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APPLICATION OF SCANNING ELECTRON MICROSCOPY AND MICROANALYSIS (SEM) IN THE STUDY OF CERTAIN PROCESSES IN MOLLIC GLEYSOLS

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A b s t r a c t. The object of the study were soils representing three profiles of Mollic Gleysols. In the genetic horizons of the soils under study, the granulometric composition, pH, $CaCO_3$, C_t, N_t, and the total content of Si, Fe, Ti, Ca, Mg, K and Na were determined. The study was conducted using a scanning microscope with microanalyser (SEM-EDXRA) on samples of undisturbed structure. It permitted more precise determination of the spatial distribution of certain components in the soils and showed the differentiation of their forms under the effect of the processes taking place in the soils, and especially redox processes.

K e y w o r d s: Mollic Gleysols, SEM, microanalysis

INTRODUCTION

Soils classified among the Mollic Gleysols are developed under the conditions of elevated ground water table, which frequently determines their periodical excessive moisture content [5]. This has a significant effect not only on the cumulation of organic matter and its transformation, but also determines the transformation of the mineral components in the particular genetic horizons [4]. These processes are considerably affected by changes in the ground water table which determine the redox processes [3,5]. Gleying processes, causing changes in the forms of certain soil components, e.g. Fe and Mn, can also facilitate their solubility and translocation within the profile. Changes in the soil mass, occurring under such conditions, can be determined by means of chemical methods, but their application not always permits accurate interpretation of micro-processes occurring within a single genetic horizon. Explanation of these phenomena requires the application of methods which, permitting soils to be studied under their natural condition, at the same time allow the acquisition of knowledge on the spatial distribution of the content of the major components of the soil material [1-3].

The objective of the study was to utilize electron scanning microscopy and microanalysis (SEM-EDXRA) for the investigation of the qualitative and quantitative differentiation of soil mass components in certain microprocesses occurring in the genetic horizons of Mollic Gleysols.

MATERIAL AND METHODS

The object of the study were three Mollic Gleysols profiles located in the Lower Silesia. Samples were taken from the genetic horizons of the soils studied, in which the following were determined: granulometric composition, pH_{KCl}, $CaCO_3$ according to Kjeldahl, the content of total forms of Si, Al, Fe, Ti, Ca, Mg, K and Na. Samples of natural structure were used to prepare single-side polished sections for observation under optical microscope. These observations were performed in order to determine zones of differentiated microprocesses which were then subjected to study using a scanning microscope with microanalyser (SEM-EDXRA) at the Environmental Laboratory of Electron Microscopy in Wrocław.

RESULTS AND DISCUSSION

The profiles under analysis represent the basic kinds of Mollic Gleysols occurring in the area of the Lower Silesia. They are complete soils or multi-element soils developed from clays (profiles 1 and 2) and from medium silty loams (profile 3), (Table 1). They are characterized by neutral reaction (profiles 1 and 2) or slightly acid reaction (profile 3). Variation in the reaction of the particular genetic horizons depends on the content of $CaCO_3$. The content of that component generally increases in the lower horizons of the soils studied (Table 1). The presence of Ca in the form of a carbonate or its high proportion in the sorptive complex of the soils are conducive towards the process of humifcation and the cumulation in the soils of relatively large amounts of C_t total [3].

The total content of N_t is very closely related to the content of organic matter and displays similar profile relations to those of total C_t (Table 1).

Differentiation in these chemical properties is the result of the effect of the parent rock and other factors on the soil formation process. Results presented in Table 2 seem to indicate that they determine the chemical composition of the soil mass in the particular genetic horizons. A characteristic feature of the Mollic Gleysols in the Lower Silesia region is the very strong differentiation in the total content of Al, Fe, and Ca in the genetic horizons (Table 2). Especially large quantities of Al (14-17 %) and Fe (5-8 %) were observed in profile 1, developed from clay. The soils studied differ also in their content of Ca whose amounts in the genetic horizons studied are mainly related to the presence of $CaCO_3$. This is confirmed by the high content of Ca in profile 2 (2.43-19.09 %) characterized by the highest quantity of $CaCO_3$.

The studies carried out indicate not only the qualitative and quantitative differentiation in the content of the major components in the genetic horizons, but show also certain differences between the soils under study.

