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Differentiation of Grain Size of the Vistulian Loesses on the Grzęda Horodelska Plateau (SE Poland)

Zróżnicowanie uziarnienia lessów Vistulianu na Grzędzie Horodelskiej (Polska SE)

Дифференциация гранулометрического состава лёссов последнего оледенения на Городельской гряде (ЮВ Польша)

ABSTRACT

On the basis of detailed studies of 18 profiles the characteristic graining features of the Vistulian loesses were determined on the Grzęda Horodelska plateau in the spatial and stratigraphical system. It was found that the granulometric indices Mz, σ_1, Sk_I, K_G (according to L. R. Folk and W. C. Ward 1957) may constitute a significant diagnostic feature helpful in determining stratigraphical loess horizons on a regional scale. The transport directions of the Vistulian loesses were differentiated. It is difficult to find the predominating direction for lower Vistulian loess; NE and E winds predominated in middle Vistulian, whereas NW and W in upper Vistulian.

The granulometric differentiation of the Vistulian loesses was analysed in vertical and horizontal directions within the loess patch on the Grzęda Horodelska. It was an attempt to elucidate whether differentiation of grain size may constitute a diagnostic feature enabling the distinction of loesses belonging to different stratigraphic units. An attempt was also made at finding whether differentiation of granulometric features can be helpful in examination of the sedimentological character of loesses. Studies were carried out for 18 loess profiles situated on the Grzęda Horodelska plateau and on the Pleistocene terraces of the Bug and Huczwa rivers (Fig. 1).

