Comparative Micromorphology of Swelling Clay Soils From Boreal and Tropical Regions

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Abstract: *Micromorophological features of swelling clay soils from the Boreal region of Saskatchewan were compared with Vertisols from India. Stress features, such as planar voids and masepic fabric were predominant in all the horizons in the Vertisols, and were higher than in the Boreal clay soils. In the Boreal clays, vughs were more common than planar voids. In semi-arid Boreal clays, masepic fabric was evident from the surface down to the lower solum, whereas in the sub-humid soils it was confined to the lower solum. Shell fragments found in Vertisols suggest a marshy or lacustrine conditions in the early stage of Vertisol development of the pedon sites in India. This seems to be important for understanding the genesis of Vertisols. The overall micromorphological features of the semi-arid Boreal clay soils were more similar to the Vertisols than to the Mollisols in the region.*

Clay soils, which are subject to swelling and shrinking with changes in moisture, occur in many parts of the world (Dudal, 1965). Mermut and St. Arnaud (1983), and Dasog *et al.* (1987) suggested that micromorphological features of clay soils resembling Vertisols are different from the associated medium-textured Chernozemic soils (Mollisols). It was therefore, of interest to compare micromorphological features of Boreal clay soils with those of Vertisols in the tropics to understand the soil forming processes in the Boreal clay soils.

MATERIALS AND METHODS

Four clay soils (Sceptre, Regina, Melfort and Tisdale) from Saskatchewan and two Vertisols (Sultanpur and Panjri) from India were studied. Saskatchewan soils are formed on glaciolacustrine parent materials, whereas the Vertisols formed on allvium derived from mafic rocks. They have high clay content (50 %) and are neutral to slightly alkaline with some carbonates. The smectite contents, are higher in Vertisols than in Saskatchewan clay soils. The morphological, physical and chemical

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TABLE 1. Soil-site characteristics

Soil	Soil Zone	Climatic Class	Soil Temperature Class
Sceptre	Brown	Sub-arid	Frigid
Regina	Dark Brown	Semi-arid	Cryic
Melfort	Black	Subhumid	Cryic
Tisdale	Dark-Gray	Subhumid	Cryic
Sultanpur		Semi-arid	Isohyperthermic
Panjri		Subhumid	Hyperthermic

properties of the Vertisols used in this study are described by Mermut and Dasog (1986) and those of Saskatchewan clay soils by Dasog *et al.* (1987). Environmental characteristics of the sites are presented in table 1.

Undisturbed samples were impregnated with Vestopal-150 as described by Jongerius and Heinzberger (1975). Terminology used for the description is according to Brewer (1976). Quantative estimation of different micromorphological features was done by counting 1000 points per thin section on an area of approximately 5 x 7 cm at a magnification of 125 times. Voids were differentiated into planar voids, vughs and channels. Less than 1 per cent channels are included in vughs. Voids which were considered artifacts were avoided. The vosepic and skelsepic plasmic fabrics are expressed as skeleton grains and total voids per cent, respectively (Blokhuis *et al,* 1970).

RESULTS AND DISCUSSION

Voids

Total voids for all the soils, are low; (characteristic of swelling soils). The percentage of voids in the surface horizons of the Vertisols (Fig. 1) is slightly higher than the Boreal soils, except for the Sceptre soil, which is even higher than Vertisols. This is related to extreme wetting and drying in the Vertisols. Planar voids are predominant in the Vertisols, whereas vughs are the major void types in Boreal soils. Formation of planar voids is a part of the cracking system and is attributed to successive wetting and drying. Fewer planar voids in Boreal clay soils is due to less severe drying.