Profile 3 is representative of a Mollic Gleysol soil which does not contain $CaCO_3$ in the surface horizon. The composition of the soil mass in this horizon is more homogeneous when compared to deeper horizons (Fig. 1). In the AC horizon (Fig. 2) the composition of the soil mass is more varied, and apart from components occurring in the A1 horizon it contains also concentrations of strongly dispersed silica (Fig. 3).

The low content of $CaCO_3$ in the A1 horizon of profile 1 occurs in strongly diffused forms, which is confirmed by microanalyses. The strongly diffused soil phase in this horizon is composed mainly of aluminosilicates containing Al, Si, K, Ca, and a slight amount of Fe (Fig. 4).

In the CG horizon of this profile the components mentioned above occur also (Fig. 5a and 5b), as well as diffused tarnishes characterized by differentiated chemical composition (Fig. 5c). Some of the tarnishes contain Al, Si, and a considerable amount of K, which indicates that they are potassium aluminosilicates. Other tarnishes contain only Si, which shows their silica origins (Fig. 6a and 6b).

In profile 2, with large amounts of $CaCO_3$ in all the horizons, the main components of the soil mass are Si and Ca (Fig. 7a and 7b) which are uniformly distributed in the A1 horizon. In the deeper horizons, which retain their natural structure, greater differentiation can be observed in the soil mass, due to the effect of soil formation processes. This is confirmed by the image of strongly dispersed soil plasma in the AC horizon, and by the microanalyses performed in various its fragments (Fig. 8a-8f). As compared to the surface distribution of

Table 1. Texture and some chemical properties of investigated soils

Profile No	Genetic horizon	Sampling depth (cm)	Percentage of fractions (mm) >1	1 - 0.02	0.2-0.06	0.06-0.002	<0.002	pH in KCl	$CaCO_3$ (%)	C_t (%)	N_t (%)	C_t:N_t
1	Ap	5 - 15	0	26	17	9	48	7.0	0.62	2.23	0.220	10.1
	Aa	27 - 37	0	22	15	10	53	6.9	0.49	2.09	0.160	13.2
	AC	45 - 55	1.5	20	17	10	53	6.8	0.41	0.94	0.070	13.4
	CG	70 - 80	0	15	9	2	74	7.0	2.31	n.d.*	n.d.	n.d.
	CG_{Ca}	130 - 140	0	9	16	0	75	6.8	8.07	n.d.	n.d.	n.d.
2	Ap_{Ca}	4 - 14	0.9	37	22	15	26	7.1	31.44	2.23	0.210	10.6
	Aa_{Ca}	30 - 40	1.1	37	24	14	25	6.9	32.79	2.00	0.190	10.5
	AC_{Ca}	48 - 54	0.1	35	25	15	25	7.2	32.00	0.62	0.060	10.3
	C_{Ca}	75 - 80	0.1	43	30	12	15	7.2	12.25	n.d.	n.d.	n.d.
	II CG_{Ca}	145 - 150	0	9	6	3	82	7.0	3.25	n.d.	n.d.	n.d.
3	Ap	5 - 15	0.2	54	21	9	16	5.9		2.17	0.200	10.8
	Aa	30 - 37	0.5	53	22	9	16	5.8		1.95	0.180	10.8
	AC	45 - 53	0.3	53	21	8	18	6.1		1.23	0.110	11.2
	CG	65 - 75	1.8	64	11	6	19	6.1		n.d.	n.d.	n.d.
	II CG_{Ca}	115 - 125	5.2	61	13	6	20	6.4	3.08	n.d.	n.d.	n.d.

* not determined.

