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Black soils in eastern India

by

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Introduction

Varieties of black soil are described in world soil science literature, but the one which has the greatest importance in the tropics is the group of Grumusols. Ando soils are another important group among dark colored soils known to occur in the tropics, but their distribution is restricted to volcanic regions because of their origin in volcanic ejecta. Grumusols occur more widely from different parent materials throughout the tropical and subtropical zones, given suitable climatic and topographical conditions. Their names differ from place to place; to mention a few examples from Southern Asia, there are *Regur* or black cotton soils in India, dark compact soils of dry savanna in Burma, and margalitic soils in Indonesia. We have seen similar soils in the Philippines, Cambodia, Thailand and Ceylon. The *Regur* or black cotton soils are most well-known due to their extensive occurrence in peninsular India.

We visited India for a field study and to take samples of paddy soils in January-March, 1968 and traveled through the Gangetic basin and the eastern part of peninsular India. During the trip we had opportunity to study some of the black soils, the mode of whose occurrence appeared so divergent that we felt the necessity of giving some order to our field observations. This is the prime purpose of the present paper.

Before going into the main discussion, we summarize what we know of the nature and properties of the black soils of the Grumusol group, to inform the reader of the criteria of our sample selection.

I Grumusols, their nature and properties[1,2]

1. Genesis

Fine-textured, alkaline earth base-rich parent materials are common to most soils of the Grumusol group. Parent rocks range from unconsolidated alluvial sediments to hard basalt or limestone. In the case of the *Regur* soils of India, many areas are derived from basaltic Deccan trap rocks either residually or alluvially (and colluvially). *Regur* soils are known to occur also in areas of slate, shale, argillaceous limestone, syenite and gneissic rocks.

The climatic conditions under which Grumusolic soils occur more frequently are those of Köppen's tropical savanna climate or Thornswaite's subhumid to semiarid tropical climate. In these climatic regions rainfall is unevenly distributed and a distinct dry season occurs in winter in Southern Asia.

Landform is normally level to gently undulating and drainage seems to be rather poor. When Grumusols occur in a landscape with a more pronounced relief they invariably form in the depressions, together with reddish-colored soils occurring on the higher ground.

Natural vegetation is usually a savanna type. But many Grumusol areas are now cultivated for upland crops, such as cotton and tobacco. Lowland rice is also grown on large areas of depressional Grumusolic soils.

The date of the formation of Grumusols will be discussed in the latter part of this paper.

2. Morphology

Horizon differentiation in the profile is generally very poor, resulting in an A/C horizon sequence. The A horizon shows a dark brown to black color and has a considerable thickness. The surface of upland soil is characterized by granular to crumbly structures (self-mulching feature), but in the lowlands where rice is grown it is massive and upon drying forms big polygonal blocks. The subsoil consists mostly of strongly developed fine to medium angular blocky structures with developed slickensides. The soil often contains lime concretions throughout the profile and gypsum crystals occasionally occur as well in the subsoil. In some cases the profile contains dark colored pisolitic concretions which are of great importance in assessing the age of the soil.

As the soil is fine-textured, the consistency is usually very sticky and very plastic when wet and very hard when dry. The climatic conditions prevalent in the black soil area result in very deep and wide cracks during the dry season, which swallow the surface soil materials. This, together with strong swelling nature of the clay during the wet season, causes self-churning phenomenon and the gilgai microrelief characteristic of Grumusols.

In addition to the generally poor surface drainage of the soil, heavy impervious clays in the subsoil also inhibit internal drainage. Thus, in lowlands gley features are sometimes observed in the profile, but mottlings are not usually very distinct.

3. Chemical characteristics

The formation of Grumusols appears to require a calcareous nature in the parent material. In one case, effervescence resulting from contact with a mineral acid occurs in the entire soil mass in the uppermost horizon, while in another, lime concretions are present only in subsoil layers. Thus, in most cases the reaction of the surface soil ranges from slightly acid to alkaline. Magnesium content is also quite high in many soils.