Skeleton grains

The skeleton grains in the Boreal soils are few and considerably smaller than those observed in the Vertisols. The average size of the skeleton grain in the Boreal clay soils ranges from 40-100 um,

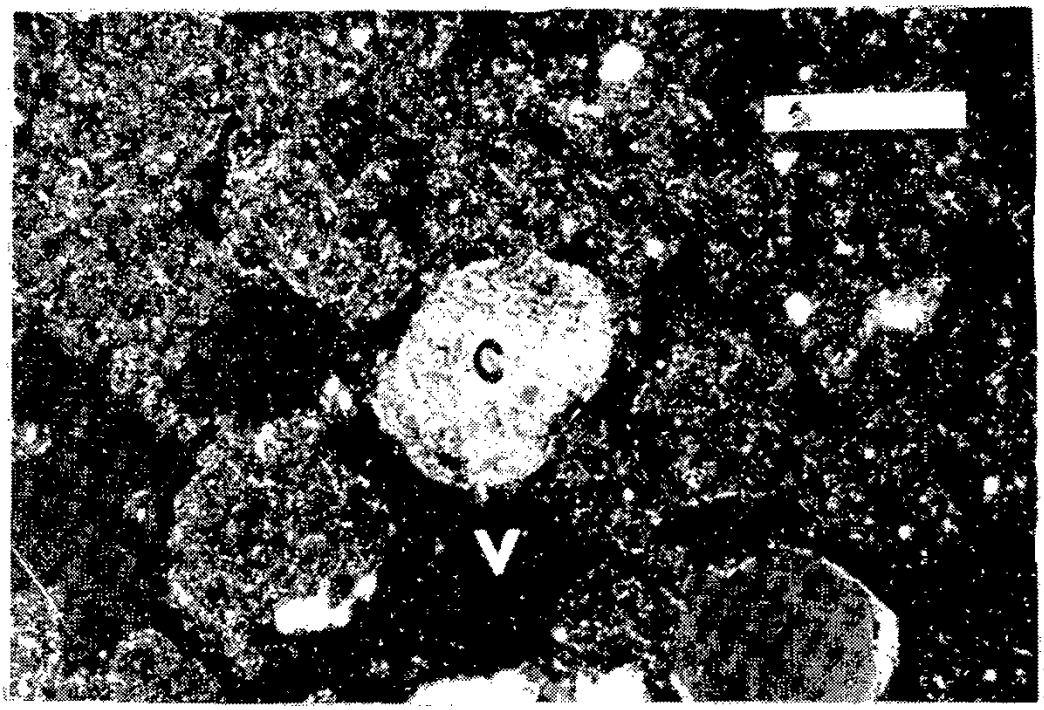

Figure 1. Granular structure in Ap horizon (0-11 cm) of Panjri soil (V = Voids; C = Carbonates)

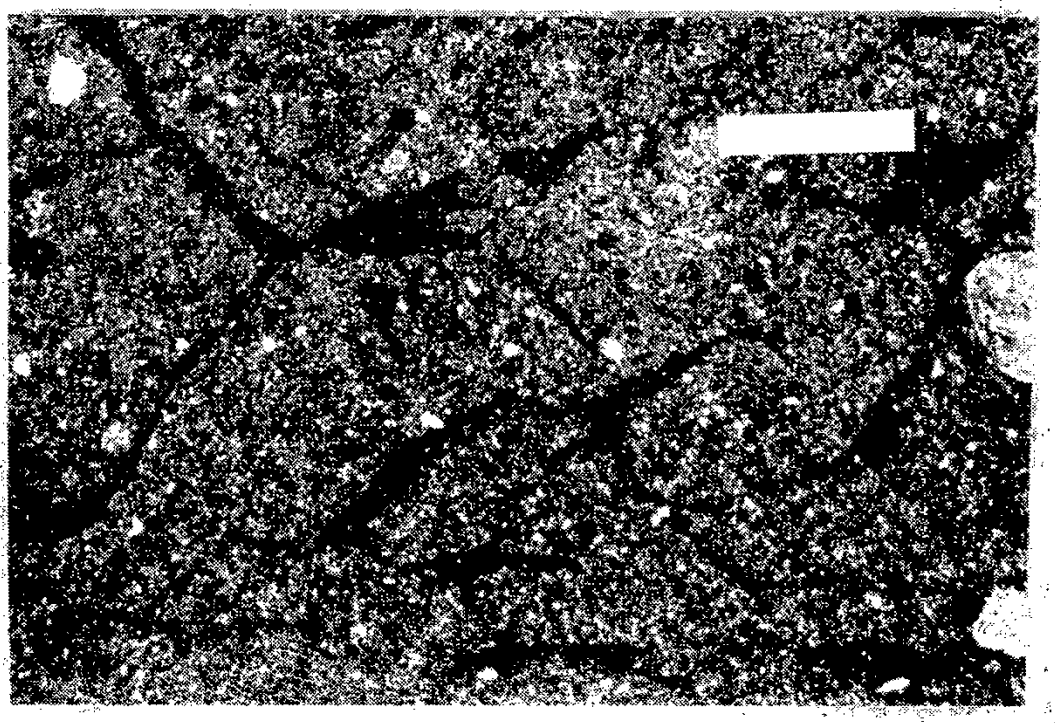

Figure 2. Planar voids in A12 horizon (40-75 cm) of Panjri soil (white bar is 250 μm long)