Table 2. Chemical composition of investigated soils

Profile No.	Genetic horizon	Sampling depth (cm)	Elemental analysis of fine particles (%)										
			Ignition loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5
1	Ap	5 - 15	14.64	61.26	14.08	4.88	1.82	0.63	1.69	0.48	0.64	0.081	0.121
	Aa	27 - 37	14.46	61.47	14.46	5.28	1.75	0.45	1.66	0.40	0.66	0.042	0.095
	AC	45 - 55	15.92	58.23	14.37	6.24	1.47	0.86	1.85	0.40	0.68	0.042	0.063
	CG	70 - 80	15.83	55.77	15.59	8.08	1.75	0.96	1.82	0.16	0.73	0.087	0.095
	CG_{Ca}	130 - 140	12.59	50.75	17.18	8.00	6.17	0.01	2.56	0.14	0.68	0.126	0.065
2	Ap_{Ca}	4 - 14	22.95	46.52	6.75	2.48	18.37	0.68	1.42	0.53	0.42	0.096	0.201
	Aa_{Ca}	30 - 40	22.96	45.67	6.92	2.64	19.09	0.98	1.20	0.48	0.42	0.081	0.182
	AC_{Ca}	48 - 54	19.61	49.03	7.27	2.00	18.92	0.91	1.42	0.61	0.38	0.087	0.096
	C_{Ca}	75 - 80	10.75	64.04	9.08	2.64	9.19	1.51	1.79	0.82	0.46	0.042	0.092
	II CG_{Ca}	145 - 150	13.37	57.07	19.17	6.88	2.45	0.96	2.43	0.14	0.64	0.042	0.088
3	Ap	5 - 15	8.85	76.48	8.79	2.32	1.02	0.23	1.66	0.63	0.50	0.055	0.138
	Aa	30 - 37	8.15	76.56	8.89	2.64	0.95	0.30	1.82	0.70	0.54	0.055	0.095
	AC	45 - 53	6.89	77.47	9.34	2.56	0.91	0.30	1.82	0.65	0.50	0.055	0.071
	CG	65 - 75	4.66	80.58	9.02	3.20	0.59	0.23	1.35	0.40	0.040	0.034	0.053
	II CG_{Ca}	115 - 125	5.65	80.10	8.53	2.08	2.04	0.25	1.23	0.40	0.035	0.034	0.060

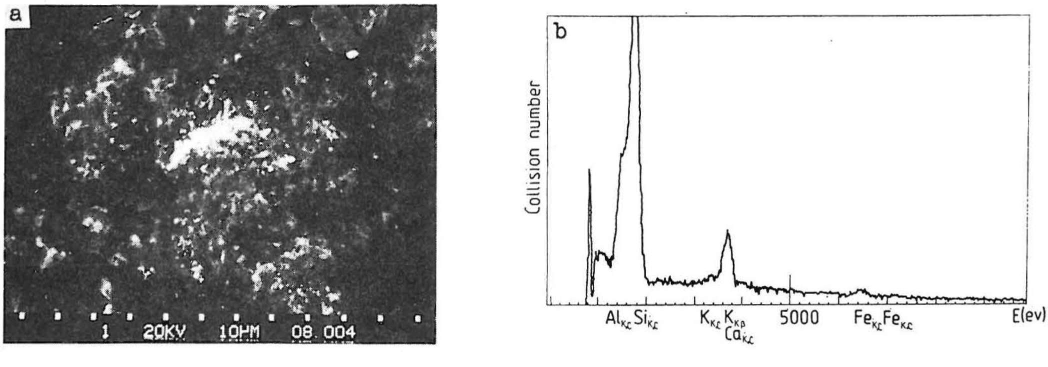

Fig. 1. SEM-EDXRA image, profile 3, horizon A1: a - fragment of soil material; b - microanalysis of the surface.

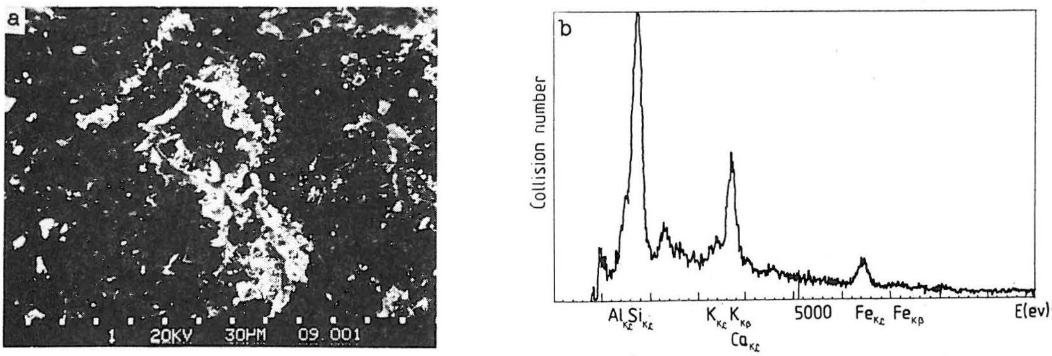

Fig. 2. SEM-EDXRA image, profile 3, horizon AC: a - fragment of soil material; b - microanalysis of the surface.

