

Characteristics and Genesis of Soils Developed on Low Physiographic Position on Different Textured Alluvial Plains in Arid Rajasthan

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Abstract Pedons on lower physiographic positions in coarse and medium to moderately fine textured older alluvial plains were studied for their characteristics and genesis. Soils (P1) on coarse textured plain are yellowish brown, columnar, having illuvial B horizon with carbonatic eyes and well formed lime segregations. In medium to moderately fine textured plain the soils (P2) are grey and prismatic, with small rounded lime segregations. Micromorphology showed the presence of crescentic coatings of fine material and also pseudomorphic infillings in voids and channels with calcitic pedofeatures in p1 whereas P2 showed limpid clay domains and infillings of sparitic calcite crystals. Lime segregations, present throughout in both pedons were soft concretions and nodules in P1 and hard concretions in P2. Beside these, both the soils vary in mechanical and elemental constituents. Leaching of lime and formation of segregations are pedogenic processes operated in the profile development of P2 whereas beside these illuviation and *in situ* weathering in P1 soils.

Key words Physiography, Micromorphology, Pedogenesis, Lime segregations, Low land Soils.

Resource inventory of arid region of western Rajasthan, India, indicated that older alluvial plain of varying textures covers major part of the landscape (Ghose et al. 1977). Within these plains there are sizeable area which are physiographically low and have soils morphologically as well as taxonomically different than the plains (Choudhari 1982). Thus, a study was undertaken to evaluate variability in characteristics and genesis of soils developed at lower physiographic positions in different textured alluvial plains.

Materials and Methods

Study area, located in Jodhpur district of Rajasthan is characteristically dominated by older alluvial plains and plain transformed by aeolian activity (CAZRI 1982). Soil profiles on lower part of coarse (P1) and on medium to moderately fine textured plains (P2) were studied at village Chirai (26° 41'N and 73° 43'E) respectively. Morphology

of pedons was described according to Soil Taxonomy (Soil Survey Staff 1975). Soil samples collected from each horizon were processed and analysed for different characteristic following the procedure outlined by Jackson (1979) and Piper (1950).

Thin sections were prepared according to the procedure described by Choudhari (1990) and were studied under polarizing microscope. Microscopic features were described following the terminology of Bullock et al. (1985).

Results and Discussion

Morphology : Despite similar low lying position of the pedons in the coarse and moderately fine textured plains the morphological features differ markedly (Table 1). The surface horizon of P1 is yellowish brown, calcareous and granular whereas in P2 it is dark greyish brown, non calcareous and subangular blocky. The B horizon in P1 is brown,

Table 1. Morphology of soils

Depth (cm)	Horizon	Colour (moist)	Texture	Structure	Effervescence	Mottles	Boundary	Lime segregations*	Special features
P1 on lower physiographic position in coarse textured alluvial plain									
0-15	A	10YR4/3	l	m1gr	es	Nil	cs	Vfw, Sm, Sh, ir	-
15-29	B1	10YR4/4	l	M1 sbk	ev	Nil	gw	Fw, Sm, H, Sp	Carbonatic eyes
29-55	B21ca	7.5YR4/4	l	M2cpr	es	Nil	gw	Fw, Sm, H, Sp	Thin clay coatings
55-90	B22ca	7.5YR4/4	cl	M2cpr	ev	YB	gw	Fw, Sm, H, ir	-do-
90-120	B23ca	5YR5/6	cl	m	ev	YB	gw	Fw, lim, H, ir	-
120-200	IIC1ca	5YR5/6	c	m	ev	YB	-	Fw, l, H, Sp	-
P2 on lower physiographic position in moderately fine textured alluvial plain									
0-15	Ap	10YR4/2	l	m2sbk	Nil	Nil	cs	Nil	-
15-33	A	10YR4/2	cl	m2sbk	e	Nil	gs	Vfw, Sm, Sh, Sp	-
33-55	C1ca	10YR4/2	cl	m1pr	es	Nil	gs	Fw, Sm, H, Sp.	-
55-73	C2ca	10YR4/2	cl	m1pr	es	YB	gs	Many, Sm, H, Sp	-
73-92	C3ca	10YR4/2	cl	m1pr	ev	YB	gs	Many, Sm, H, Sp	-
92-160	IIC4ca	10YR5/4	cl	m	ev	YB	gs	Fw, Sm, H, Sp	-
160-240	IIC5ca	10YR5/6	scl	m	ev	YB	-	Fw, Sm, H, Sp	-

Abbreviations are as given in Soil Survey Manual (IARI, New Delhi 1970).

