ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1995, z. 419, 75-81

PRELIMINARY STUDIES ON EFFECTS OF FREEZING AND THAWING ON THE STRUCTURE OF A SURFACE HORIZON OF GREY-BROWN PODZOLIC SOIL

A. I. Mikosz

Institute of Soil and Environment Management, University of Agriculture, Kr. Leszczyńskiego 7, 20-069 Lublin

A b s t r a c t. Morphological analyses of thin cross-sections showed that the cyclic processes of freezing and thawing affected the structure of a surface horizon of grey-brown podzolic soil (Orthic Luvisol) derived from silt. It was also noticed that an unwedging pressure of ice resulted in the formation of horizontal fissures and microfissures at the contact points of freezing and non-freezing zones. At the same time as thawing, rendering of a clay fraction and its accumulation took place, which resulted in the emergence of numerous horizontal, clayey and silty streaks.

K e y w o r d s: soil structure, freezing, thawing

INTRODUCTION

In winter, the structure of the soil surface horizons is shaped mostly by the freezing and thawing processes. In the course of a freezing process, ice crystals are formed in soil pores filled with water. The unwedging pressure, between the walls of micro-pores and ice crystals and between particles of clay minerals, results in larger pores, in increased swelling and shrinking and in occurrence of fissures and deformations [1,3,4,6]. Thawing is followed by easing of the tension; the fissures gradually diminish.

These phenomena contributed to granulometric and chemical differentiation of the profile of loessial soil back in the late Vistulian, and their effects have been preserved to the present times [2].

Processes, like the ones mentioned above, are particularly intense in soils of heavy granulometric composition and in the conditions of full saturation of soil with water [3].

During freezing of the soil, the water turns into a solid state, increasing its volume. This results, simultaneously, in the increased volumes of the particular soil horizons undergoing freezing. Because of the pressure of ice, the horizons are lifted up. During the thawing, a contrary process takes place, which results in the soil settlement in the surface and deep horizons. Vertical movements of soil occur in the horizon to the 30 cm; they occur sporadically in the deeper horizons [5].

The aim of the current paper is to determine effects of cyclic processes of freezing and thawing on the structure of an arable layer of grey-brown podzolic soil (Orthic Luvisol) derived from silt, when the actual moisture was similar to the field water capacity.

MATERIALS AND METHODS

The studies were carried out in Felin in the Lublin Uplands, on non-uniform, lying on limestone, grey-brown podzolic soil (Orthic Luvisol) derived from silt. At the time when samples were collected (the end of the second decade of December, 1990), winter rape was cultivated in the soil frozen about 3-4 cm deep. During the first two decades of December (preceding the collecting of samples), the average air temperatures altered, and the temperatures below 0 °C dominated. In these decades, the amount of precipitations, mostly rainfalls, was 19.6 mm. Because of the lack of snow cover, it resulted in frequent freezing and thawing of the soil.

For the morphological analysis of the soil structure, two samples were collected from a vertical plane of the soil surface horizon (0-8 cm). They were placed in metal containers, size: 9x8x4 cm. At the same time, in order to determine some physical properties, undisturbed soil cores were collected from a 0-5 cm horizon into metal cylinders of 100 cm^3 volume. The samples in the containers thawed, and they were dried in the temperature of 20 °C. Then they were saturated with a solution of resin Polimal-109. After polymerization of resin, the hardened blocks of soil were cut into slices about 1 cm thick, which underwent grinding and polishing. The obtained thin cross-sections were photographed in reflected light in the scale of 1:1. In the photograms, a solid phase of the soil is white, and pores filled with resin are black (Figs 1a and 2a).

Surfaces of the thin cross-sections were analyzed with a TV camera with 512x512 points of resolution. Then, using an analyzer IMAGER-512, black and white binary images magnified 30 times were printed in the scale of 1:1. In the obtained pictures, zones of bigger concentration are of black colour, pores and loose zones are white (Figs 1b, c, d and 2b, c, d). An optic microscope with a 30-time magnitude was used for the micromorphological analysis.

Actual moisture of the soil was determined by means of the oven-drying method. The distribution of the soil pores was determined on the basis of water capacities which were determined in pressure chambers. Dry soil density and total porosity were calculated. Granulometric composition of the soil and the content of humic compounds were determined as well.