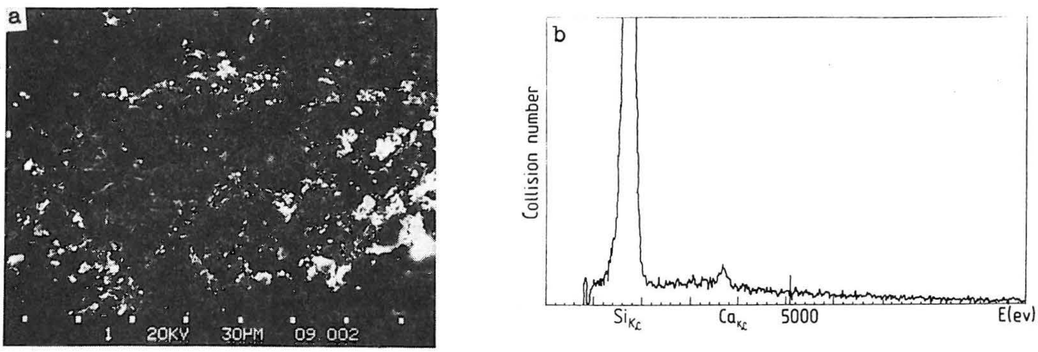

Fig. 3. SEM-EDXRA image, profile 3, horizon AC: a - accumulation of strongly dispersed SiO_2; b - microanalysis of the surface.

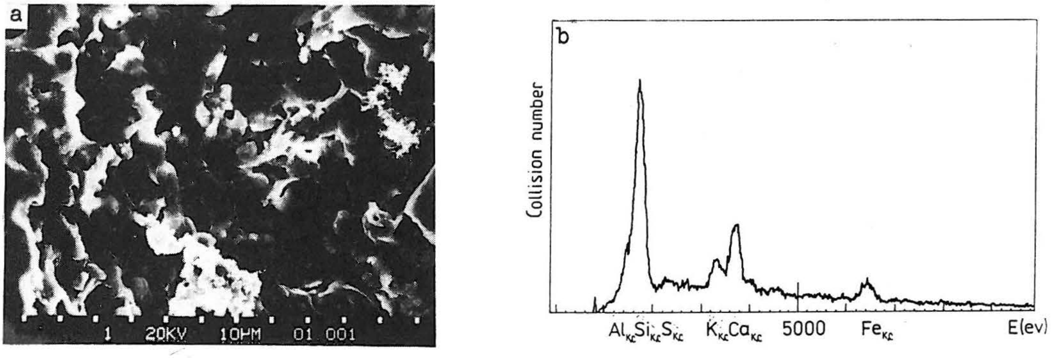

Fig. 4. SEM-EDXRA image, profile 1, horizon A: a - fragment of soil material; b - microanalysis of the surface.

