) Quantitative (Based on data on yield)

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<thead>
<tr>
<th>Crop</th>
<th>Q/ha</th>
<th>Farmers level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Unirrigated</td>
</tr>
<tr>
<td>1. Cotton</td>
<td>-</td>
<td>6-7</td>
</tr>
<tr>
<td>2. Sorghum</td>
<td>-</td>
<td>4-5</td>
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<tr>
<td>3. Red gram</td>
<td>-</td>
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<tr>
<td>4. Rice</td>
<td>-</td>
<td>3-4</td>
</tr>
<tr>
<td>5. Sugarcane</td>
<td>15-20</td>
<td>-</td>
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<tr>
<td>6. Groundnut/Peanut</td>
<td>-</td>
<td>4-5</td>
</tr>
<tr>
<td>7. Chilly</td>
<td>1-2</td>
<td>-</td>
</tr>
<tr>
<td>8. Wheat</td>
<td>7-8</td>
<td>-</td>
</tr>
</tbody>
</table>

2. Tentative soil characterisation: No data provided
3. Micromorphological data

One thin section from a deep A horizon is studied.
Depth: 65-80 cm

Macroscopic characteristics:
Dark brown, fine textured, pedal soil material, containing a few light coloured nodules, diam. up to 7 mm.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky, to which common intersected, elongated voids belong with locally enlarged intersection nodes. Other voids: Few to common elongated voids, widths generally <3 mm, length up to a few cm and few to common equant voids, most Ø <3 mm, randomly distributed.

**Groundmass:** The fine textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, which show varying stages of alteration. The fine material is largely clay-sized, includes a few particles up to 5 µm and has locally a moderate skel-vosepic plasmic fabric.

**Special features**:

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

: Commonly structural voids are locally enlarged resulting in irregular, uneven void walls.

In the groundmass: Many voids/zones, generally with diffuse external boundaries are nearly completely filled with mineral aggregates, mainly more or less wealld shaped excrements.

: Few zones containing a higher content of coarse grains than the surrounding groundmass.

: Few to common, rather rounded carbonate nodules, diameters up to 7 mm, randomly distributed. Most nodules are less than 2 mm in diameter and have clear or diffuse external boundaries.
4. Interpretation of the micromorphological data

One thin section from a deep A horizon is studied.
Depth: 65-80 cm.

- The strong coarse angular blocky structure is a result of strong swell and skrink. The angular soil aggregates occurring in partly infilled voids are split off from the groundmass during skrinkage. The roundness of carbonate nodules, the few zones, coarser grained than the surrounding groundmass (infillings) and the local moderate skel-vosepic plasmic fabric of the fine material are consequences of the vertic properties of this soil.

- The fauna plays an important role. Soil animals are responsible for the production of most of the enlarged intersection nodes, the common local enlargements of structural voids and few to common elongated and equant voids. Moreover large parts in the groundmass are occupied by zones nearly completely filled with more or less welded, shaped, excrements. This animal activity caused disappearance of the skel-vosepic plasmic fabric in most of the fine material in the groundmass.

- In the studied zone carbonate accumulation occurs. Many small carbonate nodules composed of small crystals, with diffuse external boundaries are present, besides the larger rather rounded carbonate nodules up to 7 mm Ø.
Dham series includes well drained, deep, calcareous soils formed on alluvium of basaltic origin. These occur on very gently sloping to gently sloping old levees in flood plains of the Wardha river system. The alluvium on levees shows very deep deposits in alternate stratified layers of various texture with occasional sand lenses and pockets of assorted gravels and indurated lime nodules. The soil pedons have AC profiles with brown to dark brown silty clay loam to clay loam A horizons underlain by C horizons with lithologic discontinuous. These soils have been classified in India as "Alluvial Soils". The climate of the area is tropical subhumid. The mean air temperature is 25 to 29°C rising to Max. 42°C in May and falling to min. 12°C in January in most of the years. The mean annual rainfall is 113 cm of which about 72% is received during monsoon (July-Sept) in most of the years. The principal associations are Pavnar series and Kharangna series which are deep Inceptisols and Vertisols respectively.

Dham series comprises members of fine loamy, mixed hyperthermic deep, calcareous family of Typic Ustifluvents.

Typifying pedon: Dham sandy loam-cultivated (Colours are for dry soils unless otherwise noted)

Ap 0-12 cm: Brown (10 YR 4/3) sandy loam, dark brown (10 YR 3/3) when moist; moderate medium subangular blocky, dry slightly hard, moist friable, wet slightly sticky and slightly plastic; strongly effervescent; moderately rapid permeability; common fine and medium tubular pores; common fine roots; pH 8.4; clear smooth boundary.

A12 12-23 cm: Brown (10 YR 5/3) loam, dark brown (10 YR 3/2.5) when moist; moderate medium subangular blocky; dry slightly hard, moist friable, wet slightly sticky and slightly plastic; violent effervescence; many medium and fine oblique and discontinuous pores; few fine roots; moderate permeability; pH 8.5; clear smooth boundary.
A13  23-47 cm: Brown to dark brown (10 YR 3.5/3) loam, very dark
grayish brown (10 YR 3/2) when moist; moderate medium subangular
blocky; dry slightly hard, moist friable, wet slightly sticky
and slightly plastic; irregular, subdendritic tubular porosity;
few fine roots; common very fine pseudomycelium (10 YR 8/1);
vigorous effervescence; moderate permeability; pH 8.4; abrupt
wavy boundary.

IIC1  47-71 cm: Dark brown to brown (10 YR 3.5/3) gravelly clay loam,
dark brown (10 YR 3/3) when moist; weak fine subangular blocky;
dry slightly hard, moist friable, wet sticky and slightly plastic;
moderate permeability; violent effervescence; irregular sub-
dendritic porosity; many conch shells, more than 40% (by wt.)
gravels. Artefacts and pseudomycelium present as above; pH 8.6;
abrupt broken boundary with lenses of clay loam (finer than
above).

IIC2  71-96 cm: Dark brown to brown (10 YR 3.5/3) gravelly clay loam,
dark brown (10 YR 5/3) when moist; more than 60% (wt) gravels,
few artefacts present; fine weak subangular blocky; dry
slightly hard, moist friable, wet sticky and slightly plastic;
pseudomycelium present as above; violent effervescence,
moderately rapid permeability, very few very fine roots; pH 8.2;
wavy boundary.

IVC3  96-134 cm: Dark brown (10 YR 3/3 D&M) clay loam; moderate medium
subangular blocky; dry slightly hard, moist friable, wet sticky
and slightly plastic; violent effervescence; pseudomycelium
many; moderately rapid permeability; very few very fine roots;
pH 8.3, abrupt smooth boundary.

VC4  134-165 cm+: Dark brown (10 YR 3/3 D&M) gravelly clay loam; weak
fine subangular blocky; pseudomycelium many; dry slightly hard,
moist friable, wet sticky and slightly plastic; violent
effervescence; pH 8.4.

Range in characteristics: The soil is in a very deep regolith and the
normal thickness is more than 1.0 m. The content of coarser fragments
larger than 2 mm within the depth of 15 cm to 100 cm of surface are
irregularly distributed and in the subsoil gravels range between 24 and
50% while CaCO3 17 to 18% through depth. The distribution of clay is irregular through depth while the content of organic carbon decreases irregularly. The colour of the soil in the A horizon is in hue of 10 YR with value ranging from 5 to 3 with chroma 3 for dry and 3 to 2 for moist soils. The texture of fine earth fraction of soil materials in IIC1, IIIC2, IVC3 + VC4 varies from silt loam to clay loam. Pseudomycelium and conch shells are observed in IIC1 horizon at a depth of 47-71 cm and still at lower depth. The soil colour is in hue of 10 YR with value 5 to 3 and chroma 3 for dry and moist soils. The upper part of the soil remains dry for more than 180 cumulative days while the lower part remains moist in most of the years.

Competing series and their differentiae: Pavnar is the competing series. The average thickness of the solum in Pavnar soils ranges from 1.0 to 1.5 m. Gravels and indurated lime nodules range from 16 to 23% through depth in Pavnar soils while clay content of Pavnar soils varies from 45 to 49%.

Drainage and permeability: Well drained with moderate to moderately rapid permeability.

Use and vegetation: Mostly cultivated crops: wheat, cotton, sorghum (jowar) pigeon pea (arhar). At places vegetables, banana and papaya plantations are also found. Accacia arabica, Zizyphus sp. and thorny bushes are the dominant vegetation.

Distribution and extent: Occurs along river Dham in Wardha districts; the extent is not much.

Type location: Plot No. 17, village Kharangna tahsil and district Wardha, Maharashtra.

2. Tentative soil characterisation by NBSS & LUP, 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 Total</th>
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<tbody>
<tr>
<td></td>
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<td>Sand (2-0.05) Silt (0.05-0.002) Clay (&lt;0.002) Very coarse (1-0.5) Coarse (0.5-0.25) Medium (0.25-0.1) Fine (0.1-0.05) Very fine (0.05-0.02) Fine (0.002-&lt;0.001)</td>
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<tr>
<td>Ap</td>
<td>0-12</td>
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<tr>
<td>A12</td>
<td>12-23</td>
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<td>0.00 14.02</td>
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<tr>
<td>A13</td>
<td>23-47</td>
<td>60.86 16.51 22.86 0.88 5.71 4.00 20.02 30.25 16.51 3.46 19.40 0.00</td>
<td>0.00 14.02</td>
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<tr>
<td>11C1</td>
<td>47-71</td>
<td>52.51 17.28 29.09 7.58 4.34 4.78 7.79 28.02 17.28 12.08 17.01 0.00</td>
<td>0.00 14.02</td>
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<tr>
<td>11C2</td>
<td>71-96</td>
<td>58.64 19.64 21.87 10.09 8.75 7.84 7.78 24.18 19.64 11.86 10.01 0.00</td>
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<tr>
<td>IVC3</td>
<td>96-134</td>
<td>58.27 20.26 21.46 8.65 8.62 8.99 8.25 23.76 20.26 3.66 17.80 0.00</td>
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<tr>
<td>VC4</td>
<td>134-165</td>
<td>66.47 13.38 20.34 26.56 16.90 8.56 4.64 9.81 13.38 13.78 6.56 0.00</td>
<td>0.00 14.02</td>
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</table>

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon &lt;2 mm %</th>
<th>Carbonate as CaCO$_3$ %</th>
<th>pH (1:1)</th>
<th>pH (1:2)</th>
<th>E.C. H$_2$O m/mhos/cm</th>
<th>Water retention 1/3-bar %</th>
<th>Water retention 15-bar %</th>
<th>COLE cm/cm</th>
<th>Extractable bases</th>
<th>CEC NH$_4$-Ac</th>
<th>Exchangable sodium</th>
<th>Base saturation NH$_4$OAc %</th>
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<tr>
<td>0-12</td>
<td>0.35</td>
<td>3.96</td>
<td>6.30</td>
<td>8.30</td>
<td>0.18</td>
<td>21.11</td>
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<td>13.10</td>
<td>6.25</td>
<td>8.35</td>
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<tr>
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<td>17.70</td>
<td>6.25</td>
<td>8.45</td>
<td>0.12</td>
<td>15.17</td>
<td>8.83</td>
<td>0.014</td>
<td>16.50</td>
<td>4.25</td>
<td>0.43</td>
<td>0.20</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Two thin sections are studied: one derived from the A horizon and one from the C horizon. Depths: 15-30 cm (1) and 52-67 cm (2).

1. Depth: 15-30 cm

Macroscopic characteristics

Brown, medium textured, pedal soil material.

Micromorphological characteristics

Structure: Moderate medium subangular blocky structure to which few-common, intersected voids belong. Other voids: common elongated voids, widths up to 2 mm, lengths less than a few cm and common equant voids, diam. up to 2 mm. Randomly distributed. Large voids present are artefacts due to disturbance.

Groundmass: The medium textured groundmass 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 basaltic minerals and rock fragments which mainly are fresh or slightly altered. The fine material is largely clay-sized and includes a few particles up to 5 µm, and has an asepic plasmic fabric.

Special features:

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

: Few-common voids are locally or continuously coated with carbonate mycelium.

In the groundmass: Common-many voids almost completely infilled with mineral aggregates, mainly shaped, more or less welded excrements, diam. up to 12 mm.

: Common rounded carbonate nodules, diam. up to 3 mm, with sharp external boundaries. A part of these nodules contain iron accumulations.

: A few embedded snail/shell fragments.
2. Depth: 52-67 cm

Macroscopic characteristics

Dark brown to brown gravelly apetal soil material, including gravels up to 12 mm in diameter.

Micromorphological characteristics

**Structure:** Not detectable, due to disturbance during transport.

**Groundmass:** The gravelly groundmass includes grain sizes up to gravels of 12 mm in diameter. Size limit coarse/fine material is 5 µm. Related distribution: porphyric. The coarse mineral material consists for the majority of rounded basaltic rock fragments which are mainly fresh or slightly altered and carbonate nodules, which contain varying quantities of iron accumulations. The not disturbed fine material is clay-sized, includes a few particles up to 5 µm, and has an asepic plasmic fabric.

**Special features** (due to disturbance no quantities can be given):

Associated with voids: Coatings of carbonate mycelium occur in voids.

In the groundmass: Voids are almost completely infilled with mineral aggregates, mainly shaped excrements.

4. Interpretation of the micromorphological data

Two thin sections are studied: one derived from the A horizon and one from the C horizon.

**Depths:** 15-30 cm (1) and 52-67 cm (2)

- The soil material is not homogeneous in the studied thin sections. They belong to different deposits.
- In the A horizon animal activity is high, resulting in production of voids, which often are partly or almost completely infilled with more or less welded shaped mineral excrements. Diameters of infilled voids reach up to 10 mm. In the C horizon (2) the same kind of animal activity occurs.
- Carbonate precipitation, mainly as mycelium along voids, takes place in both studied sections of the pedon. Rounded carbonate nodules are common in (1) and many occur in (2). Diameters are reach up to 3 mm in (1) and 10 mm in (2). A part of these nodules contain iron accumulations. The carbonate nodules need not to be formed in situ.

Remark: Due to disturbance of the soil material during transport only limited information could be obtained from the thin sections.
SISODRA SERIES

1. General information and typifying pedon description


Sisodra series includes deep, moderately drained, brown to dark brown soils, formed in recent alluvium in the deltaic plain of the river Purna. These soils occur near river or nala banks on level to very gently sloping midlands with gradients 1 to 2°. The soil pedon is an ABC profile with a dark brown clayey and prismatic A horizon grading to dark brown clay to clay loam structural B horizon underlain by dark brown clay loam mottled C horizon. These soils crack vertically up to a depth of 60 cm during dry periods and have been classified in India as "Deep Black Soils". The climate is tropical subhumid having mean annual temperatures ranging from 27°C to 33°C with mean annual precipitation of 1535 mm.

The associated soils are Bodali and Orgal-II series which are deep and moderately deep Entisols developed on recent alluvium on deltaic plains of the river Purna.

Sisodra series comprises members of fine, montmorillonitic, hyperthermic, deep family of Vertic Ustochrepts.

Typifying pedon: Sisodra clay - pasture. (Colour notations are for moist soils unless otherwise noted)

Ap 0-15 cm: Dark brown (10 YR 3/3) clay; dark brown (10 YR 3.5/3) when dry; prismatic structure breaking into moderate medium subangular blocky peds; dry slightly hard, moist firm, wet sticky and plastic; many fine oblique pores; moderately slow permeability; abundant fine roots; pH 7.2.; clear smooth boundary.

B21 15-39 cm: Dark brown to very dark grayish brown (10 YR 3/2.5) clay; dark brown to very dark grayish brown (10 YR 3/2.5) when dry; prismatic structure breaking into moderate medium angular blocky peds with very weak pressure faces; dry
hard, moist firm, wet sticky and plastic; few fine oblique discontinuous pores; few fine roots; slow permeability; pH 7.2; diffuse and smooth boundary.

B2 39-71 cm: Dark brown (10 YR 3/2.5) clay; coarse prismatic structure breaking into strong coarse angular blocky peds with moderately developed pressure faces; dry hard; moist firm; wet sticky and plastic; few fine oblique discontinuous pores; few fine roots; slow permeability; pH 7.1; diffuse and smooth boundary.

B3 71-90 cm: Dark brown (10 YR 3/3) clay loam; moderate slickensides breaking into moderate coarse angular blocky peds with moderately developed pressure faces; dry hard, moist very firm, wet sticky and plastic; very few very fine oblique discontinuous pores; few fine roots; slow permeability; pH 7.2; diffuse and smooth boundary.

C 90-130 cm: Dark brown (7.5 YR 4/4) clay loam; moderate slickensides breaking into moderate coarse angular blocky peds with moderately developed pressure faces, dark olive gray (5 YR 4/2) many distinct mottles; moist firm, wet sticky and plastic; few very fine broken oblique pores; very few fine roots; moderately slow permeability, pH 8.0.

Range in characteristics: The thickness of the solum ranges from 80 to 100 cm. The content of clay within the depth 15 cm to 100 cm of the surface ranges from 30 to 45% in the A horizon and 50 to 55% in the B horizon upto the base transitional to C horizon. Soil type is clay but clay loam also occurs at places. The porous Ap horizon abruptly merges to B horizon which is compact having a coarse blocky to prismatic structure in the lower part breaking into moderately developed subangular to angular blocky peds with shining pressure faces. The matrix colours of the soil in Ap horizon is dark brown with hue of 10 YR and value 3 to 5 with chroma 2.5 to 3 either in dry and moist conditions. The soil colour in the B horizon, varies from very dark grayish brown in the upper part to dark brown in the lower part having the hue 10 YR while the moist value and chroma are 3 and 2.5 respectively in B2 grading to moist value 3 and chroma 4 in the B3 horizon. Occasionally brown to reddish brown mottlings are observed in lower boundary of B3 horizon transitional to C horizon. The colour of C horizon
is dark brown to dark yellowish brown in hue of 7.5 YR and 10 YR respectively with value 3 to 4.5 and chroma 4 having peds with shiny pressure faces. The soil reaction is neutral in the upper part of the control section while it is moderately alkaline in lower part. The difference of mean summer and mean winter soil temperature is above 5°C. Soil moisture within depth ranging from 15 to 30 cm of the surface remains at or below wilting point while lower part remain moist during the dry period in most of the years. The vertical cracks that open during winter months remain open for more than 180 days in most of the years.

