STUDIES ON ASSOCIATED RED AND BLACK SOILS OF NORTH KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON ASSOCIATED RED AND BLACK SOILS OF NORTH KARNATAKA", submitted by Mr. RUDRAMURTHY H.V. for the degree MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE, of the University of Agricultural Sciences, Dharwad is a record of research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of award of degree, diploma, associateship, fellowship or other similar titles.

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Affectionately
dedicated
to my
beloved mother
Smt. Gowramma Veerappa H.

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INTRODUCTION

I. INTRODUCTION

The black and red soils are the most extensive soil groups in India next to alluvial soils. In India black soils are popularly known as black cotton soils and Regurs. The name Regur is derived from the Telugu word "Nala Ragada" meaning "Sticky black earth". The red soils are also called by different names in different localities of India, such as Masub and Chelka in Andhara Pradesh (Satyanarayana and Biswas, 1970) and as bhata, masati and dorsa in Madhya Pradesh (Biswas and Gawande, 1962).

The complexcity of soil is commoner than simplicity (Buol et al., 1975), The occurrence of diversified soils in close proximity is well known in various parts of the world. The red and black soils representing two broad soils groups observed in India often occur side by side under apparently, the same climatic and geological conditions and the mode of formation of these soil types has been long-debated issue.

The red and black complex soils are most common in the Deccan plateaue of India. About ten percent of the total geographical area of India is covered by these complex soils (Anonymous, 1987). In India these red and black complex soils are commonly reported in Andhra Pradesh (Desai, 1942; Krishnamoorthy and Govinda Rajan, 1977; Satyanarayana and Biswas, 1970), Madhya Pradesh (Biswas and Gawande, 1962), Tamilnadu (Raychaudhuri _et al_., 1942) and Karnataka (Ramaiah and Raghavendrachar, 1936). In Karnataka these soils are predominant in the northern districts.

There are two schools of thought regarding the genesis of the associated red and black soils. One school of thought attributed their genesis to the differences in the topography. Desai (1942) studied the relationships of black cotton soils and red earths of Hyderbad (Deccan plateau) and reported that due to the differences in drainage conditioned by the topography these soils were formed. On account of free drainage in the lower sites, the product of weathering would not be so readily leached away and in addition, drainage water from the higher level red soil areas would be introducing a continuous supply of bases, which resulted in the formation of montmorillonite beidellite type clay in the lower elements of slope.

Raychaudhuri _et al_. (1942) pointed that in many places in Central India and Southern India black and red soils occur together in the same districts and the granites and gneisses give rise to black soils in some places and to red soils at other places. Wherever the soil is red it is usually close to the hills and overlies a thin layer of decomposed granite and highly kaolinised feldspar. With increase in the distance from the hills black soil of increasing thickness occurs and this is found overlying a thicker layer of decomposed and kaolinised material. This suggested the convertion of red soil into black soil but without any direct experimental proof is yet available. Although extensive study from India points out the occurrence of these soils in toposequence with red earths on crests and pediments and black earths on the foot slopes, in the valleys and depressions. Very few have dealt with the close association of only red and black soils as distinct entities with clear lines of demarcation, under almost similar topography (Pal and Deshpande, 1987).

Another school of thought attributed the genesis of these complex soils to the differences in the mineralogical make up of the parent material. Ramaiah and Raghavendrachar (1936) reported that although the black and red soils in the Madras Presidency (India) are derived from granite and gneiss and occur side by side, the two types are associated with rocks containing minerals of different chemical composition.

Therefore the present study on red and black soils, occuring side by side in close proximity has been attempted to understand which one of the two schools of thought regarding the genesis of these complex soils is appropriate, or both are correct or are there some other factors other than topography and parentmaterial responsible for the occurrence of these complex soils side by side. So the present investigation has been taken up with the following objectivies.

- To know their morphological, physical and chemical properties.
- To understand the genesis of these soils and their occurrence in close proximity.
- To classify these soils as per Soil Taxonomy of U.S.D.A.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The knowledge regarding genesis, properties, classification and geographical distribution of soils are the prerequisites for the proper utilisation and conservation of soil and to improve or to maintain the soil health in good condition. In India little work has been done on the genesis of associated red and black soils. Most of the scientists have studied these complex soils occurring in a catenary association. But very few attempted to know the genesis of these complex soils occurring side by side under almost the same topography in addition to the same parent material and climate. The available literature on associated red and black soils mostly pertaining to India has been reviewed under the following headings.

-Genesis of associated red and black soils.

-Morphology.

-Physical, chemical and physico-chemical properties.

-Sand mineralogy.

-Clay mineralogy

-Classification.

2.1. Genesis of associated red and black soils

Jenny (1941) stated that soil formation is a function of five factors; climate (cl), vegetation (o), relief (r), parent material (P) and time (t) and exprerssed mathematically as S = f (cl, o, r, p, t). The passive factors topography and parent material are found to be dominant factors in the genesis of "red and black complex" soils.

The important pedogenic processes involved in the genesis of red soils are rubification, ferrugination and braunification, where as in black soil pedoturbation is the important pedogenic process. Alfisoils are relatively free of pedoturbution developed on macrotopography that range from level to hilly. They are frequently associated with other soil orders where the patterns of micro climate are related to the aspects in landscapes of topography (Buol et al., 1980)

2.1.1 Influence of relief on the genesis of associated red and black soils

Topography is one of the most important pedogenic factor which influences the formation of "red and black complex" soils. Topography is the configuration of the soil surface and includes slope, aspect, exposure and position in the landscape and the position from the surface.

Joffe (1949) quoted that parent material, biosphere and lithosphere participated in soil formation by their mass and energy and relief only conditioned the redistribution of matter and energy.

Topography plays an important role in the development of soil profile, which influences the thickness of A horizon, organic matter content, soil colour, soil depth, accumulation of salts and $CaCO_3$ It also influences both external and internal drainage conditions differential transport of eroded material, leaching and translocation, which ultimately determines soil characteristics (Buol et al., 1980).

Associated red and black soils are most common in the Deccan plateau of India. Usually red soils are distributed at the crest and pediments, where as black soils at the footslopes and in the valleys. These complex soils in many places related with the toposequence. Milne (1935) developed catena concept to indicicate a regular repetition of certain sequence of soil profiles in association with a certain topography. Drainage as influenced by topography has been an important soil forming factor in Deccan canal soils (Basu and Sirur, 1938). Two distinct sets of soil forming proceses were in operation as conditioned by drainage, one led to the accumulation of salts, while another resulted in soil with no accumulation of salts. Some low lying soils developed a hard compact A horizon possessing a very high percentage of sodium.

Desai (1942) studied the nature and relationship of black cotton soils and red earths and reported that drainage conditioned by topography played an important role in the genesis of associated red and black soils. He pointed out that red soils occupied the higher elements of macro relief, where as the black soils are confined to the valleys and of lower elevation. He also stated that because of less free drainage in the lower sites the products of weathering would not be so readily leached away and in addition drainage water from higher level red soil areas would be introducing a continuous supply of bases which resulted in the formation of montmorillonite biedellite type clay in the lower elevation of the topography.

Satyanarayana and Biswas (1970) studied the associated red and black soils of Nizamabad in Andhra Pradesh and they attributed the genesis of these "red and black complex" soils to drainage conditioned by vitrue of topography as responsible for the formation of red soils on the mound of the slope under well drained condition and black soils in the basin at the end of the slope under impeded drainage condition. Bhargava et al. (1973) studied Tungabhadra catchment soils and reported that red soils occupied relatively higher physiographic positions and black soils occupied midland position and also pointed out that topographic situation found to have played a definite role in shaping the air-water relationship within the soil body. By conditioning the micro climatic variations, topography further appeared to have influenced material movement through the depth, ultimately influencing the redistribution of matter and energy in soil development. Robinson (1936) reported that formation of red and black soils mainly influenced by drainage in tropical and subtropical regions. He pointed out that in basin shaped areas with impeded drainage calcium ions in the sphere of weathering prevented the loss of silicic acid and thus dark coloured soils with siliceous clay complex were the result, where as the red soils with low silica sesquioxide ratios were formed under the conditions of free drainage and low lime status.

Nagelschmidt et al. (1940) found in one and the same region under the same parent material and climate. Kaolinitic soils with pH 6.1 to 7.4 on slopes where drainage was good, and a montmorillonitic soil with pH between 8.0 and 8.4 in the plain, where the drainage was poor. Biswas and Gawande (1962) recognised four diversified soils in a catena on sedimentary formations of Chhatishgarh basin in Madhya Pradesh. They also reported that drainage conditions, differential transportation of eroded materials, leaching, translocations and redeposition of mobile constituents influenced the genesis of these soils, Red soil occurs on the top of the mound followed down the slope by yellow matasi, brown dorsa and finally black kankar in the valley position of the slope. Beckmann et al. (1974) reported that, shallow friable red soils (euchrozems) and shallow cracking clays (black earths) occurred in close proximity on basalt hills of Darling downs of Queensland. The euchrozems are mainly restricted to the flat hill crests and are associated with lithosoils. The shallow black earths occur on upper pediment slopes, on small convex crests, and in depressions on flat crests. They attributed the occurrence of these diversified soils in close proximity to their topographic situation and the progressive change in the topography within time. Biswas et al. (1966) studied the catenary soils in Kurnool district of Andhra Pradesh and reported that topography played an important role in the genesis of these catenary soils.

Bhattacharyya et al. (1993) studied the genesis of associated red and black pedons on the Deccan basalts in the Western Ghats on the Bhimashankar plateau, and they reported that red and black pedons were spatialy associatd with similar topography and red soils were formed under the prevailing humid tropical climate. On the contrary black soil belonging to Inceptisol occurred beside red soil under the same humid tropical climate. They attributed the occurrence of black soil adjacent to red soil under the same climatic condition to the micro depressions of the extended hills, and the continuous supply of the bases. As the first weathering product of basic igneous rocks was smectite deposited in the micro depressions of the extended hills with time these sites on hills gradually flattened and thus internal drainage documented over the surface runoff. Manickam et al. (1973) studied the catenary soils of the agricultural farm soils in Madurai and reported that both the red and black soils derived from the same parent material and they attributed their genesis to the differences in topography.

2.1.2 Influence of parent material on the genesis of associated red and black soils

Even prior to the climatic theories of soil formation were propounded, the parent material was attached with a great significance. Many difficulties arose while recognising the material from which soil has been originated. To overcome these hurdles, Jenny (1941) preferred to define parent material as the initial state of soil system and thus avoided special references to the strata below the soil which might or might not be the parent material. The C horizon in a soil is that which may be like or unlike the material from which the solum has developed and that which is relatively little affected by pedogenic processes (Soil Survey Staff, 1975).

The associated red and black soils are originated from a variety of rocks viz., basalt, granite, gneiss, shale and schists. Desai (1942) reported that red and black soils lying close together have been derived from the parent materials of the same composition, the former being definitely sedentary but the latter perhaps transported. Krishnamoorthy and GovindaRajan (1977) studied the associatd red and black soils of Andhra Pradesh, and reported that these complex soils derived from the same parent material granite-geneissic complex with minor difference in their mineralogical composition. Ramaiah and Raghavendrachar (1936) reported that the red and black soils occurring in close proximity in the Tungabhadra command area were derived from the same parent material granite and gneiss. They attributed the genesis of these two diversified soils to the differences in the mineralogical composition of the parent materials. The black soils were derived from the rocks containing soda lime feldspar where as red soils derived from the rocks containing potash feldspar.

Balakrishnan (1955) reported that black and red soils occuring side by side in the Tungabhadra command area derived from the same parent material graite and gneiss and they attributed to the rocks containing minerals of different chemical composition leading to different types of weathering. Bhargava et al. (1973) reported that, diversified soils occur in catenary sequence in the Tungabhadra catchment area are derived from the widely varying geological parent material. Two red pedons except one of colluvial origin have developed from granite - gneiss rock and have under gone prolonged weathering as evidenced by the presence of resistant minerals like garnet and zircon in significant amount. The preponderence of plagioclase feldspar was attributed to the genesis of black soils from the base rich schistose rocks.

2.1.3 Influence of climate on the genesis of associatd red and black soils

The climate is an active factor and is so complex that no single numerical value can be given to a given climate. precipitation and temperature are the two most important components which have specific or combined effect on the genesis of soils. Precipitation governs the air moisture regime of the soils and determine the character and extent of leaching to which soil is subjected. While the temperature influences the rate of chemical reaction organic matter decomposition, microbial activity and finally the efficiency of rainfall through its control on evaporation. Wherever a monsoon type of climate exist there is much seasonal variation in the distribution of rainfall which in turn affects, the soil formation.

Tardy *et al*. (1973) worked on the climatic and topographic sequences from granite and reported that weathering of granite in the region where the relief was not pronounced, the climatic influence could be characterised, by a chain of geochemical phenomena more or less temporary in character but differing in extent. The renewal and dilution of soil solution containing cations like magnesium, hydroxides, salts and silica on the one hand and evaporation and concentration of the soil solution on the other hand were directly influenced by the intensity of rainfall, temperature and thus climate.

Pal and Deshpande (1987) studied the genesis of "red and black complex" soils of south India and they reported that the present day warm semi arid climate is not conducive for the formation of red soils, and they believed that the red soils were formed in an earlier climate more humid than prevailing today. According to Brunner (1970) climate has changed from humid in the past to semiarid climate at the present following crustal movements, during the pliocene-pliestocene transition, which could have influenced the weathering. Ferguson (1954) reported that under humid climatic conditions, transformation of smectite to kaolinite was likey to occur by loss of alkaline earths, and iron from smectite, the iron being stabilised in the upper soil horizons as oxides and hydrated oxide. Once the kaolinitic red soils were produced their nature gave them an advantage over the wholly smectitic soils, in furthering the change for iron oxides coat the clay minerals to produce a preamble soils in which leaching could occur to great depths.

2.2 Morphology

Morphology of soil is the most powerful tool than physical and chemical properties of soil, because it is observed under natural, undisturbed condition. Horizonation appears to be better in the profile at the top of the slope rather than those in the middle and at the foot slope (Biswas et al., 1966). In black pedons distinct horizons are not discernible due to argillopedoturbation, which disturbs the soil horizons and impede the processes of propedanisotropic factor developing the anisotrapic properties within the soil (Bhattacharjee et al., 1974). Clay skins and iron concretions are common in red soils and in black soils cracks, slickensides and gilgais are common features.

2.2.1 Colour

Raychaudhuri (1941) studied the associatd red and black soils of Nyasaland protectorate, British central Africa and reported that colour of the black soil was mainly due to the peculiar state of iron and due to the peculiar type of humification in base saturated soils due to the presence of lime. Harrison and Ramaswamy Sivan (1912) reported that colour and physical properties of the black cotton soils of India are mainly due to the colloidal hydrated double iron and aluminium silicate, which was mainly concerned with the formation of compound particles and which possessed in a modified form the properties of ordinary clay. And the other factor to which they attributed the black colour of soil was organic compound.

Basu and Sirur (1938) reported that soil colour was more related with moisture relationships of soils than with the actual amounts of organic matter present. Fundamentally black coloured soils were usually found on the lowlying situations, where the soils remain moist over a considerable part of the year when compared with the soils on a high level where the colour was usually brown. Many workers reported that morphological featurs of the profiles were in gradation with the topography and drainage,. Down the slope soil colour changed from red at the mound of the slope to gradually yellow, brown, and finally becoming grey at the base of the slope, (Satyanarayana and Biswas, 1970; Biswas and Gawande, 1962).

2.2.2 Other morphological features

Bhattacharyya et al. (1993) studied the genesis of associatd red and black soils on the Deccan basalt in the

Western Ghats and reported that Haplustalfs possessed sub angular blocky structure whereas associated ustropepts and chromusterts had angular blocky structure. They could also observe clay cutans in red pedons and slickensides in black pedons at particular depths. They also reported that cracks developed from surface to C horizon in both red and black pedons.

Biswas and Gawande (1962) reported that calcium carbonate concretions were absent in the upper slope members and the same were abundant in the lower slope members. They attributed the abundance of lime concretions in the black soils for the impeded drainage. They could also observe numerous black shot like concretions in both red and black pedons, but relative proportion of those concretions was more in black pedon than that of associated red pedons. They attributed this to the lateral movement of run off water containing iron and other bases in solution and its subsequent deposition and precipitation in the catenary soils at lower level the iron concretions increased down the depth of the profile in the lower slope members and this may be attributed to the alternate reducing and oxidising conditions caused by seasonal variation in water table.

Pal and Deshpande (1987) reported that clay films were present in the red pedons and the same were absent in the associated black pedons. They also reported that the thickness of clay films on the pedsurface increased with depth from second horizon in the solum of red pedons.

2.3 Physical properties

Raychaudhuri et al. (1942) in Coimbtore, Krishnamoorthy and GovindaRajan (1977) in Rajolibhunda diversion canal area (Andhra Pradesh), and Satyanarayana and Biswas (1970) in Nizamabad (Andhra Pradesh) studied the associated red and black soils and reported that coarse fraction of the soil decreased down the profile and down the slope. Coarse fraction was more in red pedons than that of associated black pedons, as the chemical weathering was less rapid in the red pedons because of acid hydrolysis and good drainage. In black pedons chemical weathering was very rapid and hence the coarse fraction content was very less.

Bhargava et al. (1973) reported that, in red soils clay content increased to the extent of about 21 percent in B horizon because of the high amount of gravels favoured the physical mobility of the finer fraction as a result of percolation water ultimately giving rise to argillic horizons.

Biswas et al. (1966) studied the characteristics of catenary soils in Kurnool district of Andhra Pradesh and reported that the mechanical composition of the soils related with the position of pedons along the slope. They also pointed out that the mechanical eluviation of clay from the profile at the mound of the slope and its subsequent deposition at the foot of the slope afford possible reason for the sandy clay loam texture of the former and the clay texture of the latter.

Pal and Deshpande (1987) and Bhattacharyya et al. (1993) studied the red and black complex soils of South India and reported that fine clay fraction was more than 50 per cent of the total clay in both red and black pedons. Raychaudhuri (1942) reported that black soils possessed higher values of moisture equivalent and imbibitional moisture capacities than the associated red soil, even after the soils treatment with hydrogen peroxide, though the clay content of both the soil types were nearly same and the chemical composition of both the red and black pedon clays were almost identical.

Challa and Gaikwad (1986) studied the catenary soils from Dadra and Nagar Haveli and reported that the bulk density increased down the profile and down the slope. Raychaudhuri (1942) based on the dehydration curves of clay fractions of both red and black pedons reported that black soil clay fraction was because, black soil contained more of bidellite type of clay and the red soil contained more of kaolinitic type of clay.

2.4 Physico-chemical properties

Kulkarni and Deshpande (1970) reported that the red soils were acidic to neutral in reaction and the black *soils* were alkaline in reaction. Bhattacharyya et al (1993) reported that pH of red soils ranged from strongly acid to slightly acid and that of black soil was around neutral. Biswas and Gawande (1962), Satyanarayana and Biswas (1970), Krishnamoorthy and GovindaRajan (1977) reported that pH increased down the slope and ultimately became alkaline in the lower slope members. Bhargava et al. (1973) and Krishnamoorthy and Govinda Rajan (1977) reported that electrical conductivity of black soils was more than that of associated red soils.

Raychaudhuri (1942) reported that buffer curve of black soil was flatter than its associated red soils indicating that black soil possesed greater buffering capacity. He attributed the greater buffering capacity of black soil to its higher content of organic matter and silica.

Many workers reported that cation exchange capacity of black soil was more than that of associated red soil, and the exchange complex was dominated by calcium followed by magnesium, sodium and potassium. Base saturation percentage was also more in black pedons than that of associated red pedons (Desai, 1942; Krishnamoorthy and GovindaRajan 1977; etc).

2.5 Chemical properties

Raychaudhuri et al. (1941) reported that organic carbon content was little more in black soil compared to that of associated red soil. They also reported the C/N ratio was higher in black soils than that of associatd red soils.

Sheshagiri Rao et al. (1992b) studied the free iron oxides in an Alfisol-Vertisol toposequence in Andhra Pradesh and reported that total ferric oxide content of Alfisols increased with depth indicating intense weathering and subsequent loss of bases due to their position at the higher elements of topography. The pattern of total iron in Vertisol was not regular indicating that Vertisols were less weathered than that of Alfisols. Higher amount of Fed in Alfisols than that of vertisols suggested that more amorphous iron (Feo) had been transformed to crystalline iron in Alfisols. The precipitation, and ageing of iron in solution released during weathering of primary and secondary minerals might have produced more Fed in Alfisols which are well drained. Feo/Fed ratio was lower in Alfisols, than that of Vertisols, as the iron changed from amorphous form to crystalline form in Alfisols. Further they reported that the amount of Fed indicated the stage of soil development. They (1992a) also reported that the content of amorphous ferrialumino silicates (AFAS) was more in Alfisols than that of Vertisols. AFAS were more closely associated with fine clay fraction than that of coarse clay fraction in both red and black soils. Silica-alumina ratio of amorphous material varied from 3.01 to 4.05 in Alfisols and 3.14 to 5.26 in Vertisols indicating more siliceous nature of amorphous material of Vertisols.

Desai (1942) reported that in general red soils were devoid of free $CaCO_3$ where as associated black soils were in general rich in free $CaCO_3$. In some cases, however, free $CaCO_3$ was present in small quantity in red soils due to the semiarid climatic condition.

2.6 Chemical composition of soils and clays

Gawande and Biswas (1967), Satyanarayana and Biswas (1970) and Gaikwad, et al. (1974) reported that the red soils were more sesquioxidic where as black soils were more siliceous in nature. As silica being more soluble in the pH range of 6 and 7 (Mohr and Van Baren, 1954) had been more mobilised and transported down the slope and within the profile. The increase in the silica content down the depth of profile might also be due to the transportation of finer soil particles within the profile. Silica, calcium, magnesium and mangenese were lower in the upper slope members, whereas iron aluminium, and potassium were higher in the upper slope members. In lower slope members reverse trend observed.

Satyanarayana and Biswas (1970) reported that the change in chemical composition of non-clay fraction with depth both in red and black soils particularly in profiles in which the most pronounced pedogenic process involved clay migration than clay formation, might reveal the state of uniformity of the parent material. Kulkarni and Deshpande (1970) reported that clays of red soils were more sesquioxidic, where as clays of black soils were more siliceous.

2.7 Mineralogy of associated red and black soils

2.7.1 Sand mineralogy

Pal and Deshpande (1987) reported that sand fraction of red soil consisted mainly of quartz, microcline, plagioclase and sericite as common minerals with amphibole, pyroxene, chlorite, biotite, chloritised biotite, rutile, zircon and magnetite as accessary minerals, where as black soils contained quartz, plagioclase and pyroxene as common minerals with chlorite, microcline, sericite, magnetite, chloritised biotite and amphibole as accessary minerals. Rutile and zircon were found in traces. Sand mineralogy indicatd that both the red and black soils were of granite -gneissic origin. However, they attributed both the gneissic and basaltic rocks to the primary mineral assemblage of black soil considering the geomorphic position of the black pedon in the landscape.

Satyanarayana and Biswas (1970) reported that both the red and black soils derived from the gneissic-dolerite complex as it was revealed by the higher amount of orthoclase feldspars and quartz in the fine sand fractions of both the red and black soils. Many of the easily weatherable minerals namely augite, epidote etc were absent in red soils, where as such minerals were fairly abundant in the black soils of the lower slope. They also pointed out the possibility of washing down of some of minerals from the upper slope and redeposition in the lower slope by erosion.

Krishnamoorthy and GovindaRajan (1977) reported that fine sand fraction of black soil contained comparatively more plagioclase feldspar and ferromagnesium minerals than its associatd red soil. Gaikwad *et al*. (1974) reported that feldspar followed by quartz and few grains of muscovite constituted the light mineral fraction. Within the feldspar group orthoclase was the most dominant one. The feldspar grains were quite angular in red soils and slightly rounded in black soils showing their *in situ* and transported nature from the adjoining slope respectively. The iron ores (heamatite, magnetite and ilmenite) together constituted bulk of heavy minerals followed by epidote, augite, chlorite, hornblende and traces of zircon, tourmaline, rutile and apatite in both red and black sols but in black soil iron ore and chlorite showed increasing trend down the profile where as epidote showed decreasing trend down the profile.

Raychaudhuri *et al*. (1942) reported that the percentage of light and heavy mineral fractions in fine sand samples were almost similar in all the horizons in both red and associated black soils except surface horizons of black soil. The black soil sand fraction contained much of garnet and red soil sand fraction contained much of iron oxides.

2.7.2 Clay mineralogy

Bhattacharyya _et_ _al_. (1993) reported that red pedons were rich in interstratified smectite-kaoline minerals, whereas black pedons were rich in smectite mineral. As the montmorrillonite was the first weathering product of Deccan basalt deposited in the micro-depressions of the extended hills. With time these sites on hills gradually flattened and thus the internal drainage dominated over the surface run off. After the peneplanation, the red soils on a relatively stable surface continued to weather to form interstratified smecitite-kaoline mineral. In contrast black soils in micro depressions had smectite clay, stabilization of smectitic clay in black soil further helped by the continuous supply of bases from zeolites.

Kenchannagowda _et_ _al._ (1966) reported that the black soils were rich in montmorillonitic and illitic clays where as the red soils were rich in the kaolinitic clay. Kaolinite might have developed at the expense of montmorillonite. Gawande _et_ _al_ (1968) reported that the soils of the upper slope members were dominantly illitic (degraded illite) whereas those of the lower slope members were dominantly montmorillonitic. The degraded nature of the illite indicated excessive leaching leading to an advanced stage of laterization (Roy and Landey, 1962).

Pal and Deshpande (1987) reported that in both red and black soils smectite type of clay mineral was dominant; only difference was that chlorite mineral was absent in red soil clay whereas in black soil clay the same was present. The BC horizon of Red soil contained mainly smectite indicating in situ formation from the granite-gneiss. The clay size kaolinite decreased and smectite increased with depth. This suggested kaolinite has possibly developed at the expense of smectite with progresive weathering. The little or no kaolinite in silt and sand fraction probably precluded the formation of clay kaolinite from the partial break down scenario.

Satyanarayana and Biswas (1970) reported that clay fraction of red soils were dominantly illitic whereas associated black soil clay dominated by montmorillonite. They also reported that the potassium bearing minerals of rocks, under the prevailing conditions of the soil formation have led to the formation of illitic type of clay in red soil. High pH, high base saturation percentage, high contents of exchangeable calcium, and magnesium are conducive for the formation of montmorillonitic clay in black soils.

2.8 Classification

The purpose of soil classification is to organise the knowledge there by contributing to the economy of thought and to bring out and understand the relationships among the individuals and classes of population being classified (Buol *et al*., 1980).

Bhargava *et al*. (1973) observed red, black and alluvial soils in a catenary sequence. They put black soils under Inceptisols and red soils under Alfisols at order level. At family level Alfisols were classified as Udic Rhodustalf (Virapuram series) Udic Haplustalfs (Hadagalli series, Ramanagaram series), Vertic Haplustalf (Mylar series), and black soils were classified as Vertic Ustropepts (Hugalur series, Teligi series), and Lithic Vertic Ustropepts (Itigi series).

Gaikwad *et al*. (1974) classified the catenary soils developed on basalt. Top members of the slope were put under Entisols and bottom members under Vertisols at order level, and at great group level top members were clasified as Ustorthents, and bottom members as Chromusterts. Challa and Gaikwad (1986) classified the catenary soils, of Dadra and Nagar Haveli. At order level, Talavli, Saili, Vasona, Dapada

Surangi series were classified as Inceptisols, and were put under Vertic Ustropepts at family level. Whereas Kanadi series was put under Vertisol and Pati series under Entisol at order level. At family level Kanadi series was classified as Typic Chromustert and Pati series as Lithic Ustorthents.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 Physical features of study areas

3.1.1 Location of the study sites

The study sites are located in Bidar, Bheemarayanagudi in Gulbarga district, Raichur, Agricultural college farm Dharwad and Mantagani in Dharwad district (Fig.1). The location and other characteristics of these study sites are given in Table.1.