*Fw = Few, Vfw = Very Few, Sm = Small, l = Large, Sh, Slightly hard, H = Hard, ir = irregular, Sp = Spherical, - = Nil

columnar, strongly calcareous with patchy clay coatings on peds and lime segregations. The upper part of the C horizon (C1-C3) in P2 is dark greyish brown, calcareous and prismatic whereas lower part of C horizon in both pedons is massive, calcareous with lime segregations and yellowish. Yellowish brown mottles were however observed in both the pedons below 55 cm depth.

Both soils contained higher amounts of fines (silt and clay), lime and salt compared to that in soils of the upper part of the respective plains. This

values of pH and exchangeable Na content of the soils (Table 2).

Micromorphology : In coarse textured plain soils (P1) the Ap horizon is characterised by pellicular grain and spongy type whereas in moderately fine textured plain (P2) microstructure in all horizon was compact and prismatic with secondary microvughy type.

Crescentic clay coating in macrovoids, laminated layered coating of brown to dark yellowish brown clays and silty clay material (Fig1)

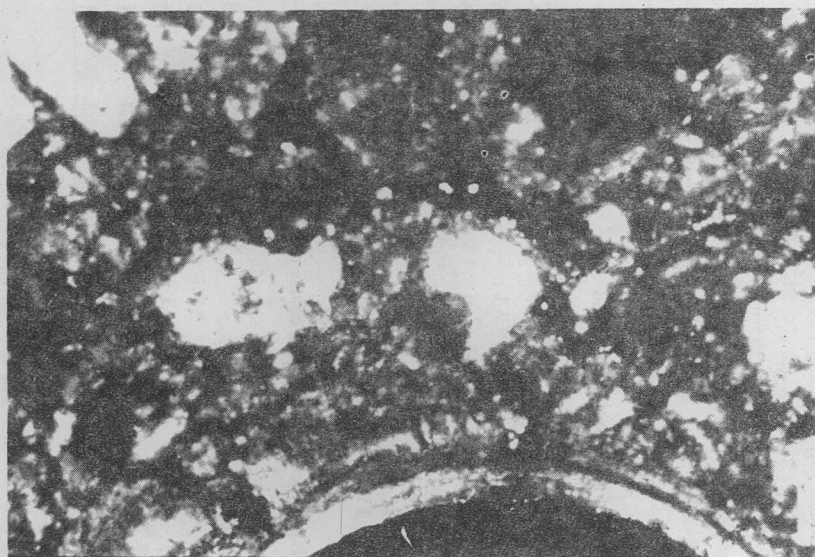


Fig 1 Crescentic clay and laminated coatings of brownish fine material and microcrystallized calcitic nodules in B horizon of P1. XP, X120.

is evident from the data presented for dominant soil P3 on coarse textured alluvial plain and P4 on moderately fine textured alluvial plain (Table 2). Further the contents are increasing with depth (Table 2). This enrichment of the soils (P1 and P2) could be due to their occurrence on lower part of the plains where runoff charged with fines and sodium dominated salts is received from the upper part of the plains. Infiltrating leessivage enriched the exchange complex with sodium and thereby sodiumization of soils. This is evident by higher

are the dominant pedotextural features in B horizon of P1. Limpid clay coatings in narrow voids and limpid clay domains were observed in upper C horizon of P2.

Coatings and hypocoatings of microsparitic calcite in channels, voids and on skeleton grains are common in both the pedons. The P1 however showed pseudomorphic infillings consist of larger calcite crystals and fine silt, replacing, the coarser grains and taking the form of root remanants (Fig 2). Beside these calcitic features, both the soils

Table 2. Physical and chemical characteristics of the soils.