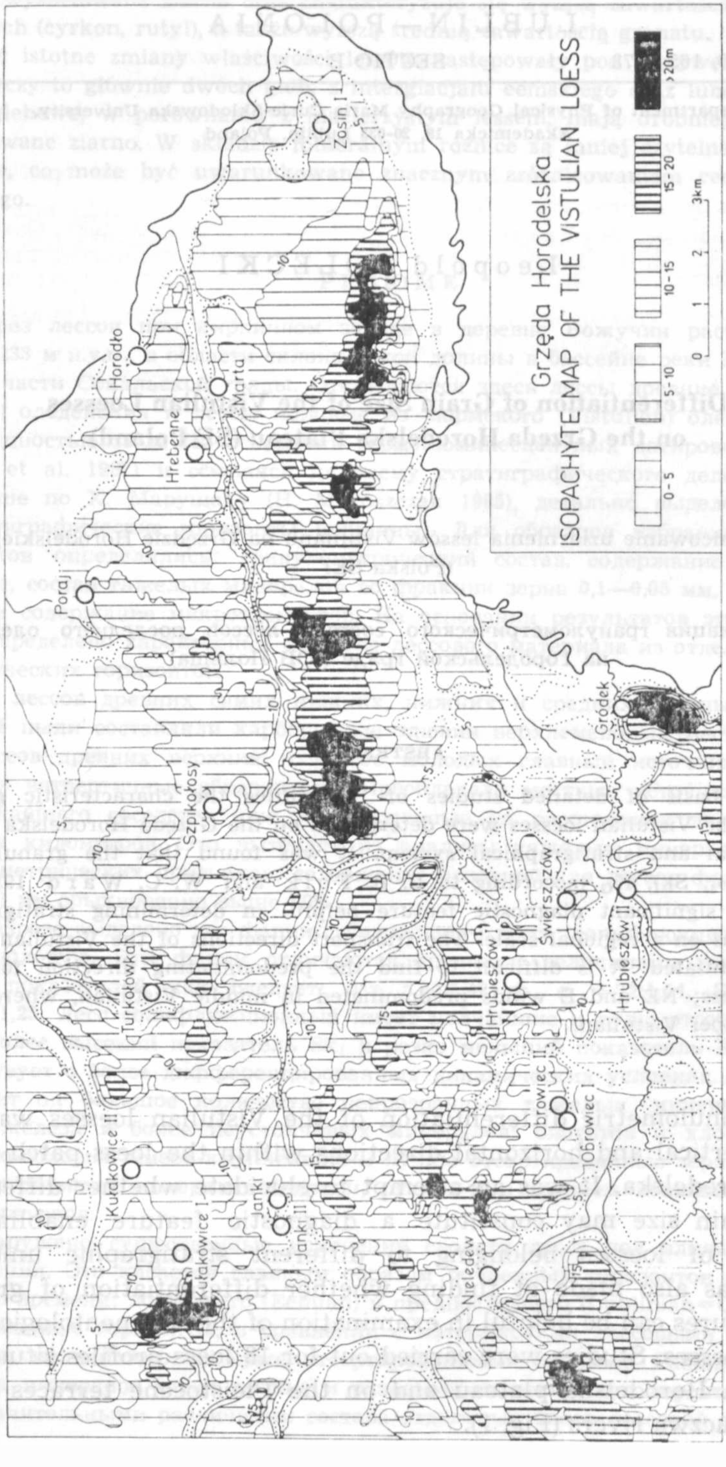


Fig. 1. Distribution of studied profiles in relation to the thickness of the Vistulian loesses on the Grzeda Horodelska plateau

METHODS

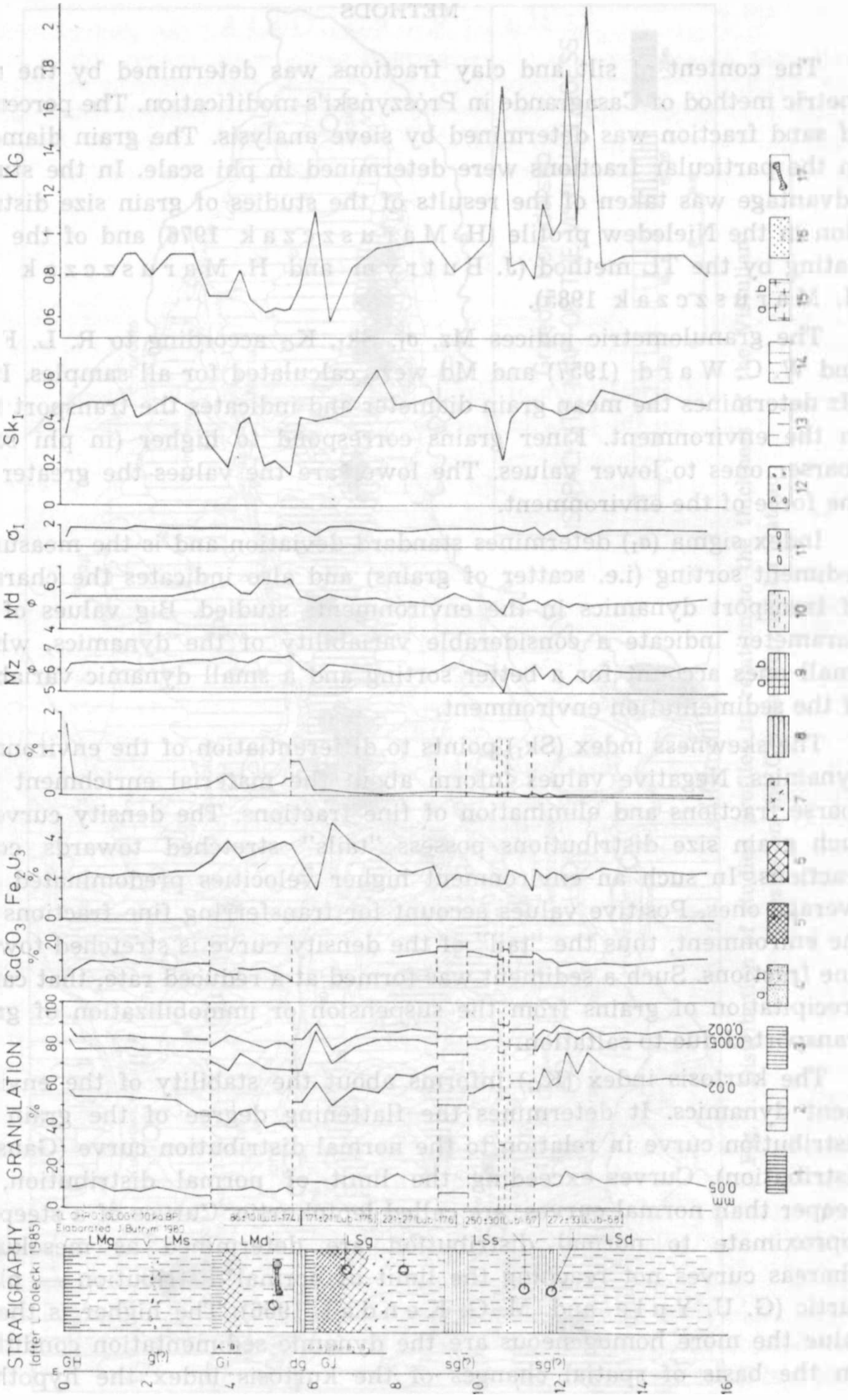
The content of silt and clay fractions was determined by the aerometric method of Casagrande in Prószyński's modification. The percentage of sand fraction was determined by sieve analysis. The grain diameters in the particular fractions were determined in phi scale. In the studies, advantage was taken of the results of the studies of grain size distribution in the Nieledew profile (H. Maruszczak 1976) and of the loess dating by the TL method (J. Butrym and H. Maruszczak 1983, H. Maruszczak 1985).