Competing series and their differentiae: Competing soils are those of Jalalpur and Kabilpur series. The average thickness of solum ranges from 80 to 100 cm in Jalalpur soils and 100 to 120 cm in Kabilpur soils. The content of clay within the control section ranges from 60 to 70% through depth in Jalalpur series while that ranges from 32 to 24% through depth in Kabilpur series. The content of CaCO3 in Jalalpur soils never exceeds 2% while in Kabilpur soils it ranges from 12 to 19% through depth.

Drainage and permeability: Moderately drained with moderate to moderately slow permeability.

Ground water table: Water table is 1.5 m of the surface.

Vegetation and land use: Mainly cultivated, with occasional pastures. Paddy, jowar, cotton, groundnut, wheat and beans are the important crops both under rainfed and irrigated condition.

Distribution and extent: Soils of Sisodra series occurs extensively on the flood plain of Purna and Tapi rivers in parts of Distts. Bulsar and Surat in Gujarat State.

Type location and series established: Sisodra clay, Pit No. 56, Vill. Sisodra, about 10 km east of Navsari town, Distt. Bulsar.

2. Tentative soil characterisation: No data provided
3. Micromorphological data

Two thin sections are studied, are from the B horizon and one from the C horizon. Depths: 48-63 cm (1) and 95-110 cm (2).

1. Depth: 48-63 cm.

Macroscopic characteristics

Dark brown, fine textured, strong pedal soil material with few to common black nodules up to 2 mm in diameter, randomly distributed.

Micromorphological characteristics

Structure: Coarse prismatic, subdivided into strong coarse 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 and less than a few cm long, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 15 µm. Related distribution: porphyric. The coarse material consists of a variety of minerals, which show varying stages of altering and few-common root fragments. The fine material is largely clay sized, contains a few particles up to 15 µm and has a moderate vo-masepic plasmic fabric.

Special features:

Associated with voids: Few to common voids partly infilled with mineral aggregates, mostly rounded, a part of them are excrements.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, partly excrements. Voids infilled with excrements have diameters up to 4 mm.

: Few isotubules, diameters up to 4 mm.
: Few to common block sesquioxidic nodules, up to 2 mm in diameter, sharp boundaries, randomly distributed, most of the nodules are dislocated.
: A few allochtone embedded fragments of soil material, most probably derived from the topsoil.
2. Depth: 95-110 cm

Macroscopic characteristics

Dark brown, fine textured moderate pedal soil material, with few black nodules up to 1 mm diameter, increasing in quantity with depth.

Micromorphological characteristics

Structure: Moderate coarse angular blocky structure, to which few to common elongated voids belong, partly intersected. Other voids: Few to common elongated voids, generally less than 2 cm long, widths <3 mm and common equant voids, $\phi$ up to 3 mm. A few enlarged elongated zones with irregular shapes on intersection nodes, $\phi$ up to 12 mm. Randomly distributed.

Groundmass: The fine textured groundmass includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material 15 $\mu$m. Related distribution: porphyric. The coarse material consists of a variety of minerals and rockfragments, which show varying stages of altering and some root fragments. The fine material is largely clay-sized, contains a few particles up to 15 $\mu$m and has a moderate vo-skelsepic plasmic fabric, locally vo-masepic.

Special features:

Associated with voids: Few to common voids, partly infilled with mineral aggregates, part of them are excrements.

In the groundmass: Common voids nearly completely infilled with mineral aggregates, partly excrements. The voids infilled with excrements, locally tend to striotubules.

: Few to common isotubules and other shapes of infillings with identical material as the groundmass or include also coarse grains up to and inclusive fine sand.

: Few to common black sesquioxidic nodules up to 2 mm in diameter, most with diffuse and some with sharp external boundaries. Increase in number with depth. The nodules with a sharp boundary are often dislocated.

: Locally horizontal zones with slight variations in grain sizes and quantities of the coarse material, indicating remnants of alluvial lamination.
1. Irregular accumulation of manganese in the groundmass, clear external boundaries; C horizon (plainlight)
4. Interpretation micromorphological data

Two thin sections are studied, one from the B horizon and one from the C horizon.
Depths: 48-63 cm (1) and 95-110 cm (2)

- The soil developed in an alluvial deposit of which in the C horizon locally remnants of geogenetic lamination are present. They are visible as horizontal zones with slight variations in grain sizes and quantities of coarse material. The mineral material shows the same varying stages of weathering in the B and the C horizon. In the C horizon larger grain-sizes are present, including rockfragments.
- The well developed coarse angular blocky structure is a result of swell and shrink of the montmorillonitic clay. In structural voids accumulations of angular soil fragments are present locally. They are split off during shrinkage and accumulated deeper in voids. The few embedded allochthone soil fragments (1), the few tubules containing a higher content of coarse grains (2), as well as the moderate vo-masepic (1) and vo-skelsepic (2) plasmic fabric of the fine material, are all consequences of the vertic properties of the soil.
- Voids produced by plant roots occur till >110 cm depth.
- The animal activity is high, especially in the B horizon. Most of their activity is visible as voids, partly or completely infilled with shaped excrements. Most isotubules and the striotubules are a result of faunal activity.
- Sesquioxides are accumulating in nodules up to 2 mm in diameter. The nodules in the B horizon have sharp external boundaries and the majority is displaced over small distances or forms a part of an infilling from upper horizons. In the C horizon (3) must nodules have a diffuse boundary and are formed in situ.
1. General information and typifying pedon description


Barsi series is a member of very fine montmorillonitic, isohyperthermic, deep family of Typic Chromusterts. Barsi soils have very dark gray to very dark grayish brown moderately to strongly alkaline clayey A horizons grading to dark yellowish brown and dark brown moderately alkaline clayey AC and C horizons. Barsi soils developed in basaltic alluvium.

Typifying pedon: Barsi clay - cultivated. (Colours are for dry soils unless otherwise noted).

**Ap**

0-12 cm: Very dark gray to very dark grayish brown (10YR 3/1.5) clay, very dark grayish brown (10YR 3/2 M); moderate medium sub-angular blocky breaking to moderate medium granular structure; the surface covered by 2 cm thick very dark gray (10YR3/1) pulverized mulch layer; dry slightly hard, moist friable, wet sticky and plastic; many medium and large lithorelicts with accretionary lime; many fine roots; common fine interstitial pores; cracks 2-3 cm wide diffuse smooth boundary; pH 8.5 (10 to 15 cm thick).

**A12**

12-36 cm: Very dark grayish brown (10YR 3/2 M) clay; strong coarse angular blocky peds with shiny pressure faces; dry hard, moist firm, wet sticky and plastic; common large basaltic lithorelicts with accretionary lime; common fine roots; few fine interstitial pores; cracks of 1-2 cm wide; diffuse smooth boundary; pH 8.4 (20 to 25 cm thick).

**A13**

36-69 cm: Very dark grayish brown (10YR 3/2) clay; coarse intersecting slickensides forming parallelepipeds with 20 to 25 cm long axes tilts at 30-35° from horizontal and break into strong coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic;
accretionary lime nodules and few large basaltic lithorelicts with accretionary lime; few fine and coarse inped and exped roots; cracks of 0.5-1 cm wide clear wavy boundary; pH 8.3 (30 to 35 cm thick).

A14 69-114 cm: Dark grayish brown to very dark grayish brown (10YR 3.5/2) clay; very coarse intersecting slickensides forming parallelepipeds with long axis 35 to 40 cm and tilted at 45-50° from horizontal that break into strong, coarse angular blocky peds with shiny pressure faces; dry very hard, moist very firm, wet very sticky and very plastic; few large basaltic lithorelicts with accretionary lime; few fine and coarse inped and exped roots; few fine pores; clear wavy boundary; pH 8.4 (40 to 45 cm thick).

Ac 114-147 cm: Dark yellowish brown (10YR 4/4 M) and very dark grayish brown (10YR 3/2) clay constituting about 60 to 40 percent of matrix coarse intersecting slickensides forming parallelepipeds with long axes 30 to 35 cm tilted at 30-35° from horizontal and that break into strong coarse angular blocky peds with shiny pressure faces; very very hard moist, very firm, wet sticky and plastic; accretionary lime giving localised effervescence; diffuse smooth boundary; pH 8.4 (30 to 35 cm thick).

C 147-167 cm: Dark yellowish brown (10YR 4/4 M) and dark brown (10YR 3/3 M) clay constituting 90 percent of the matrix; medium slickensides that separate into moderate medium angular blocky peds with shiny pressure face; dry very hard, moist very firm, wet very sticky and very plastic; many basaltic lithorelicts; with accretionary lime giving slight effervescence; pH 8.2.

Type location: Barsi Tehsil, Sholar district, Maharashtra, Kalegaon village.

Range in characteristics: The solum thickness ranges from 1.30 to 1.55 m. Within the depth 15 to 100 cm of the surface the content of CaCO₃ ranges from 0.4 to 1.05 percent and content of coarse fragments mostly lithorelicts ranges from 5 to 9%. The content of clay in fine earth varies from 64 to 75 and that of organic carbon varies from 0.50 to 0.53 through depth in the control section. A horizon is in colour of very dark gray to very dark grayish brown predominantly in hue of 10YR with value 3 and 3.5
and chroma 1.5 and 2 both for dry and moist soils. AC horizon is having dark yellowish brown and very dark grayish brown colour in hue of 10YR with value 3 and 4 and chroma 4 en 2 in the ratio of 60 to 40 percent of matrix respectively. The colour of C horizon varies from dark yellowish brown to dark brown in hue of 10YR with value and chroma 4 and 3. Surface structure is sub-angular blocky followed by sub-surface layers with angular blocky peds with shiny pressure faces. The layers at depth 35 cm of the surface show intersecting slickensides forming parallelepipeds with long axes tilted at angle of 30 to 50° from horizontal and break into angular blocky peds with shiny pressure faces. Accretion-ary lime nodules and basaltic lithorelicts present throughout the profile. The open cracks of 2-3 cm wide taper through and extend vertically upto 80-90 cm of the surface. The upper layer of the solum remains dry and cracks remain open to more than 180 days in most of the years.

Competing series and their differentiae: Hunda series is very deep, dark gray to very dark grayish brown highly clayey soils with 4-5 cm wide open cracks separating into several bigger polyhedrons during dry period. Hunda series comprises fine loamy, montmorillonitic, isohyperthermic, Typic Chromusterts.

Setting: Barsi series occur on level to very gently sloping lands (slope gradients 1 to 3%) of basaltic outwash at elevations ranging from 410 to 430 m. The climate is tropical semi-arid.

Drainage and permeability: Moderately well drained with slow permeability.

Use and vegetation: Cultivated for Sorghum, Red gram, Natural vegetation is Acacia arabica, Zizyphus jujuba.

Distribution and extent: Extensive in Barsi and Osmanabad Tehsils, Maharashtra.

**Interpretation:** Barsi soils are clayey, deep soils. These are moderately to strongly alkaline soils. These have high water and nutrient retention capacity and responsive to fertilization. As the exchangeable sodium percentage is high, under irrigated conditions without proper underground drainage, these soils may develop alkalinity hazard.

**Management interpretation:**

a) **Inductive:** (Based on physical potential of the series)
   1. Land capability classification: IIIIs
   2. Land irrigability classification: 3d
   3. Fertility management potential:
   4. Management potential/productivity:

b) **Management potential:** (Based on crop production at different levels of management).

<table>
<thead>
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<th>Crops</th>
<th>Farmers level Q/ha</th>
<th>Package of practice</th>
<th>Yield/ha</th>
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<td>Irri./Unirri.</td>
<td>Irri./Unirri. N:P:K:</td>
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<tr>
<td>Sorghum</td>
<td>15-18</td>
<td>50:25:00</td>
<td>25:00:00</td>
</tr>
<tr>
<td>Red gram</td>
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<td>X</td>
<td>00:12:00</td>
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<tr>
<td>Paddy</td>
<td>10-12</td>
<td>X</td>
<td>12:16:00</td>
</tr>
<tr>
<td>Peageon pea (Arhar or Tur)</td>
<td>X</td>
<td>X</td>
<td>12:25:00</td>
</tr>
<tr>
<td>Groundnut</td>
<td>X</td>
<td>X</td>
<td>12:25:00</td>
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<tr>
<td>Safflower</td>
<td>X</td>
<td>X</td>
<td>25:12:00</td>
</tr>
<tr>
<td>Wheat</td>
<td>18-20</td>
<td>50:25:00</td>
<td>X</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>80-90</td>
<td>200:100:00</td>
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## 2. Tentative soil characterisation by NBSS & LUP, Nagpur

### Size class and particle diameter (mm)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Very coarse (2-1)</td>
<td>Coarse (1-0.5)</td>
<td>Medium (0.5-0.25)</td>
<td>Fine (0.25-0.1)</td>
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<td>Ap</td>
<td>0-12</td>
<td>8.6</td>
<td>2.6</td>
<td>2.5</td>
<td>0.7</td>
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<tr>
<td>A12</td>
<td>12-36</td>
<td>7.2</td>
<td>1.1</td>
<td>2.2</td>
<td>0.3</td>
</tr>
<tr>
<td>A13</td>
<td>36-69</td>
<td>6.9</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>A14</td>
<td>69-114</td>
<td>2.8</td>
<td>0.1</td>
<td>0.2</td>
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<tr>
<td>Ac</td>
<td>114-147</td>
<td>10.2</td>
<td>0.5</td>
<td>1.0</td>
<td>1.8</td>
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<tr>
<td>C</td>
<td>147-167</td>
<td>18.2</td>
<td>2.3</td>
<td>1.3</td>
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### Organic carbon, Carbonate as Caco₃, Ext. iron as Fe, pH, E.C., Bulk density, Water Retention, Cole, CEC, Exchangeable sodium, CEC NH₄Ac

<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>E.C. (1:1)</th>
<th>Bulk density</th>
<th>Water Retention 1/3-bar</th>
<th>Water Retention 15-bar</th>
<th>Water Retention 1/3-to-15 bar</th>
<th>Rate of water retention cm/cm</th>
<th>COLE</th>
<th>CEC</th>
<th>Exchangeable sodium NH₄Ac mg/100g</th>
<th>Ratios to clay</th>
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<tr>
<td>0-12</td>
<td>0.53</td>
<td>0.4</td>
<td>-</td>
<td>8.5</td>
<td>0.20</td>
<td>1.58</td>
<td>45.1</td>
<td>30.6</td>
<td>0.26</td>
<td>0.13</td>
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<td>-</td>
<td>8.4</td>
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<td>47.0</td>
<td>28.8</td>
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<tr>
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<td>-</td>
<td>8.3</td>
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<td>1.70</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>65.4</td>
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<tr>
<td>69-114</td>
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<td>-</td>
<td>8.4</td>
<td>0.50</td>
<td>1.87</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
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<td>8.4</td>
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<td>-</td>
<td>8.2</td>
<td>0.75</td>
<td>1.69</td>
<td>-</td>
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<td>64.6</td>
<td>12</td>
<td>1.10</td>
<td></td>
</tr>
</tbody>
</table>
3. Micromorphological data

One thin section of a deep A horizon is studied.

Depth: 75–90 cm.

Macroscopic characteristics

Dark brown, fine textured, pedal soil material, containing common light coloured nodules, diam. up to 8 mm.

Micromorphological characteristics

Structural: Strong course angular blocky, to which common intersected, elongated voids belong. Other voids: Few to common elongated voids, widths generally < 3 mm, lengths up to a few cm and few to common equant voids, most diam. < 3 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 coarse mineral material consists of a variety of minerals, which show varying stages of alteration. The fine material is largely clay sized, includes a few particles up to 5 µm and has a moderate wo-skelsepic plasmic fabric.

Special features:

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

: Structural voids are locally enlarged resulting in irregular, uneven void walls.

In the groundmass: Few to common voids nearly completely filled with mineral aggregates, mainly more or less wealded shaped excrements.

: Common, most are rounded, carbonate nodules, diameters up to 8 mm, randomly distributed. A few carbonate nodules have an accumulation of sesquioxides in the outer zone.
Barsi (1 photograph)

Carbonate nodule (light colour) with a skelsepic plasmic fabric in adjoining groundmass. A horizon (crossed polarisers)

4. Interpretation of the micromorphological data

One thin section of a deep A horizon is studied.
Depth: 75-90 cm.

- The strong coarse angular blocky structure with an inclination of about 45° with the horizontal axis is due to strong swell and shrink of the montmorillonitic clays. The angular soil aggregates present in partly filled voids are split off during shrinkage in upper parts of the A horizon. The roundness of the carbonate nodules and the orientation of clay domains resulting in a vo-skelsepic plasmic fabric of the fine material are also both consequences of the vertic properties of the soil.
- The fauna is of minor importance. Soil animals are responsible for local enlargements of structural voids, the production of few to common elongated and equant voids and the present voids partly or nearly completely filled with more or less welded mineral excrements.
- There is no distinct evidence of current carbonate accumulation or disintegration.
The carbonate nodules are rather rounded and some have an accumulation of sesquioxides in the outer zone. The diameters of the carbonate nodules can reach 8 mm.
ADESAR SERIES

1. General information and typifying pedon description


Adesar series includes moderately well drained, deep soils developed over weathered jurassic sandstone and occurs on nearly level to gently sloping pediment toe slopes. The soil pedon exhibits a reddish brown to yellowish red gravelly sandy loam to gravelly clay loam A horizon grading to a reddish brown to dark reddish brown gravelly sandy clay loam B horizon with prominent clay skins on coarse, strong, prismatic peds; overlying the weathered jurassic sandstone. The soils are subject to moderate erosion. These soils have been classified in India as Regosols.

The climate of the area is tropical arid. The mean annual air temperature is 26°C rising to 38 to 39°C in May and falling to 10°C in January in most years. The mean annual rainfall ranges from 300 to 350 mm of which about 90% is received during July to September in most of the years. The principal associated soils are those of Lakhpat and Vejapur series which are deep Aridisols.

Adesar series comprises members of fine loamy, mixed, hyperthermic, deep family of Typic Paleargids.

Typifying pedon: Adesar gravelly sandy loam – cultivated (Colours are for dry soils unless otherwise noted).

