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Mineralogy of Soils along Toposequence in Raipur District of Chhattisgarh

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Abstract: The mineralogical compositions alongwith physical, chemical, elemental and mineralogical properties of four pedons occurring along a toposequence in Chhota Urla village (Abhanpur tehsil) Raipur district of Chhattisgarh state were studied. Landform had significant influence on physical, chemical, elemental and mineralogical properties of soils. Sand content decreased from higher topography to lower topography but clay content increased with decrease in elevation. pH of pedons ranged from strongly acid to moderately alkaline and CEC increased from upland to lowland. Quartz being dominant in sand fraction and absence of primary minerals like Ca-feldspar, K-feldspar indicated intense weathering of soils. Silt had quartz as dominant mineral followed by Ca-feldspar and K-feldspar. Kaolin was dominant mineral in clay fractions of Pedons1 and 2 (P1 and P2) with sub-ordinate amount of smectite while smectite was dominant in other two pedons followed by kaolin. Huge amount of smectite which is first weathering product of plagioclase, did not find its parental legacy with underlying geology (sandstone, limestone and shale sequence) indicative of mixed alluvium, eroded from different geological formation and contradicted the occurrence of catenary sequence as reported earlier.

Keywords : *Mineralogy, sand, silt, clay, toposequence, silica-sesquioxides ratio*

Introduction

Mineralogical composition of soils predicts the nature and source of soil parent material and their physical and chemical properties. Soil mineralogy is also important for proper understanding of the soil development and soil fertility for better crop management. The amount of different clay minerals present in soil controls the nutrient availability to crops. Milne (1935) defined catena for a sequence of topographically related soils which have comparable parent material, climate and age, but show different characteristics owing to variation in relief and drainage. Differential drainage due to different topographic condition leads to variation in accumulation of clay minerals along toposequence. These types of catenary soils were earlier reported (Biswas and Gawande 1962; Gawande *et al. 1968)* on sedimentary formation in Chhattisgarh basin of Madhya Pradesh. In their studies, authors could not explain the genesis of deep Vertisols in low land catenary sequence with huge amount of smectite and its parental legacy and hence the present investigation was carried out to study the soil mineralogy and their variation in relation to topographic position as influenced by drainage condition.

Materials and methods:

A toposequence was selected in Chhota Urla village of Abhanpur tehsil, Raipur district (Fig.1) and they are locally known as Bhatta, Matasi, Dorsa and Kanhar. The study area was situated in the mid east part of Chhattisgarh state and receives rainfall mainly from

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the south-west monsoon which usually sets in the third/fourth week of June and spread over a period from late June to early October with heaviest shower in the months of July and August. District has a tropical wet and dry climate; temperatures remain moderate throughout the year, except from March to June, which is extremely hot. The annual average rainfall and average annual temperature in the Raipur was 1185 mm and 26.4°C respectively (Fig.2).

Raipur district is underlain mainly by three distinct geological formations ranging in age from archean to recent. The crystalline basement, occupy major parts of the district, comprising of granite and gneissic rocks belonging to Dongargarh group, severally intruded by the quartz veins and basic dykes. The rocks of Chhattisgarh Super group are unconformably overlying the basement and are represented by the sandstone, limestone and shale sequence occupying the north central and central part of the district. A thin layer of alluvium/laterite belonging to the Quaternary age occurs along the flood plains of major rivers and its tributaries. Laterite capping of Cenozoic age are occurring over the Chandrapur sandstone in the central part of the district.

Morphological properties of soils were described as per Soil Survey Manual (Soil Survey Division Staff 2014). Physical and chemical properties of soils were determined as per standard procedure (Jackson 1973). Sand, silt, clay and fine clay fractions were separated as per size segregation procedure of Jackson (1979) after removal of binding agents. Sand fraction was finely ground to powder which was evenly spread on sample holder and subjected to XRD. Oriented silt and clay fractions were subjected to XRD of the parallel oriented samples using a Philips X'Pert Pro diffractometer with Ni filtered Cu-Kα radiation at a scanning speed of 2°2θ/min. Samples were saturated with (1) Ca and solvated with ethylene glycol and (2) K-