TABLE 2. Quantitative estimate of voids, skeleton grain and plasmic fabrics in selected horizon

Horizon	Depth (cm)	Skeleton grains	Total Voids	Planar Voids	Vughs	Plasma	Skelsepic (%) skeleton 0-10	Skelsepic (%) grain 10	Vosepic(%) total voids 0-10	Vosepic(%) voids 10	Masepic(%) plasma	Nodules Ferro-manganese	Nodules Carbonate
							μm						
SCEPTRE													
Apk	0-10	16	15	1	14	69	62	13	0	0	8	1	0
Bmk	35-60	11	10	5	6	79	63	8	20	0	15	1	0
REGINA													
Apk	0-20	5	7	2	5	88	70	2	13	0	7	1	0
Bmk1	20-40	3	9	5	4	88	85	4	41	0	10	1	0
Bmk2	40-62	3	10	3	7	87	61	1	27	0	10	1	0
MELFORT													
Ap	0-17	17	7	0	7	76	27	1	0	0	0	2	0
Ahe	--	29	10	2	9	60	3	0	13	0	0	3	0
Bntl	20-38	8	11	5	6	81	62	15	83	15	10	1	0
TISDALE													
BA	10-35	9	7	3	4	84	28	4	46	1	4	3	0
Btj	35-80	9	11	4	7	80	62	24	30	20	15	1	0
SULTANPUR													
Ap1	0-10	14	12	5	7	69	80	4	49	0	7	1	3
Ap2	10-17	12	13	8	5	65	73	7	50	0	17	1	4
A1	17-40	11	9	4	5	69	73	7	51	3	17	2	3
AC	40-79	13	10	6	4	72	72	10	61	2	22	2	3
C	79-135	8	9	6	3	73	67	26	72	3	18	2	5
PANJRI													
Ap	0-11	8	11	7	4	71	56	2	49	0	9	2	1
A11	11-40	10	8	4	4	79	71	0	58	0	15	3	1
A12	40-75	9	12	10	2	74	65	2	58	0	19	4	1
A13	75-100	8	8	5	3	82	80	5	68	3	16	3	0
AC	100-154	6	8	7	1	79	72	6	71	10	16	1	4
C	154+	7	4	3	1	84	80	9	68	5	19	2	1

whereas in tropical Vertisols, it is upto 500 um. There is a slight concentration of skeleton grains in the surface horizons of all the soils. In the Boreal clay soils it is attributed to sedimentation pattern rather than the uplift mechanism suggested by Yaalon and Kalmar (1978). Nearly a third of the skeleton grains in the Ap horizon of the Melfort soils consists of organic fragments.

Plasmic Fabrics

All the soils are characterized by higher content of plasma (Table 2). Unistrial fabric is the only sepic fabric observed in the C horizons (Fig. 2) of the Boreal soils, which suggests the preservation of the original rock structure in this zone. Considerable amount of unistrial fabric is observed in the transitional zones between the solum