Ap 0-8 cm: Reddish brown (5 YR 5/6 D & M); gravelly sandy loam; weak medium subangular blocky; dry slightly hard, moist friable, wet slightly sticky, many ferruginous and quartz gravels; many coarse and fine roots; moderately rapid permeability; pH 8.7; abrupt and smooth boundary.

B2lt 8-38 cm: Reddish brown (5 YR 4/4), gravelly sandy clay loam; dark reddish brown (5 YR 3/4) when moist; strong coarse prismatic breaking into medium moderate angular blocky peds with into medium moderate angular blocky peds with thin discontinuous clay
skins on the ped faces; dry hard, moist firm, wet sticky and plastic; many ferruginous and quartz gravel in the matrix; very few fine roots; moderately rapid permeability; pH 8.9; gradual and smooth boundary.

B22t 38-75 cm: Dark reddish brown (2.5 YR 3/4) gravelly sandy clay loam, reddish brown (2.5 YR 4/4) when moist; matrix is engraved with pink (5 YR 7/3) colour constituting about 30%; strong coarse angular blocky peds with thick discontinuous clay skins on the ped faces with patchy coatings of powdery lime; many scattered accretionary lime nodules in the matrix; dry hard, moist firm, wet sticky and plastic; many coarse and medium ferruginous fragments and medium quartz gravels; strongly effervescent; very few fine roots; moderate permeability; pH 9.2; gradual smooth boundary.

B23t 75-127 cm: Dark yellowish brown (5 YR 3/4 D & M) gravelly sandy clay loam, engraved with pink (5 YR 7/4 M) constituting about 40 to 45% in the matrix. Strong coarse prismatic breaking into moderate medium angular blocky peds with thick discontinuous clay skins on the ped faces engulfed by patchy coating of softy lime; many accretionary lime nodules in the matrix; dry hard, moist firm, wet sticky and plastic; many coarse and medium ferruginous fragments and medium quartz gravels; strongly effervescent; moderately slow permeability; pH 8.7; gradual and smooth boundary.

C 127-146 cm: Reddish brown (5 YR 4/3 D & M); massive weathered ferruginous shales and sandstone with accretionary lime; violently effervescent; pH 8.7.

Range in characteristics: Average thickness of the solum ranges from 106 to 130 cm. The content of coarse fragments within the depth of 15 cm to 1 metre of the surface, ranges from 25 to 40% but at places the gravel content may exceed in subsoil layers ranging from 70 to 80%. The soil reaction is moderately to strongly alkaline and the pH ranges from 8.2 to 9.0 through depth. Salt content expressed as EC ranges from less than 0.2 to 2.4 mmhos/cm while the calcium carbonate varies from 0.7 to 7% through depth. The surface layer is normally thin and abruptly underlain by an argillic horizon. The texture of the fine earth in the
A horizon varies from sandy loam to clay loam with varying content of gravel in the matrix. The soil colour is dominantly in the hue of 5 YR and 2.5 YR. The soil throughout the pedon with dry value 4 and moist value 3 and chroma 4 and 3 both for dry and moist soils. The Bt horizon is 100 to 115 cm thick with an abrupt upper boundary and gradual lower boundary transitional to the C horizon. In the upper part there is an enrichment of total clay by 15% within a vertical distance of 2.5 cm. The content of total clay in fine earth in some of the sub horizons through depth ranges from 30 to 35 percent. Clay skins on the ped faces are clear and distinct. Matrix in B2lt and B23t is somewhat coated with powdery lime in patches with a violent effervescence. Pedality is strong coarse prismatic in B2lt and B22t horizons; in B23t moderate medium subangular blocky. More than 3/4 of the pedon remains dry for more than 9 months during dry season in most of the years. The effective rooting depth is moderately deep. The depth of the groundwater table ranges from 10 to 12 m of the surface. The mean annual soil temperature varies between 27°C and 28°C while the difference of mean summer and winter soil temperature at depth of 50 cm of the surface exceeds 5°C in most of the years.

Competing series and their differentiae: The competing soils are those of Desalpar series. the thickness of solum in Desalpar series ranges from 93 to 125 cm and it is underlain by massive laterite. The soil colour is dominantly in hue of 2.5 YR while in Adesar soils it is in between 5 YR and 2.5 YR.

Drainage and permeability: Moderately well drained with moderately slow permeability.

Vegetation and land use: Mostly cultivated to cotton and bajra under rainfed conditions. Otherwise left under sparse vegetal growth of Prosophis Juliflora.

Location: About 6 km east of village Adesar, Taluka: Rapar, District: Rutch and on Adesar – Bhachau Road.
Distribution and extent: Adesar soils are soils of significance in arid areas in Rapar and Bachau talukas of Bhuj district.

Series established and type location: Adesar gravelly sandy loam. Profile No. 13, about 5 km to the east of village Adesar in Rapar taluka of Kutch (Bhuj) district, Gujarat State.

N.B. 1. Texture and values are subject to changes addition and alteration.
2. Soil survey interpretation chapter would be appended after completion of analytical in work.

2. Tentative soil characterisation: No data provided

3. Micromorphological data

Three thin sections are studied: covering the B horizon. depths: 5-20 cm (1), 48-63 cm (2) and 98-113 cm (3).

1. Depth: 5-20 cm

Macroscopic characteristics

Reddish brown, coarse textured, strong pedal soil material, containing gravels of different colour up to 8 mm φ, randomly distributed.

Micromorphological characteristics

Structure: (The structure of the soil material can not be detected with certainty from the thin section, due to disturbance during transport. Soil aggregates in voids can be artificial). The soil material is strong coarse prismatic, moderately subdivided into medium angular blocky peds, to which a few long, rather regular elongated voids, commonly intersected belong. Other voids: few elongated voids, φ < 1 mm, lengths less than a few cm and a few equant voids, φ < 1 mm.
Groundmass: The coarse textured soil material includes grain-sizes up to and inclusive gravels of 8 mm Ø. Size limit coarse/fine material: 20 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which can be fresh or completely altered. The fine material is largely clay-sized, contains a few mineral particles up to 20 µm and is mainly asepic, locally skelsepic. Plasmic fabrics are not easy observable due to the red colour of the fine material.

Special features

Associated with voids: Some voids are partly infilled with mineral aggregates, rarely excrements.

In the groundmass: Few to common carbonate nodules, composed of coarse carbonate crystals, sharp boundaries, Ø up to 2 mm, often filling former voids nearly completely, including a few other mineral grains. Carbonate nodules often include some iron.

: Common iron rich, altered rock fragments and other sesquioxidic accumulations.

: Some voids are nearly completely infilled with mineral aggregates, rarely excrements.

2. Depth: 48-63 cm

Macroscopic characteristics

Dark reddish brown, coarse-medium textured, pedal soil material, containing many gravels of different colours, up to 8 mm Ø, largely concentrated in the zone 57-63 cm.

Micromorphological characteristics

Structure: The soil material is moderately coarse angular blocky to which few to common elongated voids, commonly interconnected, belong. Other voids: few elongated voids, widths < 2 mm, less than several cm long, and few equant voids, Ø < 2 mm. Randomly distributed.

Groundmass: The coarse-medium textured soil material includes grain sizes up to and inclusive gravels of 8 mm Ø. Size limit coarse/fine material: 20 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which can be fresh or completely...
altered. The fine material is largely clay-sized, contains a few mineral particles locally including many carbonate particles up to 20 µm, and is asepic. Locally a skelsepic plasmic fabric can be observed. Plasmic fabrics are not easy detectable due to the red colour of the groundmass. Special features:

Associated with voids:

**In the groundmass** : Common to many carbonate nodules, with varying internal structures of coarse and fine carbonate particles, with sharp or diffuse boundaries. In the latter case one around nodules small particles < 20 µm present in the groundmass in varying quantities. In the carbonate nodules minor quantities of other mineral grains can be present and sesquioxides. Diameters up to 5 mm, randomly distributed.

: Common iron-rich, altered rock fragments and other sesquioxidic accumulations, ~ up to 6 mm, predominantly occurring in the zone 57-63 cm depth.

: Some voids are nearly infilled with, mainly angular, mineral aggregates.

3. Depth: 98-113 cm

**Macroscopic characteristics**

Dark reddish brown, medium textured, pedal soil material, including some gravels of different colours, ~ up to 8 mm.

**Micromorphological characteristics**

**Structure:** The soil material is moderate medium angular blocky, to which few to common, rather regular elongated voids belong, commonly interconnected, widths up to 2 mm, lengths up to about 6 cm. Other voids: Some elongated voids, widths less than 1 mm, lengths up to a few centimeters and some equant voids, ~ < 1 mm. Randomly distributed.

**Groundmass:** The medium textured soil material includes grain sizes up to and inclusive gravels of 8 mm ~. Size limit coarse/fine material: 20 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, which can be fresh or completely altered. The fine material is clay-sized and contains mineral particles up to 20 µm, locally including carbonate particles. The plasmic fabric is mainly skelsepic.
Special features:

Associated with voids: none

In the groundmass: Many carbonate nodules, the majority with mainly coarse carbonate particles varying between about 30-100 µm, with sharp or diffuse boundaries. In the latter case are around the nodules smaller carb. particles present in the groundmass in varying quantities. The carbonate nodules contain a few other mineral grains but sesquioxides are rare. They consist mainly of pure carbonate crystals. Diameters up to 8 mm, randomly distributed.

Common iron-rich altered rock-fragments and other sesquioxidic accumulations, Ø up to 2 mm, randomly distributed.

Short micromorphological description

Three thin sections one studied covering the B horizon.

Depths: 5-20 cm (1), 48-63 cm (2) and 98-113 cm (3).

- The soil material is coarse (1), coarse to medium (2) and medium (3) textured and includes grain sizes up to gravels of 8 mm diameter. The size limit between coarse and fine material is 20 µm; and the related distribution porphyric. The fine material is largely clay-sized and contains a few mineral particles in (1) and (2) and common in (3). Plasmic fabrics are only locally observable due to the red colour of the fine material. When visible they the plasmic fabric is skelsepic, best observable in (3). The coarse mineral material consists of a variety of minerals and rockfragments, which can be fresh or completely altered.

- The soil material is strong coarse prismatic, subdivided into moderately medium angular peds (1): moderate coarse angular blocky in (2) and moderate medium angular blocky in (3), to which few (1) or few to common (2, 3) elongated voids, commonly intersected belong. Other voids: few elongated voids, < 2 mm wide, length up to a few centimeters and a few equant voids < 2 mm Ø in (1) and (2), deep in the B horizon (3) a very few voids occur. The voids are randomly distributed.
- Few voids, partly or almost completely infilled with mineral aggregates, occur in the upper part of the B horizon (1, 2). These aggregates generally are soil aggregates, rarely excrements. In the upper part of the B horizon (1) the soil aggregates can be due to disturbance during transport.

- Carbonate nodules occur in the whole B horizon, increasing in quantity and size with depth. The quantity increases from few to common (1), common to many (2) to many in (3) and the diameters increase from 2 mm (1), 5 mm (2) to 8 mm in (3). In the upper part of the B horizon (1) the external boundaries generally are sharp, deeper (2, 3) they are sharp or diffuse. In (1) the nodules mainly consist of coarse carbonate crystals, deeper (2, 3) of coarse as well as fine carbonate crystals. In the upper and middle part of the B horizon (1, 2) sesquioxides, mainly iron, are commonly present in the carbonate nodules.

- Iron-rich altered rock fragments and other accumulations of sesquioxides are common in the whole B horizon.
1. A few carbonate nodules and a number of smaller carbonate crystals in the groundmass (white). B horizon (crossed polarizers)
4. Interpretation of the micromorphological

Three thin sections are studied: covering the B horizon.

Depths: 5-20 cm (1), 48-63 cm (2) and 98-113 cm (3).

- The parent material is not homogeneous throughout the profile. Zones contain different quantities of gravels; the 56-63 cm zone being rich in gravels.
- The moderate angular blocky structure of the soil is a result of physical processes. In the upper part of the B horizon (1) some angular soil fragments, split off during shrinkage, occur in a few voids.
- The effects of fauna and flora are negligible.
- Strong weathering of minerals and rock fragments has occurred in this profile. Some weathering of minerals and rock fragments is still taking place. They can be strongly altered. Sesquioxides were released, coloured the fine material of the groundmass and accumulated in nodules. Altered rock fragments and sesquioxidic nodules are common features in the studied zone.
- Carbonate nodules occur in increasing quantity with depth from few to common in the upper part of the B horizon (1) to many, deep in the B horizon (3). The diameters of the nodules increase in the same zone from 2 mm (1), via 5 mm (2) to 8 mm in (3). The nodules predominantly consist of rather coarse grained carbonate crystals (30-100 µm in diameter). Several growing phases can often be distinguished. In the upper and middle part of the B horizon carbonate nodules often contain sesquioxides, mainly iron.

Conclusion: In the studied pedon not any feature due to clay illuviation is observed and no indication for clay illuviation, past or present, occurs. These facts do not influence the classification seriously (Orthid), the profile description has to be adapted.
ANKHI SERIES

1. General information and typifying pedon description


Ankhi series includes well drained, very deep, dark brown to dark yellowish brown soils developed on Mahi alluvium originated from sand stone and basalt. They occur on nearly level to very gently sloping (1-2%) upper midland terraces in the old flood plain of Mahi river system. The soil pedons have an ABC profile with dark brown to dark yellowish brown, sandy clay loam to sandy clay A horizons underlain by clayey compact B horizons with same colours followed by dark brown sandy clay loam to silt loam C horizons. The soils are noncalcareous in nature and contain varying amounts of mica flakes, quartz gravels etc. The soils crack 0.5-1 cm wide and extend about 75 cm during the dry period. These soils have been classified as "Alluvial Soils" in India. The climate of the area is tropical semiarid. The mean annual air temperature is 27°C rising to max. 41°C in May and falling to min 11°C in January in most of the years. The mean annual rainfall is 985 mm of which about 83% is received during July-Sept. in most of the years. The annual coverage of evapotranspiration by the precipitation is 56%. The common soil associates are Haldar series which are Typic Chromusterts.

Ankhi series comprises members of fine loamy, mixed, hyperthermic, deep, family of Vertic Ustochrepts.

Typifying pedon: Ankhi sandy loam - cultivated.

(Colour notations are for dry soils unless otherwise noted)

Ap 0-15 cm: Brown (10 YR 4/3) sandy loam, dark brown (10 YR 3/3) when moist; weak medium subangular blocky; dry slightly hard, wet slightly sticky and slightly plastic, moist friable; abundant fine roots; few mica flakes; many medium and fine tubular and oblique pores; rapid permeability; pH 7.6; clear smooth boundary.

A12 15-26 cm: Dark brown (10 YR 4/3) sandy clay loam; dark brown (10 YR 3/3) when moist; moderate medium subangular blocky; dry
hard; moist friable, wet sticky and plastic; many fine tubular and few medium oblique pores; plentiful fine roots; moderately rapid permeability; pH 7.9; clear smooth boundary.

B21 26-56 cm: Dark brown (10 YR 4/3) sandy clay loam, dark brown to very dark grayish brown (10 YR 3/2.5) when moist; coarse prismatic structure breaking into moderate coarse subangular blocky peds; dry hard, moist friable, wet sticky and plastic; many fine oblique and few fine tubular pores; few fine roots; moderate permeability; pH 7.9; clear and wavy boundary.

B22 56-90 cm: Dark brown (10 YR 4/3) sandy clay loam, dark brown (10 YR 3/3) when moist; coarse prismatic structure breaking into moderate coarse angular blocky peds with weak pressure faces; dry hard, moist friable, wet sticky and plastic; few fine oblique inped pores; few fine roots; moderate permeability; pH 8.2; clear and wavy boundary.

B3 90-120 cm: Yellowish brown (10 YR 5/4) sandy clay loam; dark yellowish brown (10 YR 4/4) when moist; coarse prismatic structure breaking into moderate coarse angular blocky peds with weak pressure faces; dry hard, moist friable, wet sticky and plastic; few fine oblique pores; moderate permeability; pH 8.2; clear and smooth boundary.

C 120-155+ cm: Yellowish brown (10 YR 5/4) sandy loam; dark yellowish brown (10 YR 4/4) when moist; weak medium subangular blocky; dry slightly hard, wet slightly sticky; moderately rapid permeability; pH 8.2.

Range in characteristics: The average thickness of the solum ranges from 1.02 to 1.33 m. The clay content increases with the increase in depth in the solum. The soil reaction is of varied nature differing from mildly alkaline to moderately alkaline in nature. The mica flakes and quartz gravels are found throughout the profile and increases abundantly in the C horizon. The principal soil types are sandy loam and sandy clay loam but at places loamy sand occurs also. The texture of the fine earth in B horizon varies from sandy clay loam to sandy clay. The vertical cracks of 0.5-1 cm width extend through the soil pedon upto 75 cm of the surface. The soil colour in A horizon varies from brown to strong brown in hue of
10 YR and 7.5 YR with medium values and chroma both for dry and moist soils in the matrix. However, the soil colour in B horizon is in hue of 10 YR with dry value 5 and 4 and one unit less for moist soils while chroma ranges between 3 and 4 for both dry and moist soils. The pedality of B horizon is coarse prismatic breaking into medium to coarse moderate to strong angular blocky peds with weak pressure faces that grades to weak fine to medium subangular blocky peds in the C horizon. The control section is noncalcareous although slight effervescence is observed in the C horizon. Between 15 and 150 cm depth of the surface there are sporadic insect and white ant burrows in the upper part while there are krotovinas and pedotubules in the lower part. The mean soil temperature varies from 28 to 29°C and the difference between mean summer and mean winter soil temperature at 50 cm of the surface exceeds 5°C. About 3/4th of the upper part of the moisture control section remains dry, with moisture at or below wilting point during dry periods in most of the years while the rest remains moist.

Competing series and their differentiae: Competing soils are those of Haldar and Kabilpur series. Haldar soils are clayey soils with high clay content and deep and wide vertical cracks. Kabilpur soils have high CaCO₃ content and variegated soil reaction in different horizons.

Drainage and permeability: Well drained with moderately rapid to moderate permeability with depth.