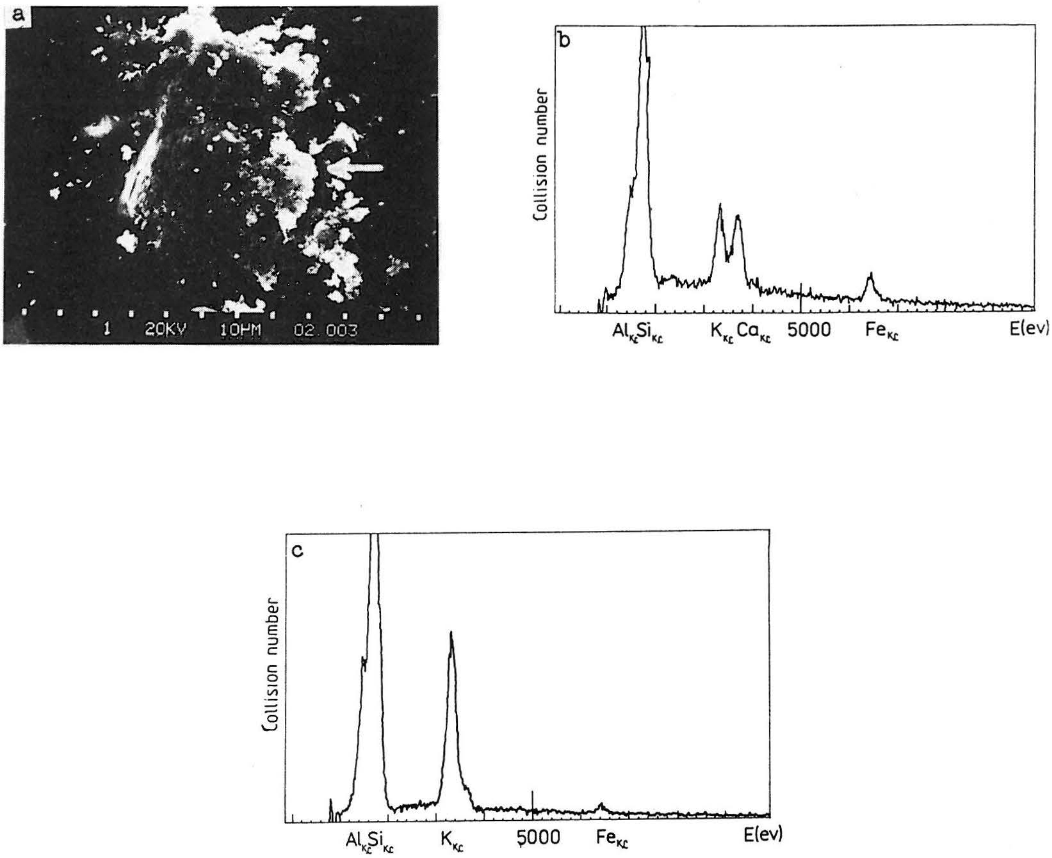

Fig. 5. SEM-EDXRA image, profile 1, horizon CG: a - fragment of soil material; b - microanalysis of the surface; c - microanalysis of the fragment indicated by pointer.

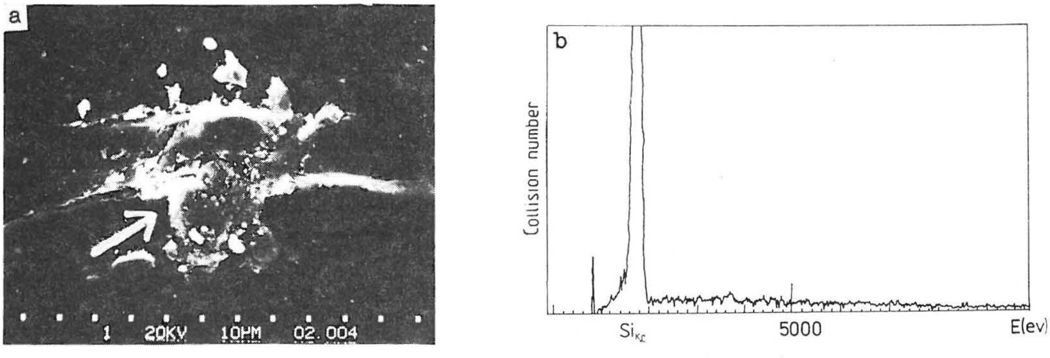

Fig. 6. SEM-EDXRA image, profile 1, horizon CG: a -cumulation of SiO_2; fragment of soil material; b - microanalysis of the fragment indicated by pointer.