An important chemical feature is that the dark color of the soil is not explained by the quantity of organic matter. In the *Regur* soils in India the organic carbon content of the soil rarely exceeds one percent. Thus we cannot apply the relationship between soil color and the organic matter content relevant to temperate zones to these black soils. Yet at the same time, there is little doubt that the color is caused by organic matter. This is evident from the ready decoloration of the soil sample upon hydrogen-peroxide treatment after a preliminary washing with a mineral acid.[3] Scheffer et al.[4] suggest that the dark color is due to catalytic, oxidative polymerization of soil humus in the weakly alkaline medium of the soil. We also found that the humus of Grumusolic soils is highly humified, possessing a deep black color.[5] Further studies are necessary, however, concerning the association of humus with soil mineral particles.

A predominance of montmorillonite in the clay mineral composition is another prominent characteristic. This and the high clay content explain the high cation exchange capacity (often exceeding 50 me/100g) of the soil.

4. Physical characteristics

The high content of montmorillonitic clays in the soil determines the major physical and morphological characteristics, for example the plastic consistency, shrinking and hardening upon drying, extensive swelling upon wetting, formation of deep cracks, formation of slickensides and pressure faces, self-churning process, microrelief feature, etc. It should be noted, however, that the montmorillonitic clays in Grumusols are normally saturated with calcium and magnesium. In view of this, these physical characteristics might be more firmly associated with the high clay content than with the clay species. In fact, our studies reveal that even in soils whose clay mineral composition is not dominated by montmorillonite (nor by kaolin minerals), when the clay content is sufficiently high, many of the above-listed physical and morphological characteristics are observed.[5] These physical characteristics bring about certain difficulties in utilizing the soil for agriculture or as a base for the construction of buildings and roads.

II Field observations

As the primary objective of our visit to India was to study the field characteristics of paddy soils and to collect samples, we could perform more detailed studies on the black soils under rice cultivation than on those in upland areas, on which only geomorphological observations were made.

Not all the black soils dealt with here are *Regur* soils, as they are called in India, but may be classified as Grumusols, judging from their morphological and clay mineralogical characteristics.

The black soils studied are grouped into the following four categories :

(1) Black soils on calcareous basements

(2) Black soils on non-calcareous basements

(3) Black soils associated with recent river terraces

(4) Black soils on deltaic and coastal alluvia

Some field and clay mineralogical characteristics for each of the four groups are given below.

(1) Black soils on calcareous basements

As far as the soils we observed are concerned, the parent material of this group is derived from calcareous rocks (limestones and calcareous slates) of the Cambrian and Precambrian periods[6] on a peneplained surface. The black soils of this group are distributed extensively, occupying both the swelling and swaling areas of gently undulating ground. Figure 1-a shows a pattern of their distribution schematically. Parent materials are inevitably calcareous, but in swaling areas a secondary accumulation of lime seems to occur. An outcrop in a swaling area is schematically shown in Fig. 1-b. The basement rock here is calcareous slate, outcropping at a depth of ca. 8.5 m. in a big well hole. A strongly weathered thin deposit with a somewhat indurated calcareous crust and many pisolitic iron concretions overlies the fresh rock. In turn a relatively young calcareous sediment of considerable thickness covers the old sediment. This younger sediment appears to have been secondarily enriched with lime and a black soil occurs in its uppermost levels. This outcrop is illustrated not because it is representative (the presence of the old, weathered sediment is rather unusual), but because the sequence of the old and the new sediments is indicative of the age relationship discussed below.

Black soils in swelling areas have shallow sola developed on residua from parent rocks. One residual soil sample we took on calcareous slate contains almost pure montmorillonite, while the acid-insoluble residue of the parent rock consists of illite

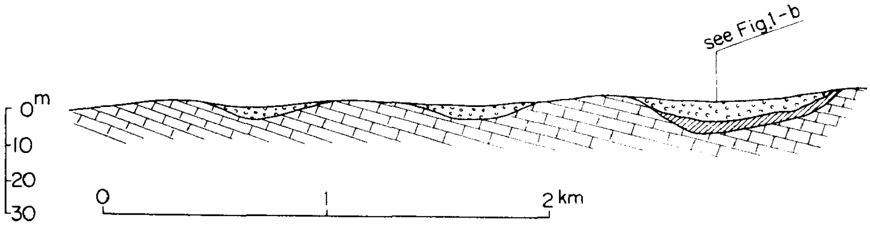
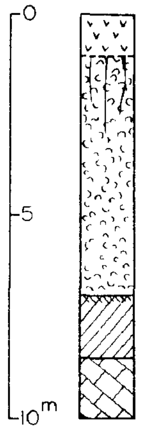