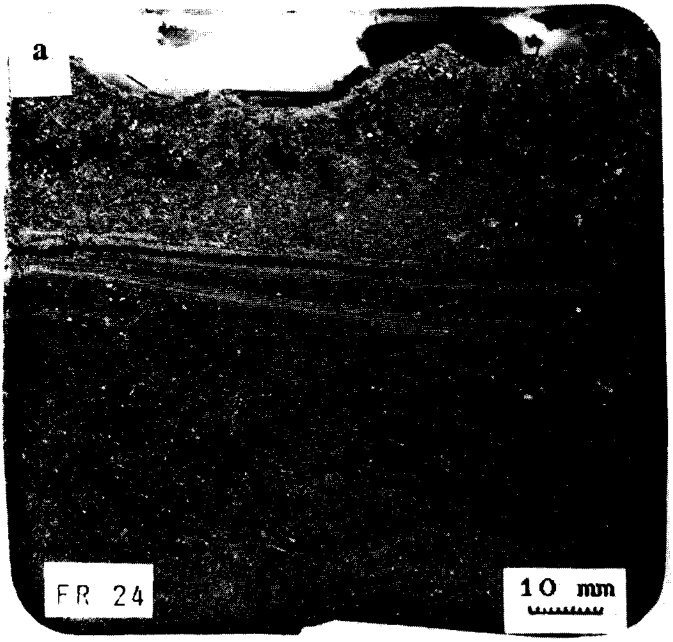
T a b l e 1. Soil properties

Grain size distribution %				Humus (%)	Density of dry soil (Mg m^{-3})
1-0.1 mm	0.1-0.02 mm	<0.02 mm	<0.002 mm		
20	53	27	5	1.76	1.38
Actual moisture % (v/v)	Field water capacity % (v,v)	Total porosity % (v,v)	Pore distribution % (v,v)		
			>20 μm	20-0.2 μm	<0.2 μm
30.0	29.5	47.2	19.7	23.6	5.9

RESULTS AND DISCUSSION

In granulometric respect, the plough-horizon of the tested soil was made up of ordinary silt containing 5 % of a fraction below 0.002 mm. The content of humic compounds was 1.76 % (Table 1). The arrangement of the soil was rather loose. Mesopores filled with water, 20-0.2 μm in diameter, dominated in the composition of pores.

The morphological analysis of the thin cross-sections showed that an aggregation structure, formed during the cultivation and modified by settling and by the activity of the soil mesofauna, occurred in both samples (No. 1 and No. 2), at about 1.5 cm of depth. It was made up of numerous, loosely connected aggregates - fragments of 0.25-7 mm in diameter, between which there were irregular, empty spaces - air pores (Figs 1a and 2a). The shapes of the aggregates and of the pores occurring between them are presented in the print of binary images magnified 30 times (Figs 1c and 2c). The processes of freezing and thawing had no effect on the structure of the soil in that zone. In the conditions of incomplete saturation of the soil with water, the volumes of the air pores (below 20 μm) did a