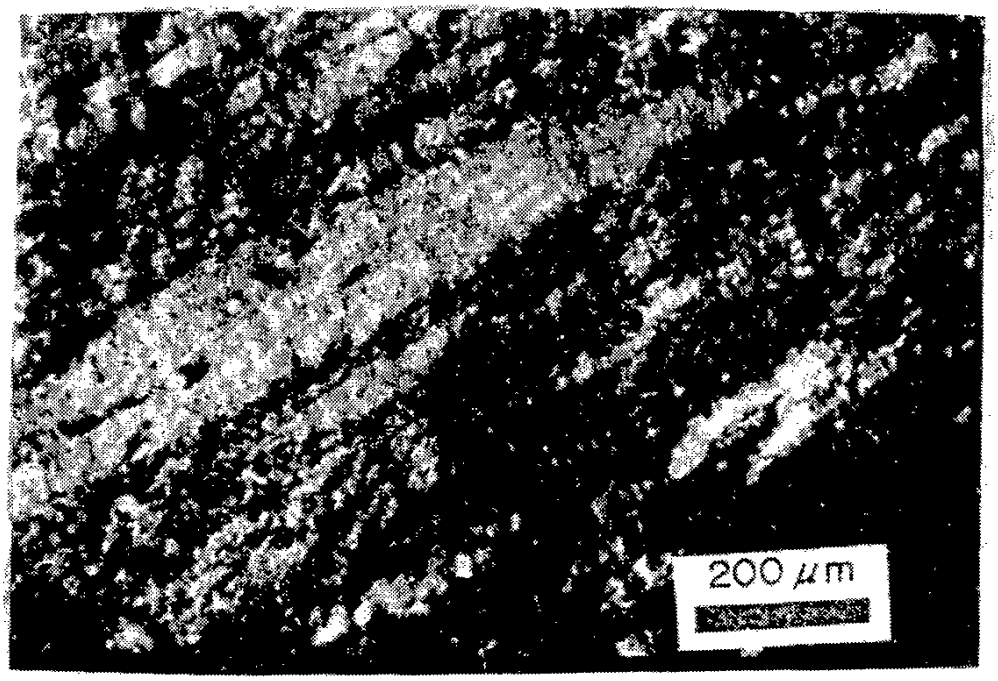

Figure 3. Soil fabric in physically altered transitional horizon (100-115 Cm.) sceptre soil; white particles are gypsum; black areas indicate the accumulation of Fe and Mn

and the parent material in all the Boreal soils (Fig. 3). Unistrial fabric is not found in the Vertisols because the parent materials are presumably formed from fluvial/colluvial processes.

The plasma separation around the voids (vosepic) was evident in the Melfort and Tisdale soils in contrast to the Sceptre and Regina soils. This is in agreement with the observation by Blokhuis *et al.* (1970) that soils in higher rainfall areas have more vosepic plasmic than those in lower rainfall regions. Skelsepic fabric was not conspicuous in all the soils as judged by the thickness of plasma separation around skeleton grains. As noted by Blokhuis *et al.* (1970), the skelsepic fabric is related not only to the degree of stress but also to the size of the skeleton grains.

There is a little difference in the proportion of masepic plasmic fabric in the lower solum, where slickensides are present, in Boreal clay soils, but it is significantly lower than that in the Vertisols (Table 2). However, the differences are more clear when the portion of soil profile with masepic fabric is considered. Masepic fabric is present in all the horizons in the Vertisols, from the surface down to a metre in the Sceptre and Regina soils and between 35 and 100 cm in the Melfort and Tisdale soils. The plasma in the Melfort and Tisdale soils was characteristically stained with organic matter in the Ap horizons, and the upper solum has no masepic fabric (Fig. 4) except in the BA horizon of the Tisdale soil which had a lattisepic fabric grading to masepic.