Use and vegetation: Most of the area is under cultivation in all three seasons. The various crops raised are Tobacco, wheat, cotton, bajra, jowar, kodra, castor, tur, beans, lucerne, banana, papaya, vegetable etc. The natural vegetation comprises species like Acacia arabica, Mangifera indica, Azadirachta indica, Zyzphyus sp., Banyan, Rayan, Drumstick etc. trees and the species of grasses are like Dicanthium annulatum, Cyperus rotundus etc.
Distribution and extent: Series is marked in association with Kareli and Bojedra series. Soils are found in wide extent in East, North-east, North-west part of Baroda and in parts of Ahmedabad, Khera, Nadiad, Broach districts in Gujarat State.

Type location and series established: Ankhi sandy loam Pit No. 90, about 1 km north-west of village Sama Tah. and Distt. Vadodara (Baroda), Gujarat State.

2. Tentative soil characterisation: no data provided

3. Micromorphological data

Two thin sections are studied: one from the transition of the A and B horizons and one of the B horizon.
Depths: 20-35 cm (1) and 85-100 cm (2).

1. Depth: 20-35 cm

Macroscopic characteristics
Dark brown, medium textured, moderate pedal soil material.

Micromorphological characteristics

Structure: The soil material is moderate coarse angular blocky to which a few long, rather regular elongated voids belong, which are commonly intersected. Other voids: common regular and irregular elongated voids, widths < 3 mm, length up to a few cm and common equant voids, Ø up to 3 mm. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 20 µm. Related distribution: mainly porphyric, locally gefu-chitonic. The coarse mineral material consists of a variety of minerals which mainly are fresh or slightly altered. A few fragments of roots are present as coarse organic matter. The fine material is largely clay-sized, contains a few fine mainly mineral particles up to 20 µm and has a skelsepic plasmic fabric.
Special features
Associated with voids: Few cutans of dark-brown mainly clay-sized material.
: A very few argillans.
: A few sesquioxide neocutans.
: Along floral and faunal voids compression zones are commonly present.
: Common partly infilled voids with mineral aggregates, mainly excrements, of different compositions, shapes and sizes.
: Common partly infilled voids with mineral grains, often in combination with voids with dark-brown cutans of clay-sized material.
In the groundmass: Few-common voids loosely infilled with mineral aggregates, mainly excrements, and mineral grains in varying quantities.
: Common voids infilled with mineral soil material occurring in laminae, aggregates and mineral grains. Laminae are sorted and mainly composed of clay-sized a fine-grained materials, locally along the walls are dark-brown cutans present.
: Few embedded fragments of clay-sized cutans.
: Few small sesquioxide accumulations (nodules).
: Few fragments of charcoal.

2. Depth: 85-100 cm

Macroscopic characteristics

Yellowish brown, medium textured, weak moderate pedal soil material.

Micromorphological characteristics

Structure: The soil material is moderate coarse prismatic with very weak coarse angular blocky peds to which a few long, rather regular, elongated voids belong. Other voids: Common, often regular elongated voids widths < 3 mm, lengths less than 2 cm and common equant voids, Ø up to 3 mm. A very few large elongated voids areas, widths up to 10 mm and several cm length, as widened areas on structural voids. Randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive medium sand. Size limit coarse/fine material: 10 µm. Related distribution: mainly gefu-chitonic, locally porphyric. The coarse
1. Sorted, mineral infilling in a faunal void, with a patchy thin argillan; B horizon (plain light).
mineral material consists of a variety of minerals which mainly are fresh or slightly altered. The fine material is largely clay-sized. This clay-sized material has a moderate to strong skelsepic plasmic fabric.

**Special features**

Associated with voids: Around biological voids commonly compression zones are present.

: Common partly infilled voids with mineral aggregates largely excrements with compositions which are nearly identical or identical to the groundmass and have a few different shapes and sizes. Along the walls of these voids locally dark brown clay-sized cutans can be present.

In the groundmass: Common loosely infilled voids with mineral aggregates, mainly excrements and mineral grains in varying quantities. External boundaries are distinct or diffuse, both can be present in one void. Locally along the walls dark brown clay-sized cutans can be present.

: Few voids infilled with mineral grains.

: Few small sesquioxidic accumulations, nodules.

4. Interpretation of the micromorphological data

Two thin sections are studied: one from the transition of the A and B horizons and one from the B horizon.

- The topsoil of this pedon is reworked till > 35 cm depth, indicated by the presence of a few embedded fragments of clay-sized cutans and charcoal.
- The voids are due to swell/shrink and biological activities. Faunal voids are often coated with dark brown clay-sized material, performed by the animals themselves. The compression zones along biological voids are due to fauna as well as plant roots. Commonly faunal voids are infilled with mineral excrements, which sometimes are disintegrating, of different species.
- The soil material in the topsoil is periodically unstable under wet conditions. Commonly voids are infilled with mineral material, sometimes sorted and present in laminae or only composed of mineral grains. A very few argillans occur in (1). The instability is due to agricultural practises probably intensified by alkaline conditions.
- The soil material is not homogeneous with depth. The quantity of fine material decreases, resulting in a change in packing from mainly porphyric (1) to mainly gefu-chitonic (2).
ACHMATTI SERIES

1. General information and typifying pedon description

Pedon described by core group members consisting of N.K. Barde, H.S. Shankaranarayana, N.G. Godse, B.V. Venkata Rao, C.S. Harindranath and Sri Kar associated. Date of study: 27.4.79

Achmatti series comprises imperfectly drained, very deep, calcareous, cracking clayey soils of very dark gray to very dark grayish brown colours developed on mixed alluvium. Achmatti soils occur on very gently sloping, basins (<1% slope) between quartzite and chlorite schist ridges of Kaladgi formation. The climate is semi arid with mean annual air temperature of 25.7°C and average annual rainfall of 663.7 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 Hirekumbhi and Hanchinal series which are non saline and non alkali fine Typic Chromusterts.

Achmatti series is a member of the very fine, montmorillonitic, calcareous, isohyperthermic family of Typic Pellusterts.

![Climatic Data and Soil Water Balance](image_url)
Typifying pedon: Achmatti clay - cultivated.

Ap  0-4 cm: Very dark gray (IOYR 3.5/D) clay and very dark gray (IOYR 3/1 M); weak fine granular; slightly hard, friable, sticky and plastic; about 2% by volume of irregularly rounded 2-10 mm sized calcium carbonate nodules; strongly effervescent; mulch layer; common very fine to medium roots; pH 8.3; clear smooth boundary.

Ap2  4-22 cm: Very dark gray (IOYR 3/1 M) clay; moderate medium sub-angular blocky breaking to granular; firm, sticky and plastic; 5% by volume of irregularly rounded 2-10 mm size lime nodules; strongly effervescent; cracks upto 3 cm width; very fine medium inped roots; few very fine discontinuous tubular vertical inped simple open pores; pH 8.6; clear smooth boundary.

A12  22-54 cm: Very dark gray (IOYR 3/1 M) clay and dark gray (IOYR 4/1 rubbed); strong coarse angular blocky with intersecting slickensides; firm, sticky and plastic; few 1-3 mm size rounded manganese concretions and very few 2-5 mm size lime concretions; strongly effervescent; none to very few stains of manganese; cracks of 1 to 1.5 mm width which widen on drying; few very fine inped roots; common very fine inped roots; tubular vertical discontinuous inped simple open pores; pH 8.7; gradual smooth boundary.

A13  54-87 cm: Very dark gray (IOYR 3/1 M) about 60% and dark grayish brown (IOYR 4/2 M) about 40%, clay and dark gray (IOYR 4/1 rubbed); strong coarse angular blocky with prominent intersecting slickensides forming sphenoids; very firm, very sticky and very plastic; few 2 mm size lime nodules; strongly effervescent; 0.5 to 1 cm thick bands of manganese; cracks about 1 cm wide which widen after drying; few fine inped roots; few very fine tubular discontinuous vertical inped simple open pores; pH 8.8; gradual irregular boundary.

AC1Ca  87-152 cm: Dark grayish brown (IOYR 4/2 M) about 70% and very dark gray (IOYR 3/1 M) about 30%; clay; dark grayish brown (IOYR 4/2 rubbed); strong coarse angular blocky with prominent intersecting slickensides forming sphenoids; firm, sticky and plastic; about 7% by volume of 10 to 20 mm size lime nodules; violently effervescent; few bands of manganese; cracks less than 1 cm wide but widen on drying; few very fine inped roots; few very
fine tubular discontinuous vertical inped simple open pores; pH 8.9; gradual broken boundary.

AC2Ca 152-170 cm: Very dark gray (10YR 3/1 M) clay, very dark grayish brown (2.5 Y 3/2 rubbed) weak coarse angular blocky with few slickensides forming sphenoids; firm, sticky and plastic; about 10% by volume of 1-5 mm size lime and manganese nodules; violently effervescent; bands of manganese; cracks less than 1 cm wide; pH 8.4.

Range in characteristics: The depth of soil ranges from 150 to 200 cm. The estimated mean annual soil temperature at 50 cm depth is 26.9°C, the mean summer soil temperature is 24.8°C and the mean winter soil temperature is 24.0°C. The colour of the Ap horizon ranges from very dark gray to dark gray in hues of 10YR and 2.5Y with value of 3 and 3.5 and chroma of 1 to 1.5. The thickness of the Ap horizon ranges from 15 to 20 cm. The eroded surface may have few fine gravel and lime concretions.

The A horizon in the subsoil has a depth range of 130 to 160 cm. Colour ranges from very dark gray to dark gray in hues of 10YR and 2.5Y with values of 3 to 4 and chroma of 1 to 1.5. The structure of the subsoil is coarse to medium angular blocky with prominent intersecting slickensides and well developed sphenoids in depth range of 22 to 100 cm from the surface. The cracks in dry soil will extend up to 1.5 m. The width of the cracks range from 2 to 5 cm. The exchangeable sodium percentage is more than 20 throughout the control section. Occasionally gypsum is present below 80 cm. Lime is in the form of splotches, of 2 to 10 mm size and manganese concretions increase with depth. The texture in the control section is clayey with clay percentages between 68.0 to 70.1.

Competing series and their differentiae: Hirekumbhi series have distinct pale yellowish to brown mottles below 60 cms from surface. Hachinal series have brownish colours in 10YR hue and are not sodic. They are Typic Pellusterts and Typic Chromusterts respectively.

Drainage and permeability: Imperfectly drained with slow permeability.

Use and vegetation: Cultivated for Cotton, Jowat and Wheat under rainfed conditions, main in Rabi. Natural vegetation consists of Acacia Arabica (babool), Acacia Indica (Jali), Prosopis sp., Azadiracta Indica (Neem).
Distribution and extent: Occurs in the Navalgund taluk of Dharwar district of Karnataka State.

Type location: Plot No. 10 about 2 km north of Gobbarumpi village Navalgund taluk, Dharwar district, Karnataka.


Management Interpretation: The soils of Achmatti series are high in clay and pose problems due to cracking, slow permeability and sodic nature. They will initially take in the moisture during early rains, need proper soil conservation measures. They are adapted to crops like Jowar, Cotton, Wheat, Safflower and Pearl Millet. They are not recommended to perennial irrigation.

a) Inductive (based on physical productive potential of the series)
1. Land capability sub-class: IVs
2. Irrigability sub-class: 4d
3. Fertility Management Potential: Moderate (due to high clay and slow permeability)
4. Management Potential/productivity: Moderate (due to high clay, slow permeability, sodic condition, tendency to stagnate during rains and cracking).

b) Quantitative (Management Potential for crop production at different levels of farming under rainfed and irrigated agriculture. Information from soil survey unit of the state).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Farmers' Level</th>
<th>Package</th>
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<tbody>
<tr>
<td></td>
<td>Rainfed/irri.</td>
<td>Rainfed/irrig.</td>
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<tr>
<td>Wheat</td>
<td>7</td>
<td>22</td>
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<tr>
<td>Hybrid Jowar</td>
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<td>62</td>
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<tr>
<td>Bengalgram</td>
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<td>25</td>
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<tr>
<td>Safflower</td>
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<td>23</td>
</tr>
<tr>
<td>Maize</td>
<td>12</td>
<td>50</td>
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<tr>
<td>Cotton (Jaydhar)</td>
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<td>27</td>
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</table>
2. Tentative soil characterisation of the Achmatti pedon by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Depth in cm</th>
<th>Horizon</th>
<th>Size class and particle diameter (mm)</th>
<th>Coarse fragments by weight of whole soil</th>
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<tr>
<td></td>
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<td>Sand (2-0.05)</td>
<td>Silt (0.05-0.002)</td>
</tr>
<tr>
<td>0-4</td>
<td>Ap</td>
<td>Coarse (2-1)</td>
<td>Medium (1-0.5)</td>
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<tr>
<td></td>
<td></td>
<td>23.5</td>
<td>21.9</td>
</tr>
<tr>
<td>4-22</td>
<td>A12</td>
<td>22.3</td>
<td>19.1</td>
</tr>
<tr>
<td>22-54</td>
<td>A13</td>
<td>13.2</td>
<td>18.8</td>
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<td>54-87</td>
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<tr>
<td>87-152</td>
<td>AC, Ca1</td>
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<tr>
<td>152-170</td>
<td>AC, Ca2</td>
<td>10.0</td>
<td>19.7</td>
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<table>
<thead>
<tr>
<th>Depth in cm</th>
<th>Organic carbon %</th>
<th>Carbonate as CaCO(_3) %</th>
<th>pH of H(_2)O (1:2.5)</th>
<th>pH of H(_2)O (1:2.5)</th>
<th>E.C. (mmhos/cm)</th>
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<tr>
<td>0-4</td>
<td>1.25</td>
<td>16.22</td>
<td>3.10</td>
<td>8.3</td>
<td>0.18</td>
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<tr>
<td>4-22</td>
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<td>1.10</td>
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<td>15.17</td>
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<td>15.03</td>
<td>4.33</td>
<td>8.9</td>
<td>0.56</td>
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<tr>
<td>152-170</td>
<td>0.48</td>
<td>13.72</td>
<td>4.93</td>
<td>8.4</td>
<td>3.30</td>
</tr>
</tbody>
</table>
3. Micromorphological data

One thin section of the AC horizon is studied.
Depth: 100 - 115 cm.

Macroscopic characteristics

Dark grayish brown with very dark gray (30%) fine textured, pedal, soil material, containing common mainly light-coloured nodules, diam. up to 10 mm.

Micromorphological characteristics

Structure: Strong coarse angular blocky, to which common, intersected, elongated voids belong. Other voids; few elongated voids, widths generally less than 3 mm, length up to a few cm and few equant voids, most diam. <3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 5 µm. Related distribution: porphyric, the coarse material consists of a 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 moderate skel-vosepic plasmic fabric.

Special features:
Associated with voids: Few voids partly filled with mineral aggregates, excrements as well as, often angular, soil aggregates.

: Few calcitans and/or neocalcitans

: Locally are structural voids and intersection nodes enlarged resulting in irregular, uneven void walls.

In the groundmass : Few voids nearly completed filled with mineral aggregates, mainly more or less wealded shaped excrements.

: Common zones/bands with a high content on small black particles, most <10 µm, in the groundmass.

: Common small irregular sesquioxidic accumulations.

: Common to many carbonate nodules, diam. up to 10 mm. A large part of the larger carbonate nodules have an accumulation of sesquioxides, mainly manganese, in the outer zone. A large number of small carbonate nodules, most <2 mm in diameter, have clear or diffuse external boundaries.
A few fragments of shells or snails are observed. A few zones in the groundmass contain a high content of rounded carbonate nodules including sometimes also other coarse grains. The carbonate nodules often have an accumulation of manganese in the outer zone.


4. Interpretation of the micromorphological data

One thin section of the AC horizon is studied. Depth: 100-115 cm.

The strong coarse angular blocky structure is due to strong swell and shrink of the montmorillonitic clays. The angular soil aggregates present in partly filled voids are split off during shrinkage in upper parts of the A horizon. A few elongated zones with a higher content of coarse particles than the surrounding groundmass and a few elongated zones with a high content of black particles, diameters <10 µm, are infilled former voids, closed after swell of the soil material. The roundness of the carbonate nodules and the orientation of clay domains resulting in a skel-vosepic plasmic fabric of the fine material are also consequences of the vertic properties of the soil.
The fauna plays a minor role. Soil animals are mainly responsible for the local enlargement of structural voids and intersection nodes, most of the few elongated and equant voids, and the few almost completely filled voids with more or less welded shaped excrements.

- In the studied zone many carbonate accumulations are present as nodules, diameters up to 10 mm, sharp or clear external boundaries; neocalcitans; calcitans and common small carbonate accumulations, diameters up to 2 mm, diffuse or clear external boundaries. The large nodules are most numerous. The last three types of carbonate accumulations are due to current processes.

- In the studied zone sesquioxides are accumulating or have been accumulated, mainly manganese as neomangans, mangans and small irregular manganese accumulations in the groundmass. Many of the large carbonate nodules have an accumulation of manganese in the outer zone.
HUNGUND SERIES

1. General information and typifying pedon description

Pedon described by the core group members consisting of Mr. Mirajkar, N.K. Barde and H.S. Shankaranarayana. C.S. Harindranath, S. Subramanyam associated. Date of study: 22.6.1979.

Hungund series comprises deep moderately well drained, dark grayish brown calcareous, cracking clayey soils. They occur on gently to very gently sloping middle pediments (interfluves) with 1 to 3% slopes. These soils are developed on weathered chlorite schists. The climate is semi-arid warm sub-tropical with average annual rainfall of 663.7 mm and mean annual temperature of 25.7° C. These soils are underlain by a Cca horizon below 80 to 100 cm depth and the sub soil has a well developed angular blocky structure exhibiting slickensides close enough to intersect with sphenoid structural aggregates. There are more than 1 cm wide cracks extending beyond 50 cm depth. The principal associated soils are Hugalur series which are very deep, Udic Chromusterts.

Hungund series is a member of the very fine, montmorillonitic, calcareous, isohyperthermic family of Udic Chromusterts.

Climatic data and soil water balance are the same as given for the Achmatti Series.

Typifying pedon: Hungund clay-cultivated.