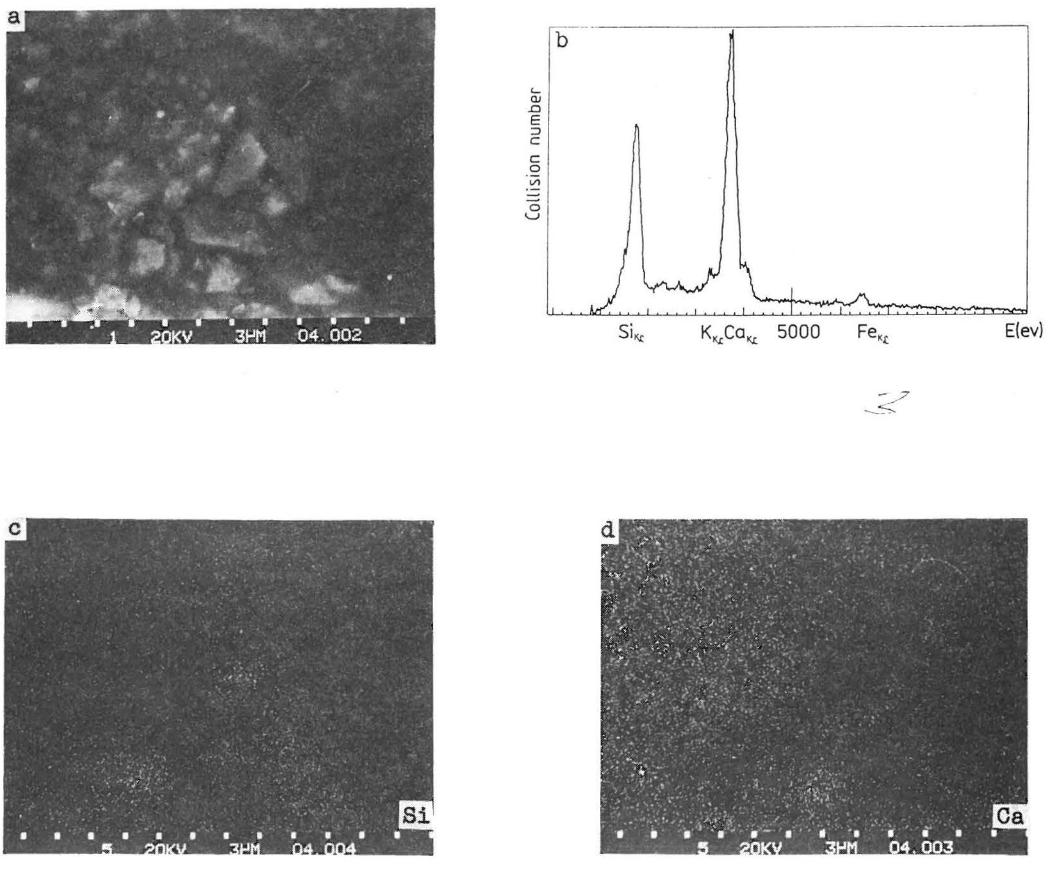

Fig. 7. SEM-EDXRA image, profile 2, horizon A1: a - fragment of soil material; b - microanalysis of the surface; c - distribution of Si; d - distribution of Ca.