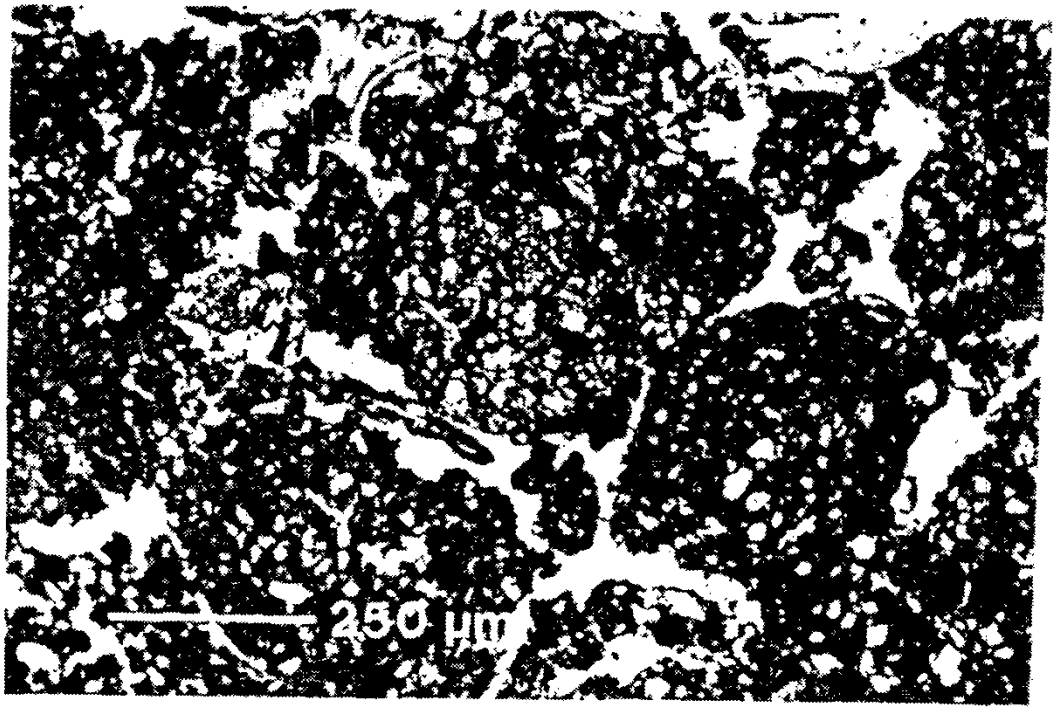

Figure 4. Asepic fabric in the AP horizon of Tisdale soil

Masepic fabrics denote microscale shearing due to unequal stresses acting on peds. The presence of masepic plasmic fabric in the horizons not accompanied by slickensides (Apk and Bmkl in Regina and Apk in Sceptre, and the horizons in the upper solum of the Sultanpur and Panjri) has at least two explanations. We postulate that masepic plasmic fabrics form near the surface and may not require the high overburden pressure, or, secondly, they form in horizons where slickensides occur but are transported to the surface by churning or upthrust processes.

Special Features

Ferriargillans are present in the Bntl horizon of the Melfort and the BA of the Tisdale soils. Argillans are rare in Vertisols; where clay soils crack, they had a coarser surface texture and were not self-mulching (Nettleton & Sleeman, 1985). Presence of Argillans in subhumid Boreal soils suggest that they have not undergone the degree of pedoturbation characteristic of Vertisols.

Soil nodules were evident in Boreal clay soils. These are reported in many Australian soils other than cracking clay soils (Stace *at al.* 1968). Such features in southern Saskatchewan have been attributed to churning (Mermut & St. Arnaud, 1983). Their abundance in the surface horizons of the Melfort and Tisdale soils suggests faunal activity and/or floral pedoturbation rather than churning. These features resemble the pedorelicts (Pawluk & Bal, 1985). Soil

nodules were not conspicuous in the Vertisols. Nevertheless, the high quantity of granular aggregates in the lower part suggests the activity of churning process in these soils. Carbonate nodules, which are one of the striking features of the Vertisols (Fig. 1), were absent in the Boreal soils.

Considerable amounts of shell fragments were found in the Vertisols. This indicates likely wetness, and possibly a marshy or shallow lacustrine condition prior to the formation of the Vertisols in India. This seems to be very important for the understanding of the genesis of the Vertisols.

Ferro-manganese nodules are concentrated in the Ahe and Ap in Melfort and Tisdale soils. Presence of these nodules signify a condition of periodic wetness in the upper solum due to impermeable Bnt and Btj horizons. Neosequans are common in the parent materials of the Boreal soils. They may be inherited or formed *in situ*.

CONCLUSIONS

The degree of expression of stress features reflected the severity of drying in the soils studied. Plasmic fabrics of the Sceptre and Regina soils more closely resembled the Vertisols. In the Melfort and Tisdale soils, masking of plasma by organic matter, presence of organic skeleton grains, and evidence of higher biological activity at the surface, and microshearing in the lower solum present the effects of processes known to operate in Chernozemic soils and Vertisols. Although classification based solely on micromorphological considerations is incomplete, a predominantly masepic fabric in the upper one meter may serve to distinguish Vertisols from other clay soils.

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