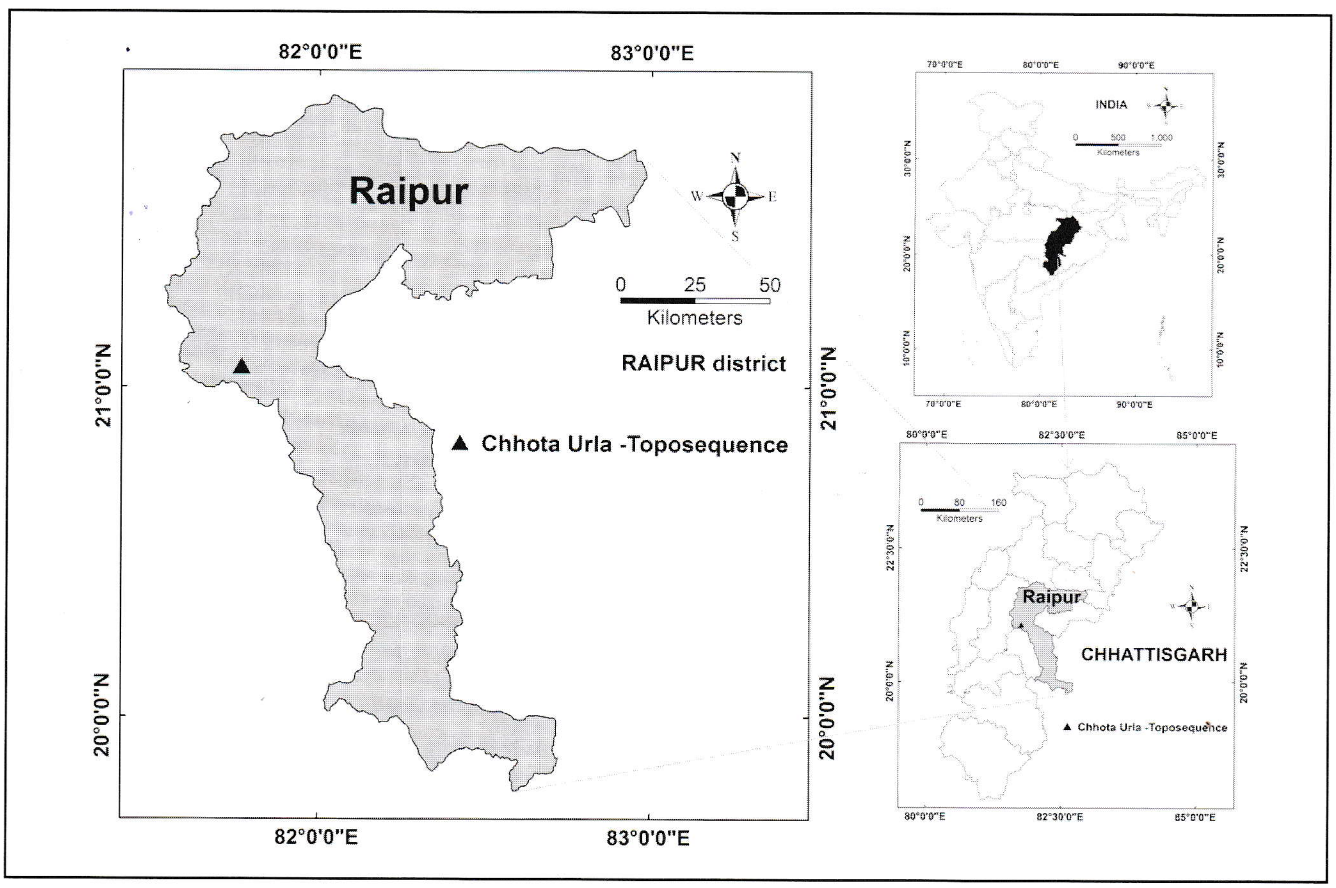

Fig. 1 . Location map of study area

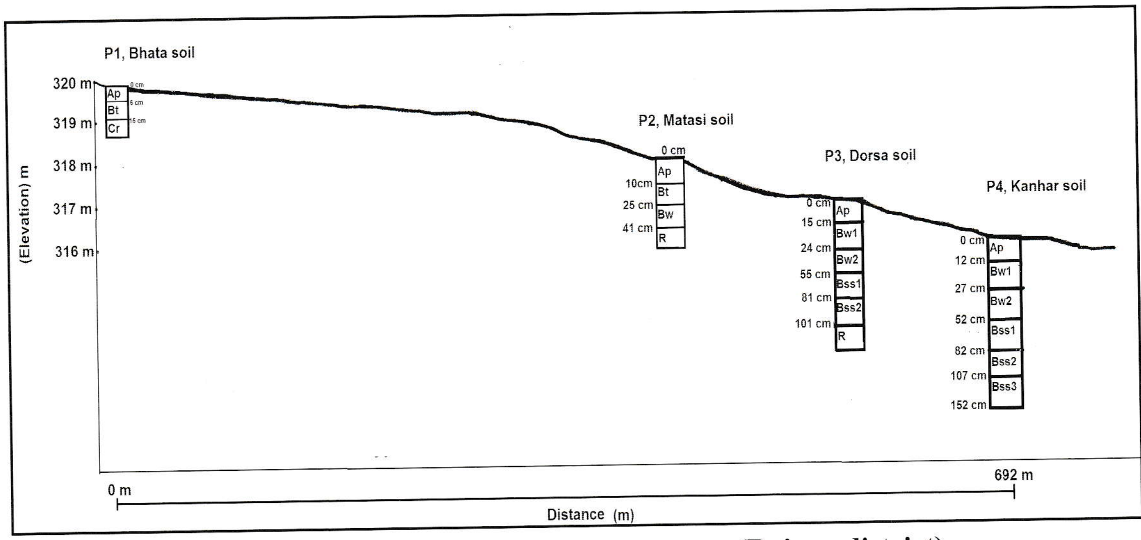

Fig. 2 Pedon position along toposequence (Raipur district)

saturated and heated to 25°C, 110°C, 300°C and 550°C and X-rayed. Identification of clay minerals in different fractions was done following the criteria laid down by Jackson (1979). The semi-quantitative estimates of minerals in the silt, total clay, and fine clay fractions were done by the method of Gjems (1967).