Horizon	pH	EC (1:2 soil water) dS m ⁻¹	O.M. %	Sand %	Silt %	Clay %	Extractable cations				CEC	CaCO ₃ %	Fe ₂ O ₃ %
							Ca	Mg	Na	K			
P1 Haplustollic Natragrid													
A	8.6	0.22	0.33	69	16	15	5.8	1.0	1.3	0.6	8.7	5.2	0.27
B1	9.1	0.40	0.42	68	15	17	5.1	1.0	4.5	0.5	10.4	7.6	0.28
B21ca	9.5	0.50	0.33	62	20	19	4.9	0.8	3.7	0.5	10.0	14.4	0.29
B22ca	9.2	4.01	0.28	55	20	25	2.9	0.7	8.9	0.6	13.1	15.3	0.56
B23ca	9.1	5.16	0.26	48	22	30	1.4	0.6	11.9	0.9	16.9	12.1	0.70
IIc1ca	9.1	3.60	0.30	35	13	53	1.4	0.6	24.3	0.8	18.2	15.8	1.07
P3 Typic Camborthid on coarse textured plain													
Ap	8.4	0.13	0.10	90	5	5	2.5	0.5	1.5	0.3	5.4	0.0	0.26
A	8.4	0.15	0.13	80	11	9	3.5	0.4	1.4	0.2	5.9	0.0	0.26
B21ca	8.2	0.19	0.15	79	11	9	4.3	0.5	1.6	0.2	5.3	0.0	0.32
B22ca	8.3	0.31	0.10	85	10	6	4.7	0.5	1.7	0.1	5.0	0.8	0.30
IIc1ca	8.4	0.32	0.10	77	14	9	4.5	0.5	1.3	0.1	5.9	6.0	0.44

Table 2 Contd..

Horizon	pH	EC (1:2 soil water) dS m ⁻¹	O.M. %	Sand %	Silt %	Clay %	Extractable cations				CEC	CaCO ₃ %	Fe ₂ O ₃ %
							Ca	Mg	Na	K			
Cmol (P ⁺) kg ⁻¹													
P2 Aquic Calciorthid													
Ap	8.6	0.30	0.47	48	23	28	17.7	2.6	3.5	0.4	22.4	4.6	0.58
A	8.9	0.42	0.47	46	24	32	18.0	2.6	3.9	0.3	24.8	7.6	0.50
C1ca	8.9	0.50	0.40	45	22	33	18.2	3.7	7.9	0.3	24.1	9.9	0.56
C2ca	9.2	0.72	0.28	4	23	34	6.8	4.4	16.4	0.3	23.5	9.9	0.57
C3ca	9.2	0.82	0.40	41	26	33	4.8	3.6	13.4	0.5	nd.	11.3	0.56
HC4ca	9.5	1.80	0.14	44	21	34	2.6	1.8	5.6	0.3	nd.	16.6	0.56
P4 Calcic Camborthisd on moderately fine textured plain													
Ap	8.1	0.31	0.63	62	20	18	10.5	1.0	1.9	0.3	13.1	6.7	0.57
B21ca	8.3	0.22	0.70	50	16	33	14.0	1.9	1.8	0.2	16.8	16.1	0.74
B22ca	8.2	0.35	0.76	53	16	29	11.6	0.8	2.0	0.2	15.9	35.8	0.77
C1ca	8.3	0.35	0.56	49	21	30	8.5	0.6	1.0	0.2	13.9	42.2	0.57