Fig. 1-a Schematic cross section of a black soil area on calcareous basements



(1) Black soil with few manganiferous concretions; gradual boundary to

(2) Gray to light gray clayey deposit with many lime nodules and few manganiferous concretions

(3) Yellowish-brown clayey deposit with indurated lime crust at the upper boundary; many pisolitic iron concretions and lime nodules

(4) Fresh calcareous slate (basement rock)

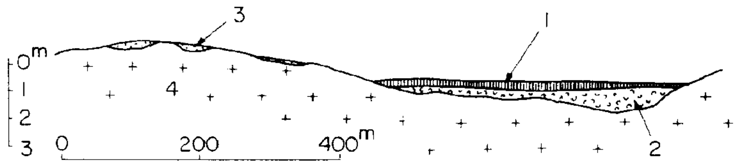
Fig. 1-b Columnar section seen on a well wall in a calcareous slate area

and a lesser amount of kaolin minerals together with quartz and a small amount of feldspars. We do not know yet the exact process of montmorillonite formation in such a soil, but we are almost certain that the montmorillonite clay was formed *in situ* from the residuum of the calcareous slate. Predominance of plagioclase with high refractive indices in the feldspar composition of both the soil and the residue, as distinguished from other soil samples, may be taken as evidence for the *in situ* formation of montmorillonite.

We did not have a chance to see black soils on the Deccan Plateau proper, where the most extensive occurrence of black soils is known. We imagine that a very flat topography would be the prime factor which conditions an extensive occurrence of black soils on basaltic rocks, because the highly weatherable basalt would readily be transformed into red latosolic soils wherever the topography favors removal of soluble weathering products.

(2) Black soils on non-calcareous basements

Black soils of this group occur mainly in Archean granite and gneiss areas and



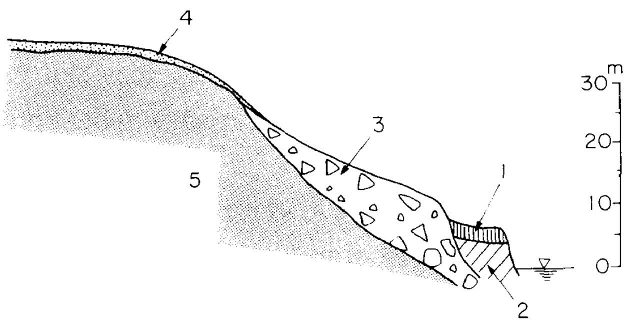
(1) Black soil ; gradual boundary to
(2) Gray to light gray clayey deposit with lime nodules of secondary origin and many rock fragments
(3) Reddish-colored, medium to coarse-textured soil with *murram* or disintegrated rock fragments in subsoil layers
(4) Fresh and weathered rocks

Fig. 2 Schematic cross section of a catenary soil distribution on non-calcareous basements have relatively narrow, patchy or belt-like distributions in depressional parts of a landscape. Higher terrain normally consists of red soils. A schematic representation of the soil distribution in non-calcareous basement rock areas is given in Fig. 2. As an example of this type of catenary soil distribution we can cite a sequence of *Bhata-Matasi-Dorsa-Kanhar* around Raipur, Madhya Pradesh. These are local names of soils occupying different terrain. The parent rock of the particular sequence we observed is non-calcareous slate. The *Kanhar* soil, the lowest member of the sequence, is a black soil with a fairly high lime content even in the surface layer. Simonson[7] described a *Kanhar* soil in the same area as a representative deep *Regur* soil from limestone. Although the parent rock is different and the solum is shallower, the general soil characteristics of the *Kanhar* soil we studied are similar to Simonson's; thus, we may regard our *Kanhar* soil as a type of *Regur* soil. The clay mineralogy of our sample also supports the view, consisting almost exclusively of montmorillonite. One prominent feature of the *Kanhar* soil in the Raipur area is its association with gilgai microrelief, which occurs rather rarely in the Indian *Regur* areas.[7]

The second lowest member, *Dorsa,* has a grayish-brown color and contains only a few discrete lime concretions. *Matasi,* the second highest member, has a more yellowish color (yellowish-brown) and no lime concretions. *Bhata,* the highest member, occupying the ridge part, is a red gravelly soil consisting of iron-coated rock fragments and iron nodules (and concretions).

