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Minerals, Plasmic fabrics and Clay Pedofeatures in Vertisols with and without Soil modifier (Zeolite)

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Abstract : *One zeolitic Vertisol from semi-arid (dry) and the other non-zeolitic Vertisol from semi-arid (moist) climatic zones viz., Jhalipura in Rajashthan and Bhatumbra in Karnataka, respectively were studied for their micromorphological characteristics. The Jhalipura soils exhibited weak plasma separation with mosaic speckled and undifferentiated b-fabric. They consisted of both non-pedogenic carbonates (NPC) and pedogenic carbonates (PC). Zeolites were predominantly observed in the soil matrix. In addition, muscovite, quartz, few tiny grains of zircons and tourmalines have also been identified. Elongated voids, septaric carbonate nodules with epicoating of PC's and shearing (off set) in channel voids and stress oriented clay pedofeatures were prominently observed. In contrast, Bhatumbra soils showed strong plasma separation with distinct zoning and exhibited parallel striated, porostriated and granostriated b-fabric. The soils have more NPCs than PCs. Non-clay minerals such as quartz, plagioclase feldspar, muscovite, biotite and heavy minerals such as zircon and tourmaline are also present. Few black carbonate nodules are only present in the coarser fraction of Bhatumbra soils. Weak plasmic separation and mosaic speckled and undifferentiated plasmic fabric in Jhalipura soils may be because of less shrink-swell activity and also because of high amount of zeolites studded in the matrix, whereas strong plasmic separation and strongly oriented plasmic fabric in Bhatumbra soils may have resulted due to high clay activity and also due to high stress related to shrink-swell potential of clay. Slightly higher amount of PC's in Jhalipura may be because of the dry pedoenvironment. The presence of zeolites in the soils of Jhalipura is attributed to their parent material (amygdoloidal basalt). Presence of elongated voids and shearing in channel voids were observed only in Jhalipura soils and this may be due to the stress generated by non-pedogenic processes.*

Although information on the type of plasmic fabrics and clay pedofeatures in Vertisols of India are available (Balpande *et al.*, 1997; Kalbande *et al.*, 1992; Pal *et al.*, 2001) but it is limited for Vertisols with soil modifiers like Ca-zeolites (Pal *et al.*, 2006). The availability of this soil modifying mineral can have substantial influence over the properties of soils (Bhattacharyya *et al.*, 1999) as the presence of Ca-zeolites creates a unique pedo-chemical environment because of their abilities to hydrate and dehydrate reversibly and to exchange some of their constituent cations (Bhattacharyya *et al.*, 1993, 1999, Pal *et al.*, 2006). Thus the present study is an attempt in this direction to record the micromorphological expression of plasmic fabrics and clay pedofeatures in two Vertisols with and without zeolites.

Materials and Methods

Two pedons one each in Jhalipura (25°11'19" N 75°57'04" E) from semi-arid dry region of Kota in Rajasthan and the other from semi-arid moist region of Bhatumbra (18° 03' 25"N; 77° 09' 06" E) in Karnataka state were chosen for the study. The parent material of the Jhalipura soils is the alluvium of weathered Deccan basalt and metamorphic rocks, whereas that of Bhatumbra is only the alluvium of weathered basalt. Mean annual rainfall (MAR) of the region is 842 mm in Jhalipura and 977 mm in Bhatumbra. The soils of Jhalipura contain Ca-zeolites whereas it is absent in soils of Bhatumbra.

The particle-size distribution was determined by the international pipette method after removal of organic matter, $CaCO_3$ and Fe oxides. Sand (2000-50 µm), silt (50-2µm), clay (<2µm) and fine clay (0.2µm) fractions were separated according to the procedure of Jackson (1979). The pH, cation exchange capacity and exchangeable cations were determined on the total fine earth (<2 mm) by standard methods (Richards, 1954; Piper, 1966). The coefficient of linear extensibility (COLE) was determined following the method of Schafer and Singer (1976). The saturated hydraulic conductivity (HC) was determined using a constant head permeameter (Richards, 1954).

The soil pedons were morphometrically examined horizonwise in the field and tentatively classified using USDA system of soil taxonomy (Soil Survey Staff, 1999). The soil samples were collected from each horizon for further analyses in the laboratory. Also undisturbed soil cores were collected from a selected horizon of the pedons using a tin box of 8 x 6 x 5 cm size. After the complete removal of moisture, impregnation was done using polyester resin. Soil thin sections were prepared using standard procedure (Jongerious and Heintzberger, 1975). They were described according to the nomenclature of Bullock *et al.* (1985).

Results

Physical and chemical properties

Both Jhalipura and Bhatumbra soils have high content of clay and moderate amount of silt. The fine clay dominates the clay fraction (>50%). Their high COLE values (>0.19-0.21) indicate the presence of dominant presence of smectite in their clay fractions. The soils are neutral to slightly alkaline in reaction, calcareous and highly base saturated in excess of 100 per cent in soils of Jhalipura indicating the presence of Ca–zeolites (Pal *et al.*, 2006). The HC decreases sharply in Bhatumbra soils of semi–arid moist bioclimate, however, it is vice-versa in Jhalipura soils of semi-arid dry bioclimate (Table 1). Soils of semi–arid dry climate in general exhibit sodicity in the subsoils and as a result HC decreases very sharply with depth (Pal *et al.*, 2000, 2003; Srivastava *et al.*, 2002). But due to the abundant release of Ca^{2+} ions from Ca-zeolites in these soils, pH of the soils are not high which is reflected in enhanced hydraulic properties of soils (Table 1).

