ВІСНИК ЛЬВІВ. УН-ТУ VISNYK LVIV UNIV.
Серія мех.-мат. 1999. Вип. 55. С. 152–157 Ser. mech.-math. 1999. No. 55. P. 152–157

UDC 624.131+539.215

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MICROSTRUCTURAL NONHOMOGENEITY OF GLACIAL TILLS

1. Introduction. In engineering geology, geotechnics or when dealing with practical problems, theoretical physical or mathematical models are applied. Physical parameters used in these models which characterize soil and its reaction to loading are statistical variables [2, 4]. Hence the parameters of soils should be described by statistical methods – as determined values talking into consideration:

– the measure of general tendency (i.e. arithmetical mean x),
– the measure of variability (i.e. coefficient of variation v),
– standard deviation σ,
– areas of changeability $R = X_{max} - X_{min}$.

The variability of properties changes and depends on the definition of the considered parameter, accuracy of its determination, as well as is conditioned by method of research (the analysis of errors is omitted).

The properties of soil, and therefore of the soil basement depend on the microstructural parameters of pore space. Their microstructural nonhomogeneity on the example of tills is for the first time presented below.

2. Geological setting and lithogenetic features of glacial tills. Glacial tills are a typical result of glacial sedimentation. They include lodgement, melt-out and flow tills. They are composed of heterogeneous material and their composition depends on rocks transported by the glacier from distant and nearly areas as well as rocks taken from the glacial base. Glacial tills represent generally unsorted sediments with various contents of particular granulometric fractions (gravel, sand, silt and clay). Tills contain quartz grains of different size as well as grains of various rocks: gneiss, granite, quarzite, limestone. The sediment matrix comprises a mixture of fine grains of calcite and particles of clay minerals (illite or montmorillonite).

In macroscopic sense tills represent nonhomogenous soils [3, 8, 9]. Microstructural tests were carried out on till samples taken from 83 places located in the area of Poland (fig. 1). The till samples represent different glaciations, the depth of sampling usually reached 1.5 – 5.0m below surface. The investigated tills contain:

– 5 – 45% of clay fraction (< 2μm),
– 5 – 70% of silt fraction (2 – 500 μm),
– 35 – 80% of sand fraction (500 – 2000 μm).

3. Microstructures of glacial tills. According to the carried out analyses (fig. 2), the investigated tills posses usually three types of known microstructures [7, 8]: skeletal, matrix, and matrix-turbulent by classification [1]. The matrix microstructure is the most common. On the basis of structural element packing the following three sub-types have been distinguished [8]:

- A – till with loosely packed matrix microstructure,
- B – till with medium packed matrix microstructure,
- C – till with tightly packed matrix microstructure.