(3) Black soils associated with recent river terraces

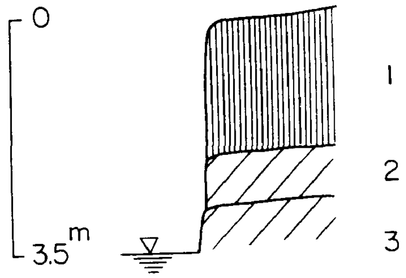
In the Machkund Valley, southern Orissa, laterites and latosols predominate. However, small patches of black soil also occur in this area on narrow terraces along small streams. The primary feature of the black soil here is that the occurrence of the soil is strictly confined to river terraces and that most of the soil characteristics seem to have been inherited from terrace deposits. Figure 3 shows the general mode of occurrence of the black soils schematically. Unit (2) is obviously a clayey deposit along a stream. A black soil with a gray clay subsoil overlies the unit (2) clay and the transition between the two



(1) Black soil; gradual boundary to
(2) Olive gray clayey deposit with common yellowish-brown spots; few fine lime nodules
(3) Gravels and red (2.5YR 4/6) clay with common hardened laterite fragments; gravels, angular to subangular and of pebble to cobble size
(4) Red (2.5YR 4/6) sandy-clay soil with common fine rock fragments
(5) Weathered basement rocks; partly lateritized

Fig. 3 Schematic cross section showing geomorphological position of black soil on recent river terrace in narrow valleys is very gradual. It seems most probable that the black soil here is a slightly modified form of a black clay deposit, a topmost member of the recent terrace deposits.

Black soils of this group appear to be rather unstable because the narrow terrace surface is relatively well drained both externally and internally. In fact, a clay mineralogical study of a sample revealed relative abundance of kaolin mineral, illite and vermiculite over montmorillonite. Thus, the soil is thought to be in transition from a black soil to a new soil adapted to the new environment.



(1) Black soil; gradual boundary to
(2) Dark gray clay deposit with few small brown spots; white efflorescence on exposed surface ; many fine gypsum crystals
(3) Dark gray clay with slightly more yellowish hue than (2); few small brown spots; fine to medium angular blocky, finer than (2); many fine gypsum crystals and common manganiferous concretions of mustard seed size

Fig. 4 Profile of black soil on coastal alluvia near Bapatla, Andhra Pradesh

In the Gangetic basin a black soil, locally called *Karail,* is known to occur in southeastern Uttar Pradesh and western Bihar, where fine-textured sediments from the Deccan Plateau are deposited. The *Karail* soil occupies depressional portions of an extensive alluvial plain. Thus, it differs from the above-stated terrace black soil in its micro-environment, but may be comparable in its stratigraphic position and age.

(4) Black soils on deltaic and coastal alluvia

In the deltaic and interdeltaic areas of the Godavari and Krishna Rivers black soils occur very extensively. A prominent feature is the close relation of their distribution to the recent deltaic and interdeltaic depositional surface. These black soils are commonly put under rice cultivation.

Most of their features as a black soil appear to be inherited from sediments, as in the case of the preceding black soil group on the recent river terrace. Segregation of lime (but not of manganese and iron) and formation of characteristic subsoil structures with slickensides and pressure faces are supposed to be the only acquisition resulting from soil formation. A clay mineralogical study of some of these soils again revealed predominance of montmorillonitic clays.

III Discussions

De Terra and Paterson[8)] studied the Quaternary geology of the Narbada Valley, central India, and proposed a schematic cross section and age determinations as shown in Fig. 5. Units (1) and (2) are very closely associated with the present river course

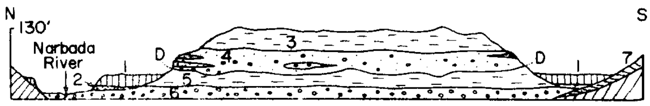


Fig. 5 Composite transverse section through Narbada Valley near Narsinghpur (after H. De Terra & T.T. Paterson, 1939) (1) cotton soil, (2) basal gravel of cotton soil, (3) upper group with pink concretionary clay, (4) upper gravel and sand, (5) lower group with red concretionary clay, (6) basal conglomerate, (7) laterite, (D) disconformity between upper and lower groups.
Age relationship.
1 & 2 postglacial
3 & 4 III interglacial to IV glacial
5 & 6 II interglacial to III glacial

and appear to be recent terrace deposits, which have undergone very little *in situ* weathering. Distribution of units (3) to (6) is not strictly confined to the present river channels, but more or less in parallel with them. These latter units are characterized by the presence of iron-manganese concretions which are most probably formed as *in situ* weathering products. Thus, they must have undergone subaerial weathering for a considerable length of time.