Results and Discussion

The site characteristics of pedons have been given in table 1.

Physical properties

In general, sand content decreased from Bhata to Kanhar (upland to lowland) and decreasing trend was recorded with depth (Table 2) but it increased in Bss2 bottom horizon of P3 and Bss3 horizon of P4. Highest sand content (42.6 per cent) was recorded in Ap horizon of P1 and lowest (4.7 per cent) in Bss1 horizon of P3. The silt content ranged from 19.4 to 44.4 per cent and it gradually decreased with depth in P1, P2 and P3 except in P4 were it had uniform distribution.

These soils contain 29.3 to 61.6 per cent clay and 18.3 to 47.1 per cent fine clay (< 0.2 μm). The total clay content gradually increased with depth in all pedons except in P4, wherein the distribution was irregular (Table.2) probably due to differential cycle of fluvial action and *in-situ* differential translocation of clay under changing pedochemical environment. In P1

Table 1. Site location of selected pedons

Pedon no.	Local name	Location	Elevation (above MSL)	Slope (%)	Soil depth
Village-Chhota Urla, tehsil - Abhanpur, district -Raipur,					
Pedon 1(P1)	Bhata	21° 03' 44" N 81°46' 02" E	320 m	3-8	Very shallow (15 cm)
Pedon 2 (P2)	Matasi	21° 03' 58" N 81°46' 13" E	318 m	3-8	Shallow (41 cm)
Pedon 3 (P3)	Dorsa	21° 03' 59" N 81°46' 13.20" E	317 m	3-5	Deep (101 cm)
Pedon 4 (P4)	Kanhar	21° 04' 03" N 81°46' 13" E	316 m	3-5	Very deep (152 cm)

Table 2. Physical, chemical properties and molar ratio of soils

Chhota Urla, tehsil-Abhanpur, district- Raipur

Horizon	Depth (cm)	Particle Size class (per cent) and Diameter (mm) Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Fine Clay (<0.0002)	Textural Class	pH (1:2, Water)	pH (1:2, KCl)	-	CEC cmol (p^+) kg^{-1}	Molar ratio SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3
					Pedon 1: (Bhata) Clay-skeletal, mixed, hyperthermic Lithic Haplustalfs								
A	0-6	42.6	28.1	29.3	18.3	Clay loam	5.3	4.4	-0.9	9.5	6.89	7.34	3.55
Bt	6-15	39.3	19.4	41.4	35.0	Clay	5.4	4.4	-1.0	14.7	3.91	5.87	2.35
2Cr	15-25		---------- Laterized material ----------								1.43	0.75	0.49
					Pedon 2: (Matasi) Fine, mixed, hyperthermic Lithic Haplustalfs								
Ap	0-10	12.9	44.4	42.7	31.4	Silty clay	6.0	4.5	-1.5	15.4	9.99	21.07	6.78
Bt1	10-25	8.7	34.0	57.4	41.1	Clay	7.3	5.4	-1.9	20.7	6.42	17.22	4.68
Bt2	25-41	6.3	32.7	60.9	40.3	Clay	7.2	5.3	-1.9	21.6	5.72	16.56	4.25
					Pedon 3: (Dorsa) Fine, smectitic, hyperthermic Typic Haplusterts								
Ap1	0-15	8.7	40.2	51.2	36.2	Silty clay	6.9	5.3	-1.6	23.4	7.36	17.09	5.15
Ap2	15-24	6.8	42.7	50.5	27.7	Silty clay	8.2	6.5	-1.7	27.5	6.24	15.98	4.49
Bw	24-55	6.5	39.6	53.8	35.4	Clay	8.3	6.6	-1.7	28.3	7.04	18.36	5.09
Bss1	55-81	4.7	33.7	61.6	47.1	Clay	8.1	6.4	-1.7	26.4	6.75	18.62	4.95
Bss2	81-101	6.0	33.3	60.6	44.4	Clay	7.8	6.0	-1.8	27.6	6.18	17.40	4.56
					Pedon 4: (Kanhar) Fine, smectitic, hyperthermic Typic Haplusterts								
Ap	0-12	8.7	35.7	55.5	39.6	Clay	6.8	5.4	-1.4	23.9	7.85	15.97	5.26
Bw1	12-27	6.9	33.9	59.2	39.5	Clay	8.2	6.6	-1.6	30.74	7.27	15.85	4.98
Bw2	27-52	6.8	40.0	53.2	29.1	Silty clay	8.2	6.5	-1.7	32.42	8.45	31.09	6.64
Bss1	52-82	5.5	37.5	56.9	39.8	Clay	8.3	6.6	-1.7	32.33	7.84	17.21	5.39
Bss2	82-107	4.6	36.2	59.1	41.9	Clay	8.3	6.9	-1.4	29.88	7.74	19.09	5.51
Bss3	107-152	8.7	35.7	55.5	39.6	Clay	8.3	6.7	-1.6	30.32	7.13	18.02	5.11

and P2, increase in clay content in lower horizons were more than 20 per cent indicating high degree of translocation and thus qualify for argillic horizon (Soil Survey Division Staff 2014).