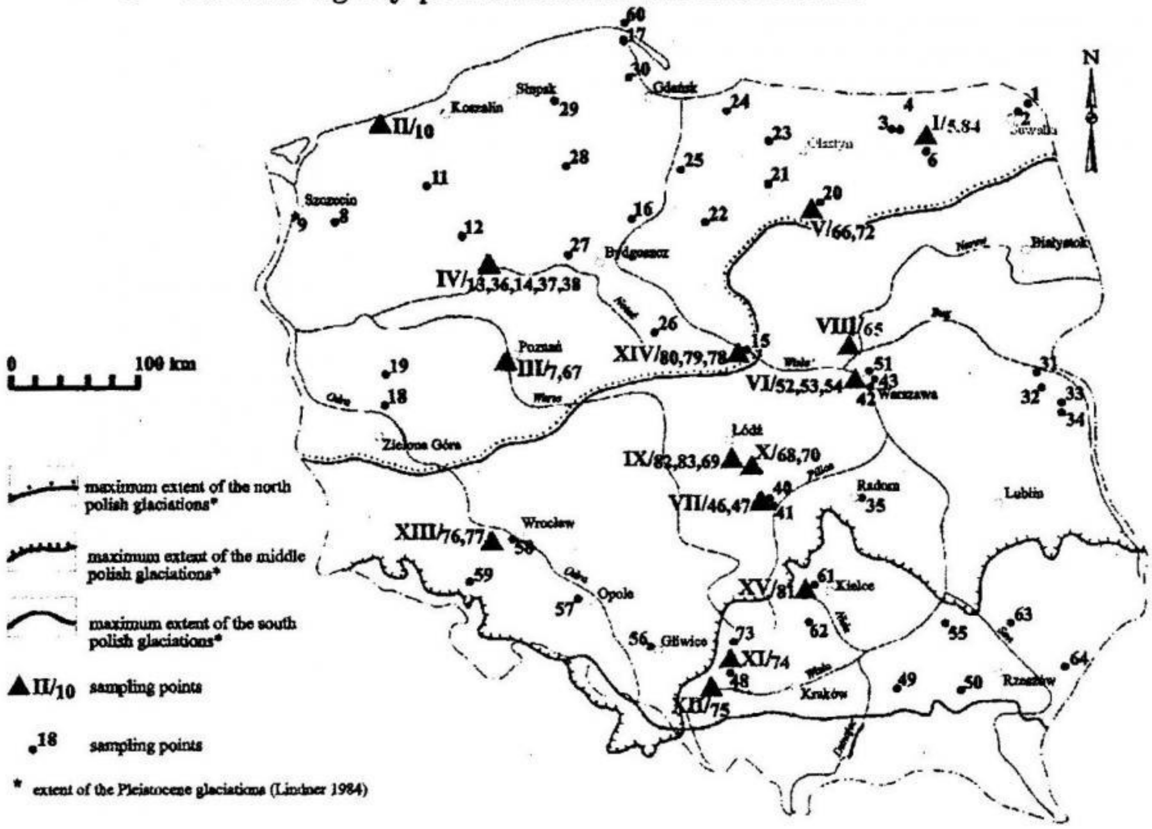

Fig. 1. Location of sampling points.

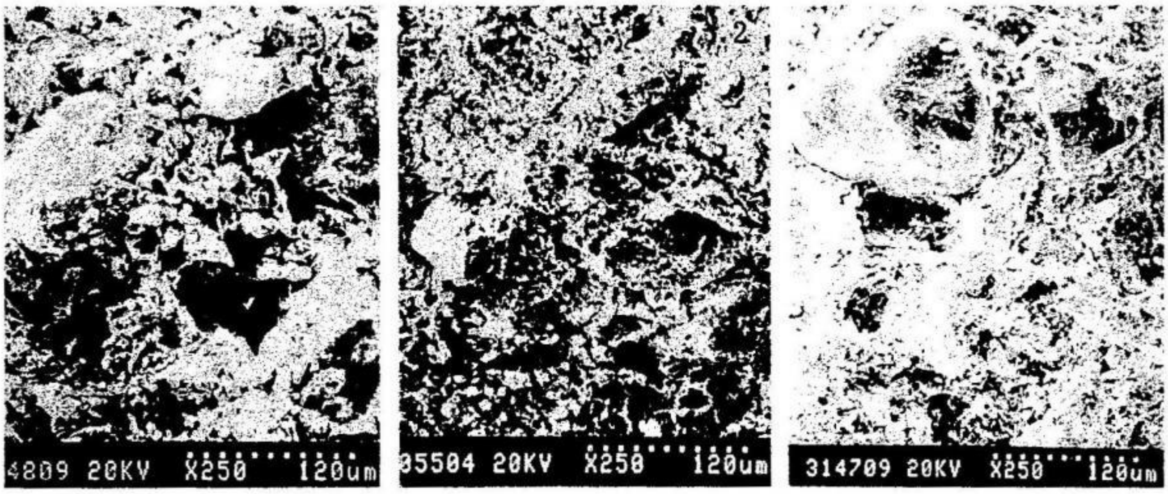

Fig. 2. Examples of: skeletal microstructure (1), matrix microstructure (2) and matrix-turbulent microstructure (3) in glacial tills.