Ap 0-9 cm: Very dark grayish brown (10 YR 3/2 M) clay; fine to very fine granular; friable, sticky and plastic; about 10 percent rounded to irregular 2-10 mm lime concretions; about 15 percent 10 to 75 mm chlorite schist pellets and banded ferruginous, gravels; matrix non-calcareous only lime nodules give strongly effervescent; fine to coarse inped and exped roots; 2 to 6.5 cm wide cracks; pH 8.7; clear smooth boundary.
A12 9-28 cm: Very dark grayish brown (10 YR 3/2 M) clay; strong medium to coarse sub-angular blocky with few angular blocky peds; firm sticky and plastic; 5 to 10 percent by volume round to irregular 2-10 mm lime nodules and 5 percent by volume 10-20 mm quartz gravels; matrix non-calcareous, lime nodules strongly effervescent; few fine to coarse inped and many fine to coarse exped roots; many very fine inped open discontinuous pores; 2 to 4 cm wide cracks; pH 8.7; clear smooth boundary.

A13 28-44 cm: very dark grayish brown (10 YR 3/ M) clay; strong coarse angular blocky with small sphenoids; extremely firm, extremely sticky and plastic; 5-10 percent by volume rounded to irregular 2-10 mm lime and manganese concretions; 5 percent by volume of 10-30 mm quartz gravels; matric non-calcareous; lime nodules strongly effervescent; many fine to very fine exped roots; many fine inped open discontinuous pores; 2 to 4 cm wide cracks; pH 8.8; gradual wavy boundary.

A14 44-70 cm: Very dark grayish brown (10 YR 3/2 M) clay; strong coarse angular blocky with prominent sphenoids and intersecting slickensides (about 8 cm wide); extremely firm, extremely sticky and plastic; 5 to 10 percent by volume rounded to irregular 2 to 10 mm lime and manganese concretions; matric non calcareous, lime nodules strongly effervescent; few very fine inped roots; many very fine inped open discontinuous vertical pores; 2-4 cm wide cracks pH 8.9; gradual smooth boundary.

A3ca 70-81 cm: Very dark grayish brown (10 YR 3/2 M) about 75 percent and dark yellowish brown (10 YR 4/4 M) about 25 percent; gravelly clay; strong medium to coarse angular blocky; many pressure faces; firm, sticky and plastic; 50 to 60 percent by volume 10 to 20 mm sub-rounded to rounded and few irregular lime and manganese concretions; violently effervescent; very few very fine inped roots; many very fine inped open discontinuous vertical pores; pH 8.9; gradual smooth boundary.

Cca 81-133 cm: Light gray (10 YR 7/2 M) 60 percent and dark yellowish brown (10 YR 4/4 M) 40 percent; (70-85%) lime concretions with weathered chlorite chist; pH 9.9.
Range in characteristics: Depth of the solum ranges from 65 to 90 cm. The estimated mean annual soil temperature at 50 cm is 26.9°C. The MSST is 24.8°C and MWST is 24.0°C. The moisture regime is Ustic.
Colour of the surface soil ranges from very dark grayish brown to very dark brown, hue of 10 YR, value of 2 to 3 and chroma of 2 to 3 up to 25-30 cm and that of the sub-soil from dark yellowish brown to very dark grayish brown hue of 10 YR, value of 2 to 4 and chroma of 2 to 4. The texture of the surface soil ranges from clay loam to clay and that of the sub soil from silty clay to clay. The content of coarse fragments ranges from 5 to 15 percent consisting mostly of quartz, banded ferruginous gravels varying in size from 10 to 75 mm. Occasionally cherts of chlorite schist are also met with. Sub-rounded to irregular lime concretions of 5-10 percent by volume are present up to 60-70 cm depth and increases with depth up to more than 50 percent by volume. Intersecting slickensides and prominent sphenoid structural aggregates are present from 30 to 70 cm depth from the surface. Cracks range in width from 2 to 15 cm on the surface and then extend up to Cca horizon during summer months. They remain open for less than 150 cumulative days. Clay percentage in the control section varies from 59.0 to 65.1.

Competing series and their differentiae: Hugalur series are very deep and Maderi series are developed on Amphibolite schist.

Drainage and permeability: These soils are moderately well drained and have moderately slow permeability. Intake of water is rapid till the cracks are sealed off.

Use and vegetation: Mostly used for cultivation of rainfed crops like Jowar, Cotton, Chillies, Acacia, Neem and local grasses constitute the natural vegetation.

Distribution and extent: Widely distributed in parts of Bijaipur and Dharwar district of Karnataka.

Type location: 2 km south of Ranibennur settlement along Ranibennur Hirekerur road (East of Karnataka).

Interpretation: Hungund soils are agriculturally important. Due to cracks initial intake of water during early rains is good. Otherwise these soils have low water intake capacity and the permeability of the soil is low. They pose the problem due to high percentage of clay and cracking nature. They require soil conservation measures to check run-off and erosion. They are suited to crops like sorghum, cotton, chillies and other climatically adapted crops under rainfed agriculture.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub class : IIIe
   2. Land irrigability sub-class : 3s
   3. Fertility management potential : moderate due to heavy textures and low permeability.
   4. Management potential/productivity: moderately high

b) Quantitative: (management potential under different levels of farming).
### 2. Tentative soil characterisation by Dr. P. Krishnan

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

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Total Sand</th>
<th>Coarse Sand</th>
<th>Medium Sand</th>
<th>Fine Sand</th>
<th>Very Fine Sand</th>
<th>INT;I</th>
<th>INT;II</th>
<th>INT;III</th>
<th>INT;IV</th>
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<td>Ap</td>
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<td></td>
<td></td>
<td>26.7</td>
<td>38.1</td>
<td>35.2</td>
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<td>8.1</td>
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<td>A13</td>
<td>28-44</td>
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#### Organic Carbon and Carbonate as CaCO3

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<tr>
<th>Depth (cm)</th>
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<th>Ext. iron as Fe</th>
<th>pH (1:2.5)</th>
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<td>28-44</td>
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<td>8.8</td>
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<tr>
<td>44-70</td>
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<td>10.22</td>
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<td>70-81</td>
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<tr>
<td>81-132</td>
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<td>9.9</td>
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</table>
3. Micromorphological data

Two thin sections are studied: one from the A horizon and one from the transition of the A and C horizon.

Depths: 46-61 cm (1) and 70-85 cm (2).

1. Depth: 46-61 cm.

Macroscopic characteristics

Dark brown, fine textured, pedal soil material with common carbonate nodules and a few minerals/rock fragments up to 8 mm in diameter.

Micromorphological characteristics

Structure: Strong, medium to coarse angular blocky structure, to which common, largely regular, intersected elongated voids belong. Other voids: Few elongated, often irregular voids, width < 1 mm and common equant voids, generally < 0.5 mm in diameter. Randomly distributed.

Groundmass: The fine textured groundmass includes grain-sizes up to gravels of 4 mm diameter. Size limit coarse/fine material: 15 µm.

Related distribution: porphyric. The coarse material consists of a small variety of minerals, mainly quartz grains, a few carbonate grains and a few rock fragments. The fine material is largely clay-sized, contains a few particles up to 15 µm and has a moderately vo-skelsepic plasmic fabric.

Special features:

In the groundmass: Common voids nearly completely infilled with mineral aggregates, which are excrements, often wealded. With exception of the larger grain sizes the composition of the excrements is identical to the groundmass.

: Common carbonate nodules, diameters up to 8 mm.

The majority has sharp external boundaries. The internal structures show large varieties in constituting carbonate grain sizes from a few microns up to 120 µm. Grains of about the same size occur in nuclei or banded zones. Rarely a few quartz grains are included. Some of the carbonate nodules have a coating and/or accumulation of mainly manganese in the outer zone, sometimes also in some bands in the nodules. In the groundmass are some small irregular accumulations of small particles observed.
A few small irregular accumulations of sesquioxides, with a random distribution, occur.

2. Depth: 70-85 cm.

Macroscopic characteristics

Dark brown, fine textured, pedal soil material with many carbonate grains and a few minerals/rock fragments up to 15 mm in diameter, increasing quantity with depth.

Micromorphological characteristics

Structure: Strong medium to coarse angular blocky structure, to which common, largely regular, intersected elongated voids belong. Other voids: Few elongated often irregular voids, widths < 2 mm and common equant voids, generally < 0.5 mm in diameter. Randomly distributed.

Groundmass: The fine textured groundmass includes grain sizes up to gravels of 6 mm in diameter. Size limit coarse/fine material: 15 µm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, mainly quartz grains, some carbonate grains and a few rock fragments. The fine material is largely clay-sized, contains a few particles up to 15 µm and has a moderately voskelsepic plasmic fabric.

Special features:
In the groundmass: Few voids nearly completely infilled with mineral aggregates, which are excrements, often walled, with exception of the larger grain sizes the composition of the excrements is identical to the groundmass.

A few carbonate nodules, diameters up to 15 mm, increasing in quantity with depth. The majority has clear external boundaries. The internal structures show large varieties in constituting carbonate grain sizes, from a few microns up to 120 µm. Grains of about the same size occur in nuclei and banded zones. Rarely a few quartz are included. Some of the carbonate nodules have a coating and/or accumulation of mainly manganese in the outer zone, sometimes also in some bands in the nodules. Locally a number of smaller carbonate nodules are linked together by a large number of small carbonate particles present in the surrounding groundmass.

A few small, irregular, accumulations of sesquioxides, with a random distribution, occur.
1. Carbonate nodules (white) and many small carbonate crystals in the groundmass. A horizon (crossed polarizers)
4. Interpretation of micromorphological data

Two thin sections are studied: one from the A horizon and one from the transition of the A and C horizon.

Depths: 46-61 cm (1) and 70-85 cm (2).

- The strong coarse angular blocky structure is due to strong swell and shrink of the montmorillonitic clays. The orientation of clay domains near voids and around larger mineral grains and nodules resulting in a vo-skelsepic plasmic fabric and the roundness of some of the larger carbonate nodules are also consequences of the vertic properties of this soil.

- The fauna plays a minor role. They produce a small number of voids, which are mainly almost completely filled with welded shaped mineral excrements. The influence of the fauna decreases with depth.

- In the studied zones carbonate nodules are present in increasing quantity, from common (1) to many in (2), and with increasing diameters, 8 mm in (1) tot 15 mm in (2), with depth. The nodules are composed of carbonate crystals of largely varying sizes (from a few microns up to 120 µm) and occur in different patterns indicating several growing phases under varying conditions. Unlike the deeper studied zone, there are no clear indications of current accumulation of carbonates in the 46-61 cm zone. Locally, carbonate nodules are growing together due to the precipitation of many small carbonate crystals in the groundmass between them.

- Manganese and iron are accumulating in small irregular sesquioxidic nodules. Manganese accumulations also occur in the outer zones of larger carbonate nodules.
KAGAL GOMB SERIES

1. General information and typifying pedon description


Kagal Gomb series comprises moderately well drained, very deep, grayish brown to very dark grayish brown, calcareous cracking clayey soils. They have developed on old alluvium of lime stones of the Bhima series of the Precambrian era. Kagal Gomb soils occur on nearly level to very gently sloping interfluve plains in slopes up to 3%. The climate is semi-arid sub-tropical with mean annual air temperature of 27.9°C and average annual rainfall of 762 mm. Gilgai micro relief is conspicuous and cracks remain open for more than 90 cumulative days and are closed for at least 60 consecutive days during monsoon months. The principal associated soils are moderately deep Kuppi series on alluvium of sedimentary shale origin and Kondaganahalli series developed on alluvium of sand stone origin.

Kagal Gomb series is a member of the very fine, montmorillonitic, calcareous isohyperthermic family of Typic Chromusterts.

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![Climatic Data and Soil Water Balance](image-url)
Typifying pedon: Kagal Gomb clay-cultivated.

**Ap**
0-10 cm: Dark grayish brown (10 YR 4/2 D) clay and very dark grayish brown (10 YR 3/2 M); weak fine sub-angular blocky breaking to granular; slightly hard, friable, sticky and plastic; about 5% by volume of lime nodules of 3-5 mm size, slightly effervescent; cracks on surface 7 cm wide; many coarse to fine roots; pH 8.5; clear smooth boundary.

**A11**
10-50 cm: Very dark grayish brown (10 YR 3/2 D & M) clay; moderate medium sub-angular blocky; hard, firm, sticky and plastic; about 5% lime nodules of 3.5 mm size; slightly effervescent; cracks 5 cm wide; many coarse to fine inped roots; many very fine to micro vertical tubular inped surface pores; pH 8.6; gradual smooth boundary.

**A12**
50-75 cm: Very dark grayish brown (10 YR 3/2 M) clay; strong coarse angular blocky with non intersecting slickensides more than 4 cm in length; very firm; very sticky and very plastic; 5% 2 to 10 mm (M 3-5 mm) size lime nodules; slightly effervescent; cracks 3 to 5 cm wide; common fine inped roots; many very fine to micro vertical tubular discontinuous pores; pH 8.8; gradual wavy boundary.

**A13**
75-131 cm: Very dark grayish brown to dark grayish brown (10 YR 3.5/2 M) clay; strong coarse angular blocky stratified plate like appearance with prominent slickensides and wedge shaped sphenoids; very firm, very sticky and very plastic; about 5% 4 to 10 mm size lime nodules; slightly effervescent; few very fine exped roots; many very fine to micro tubular discontinuous inped surface pores; pH 9.3; gradual wavy boundary.

**AC1**
131-172 cm: Dark yellowish brown (10 YR 4/4 M about 75%) and dark brown (10 YR 3/3 M about 25%) clay and dark brown (10 YR 3/3 rubbed); strong coarse angular blocky with prominent slickensides up to 22 cm size; firm, sticky and plastic; 20 to 25 percent by volume of 2 to 10 mm size lime nodules; strongly effervescent; 2-3% by volume of 2-5 mm size violet to black manganese concretions; few very fine exped roots; many very fine to micro tubular horizontal discontinuous inped pores; pH 9.0; clear smooth boundary.
AC2 172-200 cm: Olive brown (2.5 Y 4/4 M) clay; strong coarse angular blocky with prominent slickensides (10 cm wide); firm, sticky and plastic; 20-25% by volume of to 3 to 5 mm size lime nodules; strongly effervescent; very few, very fine exped roots; many very fine to micro tubular discontinuous inped pores; pH 9.3.

Range in characteristics: The solum depth ranges from 100 to 170 cm. The estimated mean annual soil temperature at 50 cm is 28.9°C. The mean summer soil temperature is 27.4°C and mean winter soil temperature is 24.4°C. The colour of the Ap horizon ranges from dark grayish brown to very dark grayish brown in hue of 10 YR, values of 3 to 4 and chroma of 2 to 3. The cracks on the surface ranges from 2 to 5 cm in width. The sub soil colour ranges from very dark grayish brown to olive brown in hue of 10 YR and 2.5 Y, with values of 3 and 4 and chroma of 3 and 4. The texture ranges from clay to silty clay. The texture in the control section is clayey with clay percentage between 47.3 to 67.7. The structure is moderate to coarse angular blocky. The slickensides are well developed between 50 to 100 cm depth and they extend up to 200 cm depth. The soil is not calcareous but there are 3 to 10 mm size lime nodules.

Competing series and their differentiae: Tumkur series are calcareous Typic Chromusterts with quartz gravel in small proportion throughout the profile and developed on calcic gneiss. Durdundi series are calcareous, developed, on basaltic alluvium. Vajjal series are sodic soils.

Drainage and permeability: Moderately well drained with slow permeability.

Use and vegetation: Mostly under dry land cultivation for Jowar and cotton. the vegetation consists of Acacia arabica (Jali), Acadirachta indica (Neem), Tamarindus indica (Tamarind) and (Bonni).

Distribution and extent: Occurs widely in the catchment of upper Krishna (Shahapur and Jewargi taluks of Gulberga district covering an area of 103,000 ha constituting 3% of U.K.P. command areas.
Type location: About 2.5 km south west of village Sirwal (Survey no. 331) along Shahpur-Sirwal road (100 m west of road).


Interpretation: The Kagal Gomb soils present problems due to high clay, cracking and characteristic gilgai relief and slow permeability. The surface cracks help in conserving the water from initial rainfall but the soils are highly susceptible to erosion when slopes are more than 2 percent. They also pose problems due to stagnation during heavy rains and limitation due to permeability and for rootening of plants. They need soil conservations measures to check erosion problem. They are adapted to Jowar, Cotton, Wheat, Safflower, Oilseeds and Pulses.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub-class : IIIa & IIIe
   2. Irrigability sub-class : 3e
   3. Fertility management potential : moderately high (problems due to heavy texture and slow permeability of the soil)
   4. Management potential/productivity: moderately high (problem due to heavy texture and nature of clay).

b) Quantitative: (Management potential for crop production under dry farming and irrigation based on the information from the State Soil Survey Unit).

Management level:

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<tr>
<th>Crops</th>
<th>Unirrigated / Irrigated</th>
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</thead>
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<tr>
<td></td>
<td>low</td>
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<tr>
<td>Jowar</td>
<td>8</td>
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<tr>
<td>Cotton (Jayadhar)</td>
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<tr>
<td>Oilseeds (Safflower)</td>
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<tr>
<td>Pulses (Pigeon pea)</td>
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</table>
### 2. Tentative soil characterisation by Dr. P. Krishnan

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

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>% of &lt; 2 mm</th>
<th>Coarse fragments</th>
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<td>(0.05-0.002)</td>
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<tr>
<td>Ap</td>
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<td>A12</td>
<td>10-50</td>
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<td>A13</td>
<td>50-75</td>
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<td>23.1</td>
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#### Organic Carbonate as Caco_3

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<th>Depth (cm)</th>
<th>Organic Carbon</th>
<th>Carbonate as Caco_3</th>
<th>Ext. iron as Fe</th>
<th>pH (1:2.5)</th>
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<td>%&lt;0.002 mm</td>
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3. Micromorphological data

Two thin sections are studied: both from a deep A horizon.
Depths: 91-106 cm (1) and 138-153 cm (2).

1. Depth: 91-106 cm.

Macroscopic characteristics

Very dark grayish brown, fine textured, pedal soil material, containing common white coloured nodules, $\varnothing < 6$ mm, randomly distributed.

Micromorphological characteristics

Structure: Strong coarse angular blocky structure, to which common, intersected elongated voids belong. Other voids: Few elongated voids, widths < 2 mm, lengths up to 10 mm and a few equant voids, $\varnothing$ up to 2 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 5 $\mu$m.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, which show varying stages of alteration. The fine material is largely clay-sized, includes common particles up to 5 $\mu$m and has a strong vosepic plasmic fabric.