Chemical properties

pH of soils ranged from 5.3 (surface horizon of P1) to 8.3 (P4) and increased from upland to low land. Surface horizon of these pedons had pH 5.3 to 6.9. This difference in pH may be due to different pedo-chemical environment during genesis of soil or differential deposition of material (Table 2) (Jondhale and Jagdish Prasad 2006).

pH_{KCl} of soil varied from 4.4 to 6.9. Negative delta pH (pH = pH_{KCl}-pH_{H2O}) has been observed in all the soils indicating that the soils are not near their point of zero charge and contains appreciable amount of clay with relatively constant surface charge.

Cation Exchange Capacity ranged from 9.5 to 23.9 cmol (p^+) kg^{-1} in surface and 14.7 to 32.42 cmol (p^+) kg^{-1} in sub-surface soil. Such variations are attributed to the associated factors like nature and quantity of clay minerals, soil reaction, nature and quantity of organic matter *etc.* which govern the CEC (Nimkar *et al.* 1992 and Balpande *et al.* 1996).

Elemental properties

Molar ratios of different element serve as means of detecting relative translocations of elements. Silica/alumina ratio (SiO_2/Al_2O_3) decreased with depth (Table 2) in P1 and P2 whereas in P3 and P4 it showed irregular pattern. Low silica–alumina (1.43) and silica-sesquioxides (SiO_2/ Al_2O_3+Fe_2O_3) (1.49) ratio in Cr horizon of P1 indicated highly weathered Cr horizon than the soils of overlying horizons and lower molar ratios of SiO_2/Fe_2O_3 (0.75) seems to be indicative of presence of laterized material. However high silica content and ratios indicate that the soils were less weathered and juvenile and contain lot of weatherable minerals.

Mineralogical properties

Sand fraction

Sand fractions in P1 were constituted by quartz, hematite, siderite, magnanite, ilmnite, phlogopite, zircon, anatase, crystalobite and goethite whereas monohydrocalcite was found in surface layer of P1 (Fig. 3, Table 3). Mineralogy of P2 had similar assemblage of minerals as that of P1, except for monohydrocalcite, in addition to reported with diaspore, feldspar, ferrihydrite, lepidocrocite and mackinawite. P3 and P4

Table 3. Minerals identified in sand (2.00 -0.05 mm) fraction

Transect one - Chhota Urla, tehsil-Abhanpur, district - Raipur

Horizon	Depth (cm)	Q	He	Si	Man	Ilm	Phl	Fer	Zir	Ana	Cry	Goe	Dio	Cor	F	MCa	Cal	Le	Li	M-M	Lz	Mc	M
Pedon 1: (Bhata) Clay-skeletal, mixed, hyperthermic Lithic Haplustalfs																							
A	0-6	+	+	+	+	+	+		+	+	+					+							
Bt	6-15	+	+			+	+			+		+											
Pedon 2: (Matasi) Fine, mixed, hyperthermic Lithic Haplustalfs																							
Ap	0-10	+	+	+	+	+	+	+		+	+		+									+	
Bt1	10-25	+	+	+	+	+	+	+	+	+	+	+	+		+			+					
Bt2	25-41	+	+	+	+	+	+	+	+	+	+												
Pedon 3: (Dorsa) Fine, smectitic, hyperthermic Typic Haplusterts																							
Ap1	0-15	+	+	+	+	+	+	+	+	+	+	+											
Ap2	15-24	+	+	+	+	+	+	+	+	+	+												
Bw	24-55	+	+	+	+	+	+	+	+	+	+												
Bss1	55-81	+	+	+	+	+	+	+		+	+												
Bss2	81-101	+	+	+	+	+	+	+	+	+			+										
Pedon 4: (Kanhar) Fine, smectitic, hyperthermic Typic Haplusterts																							
Ap	0-12	+	+	+	+	+	+	+	+	+	+										+		
Bw1	12-27	+	+	+	+	+	+	+	+	+	+	+	+	+							+		
Bw2	27-52	+	+	+	+		+	+	+		+	+											
Bss1	52-82	+	+	+	+		+	+	+	+		+	+		+								
Bss2	82-107	+	+	+		+	+	+	+	+	+	+					+				+		
Bss3	107-152	+	+	+	+	+	+	+	+	+	+								+				+