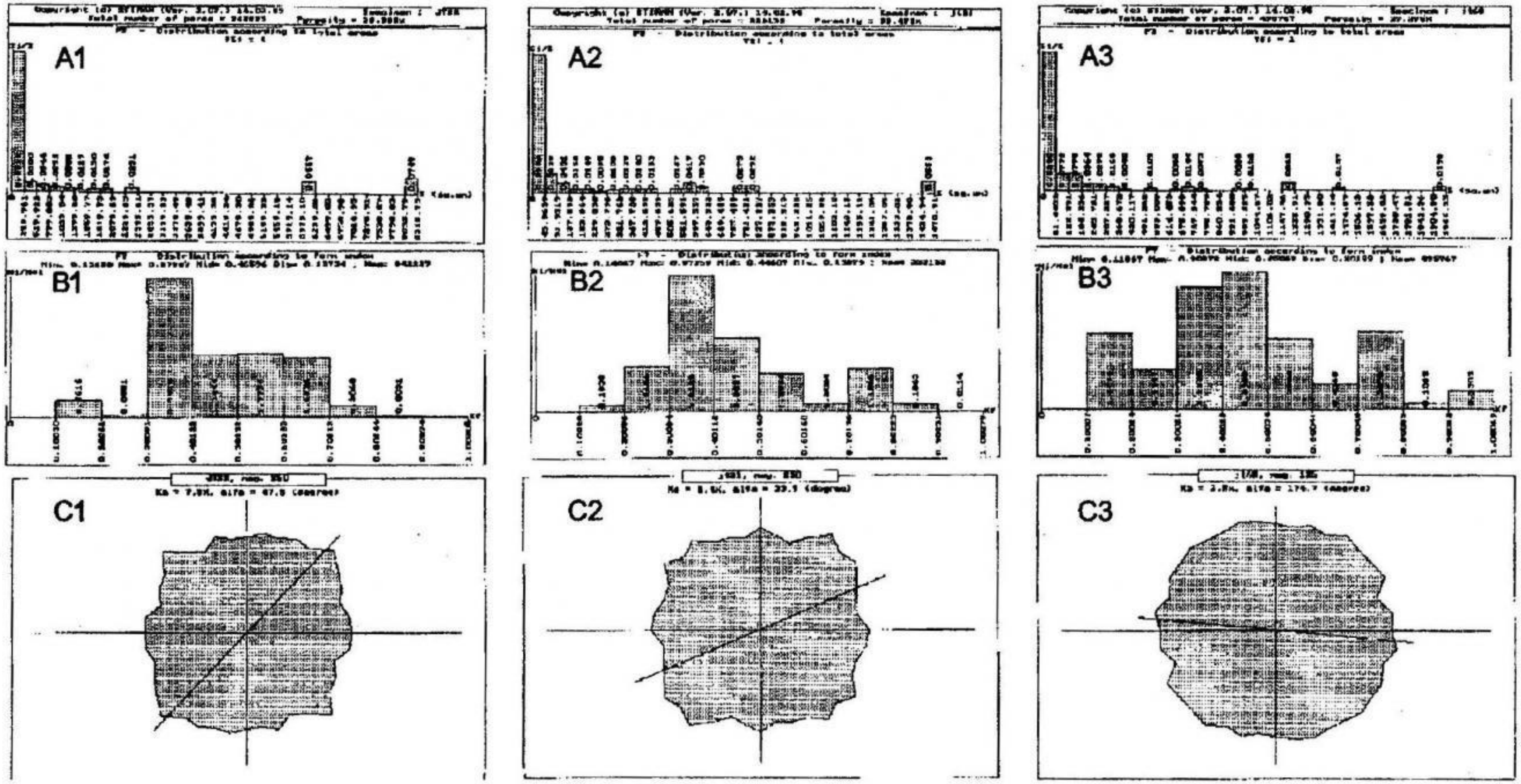

Fig. 3 Examples of: distribution according to total area (A), distribution according to form index (B), rose diagram (C).
1 - skeletal microstructure, 2 - matrix microstructure, 3 - matrix-turbulent microstructure.