The granulometric indices Mz, σ_I, Sk_I, K_G according to R. L. Folk and W. C. Ward (1957) and Md were calculated for all samples. Index Mz determines the mean grain diameter and indicates the transport force in the environment. Finer grains correspond to higher (in phi scale), coarser ones to lower values. The lower are the values the greater was the force of the environment.

Index sigma (σ_I) determines standard deviation and is the measure of sediment sorting (i.e. scatter of grains) and also indicates the character of transport dynamics in the environments studied. Big values of this parameter indicate a considerable variability of the dynamics, wheras small ones account for a better sorting and a small dynamic variability of the sedimentation environment.

The skewness index (Sk_I) points to differentiation of the environment dynamics. Negative values inform about the material enrichment with coarse fractions and elimination of fine fractions. The density curves of such grain size distributions possess "tails" stretched towards coarse fractions. In such an environment higher velocities predominated over average ones. Positive values account for transferring fine fractions into the enironment, thus the "tail" of the density curve is stretched towards fine fractions. Such a sediment was formed at a reduced rate, that caused precipitation of grains from the suspension or immobilization of grains transported due to saltation.

The kurtosis index (K_G) informs about the stability of the environment dynamics. It determines the flattening degree of the grain size distribution curve in relation to the normal distribution curve (Gaussian distribution). Curves exceeding the limit of normal distribution, i.e. steeper than normal curves, are called leptokurtic. Curves of a steepness approximate to normal distribution are determined as mesokurtic, whereas curves not reaching the limit of normal distribution — platykurtic (G. U. Yule and M. G. Kendal 1966). The higher is the K_G value the more homogeneous are the dynamic sedimentation conditions. On the basis of spatial changes of the kurtosis index the hypothetic


STRATIGRAPHY
(after L. Dolecki 1985)
GRANULATION
%
CaCO3
Fe2O3
C
Mz
Md
Sk1
KG
LMg
LMs
LMd
LSg
LSs
LSd
GH
Gi
GJ
Elaborated J. Butrym 1980
mm
0.05
0.02
0.005
0.002

directions of the sediment transport are determined. It is assumed to take place from localities with small K_G values to localities with big K_G values.

The graphic-analytical method (J. Stochlak 1968) was used for calculation of grain distribution indices. The indices were determined for the particular stratigraphic units of loesses, defined on the basis of the paleopedological criteria and TL dating according to the stratigraphic scheme of H. Maruszczak (1976, 1980). The results were plotted in diagrams for all profilles discussed. The data enabling the parallelization of the particular stratigraphic units in the compared profiles were the datings of loesses by the TL method in the profiles: Nieledew (Fig. 3), Obrowiec I (Fig. 2) and Horodło I (J. Butrym and H. Maruszczak 1983, L. Dolecki 1985a, b). The curves of the granulometric indices from the individual profiles, listed in one diagram were the basis for the graphical presentation of their oscillation amplitudes (Fig. 4, 5). Unfortunately, not all stratigraphic units of younger loesses could be presented in this way. The lowest younger loess, because of its small thickness, underwent all soil-forming processes in the early Vistulian. In some cases it was involved in the interglacial soil complex underlying the lower younger loess.