3.1.2 Climate

Climatic data of study sites is presented in Table 2. Bidar belongs to the North-eastern transitional belt (Zone-1). The climate of this area is semi-arid and is dry throughout the year except during the south-west monsoon. The average annual rainfall of this area is 907 mm. The average annual maximum and minimum temperatures of this area are 31.4°C and 20.8°C, respectively. December is thecoldest month. Bidar site is located 619 m above the mean sea level

Gulbarga belongs to the North-eastern dry zone (Zone-2). The climate of this area is semi-arid. The average annual rainfall of this area is 715.5 mm. Average annual maximum and minimum temperatures are 33.4°C and 21°C

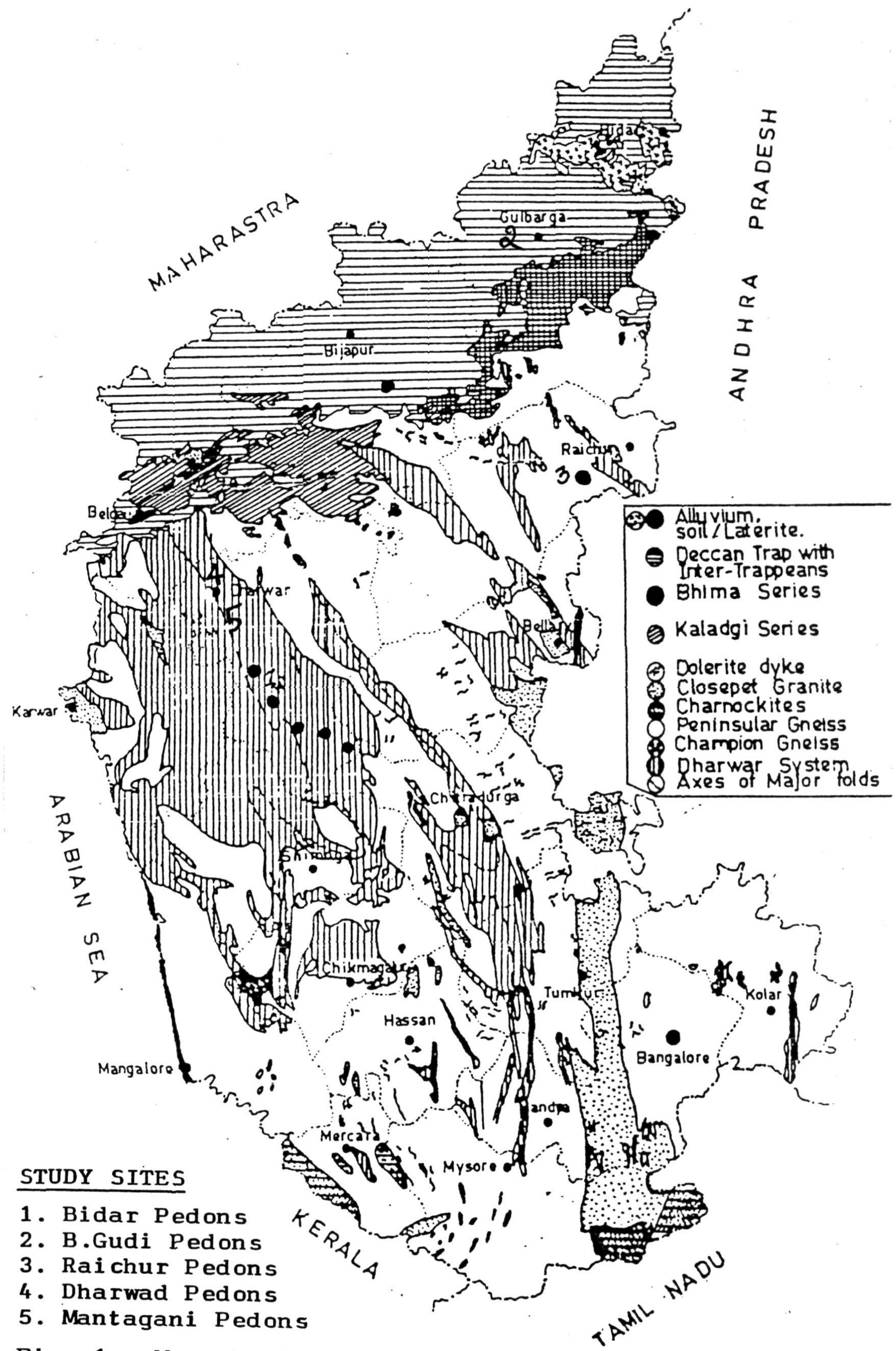

Fig. 1. Map showing geology of study sites

Table 1. Location and site characteristics

Location	Lattitude	Longitude	Agroclimatic zone	Geology	Physiography	Elevation above MSL (m)
Bidar	17°75' N	77°12' E	North-Eastern transitional zone (Zone-1).	Deccan trap	Undulating to roling with borad valleys	619
B.Gudi	16°48' N	76°47' E	North-Eastern dry zone (Zone-2).	Granite gneiss	Nearly level to very gently undulating plains broken by granite hills.	456
Raichur	16°12' N	77°21' E	Northern dry zone (Zone-2).	Granite	Gently sloping to unduluting with cluster of high hills and inselbergs.	397
Dharwad	15°26' N	75°07' E	Northern transitional zone (Zone-8).	Dharwad shale and banded heamatite quartzite(Dharwars)	Unduluting to rolling topography	678
Mantagani	14°58' N	75°21' E	Northern transitional zone (Zone-8).	Chorite schist and banded heama-tite quartzite (Dharwars)	Unduluting to rolling topography	

Table 2. Climatic data of study sites

Months	BIDAR			GULBARGA*			RAICHUR			DHARWAD**		
	Mean rainfall (mm)	Temperature (°C)		Mean rainfall (mm)	Temperature (°C)		Mean rainfall (mm)	Temperature (°C)		Mean rainfall (mm)	Temperature (°C)	
		Maximum	Minimum		Maximum	Minimum		Maximum	Minimum		Maximum	Minimum
January	5.6	28.6	16.8	6.1	30.4	16.0	1.7	30.4	18.2	0.72	29.43	14.36
February	9.4	31.2	18.6	7.1	33.4	18.5	4.3	33.3	20.2	0.08	34.08	15.30
March	11.9	34.9	22.2	9.1	36.8	21.7	4.3	36.9	23.3	7.31	34.90	18.66
April	25.8	38.8	24.6	19.1	39.1	25.0	14.5	39.1	26.1	50.73	36.33	20.46
May	25.1	33.6	25.8	27.9	40.2	26.3	33.3	39.8	26.2	88.49	35.91	20.98
June	126.5	29.2	22.7	106.4	35.0	23.8	88.8	35.2	23.9	108.60	29.25	20.69
July	206.3	29.0	21.3	136.1	31.4	22.5	124.4	32.3	22.8	159.09	26.49	20.48
August	166.6	28.8	21.1	131.6	31.2	22.3	116.4	32.2	22.7	102.68	26.58	20.19
September	238.8	29.8	21.1	185.4	31.1	21.9	148.3	31.1	22.6	101.05	28.09	19.72
October	59.4	28.5	20.8	64.3	31.9	21.0	93.9	32.2	22.3	134.76	29.60	18.68
November	26.7	28.1	18.2	32.5	30.4	17.5	22.0	30.3	19.8	35.52	28.71	15.81
December	5.8	27.3	16.4	4.1	29.5	15.1	4.3	29.3	17.7	50.70	28.62	13.61
Mean	907.9	30.7	20.8	729.7	33.4	21.0	656.2	33.5	22.2	839.73	30.67	18.25

* Represents B.Gudi
** Represents Dharwad and Mantagani

Source : Gazetteers of Bidar (Anon., 1977), Gubarga (Anon., 1966), Raichur (Anon., 1970) and Dharwad (Anon., 1959) districts.

respectively. B.Gudi site is458 m above the mean sea level. March, April and May are the hottest months where as December is the coldest month.

Raichur belongs to the Northern-dry zone (Zone-2). Raichur has semiarid monsoon type of climate. South-west monsoon accounts for 82 per cent of the total annual rain fall. The average annual precipitation is 656.2 mm. Average annual maximum and minimum temperatures are 33.7°C and 22.1°C, respectively. The winter season (November-February) is relatively cool and dry with December being the coldest month. March, April and May are the hottest months. The difference between mean annual summer and mean annual winter temperature is over 5°C, hence the temperature regime is hyperthermic.

Both Dharwad and Mantagani are located with in the Northern-transitional zone (Zone-8). However, mean annual rainfall at Dharwad is considerably greater (836 mm than Mantagani (623 mm). Mean annual maximum and minimum temperatures at Dharwad are 30.7°C and 18.3°C and the corresponding figures for Mantagani are 31.7°C and 20.1°C respectively

3.1.3 Geology

Bidar district is covered by Deccan trap of volcanic origin. A series of eruptions proceeded from fissures and cracks in the surface of the earth from which highly liquid lavas welled out intermitently, obliterating all the previously existing topography of the country (Wadia, 1987). The peculiar subaerial alteration-product known as lateritic surmounts the highest flow of the traps everywhere as a cap, having been produced by a slow meteoric alteration of the basalts (Wadia, 1987).

Geology of Dharwad is comprised of Dharwad shale, banded ferrugenous quartizites, chlorite schist etc. Dharwad rock system belongs to the Archean system. Bulk of the rocks of Dharwad region, are considered to be of sedimentary in origin. Geology of Mantagani is covered by chloritic schist of the precambrian period, and banded heamatite quartzite. Chlorite schists were all decidedly older than the gneisses, of igneous volcanic derivation, being in fact strictly basic lava-flows metamorphosed into hornblende and chlorite schist (Wadia, 1987)

Geology of Raichur is of Archean type. The entire area in Raichur is made up of peninsular complex. Geological formation of this area is of granitic complex. The granites are pink to grey colour, coarse to medium grained. The northern and southern portion of Raichur consist of pink series, the middle portion of Raichur consist of grey series. In the peninsular complex the grey series are older than pink series, which show intrusive relationship. In addition to granite, sandstone, quartzite, and schist of precambrian period also exist in Raichur (Anon, 1970).

B.Gudi site occurs within the granite-gneissic complex which are variable in mineral composition, containing microcline, oligoclase, quartz and biotite. Peninsular gneisses bear an intrusive relation ship with the Dharwars. Two types, a grey and a pink with their own respective pegamatites have been recognised. The grey gneiss is conspicuously banded and developed in force on the hilly tracts north of Shorapur and Shahapur. Pink fine grained gneisses occur extensively to the north of Sagar and Rastapur (Anon., 1966).

3.1.4 Land form, Relief and Drainage

Bidar is a part of northern maidan and is characterised by undulating to rolling landscape, with broad based valleys. Lateritic red soils are located in the upper pediments of the slope and hence they are well drained, whereas black soils are located in the lower elements, and in the valleys and hence the drainage ranges from moderate to poor.

Granite-gneissic terrain is characterised by nearly level to very gently undulating plains, broken by granitic hills, and devoid of vegetation (Anon., 1966).

In Raichur landscape is gently sloping to undulating with 1 to 5 per cent slope gradient. Cluster of high hills and inselbergs are commonly seen. The relief is excesive in undulating granite and quartzite landscape near hills. Relief is normal in gently sloping midlands and in the flat areas, where the lands are nearly level, the relief is subnormal. The gneissic region is generally more or less broken and covered with a thin mantle of red loamy soil (Anon, 1970).

Dharwad and Mantagani have undulating to rolling topography with frequent mound-like features. Soils on the rolling topography are severely affected by erosion. Isolated hills and hill ranges are also seen. These hills generally have flat tops and gradually slope towards the black *soil* plains. The soils at the flat top of hills are well drained, and the black soil plains at the footslope and toeslope are poorly drained (Anon., 1959).

3.1.5 Natural Vegetation

The natural vegetation in Bidar and Gulbarga is of tropical dry deciduous type. Important species are Anona squamosa, Acacia arabica, Tamarindus indica, Zygypous xylopora etc (Subramaniam, 1964). The natural vegetation in Raichur, is tropical thorn forest. Dharwad and Mantagani have tropical moist deciduous type of vegetation. The important species are both shrubs and trees. Shrubs are Butea superba, Gardenia gummifers, Zizypus xylopora, Anona squamosa, Cassia auriculata Tree species are Cassia fistula, Tamarindus indica, Pongamia glabra, Terminalla tomentosa, Mangifera indica, Prosophis juliflora (Subramaniam, 1964). Acacia arabica and Azadiracta indica are the common species usually grown on black and red soils respectively.

3.2 Site characters and description of pedons

The terminology used for the description of study site and pedons are as per the Soil Survey Staff (1951).

Pedon -1 (Bidar Red)

Location: Neelamhalli, about 20 Km away from Bidar city towards Gulbarga on the road side.

Natural Vegetation: Tropical dry deciduous.

Physiography: Gently sloping.

Slope: 1 to 2%.

Drainage: well drained.

Erosion: Moderate.

Geology: Deccan trap.

Present land use: Cultivated land (paddy, Jowar, Bengal-gram).

Horizon	depth(cm)	Profile description
Ap	0-9	Reddish brown (2.5YR 4/4 dry) clay; reddish brown to darkreddish brown (2.5 YR 3.5/4 moist); moderate, fine granular; hard, friable, sticky; common, medium pores; common, medium, roots; clear, smooth boundary.
Bt_1	9-30	Reddish brown (2.5 YR 4/4 dry) clay;dark reddish brown (2.5 YR 3/4 moist); moderate, coarse, subangular blocky; slightly hard, friable, very sticky and very plastic; common, fine to medium pores; common, fine roots; coarse fragments about 20 per cent; clear, smooth boundary.
Bt_2	30-43	Red to reddish brown (2.5 YR 4/5 dry) clay; red to dark red (2.5 YR 3/5 moist); moderate, coarse, subangular blocky; slightly hard, friable, very sticky, and

		very plastic; common, fine to medium pores; few, fine roots; coarse fragments about 10 per cent; diffuse, smooth boundary.
Bt_3	43-55	Reddish brown (2.5 YR 4/4 dry) clay;dry dark reddish brown (2.5 YR 3/4 moist); weak, coarse, subangular blocky; slightly hard, friable, sticky; and very plastic; few, fine roots; coarse fragments about 40 per cent; diffused, smooth boundary.
C	55+	Yellowish red (5 YR 4/6 dry and moist) gravelly clay; lateritic material.

Pedon -2 (Bidar Black)

Location: Neelamhalli about 20 Km away from Bidar city towards Gulbarga on the road side.

Natural vegetation: Tropical dry decidious.

Physiography: Nearly level.

Slope: 1%.

Erosion: Slight.

Drainage: Moderately well drained.

Geology: Deccan trap.

Present land use: Cultivated land (paddy, bengalgram).

Horizon	Depth(cm)	Profile description
Ap_1	0-14	Dark greyish brown (10 YR 4/2 dry) clay; dark greyish brown to very dark greyish brown (10 YR 3.5/2 moist); weak, medium, angular blocky; hard, firm, sticky and plastic; common, fine, pores; common, medium to fine roots; few, fine, lime nodules; slight efferevescence with dilute HCl; clear, smooth, boundary.
A_2	14-35	Dark greyish brown (10 YR 4/2 dry) clay; dark greyish brown to very dark greyish brown (10 YR 3.5/2 moist); weak, medium, angular blocky; hard, firm, sticky and plastic; common, fine, pores; few, fine, roots; few, fine, lime nodules; slight efferevescence with dilute HCl; clear, smooth, boundary.
A_3	35-54	Dark greyish brown (10 YR 4/2 dry moist) clay; weak, medium, angular blocky; indistinct, non-intersecting slickensides; very hard, firm, sticky and plastic; common, fine, pores; few, very fine,

		roots; few, very fine, lime nodules; slight efferevescence with dilute HCl; gradual, smooth boundary.
A_4	54-68	Dark greyish brown to very dark greyish brown (10 YR 3.5/2 dry and moist) clay; strong, medium, angular blocky; indistinct, non intersecting slickensides; very hard, firm, sticky and plastic; common, fine, pores; few, very fine, roots; few, fine lime nodules; slight efferevescence with dilute HCl; gradual, smooth boundary.
A_5	68-94	Dark brown (10 YR 4/5 dry and 10 YR 3.5/3 moist) clay; strong, medium angular blocky; prominent, intersecting slickensides; hard, firm, sticky and plastic; common, fine pores; common, fine, lime nodules; slight efferevescence with dilute HCl; gradual, smooth boundary.
A_6	94-118	Dark brown (10 YR 4/3 dry and moist) clay; strong, medium, angular blocky; prominent, intersecting, slickensides; hard, firm,

		sticky and plastic; common, fine, pores; common, fine lime nodules; strong efferevescence with dilute HCl; clear, smooth, boundary.
A_7	118-140	Brown to dark brown (10 YR 4.5/3 dry) clay; dark brown (10 YR 4/3 moist); moderate, medium angular blocky; very prominent, intersecting slickensides; hard, firm, sticky and plastic; common, fine lime nodules; strong efferevescence with dilute HCl; diffuse, smooth boundary.
A_8	140-160	Dark brown (10 YR4/3 dry 10 YR 3.5/3 moist) clay; moderate, medium angular blocky; very prominent, intersecting slickensides; hard, firm, sticky and plastic; common, fine lime nodules; strong efferevescence with dilute HCl; gradual, smooth, boundary.
A_c	160-177	Dark yellowish brown (10 YR 4/4 dry and 10 YR 3.5/4 moist) clay; moderate, medium *subangualr bolcky; indistinct, slicken-*sides; hard, firm, sticky and slightly

plastic; common, fine to medium lime nodules; strong efferevesence with dilute HCl; diffuse, smooth boundary.

C 177+ Yellowish brown (10 YR 5/6 dry) clay; dark yellowish brown (10 YR 4.5/6 moist); moderate, medium subangular blocky; slightly hard, firm, slightly sticky and slightly plastic; common, medium lime nodules; violent efferevescence with dilute HCl; coarse fragments about 25 per cent.

Additional Notes

Red and black pedons are situated within a distance of 10 m. Within 0.4 ha of land about 4 to 5 patches of red and black soils were seen.

Pedon -3 (B.Gudi Red)

Location: 150 m north of Agricultural Research Station Farm B.Gudi boundary.

Natural vegetation : Tropical dry deciduous.

Physiogrophy: Gently sloping to gently undulating.

Slope : 1 to 2 per cent.

Erosion : Moderate.

Drainage : Well drained.

Geology : Granite-gneiss.

Present land use: Groundnut.

Horizon	Depth(cm)	Profile description
Ap_1	0-11	Reddish brown (5 YR 4/3 dry) sandyloam; dark reddish brown (5 YR 3/3 moist); weak, medium subangular blocky; slightly hard, friable, slightly sticky; common, medium pores; common, medium and fine, roots; clear, smooth boundary.
Bt_1	11-24	Reddish brown (5 YR 4/3 dry) sandyloam; dark reddish brown (5 YR 3/3 moist); weak, medium subangular blocky; thin patchy clay skins on ped surface; slightly hard, very friable, slightly sticky; common, fine roots; common, medium pores; clear, smooth boundary.
Bt_{12}	24-47	Dark reddish brown (5 YR 3/3 dry and moist) sandy clay loam; weak, coarse subangular blocky; thin patchy clay skins on ped surface; slightly hard, very friable, slightly sticky and slightly

		plastic; common, coarse pores; few, fine roots; coarse fragments about 20 per cent; gradual, smooth boundary.
Bt_2	47-67	Reddish brown (5 YR 5/3 dry and 5 YR 4.5/3 moist) sandy clay loam; weak, very coarse, subangular blocky; thin patchy clay skins on ped surface; slightly hard, very friable, and sticky; coarse fragments about 50 per cent; gradual, smooth boundary.
Bc	67-92	Reddish brown (5 YR 5/3 dry and moist) sandy clay loam; weak, very coarse subangular blocky; thin patchy clay skins on ped surface; slightly hard, very friable, slightly sticky; coarse fragments about 20 per cent; gradual, smooth boundary.
C	>92	Yellowish red (5 YR 5/6 dry and moist) sandy loam; weak, very coarse, subangular blocky; soft, friable, non sticky; coarse fragments about 25 per cent.

Pedon -4 (B.Gudi Black)

Location: C block of the Agricultural Research Station Farm, B.Gudi.

Natural Vegetation :Tropical dry deciduous.

Physiography :Nearly level to gently sloping midland.

Slope : 1 to 2 per cent.

Erosion : Slight.

Drainage : Moderately well drained.

Geology : Granite-gneiss.

Present land use: Cultivated land (Jowar, red gram sunflower, Bengal gram).

Horizon	Depth (cm)	Profile discription
Ap_1	0-9	Dark grey (10 YR 4/1 dry) clay; very dark grey (10 YR 3/1 moist); strong, medium subangular blocky; hard, firm, slighty sticky and plastic; common, fine to medium pores; common, medium roots; few, fine lime nodules; slight efferevescence with dilute HCl; clear, smooth boundary.
A_3	9-27	Dark grey (10 YR 4/1 dry) clay;very dark grey (10 YR 3/1 moist); strong, medium subangular blocky; pressure faces on ped

		surface; common, fine, pores; hard, firm, slightly sticky and plastic; common, fine lime nodules; strong efferevescence with dilute HCl; clear, smooth boundary.
A_3	27-49	Dark grey (10 YR 4/1 dry) clay; very dark grey (10 YR 3/1 moist); strong, fine, angular blocky; prominent, intersecting slickensides; hard, firm, sticky and plastic; few, fine roots; common, fine lime nodules; strong efferevescence with dilute HCl; gradual, smooth boundary.
A_4	49-80	Dark grey (10 YR 4/1 dry) clay; dark grey to very dark grey (10 YR 3.5/1 moist); strong, medium, angular blocky; prominent, intersecting slickensides; hard, firm, sticky and plastic; few, fine roots; common, fine pores; common, fine to medium lime nodules; strong efferevescence with dilute HCl; coarse fragments about 10 per cent; gradual, smooth boundary.
A_5	80-118	Very dark grey (10 YR 3/1 dry and moist) clay; strong, medium angular blocky;

		prominent, intersecting slickensides; hard firm sticky and plastic; few, fine roots; common, fine pores; comon, fine to medium lime nodules; strong efferevescence with dilute HCl; clear, smooth boundary.
Ac	118-132	Dark grey (10 YR 4/1 dry and moist) clay; strong, medium subangular blocky; indistinct, non interesecting slickensides; hard, firm, slightly sticky and plastic; common, medium lime nodules; violent efferevescence with dilute HCl; coarse fragments about 30 per cent; clear, smooth boundary.
Cca	132-186	Weathered gneiss with abundant $CaCO_3$ nodules

Pedon-5 (Raichur Red)

Location: 150 m to the south of agricultural college building at Raichur in agroforestry block.

Natural vegetation : Tropical thorn forest.

Physiogrophy: Gently sloping.

Slope : 1-2%.

Drainage : Well drained.

Erosion : Moderate.

Geology : Granite.

present land use : Casurrina.

Horizon	Depth (cm)	Profile description
Ap_1	0-10	Reddish grey (5 YR 5/2 dry) sandy loam; dark reddish grey (5YR 4/2 moist); weak, fine, subangular blocky; slightly hard, very friable, slightly sticky and non plastic; common, medium, roots; clear, smooth boundary.
Bt_1	10-22	Reddish grey (5 YR 5/2 dry) sandy clay loam; dark reddish grey (5 YR 4/2 moist); loam; weak, fine subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; clear, smooth boundary.
Bt_2	22-43	Dark reddish grey (5 YR 4/2 dry) clay; dark reddish brown (5 YR 3/2 moist); moderate, medium subangular blocky; thin patchy clay skins on ped surface; hard, friable, sticky and plastic, diffuse, smooth boundary.

Bt_3	43-65	Dark reddish brown (5 YR 3/2 dry and moist) clay; moderate, medium subangular blocky; thin patchy clay skins on ped surfaces; hard, friable, sticky and plastic; diffuse, smooth boundary.
Bc	65-76	Dark reddish brown (5 YR 3/2 dry and moist) clay loam; weak, fine subangular blocky; hard, friable, sticky and plastic; coarse fragment about 65 per cent; clear, smooth boundary.
C	76-100	Sandy clay loam; massive; loose, very friable, slighty sticky and slightly plastic.

Pedon-6 (Raichur Black)

Location : In the Soil Science experimental block to the east of RRS building.

Natural vegetation : Tropical thorn forest.

Physiography : Nearly level.

Slope : 1%.

Drainage : Moderately well drained.

Errosion : Slight.

Geology : Granite.

Present land use :Cultivated land (Sunflower).

Horizon	Depth(cm)	Profile description
Ap	0-18	Dark grey brown (10 YR 4/2 dry) clay; very dark grey brown (10 YR 3/2 moist); weak, fine subangular blocky; very hard, firm, sticky and plastic; common, medium roots; few, fine lime nodules; slight efferevescence with dilute HCl; diffuse, smooth boundary.
A_2	18-42	Dark grey (10 YR 4/1 dry) clay;very dark grey (10 YR 3/1 moist); platy, breaking to moderate, medium subangular blocky; hard, firm, very sticky, and plastic; common, medium roots; common, fine lime nodules; slight efferevescence with dilute HCl; diffuse, smooth boundary.
A_3	42-70	Dark greyish brown (10 YR 4/1 dry and moist) clay; moderate, medium subangular blocky; prominent, slickensides; hard, very firm, very sticky and very plastic; few, fine to medium roots; common, medium

		lime nodules; strong efferevescence with dilute HCl; diffuse, smooth boundary
A_4	70-150	Dark greyish brown (10 YR 4/2 dry and moist) clay; moderate, coarse angular blocky; prominent slickensides; hard, very firm, very sticky and very plastic; abundant lime nodules; strong efferevescence with dilute HCl; abrupt, smooth boundary.
2C	150-180	Sandy loam, abundant lime nodules.

Pedon -7 (Dharwad Red)

Location : Near library block of Univesity of Agricultural Sciences Dharwad.

Natural vegetation : Tropical moist deciduous.

Physiogrophy : Gently sloping.

Slope : 1 to 3 per cent.

Erosion : Slight.

Drainage : Well drained.

Geology : Dharwad shale and BHQ Complex.

Present land use :Cultivated land (Maize).

Horizon	Depth(cm)	Profile description
Ap	0-12	Reddish brown (5 YR 4/4 dry) sandy clay loam;dark reddish brown (5 YR 3/3 moist);

		moderate, medium subangular blocky; very hard, friable, slightly sticky and plastic; common, coarse, roots; coarse, fragments about 20 per cent; clear, smooth boundary.
Bt_1	12-32	Reddish brown (5 YR 4/4 dry) clay;dark reddish brown (5 YR 3/3 moist); moderate, medium subangular blocky; very hard, friable, sticky and plastic; common, coarse roots; coarse fragments about 15 per cent; clear, smooth boundary.
B_2	32-6-	Reddish brown (5 YR 4/4 dry) clay; dark reddish brown (5 YR 3/3 moist); weak, fine subangular blocky; slightly hard, friable, sticky and plstic; few, fine roots; coarse fragments about 50 per cent; diffuse, smooth boundary.
BC	60-150	Reddish brown (5 YR 4/3 dry and moist) clay loam; weak, fine subangular blocky; slightly hard, friable, slightly sticky and plastic; coarse fragments about 50 per cent; diffuse, smooth boundary.

C	> 150	Yellowish red (5 YR 4/6 dry and moist) clay loam; weak, fine subangular blocky; very hard, friable, slightly sticky and plastic; coarse fragments about 50 per cent.

Pedon-8 (Dharwad Black)

Location : D block of College farm, University of Agricultural Sciences,Dharwad.

Natural vegetation :Tropical moist deciduous.

Physiogrophy: Gently sloping.

Slope : 1-2 per cent.

Erosion : Slight.

Drainage : Moderately well drained.