Micromorphological characteristics

Jhalipura soils exhibit mosaic

Table 1. *Selected physical and chemical properties of the soils*

Hori-zon	Depth (cm)	pH (1:2)	Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Fine clay (%)	COLE	HC cm/	BS (%)	$CaCO_3$ (%)
				JHALIPURA SOILS						
Ap	0-12	8.3	9.8	45.2	45.0	25.1	0.19	0.8	98	0.9
Bw1	12-31	8.3	7.8	44.6	47.6	27.9	0.20	1.5	108	5.7
Bw2	31-48	7.7	6.5	41.1	52.4	31.4	0.19	0.7	105	5.4
Bss1	48-74	8.1	9.2	41.6	49.2	31.4	0.21	0.6	110	5.9
Bss2	74-110	8.3	8.5	41.5	50.0	31.2	0.20	1.3	106	7.3
Bss3	110-148	8.1	8.4	40.7	50.9	32.6	0.19	1.4	109	7.1
Bss4	148-165	8.4	7.9	39.7	52.4	29.1	0.20	3.0	112	7.1
				BHATUMBRA SOILS						
Ap	0-12	8.2	3.6	36.3	60.1	25.3	0.28	1.3	98	9.0
Bw	12-37	8.1	5.2	35.8	59.0	27.4	0.24	0.7	98	10.2
Bss1	37-79	7.7	5.6	33.8	60.6	34.6	0.20	0.5	95	10.0
Bss2	79-110	8.00	4.6	25.8	69.6	45.3	0.29	0.6	97	10.8