b

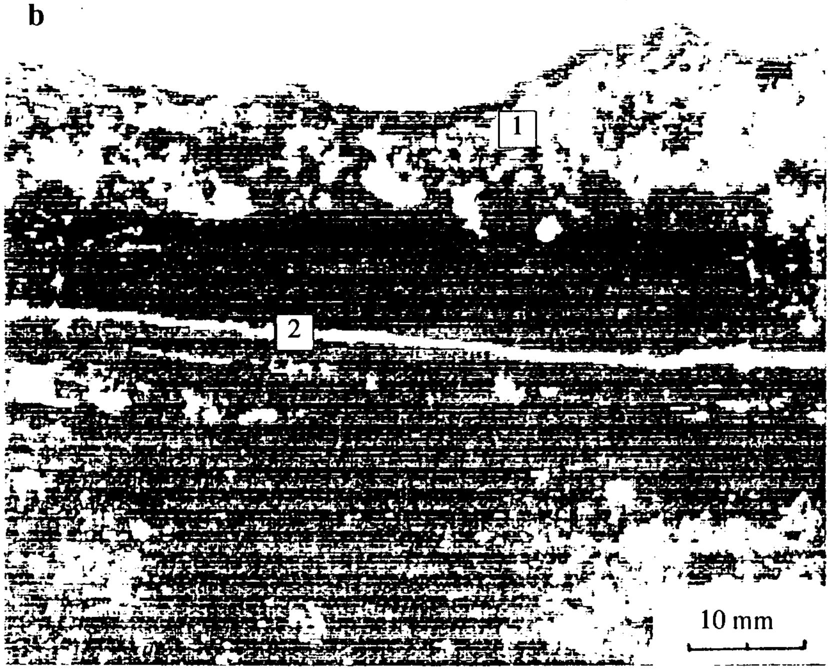


Fig. 1. Sample 1: a) photogram; b-d) prints of binary images made with an analyzer IMAGER-512: b) sections magnified 30 times are marked: 1 - refers to Fig. 1c, 2 - refers to Fig. 2d; c) image magnified 30 times; d)image magnified 30 times.