4. Microstructural parameters of pore space. Quantitative and qualitative microstructural investigations of glacial tills were carried out with the use of Stiman software (v. 2.07) connected to a SEM. The software based on Fourier and Walsh analysis was developed by [6] from the Moscow State University. Results of the analysis enabled to determine microstructural parameters of pore space in the tested soils (tab., fig. 3): porosity, number of pores, total area of pores, total perimeter of pores, average area of pores, average perimeter of pores, average diameter of pores. Evaluation of the degree of image intensity enabled to determine the degree of structural elements orientation – the quantitative parameter: anisotropy index of microstructure.

The microstructural parameters of glacial tills

Type/sub-type of microstructure	Skeletal		Matrix		Matrix sub-type A		Matrix sub-type B		Matrix sub-type C		Matrix-turbulent		Micro-structures (All types)	
Parameters of microstructure	$\overline{X}$	ν	$\overline{X}$	ν	$\overline{X}$	ν	$\overline{X}$	ν	$\overline{X}$	ν	$\overline{X}$	ν	$\overline{X}$	ν
Porosity n %	**38.0**	9	**33.9**	19	**38.5**	10	**34.1**	16	**27.6**	19	**29.6**	8	**34.3**	19
Number of pores $N \times 10^3$	**354**	102	**177**	99	**192**	82	**211**	97	**195**	47	**501**	93	**214**	110
Average diameter of pores D_{av} μm	**2.43**	128	**1.02**	126	**0.91**	138	**1.12**	105	**0.88**	131	**1.05**	99	**1.19**	134
Total area of pores $S_t \times 10^3$ μm^2	**882**	90	**619**	186	**316**	236	**1115**	127	**391**	205	**395**	83	**640**	173
Average area of pores S_{av} μm^2	**34.4**	153	**7.6**	251	**7.8**	221	**7.0**	193	**5.6**	254	**3.5**	114	**10.7**	241
Total perimeter of pores $P_t \times 10^3$ μm	**1263**	63	**923**	168	**584**	152	**1494**	119	**903**	164	**1211**	27	**978**	151
Average perimeter of pores P_{av} μm	**17.1**	127	**7.5**	123	**6.9**	142	**7.8**	103	**6.6**	123	**7.8**	100	**8.6**	133
Average form index of pores $K_{fav} \times 10^{-1}$	**4.73**	11	**4.86**	12	**5.12**	10	**4.97**	12	**4.47**	11	**4.81**	8	**4.82**	12
Anisotropy index of microstructure K_a %	**10.6**	52	**10.3**	59	**10.0**	37	**9.1**	51	**10.5**	74	**10.6**	67	**10.4**	58
Dominant orientation direction of pores α°	**98**	37	**75**	53	**80**	46	**80**	53	**71**	49	**90**	63	**78**	51

$\overline{X}$ – arithmetic average, ν – coefficient of variation, number of samples – 83.

The quantitative analysis of microstructural parameters reveals that (table):

- tills with C sub-type matrix microstructure have the smallest porosity. The smallest mean diameter of pores, mean area of pores and mean perimeter of pores for these tills also reach the lowest values. For tills with B and A sub-type matrix microstructure the values of these parameters increase, reaching the highest values for tills with skeletal microstructure,
- the form index of pores reaches highest values for A sub-type matrix tills, and the lowest for sub-type C. The values of this index in tills with the

matrix-turbulent microstructure increases in comparison to these values for tills the C sub-type matrix microstructure,
- the anisotropy index of microstructure does not vary in the analysed tills.

5. Microstructural nonhomogeneity. Tab. 1 presents the results of investigations for glacial tills, occurring within the depths of 1.5-5.0m, taken from 83 places in the area corered by sediments of the North Polish, Middle Polish and South Polish glaciations.