Geology : Dharwad shale and BHQ complex.

Present land use: Cultivated land (jowar, groundnut, cotton and chilli).

Horizon	Depth(cm)	Profile description
Ap	0-16	Dark brown (10 YR 4.5/2 dry and 10 YR 4/2 moist) clay; strong, medium subangular blocky; hard, firm, sticky and plastic; medium, common pores; common, medium roots; few, fine lime nodules; slight

efferevescence with dilute HCl; clear, smooth boundary.

A_2	16-35	Dark greyish brown (10 YR 4/2 dry) clay; dark greyish brown to very dark greyish brown (10 YR 3.5/2 moist); strong, medium subangular blocky; common, pressure faces; hard, very firm, sticky and plastic; many, fine pores; common, fine roots; few, fine lime nodules; slight efferevescence with dilute HCl; gradual, smooth boundary.
A_3	35-55	Grayish brown to dark greyish brown (10 YR 4.5/2 dry) clay; dark greyish brown (10 YR 4/2 moist); strong, medium subangular blocky; prominent, intersecting, slickensides; hard, firm, stickey and very plastic; many, fine pores; few, fine roots; common, fine to medium, lime nodules; strong efferevescences with dilute HCl; diffuse, smooth boundary.
A_4	55-85	Dark greyish brown to very dark greyish brown (10 YR 3.5/2 dry) clay;very dark greyish brown (10 YR 3/2 moist); strong,

		medium subangular blocky; prominent, intersecting, slickensides; hard, firm, very sticky and very plastic; few, fine roots; common, medium lime nodules; strong efferevescence with dilute HCl; diffuse, wavy boundary.
A_5	85-105	Dark greyish brown (10 YR 4/2 dry and 10 YR 3.5/2 moist) clay; strong, medium subangular blocky; very prominent, slickensides; hard, firm, sticky and plastic; few, fine roots; common, medium lime nodules; strong efferevescence with dilute Hcl; diffuse, wavy boundary.
A_6	105-125	Dark greyish brown (10 YR 4/2 dry) clay; dark greyish brown to very dark greyish brown (10 YR 3.5/2 moist); strong, medium; subangular blocky; very prominent, interesecting slickensides; hard, firm, sticky and plastic; few, very fine roots; many, medium lime nodules; strong efferevescence with dilute HCl; diffused, wavy boundary.

C 125+ Yellowish brown (10 YR 5/4 dry) gravelly clay; dark yellowish brown (10 YR 4/4 moist); weak, medium subangular blocky; slightly hard, firm, slightly sticky and plastic; abundant, medium lime nodules; violent efferevescence with dilute HCl; coarse fragments about 50 per cent.

Additional Note

Black pedon is situated at somewhat higher elevation compared to that of red counterpart.

Pedon - 9 (Mantagani Red)

Location : Mantagani village at Shiggon taluk in Dharwad district.

Vegetation : Tropical moist deciduous.

Physiogrophy : Slopy.

Slope : 3 to 5 per cent.

Erosion : Moderate.

Drainage : Well drained.

Geology : Chloritic schist (Dharwars).

Present land use :Cultivate land (Chilli, Jowar).

Horizon	depth(cm)	Profile description
Ap	0-16	Reddish brown 5 YR 4/4 dry) clay; dark reddish brown (5 YR 3/4 moist); moderate,

		medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; common, coarse roots; common, medium pores; clear, smooth boundary.
B_1	16-30	Dark reddish brown (5 YR 3/4 dry and moist) clay; weak, medium subangular blocky; pressure faces on ped surfaces; hard, friable, sticky and plastic; clear, smooth boundary.
B_1t_1	30-50	Dark reddish brown (2.5 YR 3/4 dry and moist) clay;weak, medium subangular blocky; pressure faces on ped surfaces; slightly hard, friable, slightly sticky and plastic; few, fine roots; coarse fragments about 10 per cent; clear, smooth boundary.
B_2	50-70	Light reddish brown (2.5 YR 5/4 dry and moist) clay; moderate, fine subangular blocky; pressure faces on ped surfaces; slightly hard, friable, sticky and slightly plastic; coarse fragments about 25 per cent; clear, wavy boundary.

C	>70	Light reddish brown (2.5 YR 6/4 dry and moist) sandy loam; weak, medium subangular blocky; soft, friable, slightly sticky and slightly plastic; coarse fragments about 50 per cent.

Pedon -10 (Mantagani Black)

Location: Mantagani village in Savanur taluk in Dharwad district.

Vegetation : Tropical moist deciduous.

Physiography: : Nearly level plain.

Slope : 1 per cent.

Erosion : Slight.

Drainage : Imperfectly drained.

Geology : Chlorite schist (Dharwars).

Present land use: Cultivated land (cotton, chilli and jowar).

Horizon	Depth (cm)	Profile description
Ap_1	0-15	Dark greyish brown (10 YR 4/2 dry) clay; dark greyish brown to very dark greyish brown (10 YR 3.5/2 moist); moderate, medium granular; hard, firm, sticky and plastic; common, fine to medium pores; common, medium roots; few, very fine lime

nodules; slight efferevescence with dilute HCl; clear, smooth boundary.

A_2	15-35	Dark greyish brown (10 YR 4/2 dry) clay; very dark greyish brown (10 YR 3/2 moist); moderate, medium subangular blocky; indistinct, non intersecting slickensides; hard, firm, sticky and plastic; common, fine pores; common, fine to medium roots; few, fine lime nodules; slight efferevescence with dilute HCl; clear, smooth boundary.
A_3	35-60	Dark greyish brown (10 YR 4/2 dry and moist) clay; strong, medium subangular bolcky; prominent, intersecting slickensides; hard, very firm, very sticky and plastic; common, fine pores; few, fine roots; few, medium lime nodules; strong efferevescence with dilute HCl; gradual, smooth boundary.
A_4	60-80	Grayish brown (10 YR 5/2 dry) clay; dark greyish brown (10 YR 4/2 moist); strong, medium subangular blocky; prominent,

		intersecting slickensides; hard, very firm, very sticky and plastic; many very pores; few fine, roots; few, fine to medium, lime nodules; strong efferevescence with dilute HCl; gradual, smooth boundary.
A_5	80-100	Dark greyish brown (10 YR 4/2 dry) clay; very dark greyish brown (10 YR 3/2 moist); strong, medium, subangular blocky; prominent, intersecting, slickensides; hard, very firm, very sticky and plastic; many, fine, pores; few, fine to medium, lime nodules; strong efferevescence with dilute HCl; diffuse, smooth boundary.
A_6	100-130	Dark greyish brown (10 YR 4/2 dry) and very dark greyish brown (10 YR 3/2 moist) clay; moderate, medium subangular blocky; prominent, intersecting, slickensides; hard, firm, very sticky and plastic; few, fine pores; few, medium lime nodules strong efferevescence with dilute HCl; gradual, smooth boundary.

A_7	130-153	Yellowish brown (10 YR 5/4 dfry) clay; dark yelowish brown (10 YR 4/4 moist); storng, medium subangular blocky; prominent, intesecting slickensides; hard, firm, sticky and plastic; medium, fine pores; common, fine to medium lime nodules; strong efferescence with dilute HCl; clear, wavy boundary.
A_8	153-170	Yellowish brown (10 YR 5/4 dry) clay; dark yellowish brown (10 YR 4/4); moderate, medium subangular blocky; prominent, intersecting slickensides; hard, firm, sticky and plastic; many, medium lime nodules. violent efferevescence with dilute HCl; clear, smooth boundary.
AC	170-185	Dark yellowish brown (10 YR 4/4 dry and 10 YR 3.5 /4 moist) clay; moderate, medium subangular blocky; indistinct, slickensides; slightly hard, firm, sticky and slightly plastic; common, medium lime nodules; violent efferevescence with dilute HCl; coarse fragments about 15 per cednt; clear, smooth boundary.

C 185-235 Yellowish brown (10 YR 5/6 dry and moist) gravelly clay; weak, medium, subangular blocky; slightly hard, firm, slightly sticky and slightly plastic; abundandant, medium lime nodules; violent efferevescence with dilute HCl; coarse fragments about 50 per cent.

Additional Note

Within a short distance of 50 feet both red and black pedons were situated. In both the pedons cracks were present. Near by these study sites Varada river flows. Red pedon patch ran in between two extensive black pedon patches.

3.3 Methods of soil analysis

3.3.1 Preparation of soil samples

Soil samples were collected horizon wise from each profile. These samples were dried under shade. These were ground in a wooden pestle and mortar, and then passed through 2 mm sieve. The mineral material left on the 2 mm sieve was considered as gravels. They were washed, dried, weighed and expressed as percentage of total soil. Two mm sieved soil samples were stored in polythene jars, for the various soil analysis. A portion of sample was drawn from the 2 mm sieved soil and was ground in a agate mortar and then passed through 0.2 mm sieve (70 mesh). These samples were stored in butter paper bags for the analysis of organic carbon, dithionite extractable iron, oxalate extractable iron and surface area of soil.

3.3.2 Physical properties

Particle size analysis

Particle size analysis was done by International pipette method (Piper, 1966) using 1 N sodium hydroxide as a dispersing agent. The treatment with 1 N hydrochloric acid was skipped in case of red soils. From the dispersed suspension, an aliquot of clay plus silt and clay were pipetted at 10 cm depth after a lapse of specified time depending on temperature. The total sand was obtained by repeated decantation using a tall beaker. The total sand was passed through different sized sieves to quantify very coarse sand (> 1 mm), coarse sand (1.0 to 0.5 mm), medium sand (0.5 to 0.25 mm), fine sand (0.25 to 0.1 mm), and very fine sand (0.1 to 0.05 mm). The fraction that was finer than 0.05 mm was added to silt determined initially by pipetting.

Determination of fine clay

An aliquot containing suspension of clay and silt was centrifuged at a specified period of time employing a speed of 2500 rpm to separate the fine clay (< 0.2 μm).The time required for centrifugation has been calculated by means of a formula (Jackson, 1969).

$$t \text{ (minutes)} = \frac{63.0 \times 10^8 \times \eta \times \log R/S}{(N)^2 \times (r)^2 \times (PD-1)}$$

Where R = Radius of rotation of the top of the sediment in the tube (cm).

R = Radius of rotation of the surface of the suspension in the tube (cm).

N = 2500 rpm

r = particle radius

η = 0.00935 Viscocity of the medium (poise)

Twenty ml of suspension was pipetted out into a cleaned container, and was oven dried. This was weighed as fine clay.

Bulk density

Bulk density of soils was determined by clod method using saran as a coating resin. Saran solution was prepared by dissolving one part of Dow Saran F-310 in seven parts by weight of methyl-ethyl ketone for black soils. For red soils the corresponding ratio employed was 1:4 (Brasher et al., 1966).

Moisture retention capacity of soils at 33 Kpa and at 1500 Kpa

Moisture retention capacity of soils at 33 Kpa and 1500 Kpa was determined by using pressure plate appraratus (Richards, 1954).

Specific surface area

One gram of 0.2 mm (80 mesh) soil was oven dried for 24 hrs. The dried soil was saturated with three ml of EGME (Ethyle Glycol Monoethyl Ether), and then kept in an evacuating desiccator, and evacuated for 45 minutes by applying pressure using suction pump and the sample was weighed three hours after shutting the pump. Evacuation was repeated until a constant weight was obtained. The specific surface area was computed from the quantity of EGME retained (Carter et al., 1965).

3.3.4 Physico-chemical properties.

Soil reaction (pH)

pH of the soil samples was determined in 1:2 soil-water suspension and 1:2 soil-KCl solution using Elico model LI-10T pH meter (Jackson, 1967).

Electrical conductivity (EC)

Electrical conductivity of 1:2 soil-water extract was determined on a conductivity bridge (Systronics 304, digital direct reading conductivity-bridge).

Cation exchange capacity (CEC)

Cation exchange capacity of soils was determined, using 1 N sodium acetate (pH 8.2) as described by Richards (1954).

Exchangeable cations

The exchangeable cations were extracted using 1 N ammonium acetate (Thomas, 1982). From the extract, the exchangeable sodium and potassium were determined by using a flame photometer (Jackson, 1967), and exchangable calcium plus magnesium were determined by standard EDTA titration using Erichrome Black-T (EBT) indicator. Calcium was separately determined using muroxide indicator (Jackson, 1967). Magnesium was estimated by deducting calcium from calcium plus magnesium.

3.3.5 Chemical properties

Organic Carbon

Finely ground (70 mesh) soil samples were analysed for organic carbon content as per the Walkley and Black's wet oxidation method, using ferroin as an indicator (Jackson, 1967).

Calcium Carbonate

It was estimated by rapid titration method using bromothymol blue indicator (Piper, 1966).

$BaCl_2$- TEA Extractable acidity

Ten grams of soil (< 2 mm) was leached with a solution containing 0.5 N $BaCl_2$ and 0.055 N TEA, neutralized to pH 8.9 with HCl. The rsulting acidity due to the replacement of H^+, Al^{3+} and dissociation of acidic groups was neutralized by weak base triethonalamine (TEA). The left over weak base was determined by titrating against 0.2 N HCl, using mixed indicator bromocresol green-methyl red. The end point observed was in the range of green-purple (Thomas, 1982).

Dithionite extrtactable iron (Fed)

Fed was extracted by dithionite-citrate-bicarbonate after digesting on water bath at 80°C for 15 minutes with intermittent stirring (Mehra and Jackson, 1960). Fed in the extract was determined colorimetrically using orthophenanthroliene after reducing with hydroxyleamine hydrochloride. Absorption was read at 510 nm in spectronic 21D.

Oxalate extractable iron (Feo)

Acid ammonium oxalate method was employed to determine oxalate extractable iron. Feo was extracted under dark condition. Finely ground (70 mesh) 0.25 g soil was taken in a 50 ml centrifuge tube to which 10 ml of ammonium oxalate solution was added and centrifuge tube was covered by black polythene sheet to create darkness. It was shaken for 4 hrs, and then centrifuged. Centrifugant containing Feo was decanted into vials for further analysis (Schewertmann, 1973). Feo content in the centrifugant was determined using Atomic Absorption Spectrometre (AAS).

3.3.6 Chemical composition of fine sand

The method employed for the total elemental analysis was HF-$HClO_4$ decomposition (Jackson, 1967). Finely ground 0.1 g oven dried fine sand was weighed in to a platinum crucible. It was treated with Conc. HNO_3, perchloric acid and hydrofluric acid, 20 ml each and was digested at approximately 225° C, for specified period and then cooled and the inner walls of platinum crucibles were washed with 25 ml of 6 N HCl and then volume was made up to 50 ml with distilled water.

Na_2O and K_2O

From the acid digested extractant Na and K was estimated using flame photometre.

CaO and MgO

Appropriate aliquot was taken from the $HClO_4$-HF extract and then treated with 2 per cent zirconium oxychloride to avoid interfering ions, and then versanate titration method was followed (Jackson, 1967) to estimate calcium plus magnesium and calcium. Magnesium content was estimated by deducting calcium from calcium plus magnesium.

Fe_2O_3

Appropriate aliquote was taken from the $HClO_4$-HF extract and then treatd with required amount of 5 N NH_4OAc. Fe_2O_3 content was determined colorimetrically using orthophenanthroliene as an indicator after reducing with hydroxyleamine hydrochloride. To which required amount of 6 N HCl was added to maintain the pH of solution in between 3 to 5 (Olson, 1965). The transmittancy was read in spectronic 21-D at 510 nm.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The morphological, physical and chemical properties of red and associatd black soils are presented under the following headings.

- Morphological features.
- Physical properties.
- Physico-chemical properties.
- Chemical properties.
- Chemical composition of fine sand.

4.1 Morphological features of soils

The detailed morphological features of these complex soils are given in chapter-III and the salient morphological features are presented in Table 3.

In general red pedons were shallower than that of associated black pedons, except Dharwad red pedon where reverse was true. All the black pedons were very deep. Bidar and Mantagani red pedons were deep and the remaining red pedons were very deep. Among the red pedons Dharwad pedon was the deepest (150 cm), followed by B.Gudi (92 cm) Raichur (76 cm), Mantagani (70 cm) and Bidar (50 cm) pedons. Among the black pedons, Mantagani pedon was the deepest (185 cm)

Table 3. Salient morphological features of pedons

Horizon	Depth (cm)	Colour Dry	Colour Moist	Texture	Structure	Consistency	Salient pedological features
1	2	3	4	5	6	7	8
					Pedon-1 (Bidar Red)		
Ap	0-9	2.5 YR 4/4	2.5 YR 3.5/4	c	2 f gr	dh, mfr, ws	
Bt1	9-30	2.5 YR 4/4	2.5 YR 3/4	c	2 c sbk	dsh, mfr, wvs, wvp	
Bt2	30-43	2.5 YR 4/5	2.5 YR 3/5	c	2 c sbk	dsh, mfr, wvs, wvp	
Bc	43-55	2.5 YR 4/4	2.5 YR 3/4	c	1 c sbk	dsh, mfr, ws, wvp	
C	55+	7.5 YR 7/8	7.5 YR 6/8	gc	-	-	
					Pedon-2 (Bidar Black)		
Ap	0-14	10 YR 4/2	10 YR 3.5/2	c	1 m sbk	dh, mfi, ws, wp	
A2	14-35	10 YR 4/2	10 YR 3.5/2	c	1 m abk	dh, mfi, ws, wp	
A3	35-54	10 YR 4/2	10 YR 4/2	c	1 m abk	dvh, mfi, ws, wp	Indistinct, nonintersecting, slickensides
A4	54-68	10 YR 3.5/2	10 YR 3.5/2	c	3 m abk	dh, mfi, ws, wp	Indistinct, nonintersecting, slickensides
A5	68-94	10 YR 4/3	10 YR 3.5/3	c	3 m abk	dh, mfi, ws, wp	Prominent intersecting slickensides
A6	94-118	10 YR 4/3	10 YR 4/3	c	3 m abk	dh, mfi, ws, wp	Prominent intersecting slickensides
A7	130-153	10 YR 5/4	10 YR 4/4	c	3 m sbk	dh, mfi, ws, wp	Very prominent intersecting slickensides
A8	153-170	10 YR 5/4	10 YR 4/4	c	2 m sbk	dh, mfi, ws, wp	Very prominent intersecting slickensides
Ac	170-185	10 YR 4/4	10 YR 3.5/3	c	2 m sbk	dsh, mfi, ws, wsp	Indistinct, slickensides
C	185-235	10 YR 5/6	10 YR 5/6	gc	1 m sbk	dsh, mfi, ws, wsp	
					Pedon-3 (B.Gudi Red)		
Ap	0-11	5 YR 4/3	5 YR 3/3	sl	1 m sbk	dsh, mfr, wss	
Bt	11-24	5 YR 4/3	5 YR 3/3	sl	1 m sbk	dsh, mvfr, wss	Thin patchy clay skins on ped surfaces
Bt2	24-47	5 YR 3/3	5 YR 3/3	scl	1 c sbk	dsh,mvfr,wss,wsp	Thin patchy clay skins on ped surfaces
Bt3	47-67	5 YR 5/3	5 YR 4.5/3	scl	1 vc sbk	dsh, mvfr, wss	Thin patchy clay skins on ped surfaces
BC	67-92	5 YR 5/3	5 YR 5/3	scl	1 vc sbk	dsh, mvfr, wss	
C	>92	5 YR 5/6	5 YR 5/6	sl	1 vc sbk	ds, mfr, wso	
					Pedon-4 (B.Gudi Black)		
Ap1	0-9	10 YR 4/1	10 YR 3/1	c	3 m sbk	dh, mfi, wss, wp	
A2	9-27	10 YR 4/1	10 YR 3/1	c	3 m sbk	dh, mfi, wss, wp	Pressure faces
A3	27-49	10 YR 4/1	10 YR 3/1	c	3 f abk	dh, mfi, ws, wp	Prominent intersecting slickensides
A4	49-80	10 YR 4/1	10 YR 3.5/1	c	3 m abk	dh, mfi, ws, wp	Prominent intersecting slickensides
A5	80-118	10 YR 3/1	10 YR 3/1	c	3 m abk	dh, mfi, ws, wp	Prominent intersecting slickensides
A6	118-132	10 YR 4/1	10 YR 4/1	c	3 m sbk	dh, mfi, wss, wp	Indistinct, nonintersecting, slickensides
Cca	132-186	10 YR 6/6	10 YR 6/6	c	0 c sbk	dh, mfi, wss, wp	Abundant $CaCO_3$ nodules

Table 3. (Contd.)

1	2	3	4	5	6	7	8
					Pedon-5 (Raichur Red)		
Ap	0–10	5 YR 5/2	5 YR 4/2	sl	1 f sbk	dsh, mvfr, wss, wop	
Bt1	10–22	5 YR 5/2	5 YR 4/2	scl	1 f sbk	dsh, mfr, wss, wsp	
Bt2	22–43	5 YR 4/2	5 YR 3/2	c	2 m sbk	dsh, mfr, ws, wp	Thin patchy clay skins on ped surfaces
Bt3	43–65	5 YR 3/2	5 YR 3/2	c	2 m sbk	dsh, mfr, ws, wp	Thin patchy clay skins on ped surfaces
Bc	65–76	5 YR 3/2	5 YR 3/2	cl	1 f sbk	dsh, mvfr, ws, wp	
C	76–100	–	–	sl	massive	dl, mfr, wms, wsp	
					Pedon-6 (Raichur Black)		
Ap	0–18	10 YR 4/2	10 YR 3/2	c	1 f sbk	dvh, mfi, ws, wp	
A2	18–42	10 YR 4/1	10 YR 3/1	c	2m sbk	dh, mfi, ws, wp	Pressure faces on ped surfaces
A3	42–70	10 YR 4/1	10 YR 4/1	c	2 m sbk	dh,mfi,wvs,wvp	Prominent slickensides
A4	70–150	10 YR 4/2	10 YR 4/2	c	2 c abk	dh,mfi,wvs,wvp	Prominent slickensides
2c	150–180	–	–	sl	Structure less	dsh,mvfr,wso,pwpo	
					Pedon-7 (Dharwad Red)		
Ap	0–12	5 YR 4/4	5 YR 3/3	scl	2 m sbk	dvh, mfr, wss, wp	
Bt1	12–32	5 YR 4/4	5 YR 3/3	c	2 m sbk	dvh, mfr, ws, wp	
B2	32–60	5 YR 4/4	5 YR 3/3	c	1 f sbk	dsh, mfr, ws, wp	
Bc	60–150	5 YR 4/3	5 YR 4/3	cl	1 f sbk	dsh, mfr, wss, wp	
C	>150	5 YR 4/6	5 YR 4/6	cl	1 f sbk	dvh, mfr, wss, wp	
					Pedon-8 (Dharwad Black)		
Ap	0–16	10 YR 4.5/2	10 YR 4/2	c	3 m sbk	dh, mfi, ws, wp	
A2	16–35	10 YR 4/2	10 YR 3.5/2	c	3 m sbk	dh, mfi, ws, wp	Common pressure faces
A3	35–55	10 YR 4.5/2	10 YR 4/2	c	3 m sbk	dh, mfi, ws, wvp	Prominent intresecting slickensides
A4	55–85	10 YR 3.5/2	10 YR 3/2	c	3 m sbk	dh, mfi, wvs, wvp	Prominent intresecting slickensides
A5	85–105	10 YR 4/2	10 YR 3.5/2	c	3 m sbk	dh, mfi, ws, wp	Very prominent slickensides
Ac	105–125	10 YR 4/2	10 YR 3.5/2	c	3 m sbk	dh, mfi, ws, wp	Very prominent intersecting slickensides
2c	>125	10 YR 5/4	10 YR 4/4	gc	1 m sbk	dsh, mfi, wss, wp	Abundant lime nodules
					Pedon-9 (Mantagani Red)		
Ap	0–16	5 YR 4/4	5 YR 3/4	c	2 m sbk	dsh, mfr, wss, wsp	
B1	16–30	5 YR 3/4	5 YR 3/4	c	1 m sbk	dh, mfr, ws, wp	Pressure faces on ped surfaces
Bt1	30–50	2.5 YR 3/4	2.5 YR 3/4	c	1 m sbk	dsh, mfr, wss, wp	Pressure faces on ped surfaces
B2	50–70	2.5 YR 5/4	2.5 YR 5/4	c	2 m sbk	dsh, mfr, ws, wsp	
C	>70	2.5 YR 6/4	2.5 YR 6/4	sl	1 m sbk	ds, mfr, wss, wsp	
					Pedon-10 (Mantagani Black)		
Ap	0–15	10 YR 4/2	10 YR 3.5/2	c	2 m gr	dh, mfi, ws, wp	
A2	15–35	10 YR 4/2	10 YR 3/2	c	2 m sbk	dh, mfi, ws, wp	Pressure faces on ped surfaces
A3	35–60	10 YR 4/2	10 YR 4/2	c	3 m sbk	dh, mvfi, wvs, wp	Prominent instersecting slickensides
A4	60–80	10 YR 5/2	10 YR 4/2	c	3 m sbk	dh, mvfi, wvs, wp	Prominent instersecting slickensides
A5	80–100	10 YR 4/2	10 YR 3/2	c	3 m sbk	dh, mvfi, wvs, wp	Prominent instersecting slickensides
A6	100–130	10 YR 4/2	10 YR 3/2	c	2 m sbk	dh, mfi, wvs, wp	Prominent instersecting slickensides
A7	130–153	10 YR 5/4	10 YR 4/4	c	3 m sbk	dh, mfi, ws, wp	Prominent instersecting slickensides
A8	153–170	10 YR 5/4	10 YR 4/4	c	2 m sbk	dh, mfi, ws, wp	Prominent instersecting slickensides
Ac	170–185	10 YR 4/4	10 YR 4/4	c	2 m sbk	dsh, mfi, ws, wsp	Indistinct slickensides
C	185–235+	10 YR 5/6	10 YR 5/6	gc	1 m sbk	dsh, mfi, wss,wsp	

followed by Bidar (177 cm), Raichur (150 cm), B. Gudi (132 cm) and Dharwad (125 cm).

In red pedons soil colour varied from reddish brown to dark reddish brown in the solum of Bidar, B.Gudi and Dharwad pedons. In Mantagani Pedon soil colour was reddish brown to dark reddish brown in the upper solum and was light reddish brown in B_2 and C horizons. In Raichur pedon it was reddish grey to dark reddish grey in the upper solum and was dark reddish brown in the lower solum. Hue was 5 YR in the solum of all the pedons except Bidar and Mantagani pedons. It was 2.5 YR throughout the solum of Bidar pedon. In Mantagani pedon it was 5 YR in the upper solum and was 2.5 YR in the lower solum. It was yellowish red in the C horizons of all the pedons. Hue was 5 YR in the C horizons of all the pedons except that of Bidar pedon where it was 7.5 YR. In the solum of these pedons value was within 5 and most frequently 3 and 4, and Chroma was within 4 and more than 2. Among these pedons Bidar pedon was redder followed by Mantagani, Raichur, B. Gudi, and Dharwad pedons.

In black pedons most commonly soil colour varied from dark greyish brown to very dark greyish brown in the upper solum and yellowish brown to dark yellowish brown in the lower solum. Hue was at 10 YR throughout the profile in all the pedons. Value was within 5 and most frequently 3 and 4 where as chroma was less than 2 and was more than 2 in the lower solum of Bidar pedon.

In the solum of red pedons texture varied from sandy loam to sandy clay loam, to clay loam to clay. It was clay throughout the solum of Bidar and Mantagani pedons. In the C horizons of all these pedons texture was sandy loam or gravelly clay. In black pedons texture was clay throughout the solum.

Structure varied from weak to moderate, fine to medium to coarse to very coarse, granular to subangular blocky in red pedons and in black pedons it varied from weak to moderate to strong, fine to medium, subangular blocky to angular blocky. Among the red pedons structure was good in Dharwad followed by Mantagani and Bidar pedons. It was poor in B.Gudi and Raichur pedons.