Q=Quartz; Hem=Hematite; Sid=Siderite; Mang=Manganite; Ilm=Ilmenite; Phl= Phlogopite; Ferr=Ferrihydrite; Zir=Zircon; Ana=Anatase; Cry=Cristobalite; Goe=Goethite; Dio=Diospore; Corr=Corrumdum; F=Feldspar ; MCa=Monohydrocalcite; Lep=Lepidocrocite; Lit=Lithiophorite; M -M=Magnetite-Maghemite; Lz=Lizardite; Cal-Calcite; Mc=Mackinawite. (+ indicate presence of mineral)

were also detected with similar minerals as P1 soil except monohydrocalcite. Additionally diaspore, corundum, feldspar, calcite, lithiophorite, lizardite, magnetite-maghemite were also found in P4. Mineralogy of sand in these pedons was dominated by quartz and lesser amount of hematite, goethite, zircon and anatase. Primary minerals like Ca-feldspar, K-feldspar, mica and chlorite were not identified indicating that parent material had gone under very intense weathering.

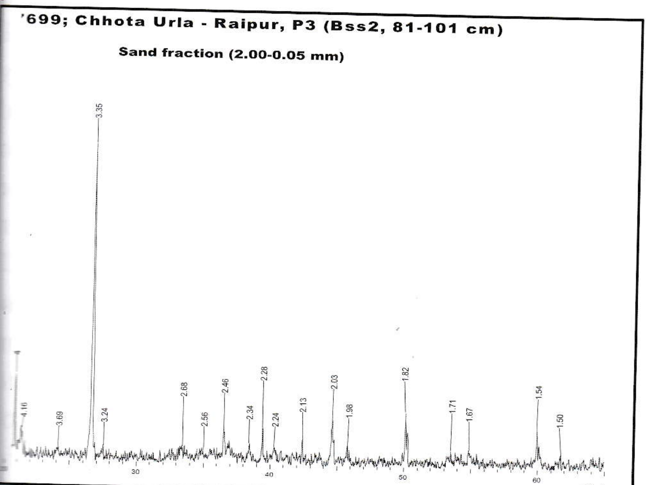

Fig. 3. Representative X-ray diffractogram of sand fraction of Pedon 3

Silt fraction

Smectite was identified in all samples by the appearance of 1.4 nm peak in Ca-saturated samples which shifted to 1.7 nm on glycolation (fig. 4). The small hump at 1.4 nm after heating to 550 °C for 1 hr indicated the presence of chlorite. The presence of

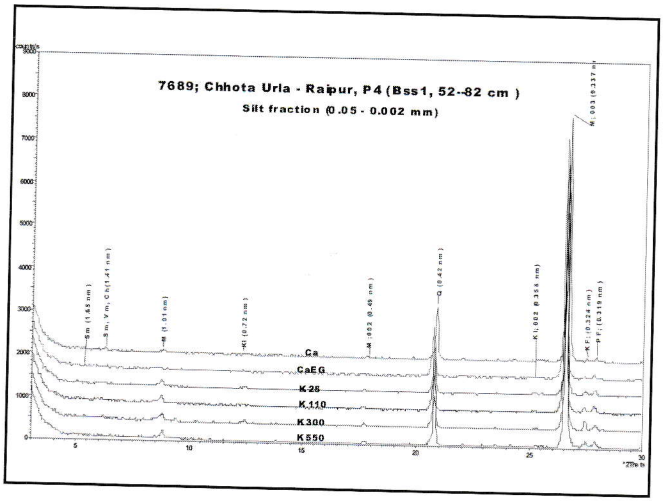

Fig. 4. Representative X-ray diffractogram of silt fraction of Pedon 4. Ca=Ca-saturated, CaEG= Ca-saturated plus ethylene glycol vapour, K25/110/300/550= K-saturated at 25°C, 110°C, 300°C, 550°C, Sm=smectite, Vm=Vermiculite, Ch=Chlorite, M=Mica, Kl=Kaoline, Q=Quartz, KF=K-feldspar, PF=Plagioclase (Ca-feldspar)

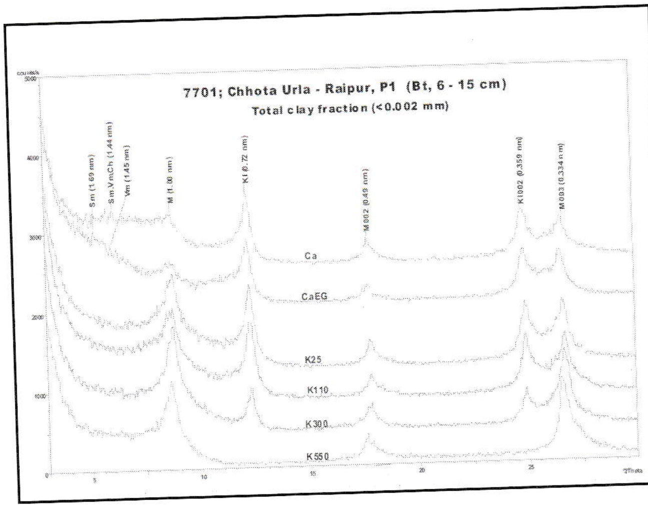

Fig. 5. Representative X-ray diffractogram of total clay fraction of Pedon 1. Ca=Ca-saturated, CaEG= Ca-saturated plus ethylene glycol vapour, K25/110/300/550= K-saturated at 25°C, 110°C, 300°C, 550°C, Sm=smectite, Vm=Vermiculite, Ch=Chlorite, M=Mica, Kl=Kaoline, Q=Quartz, KF=K-feldspar, PF=Plagioclase (Ca-feldspar)