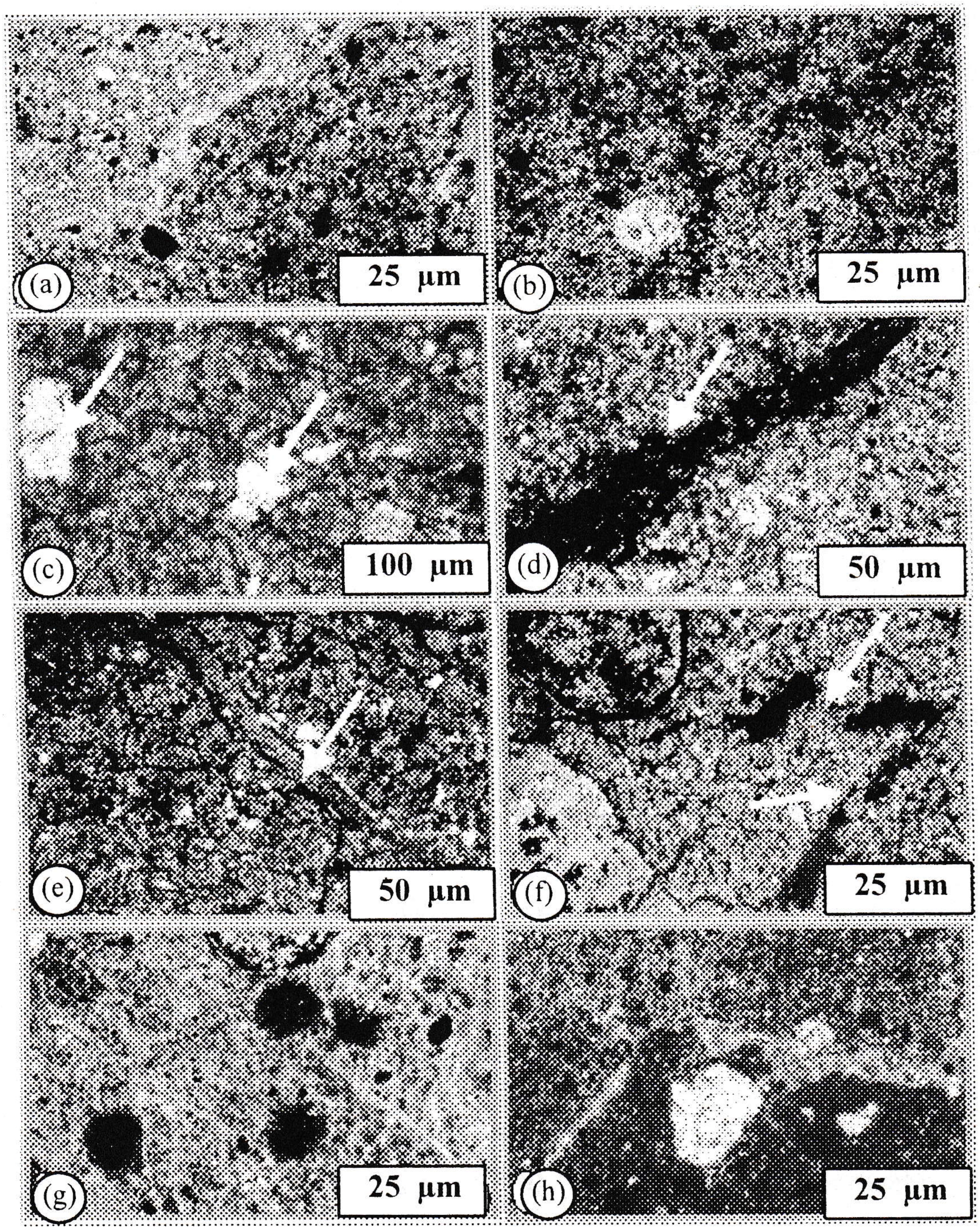

Fig. 1. Representative photomicrographs a) mosaic speckled b-fabric, Jhalipura soils (20-28 cm); (b) undifferentiated b-fabric, Jhalipura soils, (20-28 cm); (c) zeolites in the soil matrix, Jhalipura soils, (160 cm+); (d) planar voids in the matrix, Jhalipura soils; (62-70 cm); (e) stress argillans in the soil matrix, Jhalipura soils, (160 cm+); (f) offset in channel voids, Jhalipura soils, (62-70 cm). (g) poro- and granostriated b-fabric, Bhatumabra soils, (49-57 cm); (h) zig-zag voids in an impure clay matrix, Bhatumbra soils, (19-27 cm). All are under cross polarised light.

speckled (Fig. 1a) and undifferentiated *b*-fabrics (Fig. 1b), and occasionally porostriated fabric. Prominent presence of mosaic speckled *b*-fabric is generally observed in Vertisols of semi-arid dry climate (Pal *et al.*, 2000; 2003). It is generally related to sodicity of soils that causes shrink-swell activity of smectitic clay with a lesser magnitude (Pal *et al.*, 2003). However, Jhalipura soils are nonsodic. Moreover, they exhibit porostriated *b*-fabric indicating moderate shrink–swell activity. This indicates that natural degradation process in terms of formation of pedogenic carbonates (PC) (Pal *et al.*, 2000) is very active in these soils. PC's are abundantly present in the soil matrix. Zeolites are also in ubiquitous amount (Fig.1c). It is clear that typical character of *b*-fabric in Vertisols of semiarid dry climate (Pal *et al.*, 2006) has been modified by the presence of zeolites. Besides, muscovite mica, quartz, few tiny grains of zircons and tourmalines are also identified. Planar voids and stress argillans are common (Fig. 1d & e). Offsetting in channel voids are also commonly observed (Fig. 1f). The Bhatumbra soils exhibit parallel, poro- and granostriated *b*-fabrics (Fig. 1g). Non-clay minerals such as quartz, plagioclase, muscovite, biotite and heavy minerals such as zircon and tourmaline are also present. Pedogenic carbonates are less in these soils than in soils of Jhalipura. Zigzag voids are also common in Bhatumbra soils (Fig. 1h). Despite a high degree of clay activity and shrink-swell process, the plasmic fabrics between Jhalipura and Bhatumbra is not uniform. The plasma separation is more pronounced in Bhatumbra soils than Jhalipura. Similar observation were also made by other researchers (Kalbande *et al.*, 1992; Balpande *et al.*, 1997; Pal *et al.*, 2001; Vaidya and Pal, 2002). According to these authors the shrink-swell magnitude is greater in Bhatumbra soils than Jhalipura.

Discussion

The abundance of PC in Jhalipura soils is attributed to drier pedoenvironment. Hydraulic conductivity of the soils is high (>1 cm/hr) and increases with depth due to the abundant presence of zeolites. Many voids are filled with PC's. Results indicate that the lower MAR causes more PC accumulation. But the adverse effect of PC and concomitant impairment of hydraulic properties mediated through subsoil sodicity is prevented by the release of Ca^{2+} ions from zeolites. This is also reflected in the occasional presence of porostriated *b*-fabric amidst mosaic speckled and undifferentiated *b*-fabrics. Bhatumbra soils exhibit strong plasmic separation. In Bhatumbra soils the presence of less amount of PC and the porostriated *b*-fabric indicate much higher shrink-swell activity due to favourable hydraulic properties. Offset in the channel voids of Jhalipura soils indicates the exertion of greater stress over the matrix. High COLE values are also conducive for the development of greater stress (Sleeman, 1962). Such feature can also be due to stress caused by tectonic activity (Pal *et al.*, 2003). To resolve whether the offsetting of voids is due to stress caused by pedogenic or non-pedogenic process further research is necessary.

Conclusions

The study indicates that the lower MAR causes more PC accumulation. But the adverse effect of PC and concomitant development of subsoil sodicity is prevented by the presence of zeolites in Jhalipura soils. This is reflected in the occasional presence of porostriated plasmic fabric in Jhalipura soils. In Bhatumbra soils the presence of less amount of PC and the porostriated *b*-fabric indicate much higher shrink-swell activity. Offset in the channel voids of Jhalipura soils is possibly due to their high COLE values. However, the role of non–pedogenic processes to cause such stress cannot be totally ruled out.

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