Consistency was generally friable to very friable when moist and sticky to non sticky when wet in red pedons. It was firm to very firm when moist and sticky to very sticky and plastic to very plastic when wet in the black counterparts.

4.1.1 Other morphological features

Lime concretions, slickensides pressure faces were a common feature in all the black pedons, and the same were absent in their red counterparts. Cracks were present in black pedons and the same were absent in red pedons, except Mantagani red pedon where the surface cracks were visible. Thin patchy clayskins were present on the ped surfaces of B.Gudi and Raichur red pedons and in other red pedons they were not and clearly identifiable. Pressure faces were observed in Mantagani red pedon.

Horizon sequence observed in Bidar red pedon was Ap-Bt-C, and in B.Gudi Raichur and Dharwad pedons it was Ap-Bt-BC-C. In Mantagani red pedon it was Ap-B-Bt-B-C. In black pedons horizon sequence observed in Bidar and Mantagani pedons was A-AC-C, and in B.Gudi pedon it was A-AC-Cca. In Raichur and Dharwad pedon it was A-C.

4.2 Physical properties

4.2.1 Particle size distribution

Data pertaining to it is presented in the Table 4.

Coarse fragments

The coarse fragment content was much greater in red pedon (4 to 36 per cent) compared to the black pedon (1 to 4

Table 4. Particle size distribution (%) on oven dry basis

Horizon	Depth (cm)	Coarse fragments >2mm	Very coarse sand 1-2mm	Coarse sand 1.0–0.5 mm	Medium sand 0.25–0.1 mm	Fine sand 0.25–0.1 mm	Very fine sand 0.1–0.05 mm	Total sand 2-0.05 mm	Silt 0.05-0.002mm	clay <0.002 mm	Fine clay <0.2 μm	Fine caly as % of total clay	Textural class
1	2	3	4	5	6	7	8	9	10	11	12	13	14
						Pedon–1 (Bidar Red)							
Ap	0–9	4	2.8	2.2	0.9	0.5	0.4	6.8	29.7	63.5	39.5	62.2	clay
Bt1	9–30	26	5.3	2.8	0.9	0.4	0.4	9.8	15.9	74.3	43.2	58.1	clay
Bt2	30–43	10	3.7	2.0	0.8	0.3	0.1	6.9	16.0	77.1	47.5	61.6	clay
BC	43–55	36	9.3	4.6	2.1	1.5	0.7	18.2	20.5	61.3	37.0	60.4	clay
C	55+												
						Pedon–2 (Bidar Black)							
Ap	0–14	4	1.0	0.8	0.7	0.8	1.0	4.3	31.0	64.7	38.8	60.0	clay
A2	14–35	2	1.3	0.8	0.6	0.7	1.1	4.5	27.0	68.5	40.1	58.5	clay
A3	35–54	2	1.3	0.8	0.6	0.8	0.9	4.4	25.0	70.6	45.7	64.7	clay
A4	54–68	1	1.0	0.6	0.7	1.1	1.5	4.9	21.0	74.1	49.3	66.5	clay
A5	68–94	2	1.3	0.8	0.5	0.8	0.9	4.3	19.0	76.7	52.4	68.3	clay
A6	94–118	2	2.2	1.0	1.3	1.0	1.9	7.4	21.5	71.1	46.5	65.4	clay
A7	130–153	1	1.7	0.9	0.5	1.1	1.3	5.5	26.0	68.5	44.2	64.5	clay
A8	153–170	2	0.8	0.5	0.5	1.4	1.1	3.8	29.0	66.7	43.5	65.2	clay
Ac	170–185	3	0.3	0.3	0.1	0.5	0.7	1.9	32.1	66.0	41.0	62.1	clay
C	185–235	2	0.7	0.1	0.5	1.3	1.4	4.0	31.5	64.5	40.0	62.0	clay
						Pedon–3 (B.Gudi Red)							
Ap	0–11	4	14.6	13.8	14.1	13.0	4.7	60.2	23.1	17.3	10.2	58.9	sandy loam
Bt	11–24	6	14.7	12.0	13.2	13.1	4.0	57.0	19.0	24.0	15.0	62.5	sandy loam
Bt2	24–47	17	26.7	9.2	8.3	7.3	3.4	54.9	19.9	25.2	15.6	62.0	sandy clay loam
Bt3	47–67	50	24.7	8.2	8.1	6.6	2.7	50.3	17.1	32.6	20.4	62.6	sandy clay loam
BC	67–92	19	27.0	15.0	13.0	10.4	3.6	69.0	8.0	23.0	12.8	55.7	sandy clay loam
C	>92	25	25.8	17.5	16.9	11.9	5.0	77.1	9.6	13.3	7.7	58.0	sandy loam
						Pedon–4 (B.Gudi Black)							
Ap	0–9	5	7.0	7.2	8.4	8.0	3.7	34.3	19.0	46.7	31.5	67.5	clay
A2	9–27	1	5.5	7.1	7.2	7.6	3.3	30.7	17.0	52.3	35.8	68.5	clay
A3	27–49	4	5.0	7.2	8.0	8.2	3.6	32.0	14.0	54.0	37.3	69.1	clay
A4	49–80	10	5.1	6.3	6.0	6.5	3.4	27.3	17.0	55.7	38.0	68.2	clay
A5	80–118	6	9.6	4.3	4.2	4.7	3.0	25.8	16.0	58.2	39.6	68.0	clay
A6	118–132	27	5.0	5.5	5.0	9.5	3.6	28.4	22.1	49.5	29.6	59.8	clay
Cca	132–186	29	19.2	9.5	8.2	8.6	4.3	49.8	12.1	38.1	25.3	66.4	clay
						Pedon–5 (Raichur Red)							
Ap	0–10	3	15.2	23.0	19.0	15.0	4.3	76.5	3.5	20.0	12.6	63.0	sandy loam
Bt1	10–22	1	9.4	19.8	15.3	10.9	4.5	59.9	6.4	33.6	20.0	59.5	sandy loam
Bt2	22–43	1	6.6	13.6	13.0	8.2	3.5	44.9	13.4	41.7	24.0	57.6	clay
Bt3	43–65	5	7.4	13.6	12.5	8.1	2.8	44.4	10.5	45.1	26.5	58.8	clay
Bc	65–76	65	17.7	11.4	9.5	6.8	3.3	48.7	11.8	39.5	21.5	54.4	clay loam
C	76–100	20	20.0	10.3	9.2	6.8	3.2	49.5	28.0	22.5	15.0	66.6	sandy loam

Table 4. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pedon-6 (Raichur Black)													
Ap	0–18	ND	1.2	2.3	2.3	2.4	1.7	9.9	28.7	61.4	35.4	57.7	clay
A2	18–42	ND	1.6	2.0	1.8	1.6	1.5	8.5	28.5	63.0	37.4	59.4	clay
A3	42–70	ND	1.2	1.6	1.7	2.0	1.7	8.2	26.5	65.3	37.8	57.9	clay
A4	70–150	ND	0.9	1.5	1.4	1.5	1.2	6.5	26.0	67.5	39.3	58.2	clay
2c	150–180	ND	17.2	18.0	16.1	12.7	4.7	68.7	11.3	20.0	9.8	49.0	sandy loam
Pedon-7 (Dharwad Red)													
Ap	0–12	17	13.0	7.6	11.4	18.1	7.1	57.2	10.8	32.0	17.5	54.7	sandy clay loam
Bt1	12–32	15	7.8	6.0	9.6	15.0	6.0	44.4	9.6	46.0	29.0	63.0	clay
B2	32–60	51	31.3	3.4	4.2	5.7	2.1	46.7	11.5	41.8	23.8	56.9	clay
Bc	60–150	55	24.6	6.2	5.4	5.5	2.1	43.8	24.6	31.6	16.7	52.8	clay loam
C	>150	49	16.0	8.0	8.3	8.0	2.2	42.5	29.2	28.3	13.5	47.7	clay loam
Pedon-8 (Dharwad Black)													
Ap	0–16	1	1.5	1.3	2.3	4.5	4.1	13.7	25.8	60.5	39.3	65.0	clay
A2	16–35	1	1.7	1.2	2.0	4.0	2.5	11.4	26.2	62.4	42.5	68.1	clay
A3	35–55	1	1.8	1.0	2.0	3.5	3.0	11.3	24.7	64.0	44.7	69.8	clay
A4	55–85	1	1.8	1.0	2.2	4.0	2.5	11.5	26.2	62.3	43.2	69.3	clay
A5	85–105	1	1.9	1.0	1.9	3.4	2.7	10.9	27.6	61.5	40.1	65.2	clay
Ac	105–125	3	2.5	1.6	2.0	3.3	2.0	11.4	26.4	62.2	41.6	66.9	clay
2c	>125	53	7.5	2.2	2.6	2.0	2.6	9.4	25.4	57.5	37.4	65.0	clay
Pedon-9 (Mantagani Red)													
Ap	0–16	2	2.5	2.1	5.9	15.8	5.3	31.6	21.0	47.4	27.2	57.4	clay
B1	16–30	3	2.8	2.7	5.6	12.8	6.6	30.5	24.1	45.7	29.0	63.5	clay
Bt1	30–50	11	2.5	2.2	5.7	12.7	7.1	30.2	18.4	51.4	31.6	61.5	clay
B2	50–70	25	4.3	3.1	6.4	11.4	6.4	31.6	17.6	50.8	30.1	59.3	clay
C	>70	53	7.3	9.6	19.9	17.7	7.6	62.1	20.9	17.0	9.4	55.3	sandy loam
Pedon-10 (Mantagani Black)													
Ap1	0–15	1	1.1	1.2	2.5	7.1	5.1	17.0	20.2	62.7	41.5	66.2	clay
A2	15–35	1	0.7	1.0	3.0	8.0	5.0	17.7	19.0	63.3	42.3	66.8	clay
A3	35–60	1	1.0	1.1	2.1	2.1	5.0	15.7	18.5	65.8	45.7	69.5	clay
A4	60–80	2	1.0	1.1	2.0	6.0	4.5	14.6	18.7	66.7	46.8	70.1	clay
A5	80–100	1	0.5	0.8	1.8	5.5	4.5	13.1	22.4	64.5	44.5	68.9	clay
A6	100–130	2	0.5	0.8	1.5	5.0	4.2	12.0	23.0	65.0	45.8	70.5	clay
A7	130–153	5	1.4	0.7	1.1	3.7	3.6	10.5	26.5	63.0	42.7	67.8	clay
A8	153–170	17	2.3	0.8	1.0	3.3	3.3	10.7	30.0	59.3	39.4	66.4	clay
Ac	170–185	14	8.5	8.1	3.1	5.4	6.6	31.7	22.0	46.3	31.0	66.9	clay
C	185–235+	47	7.8	5.5	3.3	16.3	6.2	39.1	19.8	41.1	28.3	68.9	clay

per cent) at Bidar. The distribution of coarse fragments was irregular in red pedon, where as in black pedon coarse fragments content decreased with depth, from the surface upto 68 cm depth, below which it was nearly uniform.

In B.Gudi red and black pedons coarse fragments content ranged from 4 to 50 per cent and 1 to 29 per cent respectively. In red pedon it showed increasing trend upto 67 cm depth, and then decreased in between 67 to 92 cm depth and again increased in the C horizon. In black pedon its content increased upto 80 cm depth from A2 horizon and then decreased in between 80-118 cm depth and then increasing trend was observed with depth. In Raichur red pedon its content ranged from 1 to 65 percent.

In Dharwad red pedon coarse fragments content ranged from 15 to 55 per cent and from 1 to 53 per cent in the associated black pedon. In red pedon its content showed increasing trend from Bt1 horizon upto 150 cm depth and then decreased in the C horizon. In black pedon its content was almost uniform from surface upto 105 cm depth and then increasing trend with depth was observed.

In Mantagani red pedon coarse fragments content ranged from 2 to 53 per cent and from 1 to 47 per cent in the associated black pedon. It showed increasing trend with depth in red pedon. In black pedon its content was almost uniform upto 130 cm depth and below which it was irregular.

In general coarse fragments content ranged from 1 to 65 per cent in red pedons and from 1 to 53 per cent in the associated black pedons. Comparatively the coarse fragments content was more in red pedons than that of the associated black pedons.

Sand

In Bidar red pedons bulk of the total sand was made up of very coarse and coarse sand, where as in the asociated black pedon all the sand fractions almost equally contributed to the total sand.

In B.Gudi red pedon sand content showed decreasing trend upto 67 cm depth and below which it increased. In the associated black pedon sand content showed decreasing trend upto the 118 cm depth, and below which it increased. In both red and black pedons of B.Gudi, coarse, medium and fine sand fractions content were nearly equal in majority of the horizons. Very coarse sand content was distinctly more in red pedon compared to that in black pedon.

The total sand content in the Raichur red pedon was high (44.4 to 76.5 per cent) compared to that in the solum of black pedon (6.5 to 9.9 percent). Coarse, medium, and fine sand fractions have contributed to the bulk of the total sand in the Raichur red pedon. Total sand showed decreasing trend down the profile upto 65 cm and then a slight increase in red pedon. No sub fraction of sand was predominant in Raichur black pedon as above in red pedon.

In Dharwad red pedon also sand content was relatively high (42.5 to 57.2 per cent) compared to that of associated black pedon (9.4 to 13.7 per cent). Total sand content was more in the surface horizon of both the pedons below which it was almost uniformly distributed. In red pedon the content of very coarse sand in the upper solum was lesser compared to lower depth, wherein a sharp increase was observed. With respect to other sand fractions the converse was true. In black pedon medium, fine and very fine sand fractions have contributed bulk to the total sand.

In Mantagani red pedon the sand was uniformly distributed in the solum (30.2 to 31.6 per cent) and was twice as high as in C horizon. In red pedon fine sand was the predominent fraction followed by very fine and medium sand fractions. In the associated black pedon bulk of the total sand was made up of fine and very fine sand fractions. The sand content showed decreasing trend with depth from A2 horizon upto 170 cm depth and below which it increased considerably. All the sand fractions followed the distribution of total sand.

In general total sand content was more in red pedons than that of the associated black pedons. Total sand content ranged from 6.8 to 77.1 per cent in red pedons and from 1.9 to 68.7 per cent in the associated black pedons. Among the red pedons the highest sand content was observed in B.Gudi pedon (50.3 to 77.1 per cent), followed by Raichur (44.4 to 76.5 per cent), Mantagani (30.2 to 62.1 per cent), Dharwad (42.5 to 57.2 per cent) and Bidar pedons (6.8 to 18.2 per cent). Among the black pedons the highest content of sand was observed again in B.Gudi pedon (25.8 to 49.8 per cent), followed by Mantagani (10.5 to 39.1 per cent), Dharwad (9.4 to 13.7 per cent), Raichur (6.5 to 9.9 per cent in the solum) and Bidar (1.9 to 7.4 per cent) pedons.

Silt

In Bidar red pedon silt content was the highest at the surface and decreased in Bt_1 and Bt_2 horizons and increased slightly in BC horizon. In the associated black pedon silt content at the surface was above the same as in red pedon and steadily decreased down the depth upto 94 cm and then increased with depth. In B.Gudi red pedon silt content decreased from 23.1 per cent in Ap to 8.0 per cent in C horizon. In the associated black pedon its content was marginally lower compared to its red counterpart ranging from 12.1 to 22.1 per cent. In Raichur red pedon silt content ranged from 3.5 to 13.4 per cent in the solum and was distinctly lower compared to the solum of associated black pedon (26.0 to 28.7 per cent).

In Dharwad red pedon silt content was relatively less (9.6 to 11.5 per cent) in the upper 60 cm below which it was considerably higher (24.6 to 29.2 per cent). In the associated black pedon however its content was more than the red counterpart and varied little with depth (24.7 to 27.6 per cent). In Mantagani red pedon silt content ranged from 17.6 to 24.1 per cent and from 18.5 to 30 per cent in the associated black pedon. The silt content in both red and black pedons wre comparable especially in the upper solum. In Mantagani black pedon silt content showed decreasing trend upto 60 cm depth and then increasing trend upto 170 cm depth and again a decreasing trend.

In general silt content ranged from 3.5 to 29.7 per cent in red pedons and from 11.3 to 32.1 per cent in black pedons. Among the red pedons the highest silt content was observed in Bidar (15.9 to 29.7 per cent), Dharwad (9.6 to 29.2 per cent), and Raichur (3.5 to 28.0per cent) pedons, followed by Mantagani (17.6to 24.1 per cent) and B.Gudi (8 to 23.1 per cent) pedons. Among the black pedons the highest content of silt was observed in Mantagani pedon (18.5 to 30.0 per cent) followd by Raichur (11.3 to 28.7 per cent), Dharwad (24.7 to 27.6 per cent), B.Gudi (12.1 to 22.1 per cent) and Bidar (19.0 to 32.1 per cent).

Clay

In Bidar red pedon clay content ranged from 61.3 to 77.1 per cent and from 64.5 to 76.7 per cent in the associated black pedon. The clay content in both red and black pedons were remarkably similar. Further in both the pedons clay showed increasing trend down the profile, upto some depth (upto 43 cm in red pedon and upto 94 cm in black pedon) and below which it decreased. In Bidar red pedon fine clay content ranged from 37.0 to 47.5 per cent and from 38.8 to 52.4 per cent in the associated black pedon. Fine clay followed the trend of total clay in distribution.