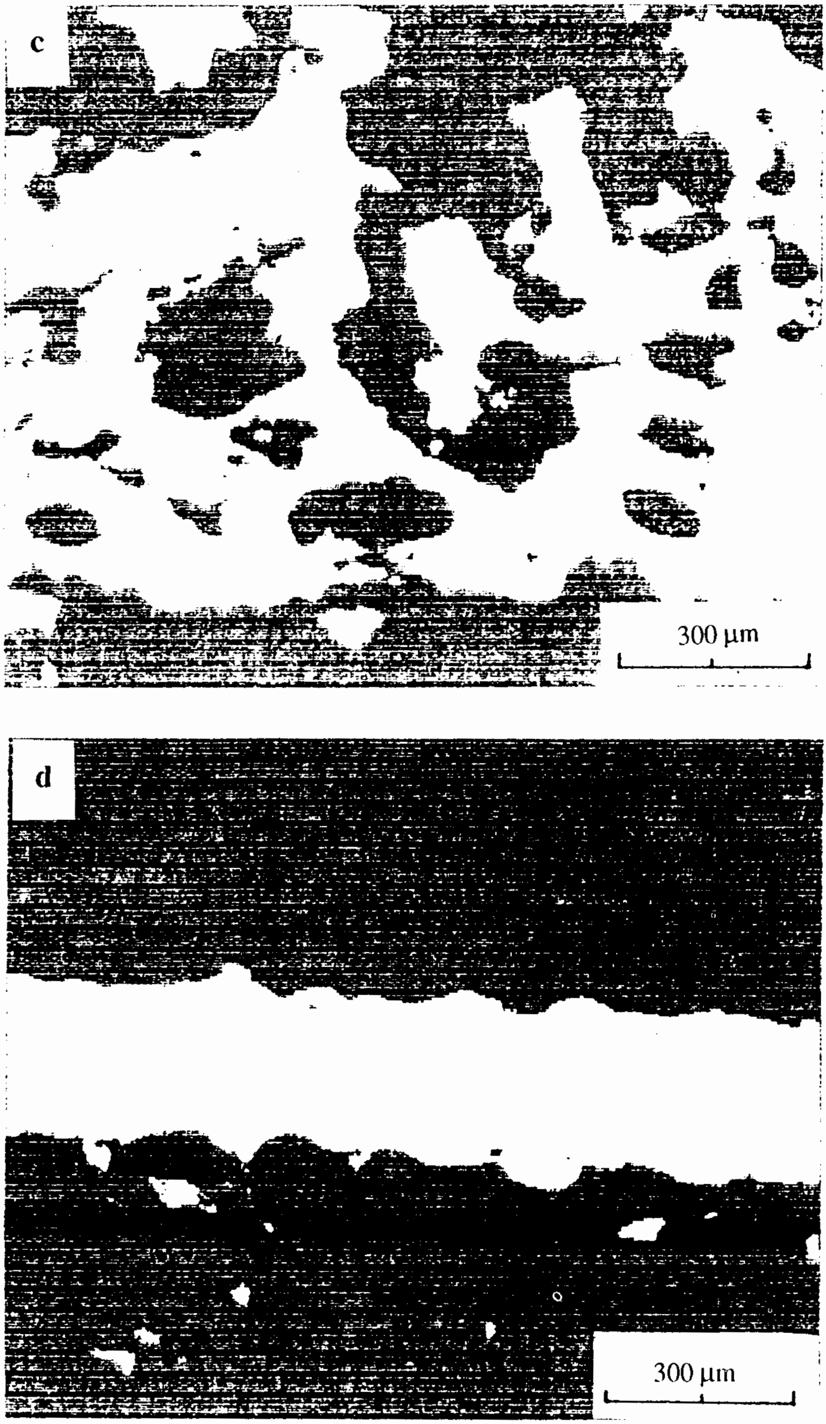


Fig. 1. Continuation

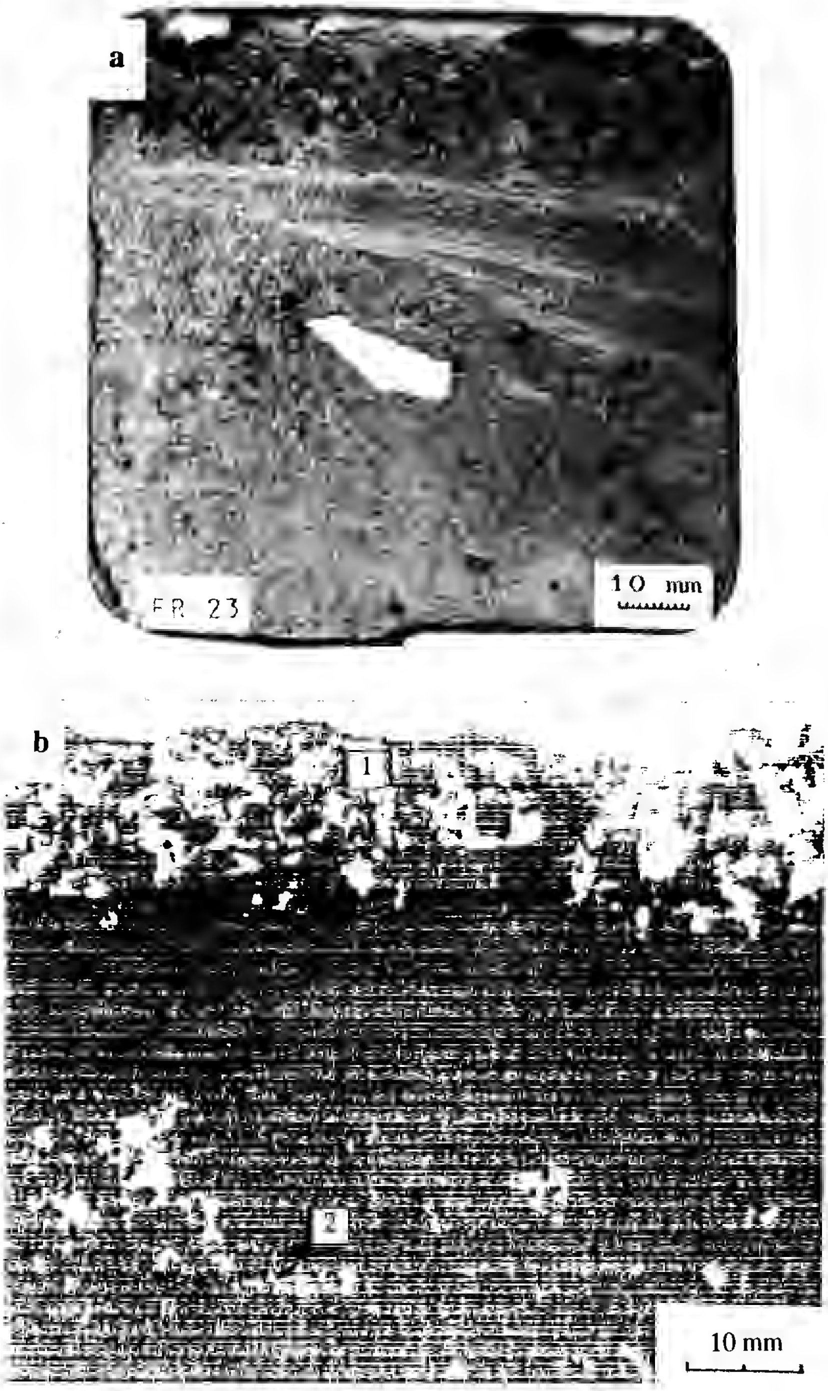


Fig. 2. Sample 2: a) photogram; b-d) prints of binary images made with an analyzer IMAGER-512: b) sections magnified 30 times are marked: 1 - refers to Fig. 2c, 2 - refers to Fig. 2d; c) image magnified 30 times; d) image magnified 30 times.