LOWER YOUNGER LOESS (LMd)
(90—45 ka BP)

Lower younger loess in the interfluve profiles does not usually possess a thickness bigger than 3 m. Index Mz of this loess ranges from 5.6 to 6.8 phi, at a mean phi 6.43 for all profiles studied. In the vertical LMd

Fig. 2. Loess section at Obrowiec I

1 — humus horizons of the chernozem type; 2 — other well pronounced humus horizons; 3 — poorly pronounced humus horizons; 4 — washing horizons: a — well pronounced, b — poorly pronounced; 5 — upper, more intensely coloured portion of brow-earth and illuvial horizons; 6 — middle, less intensely coloured portion of brow-earth and illuvial horizons; 7 — lower portion of illuvial horizons with irregular brownish and yellowish streaks; 8 — deluvia of chernozem horizons; 9 — soil sediments with symptoms of initial humus horizons: a — well pronounced, b — b — poorly pronounced; 10 — soil sediments with browning evidence; 11 — relics of humus horizon with a high concentration of manganese compounds; 12 — gleying symptoms; 13 — carbonate loess; 14 — carbonate sandy loess with intercalations of fine and silty sands; 15 — carbonate free loesses (decalcified): a — typical, b — sandy; 16 — sands; 17 — bone remnants. Letter symbols of the stratigraphic units of the loess cover: L — loess, M — younger, S — older, N — oldest, g — upper, s — middle, d — lower, n — the lowest. Letter symbols of soil units: G — soil with well developed genetical horizons, H — recent, Holocene soil, J — fossil interglacial soil, i — fossil interstadial soil, sg — soil sediments, dg — soil deluvia, g — symptoms of the development of soil-forming processes