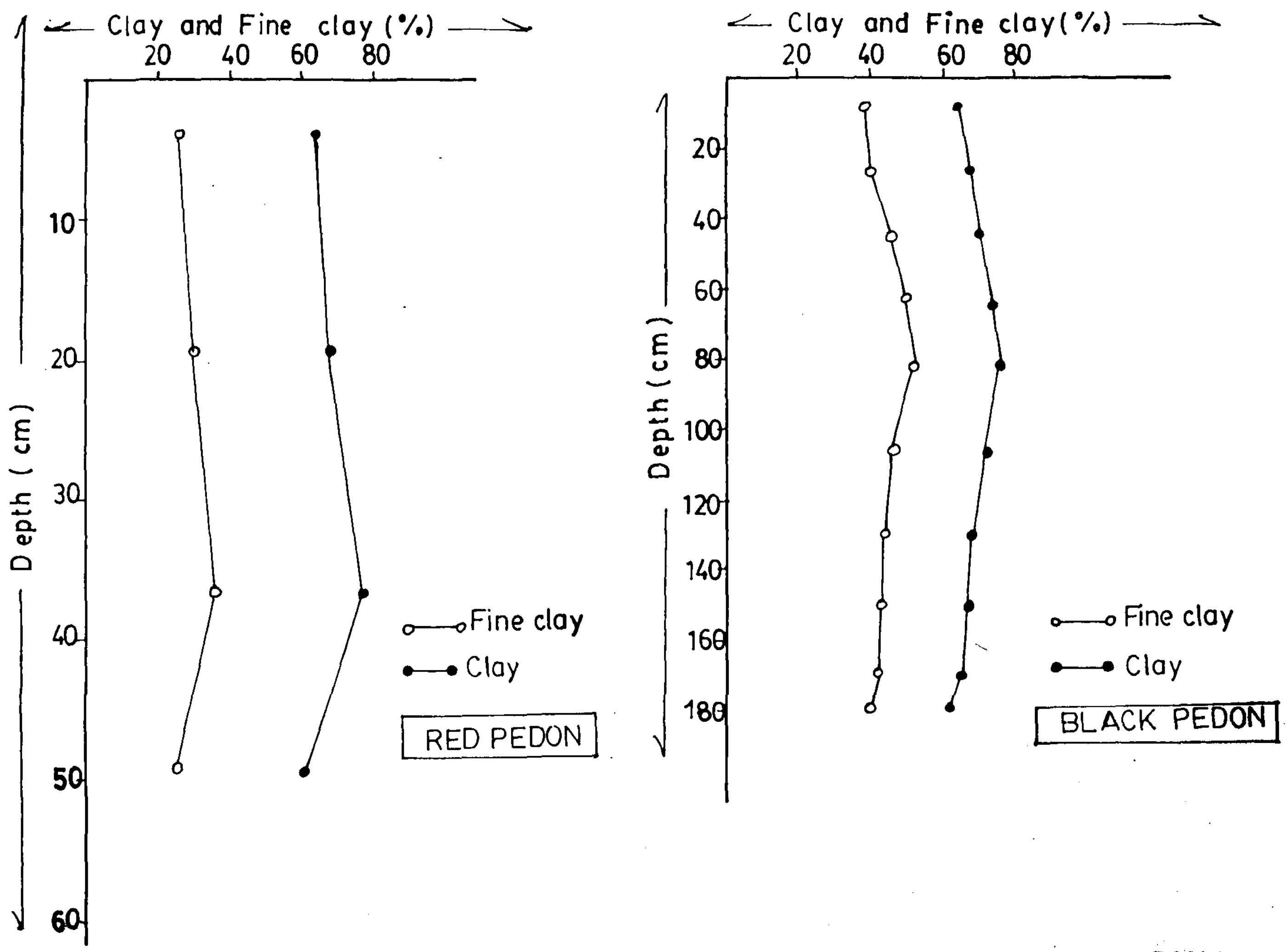

Fig. 2 CLAY AND FINE CLAY DISTRIBUTION IN BIDAR PEDONS

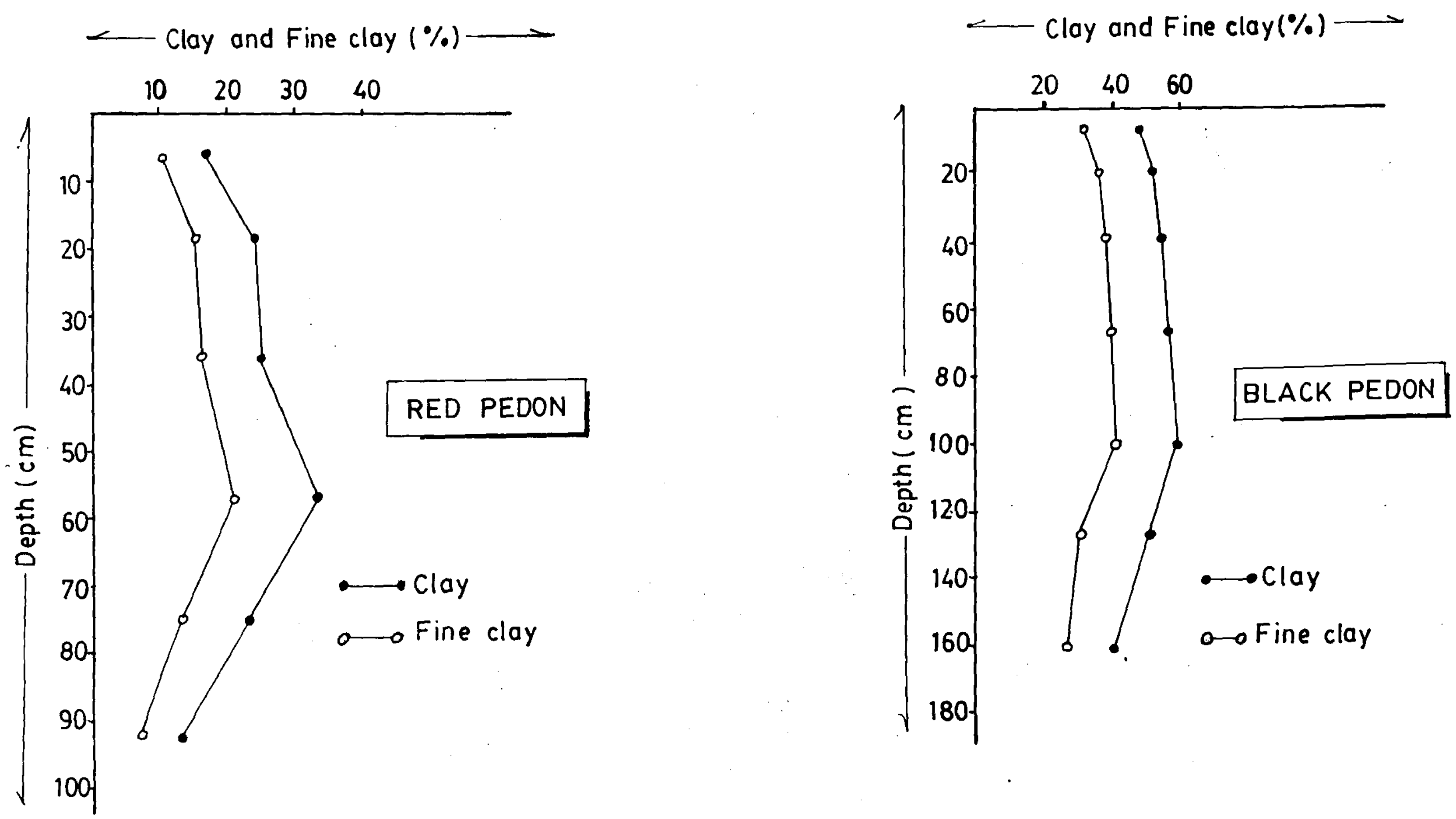

Fig. 3 CLAY AND FINE CLAY DISTRIBUTION IN B.GUDI PEDONS

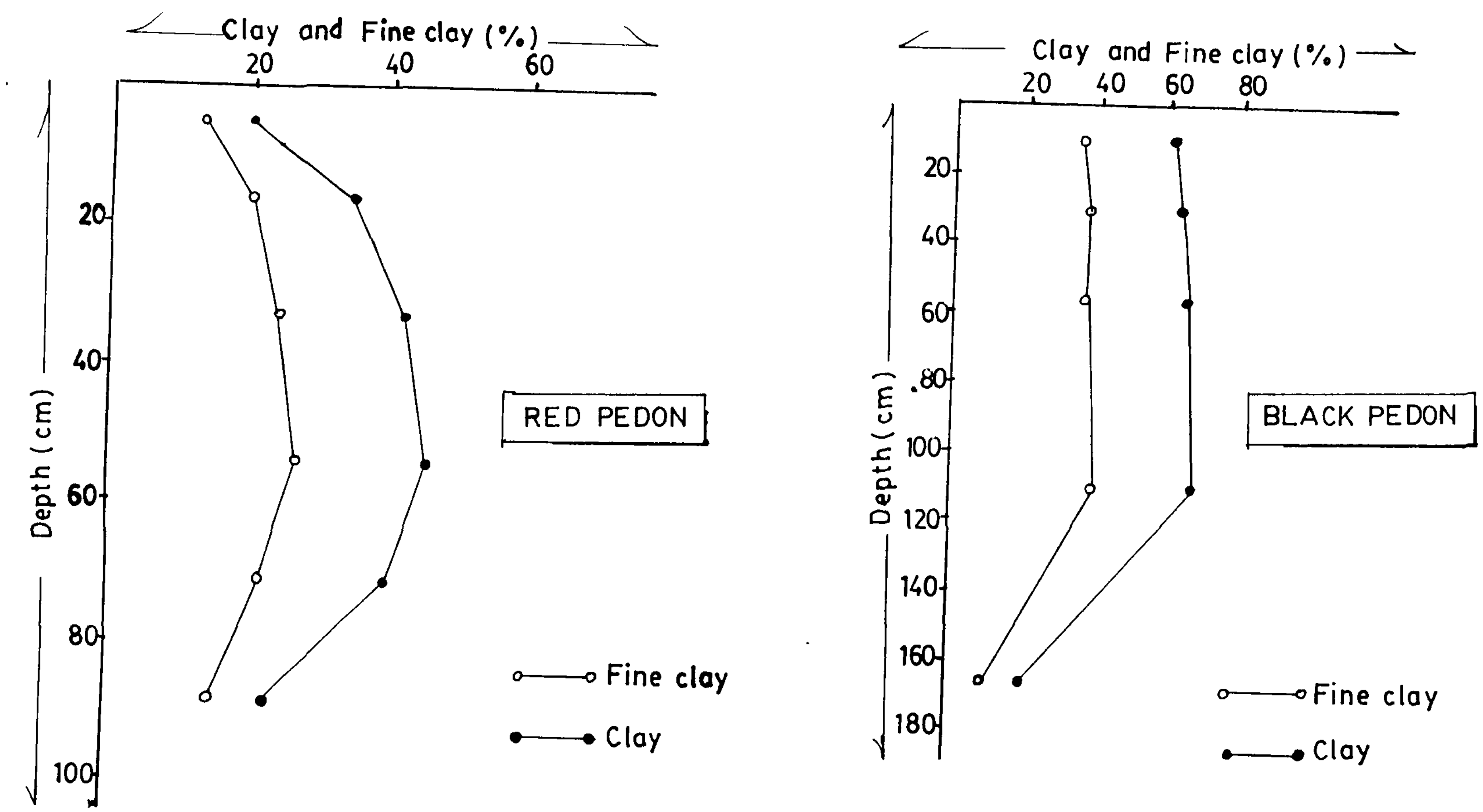

Fig. 4 **CLAY AND** FINE CLAY **DISTRIBUTION** IN RAICHUR **PEDONS**

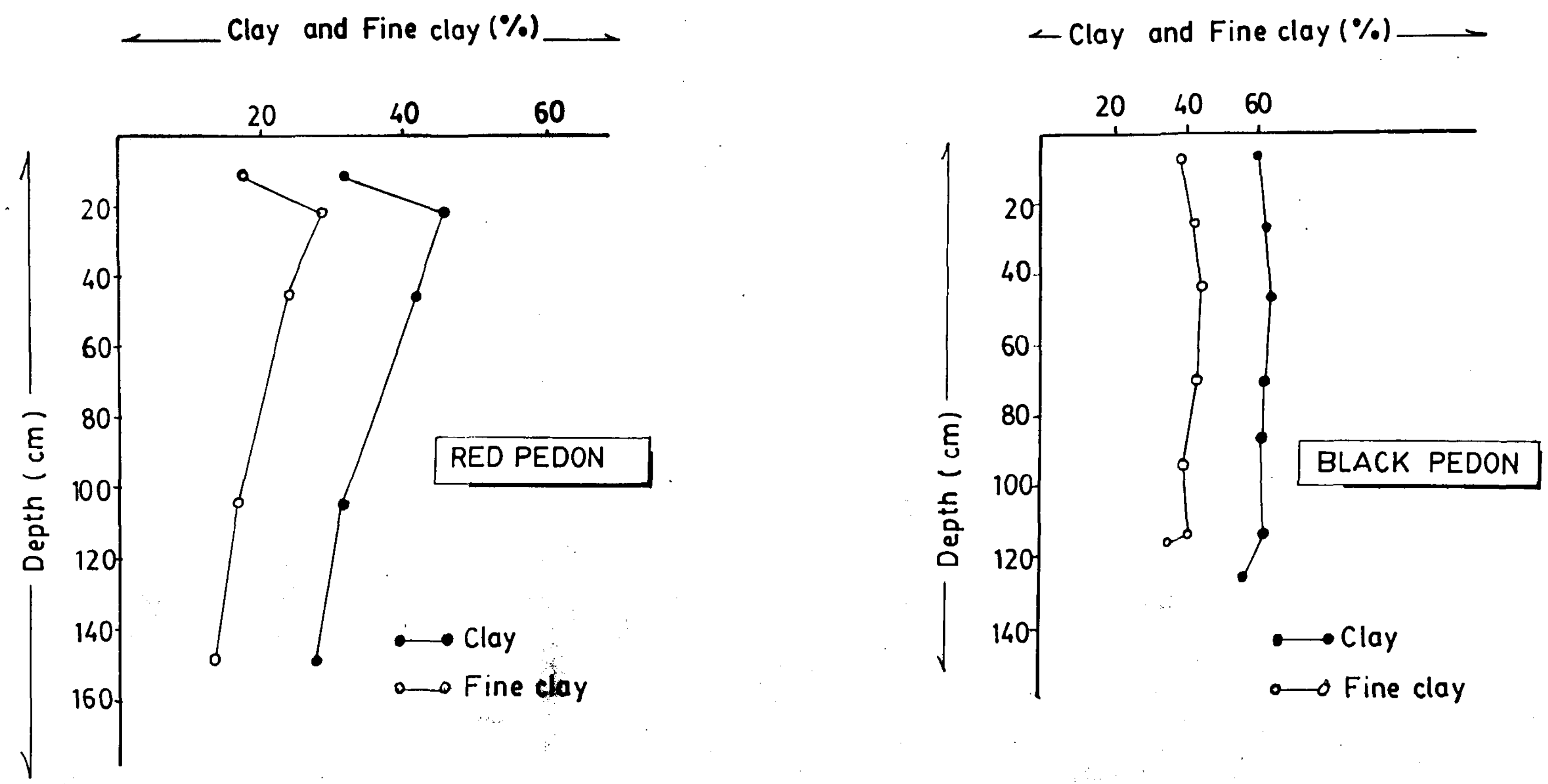

Fig. 5 CLAY AND FINE CLAY DISTRIBUTION IN DHARWAD PEDONS.

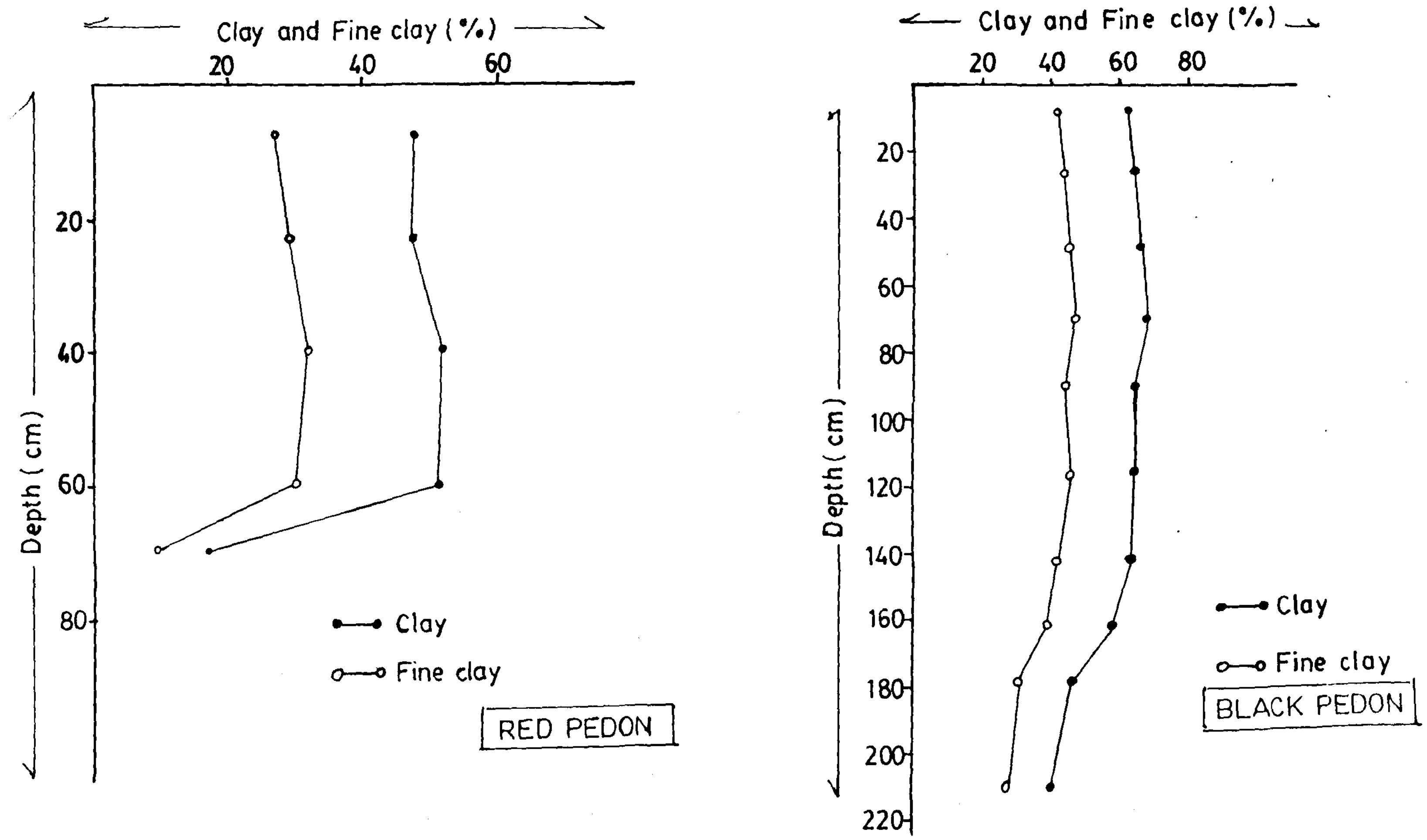

Fig.6 CLAY AND FINE CLAY DISTRIBUTION IN MANTAGANI **PEDONS**

In B.Gudi red pedon clay content increased from surface horizon to a maximum of 32.6 per cent in Bt_3 horizon below which it decreased. In B.Gudi black pedon clay content varied from 38.1 to 58.2 per cent. The clay content showed increasing trend with depth upto 118 cm below which it decreased. Fine clay content varied from 7.7 to 20.4 per cent in B.Gudi red pedon and from 25.3 to 39.6 per cent in B.Gudi black pedon and the fine clay distribution followed the total clay distribution. The ratio of fine to total clay was rather uniform through most part of the black pedon whereas in red pedon fine to total clay ratio was relatively greater in Bt horizons.

In Raichur red pedon clay content increased from surface to a maximum of 45.1 per cent in Bt_3 horizon, below which it decreased. Fine clay ranged from 12.6 to 26.5 per cent and its distribution followed the trend of clay. In Raichur black pedon clay content ranged from 20 to 67.5 per cent and fine clay ranged from 9.8 to 39.3 per cent. Both clay and fine clay content increased with depth to a maximum of 67.5 per cent and 39.3 per cent in A_4 horizon respectively. Both clay and fine clay content was less in the C horizon.

In Dharwad red pedon clay content was maximum in Bt_1 horizon and then decreasing trend with depth was observed.

The content of fine clay was also maximum in Bt_1 horizon and its distribution followed the trend of total clay. In Dharwad black pedon total clay and fine clay showed slight increase with depth upto A_3 horizon below which both were almost uniformly distributed upto AC horozon and decreased in C horizon.

In Mantagani red pedon clay content was maximum in Bt_1 horizon and below which it decreased. Fine clay showed increasing trend with depth from surface upto Bt_1 horizon and below which it decreased.

In Mantagani black pedon both clay and fine clay increased with depth from surface upto A_4 horizon and then decreased in A_5 horizon and again increased in A_6 horizon below which both decreased.

In general clay and fine clay content ranged from 13.3 to 77.1 per cent and from 7.7 to 44 per cent in red pedons respectively. Among the red pedons clay and fine clay contents were the highest in Bidar pedon followed by Mantagani, Dharwad, Raichur and B.Gudi pedons. In black pedons clay and fine clay contents ranged from 20.0 to 76.7 per cent and from 28.3 to 52.4 per cent respectively. Among the black pedons clay content was again highest in Bidar pedon followed by Raichur, Mantagani, Dharwad and B.Gudi pedons where as fine clay content was again highest in Bidar pedon followed by Mantagani, Dharwad, B.Gudi and Raichur pedons.

Fine clay as percent of total clay ranged from 47.7 to 63 per cent in red pedons and from 49 to 70.5 per cent in black pedons. Among the red pedons the highest fine clay as per cent of total clay was observed in Mantagani pedon followed by Dharwad, Raichur, B.Gudi and Bidar pedons, where as in black pedons it was highest again in Mantagani followed by Dharwad, B.Gudi, Bidar and Raichur pedons.

4.2.2 Other physical properties

Data pertaining to it is presented in table.5

Bulk density

The bulk density of red pedons ranged from 1.41 to 1.56 Mg m^{-3} and from 1.37 to 1.69 Mg m^{-3} in black pedons. In both the pedons bulk density was found to decrease in the upper solum and increase in the lower solum. The bulk density of black pedons was comparatively slightly more than that of associated red pedons. Among the red pedons the highest bulk density was observed in Bidar pedon (1.46 to 1.56 Mg m^{-3}), followed by Raichur (1.43 to 1.53 Mg m^{-3}), B Gudi (1.44 to 1.51 Mg m^{-3}), and Mantagani (.1.41 to 1.49 Mg m) pedons. In

Table 5. Bulk density, moisture retention capacity and surface area of soils

Horizon	Depth (cm)	Bulk density of dry clod (Mg m^{-3})	Moisture retention (%)		Surface area (m^2/g)
			33 KPa	1500 KPa	
1	2	3	4	5	6
		Pedon–1 (Bidar Red)			
Ap	0–9	1.52	21.2	11.4	138
Bt1	9–30	1.47	25.6	16.4	165
Bt2	30–43	1.46	26.8	19.0	173
BC	43–55	1.56	23.4	13.5	110
C	55+	–	–	–	–
		Pedon–2 (Bidar Black)			
Ap	0–14	1.52	35.2	18.2	401
A2	14–35	1.50	37.8	19.4	514
A3	35–54	1.48	40.3	21.3	577
A4	54–68	1.46	40.8	22.5	589
A5	68–94	1.43	41.2	22.7	607
A6	94–118	1.46	41.0	21.0	568
A7	130–153	1.52	39.5	19.8	510
A8	153–170	1.55	39.8	20.2	484
Ac	170–185	1.59	36.7	18.3	481
C	185–235	1.62	36.0	18.4	467
		Pedon–3 (B.Gudi Red)			
Ap	0–11	1.50	14.8	7.4	44
Bt	11–24	1.49	16.5	8.0	60
Bt2	24–47	1.49	20.6	9.4	77
Bt3	47–67	1.44	22.0	10.6	113
BC	67–92	1.48	18.4	9.3	59
C	>92	1.51	18.1	9.0	48
		Pedon–4 (B.Gudi Black)			
Ap	0–9	1.59	33.1	14.0	392
A2	9–27	1.61	34.0	16.0	414
A3	27–49	1.59	34.6	18.0	424
A4	49–80	1.55	37.2	20.0	432
A5	80–118	1.50	39.3	20.6	443
A6	118–132	1.61	33.7	19.4	326
Cca	132–186	1.64	29.4	18.0	296
		Pedon–5 (Raichur Red)			
Ap	0–10	1.51	9.3	4.6	78
Bt1	10–22	1.48	15.1	9.6	84
Bt2	22–43	1.45	20.5	11.5	120
Bt3	43–65	1.43	24.5	14.8	131
Bc	65–76	1.48	23.4	13.0	123
C	76–100	1.53	9.7	5.2	67

Table 5. (Contd.)

1	2	4	5	6	7
		Pedon–6 (Raichur Black)			
Ap	0–18	ND	35.5	17.5	378
A2	18–42	ND	37.7	19.3	388
A3	42–70	ND	39.3	21.1	439
A4	70–150	ND	40.6	22.6	445
2c	150–180	ND	15.3	9.2	162
		Pedon–7 (Dharwad Red)			
Ap	0–12	ND	17.3	8.8	91
Bt1	12–32	ND	23.7	13.3	123
B2	32–60	ND	21.2	12.0	116
Bc	60–150	ND	18.7	11.4	109
C	>150	ND	18.2	10.0	88
		Pedon–8 (Dharwad Black)			
Ap	0–16	1.48	35.4	19.3	382
A2	16–35	1.45	36.0	20.0	456
A3	35–55	1.40	37.2	22.0	467
A4	55–85	1.46	36.2	21.2	456
A5	85–105	1.45	36.0	20.3	455
Ac	105–125	1.50	36.4	21.0	446
2c	>125	1.68	34.2	19.1	391
		Pedon–9 (Mantagani Red)			
Ap	0–16	1.47	21.9	10.4	102
B1	16–30	1.45	22.3	12.7	110
Bt1	30–50	1.41	24.6	13.3	136
B2	50–70	1.43	26.2	14.7	131
C	>70	1.49	11.0	7.3	57
		Pedon–10 (Mantagani Black)			
Ap	0–15	1.47	35.2	17.4	395
A2	15–35	1.45	36.8	18.3	467
A3	35–60	1.46	37.2	19.5	516
A4	60–80	1.37	38.5	19.8	579
A5	80–100	1.40	39.0	20.2	559
A6	100–130	1.43	39.5	20.6	578
A7	130–153	1.45	36.2	18.0	473
A8	153–170	1.53	35.5	17.9	448
Ac	170–185	1.67	33.1	17.4	338
C	185–235+	1.69	31.2	16.8	325

the solum of black pedons it was highest in B.Gudi (1.50 to 1.61 Mg m^{-3}), followed by Bidar (1.43 to 1.55 Mgm^{-3}), Dharwad (1.40 to 1.50 Mg m^{-3}) and Mantagani (1.37 to 1.53 Mg m^{-3}).

Moisture retention capacity of soils at 33 KPa and 1500 KPa

The moisture retention capacity of red pedons at 33 KPa ranged from 11.0 to 26.8 per cent and from 7.3 to 19 per cent at 1500 KPa. The corresponding figures for black pedons were 31.2 to 41.2 per cent and 9.2 to 22.7 per cent. Among the red pedons the highest moisture retention capacity at 33 KPa and 1500 KPa was in Bidar pedon (21.2 to 26.8 per cent and 11.4 to 19.0 per cent), followed by Mantagani (11 to 26.2 per cent and 7.3 to 14.7 per cent), Dharwad (17.3 to 23.7 per cent and 8.8 to 13.3 per cent), B.Gudi (14.8 to 22.0 per cent and 7.4 to 10.6 per cent) and Raichur (9.3 to 24.5 per cent and 4.6 to 14.8 per cent). Among the black pedons the highest moisture retention capacity at 33 KPa and 1500 KPa was in Bidar (35.2 to 41.2 per cent and 18.2 to 22.7 per cent) followed by Raichur (15.3 to 40.6 per cent and 9.2 to 22.6 per cent), Mantagani (31.2 to 39.5 per cent and 16.8 to 20.6 per cent), B.Gudi (29.4 to 39.3 per cent and 14.0 to 20.6 per cent) and Dharwad (34.2 to 37.2 per cent and 19.1 to 22 per cent) pedons. In all the pedons moisture at 33 KPa and at 1500 KPa increased with depth upto certain depth and then decreased. Moisture retention capacity at both 33 KPa and 1500 KPa in red pedons was less than that of associated black pedons.

Specific surface area of soils

In red pedons specific surface area of soil ranged from 44 to 173 m^2/g and the corresponding figures for black pedons were 162 to 607 m^2/g. In all the pedons specific surface area showed increasing trend with depth, upto certain depth and then decreased. The specific surface area of red pedons was less than that of associated black pedons. Among the red pedons the highest specific surface area (110 to 173 m^2/g) observed in Bidar pedon, followed by Mantagani (57 to 136 m^2/g), Raichur (67 to 131 m^2/g), Dharwad (88 to 123 m^2/g) and B. Gudi (44 to 113 m^2/g) pedons. Among the black pedons the highest specific surface area (401 to 607 m^2/g) observed again in Bidar pedon followed by Mantagani (325 to 579 m^2/g), Dharwad (382 to 467 m^2/g), Raichur (162 to 445 m^2/g), and B.Gudi (296 to 443 m^2/g) pedons.

4.3 Physico-chemical properties

Data pertaining to it is presented in Table 6 and 7.

4.3.1 Soil reaction (1:2, soil:water)

In Bidar red pedon soil reaction was medium to strongly acid (pH 5.3 to 5.5), and in black pedon it was mildly alkaline to moderately alkaline (pH 7.6 to 8.0). pH in both the pedons slightly icreased with depth. In B.Gudi and Raichur red pedons the soil reaction was neutral (pH 7 to 7.3 and 6.8 to 7.0) and was nearly uniformly distributed in the solum. In B.Gudi black pedon soil reaction was moderately alkaline to strongly alkaline (pH 8.0 to 8.7). pH showed increasing trend with depth. In Dharwad red pedon pH ranged from medium acid to neutral (pH 6.0 to 7.1) and in the associated black pedon it was neutral to moderately alkaline (pH 6.6 to 7.9). Unlike in other soils the pH values were very similar in the solum of red pedon and the upper solum of black pedon. In both the pedons pH showed increasing trend with depth. In Mantagani red pedon pH ranged from slightly acid to neutral acid (pH 6.5 to 7.3) and it decreased upto 50 cm depth and then increased. Mantagani black pedon had neutral to moderately alkaline (pH 7.0 to 8.2) soil reaction and decreased upto 80 cm depth and then increased.

In general pH of red pedons ranged from strongly acid to neutral (pH 5.3 to 7.0) and that of black pedons from neutral to strongly alkaline (pH 6.6 to 8.8). Among the red pedons the lowest pH was observed in Bidar pedon and the highest pH was observed in B. Gudi pedon followed by Dharwad Raichur and Mantagani pedons. Among the black pedons the lowest pH was observed in Dharwad pedons and the highest was observed in Raichur pedon followed by B. Gudi Mantagani and Bidar pedons.

4.3.2 Electrical conductivity

Electrical conductivity ranged from 0.1 to 0.4 dS/m in red pedons and from 0.11 to 1.10 dS/m in black pedons. Among the red pedons the lowest Ec (0.1 dS/m) was observed in Bidar pedon and the highest Ec (0.15 to 0.31 dS/m) observed in Mantagani followed by Dharwad (0.1 to 0.47 dS/m), Raichur (0.1 to 0.3 dS/m) and B.Gudi (0.1 to 0.3 dS/m) pedons. Among the black pedons the lowest Ec (0.11 to 0.47 dS/m) observed in Dharwad pedon and the highest Ec (0.24 to 1.10 dS/m) observed in B.Gudi pedon followed by Raichur (0.4 to 0.9 dS/m), Mantagani (0.26 to 0.8 dS/m) and Bidar (0.4 to 0.6 dS/m) pedons.

4.3.3 Exchangeable cations

Data on exchangeable cations is given in the table.6.

Exchangeable Calcium

Exchangeable calcium content ranged from 3 to 26 C.mol (p^{+}) kg^{-1} in red pedons and from 10.8 to 55.1 C mol (P^{+}) kg^{-1} in black pedons. Comparatively black pedons had more

Table 6. Cation exchange capacity, exchangeable cations, $BaCl_2$ – TEA extractable acidity and base saturation percentage

Horizon	Depth (cm)	C.mol(P^+) kg^{-1}						Base saturation percentage
		Exchangeable cations				C.E.C.	$BaCl_2$ – TEA extractable acidity	
		Ca	Mg	Na	K			
1	2	3	4	5	6	7	8	9
Pedon–1 (Bidar Red)								
Ap	0–9	12.5	11.4	0.5	0.6	29.4	3.5	88.3
Bt1	9–30	11.7	8.7	0.3	0.3	23.2	3.9	84.3
Bt2	30–43	12.1	9.0	0.3	0.5	24.1	3.4	86.6
BC	43–55	12.1	9.0	0.3	0.5	23.9	2.7	89.0
C	55+	–	–	–	–	–	–	–
Pedon–2 (Bidar Black)								
Ap	0–14	33.0	14.8	0.4	0.7	52.6	ND	ND
A2	14–35	33.2	18.2	0.4	0.6	56.7	ND	ND
A3	35–54	34.3	18.0	0.5	0.7	58.2	ND	ND
A4	54–68	35.3	20.4	0.5	0.6	61.4	ND	ND
A5	68–94	35.9	22.5	0.6	0.6	63.5	ND	ND
A6	94–118	34.0	25.0	0.6	0.7	65.5	ND	ND
A7	130–153	33.5	26.6	0.7	0.7	67.4	ND	ND
A8	153–170	31.9	26.2	0.2	0.7	63.0	ND	ND
Ac	170–185	29.5	29.2	0.3	0.7	62.9	ND	ND
C	185–235	26.4	25.0	0.4	0.7	54.2	ND	ND
Pedon–3 (B.Gudi Red)								
Ap	0–11	7.1	2.2	0.2	0.2	10.5	1.2	89.0
Bt	11–24	9.1	4.1	0.2	0.3	14.6	1.6	89.5
Bt2	24–47	10.2	4.8	0.3	0.2	16.0	1.4	91.7
Bt3	47–67	11.3	5.6	0.2	0.2	18.4	0.6	96.6
BC	67–92	10.2	9.4	0.2	0.2	16.3	1.8	89.2
C	>92	7.5	3.2	0.3	0.2	10.3	1.0	91.8
Pedon–4 (B.Gudi Black)								
Ap	0–9	30.7	12.7	1.2	0.8	50.5	ND	ND
A2	9–27	32.3	12.6	2.0	0.7	54.7	ND	ND
A3	27–49	32.9	15.4	3.2	0.9	59.5	ND	ND
A4	49–80	33.6	20.1	4.7	0.9	62.3	ND	ND
A5	80–118	41.3	16.4	6.6	1.2	66.7	ND	ND
A6	118–132	41.9	20.1	7.1	1.4	54.2	ND	ND
Cca	132–186	34.3	18.7	5.3	0.8	41.5	ND	ND
Pedon–5 (Raichur Red)								
Ap	0–10	3.0	2.0	0.2	0.3	7.5	2.2	71.4
Bt1	10–22	6.1	2.0	0.2	0.2	11.2	2.0	81.0
Bt2	22–43	8.2	2.1	0.4	0.2	14.5	3.1	77.9
Bt3	43–65	9.3	4.0	0.4	0.2	19.5	1.7	89.1
Bc	65–76	10.2	3.1	0.5	0.2	21.0	1.4	91.0
C	76–100	10.3	6.2	0.5	0.3	22.0	1.7	91.1

Table 6. (Contd.)

1	2	3	4	5	6	7	8	9
			Pedon–6 (Raichur Black)					
Ap	0–18	42.9	9.3	0.7	0.9	59.1	ND	ND
A2	18–42	45.4	10.7	0.8	1.1	61.5	ND	ND
A3	42–70	46.0	10.8	0.2	1.1	62.6	ND	ND
A4	70–150	42.1	11.9	3.2	0.9	64.3	ND	ND
2c	150–180	ND	ND	ND	ND	ND	ND	ND
			Pedon–7 (Dharwad Red)					
Ap	0–12	5.7	6.5	0.2	0.3	18.7	4.0	76.0
Bt1	12–32	10.0	3.8	0.2	0.2	19.3	4.2	77.2
B2	32–60	10.2	2.5	0.6	0.3	21.2	4.3	76.0
Bc	60–150	4.9	2.5	0.9	0.4	11.5	3.9	69.0
C	>150	4.1	1.2	0.9	0.2	9.6	3.5	64.6
			Pedon–8 (Dharwad Black)					
Ap	0–16	43.7	9.4	1.1	0.4	61.5	ND	ND
A2	16–35	39.5	9.5	0.5	0.5	63.8	ND	ND
A3	35–55	40.3	10.4	0.7	0.5	64.5	ND	ND
A4	55–85	40.3	13.8	0.7	0.5	66.4	ND	ND
A5	85–105	41.3	16.0	0.8	0.5	67.0	ND	ND
Ac	105–125	47.8	16.0	0.9	0.7	69.0	ND	ND
2c	>125	55.1	5.2	1.1	0.7	63.0	ND	ND
			Pedon–9 (Mantagani Red)					
Ap	0–16	17.8	10.8	1.1	0.5	29.8	3.7	87.4
B1	16–30	17.2	9.6	3.1	0.5	35.0	4.4	88.2
Bt1	30–50	12.4	10.0	0.8	0.3	37.3	4.2	88.8
B2	50–70	12.2	10.2	0.4	0.3	37.9	3.7	90.0
C	>70	12.3	4.0	0.3	0.3	18.4	2.5	87.1
			Pedon–10 (Mantagani Black)					
Ap1	0–15	36.4	17.2	1.8	0.3	59.3	ND	ND
A2	15–35	37.5	10.7	1.1	0.3	52.4	ND	ND
A3	35–60	40.6	11.8	1.1	0.4	57.2	ND	ND
A4	60–80	40.7	8.6	1.4	0.4	58.4	ND	ND
A5	80–100	41.7	11.4	1.8	0.4	59.2	ND	ND
A6	100–130	45.0	8.6	3.2	0.4	61.1	ND	ND
A7	130–153	46.0	12.8	4.1	0.5	65.5	ND	ND
A8	153–170	48.2	13.9	3.9	0.5	68.7	ND	ND
Ac	170–185	25.5	9.5	2.1	0.3	42.5	ND	ND
C	185–235+	30.2	8.3	2.1	0.4	45.7	ND	ND

exchangeable calcium than that of associatd red pedons. Exchangeable calcium increased with depth in majority of cases except in Dharwad red pedon. Among the red pedons exchangeable calcium was lowest (3 to 10.3 C mol (p^{+}) kg^{-1}) in Raichur pedon and the highest (12.2 to 17.8 C mol (P^{+}) kg^{-1} in Mantagani followed by Dharwad (4.1 to 10.2 C mol (P^{+}) Kg^{-1} Bidar (11.7 to 12.5 C mol $(p^{+})kg^{-1}$) and B.Gudi (7.1 to 11.3 C mol (p^{+}) kg^{-1}) pedons. Among the black pedons exchangeable calcium was lowest (26.4 to 35.9 C mol (P^{+}) kg^{-1}) in Bidar pedon and was highest (39.5 to 55.1 C mol (P^{+}) kg^{-1}) in Dharwad pedon followed by Mantagani (25.5 to 48.2 C mol (P^{+}) kg^{-1}), Raichur (42.1 to 46.0 C mol (p^{+}) kg^{-1}) B.Gudi (30.7 to 41.9 C mol (p^{+}) kg^{-1}) pedons.