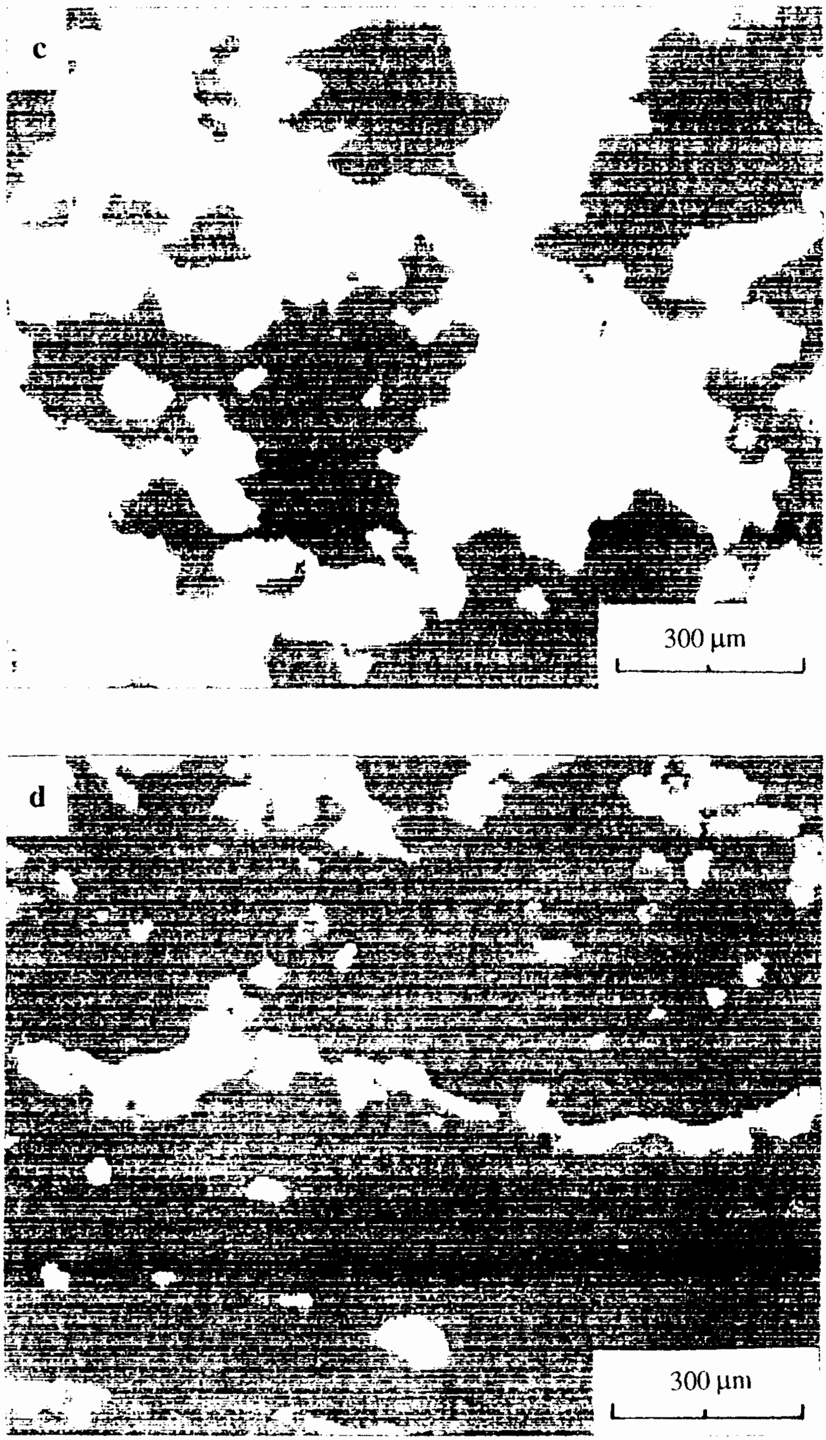


Fig. 2. Continuation.

not undergo any changes.