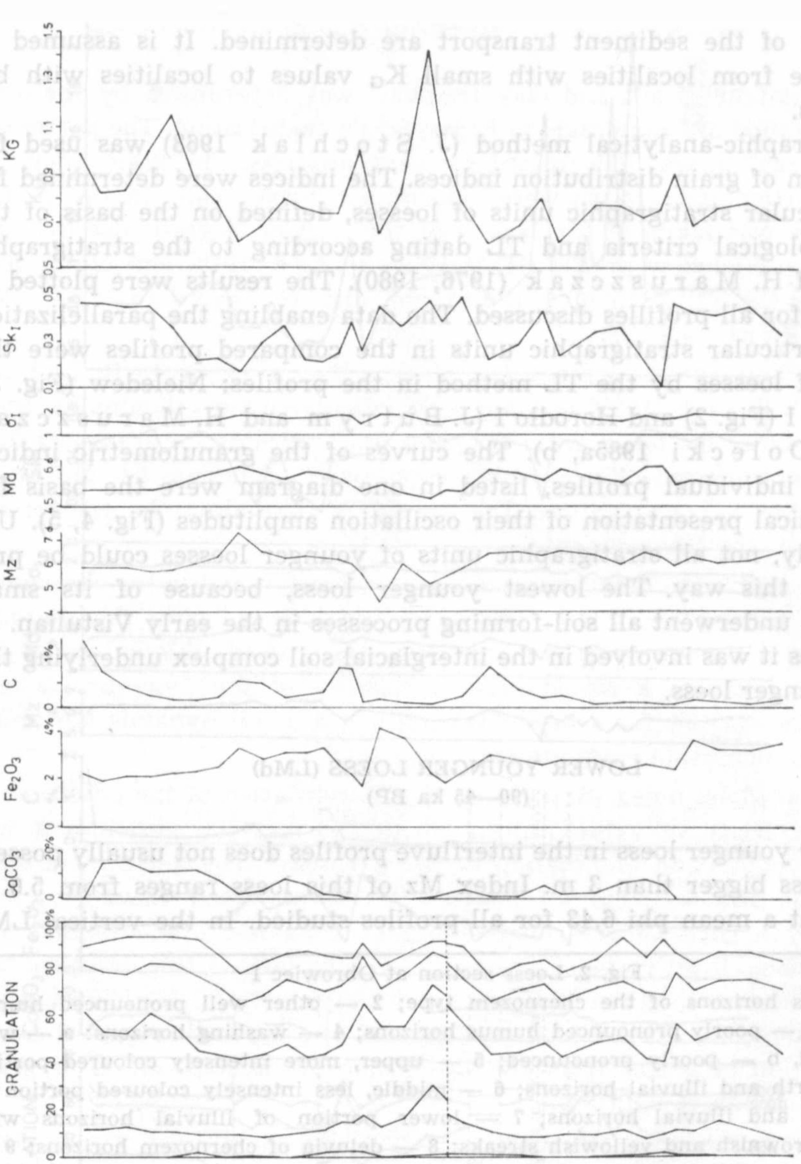


Fig. 3. Loess section at Nieledew (according the data of H. Maruszczak 1985, J. Butrym and H. Maruszczak 1983). Explanations to the profile as in Fig. 2

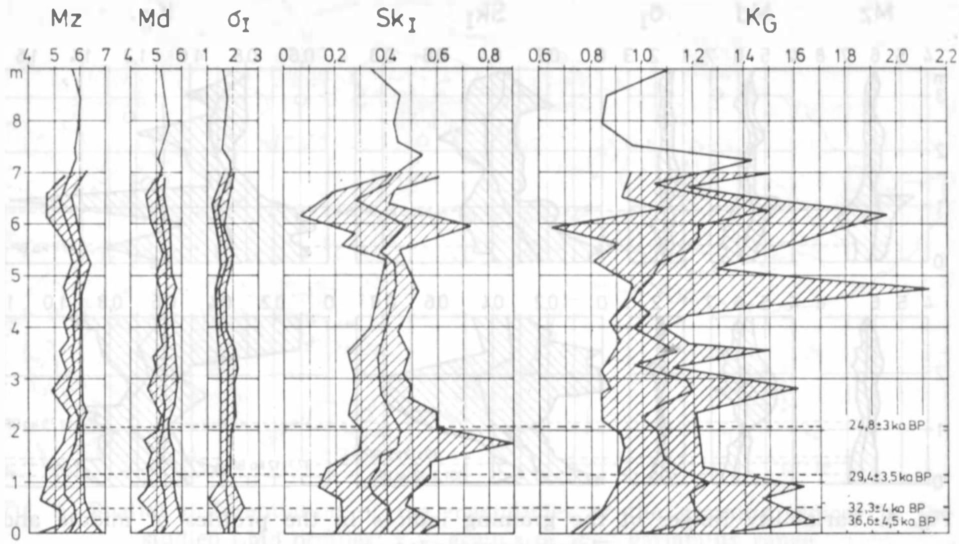


Fig. 4. Variability ranges of the graining indices in the profiles of upper younger loesses

profiles a decrease of the Mz index from the floor upwards is observed (i.e. an increase of the grain diameter expressed in mm). This decrease proceeded to about 60 ka BP. Of such TL age is the specimen of the loess at Nieledew (1.2 m over the roof of interglacial soil) at the site of a distinct change of the Mz curve course, also observed in other profiles. Then the Mz values increase (the grains are getting finer), but differently in the particular profiles. σ_I indices oscillate in the range from 1.5 to 2.3; if the maximal magnitude were excluded in the profiles at Janki I and Szpikołosy we would obtain a range 1.5—2.0. Thus, lower younger loess is characterized by a weak sorting, or a similar one in the whole area studied.

Sk_I indexes of LMd show that in the interval 100—60 ka BP a distinct increase of positive skewness occurred. In the middle part of the profiles it reaches a magnitude of 0.8 at Obrowiec III and 0.6 at Kułakowice II; these are positively very skew distributions. The skewness indices in the profiles decrease from 60 ka BP, but are maintained within the positive skew magnitudes.

K_G indices are contained in the interval of platykurtic and very platykurtic systems. The oscillations are considerable in the particular profiles, e.g. at Janki I from 0.35 to 0.9, and at Kułakowice II from 0.45 to 0.73. A distinct tendency in passing from very platykurtic to platykurtic systems is observed in the vertical direction.