Exchangeable Magnesium

Exchangeable magnesium ranged from 0.2 to 11.4 C mol (p^{+}) kg^{-1} in red pedons and from 4.3 to 29.2 C mol $(p^{+})kg^{-1}$ in black pedons. Among the red pedons the exchangeable magnesium was the lowest (2.2 to 9.4 C mol $(p^{+})kg^{-1}$) in B.Gudi pedon and was the highest (8.7 to 11.4 C mol (p^{+}) kg^{-1}) in Bidar pedon followed by Mantagani (4 to 10.8 C mol $(p^{+})kg^{-1}$) , Dharwad (1.2 to 6.5 C mol $(p^{+})kg^{-1}$), and Raichur (2 to 6.2 C mol $(p^{+})kg^{-1}$) pedons. Among the black pedons . exchangeable magnesium was the lowest (9.3 to 11.9 C mol $(p^{+})kg^{-1}$) in

Raichur pedon and was the highest (14.8 to 29.2 C mol (p^+) kg^{-1}) in Bidar pedon followed by B.Gudi (12.6 to 20.1 C mol (p^+) kg^{-1}), Mantagani (8.3 to 17.2 C mol (p^+) kg^{-1}) and Dharwad (5.2 to 16 C mol (p^+) kg^{-1}) pedons. In majority of pedons exchangeable magnesium increased with depth. In Mantagani black pedon exchangeable magnesium increased and decreased alternatively with depth from surface except in between 150 to 170 cm depth.

Exchangeable Sodium

Exchangeable sodium ranged from 0.2 to 3.1 C mol (P^+) kg^{-1} in red pedons and from 0.2 to 7.1 C mol (p^+)kg^{-1} in black pedons. Among the red pedons exchangeable sodium was lowest (0.2 to 0.3 C mol (p^+) kg^{-1}) in B.Gudi pedon and was highest (0.3 to 3.1 C mol(p^+) kg^{-1}) in Mantagani pedon followed by Dharwad (0.2 to 0.9 C mol (p^+) kg^{-1}), Bidar (0.3 to 0.5 C mol (p^+) kg^{-1}), and Raichur (0.2 to 0.5 C mol (p^+) kg^{-1}) pedons. Among the black pedons exchangeable sodium was lowest 0.2 to 0.7 C mol (p^+) kg^{-1}) in Bidar pedon and was highest (1.2 to 7.1 C mol (p^+) kg^{-1}) in B.Gudi pedon followed by Mantagani (1.1 to 4.1 C mol (p^+) kg^{-1}), Raichur (0.2 to 5.1 C mol (p^+) kg^{-1}), and Dharwad (0.5 to 1.1 C mol (p^+)Kg^{-1}) pedons. In Majority of pedons exchangeable sodium increased with depth. In Bidar (excluding surface horizon) and B.Gudi red pedons exchangeable sodium was almost uniformly distributed throughout the profile. Mantagani red pedon showed decreasing trend with depth from second horizon. In general exchangeable sodium content was more in black pedons than that of associated red pedons.

Exchangeable Potassium

Exchangeable potassium ranged from 0.2 to 0.6 C mol (p^+) kg^{-1} in red pedons and from 0.2 to 1.4 C mol (p^+) kg^{-1} in black pedons. Among the red pedons exchangeable potassium was lowest (0.2 to 0.3 C mol (p^+) kg^{-1}) in B.Gudi pedon and was highest (0.3 to 0.6 C mol (P^+) kg^{-1}) in Bidar pedon followed by Mantagani (0.3 to 0.5 C mol (P^+) kg^{-1}), Dharwad (0.2 to 0.4 C mol (p^+) kg^{-1}) and Raichur (0.2 to 0.3 C mol (p^+) kg^{-1}) pedons. Among the black pedons exchangeable potassium was highest (0.7 to 1.4 C mol (P^+) Kg^{-1}) in B.Gudi pedon followed by Raichur (0.9 to 1.1 C mol (p^+) kg^{-1}), Bidar (0.6 to 0.7 C mol (p^+) kg^{-1}), Dharwad (0.4 to 0.7 C mol (p^+) kg^{-1}) and Mantagani (0.3 to 0.5 C mol (p^+) kg^{-1}) pedons. In majority of pedons, exchangeable potassium was almost uniformly distributed through out the profile. In B.Gudi and Mantagani black pedons exchangeable potassium showed slight increase with depth. In Mantagani red and black pedons exchangeable potassium content was same.

In both red and black pedons exchange complex was dominated by calcium followed by magnesium, sodium and potassium.

4.3.4 Cation exchange capacity

Data on CEC is given in Table 6. Cation exchange capacity ranged from 7.5 to 37.9 C mol (p^+) kg^{-1} in red pedons and from 18.3 to 72.1 C mol $(p^+)kg^{-1}$ in black pedons. Among the red pedons CEC was highest (18.4 to 37.9 C mol (p^+) kg^{-1}) in Mantagani pedon followed by Bidar (23.2 to 29.4 C mol $(p^+)kg^{-1}$), Raichur (7.5 to 22 C mol $(p^+)kg^{-1}$) Dharwad (9.6 to 21.2 C mol $(p^+)kg^{-1}$), and B.Gudi (10.3 to 18.4 C mol (p^+) kg^{-1}) pedons. Among the black pedons CEC was highest (61.5 to 69.0 C mol (p^+) kg^{-1})in Dharwad pedon followed by Mantagani (42.5 to 68.7 C mol (p^+) kg^{-1}), Bidar (52.6 to 67.4 C mol$(p^+)kg^{-1}$), B.Gudi pedon (41.5 to 66.7 C mol (p^+) kg^{-1}), and Raichur (59.1 to 64.3 C mol (p^+) kg^{-1}) pedons. In almost all pedons CEC increased down the profile to some depth and then decreased.

4.3.5 $BaCl_2$ - TEA Extractable acidity

The $BaCl_2$ - TEA extractable acidity was carried out only in red pedons,and the data pertaiing to it is presentd in the Table 6.

It showed decreasing trend with depth from Bt_1 horizon in Bidar pedon, where as no trend with depth observed in B.Gudi pedon. In Raichur pedon it was almost uniform in Ap_1 and Bt_1 horizons and then increased in Bt_2 horizon and again decreased in Bt_3 and BC horizons and then increased in C horizon. In Dharwad pedon it showed slighty increasing trend with depth from surface upto 60 cm depth below which it decreased. In Mantagani pedon it showed increasing trend with depth upto 30 cm depth from surface below which decreasing trend osberved.

In general $Bacl_2$-TEA extractable acidity ranged from 0.6 to 4.4 C mol (p^+) kg^{-1} in red pedons. Among these red pedons it was lowest (0.6 to 1.8 C moil (p^+) kg^{-1}) in B.Gudi pedon and was highest (2.5 to 4.4 C.mol (p^+) kg^{-1}) in Mantagani pedon, followed by Dharwad (3.5 to 4.3 C mol(p^+) kg^{-1}, Bidar (2.7 to 3.9 C mol$(p^+)kg^{-1}$) and Raichur (1.4 to 3.1 C mol (p^+) kg^{-1}) pedons.

4.3.6 Base saturation percentage

It was determined only in red pedons and the data pertaining to it is presentd in Table 6.

In Bidar pedon it showed increasing trend with depth from Bt_1 horizon. In B.Gudi pedon it showed increasing trend with depth upto 67 cm depth and then decreased in between 67 -92 cm depth and again increased in C horizon. In Raichur pedon increasing trend with depth was observed. In Dharwad pedon it decreased with depth from 60 cm depth. In Mantagai pedon it showed increasing trend with depth in the solum, and it decreased in C horizon.

In general base saturation per centage ranged from 64.6 to 95.2 in red pedons. It was lowest (64.6 to 77.2) in Dharwad pedon and was highest (89.0 to 96.6) in B.Gudi pedon followed by Raichur (71.4 to 91.1), Mantagani (87.1 to 90.0) and Bidar (88.3 to 89.0) pedons.

4.4 Chemical properties

Data pertaining to chemical properties is presented in Table 7.

4.4.1 Free $CaCO_3$

Free $CaCO_3$ was determined only in black pedons. In Bidar pedon it showed increasing trend with depth from A_3 horizon in the solum, and it decreased in Ac and C horizons. In B.Gudi pedon also it showed increasing trend with depth from A_2 horizon in the solum. In Raichur pedon it showed increasing trend with depth upto 70 cm depth and then decreased in between 70 to 150 cm depth again increased in the

Table 7. pH, EC, organic carbon, $CaCO_3$, Fed and Feo

Horizon	Depth (cm)	pH (1:2) (soil:water)	EC (1:2) (soil:water) dS/m	Organic carbon (%)	Free $CaCO_3$ (%)	Fed (%)	Feo (%)	Feo/Fed
1	2	3	4	5	6	7	8	9
Pedon–1 (Bidar Red)								
Ap	0–9	5.3	0.10	0.87	ND	2.37	0.74	0.31
Bt1	9–30	5.3	0.10	0.75	ND	3.33	0.83	0.25
Bt2	30–43	5.4	0.10	0.54	ND	3.86	0.80	0.21
BC	43–55	5.5	0.10	0.42	ND	3.87	1.47	0.38
C	55+	-	-	-	-	-	-	-
Pedon–2 (Bidar Black)								
Ap	0–14	7.7	0.40	0.60	5.9	3.39	0.56	0.17
A2	14–35	7.8	0.40	0.60	6.6	2.38	0.63	0.26
A3	35–54	7.6	0.50	0.54	5.3	2.76	0.57	0.21
A4	54–68	7.8	0.40	0.31	5.8	2.90	0.65	0.22
A5	68–94	7.9	0.50	0.31	6.0	2.68	0.66	0.25
A6	94–118	7.8	0.60	0.47	6.4	2.93	0.51	0.17
A7	130–153	7.9	0.60	0.43	6.4	3.14	0.44	0.14
A8	153–170	7.9	0.60	0.31	7.0	2.44	0.41	0.17
Ac	170–185	8.0	0.50	0.10	6.0	1.74	0.38	0.22
C	185–235	8.0	0.50	0.10	6.0	2.54	0.35	0.14
Pedon–3 (B.Gudi Red)								
Ap	0–11	7.3	0.10	0.40	ND	1.06	0.18	0.17
Bt	11–24	7.2	0.10	0.44	ND	1.07	0.22	0.21
Bt2	24–47	7.2	0.10	0.43	ND	1.41	0.25	0.18
Bt3	47–67	7.3	0.10	0.32	ND	1.58	0.28	0.18
BC	67–92	7.1	0.10	0.21	ND	1.16	0.13	0.11
C	>92	7.0	0.30	0.18	ND	0.67	0.09	0.13
Pedon–4 (B.Gudi Black)								
Ap	0–9	8.1	0.24	0.60	18.1	0.40	0.13	0.33
A2	9–27	8.0	0.26	0.40	17.2	0.36	0.14	0.39
A3	27–49	8.3	0.32	0.50	19.1	0.34	0.13	0.38
A4	49–80	8.3	0.58	0.48	19.7	0.36	0.13	0.36
A5	80–118	8.5	0.90	0.40	21.6	0.36	0.09	0.25
A6	118–132	8.7	0.90	0.35	25.8	0.29	0.09	0.31
Cca	132–186	8.6	1.10	0.30	10.1	0.44	0.05	0.11
Pedon–5 (Raichur Red)								
Ap	0–10	6.9	0.10	0.40	ND	0.83	0.13	0.16
Bt1	10–22	6.8	0.10	0.20	ND	1.60	0.19	0.12
Bt2	22–43	7.0	0.10	0.22	ND	2.02	0.34	0.17
Bt3	43–65	6.9	0.10	0.20	ND	2.04	0.29	0.14
Bc	65–76	6.9	0.30	0.07	ND	2.41	0.32	0.13
C	76–100	7.0	0.20	0.03	ND	1.63	0.16	0.10

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9
			Pedon–6 (Raichur **Black**)					
Ap	0–18	7.5	0.40	0.35	4.2	0.40	0.17	0.43
A2	18–42	7.9	0.40	0.32	4.8	0.34	0.20	0.59
A3	42–70	8.0	0.50	0.30	5.8	0.38	0.18	0.47
A4	70–150	8.1	0.90	0.24	4.3	0.41	0.17	0.41
2c	150–180	8.8	0.60	0.02	7.0	0.16	0.05	0.31
			Pedon–7 (Dharwad **Red**)					
Ap	0–12	6.5	0.27	0.83	ND	2.81	0.75	0.27
Bt1	12–32	6.8	0.10	0.54	ND	3.76	0.65	0.17
B2	32–60	6.9	0.12	0.43	ND	4.61	0.30	0.07
Bc	60–150	7.1	0.17	0.28	ND	3.84	0.92	0.24
C	>150	6.0	0.47	0.14	ND	3.10	1.35	0.44
			Pedon–8 (Dharwad **Black**)					
Ap	0–16	6.6	0.45	0.68	1.0	2.45	0.50	0.20
A2	16–35	6.9	0.14	0.60	1.6	2.61	0.50	0.19
A3	35–55	6.9	0.11	0.55	2.0	2.70	0.41	0.15
A4	55–85	6.9	0.20	0.53	5.2	2.80	0.95	0.34
A5	85–105	7.2	0.44	0.52	6.8	2.95	1.01	0.34
Ac	105–125	7.8	0.47	0.50	7.8	2.48	0.85	0.34
2c	>125	7.9	0.46	0.21	18.9	2.92	0.72	0.25
			Pedon–9 (**Mantagani** Red)					
Ap	0–16	7.3	0.20	0.52	ND	3.00	0.37	0.12
B1	16–30	6.6	0.20	0.42	ND	2.60	0.32	0.12
Bt1	30–50	6.5	0.15	0.42	ND	2.43	0.38	0.16
B2	50–70	6.8	0.28	0.33	ND	1.80	0.36	0.20
C	>70	7.1	0.31	0.11	ND	1.84	0.13	0.07
			Pedon–10 (**Mantagani Black**)					
Ap	0–15	7.9	0.34	0.60	2.1	1.48	0.34	0.23
A2	15–35	7.7	0.26	0.50	3.6	1.44	0.29	0.20
A3	35–60	7.4	0.37	0.54	3.7	1.25	0.34	0.27
A4	60–80	7.0	0.85	0.54	3.7	1.64	0.33	0.20
A5	80–100	7.6	0.41	0.48	4.2	1.72	0.32	0.19
A6	100–130	7.7	0.49	0.50	6.3	1.60	0.33	0.21
A7	130–153	7.9	0.66	0.40	6.4	1.52	0.21	0.14
A8	153–170	7.8	0.80	0.31	11.5	1.60	0.16	0.10
Ac	170–185	7.8	0.80	0.15	3.1	1.51	0.15	0.10
C	185–235+	8.2	0.61	0.11	2.0	1.10	0.10	0.10

C horizon. In Dharwad pedon it showed increasing trend with depth. In Mantagani pedon also same trend observed with depth upto 170 cm depth below which it decreased.

Free $CaCO_3$ content ranged from 1 to 25.8 per cent. Among these pedons, it was lowest (4.2 to 7.0 pe cent) in Raichur pedon and was highest (10.1 to 25.8 per cent) in B.Gudi pedon followed by Dharwad (1 to 18.9 per cent), Mantagani (2.0 to 11.5 per cent) and Bidar (5.3 to 7 per cent) pedons.

4.4.2 Organic Carbon

In Bidar red pedon organic carbon decreased with depth. In black pedon organic carbon showed decreasing trend with depth upto 94 cm depth, and its content increased in between 94 to 118 cm and decreased steadily below. In the remaining red and black pedons organic carbon showed decreasing trend with depth.

Organic carbon content ranged from 0.11 to 0.87 per cent in red soils and from 0.10 to 0.68 per cent in black soils. Among the red pedons it was lowest (0.03 to 0.40 per cent) in Raichur pedon and was highest (0.42 to 0.87 per cent) in Bidar pedon followed by Dharwad (0.14 to 0.83 per cent), Mantagani (0.11 to 0.52 per cent) and B.Gudi 0.18 to 0.44 per

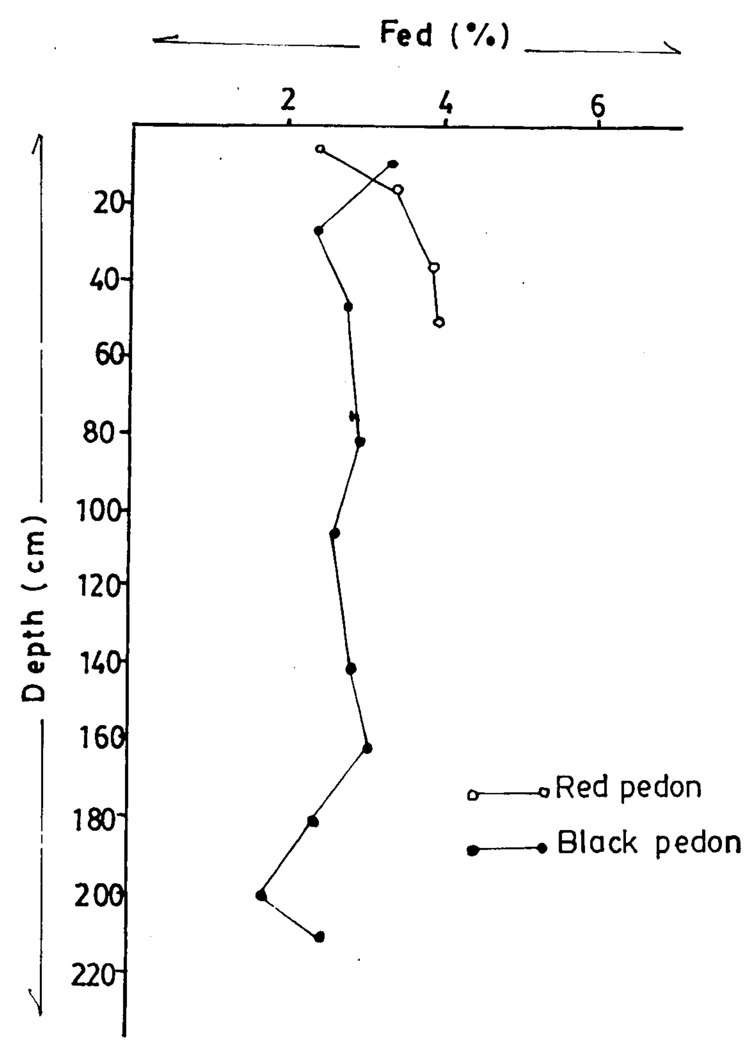

Fig. 7 Fed DISTRIBUTION IN BIDAR PEDONS

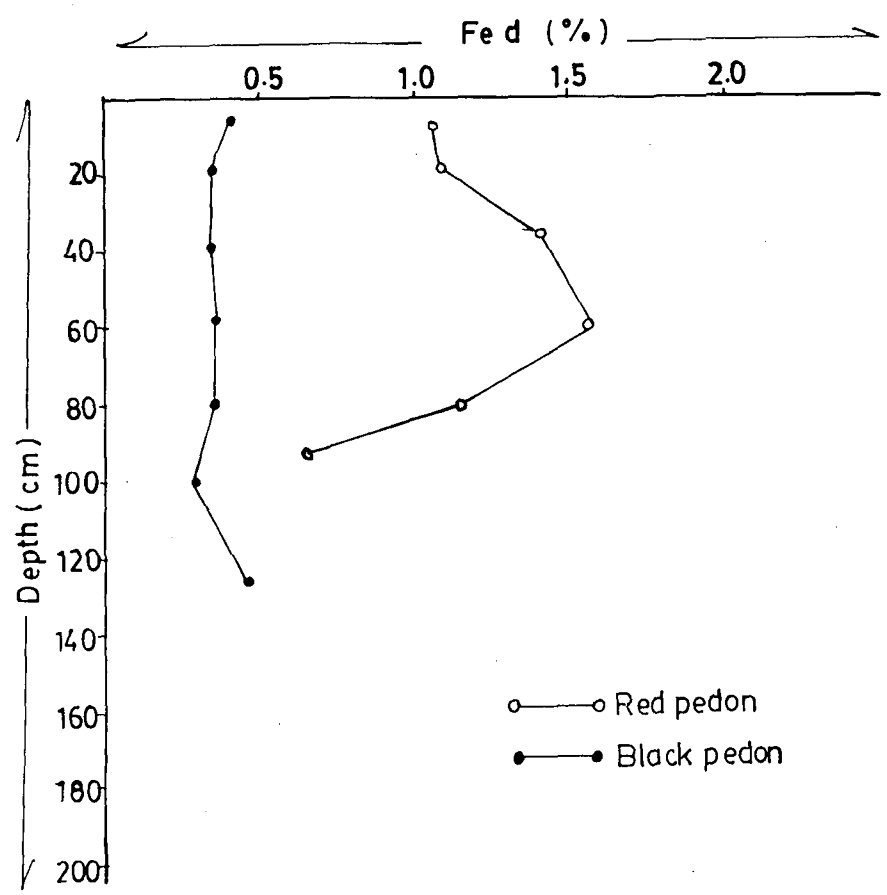

Fig: 8 Fed DISTRIBUTION IN B.GUDI PEDONS

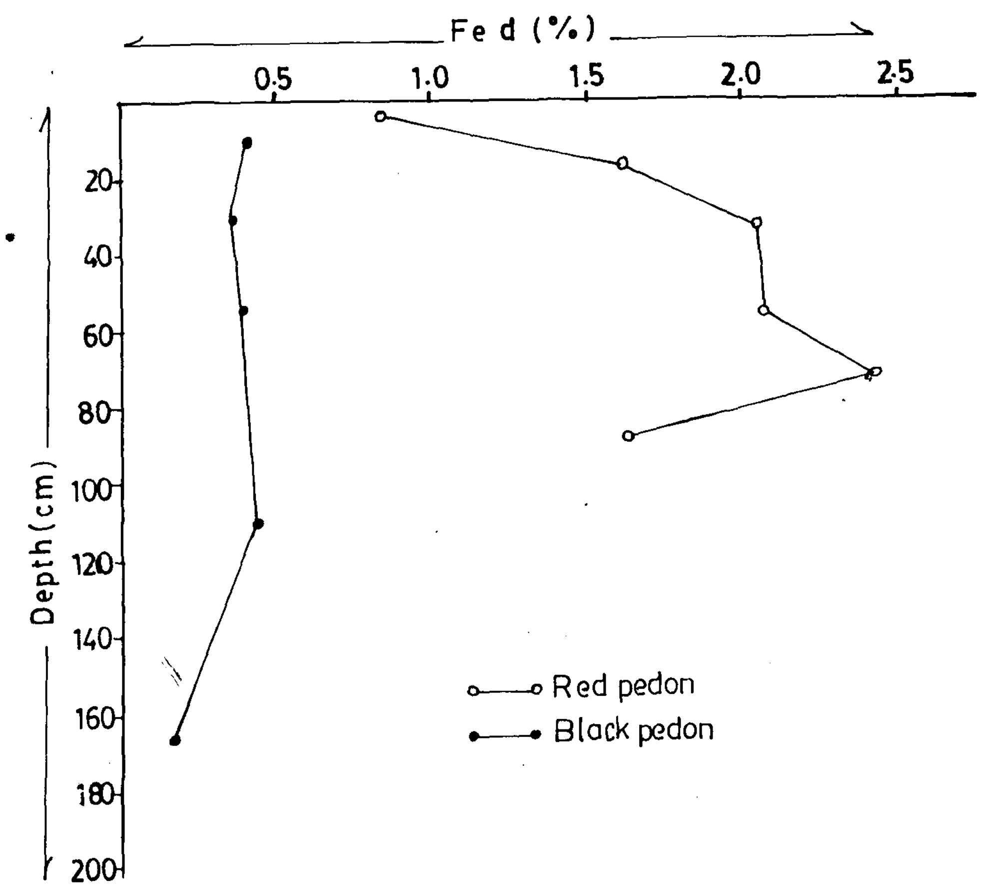

Fig: 9 Fed DISTRIBUTION IN RAICHUR PEDONS

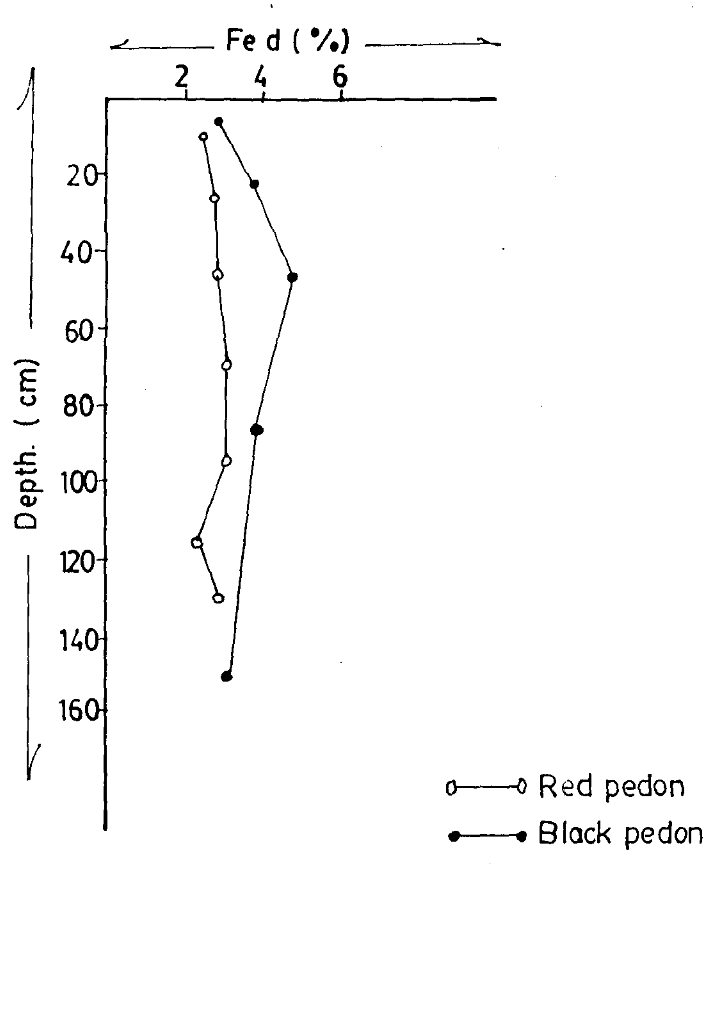

Fig.10 Fed DISTRIBUTION IN DHARWAD PEDONS

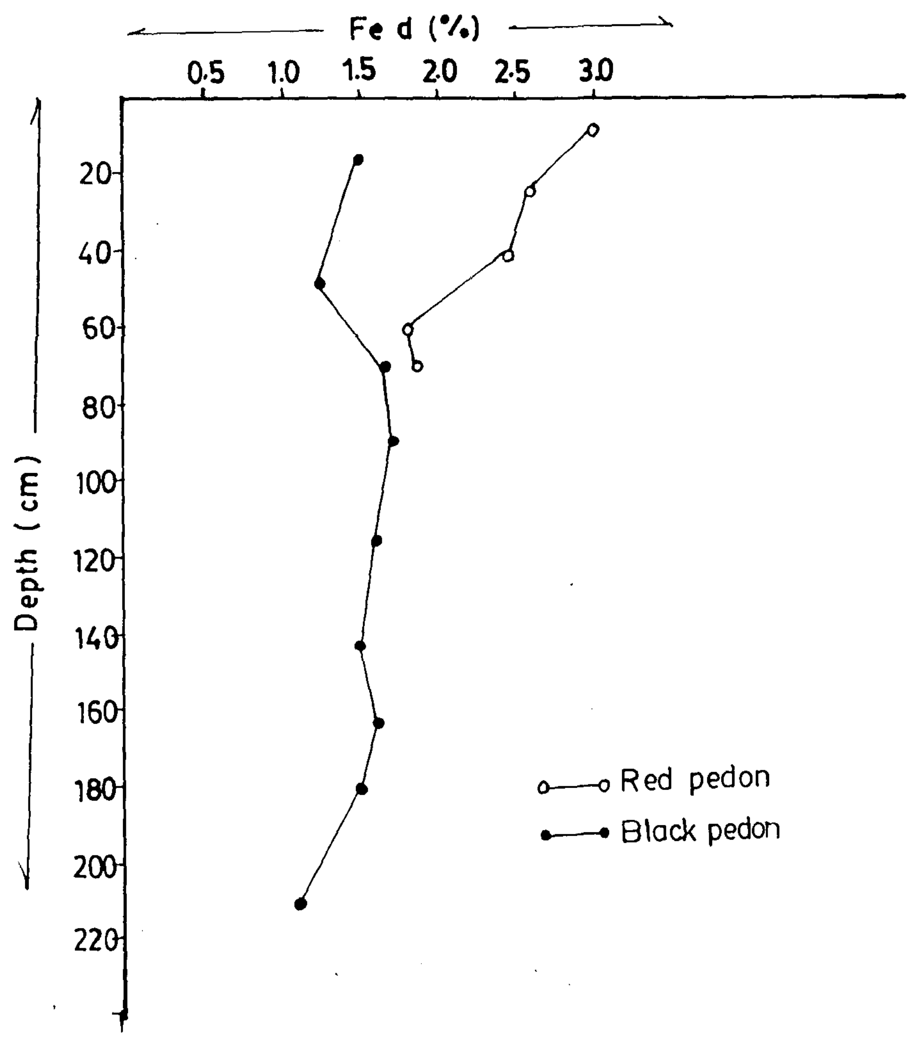

Fig.11 Fed DISTRIBUTION IN MANTAGANI PEDONS

cent) pedons. Among the black pedons again it was lowest (0.02 to 0.35 per cent) in Raichur pedon and was highest (0.21 to 0.68 per cxent) in Dharwad pedon. It`s content was almost same in B.Gudi (0.3 to 0.6 per cent), Mantagani (0.11 to 0.6 per cent) and Bidar (0.1 to 0.6 per cent) pedons. Comparatively black pedons contained more organic carbon than that of associated red pedons except Bidar and Dharwad pedons where reverse was true.