Non-aggregate structures, a bulky structure mainly, dominated in a plough-horizon below 1.5 cm. It was a considerably thick, uniform soil bulk without any larger pores. The influence of cyclic processes of freezing and thawing was particularly significant at the depth of 2-4 cm. Numerous lighter and darker horizontal streaks, from 0.5 to 3 mm wide, were observed in both samples (Figs 1a and 2a). The streaks were formed during the soil thawing as a result of rendering of the clay fraction and its accumulation in micro-fissures which emerged because of an unwedging pressure of the ice, on the border between the freezing and thawing zones. The dark streaks were made up of a clay fraction, whereas the lighter ones - mostly of quartz silt.

In the sample No. 1, separation of a top frozen horizon and forming of a fissure about 0.3-1 mm wide took place under the influence of frost and drying processes. A picture magnified with the microscope showed a regular shape of the fissure's walls (Fig. 1d).

In the sample No. 2, the lack of an uniform frozen horizon prevented the formation of fissures which could be seen with the naked eye. However, micro-fissures, little rifts 10-50 μm in diameter, occurred there (Fig. 2d).

Below the streaked freezing zone, at the depth from 4 down to 8 cm, there was a zone of a bulky structure with few channels remaining after soil fauna in it.

Summarizing the results of these studies, it ought to be stressed that the cyclic processes of freezing and thawing distinctively affected the structure of the plough-horizon of Orthic Luvisol derived from silt, but they did not determine its properties. The changes of the structure were much smaller than those in soils derived from clays and heavy loams [1,3].

CONCLUSIONS

1. Structure-forming activity of frost processes in a surface horizon of grey-brown podzolic soil (Orthic Luvisol) derived from silt resulted in the formation of vertical fissures and micro-fissures at the meeting points of freezing and non-freezing zones.

2. Cyclic freezing and thawing resulted in rendering of a clay fraction and in its accumulation in fissures, which contributed to the formation of horizontal, clayey and silty streaks.

REFERENCES

1. **Domżał H., Usjarow O.G.**: Formirowanije nieodnorodnosti porowogo prostranstwa w tiażełych nabuchajuszczych poczwach pro promierzanii - ottaianii. Kolloid. Żurn. 1994, 56, 3, 349-355.
2. **Górniak A.**: Późnowistuliańska i holeceńska ewolucja gleb regionu lubelskiego wytworzonych z lessu. Praca doktorska. AR Lublin 198?.
3. **Kay B.D., Grant C., Groentvelt P.H.**: Significance of ground freezing on soil bulk density under zero tillage. Soil Sci. Am. J., 49, 973-978, 1985.
4. **Kay B.D., Perfect E.**: Heat and mass transfer in freezing soils. Proc. 5th Intern. Symp. on Ground Freezing Nottingham, offprint, p. 3, 1988.
5. **Kołodziej J., Galant H.**: Pionowe ruchy gleby w procesie zamarzania i rozmarzania w RZD Felin w latach 1961-1970. Folia Soc. Sci. Lubl., Geografia, 18, 1, 1976.
6. **Perfect E., Groentvelt P.H., Kay B.D.**: Transport processes in porous media. Pullman, Washington, 1989.

WSTĘPNE BADANIA WPŁYWU ZAMARZANIA I ROZMARZANIA NA STRUKTURĘ POWIERZCHNIOWEJ WARSTWY GLEBY PŁOWEJ

Analiza morfologiczna zgladów glebowych wykazała wpływ cyklicznych procesów zamarzania i rozmarzania na strukturę warstwy powierzchniowej gleby plowej (Orthic Luvisol) wytworzonej z utworu pyłowego. Stwierdzono, że rozklinowujący nacisk lodu spowodował powstanie poziomych szczelin i mikroszczelin na styku strefy zamarzającej i niezamarzającej. Równocześnie podczas rozmarzania występowalo zjawisko wytopienia frakcji ilastej i jej akumulacja w szczelinach, dzieki czemu powstały liczne poziome smugi ilaste i pylaste.

S ł o w a k l u c z o w e: struktura gleby, zamarzanie, rozmarzanie.