Special features:

- Associated with voids: Few voids partly infilled with mineral aggregates, mainly angular soil aggregates.

- In the groundmass:
  - Few to common voids nearly completely infilled with mineral aggregates, often wealded excrements.
  - Few elongated zones with a higher content on coarser grains which are oriented parallel to the length axis.
  - Few to common weathering minerals surrounded by sesquioxidic accumulations, with diffuse or clear boundaries, diameters up to 1 mm, randomly distributed.
  - Common carbonate nodules, mainly composed of fine particles, with clear or diffuse external boundaries, diameters up to 6 mm. A part are small accumulations < 1 mm $\varnothing$, of fine particles in the groundmass, with diffuse boundaries. All randomly distributed.
2. Depth: 138-153 cm.

Macroscopic characteristics

Dark yellowish brown, fine textured, pedal soil material, containing few to common, mainly white coloured nodules, Ø < 6 mm, randomly distributed.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure, to which common, intersected, elongated voids belong. Other voids: few to common mainly curved elongated voids forming a kind of sphenoids in the coarse angular blocky peds, widths < 1 mm, lengths several cm, and few equant voids, Ø up to 1 mm, randomly distributed.

**Groundmass:** The fine textured soil material includes grain sizes up to and inclusive coarse sand. Size limit coarse/fine material: 5 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals, which show varying stages of altering. The fine material is largely clay sized, includes common particles up to 5 µm and has a moderately, locally strong vosepic plasmic fabric, around large coarse grains and nodules a moderate skelsepic plasmic fabric.

**Special features:**

Associated with voids: Few voids partly infilled with mineral aggregates, mainly angular soil aggregates.

In the groundmass: Few to common voids nearly completely infilled with mineral aggregates, often wealed excrements, which sometimes are darker coloured than the groundmass.

: Few to common weathering minerals surrounded by sesquioxic accumulations and pure sesquioxic accumulations, with diffuse or clear boundaries, diameters up to 1 mm, randomly distributed.

: Common carbonate nodules, mainly composed of fine particles, with clear or diffuse external boundaries, diameters up to 6 mm. A part are small accumulations < 1 mm Ø of fine particles in the groundmass with diffuse boundaries. Apart of the larger carbonate nodules have thin sesquioxic, mainly manganese, coatings. All randomly distributed.
Kagel Gomb (1 photograph)

1. Rounded carbonate nodule with an accumulation of iron and manganese in the outer zone (black) and irregular small accumulations of the same material in the groundmass. A horizon (plain light)
4. Interpretation of the micromorphological data

Two thin sections are studied: both from a deep A horizon. Depths: 91-106 cm (1) and 138-153 cm (2).

- The strong coarse angular blocky structure of the studied part of the A horizon is due to strong swell and shrink of the montmorillonitic clays, resulting in the formation of slickensides. Strong swell and shrink also caused orientation of clay domains in zones most exposed to pressure, namely near voids and along coarse mineral grains and nodules, forming vosepic and skelsepic plasmic fabrics. Angular soil fragments are present in some voids. They are split off during shrinkage and accumulate in existing voids deeper in the pedon. A few elongated zones with a relatively high content of coarser grains occur. These are infilled former voids, closed after swell of the soil material.

- The fauna plays a minor role. At these depths, most voids not belonging to the structure, are of faunal origin. The majority of the few to common voids are infilled with welded mineral excrements. Some of the mineral material of excrements present in (2) is derived from the upper zone of the pedon, which has a darker colour.

- Carbonate nodules are common in the studied part of the A horizon. They have clear or diffuse external boundaries. Some are small accumulations, <1 mm in diameter, with diffuse external boundaries. All features indicate that carbonate precipitation is a current process. In (2) some of the large carbonate nodules (up to 6 mm in diameter) have a thin accumulation of (mainly) manganese in the outer zone.

- Minerals are altering in the soil. Around these grains accumulations of sesquioxides occur and, in (2), some pure sesquioxidic accumulations, diameters up to 1 mm, are also present. In this part of the A horizon the carbonate nodules with an accumulation of (mainly) manganese in the outer zone are also found, all due to rather recent or current redistributions of sesquioxides.

Remark: The manganese concretions mentioned in the field description are carbonate nodules with an accumulation of predominantly manganese in the outer zone.

2nd Remark: The soil temperature data are not correct.
1. General information and typifying pedon description

Pedon examined by: Core group members consisting of M.A. Mirajkar, N.K. Barde, H.S. Shankaranarayana, C.S. Harindranath and S. Subramanyam associated. Date of study: 17.6.79.

Raichur series comprises, very deep, moderately well drained, dark gray to very dark gray, cracking clayey soils. They have developed on old alluvium occurring on very gently sloping infilled valleys with slopes upto 1% in the granitic landscape. The climate is semi arid subtropical with mean annual air temperature of 27.8°C and average annual rainfall of 717.3 mm. The cracks remain open for more than 90 cumulative days in most years and are closed for at least 60 consecutive days.

The principal associated soils are Rampur series which are Lithic Ustochrepts representing moderately deep black soils on granites and Aghsahale series which are clayey skeletal Typic Haplustalfs.

Raichur series is a member of the very fine, montmorillonitic, isohyperthermic family of Typic Pellusterts.
Typifying pedon: Raichur clay-cultivated.

Ap 0-12 cm: Dark gray (10 YR 4/1 D) clay and very dark gray (10 YR 3/1 M); moderate medium subangular blocky breaking to granular; hard, firm, sticky and plastic; few 1-2 mm size quartz and lime nodules; cracks at surface more than 2 cm wide; many coarse to fine inped roots; pH 8.0; clear smooth boundary.

A12 12-60 cm: Very clark gray to dark gray (10 YR 3.5/1 M) clay; moderate medium subangular blocky with partially developed sphenoids; firm, sticky and plastic; few, less than 2 mm size silica grains; cracks 1 cm wide upto 56 cm depth; many discontinuous tubular, oblique inped open pores less than 1 mm deep; pH 8.0; clear smooth boundary.

A13 60-112 cm: Very dark gray to gray (10 YR 3.5/1) clay; strong medium to coarse angular blocky with prominent (10 cm) nearly intersecting slickensides forming sphenoids; very firm, very sticky and very plastic; few 3 to 5 mm size irregular to elliptical lime and quartz gravels; slightly effervescent in localised pockets; few very fine inped and exped roots; many discontinuous tubular oblique inped open pores less than 1 mm deep; pH 8.5; clear smooth boundary.

A14 112-150 cm: Very dark gray to dark gray (10 YR 3.5/1 M): clay; strong coarse angular blocky with prominent (20 cm), nearly intersecting slickensides forming sphenoids breaking into strong coarse angular blocky peds; very firm, very sticky and very plastic; few very fine inped and exped roots; many discontinuous tubular oblique inped open pores less than 1 mm deep; pH 8.0; clear smooth boundary.

C 150+ cm: Few pieces of fine shells mixed with sand.

Range in characteristics: The thickness of the solum ranges from 110 to 150 cm. The estimated mean annual soil temperature is 28.8°C, the mean summer soil temperature is 27.5°C and the mean winter soil temperature is 25.8°C. The colour of the Ap horizon ranges from very dark gray to dark gray in hue of 10 YR value of 3 to 4 and chroma less than 1.5.
The thickness of the Ap horizon ranges from 12 to 22 cm. The horizon below the Ap ranges in thickness from 75 to 140 cm and the colour ranges from very dark gray to dark grayish brown to dark gray in hue of 10 YR value of 3 to 3.5 and chroma is always less than 1. The texture in control section is clayey and the clay percentage is more than 60%. The C horizon has a colour range from dark grayish brown to dark gray in hues of 10 YR and 7.5 YR values of 2 to 4 and chromas of 1 to 3. The C horizon occasionally has shells of Mollusca: Gastropoda and Lamellibranchia. Cracks of 2 to 3 cm width occur up to 56 to 150 cm. Prominent nearly intersecting slickensides with well developed sphenoids tilting at 10-40° from the horizontal occur below 60 cm from the surface.

Competing series and their differentiae: Rampur series are moderately deep black soils. Lakshmapur series are very deep Pellusterts and Sindhanoor series are derived from gneissic complex underlained by a calcic horizon.

Drainage and permeability: Moderately well drained with slow permeability.

Use and vegetation: The common crops grown are cotton, jowar and sunflower under canal irrigation. Natural vegetation consists of Acacia Sp. (Babool) and Azadirchta indica (Neem).

Distribution and Extent: Occurs in the infilled valleys in Raichur district.

Type location: Plot No. 17, Regional Research Station (UAS) Raichur about 200 m south of Raichur-Sindhanoor road.

Series proposed: UAS Banglore.

Management Interpretation: These soil are suitable for a variety of climatically adapted crops like, cotton, sunflower, jowar, under rainfed, condition light relief irrigation for jowar during Rabi and
cotton during early sowing period and late flowering and picking period, Rabi irrigation to safflower and wheat, Bengal gram. Light irrigation on Kharif and summer groundnut, in moderately deep black soils.

Green manuring once in three years.

Management interpretation:

a) Inductive (based on physical productive potential of the series)
   1. Land capability sub class : IIIa, IIIb
   2. Irrigability Sub-class : 3s
   3. Fertility management potential: moderately high
   4. Productivity/Potentiality : moderately high

b) Quantitative (Management potential of crops under farmers level and package of practices based on information from Regional Research Station Raichur)

<table>
<thead>
<tr>
<th>Management level:</th>
<th>Yield Q/ha</th>
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<td>Crops</td>
<td>Farmers level</td>
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<tr>
<td></td>
<td>Unirrigated</td>
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<td>Jowar (Sorghum)</td>
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</tr>
<tr>
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<tr>
<td>Cotton</td>
<td>-</td>
</tr>
<tr>
<td>Wheat</td>
<td>-</td>
</tr>
<tr>
<td>Paddy</td>
<td>-</td>
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2. Tentative soil characterisation by Dr. P. Krishnan

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Organic carbon %</th>
<th>Carbonate %</th>
<th>pH</th>
<th>Coarse fragments % by weights of whole soil</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(1: 2.5: 2.5)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
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<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 % by weights of whole soil</th>
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<tr>
<td></td>
<td></td>
<td>Total Sand Silt Clay Very coarse Medium Fine Very fine INT I INT II INT III INT IV</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>% of &lt;2 mm (2-0.05) (0.05-0.002) (0.002) (1-0.5) (0.5-0.25) (0.25-0.1) (0.1-0.05)</td>
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<tr>
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<td>0-12</td>
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<td>60-112</td>
<td>4.3</td>
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<td>112-150</td>
<td>4.0</td>
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</table>
3. Micromorphological data

One thin section is studied: from the lower part of the A horizon. Depth: 113-128 cm.

Macroscopic characteristics

Very dark grey, fine textured strong angular blocky soil material, containing a few white nodules, diam. up to 5 mm randomly distributed.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure to which common intersected voids belong with some enlarged intersection nodes. Other voids: Few elongated voids, widths up to 2 mm, length up to a few cm. Few 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 is 5 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals which mainly are fresh or slightly altered. The fine material is largely clay-sized and includes a few particles up to 5 µm and has a strong skel-sepic plasmic fabric. **Special features**

Associated with voids: Few voids partly filled with mineral aggregates, mainly soil fragments. In the groundmass: Few zones almost completely filled with mineral aggregates, soil fragments as well as excrements. Few-common carbonate nodules, diam. up to 5 mm. A part have accumulations of sesquioxides, mainly manganese. The nodules have clear or sharp external boundaries. A few shell fragments. Few to common small local accumulations of sesquioxides, mainly manganese, <2 mm Ø

Thin sections of two samples, from 30-45 cm and 75-90 cm depth, could not be prepared.
Reichur (2 photographs)


4. Interpretation of the micromorphological data

One thin section is studied: from the lower part of the A horizon.
Depth: 113-128 cm

- The strong coarse angular blocky structure with inclined horizontal axis is due to strong swell and shrink of montmorillonitic clay. The few angular soil fragments present at, sometimes enlarged, intersection nodes, and a few other voids are split off during shrinkage. Clay domains are oriented resulting in a strong skel-vosepic plasmic fabric. This is also a consequence of vertic properties of this pedon.
- The fauna plays a minor role. The influence is restricted to the production of few to common small voids, including some enlarged intersection nodes, and some zones almost completely filled with more or less welded, shaped mineral excrements, often including some angular soil fragments.
- A few carbonate nodules occur with diameters up to 5 mm. Some of these nodules contain sesquioxides, mainly manganese.
- Very few fragments of shells or snails are present.
- Sesquioxides, mainly manganese, are accumulating in this zone. Few to common small accumulations up to 2 mm in diameter occur with a random distribution.
CHOUGEL SERIES

1. General information and typifying pedon description

Pedon described by:

Chougel series is a member of fine loamy, mixed, hyperthermic, deep family of Udic Plinthustalfs. Chougal soils have pale brown to dark brown sandy loam A horizons followed by light yellowish brown to brownish yellow clay to sandy clay B horizon developed on mixed outwash, of felspathic quartzitic schist and granite gneiss. They occur on nearly level to gently sloping upper piedmont plain. The climate is tropical subhumid with hot summer and mild winter. Principal associated soils are Khanhargoan and Durgkondal which are deep Alfisols.

Typifying pedon: Chougel sandy loam – Forest.

(Colours are for dry soils unless otherwise mentioned).

A1 0-11 cm: Pale brown (10YR 6/3) sandy loam, dark brown to brown (10YR 4/3) when moist; weak fine sub-angular blocky; slightly hard, friable, slightly sticky and non-plastic; many coarse roots; rapid permeability; clear and smooth boundary; pH 5.7 (10 to 15 cm thick).

B21t 11-34 cm: Light yellowish brown (10YR 6/4) sandy clay loam, yellowish brown (10YR 5/6) when moist; medium moderate sub-angular blocky; slightly hard, friable, sticky and plastic; thin patchy clay skins, bridging coarse grains; many coarse roots; moderate permeability; gradual and smooth boundary; pH 5.7 (15 to 25 cm thick).

B22t 34-49 cm: Brownish yellow (10YR 6/6) sandy clay loam, yellowish brown (10YR 5/6) when moist; medium moderate sub-angular blocky; hard, friable, sticky and plastic; thin patchy clay skins, bridging coarse grains; coarse to medium plentiful roots; moderate permeability; gradual and smooth boundary; pH 5.8 (10 to 20 cm thick).

B23t 49-71 cm: Brownish yellow (10YR 6/6) sandy clay, yellowish brown (10 YR 5/6) when moist; medium moderate sub-angular blocky; very hard, friable, sticky and plastic; thin patchy clay skins, bridging
coarse grains; few fine plinthite mottles appear in the lower part transitional to subjacent horizon having colour, strong brown (7.5 YR 5/6), and dark red (2.5 YR 3/6) and constitutes about 2% of matrix; few coarse and medium roots; moderate permeability; gradual and smooth boundary; pH 6.0 (15 to 25 cm thick).

B24tcn 71-104 cm: Light yellowish brown (10YR 6/4) (Gritty) clay, yellowish brown (10YR 5/4) when moist; medium moderate sub-angular blocky; very hard, friable, sticky and plastic; thin patchy clay skins, bridging the coarse grains; common medium distinct plinthite mottles of colour, strong brown (7.5 YR 5/6), and red (2.5 YR 5/8), constitute 18% of matrix; moderate permeability; clear and smooth boundary; pH 6.15 (30 to 35 cm thick).

B25tcn 104-143 cm: Brownish yellow (10YR 6/6 M) clay; medium moderate sub-angular blocky; very hard, friable, sticky and plastic; thick discontinuous clay skins; common medium distinct plinthite mottles of colours, strong brown (7.5 YR 5/6), yellowish red (5 YR 5/6) constitute 20% of matrix; moderate permeability; clear and smooth boundary, pH 6.20 (35 to 40 cm thick).

B26tcn 143-150 cm: Brownish yellow (10YR 6/6 M) gravelly clay; moderate medium sub-angular blocky; very hard, friable, sticky and plastic; thick discontinuous clay skins; common coarse distinct mottles of strong brown (7.5 YR 5/6), and yellowish red (5 YR 5/6), constitute 25% of matrix, moderately slow permeability; clear and smooth boundary; pH 6.25 (15 to 20 cm thick).

B27tcn 159-172 cm: Brownish yellow (10 YR 6/6 M) gravelly clay; medium moderate sub-angular blocky; very hard, friable, sticky and plastic; thick discontinuous clay skins; common coarse distinct mottles of strong brown (7.5 YR 5/6) and yellowish red (5 YR 5/6) constitute 30% of matrix; moderately slow permeability; clear and smooth boundary; pH 6.20 (10 to 15 cm thick).

B3 172-191 cm: Pale brown (10 YR 6/3) gravelly clay; medium moderate sub-angular blocky; very hard, friable, sticky and plastic; thick discontinuous clay skins; many coarse distinct mottles of strong brown (7.5 YR 5/6), yellowish red (5 YR 5/6) and red 2.5 YR 4/6) constitute 30% of matrix; moderately slow permeability; clear and smooth boundary; pH 6.40 (15 to 25 cm thick).
Range in characteristics: The thickness of the solum ranges from 50 to 85 cm. The content of coarse fragments increases through depth varying from 6-10 percent and abruptly increases up to 60 percent below 120 cm. The soil up to a depth of 20 to 25 cm remain dry and moisture level remains at wilting point while the sub-soil layers remain moist during dry period in most of the years. The effective rooting depth ranges from 50 to 60 cm of the surface. The colour of soil in A horizon is in the hue of 10 YR with dry value 6 and moist value 4 and chroma 3 for both dry and moist soils. The structure is moderate medium sub-angular blocky. The colour in B horizon is similar to A horizon and hue remaining the same value, at places, may range between 6 and 4 chroma 3 and 6 for dry as well as moist soils. The structure is moderate medium sub-angular blocky to strong coarse sub-angular blocky with thin patchy clay cutans. Few to many coarse dark red (2.5 YR 3/6; 10 R 3/6), strong brown (7.5 YR 5/6) and yellowish red (5 YR 5/6) mottles are noticed.