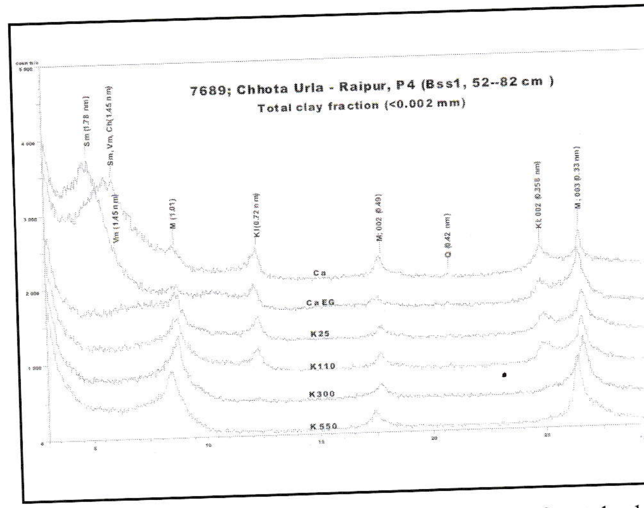

Fig. 6. Representative X-ray diffractogram of total clay fraction of Pedon 4. Ca=Ca-saturated, CaEG= Ca-saturated plus ethylene glycol vapour, K25/110/300/550= K-saturated at 25°C, 110°C, 300°C, 550°C, Sm=smectite, Vm=Vermiculite, Ch=Chlorite, M=Mica, Kl=Kaoline, Q=Quartz, KF=K-feldspar, PF=Plagioclase (Ca-feldspar)

vermiculite was ascertained by the 1.4 nm peak in Ca-EG treated samples and reinforcement of the 1.0 nm peak of the K treated samples at 25 °C and 110 °C. The peak around 1.0 nm with its 002 reflection at 0.49 nm indicates the presence of mica. The presence of kaolin was ascertained by the persistence of 0.72 nm with its 002 reflection at 0.359 nm Ca and in K-saturation and heating up to 300 °C and its disappearance at 550 °C. The peak at 0.42 nm indicates the presence of quartz in all the samples. The feldspar peaks were detected between 0.318 to 0.319 nm for Ca-feldspar and at 0.326 to 0.323 nm for K-feldspar. Quartz was the dominant mineral in pedon 1 followed by Ca-feldspar and K-feldspar, mica, kaolin with traces of vermiculite and smectite. P2, P3 and P4 had preponderance of quartz as compared to other minerals. In P2 and 3, K-feldspar was second dominant minerals after quartz followed by Ca-feldspar, mica and kaolin. However, in P4 Ca-feldspar was second dominant mineral followed by mica, kaolin and K-feldsapar. In Pedon 4, predominance of Ca-feldspar over a K-feldsapar as compared to other pedons revealed that this pedon had experienced less pedogenic processes. This conclusion was based on the fact that Ca-feldspar is more susceptible to weathering and got preserved in poorly drained kanhar soil (Satyavathi *et al.* 2005).

Clay fraction

Presence of smectite was established by basal reflection around 1.4 nm of Ca-saturated samples which expand to around 1.7 nm on glycolation. On K-saturation, the peak in the form of hump was indentified in the range of 1.2 to 1.4 nm. This peak got reinforced on heating at 110 °C and 300 °C till at 550 °C. Presence of mica was confirmed by peak around 1.0 nm which was not affected by glycolation, K-saturation and heating. The X-ray intensity ratio of peak heights of 001 and 002 basal reflections of mica was greater than unity in the clay fractions thus contains both biotite and muscovite (Pal *et al.* 2001 and Pal and Srinivas Rao 2002). If muscovite minerals were present alone, the ratio would have been very close to unity (Tan 1982). In the event of a mixture of these two micas, both will contribute to the intensity of the 10 A° reflections, whereas contribution of biotite to the 0.5 nm reflection would be nil or negligible, thus giving a higher value to the intensity ratio of these reflections. Presence of vermiculite was established by peak around 1.4 nm in CaEG saturated samples which on K-saturation and subsequent heating collapsed to 1.0 nm (25 °C to 300

°C). Small amount of vermiculite which was not detected around 1.4 nm region on Ca-saturation but was detected by the reinforcement of 1.0 nm peak on K-saturation at 25 °C to 110 °C. The 0.72 nm and 0.359 nm peak indentified in Ca-saturated indicated the presence of kaolin.