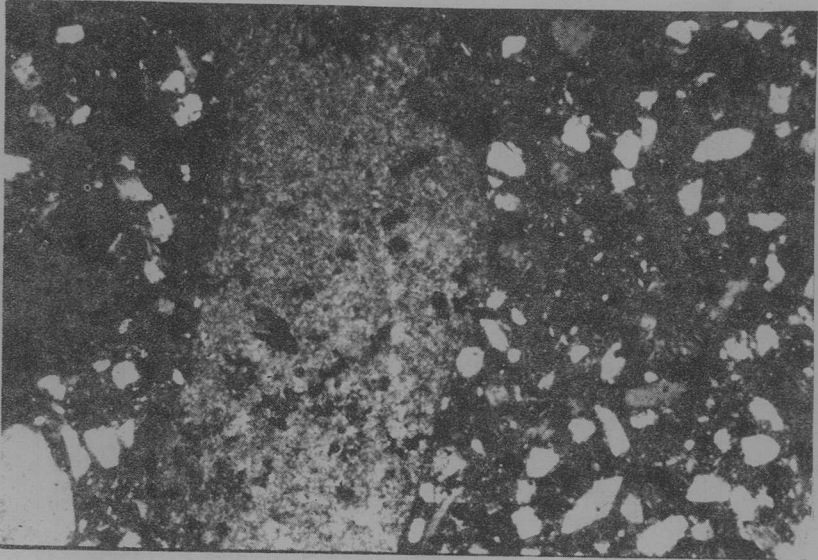


Fig 2 Pseudomorphic infillings of calcite and silt showing the form of root remnants in horizon of P1. XP, X 120.

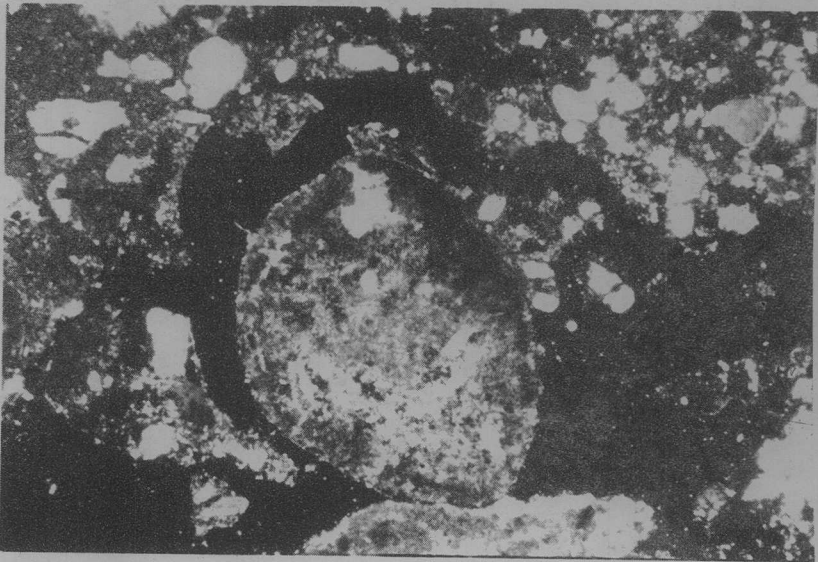


Fig 3 Dense hard nodule in the C2 horizon of P2. XP, X 60.

showed pure as well as impregnative type lime segregations in all the horizons. Very dense nodules (Fig 3) are densely packed with microsparitic to sparitic calcite crystals and are present

as clear boundary with adjacent soil matrix. However, segregations in C horizons were impregnated with iron oxides.

Table 3 Elemental composition of soils and clay fractions (HCl extract)

Horizon	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	Cu	Zn ppm	Clay %		F Clay	T Clay
										C	F		
P 1													
Ap	3.8	2.8	0.2	1.3	0.19	0.02	0.05	12	24	7.4	7.5	0.5	0.5
B1	4.0	2.9	0.3	1.3	0.28	0.08	0.06	13	26	6.6	10.6	1.6	1.6
B21ca	4.6	3.1	0.4	1.3	0.20	0.04	0.06	14	30	6.4	12.1	0.6	0.6
B22ca	7.1	3.9	0.5	2.2	0.27	0.6	0.06	18	32	7.4	17.6	1.7	1.7
B23ca	6.8	3.9	0.5	1.8	0.26	1.06	0.07	18	34	10.6	19.5	0.6	0.6
IIc1ca	14.3	5.8	0.6	1.4	1.15	2.02	0.09	29	26	31.1	21.4	0.4	0.4
P 2													
Ap	8.2	3.8	0.6	1.8	0.19	0.05	0.06	16	266	9.6	18.8	0.7	0.7
A	10.2	3.9	0.5	1.8	0.16	0.16	0.06	16	38	11.5	20.7	0.6	0.6
C1ca	9.4	4.0	0.3	1.9	0.15	0.16	0.07	16	36	11.4	21.9	0.7	0.7
C2ca	9.9	4.1	0.3	2.1	0.16	0.25	0.04	18	39	11.0	22.6	0.7	0.7
C3ca	10.0	4.1	0.7	2.3	0.24	0.34	0.04	17	39	11.3	21.3	0.7	0.7
IIc4ca	9.1	4.1	2.6	2.3	0.23	0.44	0.06	18	59	9.0	25.3	0.7	0.7