4.4.3 Dithionite (Fed) and Oxalate (Feo) Extractable iron

In red pedons Fed ranged from 0.67 to 4.61 per cent and from 0.16 to 3.39 per cent in black pedons. Among the red pedons it was lowest (0.67 ro 1.58 per cent) in B. Gudi pedons and was highest (2.81 to 4.61 per cent) in Dharwad pedon followed by Bidar (2.37 to 3.87 per cent), Mantagani (1.8 to 3.0 per cent) and Raichur (0.83 to 2.41 per cent) pedons. Among the black pedons it was lowest (0.16 to 0.41 per cent) in Raichur pedon and was highest (1.74 to 3.39 per cent) in Bidar pedon followed by Dharwad (2.45 to 2.95 per cent) Mantagani (1.1 to 1.72 per cent), and B.Gudi (0.29 to 0.44 per cent) pedons.

Feo content ranged from 0.13 to 1.47 per cent in red pedons and from 0.05 to 1.01 per cent in black pedons. Among the red pedons it was lowest (0.09 to 0.28 per cent) in B.Gudi pedon and was highest (0.74 to 1.47 per cent) in Bidar pedon followed by Dharwad (0.3 to 1.35 per cent) Mantagani (0.13 to 0.38 per cent) and Raichur (0.16 to 0.34 per cent) pedons. Among the black pedons it was lowest (0.05 to 0.14 per cent) in B. Gudi pedon and was highest (0.41 to 1.01 per cent) in Dharwad pedon followed by Bidar (0.35 to 0.66 per cent), Mantagani (0.1 to 0.34 per cent) and Raichur (0.05 to 0.2 per cent) pedons.

Feo/Fed ratio ranged from 0.07 to 0.44 in red pedons and from 0.1 to 0.59 in black pedons. Among the red pedons Feo/Fed ratio was lowest (0.07 to 0.20) in Mantagani pedon and was highest (0.07 to 0.44) in Dharwad pedon followed by Bidar (0.21 to 0.38), B.Gudi (0.11 to 0.21) and Raichur (0.1 to 0.17) pedons. Among the black pedons this ratio was lowest (0.14 to 0.26) in Bidar pedon and was highest (0.31 to 0.59) in Raichur followed by B. Gudi (0.11 to 0.39), Dharwad (0.15 to 0.34), and Mantagani (0.1 to 0.27) pedons.

In general Fed and Feo increased with depth in both red and black pedons. In Mantagani pedon Fed showed decrasing trend with depth and in Dharwad red pedon Feo showed decreasing trend in the upper solum and then increased in the lower solum. Feo/Fed ratio decreased with depth or almost uniformly distributed throughout the solum or irregularly distributed in the profiles of both red and black pedons.

4.5 Chemical composition of fine sand in the selected horizons

Data on chemical composition of fine sand is presented in the Table 8.

4.5.1 CaO

In both red and black pedons its content was more in the subsurface horizons than that of surface horizon. In almost all the pedons, its content increased with depth among the selected horizons. CaO content was more in black pedons compared to their red counterparts.

In red pedons CaO content ranged from 0.35 to 2.51 per cent and from 0.40 to 4.61 per cent in black pedons. Among the red pedons its content was highest (0.41 to 2.51 per cent) in Mantagani pedon followed by Bidar (0.42 to 2.15 per cent) Raichur (1.11 to 1.81 per cent) pedon and its content was same in Dharwad and B.Gudi (0.41 to 1.11 per cent) pedons. Among the black pedons its content was more (1.11 to 4.61 per cent) in Dharwad followed by Raichur (1.11 to 2.51 per .cent),

Table 8. Chemical composition of fine sand in the selected horizons

Horizon	Depth (cm)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	Fe_2O_3 (%)
			Pedon-1 (Bidar Red)			
Bt1	9-30	0.35	2.50	0.29	0.25	3.25
Bt2	30-43	0.90	2.90	0.30	0.50	2.90
BC	43-55	1.90	6.20	0.90	0.95	10.00
			Pedon-2 (Bidar Black)			
A3	35-54	0.40	2.00	0.35	0.09	2.20
A5	68-94	1.50	2.80	0.42	0.10	2.95
AC	170-185	2.15	4.83	1.40	0.56	7.35
			Pedon-3 (B.Gudi Red)			
Bt1	11-24	0.00	0.00	4.08	8.74	0.40
Bt3	47-67	0.41	1.72	1.47	3.67	0.80
C	>92	1.11	2.22	4.02	4.46	1.60
			Pedon-4 (B.Gudi Black)			
A2	9-27	0.41	0.77	1.08	1.68	0.11
A4	49-80	0.76	0.97	0.57	1.09	0.07
C	132-186	1.11	1.22	1.13	1.27	0.04
			Pedon-5 (Raichur Red)			
Bt1	10-22	1.11	1.22	1.42	3.52	0.60
Bt2	22-43	1.11	1.22	1.65	3.87	0.90
C	76-100	1.81	1.70	3.63	3.97	1.10
			Pedon-6 (Raichur Black)			
Ap	0-18	1.81	0.70	2.21	1.48	0.80
A2	18-42	1.11	1.22	1.93	1.25	0.40
A4	72-150	2.51	0.72	1.81	1.62	0.30
			Pedon-7 (Dharwad Red)			
Ap	0-12	0.41	1.22	0.18	0.13	2.50
Bt1	12-32	1.11	1.70	0.18	0.06	1.80
B3	60-150	1.11	1.22	0.28	0.44	8.10
			Pedon-8 (Dharwad Black)			
A2	16-35	1.11	1.70	0.39	0.06	2.50
A3	35-55	1.11	0.77	0.57	0.05	1.80
Ac	105-125	4.61	1.72	0.18	0.10	2.10
			Pedon-9 (Mantagani Red)			
Ap	0-16	0.41	1.22	0.39	0.16	0.90
Bt2	30-50	0.76	1.47	0.51	0.69	1.30
C	>70	2.51	4.73	7.76	0.92	8.40
			Pedon-10 (Mantagani Black)			
A2	15-35	0.41	0.77	0.34	0.05	2.70
A5	80-100	1.11	0.77	0.39	0.06	4.90
C	185-235+	2.51	3.72	1.76	0.74	5.60

Mantagani (0.41 to 2.51 per cent), Bidar (0.42 to 2.15 per cent) and B.Gudi (0.41 to 1.11 per cent) pedons.

4.5.2 MgO

MgO content was more in the subsurface horizons than that of surface horizons in both red and black pedons. Its content increased with depth among the selected horizons. In general MgO content was more in red pedons compared to their black counterparts.

MgO content ranged from 0 to 6.20 per cent in red pedons and from 0.70 to 4.83 per cent in black pedons. Among the red pedons its content was more (2.52 to 6.20 per cent) in Bidar pedon followed by Mantagani (1.22 to 4.73 per cent), B.Gudi (0 to 2.22 per cent), Raichur (.1.22 to 1.70 per cent) and Dharwad (1.22 to 1.70 per cent) pedons. Among the black pedons its content was again more in Bidar (2.20 to 4.83 per cent followed by Mantagani (0.77 to 3.72 per cent) pedon, Dharwad (0.77 to 1.72 per cent), B. Gudi (0.77 to 1.22 per cent) and Raichur (0.7 to 1.22 per cent) pedons.

4.5.3 Na_2O

Its content was more in red pedons compared to their black counterparts, with exception of Dharwad and Bidar black pedons where reverse was true. Na_2O content in B.Gudi red pedon was four times that of black counterpart. In Raichur red pedon its content increased with depth and in their black counterpart it decreased with depth. In Dharwad red pedon it slightly increased in between 60 to 150 cm depth. Whereas in Mantagani pedons its content increased with depth among the selected horizons in both red and black pedons.

Na_2O content ranged from 0.18 to 7.76 per cent in red pedons and from 0.18 to 2.21 per cent in black pedons. Among the red pedons Na_2O content was more (0.39 to 7.76 per cent) in Mantagani pedon, followed by B.Gudi (1.47 to 4.08 per cent), Raichur (1.42 to 3.63 per cent), Bidar (0.29 to 0.90 per cent and Dharwad (0.18 to 0.28 per cent) pedons. Among the black pedons Na_2O content was more (1.81 to 2.21 per cent) in Raichur pedon followed by Mantagani (0.34 to 1.76 per cent), Bidar (0.35 to 1.40 per cent), B. Gudi (0.57 to 1.13 per cent) and Dharwad (0.18 to 0.57 per cent) pedons.

4.5.4 K_2O

Its content was more in the surface horizons of B. Gudi red and black pedons. In general its content was more in the subsurface horizons compared to surface horizons. Its content increased with depth among the selected horizons or almost uniformly distributed in the surface horizons and was less compared to sub surface horizons. K_2O content was very high in B.Gudi red pedon compared to its black counterpart.

Comparatively K_2O content was very high in red pedons than that of associated black pedons. K_2O content ranged from 0.06 to 8.74 per cent in red pedons and from 0.05 to 1.68 per cent in black pedons. In both red and black pedons K_2O content was more in B. Gudi pedons followed by Raichur, Mantagani. Bidar and Dharwad pedons.

4.5.5 Fe_2O_3

Fe_2O_3 content was more in the red pedons compared to their black counterparts with exception to Mantagani where the converse was true. Its content was more in red and black pedons of Bidar, Mantagani and Dharwad pedons compared to all other pedons. In red pedons Fe_2O_3 showed increasing trend with depth among the selected horizons. Among the black pedons its content decreased in B. Gudi and Raichur pedons and increased in Mantagani pedon with depth among the selected horizons. In Dharwad black pedon no trend observed.

DISCUSSION

V. DISCUSSION

Five pairs of associated red and black pedons from the northern districts (viz., Bidar, Gulbarga, Raichur and Dharwad) of Karnataka were studied for their morphological features in the field and for physical and chemical properties in the laboratory with an objective to know the genesis of these complex soils. Geology of each of these sites was different. Bidar sites were on Deccan trap where as B.Gudi and Raichur sites on granite-gneiss. Geology of Dharwad and Mantagani sites belong to Dharwad system consisting of banded heamatite quartzite with shale in the former and with chlorite schist in the latter. All the sites have semiarid climate except Dharwad which is dry subhumid (Ratnam and Raje Gowda, 1992).

5.1 Morphological features

Horizon differentiation in red pedons was relatively easy compared to that of black pedons, because of argilli-pedoturbation in the latter. Horizons were identified in red pedons based on colour, texture, abundance of coarse fragments and on presence or absence of clay skins on ped surfaces. Whereas in black pedons horizon differentiation was mostly based on the prominance, abundance and intersection of slicken sides. Based on this three to four horizons could be identified namely self mulching surface, blocky peds with pressure faces, and wedge shaped slickensided subsoil.

All the black pedons were very deep compared to red pedons. Krishnamoorthy and Govinda Rajan (1977) also observed the same and related this to more chemical weathering in the former. Bidar red pedon exhibited redder hue of 2.5 YR throughout the solum where as in Mantagani red pedon hue was 2.5 YR in the subsurface horizons. In all the remaining red pedons hue was yellower (5 YR) because they contained less CDB extractable Fe_2O_3 compared to Bidar and Mantagani pedons, with the exception of Dharwad.

All the black pedons exhibited hue of 10 YR throughout the profile and the dominant colour was dark grayish brown to very dark grayish brown, due to the clay-humus complex in the presence of lime (Singh, 1956). In Bidar and B.Gudi colour value of black pedons at lower depths was higher due to high $CaCO_3$ at that depth.

In red pedons chroma was 3 and 4, most frequently. Where as in black pedons it was 2 or less in most of the cases, which indicated poor internal drainage with the exception of Bidar pedon where the chroma was uniformly 3 throughout the profile indicating moderately well drainage.

Structure in red pedons was predominantly subangular blocky. Granular structure observed in the surface horizon of Bidar red pedon may be due to high dithionite iron and high organic matter. In black pedons also the predominant structure was subangular blocky. Angular blocky structure in the subsoil horizons was due to slickensides formation in these soils.

Moist consistency varied from friable to very friable in red pedons and from firm to very firm in black pedons. Consistency was directly related to nature and amount of clay. Friable moist consistancy in red pedons indicated good soil-water-air relationship.

Thin patchy clay skins were visible on the ped surfaces of B.Gudi and Raichur red pedons. Whereas in other red pedons they were not conspicuous because of redder hue. In B.Gudi red pedons clay skins were present even at the lower depths, which indicated less disturbances of subsurface horizons. Pressure faces were observed on ped surfaces of Mantagani red pedon may be due to presence of smectite type of clay.

Slickensides were a common feature in black pedons because of argillopedoturbation. Abundance and intensity of slickensides was more in the middle of the solum because of maximum swelling pressure generated there as decribed by Yaalon and Kalmar (1978).

5.2 Physical properties

Coarse fragments content was more in red pedons than that of black counterparts becuase of less chemical weathering in the former (Desai, 1942; Krishnamoorthy and Govindarajan, 1977). In all the black pedons bulk of the coarse fragments constituted of lime concretions. In both red and black pedons of Bidar small round to subrounded dark coloured ferrugenous materials were present.In the C horizon lateritic gravels were present and the same was absent in the black counterpart.

Bulk of the coarse fragments content was contributed by quartzite in both red and black pedons of B.Gudi and Raichur as the parent rock of these pedons was granite gneiss.

At the surface of both B.Gudi and Raichur red pedons texture was sandy loam and at the subsurface horizons of B.Gudi it was sandy clay loam and in Raichur it was clay, may be due to greater movement of clay in the latter. Texture was clay in the Bt horizons of red pedons because higher amount of finer particles. Whereas in black pedons texture was clay throughout the profile. In the Deccan plateaue of India clay texture in the black pedons was a common feature (Desai, 1942; Biswas and Gawande, 1962). Percent increase in clay content with depth was more in red pedons compared to their black counter parts may be due to absence of argillipedoturbation in the former.

Fine clay was directly related with clay in its content and distribution in both red and black pedons. Fine clay content was more in Bidar and Mantagani red pedons compared to all other red pedons,. However, proportion of fine clay expresed as per cent of total clay was generally in between 55 to 65 per cent (may be due to higher amount of clay in these pedons). Content of fine clay as percent of total clay was slightly more in the black pedons, especially in Dharwad and Mantagani compared to their red counterparts may be due to the presence of smectite type of clay in the former. Pal and Deshpande (1987) and Bhattacharyya et al. (1993) also observed that fine clay constituted around 50 per cent of total clay in both red and associated black soils.

Bulk of the particle size distribution in red pedons constituted of coarser fractions with exception of Bidar pedons. Where as in the black pedons bulk of it was constituted of finer particles due to more chemical weathering. in the latter and less chemical weathering in the former mainly because of acid hydrolysis and good drainage in the red pedons (Krishnamoorthy and Govindarajan, 1977). In Bidar red pedon high clay content may be related to easily weatherable and clay- forming minerals in the Deccan trap.

Irrespective of red and black pedons sand content was more in the B.Gudi and Raichur pedons compared to all other pedons, this could be attributed to the nature of the parent rocks as the former pedons developed on the granite and granite gneissic complex which contained more of quartz than the pedons derived from Deccan trap, Dharwad shale and chlorite schist.

Silt content was lowest in B.Gudi and Raichur red pedons compared to other pedons. Among the black pedons silt content was highest in Mantagani pedon because of the parent rock chloritic schist. In a comparative study, Krishnamurthy (1993) observed higher silt content in schist derived soils compared to granite -gneiss derived soils.

Despite high clay content generally high bulk density of black pedon was due to the shrinkage of these soils

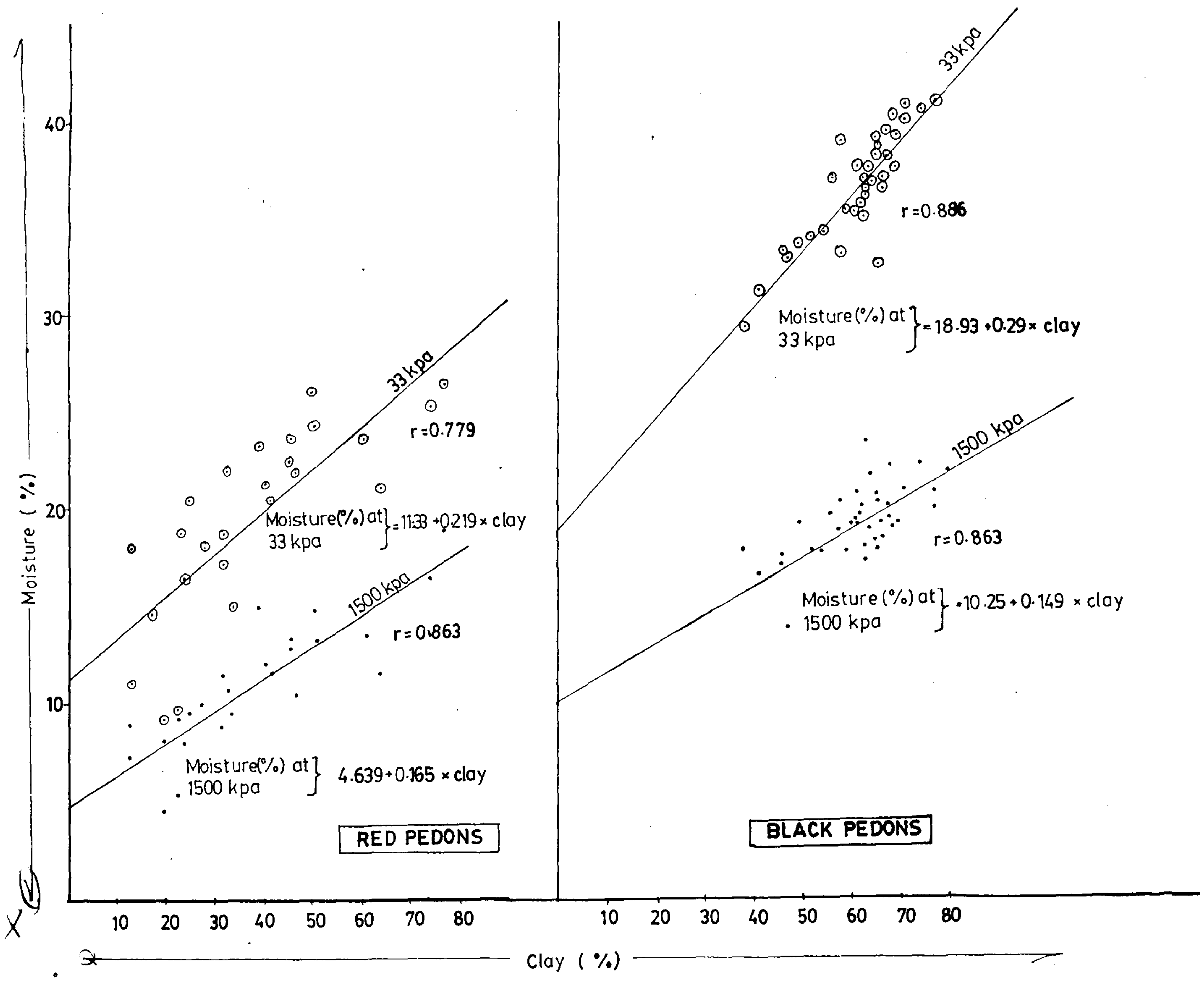

Fig. 12 RELATIONSHIP BETWEEN CLAY AND MOISTURE

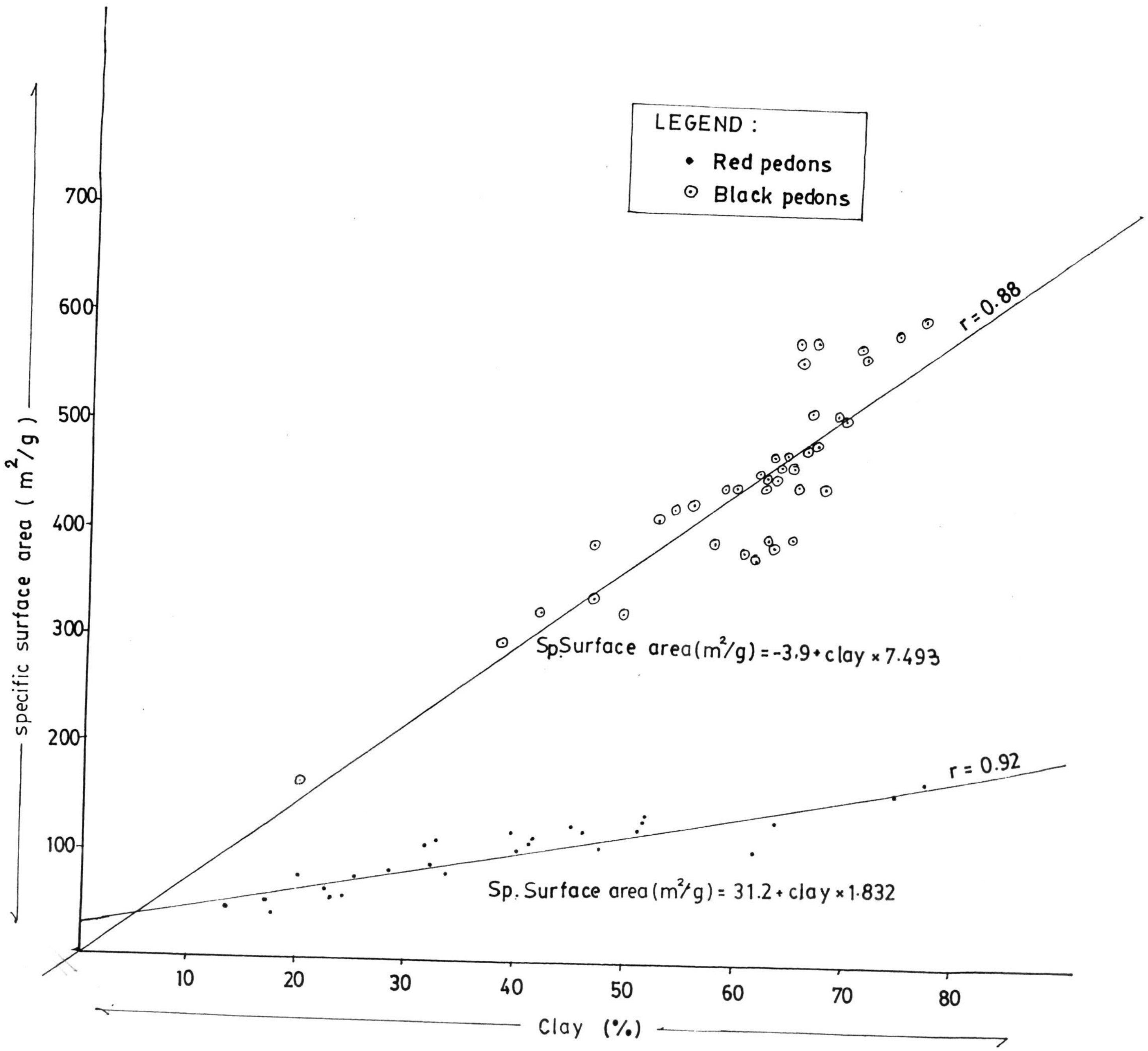

Fig. 13 RELATIONSHIP BETWEEN CLAY AND SPECIFIC SURFACE AREA

upon drying. Bulk density of these clod samples varied with moisture content and they were nearly air dry at the time of determination. Bulk density slightly decrased in the Bt horizons of red pedons, because of higher clay content. Among the red pedons bulk density was more in Bidar pedon though the clay and organic matter content were more, because of their lateritic nature.