Competing series and their differentiae: Basala is the competing series which is very deep having yellowish brown (10 YR 5/4) to pale olive (5 Y 5/3, 6/3) colour. Few iron concretions with quartz particles are found throughout the pedon in Basala soils. The soils are classified as Plinthustalfs.

Drainage and permeability: Well drained with moderate or moderately slow permeability.

Use and vegetation: Mostly under forest vegetation like Terminalia tomentosa, Diospyrum melanoxylon, Tectona grandis, Casia auriculata. Occasionally cultivated to Mustard, Kodo and Kutaki.

Distribution and extent: Extensive in Jagdalpur district of Madhya Pradesh.

Type location: 150 m west of 3.2 km stone on Bhanupratappur, Rajnangaon road on State High Way No. 32 in Bhanupratappur taluka of Jagdalpur district, Madhya Pradesh.

Series established: Village, Bhanupratappur of Jagdalpur district, (M.P.)
Interpretation: Chougel soils have good soil air water relationship in the rooting zone. Acidic nature of the soils may pose problem of management in selection of crops and P fertilization.

Management interpretation:

a) Inductive: (based on physical productive potential of the series).
   1. Land capability sub-class : IIIs
   2. Irrigability class : 2d
   3. Fertility management potential : medium

b) Quantitative: (management potential for crop production at different levels of management based on observation or based on demonstration trial data).

Crops: Mustard, Kodo, Kutaki.
## Tentative soil characterization by NBSS & L1P, Nagpur

### Size class and particle diameter (μm)

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Sand (&lt;2.0 μm)</th>
<th>Silt (0.02–0.05)</th>
<th>Clays (0.002)</th>
<th>Very coarse (1–2.0 μm)</th>
<th>Coarse (0.5–1.0 μm)</th>
<th>Medium (0.25–0.5 μm)</th>
<th>Fine (0.1–0.25 μm)</th>
<th>Very Fine (&lt;0.1 μm)</th>
<th>&gt; 2 μm</th>
<th>% of &lt; 2 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt</td>
<td>0–11</td>
<td>82.4</td>
<td>10.9</td>
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<tr>
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<td>5.8</td>
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<td>11.6</td>
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<td>10.4</td>
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<td>16.2</td>
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<td>11.7</td>
<td>7.3</td>
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<td>16.3</td>
<td>1.4</td>
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<td>12.9</td>
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<td>7.8</td>
<td>9.9</td>
<td>9.9</td>
<td>8.3</td>
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</tbody>
</table>

### Organic carbon (%), pH (1:1 HCl), pH (1:1 KCl), Bulk density (g/cc), and water Retention (1/3-bar, 15-bar, 13-bar to 15-bar cc/gm)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Organic carbon</th>
<th>pH (1:1 HCl)</th>
<th>pH (1:1 KCl)</th>
<th>Bulk density</th>
<th>Water Retention</th>
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### Extractable bases

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<th>Depth (cm)</th>
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<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Exchangeable sodium</th>
<th>Sum Cations</th>
<th>Sum Exchangeable sodium</th>
<th>Sodium absorption ratio</th>
<th>Sum Cations</th>
<th>CEC</th>
<th>Sodium absorption ratio</th>
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<td>7.5</td>
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<td>0.4</td>
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<td>67</td>
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</table>

### Cation exchange capacity (CEC), exchangeable sodium, and sodium absorption ratio

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<th>Depth (cm)</th>
<th>CEC</th>
<th>NH4Ac</th>
<th>Exchangeable sodium %</th>
<th>Sodium absorption ratio</th>
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<td>13.6</td>
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<td>11–24</td>
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<td>143–193</td>
<td>49</td>
<td>0.47</td>
<td>16.2</td>
<td>16.2</td>
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<tr>
<td>193–242</td>
<td>52</td>
<td>0.40</td>
<td>18.9</td>
<td>18.9</td>
</tr>
<tr>
<td>242–406</td>
<td>67</td>
<td>0.55</td>
<td>18.8</td>
<td>18.8</td>
</tr>
</tbody>
</table>
3. Micromorphological data

Three thin sections are studied: one from the A horizon and two from the B horizon.
Depths: 5-20 cm (1); 74-89 cm (2) and 143-158 cm (3).

1. Depth: 5-20 cm.

Macroscopic characteristics

Pale brown, medium textured, weak sub-angular blocky soil material, containing a few rounded sesquioxidic nodules up to 4 mm.

Micromorphological characteristics

Structure: The soil material has a weak fine sub-angular blocky structure, to which few short elongated, sometimes intersected, voids belong. Other voids: common to many short elongated, mainly irregular, voids which are commonly interconnected, widths up to 2 mm, lengths up to a few cm, common equant voids, diam. up to 2 mm, randomly distributed.

Groundmass: The medium textured soil material includes grain sizes up to and inclusive gravels up to 4 mm. Size limit coarse/fine material is 20 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments, of which a part is strongly altered. A few coarse organic fragments, mainly root fragments, occur. The fine material is largely clay-sized and includes common fine particles up to 20 µm, most mineral but also organic. The plasmic fabric is moderate skelsepic.

Special features:

Associated with voids: Few to common voids are partly filled with mineral aggregates, mainly excrements and some soil fragments.

In the groundmass: Few voids are completely filled with pure clay.

- Commonly argillans are present voids. Sometimes a thin cutan of clay-sized material is incorporated.
- A very few papules occur.
- A very few manganese root pseudomorphs are present.
- Few voids are largely filled with mineral aggregates.
- Few rounded sesquioxides nodules up to 4 mm in diam.
- Few iso-tubulic zones with a higher content of fine grained material than the surrounding groundmass.
2. Depth: 74-89 cm.

Macroscopic characteristics

Light yellowish brown, gravelly fine textured, moderate sub-angular blocky soil material, containing common brown and red mottles.

Micromorphological characteristics

Structure: The soil material has a moderate medium sub-angular blocky structure to which common elongated, often intersected, voids belong.

Other voids: common short elongated voids, mainly irregular, which are often interconnected, widths up to 2 mm, lengths up to a few cm, common equant voids diam. up to 2 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 4 mm in diameter. Size limit coarse/fine material is 20 µm.

Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments of which a part is strongly altered. The fine material is largely clay-sized and includes a few fine mineral particles up to 20 µm. The plasmic fabric is moderate skelsepic.

Special features:

- Associated with voids: Common voids are partly filled with mineral aggregates, excrements and/or soil fragments.
  - Very few argillans.

- In the groundmass: Very few voids completely filled with pure clay.
  - Few papules.

- Few to common voids largely filled with mineral aggregates - excrements as well as soil fragments.
  - Common sesquioxidic nodules with sharp, clear and diffuse external boundaries, most sharp or clear.

Some of the nodules have a central zone composed of manganese; the rest of the nodules consist largely of iron compounds, diam. up to 10 mm. In voids present in most of these nodules occur argillans. Complete infillings with pure clay, often containing iron, are also common.

- Few fragments of sesquioxidic nodules occur embedded in the groundmass.
3. Depth: 143-158 cm.

Macroscopic characteristics

Brownish yellow, gravelly fine textured moderate sub-angular blocky soil material, containing common brown and red mottles.

Micromorphological characteristics

Structure: The soil material has a moderate medium sub-angular blocky structure to which common elongated, often intersected, voids belong. Other voids: common elongated voids, mainly irregular, often interconnected, widths up to 3 mm; length up to a few cm and common equant voids diam. up to 3 mm, randomly distributed.

Groundmass: The fine textured soil material includes grain sizes up to gravels of 4 mm in diam. Size limit coarse/fine material is 20 µm. Related distribution: porphyric. The coarse mineral material consists of a variety of minerals and rock fragments of which a part is strongly altered. The fine material is largely clay-sized and includes a few fine mineral particles up to 20 µm. The plasmic fabric is moderately skelsepic.

Special features:

Associated with voids: Common voids are partly filled with mineral aggregates, excrements and/or soil fragments.

- Few-common argillans in the groundmass.
- Few silt and clay-sized cutans.

In the groundmass:

- Few to common voids completely filled with pure clay.

- Few papules.
- Few voids largely filled with mineral aggregates, excrements as well as soil fragments.

- Common sesquioxidic nodules, with sharp, clear or diffuse external boundaries, most are diffuse or clear. Some nodules have a manganese accumulation as central zone, the rest largely consists of iron compounds; diam. up to 10 mm. In voids present in most of these nodules occur (ferri)argillans; complete infillings with pure clay, often containing iron are also common.

- Few fragments of sesquioxide accumulations occur embedded in the groundmass.
Short micromorphological description

Three thin sections are studied: one from the A horizon and two from the B horizon.

Depths: 5-20 cm (1); 74-89 cm (2) and 143-158 cm (3).

The soil material is medium textured in the A horizon (1) and is gravelly fine textured in the B horizon (2, 3) and includes grain sizes up to gravels of 4 mm in diameter. The size limit between coarse and fine material is 20 µm, the related distribution: porphyric. The coarse material consists of a variety of minerals and rock fragments of which a part is strongly altered. A few coarse organic fragments, mainly root fragments, occur in the A horizon. The fine material is largely clay-sized and includes common fine particles in the A horizon, most mineral but also organic, and a few fine particles up to 20 µm in the B horizon. The plasmic fabric is moderate skelsepic.

The soil material has a weak fine sub-angular blocky structure in the A horizon and a moderate medium sub-angular blocky structure in the B horizon, to which in the first case a few, in the last one common elongated often intersected, voids belong. Other voids: Common to many (1) and common, (2, 3) elongated voids, mainly irregular and often interconnected, widths up to 2 mm in (1) and (2); up to 3 mm in (3); lengths up to a few cm. Common equant voids, diam. up to 2 mm in (1) and (2), up to 3 mm in (3). All voids are randomly distributed.

In all thin sections argillans are present. The quantities vary from common in (1), a very few in (2) to few to common in (3). Voids completely infilled with illuviated clay occur too. Their quantities vary from a few in (1), a very few in (2) to few-common in (3). A very few papules are observed in the A horizon, a few in the B horizon. Deeper in the B horizon (3) also a few cutans occur composed of silt and clay sized soil material.

In the A horizon occur few to common, in the B horizon common, voids partly infilled with mineral aggregates which are mainly excrements in the A horizon and excrements and/or soil fragments in the B horizon. In the A horizon are a few voids completely infilled with mineral aggregates; in the B horizon few-common (2) and a few (3) which consists of excrements and/or soil fragments. In the A horizon occur a few iso-tubulic zones with a higher content on fine-grained material than the surrounding groundmass.
Sesquioxidic nodules occur in all thin sections. In the A horizon are a few rounded nodules present, diam. up to 4 mm. In the B horizon common nodules occur, with sharp, clear and diffuse external boundaries. In the upper part of the B horizon (2) the external boundaries are mainly sharp or clear, in the deeper part (3) predominantly clear or diffuse. Some of the nodules in the B horizon have a central zone composed of manganese, the rest of the nodules largely consists of iron compounds. In voids in the nodules argillans can be present as well as complete infillings of clay. Diameters of the nodules up to 10 mm. In the B horizon are a few fragments of sesquioxide accumulations embedded on the groundmass present. In the A horizon occur a very few manganese root-pseudomorphs.
1. Black pseudomorph of manganese after a root remain (centre) and a small sesquioxidic nodule (left). A horizon (plain light).

2. Thin argillans in voids (white) near a sesquioxidic nodule with a diffuse external boundary (right). B horizon (plain light).
4. Interpretation of the micromorphological data

Three thin sections are studied: one from the A horizon and two from the B horizon. Depths: 5-20 cm (1); 74-89 cm (2) and 143-158 cm (3).

- There is not much evidence of current processes in this pedon. Most features are due to former processes.

- Features related to a clay illuviation occur over the whole studied zone. They are most numerous in the A (1) and deep in the B2 (3) horizon and consist of argillans, infillings of, often laminated, oriented clay and papules (embedded fragments of the first two groups of features). Argillans are common in the A horizon (1), decrease in quantity to very few in the top of the B2 horizon (2) and increase again to few - common deep in the B2 horizon (3). The same order of changes in quantity occurs with depth for the infillings with pure clay, but their number is lower. Very few papules are present in the A horizon (1); a few in the B2 horizon (2, 3).

- The soil fauna played, and is still playing, an important role. They produce most of the voids, which in many cases are irregular, commonly interconnected, elongated and equant. These voids strongly influence the subangular blocky structure. The soil fauna also causes considerable homogenization of the groundmass. Due to this homogenization the clay illuviation features in the top of the B2 horizon (2) have almost disappeared. Deeper in the B2 horizon (3) homogenization has occurred to a lesser extent.

- Roots also produce some voids. These are regular ones, which are most numerous in the A horizon (1). Here, a few pseudomorphs of manganese after root-remnants are also present. In the fine material, a limited number of small organic particles (<20 µm) are incorporated, giving the groundmass a mull-like appearance.

- In the soil, minerals and rock fragments are partly strongly altered.

- In the whole studied zone features related to accumulation and depletion of sesquioxid occur. In the A horizon (1) a few rounded sesquioxidic nodules, diameters up to 4 mm, are present. In the B2 horizon (2, 3) sesquioxidic nodules, diameters up to 10 mm, are common. Some have a black central zone of manganese and argillans, which contain iron compounds, occur in voids present in these nodules. In the upper part of the B2 horizon (2) the external boundaries are mainly sharp or clear; in the lower part of the B2 horizon (3) they are diffuse or clear. In the latter, the shapes of the accumulations are more irregular. Homogenization of the groundmass by animals has caused changes in sharpness of external boundaries from diffuse to sharp and changes in shape from irregular to more regular and rounded. Fragments of sesquioxidic accumulations occur (2, 3) embedded in the groundmass in the same way as papules are present, both also due to faunal activity.

The influence of the soil fauna was greatest in the upper part of the B2 horizon (2). The groundmass in the B2 horizon (2, 3) has a light colour due to depletion of iron. The argillans present in the groundmass are almost white.
Remarks: The studied pedon is truncated. Clay illuviation features are common in the A horizon. In the B horizon the quantity on clay illuviation features is low for an argillic horizon. The field classification of this pedon as alfisol seems not correct. Other soils of the Chougel series, however, still can be alfisols.
MERO SERIES

1. General information and typifying pedon description

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fine loamy, mixed, hyperthermic, deep family of Typic Plinthaqualta.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>About ½ km to the east of village Kodapakha, in Bhanupratappur taluka of Jagdalpur district (M.P.).</td>
</tr>
<tr>
<td>Physiography</td>
<td>Lower piedmont</td>
</tr>
<tr>
<td>Topography</td>
<td>Nearly level to gently sloping</td>
</tr>
<tr>
<td>Drainage</td>
<td>Well drained</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Tendu, Mahua, Karra, Saja, Bamboo, Grass and cultivated paddy.</td>
</tr>
<tr>
<td>Parent material</td>
<td>Mixed alluvium.</td>
</tr>
<tr>
<td>Sampled by</td>
<td>Members of the Core Committee Study group.</td>
</tr>
<tr>
<td>Soil No.</td>
<td>Benchmark soil pedon No. 23.</td>
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<tr>
<td>Date of examination</td>
<td>20th December, 1979.</td>
</tr>
<tr>
<td>Remarks</td>
<td>(Colour notations are for dry soils unless otherwise noted).</td>
</tr>
</tbody>
</table>

**Ap**

0-12 cm: Pale brown (10 YR 6/3) sandy loam, brown (10 YR 5/3) when moist; moderate medium, subangular blocky; dry slightly hard, moist friable, wet slightly sticky and non plastic; many coarse roots; rapid permeability; clear and smooth boundary.

**B2ltg**

12-35 cm: Pale brown (10 YR 6/3) sandy loam, brown (10 YR 5/3) when moist; coarse prismatic breaking into moderate medium subangular blocky peds; dry hard, moist friable, wet sticky and plastic; thin patchy clay skins bridging coarse grains; strong brown (7.5 YR 5/6) common, medium, plinthite mottles in the lower part transitional to subjacent horizon; plentiful fine roots; moderate permeability; gradual and smooth boundary.

**B22tg**

35-62 cm: Brown (10 YR 5/3 M) sandy clay; coarse prismatic breaking into moderate medium angular blocky peds; dry very hard, moist friable, wet sticky and plastic; thick discontinuous clay skins; common medium distinct plinthite mottles of colours, brown (7.5 YR 5/6), and dark brown to brown (7.5 YR 5/6), and
dark brown to brown (7.5 YR 4/4), constitutes 15% of matrix; few fine roots; slow permeability; clear and smooth boundary.

**B23tg** 64-105 cm: Brown (10 YR 5/3 M) (grity) clay; coarse prismatic structure breaking into strong coarse angular blocky peds; dry very hard, moist friable, wet very sticky and plastic; thick discontinuous grayish clay skins; common, medium distinct plinthite mottles of colours dark red (2.5 YR 3/6), light red (10 YR 6/8), and light gray (5 YR 7/1) constitutes about 25% of matrix; few fine roots; slow permeability; gradual and smooth boundary.

**B24tg** 105-130 cm: Gray to light gray (10 YR 6/1 M) (grity) clay; coarse prismatic breaking into strong coarse angular blocky peds; dry very hard, moist friable, wet sticky and plastic, thick discontinuous grayish clay skins; common medium distinct plinthite mottles of colours dark red (2.5 YR 3/6), light red (2.5 YR 6/8) and light gray (5 YR 7/1), constitutes about 30-35% of matrix; slow permeability; gradual and smooth boundary.

**B25tg** 130-170+ cm: Gray to light gray (10 YR 6/1 M) (grity) clay; coarse prismatic breaking into coarse strong angular blocky structure; dry very hard, moist friable, wet sticky and plastic; thick discontinuous grayish clay skins; common medium distinct plinthite mottles of colours dark red (2.5 YR 3/6), light red (2.5 YR 6/8), and light gray (5 YR 7/1), constitutes, about 40-50% of matrix, slow permeability; gradual and smooth boundary.

2. Tentative soil characterisation: no data provided

3. Micromorphological data

Four thin sections are studied all derived from the B horizon. Depths: 35-50 cm (1), 64-79 cm (2), 105-120 cm (3) and 130-145 cm.