Parameters describing the pore space of tills, regardless of type and subtype of microstructure, reveal a large heterogeneity. The coefficient of variation usually exceed 100%, sometimes even 200%. Microstructure treated as a whole is characterised by the largest nonhomogeneity. Division into types and sub-types decreases values of the coefficients of variation. However, for some types or sub-types the parameters have a larger heterogeneity than tills treated as a whole. In comparison to tills with skeletal and matrix-turbulent microstructures, tills with matrix microstructure have the largest nonhomogeneity. Within the matrix microstructure, sub-types A, B and C generally have a smaller nonhomogeneity, but sometimes (< 50% cases) sub-types A and C have a higher value of variability than the matrix microstructure treated as a whole.

6. Conclusions. The carried out microstructural investigations and their analysis reveal that:
1. microstructural nonhomogeneity of tills is generally large, the coefficient of variation usually exceeds 100%, sometimes even 200%,
2. the coefficient of variation of pore space parameters for the distinguished types and sub-types of microstructures is smaller than the variability for the microstructure treated as a whole,
3. occasionally in some types (matrix) and sub-types (A, C) of till microstructures, some parameters (< 50%) reveal a larger variability than that for all types and subtypes.

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1. *Grabowska-Olszewska B., Osipov V., Sokolov V.* Atlas of the microstructure of clay soils. –Warszawa: PWN, 1984.
2. *Frankowski Z., Kaczyński R., Bogucki A., Voloshyn P.* Nonhomogeneity of the physical-mechanical properties of soil medium composed of Tertiary clays and Quaternary loesses // J. of Theoretical and Applied Mechanics. – 1998. – **3**, No. 36. – P. 581–595.
3. *Kaczyński R., Trzciński J.* The physical-mechanical and structural properties of boulder clays of the Vistula Glaciation in the area of Poland // Geological Quarterly. – 1992. – **36**, No. 4. – P. 481–508.
4. *Kaczyński R.* Geological nonhomogeneity of the subgrade // Metematicheskie Metody i Fizykomechanicheskie Polya. – 1996. – No. 36. – P. 1–8.
5. *Lindner L.* An outline of Pleistocene chronostratigraphy in Poland // Acta Geologica Polonica. – 1984. – **34**, No. 1–2. – P. 27–49.

6. *Osipov V. I., Sokolov V. N., Rumjanceva N. A.* Mikrostruktura glinistych porod. – M.: Nedra, 1989.
7. *Sokolov V. N.* Engineering-geological classification of clay microstructures // Proc. 6th Inter. IAEG Congress. – 1990. – No. 1. – P. 753–760.
8. *Trzciński J.* Qualitative and quantitative analysis of microsteructures in Polish glacial tills with respect to their age // Geological Quarterly. – 1995. – **39**, No. 3. – P. 403–422.
9. *Trzciński J.* The microstructures and geological-engineering properties of glacial tills. Ph. D. thesis. Faculty of Geology, Warsaw University, 1999. – Vol 1, 2. – P. 371. (In Polish).

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МІКРОСТРУКТУРАЛЬНА НЕОДНОРІДНІСТЬ ЛЬОДОВИКОВИХ ҐРУНТІВ (ВАЛУНОВИХ ГЛИН)

Досліджено мікроструктуральну неоднорідність льодовикових глин. Аналіз неоднорідності обмежувався дослідженням значення коефіцієнта змінності. Аналіз виконано для декількох параметрів поруватого простору, а саме: поруватості, кількості та діаметра пор. Проаналізовано значення цих параметрів для всіх типів мікроструктур загалом і для певних типів (скелетний, матрицевий, матрицево-турбулентний), а також у межах матрицевої мікроструктури для її підтипів A, B і C. Мікроструктуральна неоднорідність досліджуваних глин значна. Часто коефіцієнт змінності перевищує 100%, а інколи навіть 200%. Переважно значення коефіцієнта змінності зменшується в межах виділених типів чи підтипів. Іноді спостерігаємо, що в типах (матричні) і підтипах (A, C) *деякі параметри* (< 50%) *характеризуються більшою змінністю, ніж мікроструктуральна змінність, описувана загалом.*

Стаття надійшла до редколегії 14.09.99