Moisture at both 33 KPa and 1500 KPa was strongly correlated with clay content in these soils. However moisture at 1500 KPa was more closely related to clay content (r =0.863) than at 33 KPa (r = 0.779) in red soils,. Whereas 33 KPa water was highly correlated with clay content (r= 0.886) than at 1500 KPa water (r=0.863) in black soils (Fig.12) Challa and Gaikwad (1987) also observed more water retention in black soils at 33 KPa than at 1500 Kpa.Moisture retention at 33 Kpa was strongly correlated (r= 0.438) with clay. As was expected surface area was related to clay content in both red and black pedons. The correlation co-efficient was high in both red (r=0.92) and black (r= 0.88) pedons (Fig.13). The regression co-efficient was nearly four times in black than in red soils suggesting the difference in the clay mineralogy of these two group of soils. These values coupled with CEC

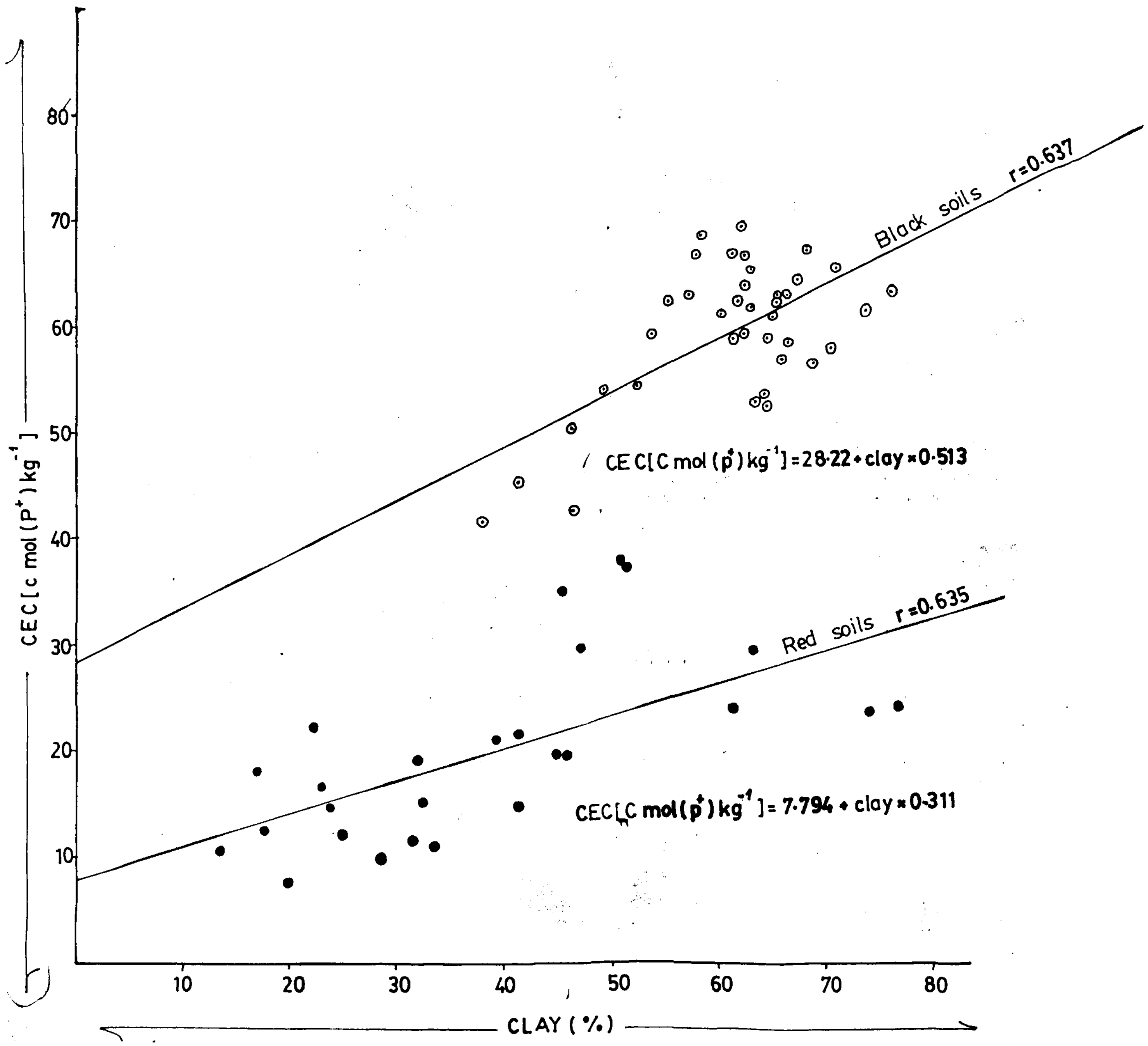

Fig.14 RELATIONSHIP BETWEEN CLAY AND CEC

suggested a predominantly smectitic minerology in case of black pedons.

5.4 Chemical properties

In red pedons pH ranged from strongly acid to neutral and from neutral to strongly alkaline in black pedons, as the red pedons were well drained compared to their black counterparts. In red pedons large amount of bases leached out of the solum leaving behind iron and aluminium oxides, and hence the pH in red pedons was less compared to their black counterparts. High pH in black pedons due to their calcareous nature and the accumulation of bases in the solum as they were poorly leached (Satyanarayana and Biswas, 1970) pH increased with depth in both red and black pedons as the bases increased with depth.

Electrical conductivity was less in red pedons compared to their black counterparts, which indicated the red pedons were more leached compared to that of associated black pedons.

Cation exchange capacity (CEC) increased with depth and followed the trend of clay. In these soils CEC is largely governed by clay content. There was a high degree of correlation between the two in both red (r = 0.635) and black (r = 0.637) soils. However, the relationship in red pedon was closer and the slope of the line less steeper than in case of black pedons, suggested that CEC was higher per unit clay content in the latter (Fig 14). The CEC/clay ratio also suggested the same and these ratios in black pedons were nearly three times that observed in red pedons in general. In Mantagani red pedon however the ratio tend to be greater with depth and approached that of black counterpart.

$BaCl_2$-TEA extractable acidity was less in B.Gudi and Raichur and pedons compared to all other red pedons, as the organic matter and clay content was less in the former pedons (Krishnamurthy, 1993) because they act as buffers.

Base saturation percentage by sum of cations was least in Dharwad red soil and was highest in B.Gudi red soil. Further black pedon at B.Gudi was most calcareous and Dharwad was the least which reflected the leaching regime as imposed by climate of these study sites (Desai, 1942)

Organic carbon content was highest in both red and black pedons of Dharwad and Bidar due to high rainfall and relatively lesser temperature as they were situated in higher rainfall zones.

Both dithionite extractable iron (Fed) and ammonium oxalate extractable iron (Feo) were more in red pedons than that of associated black pedons. More Fed in red pedons than that of associated black pedons suggested that more amorphous iron had been tansformed to crystalline iron in the former pedons (Sheshagiri Rao et al., 1992b). In both red and black pedons Fed and Feo content were lowest in B.Gudi and Raichur pedons and were highest in Bidar followed by Dharwad and Mantagani pedons because B.Gudi and Raichur pedons were almost devoid of iron bearing primary minerals. In Bidar, parent rock was Deccan trap and hence is rich in ferromagnesium minerals and in both Dharwad and Mantagani the parent rocks were associated with the banded heamatite quartzite. Feo/Fed ratio was more (0.1 to 0.59) in black pedons than that of associated red pedons (0.07 to 0.44). Feo/Fed ratio decreased as the amorphous iron changed to crystalline iron with progressive weathering and soil develoment. Same thing was reported by Sheshigiri Rao, et al. (1992b) in their work on associated Alfisol-Vertisol toposequence.

In all the pedons both Fed and Feo increased with depth as the clay content increased with depth. With exception to this statement Fed decreased with depth in

Mantagani red pedon and Feo decreased with depth in the upper solum of Dharwad red pedon.

5.4 Genesis of red and associated black soils

The prevailing hypotheses in respect of origin of these soils are examined and their validity in the present study is discussed.

It was stated by Ramaiah and Raghavendrachar (1936) that the origin of black and red soils in close proximity is due to the variation in mineralogical composition of the parent rock. According to them black soils originated in rocks rich in soda lime feldspar and the red soils on rocks rich in potash feldspar. This hyposhteis is made based on their observation in granite-gneissic terrain. In others the variation in minerological composition to such a great degree does not exists. Deccan trap consists prodominantly of augite and some plagio-clase and is not expected to vary a great deal (Wadia, 1987).

The mineralogical composition of sand fraction in both red and black soils of Mantagani were remarkably similar with respect to all the constituents except Fe_2O_3, where it was more in red soil compared to its black counterpart. In both B.Gudi and Raichur the geology is granite-gneiss. It is in this geological formation extensive areas of red and black soils occur often in close proximity. The C horizon sand fraction of both B.Gudi and Raichur red pedons are similar (Table 8). A comparison of the composition of C horizon fine sand fraction between red and black soils of B.Gudi, where in both are developed _in situ_ reveals that Na_2O, K_2O and Fe_2O_3 were high in red soil compared to black soil. Similar was the case in the Raichur pedons. This is mainly due to the predominance of both potassium and sodium feldspars and biotite as there is considerable MgO and Fe_2O_3 as well. The persistance of sodium feldspars in red soils suggests that they have not undergone intensive weathering.

Desai (1942) and Bhargava _et al_. (1973) also reported plagioclases in red soils of Hyderbad state and in Tungabhadra catchment area. The hypothesis that the black soils are formed from rocks rich in soda lime feldspars and red soils on rocks rich in potash feldspars is not applicable to the soils in these two locations.

In B.Gudi the red soil changes to black within few metres. The topographic changes are subtle. The slope of the land hardly ranges from 1 to 2 per cent and on such a surface black soils situated slightly lower in the landscape. The black soil has lot of $CaCO_3$ where as red soil is non-calcareous. This can't be relatd to the differences in the parent rock but the redistribution of the soluble constitutents through lateral movement and particulate matter through erosion. Particle size data and chemical composition of sand suggests that there is no justification to ascribe the changes in genesis of these soils to differences in the parent rocks or mineralogical make up of the same rock.

Further it must be visualised that the present topography is somewhat smoothened due to erosion of uplands and deposition of the material in lower position. The differences may have been more clear in the past. Then it is drainage as differences in the nature of clay minerals found. The high CEC/clay ratios of black soils, their sticky nature and high surface area amply suggest of their smectitic nature. On the contrary the lower CEC/clay ratio, lower surface area of the red soils suggest that smectite content is less. The available data does not permit to precisely point out the presence of a specific minerals. However, the CEC data rules out the predominance of kaolinite. The proportion however varies,and directly related to CEC. These soils are likely to have illite as pointed out by Satyanarayana and Biswas (1970) and Bhargava et al. (1973).

In Bidar too the clay content is high in red soil. The parent rock itself is highly clay forming type. Yet the difference in free Fe_2O_3 content, $CaCO_3$ content in these two clearly point out to the differences in the leaching environment in these two soils.

In Mantagani, there is a remarkable similarity in fine sand composition between red and black pedons. The clay mineral also is similar especially as one goes to lower layers judged by clay/CEC ratio. Close to surface however, there is decrease in CEC tending to kaolinization. This is comparable to what Pal and Deshpande (1987), who observed similar clay mineralogy in red and associated black soils. The low content of coarse fragments especially in the upper solum also suggests that the parent material is predominantly chlorite schist. The high clay content in both red and black soils also emphasis the absence of quartzites (ferrugenous or otherwise) which abound these soils as coarse fragments (Krishnamurthy, 1993). In fact cracks are observed in red soils, a fact which highlights that there is considerable amount of smectite in this soil too. Despite all these a reddish colour indicates relatively well drained condition.

In the present study it is recorded that the topographic vatiations are not readily apparent as in a catenary study (Biswas and Gawande, 1962; Satyanarayana and Biswas, 1970; and Gaikwad et al., 1974). However this theory has credence in most of the situations, wherever there is reason to believe that parent material is similar as judged by morphology and chemical composition of fine sand. Greater solum depth in black soils compared to red suggests that the latter were situated in erosional surfaces and the former in depressions. The black colour and other properties were acquired due to impeded drainage condition as conditioned by relief. Higher chroma of red soils compared to black counterparts speaks of their free drainage.

In Raichur the red soils are similar to those in B.Gudi soils to their parent rock similarity. However the black soils may not have originated as in B.Gudi, though topography can be a factor here also.The stratification at a depth of 150 cm suggests that these soils are transported by fluvial action. In fact the vast expanse of black soils to the north of the red soil suggests that there must have been a lake.

The proportion of different fractions of sand expressed as percent of total sand in black soils is different from that of red soils (Appendix I). The 2C material however compared well with the red soil material suggesting that the 2C material is derived from granitic material. The overlying fine material must have been transported from elsewhere.

In Dharwad site the black soil is infact located physiographically on an upland position compared to the red soil site. This is again related to the black soil material being transported. The black soil at Dharwad agricultural farm is a part of the vast black soil plain extending to Amminabhavi and into Malaprabha basin. It just happens that it terminates behind the main building of the college. Vast cover of black soil in Malaprabha basin is often seen covering ferruginous materials as revealed in deep cuts (Bharabhari, 1991). Earlier Kulkarni and Deshpande (1970) have related the genesis of these two soils to drainage conditioned by relief but stated that both were derived from the same parent rock. The transported nature of the black soils is apparent from near absence of coarse fragments, high silt content and lower sand content. The abrupt increase in coarse fragments in 2C horizon suggests that it was the original surface on which the black soil was deposited.

5.6 Classification

All the red pedons except Mantagani and Bidar pedons were classified as Alfisols at order level. Though the

Mantagani and Bidar pedons have high clay content, did not full fill the requirements of Alfisols hence classified as Inceptisols at order level.

In B.Gudi and Raichur red pedons the total clay content in the argillic horizon was 20 per cent or more higher than in the eluvial horizon. In Dharwad red pedon argillic horizon had 8 per cent more clay than that of eluvial horizon. Hence these pedons were put under Alfisols.

B.Gudi, Raichur and Dharwad red pedons were classified as Ustalfs as they possessed ustic moisture regime, and Mantagani and Bidar red pedons as Tropepts as they had isomesic or a warmer isotemperature at suborder level. At greatgroup level B.Gudi, Raichur and Dharwad red pedons were classified as Haplustalfs, as the pedons did not have duripan, plinthite, natric, oxic, Kandic and cambic horizons. Whereas Mantagani and Bidar red pedons were put under Ustropepts at greategroup level as they had ustic moisture regime. At subgroup level Mangagani red pedon was classified as Vertic Ustropept as it exhibited cracks of size more than 5 mm width to a depth of 30 cm for some time in most of the years. B.Gudi, Raichur and Dharwad red pedons were classified as typic Haplustafls at subgroup level as they convey the central concept of Haplustalfs, and Bidar red pedons as Typic Ustropepts as it satisfied the central concept of Ustropepts.

All the black pedons were classified as vertisols at order level, as these pedons did not have lithic or paralithic contact within 50 cm of soil surface and had more than 30 per cent clay in all the horizons down to the depth of 1 m and had cracks more than 1 cm wide at a depth of more than 50 cm. They had slickensides at the depth between 25 cm to 100 cm.

In these soils crack remains open for more than 90 cumulative days during the year but not throughout the year in most years.

All these pedons were classified as Usterts at suborder level because they exhibit following properties.

- Cracks that open and close more than once during the year in most years
- A mean annual soil temperature of more than 22° C

Except B.Gudi pedon all the pedons were put under Haplusterts at greatgroup level as they did not posses salicic, gypsic and calcic horizons. Whereas, B.Gudi pedon was classified as Calci Usterts at greatgroup level as it possessed Calcic horizon. At subgroup level B.Gudi pedon was put under Typic Calci Usterts as it exhibit central concept of Calci Usterts. At subgroup level Dharwad pedon was classified as Chromic Udic Haplusterts, because within 50 cm depth horizon posessed colour value moist of 4. Remaining pedons were put under Typic Haplusterts at subgroup level as they posessed central concept of Haplusterts.

Red pedons	Order	Suborder	Great group	Sub group
Bidar	Inceptisol	Tropept	Ustropept	Typic Ustropept
B.Gudi	Alfisol	Ustalf	Haplustalf	Typic Haplustalf
Raichur	Alfisol	Ustalf	Haplustalf	Typic Haplustalf
Dharwad	Alfisol	Ustalf	Haplustalf	Typic Haplustalf
Mantagani	Inceptisol	Tropept	Ustropept	Vertic Ustropept
Black pedons				
Bidar	Vertisol	Usterts	Haplusterts	Typic Haplusterts
B.Gudi	Vertisol	Usterts	Calciusterts	Typic Calciusterts
Raichur	Vertisol	Usterts	Haplusterts	Typic Haplusterts
Dharwad	Vertisol	Usterts	Haplusterts	Chromic Udic Haplusterts
Mantagani	Vertisol	Usterts	Haplusterts	Typic Haplusterts

SUMMARY

VI. SUMMARY

Morphological, physical and chemical properties of five pairs of associated red and black pedons were studied to compare their properties and to understand their genesis. Geology of Bidar sites was Deccan trap, Raichur and B.Gudi was granite-gneiss,and that of Dharwad and Mantagani were shale and chloristic schist respectively. Bidar site was located within North eastern transitional zone (Zone-1), where as Dharwad and Mantagani pedons belonged to Northern transitional zone (Zone -8). B.Gudi and Raichur pedons were from Northern eastern dry zone (Zone-2).

The predominant soil colour was reddish brown to dark reddish brown in all the red pedons except in the Raichur pedon where the colour was reddish grey to dark reddish grey. Bidar red pedon had redder hue (2.5YR) throughout the solum because of the Deccaan trap parent rock rich in ferromagnesium minerals. Mantagani red pedon also had redder hue (2.5 YR) in the lower solum. Other red pedon were predominantly of 5 YR hue.

In Black pedons soil colour varied from dark greyish brown to very dark greyish brown in the upper solum and yellowish brown to dark yellowish brown in the lower solum. Hue was 10 YR in all the black pedons throughout the profile.

Red pedons predominantly had weak to moderate subangular structure. In black pedons moderate angular to subangular structure was dominant. Among the red pedons structure was relatively better developed in Dharwad, Mantagani and Bidar pedons becuase of high organic matter and iron oxide content. Where as in B.Gudi and Raichur red pedons structure was not well developed.

Raichur and B.Gudi red pedons exhibited thin patchy clay skins and in other red pedons, they could not be identified because of more iron oxide content. In Mantagani red pedon pressure faces on subsurface peds and cracks in the surface were observed. Lime concretions, slickensides, and pressure faces were common in all the black pedons.

Coarse fragments content was more in red pedons than that of black pedons. In all the black pedons bulk of the coarse fragments constituted of lime concretions. In both red and black pedons of Bidar rounded dark coloured ferrugenous materials were present as the parent rock was Deccan trap. In B.Gudi and Raichur red and black pedons bulk of the coarse fragments contributed by quartzite.

Bidar and Mantagani red pedons exhibited clay texture throughout the profile. Both Raichur and B.Gudi red pedons had sandy loam texture at the surface which graded in the subsurface to clay in the former and sandy clay loam in the latter, due to the greater movement of clay in the former. Whereas in black pedons texture was clay throughout the profile.

Fine clay followed the trend of total clay with depth in both red and black pedons. Fine clay content was more in Bidar and Mantagani red pedons compared to all other red pedons. However, proportion of fine clay expressed as percent of total clay was generally between 55 to 60 per cent range. Fine clay as percent of total clay was slightly more in black pedons than their red counterparts.

Sand content was more in B.Gudi and Raichur pedons as they developed on granite gneiss, which is rich in quartz.

Clod bulk density of black pedons was more despite high clay content due to shrinkage of these soils upon drying. Bulk density decreased slightly in the Bt horizons of red pedons because of high clay content. Moisture holding capacity was more in black pedons compared to the red pedons due to differences in quantity and nature of clay in these two soils, in general. Moisture retention at both 33 KPa and 1500 KPa was highly correlated with clay content in both red (r=0.779 and 0.863) and black (r= 0.886 and 0.863) soils. In both red and black pedons surface area was more in Bidar and Mantagani pedons because of more clay. Surface area was highly correleted with clay in both red (r= 0.92) and black soils (r = 0.88).

pH of red pedons was almost neutral except Bidar pedon. Whereas all black pedons were alkaline except Dharwad which was neutral. pH increased with depth in all the pedons. Electrical conductivity ranged from 0.1 to 0.4 dS/m in red pedons and from 0.11 to 1.10 dS/m in black pedons.

Organic carbon was more in Bidar and Dharwad pedons because of higher rainfall. Fed and Feo content were more in red pedons compared to black pedons and was highest in the Bt horizons of red pedons. Fed and Feo content was more in Bidar and Dharwad pedons as the parent rock in former was Deccan *trap and the parent rock in the latter was associated with* banded hematite quartzite. Free $CaCO_3$ content was more (10.1 to 25.8 per cent) in B.Gudi black pedon.

CEC was more in black pedons compared to that of associated red peodns. Among the red pedons it was highest in

Mantagani pedon. CEC was directly related with clay content in both the soils with about the same degree of correlation in red (r = 0.635) and black (r=0.637) soils. $BaCl_2$-TEA extractable acidity was relatively more in Dharwad, Mantagani and Bidar red pedons compared to B.Gudi and Raichur red pedons. Base saturation percentage, was least in Dharwad red pedon and was highest in B.Gudi red pedon which reflect the climatic condition of these two study sites.

Among the red pedons exchangeable calcium was lowest in granite gneiss derived soils compared to all other red soils. Among the black pedons it was highest in Dharwad and Mantagani pedons compared to all other pedons. Exchangable magnesium was more in both red and black pedons of Bidar and Mantagani pedons reflecting the influence of parent material. In majority of pedons both calcium and magnesium showed increasing trend with depth. Exchangeable sodium is relatively more in B.Gudi and Raichur black pedons.

From the study of these associated red and black pedons, it is found that the passive factors, parent material and topography played an important role in the genesis of these complex soils.

From the morphological physical and chemical properties it is found that in Bidar, B.Gudi, and Mantagani sites,both black and red soils are derived from the same rock but due to variation in drainage as conditioned by topography. Deeper solum of black soils also suggests that they are located on depositional surfaces whereas red soils occupied erosional surfaces. The topographic differences are subtleand not as clear as in a catenary association. It appears that over a period of time these land surfaces got smoothened out. The differences in degrees of calcareousness, salinity levels, free Fe_2O_3 content, clay to CEC ratios between red and black soils in each site points out that the red soils were better leached than black soils. In Raichur and Dharwad, the black soils are of transported origin and form a part of extensive black soil plains. In both the sites the red soils are formed *in situ*.

These associated red and black pedons were classified, as per the U.S.D.A. Soil Taxonomy. All the red pedons except Mantagani and Bidar were classified as Alfisols at order level, due to the presence of agrillic horizon, where as Mantagani and Bidar red pedons failed to fulfill the requirements of Alfisols, hence they were put under Inceptisols. At suborder level Mantagani and Bidar red pedons were put under tropepts because of isomesic regime and all other red pedons under Ustalfs because of Ustic moistureregime. At greatgroup level Mantagani and Bidar red pedons were classified as Ustropepts and the remaining red pedons as Haplustalfs. All the black pedons belonged to the order Vertisols and suborder Usterts. At great group level except B.Gudi all were classified as Haplusterts, and the B.Gudi pedon as Calciusterts. The subgroup level classification of red and bladk soils is given below.

Place	Red	Black
Bidar	Typic Ustropepts	Typic Haplusterts
B.Gudi	Typic Haplustalf	Typic Calciusterts
Raichur	Typic Haplustalf	Typic Haplusterts
Dharwad	Typic Haplustalf	Chromic Udic Haplusterts
Mantagani	Typic Ustropepts	Typic Haplusterts

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APPENDIX

Appendix 1. Different sand fractions as per cent of total sand

Horizon	Depth (cm)	Very coarse sand >1mm	Coarse sand 1.0–0.5 mm	Medium sand 0.25–0.1 mm	Fine sand 0.25–0.1 mm	Very fine sand 0.1–0.05 mm
1	2	3	4	5	6	7
Pedon–1 (Bidar Red)						
Ap	0–9	41.2	32.4	13.2	7.4	5.9
Bt1	9–30	54.1	28.6	9.2	4.1	4.1
Bt2	30–43	53.6	29.9	11.6	4.3	1.4
BC	43–55	51.1	25.2	11.5	8.2	3.8
C	55+					
Pedon–2 (Bidar Black)						
Ap	0–14	23.3	18.6	16.3	18.6	23.3
A2	14–35	30.2	18.6	14.0	16.3	25.6
A3	35–54	29.5	18.2	13.6	18.2	20.5
A4	54–68	20.4	12.2	14.3	22.4	30.6
A5	68–94	30.2	18.6	11.6	18.6	20.9
A6	94–118	29.7	13.5	17.6	13.5	25.7
A7	130–153	30.9	16.4	9.1	20.0	23.6
A8	153–170	21.1	13.2	13.2	36.8	28.9
Ac	170–185	15.8	15.8	5.3	26.3	36.8
C	185–235	17.5	2.5	12.5	32.5	35.0
Pedon–3 (B.Gudi Red)						
Ap	0–11	24.2	22.9	23.4	21.6	7.8
Bt	11–24	25.7	21.0	7.5	22.9	7.0
Bt2	24–47	48.6	16.8	15.1	13.3	6.2
Bt3	47–67	49.2	15.6	15.4	12.5	5.1
BC	67–92	39.1	21.7	18.8	15.1	5.2
C	>92	33.5	22.7	21.9	15.4	6.5
Pedon–4 (B.Gudi Black)						
Ap	0–9	20.4	21.0	24.5	23.3	10.8
A2	9–27	17.9	23.1	23.5	24.8	10.7
A3	27–49	15.7	22.5	25.0	25.6	11.3
A4	49–80	18.6	23.1	22.0	23.8	12.5
A5	80–118	37.2	16.7	16.3	18.2	11.6
A6	118–132	17.6	19.4	17.6	33.5	12.7
Cca	132–186	38.6	19.1	16.5	17.3	8.6
Pedon–5 (Raichur Red)						
Ap	0–10	19.9	30.0	24.8	19.6	5.6
Bt1	10–22	15.7	33.1	25.5	18.2	7.5
Bt2	22–43	14.7	30.2	29.0	18.3	7.8
Bt3	43–65	16.7	30.6	28.2	18.2	6.3
Bc	65–76	36.3	23.4	19.5	14.0	6.8
C	76–100	40.4	20.8	18.6	13.7	6.5

Appendix 1. (Contd.)

1	2	3	4	5	6	7
			Pedon-6 (Raichur Black)			
Ap	0–18	12.1	23.2	23.2	24.2	17.2
A2	18–42	18.8	23.5	21.2	18.8	17.6
A3	42–70	146.0	19.5	20.7	24.4	20.7
A4	70–150	13.8	23.1	21.5	23.1	18.5
2c	150–180	25.0	26.2	23.4	18.5	6.8
			Pedon-7 (Dharwad Red)			
Ap	0–12	22.7	13.3	19.9	31.6	12.4
Bt1	12–32	176.0	13.5	21.6	33.8	13.5
B2	32–60	67.0	7.3	9.0	12.2	4.5
Bc	60–150	56.2	14.2	12.3	12.6	4.8
C	>150	37.6	18.8	19.5	18.8	5.2
			Pedon-8 (Dharwad Black)			
Ap	0–16	10.9	9.5	16.8	32.8	29.9
A2	16–35	14.9	10.5	17.5	35.1	21.9
A3	35–55	15.8	8.8	17.5	30.7	26.3
A4	55–85	15.6	8.7	19.1	34.8	21.7
A5	85–105	27.5	9.2	17.4	31.2	24.8
Ac	105–125	21.9	14.0	17.5	28.9	17.5
2c	>125	44.3	14.0	15.3	11.8	15.3
			Pedon-9 (Mantagani Red)			
Ap	0–16	7.9	6.6	18.7	50.0	16.8
B1	16–30	9.2	9.2	18.4	42.0	21.6
Bt1	30–50	8.3	7.3	18.9	42.1	23.5
B2	50–70	13.6	9.8	20.2	36.1	20.3
C	>70	11.8	15.5	32.0	28.5	12.2
			Pedon-10 (Mantagani Black)			
Ap	0–15	6.5	7.1	14.7	41.8	30.0
A2	15–35	4.0	5.6	17.0	45.2	28.2
A3	35–60	6.3	7.0	13.4	13.4	31.8
A4	60–80	6.8	7.5	13.7	41.0	30.9
A5	80–100	3.8	6.1	13.7	42.0	34.4
A6	100–130	4.0	6.7	12.5	41.7	35.0
A7	130–153	13.3	6.7	10.4	35.2	34.4
A8	153–170	21.5	7.5	9.3	31.0	30.8
Ac	170–185	26.8	25.6	9.8	17.0	20.8
C	185–235+	19.9	14.1	8.4	41.7	15.9