1. Depth: 30-50 cm

Macroscopic characteristics

Brown, fine to medium textured, pedal soil material containing common yellowish red mottles, ø up to 8 mm, with clear or diffuse external boundaries.
Micromorphological characteristics

**Structure:** Moderate medium to coarse angular blocky structure to which few-common elongated, intersected voids belong. Other voids: common elongated voids, widths up to 4 mm, lengths less than a few cm and common equant voids, diam. up to 4 mm, randomly distributed.

**Groundmass:** The fine to medium 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, mainly quartz and feldspars, and rock fragments. The fine material is largely clay-sized and includes a few particles up to 5 µm. The plasmic fabric is weak skelsepic.

**Special features:**

Associated with voids: Common voids with argillans, often finely laminated, sometimes including impurities. Colour of the argillans predominantly yellow to white.

- Few voids partly infilled with mineral aggregates, soil fragments as well as some excrements.

In the groundmass: Few to common voids completely infilled with oriented laminated clay, sometimes including impurities. Colour of the clay predominantly yellow to white. Red colours occur too.

- Few voids almost completely infilled with mineral aggregates, soil fragments as well as some excrements.

- Common accumulations of mainly iron oxides, diam. up to 8 mm, diffuse and/or clear external boundaries, randomly distributed.

2. Depth: 64-79 cm

Macroscopic characteristics

Brown, fine to medium textured, pedal soil material, containing common dark red mottles, diam. up to 12 mm, with sharp or clear external boundaries.

Micromorphological characteristics

**Structure:** Moderate coarse angular blocky structure, to which few-common elongated, intersected voids belong. Other voids: Common elongated voids, widths up to 4 mm, lengths less than a few cm and common equant voids, diam. up to 4 mm, randomly distributed.
Groundmass: The fine to medium 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, mainly quartz and feldspars, and rock fragments. The fine material is largely clay-sized and includes a few particles up to 5 µm. The plasmic fabric is weak skelsepic, locally masepic.

Special features:

Associated with voids: Common voids with argillans, often finely laminated, sometimes including impurities. Argillans occur in voids in the groundmass, where they are yellow to white coloured or in iron accumulations, where they also are red coloured.

: Few to common thin ferrans, sometimes in combination with argillans, occurring in voids in the groundmass as well as in iron accumulations.

: Few voids partly infilled with mineral aggregates, generally soil aggregates.

In the groundmass: Common voids almost completely or completely infilled with oriented laminated clay, sometimes including impurities. They occur in the groundmass where they are predominantly yellow and white coloured and in iron accumulations where they also are red coloured.

: Few voids almost completely infilled with mineral aggregates, mainly soil fragments.

: Common accumulations of mainly iron oxides, diam. up to 12 mm, sharp and or clear external boundaries, regular to irregular shaped.

: Locally zones with a high concentration of coarser grains and rock fragments.

3. Depth: 105-120 cm

Macroscopic characteristics
Gray, fine to medium textured, pedal soil material, containing common dark red mottles, diam. up to 12 mm, with sharp or clear external boundaries.

Micromorphological characteristics
Structure: Strong coarse angular blocky structure to which common elongated, intersected voids belong. Other voids: common elongated voids widths up to 4 mm, lengths less than a few cm and common equant voids, diam. up to 4 mm, randomly distributed.

Groundmass: The fine to medium 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, mainly quartz and feldspars, and rock fragments. The fine material is largely clay-sized and includes a few particles up to 5 µm. The plasmic fabric is very weak skelsepic, locally masepic.

Special features:

Associated with voids: Common- many voids with argillans often finely laminated, sometimes including impurities. Argillans occur in voids in the groundmass, where they are yellow to white coloured or in iron accumulations, where they also are red coloured.

Few to common thin ferrans, sometimes in combination with argillans, occurring in voids in the groundmass as well as in iron accumulations.

Few voids partly infilled with mineral aggregates, generally soil aggregates and minerals and rock fragments.

In the groundmass: Common to many voids almost completely and completely infilled with oriented laminated clay, sometimes including impurities. They occur in the groundmass where they are predominantly yellow and white coloured and in iron accumulations where they also are red coloured.

Few voids almost completely infilled with mineral aggregates, mainly soil fragments, minerals and rock fragments.

Common accumulations of mainly iron oxides, diam. up to 12 mm, mainly sharp external boundaries, rather irregular shapes.

Irregular distribution of grain sizes. Locally occur zones with higher concentrations of larger or finer grained mineral material.
4. Depth: 130-145 cm

Macroscopic characteristics

Gray to light gray, fine to medium textured pedal soil material, containing few-common red mottles, diam. up to 12 mm, with mainly diffuse external boundaries.

Micromorphological characteristics

**Structure:** Strong coarse angular blocky structure to which common elongated, intersected voids belong. Other voids: few to common elongated voids widths up to 4 mm, lengths less than a few cm and common equant voids, diam. up to 4 mm, randomly distributed.

**Groundmass:** The fine to medium 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, mainly quartz and feldspars, and rock fragments. The fine material is largely clay-sized and includes a few particles up to 5 µm. The plasmic is locally weak skelsepic and masepic.

**Special features:**

*Associated with voids:* Many voids with argillans, often finely laminated, sometimes including impurities. Argillans occur in voids in the groundmass as well as in iron accumulations and are mainly yellow or white coloured.

*In the groundmass:* Many voids almost completely and completely infilled with oriented laminated clay, sometimes including impurities. They occur in the groundmass as well as in iron accumulations and are mainly yellow and white coloured.

*Few to common accumulations of mainly iron oxides,* diam. up to 12 mm, irregularly shaped with generally diffuse external boundaries.
Short micromorphological description

Four thin sections are studied: all derived from the B horizon. Depths: 35-50 cm (1), 64-79 cm (2), 105-120 cm (3) and 130-145 cm (4).

- The soil material is fine to medium textured and contains grain sizes up to and inclusive very coarse sand. The size limit coarse/fine material is 5 µm; the related distribution porphyric. The fine material is largely clay-sized and includes a few particles up to 5 µm. The plasmic fabric changes slightly with depth from weak skelsepic (1); weak skelsepic, locally masepic (2); very weak skelsepic, locally masepic (3) to locally weak skelsepic and masepic (4). The coarse mineral material consists of a variety of minerals, mainly quartz and feldspars, and rock fragments.

- The soil material has an angular blocky structure in the B horizon which is moderate medium to coarse developed in (1), moderate coarse in (2) and strong coarse in (3, 4), to which few to common (1, 2) and common (3, 4) intersected elongated voids belong.

- Argillans occur in the whole B horizon, increasing in quantity with depth from common (1, 2), common-many (3) to many (4). They are often finely laminated, sometimes including impurities. Argillans occur in voids in the groundmass, where they are yellow to white coloured, but in iron accumulation (2, 3) they are also red coloured. Voids are also almost completely or completely infilled with oriented laminated clay, increasing in quantity with depth from few-common (1), common (2), common-many (3) to many (4). The infilled clay has the same characteristics as the argillans.

- Few voids are partly infilled (1, 2, 3, 4) and almost completely infilled (1, 2, 3). The infilling consists of mineral aggregates, mainly soil aggregates over the whole studied depth. Deeper in the B horizon (3, 4) mineral grains and rock fragments are also present in the infilling.

- From 64 cm depth onwards (2, 3, 4) few to common thin terrans occur, sometimes in combination with argillans, present in voids in the groundmass as well as in iron accumulations.
- Iron accumulations are present in the whole B horizon. They slightly decrease in quantity with depth from common (1, 2, 3) to few-common (4); diameters increase from ca. 8 mm (1) to 12 mm (2, 3, 4). The external boundaries vary with depth from diffuse to clear (1), sharp or clear (2), mainly sharp (3) to mainly diffuse in (4). The boundaries are irregular in (1, 3) and (4) and rather regular in (2).
- In the groundmass in (2) occur locally zones with a high concentration of coarser grains and rock fragments.
1. Laminated infilling of clay due to clay illuviation (centre); B horizon (plain light).

2. Irregular shaped accumulation of sesquioxides (black) with clear external boundaries; B horizon (plain light).
4. Interpretation of the micromorphological data

Four thin sections are studied: all derived from the B horizon. Depths: 35-50 cm (1), 64-79 cm (2), 105-120 cm (3) and 130-145 cm (4).

- Clay illuviation has occurred on a large scale and probably still occurs. The features indicating clay illuviation, argillans and voids infilled with oriented laminated clay, are numerous and increase in quantity with depth from common to many. These features are often finely laminated and well developed.

- In the whole B horizon iron accumulations occur. They are present as nodules in the groundmass with a maximum development between 60-120 cm depth. In this zone common distinct, red nodules, diameters up to 12 mm, with sharp or clear external boundaries, are formed with rather regular boundaries in (2) and irregular ones in (3). In voids in these accumulations argillans and completely infilled voids with oriented clay are present, which can be yellow or white coloured as well as red coloured. This occurrence forms an indication that clay illuviation and accumulation of iron for a part occurred in the same period, not necessarily at the same time. Clay illuviation is a more continuous process. Iron has also accumulated as cutans. From 64 cm depth onwards, few to common thin ferrans are found, sometimes in combination with argillans.

- Macrofauna is nearly absent and the structure is due to physical processes. Locally soil aggregates, minerals and rock fragments are accumulated in voids, partly or completely filling them. These features are not numerous (few) and decrease in quantity with depth and are due to physical processes related to dry periods.

Remark: Micromorphologically this pedon is the best example of a Typic Plinthaquealf encountered in the Benchmark soils studied.
NEGHUR SERIES

1. General information and typifying pedon description

Neghur series includes well drained, deep dark red soils formed in the outwash material of feldspathic schist and gneiss in origin. They occur on nearly level to very gently sloping (1-3%) upper piedmont plain. The soil pedon exhibits an ABC profile with a reddish brown to dark reddish brown sandy loam to sandy clay loam A horizon grading to dark reddish brown to dark red clay loam to gravelly clay loam B horizon, underlain by unconsolidated matrix of weathered and altered assorted pebbles, cobbles and gravels of feldspathic schists and granitic gneiss with dark red dusky red clay loam fills. The B horizon exhibits clay pick up and the red colour intensify through depth of the pedon having moist value 4 and less with higher chroma. These soils have been classified in India as "Red loamy" soils.

The climate of the area is tropical subhumid. The mean annual temperature is 26°C rising to Max. 40°C in May and falling to Min. 11°C in December in most of the years. The mean annual rainfall is 1397 mm of which about 70% is received during monsoon July to September, 15.6% as premonsoonic cloud burst and 7.1% as post monsoonic storm. About 96.3% of the annual potential evapotranspiration is covered by the rainfall in the area. The common associated soils are those of Bodel and Durgkondal series which are moderately deep to deep Alfisols.

Neghur series comprises the members of fine loamy, mixed, hyperthermic, deep family of Udic Rhodustalfs.

Typifying pedon: Neghur sandy clay loam-Medium forest land.

(Colour notations are for dry soils unless otherwise noted).

A1 0-14 cm: Dark reddish brown (5 YR 3/4) sandy clay loam, dark reddish brown (5 YR 2.5/4) when moist; moderate medium subangular blocky; dry slightly hard, moist friable, wet slightly sticky and plastic; many medium and coarse tubular pores; many coarse roots; moderately rapid permeability; pH 6.1; clear and smooth boundary.
B2lt 14-30 cm: Dark reddish brown (5 YR 3/4) clay loam; dark reddish brown (5 YR 2.5/4) when moist; medium moderate subangular blocky coated with thin patchy clay skins; dry slightly hard, moist very friable, wet sticky and plastic; few fine exped and inped oblique pores; many coarse roots; moderately rapid permeability; pH 5.9; clear and smooth boundary.

B22t 30-47 cm: Dark reddish brown (2.5 YR 3/4) clay loam, dusky red (10 R 3/4) when moist; moderate medium subangular blocky peds with thick discontinuous clay skins; dry hard, moist friable, wet sticky and plastic; few fine exped and inped oblique pores; many coarse and fine roots; moderately rapid permeability; pH 5.7; gradual and smooth boundary.

B23t 47-62 cm: Dark red (10 R 3/6) gravelly clay loam, dusky red (10 R 3/4) when moist; moderate medium subangular blocky peds with thin distinctly broken clay skins; dry slightly hard, moist friable, wet sticky and plastic; few fine exped and inped oblique pores; many coarse and fine roots; mod. rapid permeability; pH 5.5; gradual and smooth boundary.

B3t 62-85 cm: Dark red (10 R 3/6) gravelly clay loam, dusky red (10 R 3/2) when moist; weak medium subangular blocky; with thin distinctly broken clay skins; dry loose, moist friable, wet sticky and plastic; many coarse and fine roots; mod. rapid permeability; pH 5.6; diffuse and smooth boundary.

C 85-100 cm+: Gravelly matrix of weathered feldspatic quartzitic schist, granite gneiss and assorted gravels and pebbles and cobbles with dark red (10 R 3/6) to dusky red (10 R 3/2) clay loam fill; pH 5.6.

Range in characteristics: The average thickness of the solum ranges from 75 cm to 100 cm. The principal soil types encountered are sandy clay loam and clay loam. Within the depth of 15 cm to 1.0 m of the surface the content of coarse fragments larger than 2 mm size is negligible in the upper part but increases abruptly through depth ranging from 40 to 70%. The colour of soil in A horizon dominates in hue of 5 YR with dry value 3 and moist value 2.5 while chroma is 4 and at places 6 both for dry and moist soils. The soil colour in B2lt is similar to that in the A horizon.
but it grades to still redder hue of 2.5 YR and 10 R in lower parts of the B horizon with dry and moist value 3 and chroma 4 to 6 both for dry and moist soils. The clay pick up through the B horizon is evidenced by the presence of thin to thick patchy and discontinuous clay skins on ped faces and in empty voids. The pedality of the B horizon is moderately developed and it varies from medium moderate to medium weak subangular blocky peds through depth. The soil reaction is medium acid to strongly acid and soil pH ranges from 5.9 to 5.5 through depth. The effective rooting depth is moderately deep to deep extending upto 80 cm of the surface. The depth of groundwater table ranges from 12 to 18 m of the surface. The mean annual soil temperature varies from 28 to 29°C and the difference between mean summer and mean winter soil temperature exceeds 5°C in most of the years.

Competing series and their differentiae: Competing soils are those of Bodeli series. Bodeli soils are deep and clay pick up is evidenced by thin patchy clay skins on moderate medium angular blocky peds through the B horizon. The texture of the fine earth in the control section is finer than that in Neghur soils. The soil colour within control section is in hue of 5 YR and 2.5 YR through depth with moist values 3 and 4 and chroma 6 both for dry and moist soils.

Drainage and permeability: Well drained moderate to moderately rapid permeability.

Vegetation and land use: Most of the area is under medium to thick mixed forest of moist deciduous species, while at places species of lesser millets are cultivated.

Distribution and extent: The soils are distributed extensively on the upper piedmont plain in the reserved forest areas growing mostly Shorea robusta (sal) and at places Tectona grandis Linn (Teak) in district Jagdalpur (Bastar), M.P.

Type location and series established: Neghur sandy clay loam, Pit No. 38, About 1½ km, to north west from village Neghur, Taluka Bhanupratappur, Distt. Jagdalpur (Bastar), M.P.
2. Tentative soil characterisation: no data provided

3. Micromorphological data

Two thin sections are studied, both of the B horizon.
Depths: 14-29 cm (1) and 47-62 cm (2).

1. Depth 14-29 cm

Macroscopic characteristics

Dark reddish brown fine to medium textured, moderate pedal soil material, containing coloured nodules and gravels up to 4 mm in diameter.

Micromorphological characteristics

Structure: Moderate medium subangular blocky structure, to which few to common long elongated voids belong. Other voids: few elongated voids, widths up to 3 mm, lengths several cm and common equant voids, Ø up to 3 mm, locally interconnected; randomly distributed.

Groundmass: The fine to medium textured soil material includes grain sizes up to gravels of 4 mm in diameter. Size limit coarse/fine material: 15 mm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, which except for quartz and quartzite are strongly altered. The coarse organic matter consists of few-common root fragments. The fine material is largely clay-sized and includes common particles up to 15 mm. The plasmic fabric is masked by the red colour of the fine material.

Special features:

Associated with voids: Locally in undisturbed parts of the soil material occur a few thin discontinuous ferri-argillans.

: Few to common voids are partly infilled with mineral aggregates, mainly excrements. Some of these voids have a coating of mainly fine-grained soil material.

: A few voids have a coating of mainly fine-grained soil material.
In the groundmass: Common voids are almost completely infilled with mineral aggregates, mainly excrements which can be single to moderately welded. A part of these voids have coatings of mainly fine-grained soil material.

: Few to common, rather rounded, sesquioxide nODULES with sharp external boundaries, diam. up to 4 mm.

2. Depth: 47-62 cm

Macroscopic characteristics

Dark red gravelly, fine to medium textured, soil material.

Micromorphological characteristics

Structure: The structure is not detectable, due to disturbance during transport and no indication of other voids can be given.

Groundmass: The fine to medium textured soil material includes grain size up to gravels of 8 mm in diameter. Size limit coarse/fine material: 15 mm. Related distribution: porphyric. The coarse mineral material consists of a small variety of minerals, which except for quartz and quartzite are strongly altered. The fine material is largely clay-sized and includes common particles up to 15 mm. The plasmic fabric is masked by the red colour of the fine material.

Special features:

Associated with voids: Due to disturbance not detectable.

In the groundmass: Voids are nearly completely infilled with mineral aggregates, mainly excrements, which can be single or strongly welded. Coatings of fine-grained soil material are sometimes present.

: Common to many, rather rounded, sesquioxide nODULES, with sharp external boundaries, diam. up to 4 mm.
4. Interpretation of the micromorphological data

Two thin sections are studied, both of the B horizon.
Depths: 14-29 cm (1) and 47-62 cm (2)

- In 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 shaped, single to strongly welded, mineral excrements. A part of the voids have, often thick, coatings of fine-grained soil material along the walls. These coatings are the result of 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 a very few ferri-argillans occur in small voids in undisturbed parts of the groundmass. No argillans are observed in the middle part of the B horizon (2).

- The rather rounded sesquioxicodic nodules which increase in quantity and size with depth can be of geogenic or pedogenic origin or a combination.

Remark: The clay cutans visible in the field are coatings of fine-grained soil material, a result of animal activity. The pedon studied can be eroded, as no argillans are observed in the middle part of the B horizon (2).
Price of the basic reference set: £