It was confirmed by its persistence on K-saturation and heating up to K300 °C and total disappearance at K550 °C. Small hump was noticed around 1.4 nm at K550° confirmed the presence of Chlorite. Quartz was ascertained by the presence of 0.42 nm peak. Ideally smectite on K-saturation registered a strong peak at 1.2 nm which gradually collapsed to 1.0 m on thermal treatment (550 °C). In present case, smectite peak on K-saturation at 25 °C registered number of small peak in 1.4 to 1.1 nm. On further heat treatment these peak gradually collapsed toward 1.0 nm but registered peak around 1.1 nm at 300°C and then totally collapsed to 1.0 at 550 °C which indicate presence of hydroxyl inter-layring in these smectite. Quartz in total clay fraction was identified with peak at 0.42 nm. In some pdeons, K-feldspar and Ca-feldspar were also confirmed by peak at 0.325 nm and 0.318 nm respectively.

A closer examination of diffractogram showed (Fig. 5 and 6) that the 0.72 nm peak shifted on glycolation indicating presence interstratified Sm/K. The smectites peak on K-saturation and thermal treatment registered a plateau between 1.2 to 1.3 nm with tailing towards low angle sides. Besides, the K-saturated samples heated to 550 °C also produced a broad base of 1.0 nm peak showing a shoulder and broadening on low angle side. These criteria are indicative of chloritization of smectite interlayers (Wildman *et al.* 1968) due to induction of hydroxyl – interlayering at higher soil pH condition (Jackson 1963) whereas Pal *et al.* (1999) had a thought that humid tropical climate and acid weathering under plenty of Al in soil was more conducive for hydroxyl interlayering phenomenon.

Semi-quantitative estimation of minerals

Silt fraction

All the pedons (Table 4) were dominated by quartz (64.2 to 89 per cent). Mica (~6 per cent), K-

Table 4. Semi-quantitative estimate (relative per cent) of minerals present in silt fraction (0.05 -0.002 mm)

Horizon	Depth (cm)	Sm	Ch	Vm	M	Kl*	Q	KF	PF
	Pedon 1: (Bhata) Clay-skeletal, mixed, hyperthermic Lithic Haplustalfs								
A	0-6	Tr	Tr	Tr	5.5	5.0	75.5	Tr	5.0
Bt	6-15	Tr	Tr	Tr	6.6	5.4	69.6	6.1	6.9
	Pedon 2: (Matasi) Fine, mixed, hyperthermic Lithic Haplustalfs								
Ap	0-10	Tr	Tr	Tr	5.0	Nil	76.2	8.7	5.0
Bt1	10-25	Tr	Tr	Tr	5.5	5.2	76.1	Tr	Tr
Bt2	25-41	Tr	Tr	Tr	5.0	Nil	78.9	7.8	Tr
	Pedon 3: (Dorsa) Fine, smectitic, hyperthermic Typic Haplusterts								
Ap1	0-15	Tr	Tr	Tr	Tr	Tr	83.7	Tr	Tr
Ap2	15-24	Tr	Tr	Tr	5.0	Tr	68.6	15.4	5.0
Bw	24-55	Tr	Tr	Tr	Tr	Nil	89.1	6.4	Nil
Bss1	55-81	Tr	Tr	Tr	7.8	5.0	69.9	6.3	5.9
Bss2	81-101	Tr	Tr	Tr	5.0	7.0	64.2	10.6	6.7
	Pedon 4: (Kanhar) Fine, smectitic, hyperthermic Typic Haplusterts								
Ap	0-12	Tr	Tr	Tr	5.5	5.0	75.5	Tr	5.1
Bw1	12-27	Tr	Tr	Tr	6.6	5.4	69.6	6.1	6.9
Bw2	27-52	nd	Nd	nd	nd	Nd	nd	Nd	nd
Bss1	52-82	Tr	Tr	Tr	Tr	Tr	76.9	5.0	8.8
Bss2	82-107	Tr	Tr	Tr	Tr	Tr	78.0	Tr	6.5
Bss3	107-152	5.0	Tr	Tr	7.1	6.5	65.3	Tr	8.5

Table 5. Semi-quantitative estimate (relative per cent) of minerals present in clay fraction (< 0.002 mm)