The mean values of the granulometric indices calculated for the whole

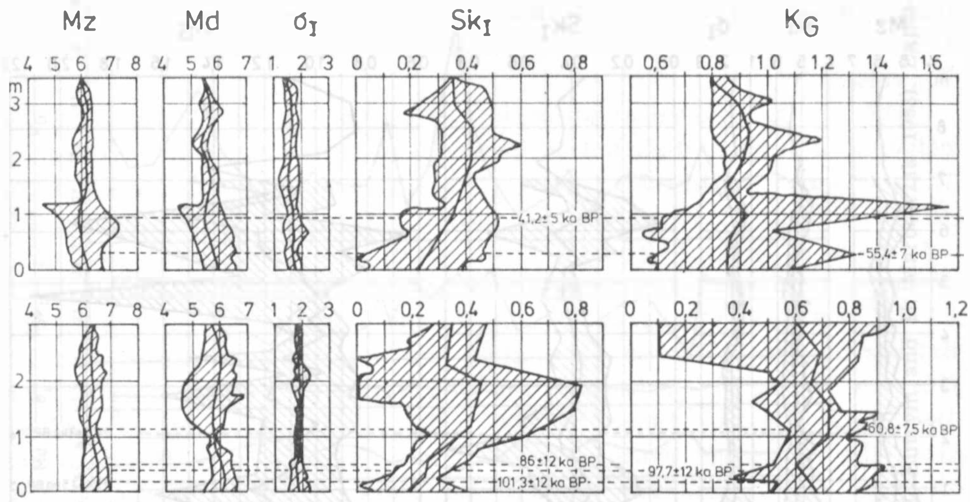


Fig. 5. Variability ranges of the graining indices in the profiles of middle and lower younger loesses

LMd profiles are shown in Fig. 6. From this figure the spatial distribution of indices can be learned. It seems that the interfluve parts of the Grzęda Horodelska underwent deflation in the period of LMd accumulation. This seems to be accounted for by smaller Mz values in the other profiles, weak sorting and high kurtosis magnitudes. However, the predominating direction of the sediment transfer cannot be determined.

MIDDLE YOUNGER LOESS (LMs)
(42—33 ka BP)

Its thickness does not exceed 2 m in most of the profiles studied. Index Mz oscillates in the range 5.8—6.6 phi, except the profiles at Poraj and Janki II, where grains are coarser in the interval 4.5—5 phi. The mean of this loess for all samples studied is 6.1 phi. The smallest average grains occur in the profiles at Janki I (6.6 phi) and at Kułakowice I (6.8 phi). In the vertical direction a weak size increase of medium grains is observed upwards to the horizon, the TL age of which is 41 ka BP at Nieledew. Above this horizon the sedimentation proceeded regularly, Mz index is of the order 5.5 phi.

The magnitude of σ_I is relatively constant, contained in the interval 1.2—2.0. LMs sedimentation occurred at a very distinct change of the distribution skewness — from positively skew in the floor to very skew in the roof. The roof LMs parts have been well preserved only in the profiles at Marta, Szpikołosy and Obrowiec I. On the basis of studies of

Fig. 6. Spatial differentiation of the magnitudes of the graining indices in the studied LMd profiles: x — grain size, R — variability range

these profiles it can be found that the magnitude of Mz and σ_I decreases. Thus the sediment is coarser and better sorted.

Kurtosis (K_G) in the floor parts changes from very platykurtic (Kułakowice II, Janki I, Marta) to mesokurtic (Turkołówka, Szpikołosy) and leptokurtic (Poraj). Above the horizon dated 41 ka BP at Nieledew, a distinct change in the direction of the kurtosis curves can be noticed; the index magnitudes decrease and oscillate from the leptokurtic to platy-