The stratigraphic feature as shown in Fig. 5 may not be confined to the Narbada Valley, but also applicable to other parts of peninsular India. We take this scheme of De Terra and Paterson as a standard for the correlation attempted below.

Black soils associated with the recent river terrace are obviously correlated with the black cotton soils of unit (1) in the Narbada Valley. From the geomorphological viewpoint, it is possible to trace a geological body equivalent to the black cotton soil (unit 1) to downstream parts of watercourses and even to deltaic and coastal regions. Thus, the black soils on deltaic (and coastal) alluvia that we studied may be regarded as a deltaic version of the black cotton soils in the Narbada Valley.

We have so far dealt with black soils on recent river terraces and recent deltaic and coastal sediments. Now we should ask what possibility is there of black soils occurring on older terrace formations? In view of the relatively young pedogenetic age of black soils as indicated by the poor horizonation and the montmorillonitic clay mineral composition, there is little possibility of old terraces, with a fair relative height above the present river, retaining black soils. Only in areas where soil materials are continuously furnished with bases from some base-rich source or in depressions where bases are accumulated from the surroundings, the occurrence of black soils may be possible. We did indeed observe a black soil on an older terrace near Eloru, Andhra Pradesh. This soil occupies a relative depression and is surrounded by yellow soils. It contains lime nodules and pisolitic iron-manganese concretions, which can be taken as evidence of a long weathering history. A clay mineralogical study revealed a fairly high content of kaolin minerals together with illite and vermiculite. This may again be suggestive of the old age of the soil. Although montmorillonite is a relatively minor clay constituent, this soil may still be placed in the Grumusol group because of its morphological characteristics, but in a different subgroup from the modal one.

The mode of occurrence of black soils on older terraces as stated above may be regarded as a subtype of the occurrence of black soils on non-calcareous basement rocks. There are other modes of occurrence which may be regarded as subtypes of the occurrence of black soils on calcareous basement rocks. For example, black soils can develop on erosional terraces formed on calcareous rocks or on older terraces of marly sediments. Black soils occurring extensively along the coast to the south of Guntur, Andhra Pradesh, possibly falls into one of these categories.

For the age assessment of the black soils of residual origin, the scheme for the clastic deposits in the Narbada Valley is not directly applicable. However, the schematic column shown in Fig. 1-b provides a clue to the solution of this problem. A geological break can clearly be recognized between an old, strongly weathered sediment with many pisoliths and a thick, younger deposit with a black soil. The weathering feature possibly allows correlation of the old deposit with unit (3) of the Narbada Valley, which is supposed to have been deposited during the last interglacial period. If so correlated, the younger thick sediment is assumed to be an eluvium from the surroundings since the last glacial period and the black soil in that outcrop should have been formed over a period of ca. 20,000 years.

This age assessment seems to be verified by other evidence. First of all, these residual black soils contain moderately developed pisolitic concretions rich in lime and manganese but relatively poor in iron. Pisoliths in a black soil on an older terrace equivalent to unit (3) in the Narbada Valley, such as the one we observed near Eloru (referred to above), are much more developed in their size and iron content than in these residual soils. On the other hand, black soils on the recent deltaic alluvium do not contain any such pisolitic concretions. Therefore, with respect to their age the residual black soils may be placed between the older terrace soil and the recent deltaic soil. Furthermore, predominance of montmorillonitic clays in the residual black soils may also be taken as supporting evidence. If they were as old as, or older than the older terrace soil near Eloru, the montmorillonitic clays could not have been preserved so well.

The correlations and the age determinations attempted so far, however, are still very tentative. Further field evidence and laboratory data should be accumulated in order to settle these problems definitively.

IV Summary

Black soils of the Grumusol group studied in the eastern part of India are grouped into the following four categories according to their mode of occurrence : (1) Black soils on calcareous basements, (2) Black soils on non-calcareous basements, (3) Black

soils associated with recent river terraces, (4) Black soils on deltaic and coastal alluvia. Field and clay mineralogical characteristics are given and stratigraphic positions are discussed for each of the four groups.

Acknowledgement

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