* C = Coarse, F = Fine, and T = Total

Table 4. Carbonates and dilute acid soluble alkaline earth carbonates

Horizon	Total CaCO ₃ %	CaCO ₃ %	MgCO ₃ %	Morphology of segregates				M • Color	Hardness**	Segregations		
				Form*			Size (cm)			Acid insoluble	CaCO ₃	MgCO ₃
				A	B	C						
P 1												
A	5.2	3.8	0.3	VC	F	-	0.3-1.5	10YR 6/4	Sh	27	63	1.1
B1	7.6	7.0	0.3	VC	F	-	0.5-2.0	10YR 6/4	Sh	28	56	1.1
B21ca	14.4	10.2	0.5	VC	F	-	0.5-7.0	5YR 4/3	Soft	21	-	-
B22ca	15.3	13.9	0.9	VC	VF	F	0.5-1.0	5YR 4/3	Soft	29	64	2.0
B23ca	12.1	9.5	0.2	VC	VF	F	0.5-3.0	5YR 4/3	Soft	30	66	2.0
										22	59	0.9
P 2												
Ap	4.6	5.6	0.6	VF	VC	-	0.3-0.5	10YR 4/2	H	17	73	1.9
A	7.6	6.4	0.4	VF	VC	-	0.3-0.5	10YR 4/3	H	18	73	1.9
C1ca	9.9	6.4	0.4	VF	VC	-	0.3-1.5	10YR 4/1	H	15	80	2.4
C2ca	9.9	8.7	0.9	VC	VF	-	0.3-1.0	10YR 4/1	Soft	13	73	1.9
C3ca	11.3	-	-	VC	VF	-	0.3-0.8	10YR 4/1	Soft	14	81	1.8
IIC4ca	16.3	3.6	0.3	VC	VF	-	0.3-0.8	10YR 4/1	Soft	13	85	2.4

*A = Soft nodules concretion, B = Hard concretion, C = Hard nodules, **Sh = Slightly hard, H = Hard, - = Not determined