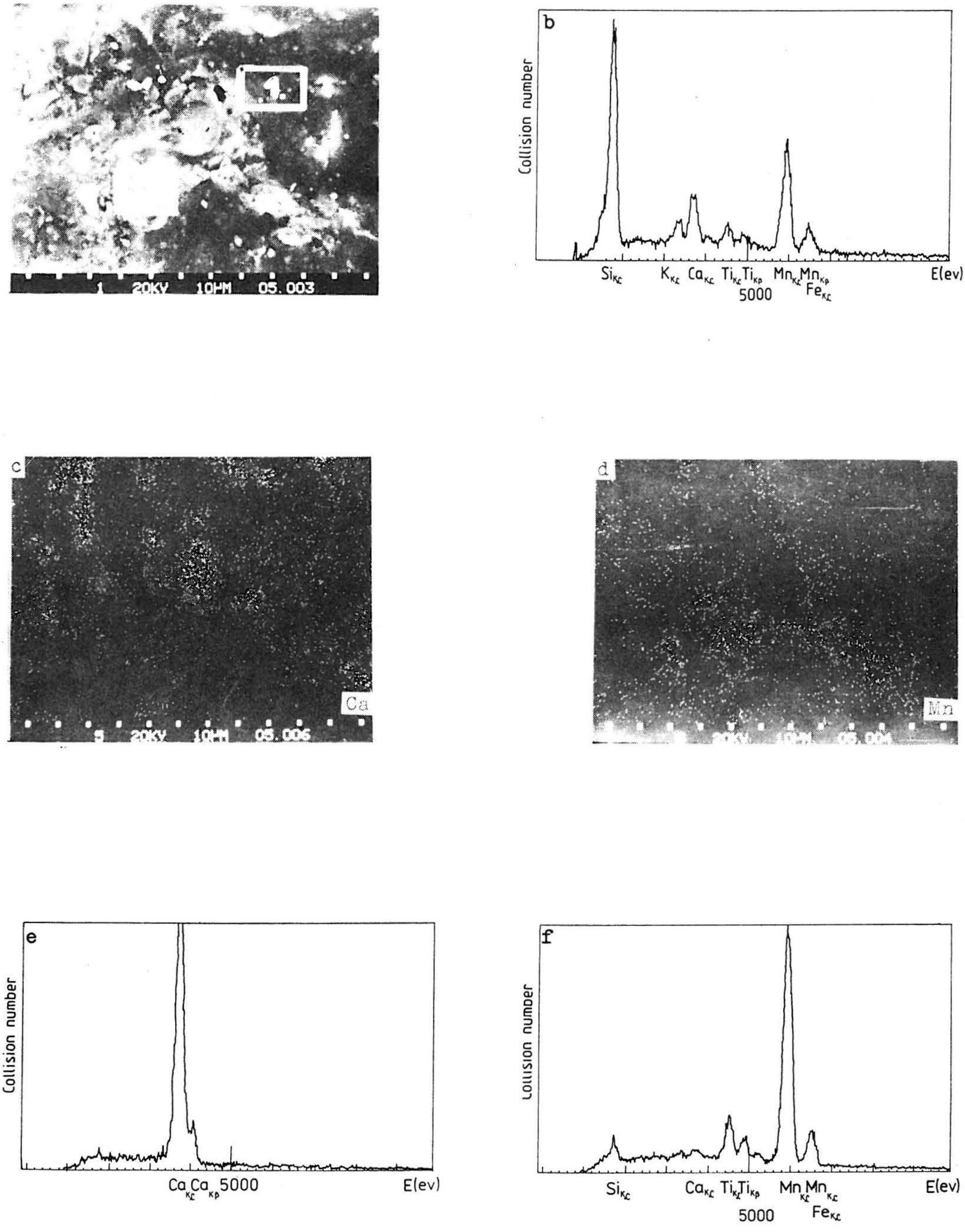

Fig. 8. SEM-EDXRA image, profile 2, horizon. AC: a - fragment of soil material; b - microanalysis of the surface; c - distribution of Ca; d - distribution of Mn; e - microanalysis in frame 1; f - microanalysis in frame 2.

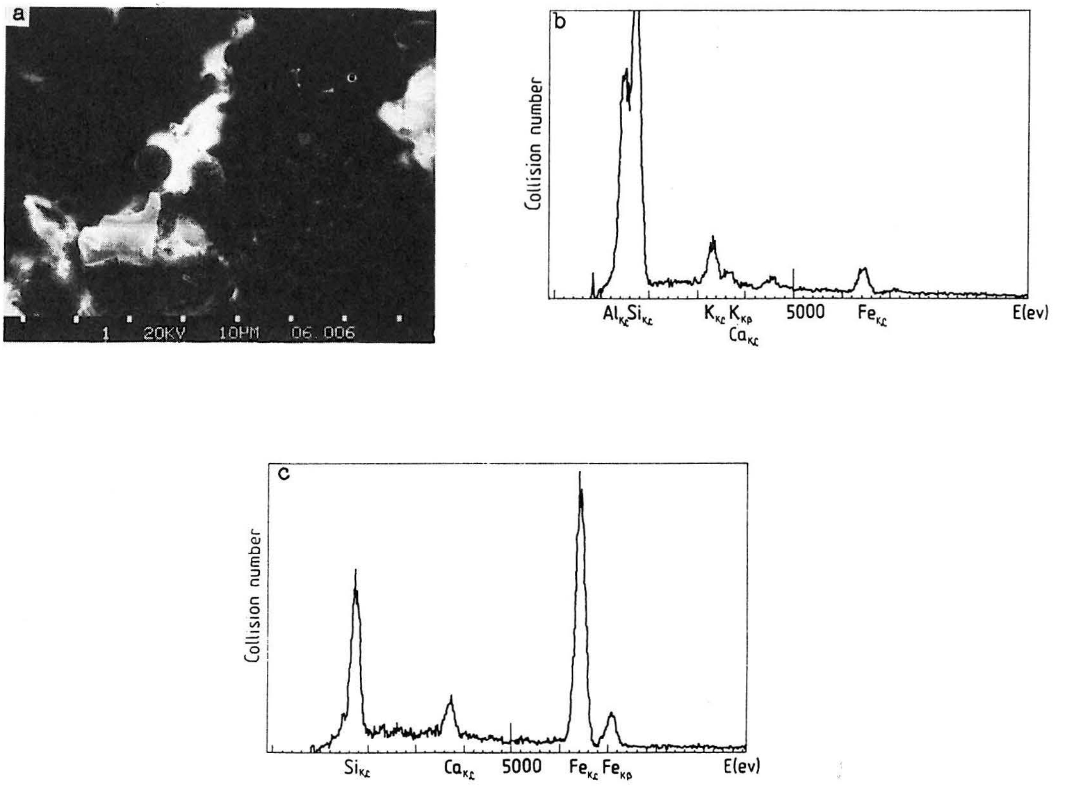

Fig. 9. SEM-EDXRA image, profile 2, horizon CG: a - fragment of soil material with visible globular forms; b - microanalysis of right globule; c - microanalysis of light globule.