Horizon	Depth (cm)	Sm	Ch	Vm	M	Kl	Q	KF	PF
Pedon 1: (Bhata) Clay-skeletal, mixed, hyperthermic Lithic Haplustalfs									
A	0-6	19.5	6.8	8.7	17.7	37.1	Tr	5.0	Tr
Bt	6-15	12.2	5.0	15.0	16.7	46.1	Tr	Tr	Tr
Pedon 2: (Matasi) Fine, mixed, hyperthermic Lithic Haplustalfs									
Ap	0-10	21.0	9.3	Tr	17.9	46.9	Tr	Nil	Nil
Bt1	10-25	26.1	6.9	12.1	8.3	44.3	Tr	Nil	Nil
Bt2	25-41	23.9	5.0	16.5	12.9	41.4	Tr	Nil	Nil
Pedon 3: (Dorsa) Fine, smectitic, hyperthermic Typic Haplusterts									
Ap1	0-15	38.1	Tr	14.5	15.7	23.7	Tr	Tr	Nil
Ap2	15-24	41.4	Tr	15.6	13.4	20.0	Tr	Tr	Tr
Bw	24-55	40.1	6.1	13.1	11.4	23.7	Tr	Tr	Nil
Bss1	55-81	46.0	6.5	13.8	11.2	16.0	Tr	Tr	Tr
Bss2	81-101	54.1	8.0	10.1	9.6	11.7	Tr	5.4	Nil
Pedon 4: (Kanhar) Fine, smectitic, hyperthermic Typic Haplusterts									
Ap	0-12	42.8	5.4	11.5	15.7	20.6	Tr	Tr	Nil
Bw1	12-27	45.0	Tr	13.6	11.3	19.1	Tr	Tr	Tr
Bw2	27-52	57.9	7.4	Tr	15.4	11.3	Tr	Tr	Nil
Bss1	52-82	59.7	Tr	9.0	9.2	15.5	Tr	Tr	Nil
Bss2	82-107	51.4	5.0	14.2	9.6	13.2	Tr	Tr	Tr
Bss3	107-152	nd	Nd	nd	nd	Nd	nd	nd	Nd

Sm=smectite; Ch= Chlorite; Vm= Vermiculite; M=Mica; Kl=Kaoline; Q=Quartz; KF=K -feldspar; PF=Plagioclase (Ca-feldspar); Tr=Trace. * Kaolin (kaolinite + interstrafied smectite), ** Trace < 5 per cent

feldspar (traces to 10.6 per cent) and Ca-feldspar (traces to 8.8 per cent) were present in sub-ordinate amount. Smectite, chlorite and vermiculte were semi-quantified and present in traces (< 5 per cent). P3 and P4 had more reserve of weatherable minerals (mica+K-feldspar+Ca-feldspar) as compared to P1 and P2 which indicated that P1 and P2 had more intense weathering environment. Feldspar content increased from higher topography to lower topography owing to free drainage condition on higher topography and rapid removal of weathered material and bases from site of weathering and its subsequent deposition and accumulation of weathered material in lower topographic position due to restricted drainage. It may be inferred that internal drainage played a major role in accumulation of mineral in silt fraction (Gawande and Biswas 1967; Diwakar and Singh 1994; Rudramurthy and Dasog 2001).

Clay fractions

In P3 and P4 smectite (38.1 to 59.7 per cent) was dominant (table 5) followed by kaolin (11.3 to 23.7per cent) with sub-ordinate amount of vermiculite (9.0 to 15.6 per cent) and mica (9.2 to 15.7 per cent). However, P1 and P2 were dominated by kaolin (37.1 to 46.9 per cent) followed by smectite (12.2 to 26.1 per cent) with sub-ordinate amount of mica (8.3 to 17.7 per cent) and vermiculite (traces to 16.5 per cent). Chlorite was in traces in three pedons (P2, P3 and P4) but in P1, it was around 8 per cent. Quartz and Ca-feldspar were in traces while K-feldspar constituted about 5 per cent.

The present knowledge of geology of the study area did not explain formation of huge amount of smectite. As smectite is first weathering product of plagioclase which is main constituent of basalt (Pal *et al.* 1999). As mica and vermiculite also reported in appreciable amount and mica is major constituent in granite gneiss rock (Dixon and Weed 1989) and vermiculite is weathering product of mica (Aoudjit *et al.* 1996). It may be inferred that material deposited in studied area is of mixed alluvium, eroded from different geological formation and thus contradicted the occurrence of as Bhata, Matasi, Dorsa and Kanhar soils in catenary sequence as reported by (Biswas and Gawande 1962; Gawande and Biswas, 1967; Gawande and Biswas 1968).

Conclusions

The topographic position along toposequence has prominently influenced physical, chemical, elemental and mineralogical properties of soils. Sand content decreased from higher topographic to lower topographic position but it was not so for clay. pH ranged from strongly acid to moderately alkaline and it increased from upland to low land. Lower molar ratios of SiO_2/Fe_2O_3 of Cr horizon of P1 indicated laterization process.

Mineralogy of sand in all pedons was dominated with quartz with lesser amount of hematite and devoid of primary minerals like Ca-feldspar, K-feldspar, mica and chlorite indicating that parent material had gone under very intense weathering. Silt fraction of P1, P2 and P3 was dominant in quartz followed by Ca-feldspar and K-feldspar whereas silt fraction of P4 had predominance of Ca-feldspar over a K-feldsapar indicative of less pedogenic weathering. In clay fraction, kaolin was dominant mineral in P1 and P2 with sub-ordinate amount of smectite, mica, vermiculite, and chlorite with traces of quartz, K-feldspars and Ca-feldspar. P3 and P4 had preponderance of smectite followed by kaolin, mica, vermiculite, chlorite with traces of quartz, K-feldspars and Ca-feldspar. It is concluded that material deposited in area was of mixed alluvium, eroded from different geological formation and did not explain formation of huge amount of smectite from existing rock type and contradicted the occurrence of catenary sequence as reported earlier.

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