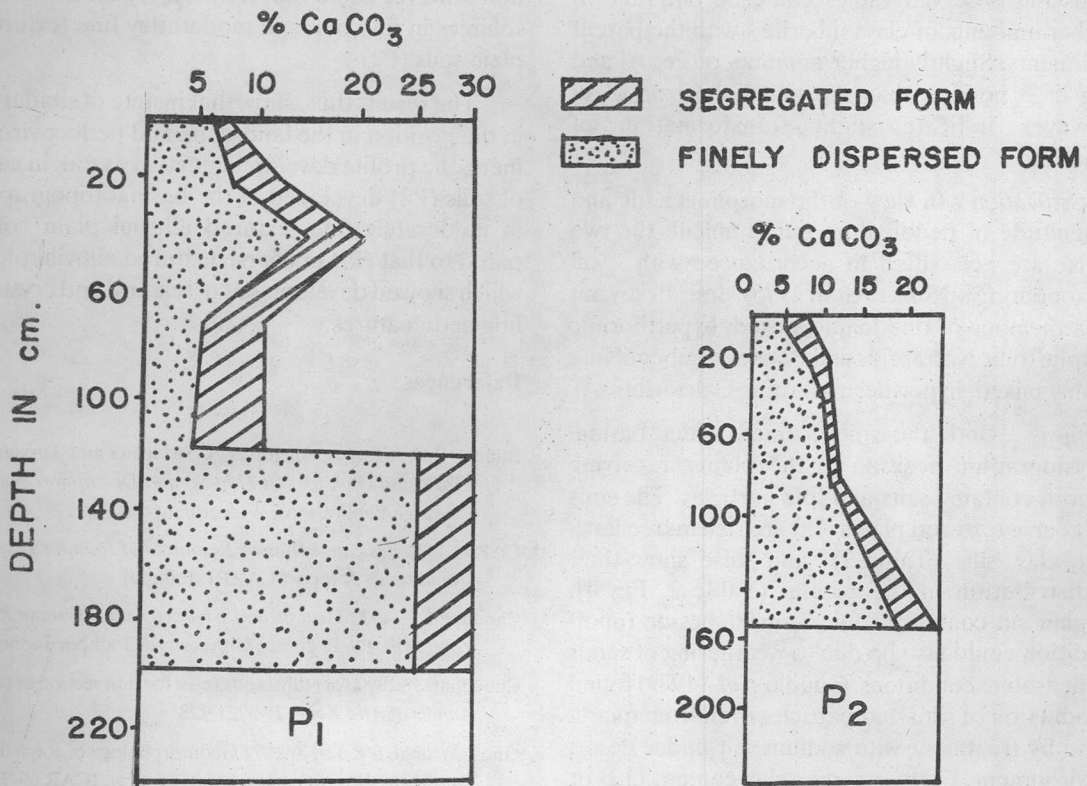


Fig 4 Distribution of calcium carbonate and its forms in pedons.

Forms and distribution of calcium carbonate :

The CaCO₃ present in these soils varied in form, content and distribution pattern (Fig 4). Finely dispersed form gradually increased with depth and was present as silt and very fine sand sized particles. Segregated form, which was present through out the pedon varied in their morphology, chemical composition (Table 4) and micro fabric (Fig 3). Segregations of coarse textured plain comprised of higher proportion of insoluble residues (21-28%) and are yellowish brown, larger in size and dominantly soft nodules and concretions. In moderately fine textured plain (P2) the segregates in upper part are smaller, hard, low in insolubles (13-18%) and greyish in colour whereas below C2 horizon these were softer and contained higher

proportion of insolubles (Table 4). Few nodules, present are impregnative and pure in case of P2 whereas these were impregnative in case of P1. However, in both the cases iron oxide impregnation was observed. Microscopic analysis indicated that dark coloured one are crystallized and impregnated with iron oxide whereas softer ones are impregnative type where microcrystallized calcite bridged the skeleton grains completely and gives a compact ground mass.

Chemical composition : Elemental composition (Table 3) shows that the content of oxides of Al, Fe, Ca and Mg were higher in P2 than in P1. The uniform distribution of these elements (Table 3), free iron oxides (Table 2) and angular grains do not indicate any sign of weathering in P2 profile.

Thus the observed values could be only due to higher amounts of clays inherited with the parent sediments. Slightly higher amounts of Fe, Al and Mg in B horizon than Ap and C horizon of P1 however indicate slight transformation of minerals.

Classification : In view of the morphogenetic and magnitude of pedofeature development, the two soils are classified in accordance with Soil Taxonomy (Soil Survey Staff 1975). Soils P1 key out as a member of fine loamy, mixed, hyperthermic Haplustollic Natrargids and P2 as a member of fine loamy mixed, hyperthermic Aquic Calciorthids.

Genesis : Both the soils formed under basinal physiographic position in the plains, receiving runoff, containing salts and fine particles. The soils on coarse textured plains (P1) are rich in free lime, salt, clay, silt (Table 2) and also show their redistribution in the profile (Table 2, Fig 4). Higher silt content (Table 2) in P1, beside runoff addition could also be due to weathering of sands under saline conditions. Goudie *et al.* (1979) found production of silt sized particles even from quartz sand by treatment with sodium salt under desert environment. Further higher clay content in B or lower horizon though mainly due to lithological factors, but some of this enrichment is attributable to illuviation. This is evident by the presence of clay coatings, textural and crystallitic pedofeatures (Fig 1-3) and higher fine to total clay ratio (Table 3). The coarse nature of parent material of P1 facilitated the mobility of solubles and insolubles constituents and also high evaporation thereby favoured the crystallization of soluble and orientation of particles in channels, voids and on skeleton grains. Slow infiltration and low rate of evapora-

tion however could only allowed crystallization of solubles in fine pores in moderately fine textured plain soils (P2).

The results thus, show that in spite of similarity in the position in the landscape and pedoenvironment, the profile development is very weak in case of soils (P2) developed at the basinal topography in moderately fine textured alluvial plain compared to that (P1) in coarse textured alluvial plain which showed development of textural and crystallitic pedofeatures.

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