Si, Ca, and Mn, they indicate an irregular distribution of Al, Si, Ca, Mn, and Fe in that horizon. With a high content of $CaCO_3$, the distribution of Ca in the horizon is non-uniform (Fig. 8a). The occurrence of large amounts of Mn in certain fragments of the sample indicates that it forms Fe-Mn or Mn concretions (Fig. 8f). Cumulation of those components is probably the result of microprocesses occurring in those areas of the soil mass. Another effect of those processes can be the occurrence of morphologically similar forms of spherical intrusions in the CG horizon (Fig. 9) which are characterized by a different chemical composition.

In the lower horizons of all the three profiles under study an effect of excessive moisture can be observed, manifested in the occurrence of bluish-greenish colouration of the gleyed horizons - Cg or II CG. Micromorphological studies and macroscopic observations showed soil mass differentiation in those horizons, caused by reduction processes. Apart from zones affected by reduction, in the CG horizons there are also localized areas of brownish colouration, which indicates the occurrence of microprocesses of oxidative character. Observations carried out in both differentiated zones indicate changes in the qualitative composition between the reduction and oxidation zones (Fig. 10a-10d). Analysis of the former indicates an increased presence of Al and Si, and a lower content of Fe (Fig. 10b). In areas with predominance of oxidative processes, a considerably greater number of counts in the range characteristic

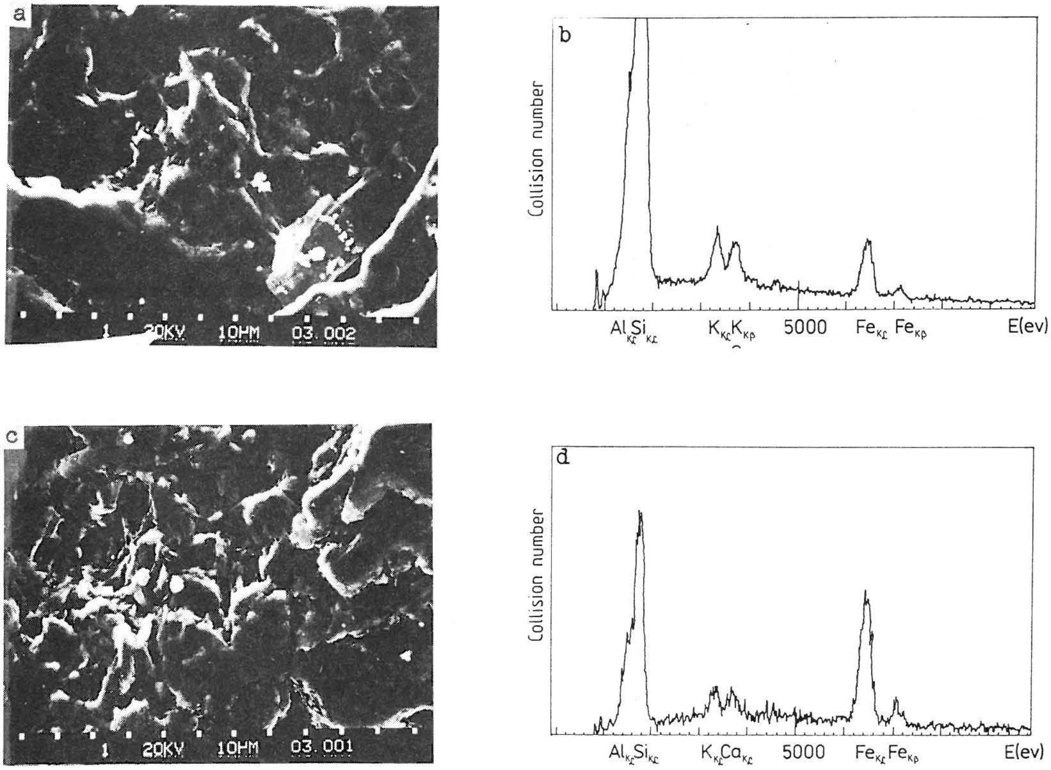

Fig. 10. SEM-EDXRA image, profile 2, horizon CG: a - fragment of reduction zone; b - microanalysis of the surface; c - fragment of oxidized zone; d - microanalysis of the surface.

of Fe is observed among the components of the soil mass. This indicates a significant effect of the reduction processes on the quantitative presence of some components of the soil mass.

CONCLUSIONS

1. The results presented above confirm the great applicability of scanning electron microscopy and microanalysis in the study of the effects of microprocesses occurring in the adjacent zones of genetic horizons of Mollic Gleysols.

2. The reduction processes occurring in the lower horizons of Mollic Gleysols have a differentiating effect on the soil mass and can be the cause of a decrease in Fe content in the reduction zones.

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