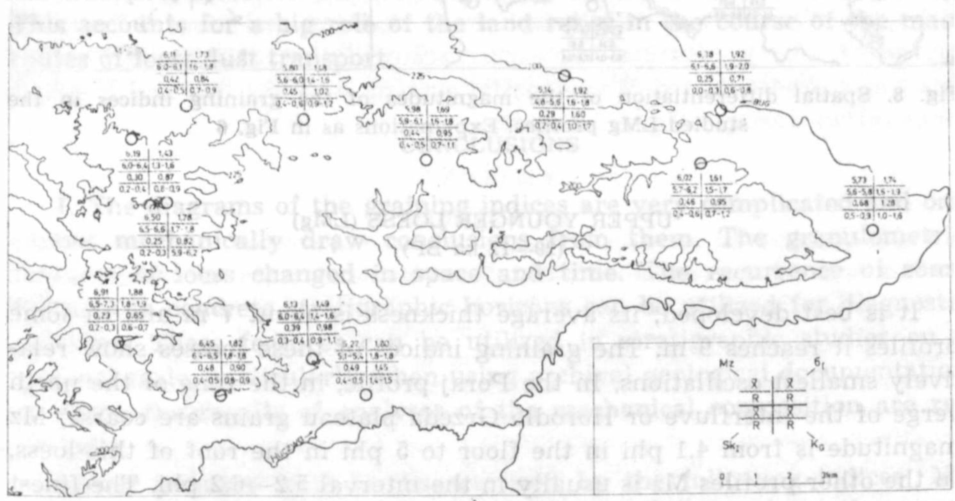


Fig. 7. Spatial differentiation of the magnitudes of the graining indices in the studied LMs profiles. Explanations as in Fig. 6

kurtic range. In comparison with lower younger loesses a highly distinct skewness increase of the systems can be observed.

A relatively distinct spatial differentiation is apparent (Fig. 7). The coarsest grains occur in the north and central part of the patch on the Grzęda Horodelska plateau as well as on the peripheries of the patch near the valleys, whereas the finest in the west part, particularly at Nieledew. The Mz and K_G relations seem to point to the predominating transport directions of sediments from sector N and E. Higher σ_I and K_G on the perpheries of the Horodło area indicate an intensive transport of dusts under relatively homogeneous dynamic environment conditions. An intensive deflation may occur there, and dusts were transferred to higher parts of the slopes and onto the interfluve.

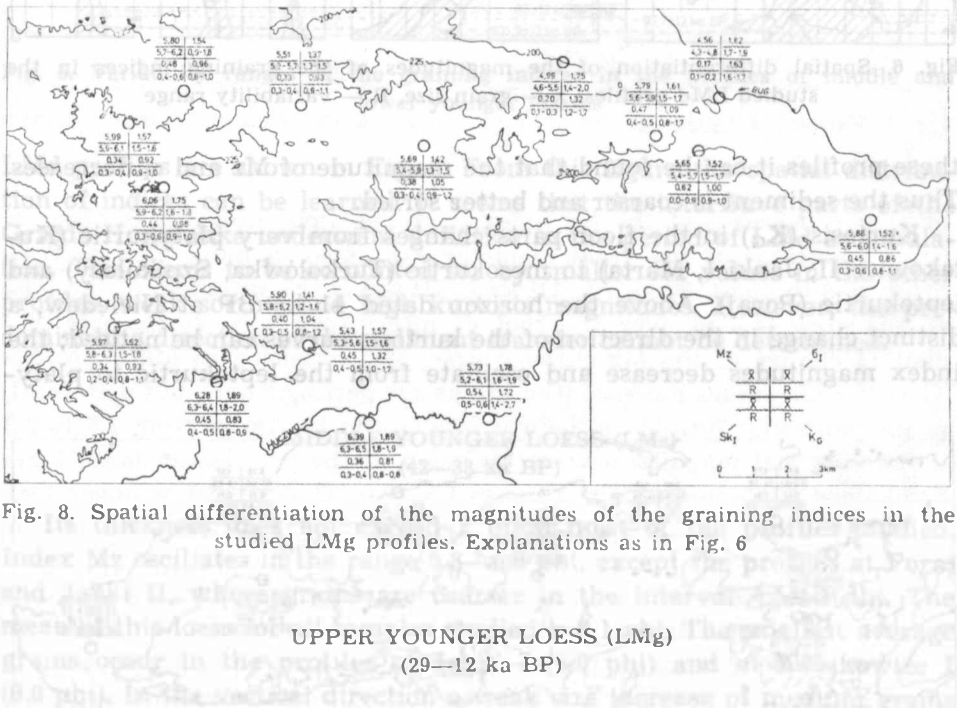


Fig. 8. Spatial differentiation of the magnitudes of the graining indices in the studied LMg profiles. Explanations as in Fig. 6

UPPER YOUNGER LOESS (LMg)
(29—12 ka BP)

It is best developed; its average thickness is about 7 m and in some profiles it reaches 9 m. The graining indices of these loesses show relatively smallest oscillations. In the Poraj profile, in the zone of the north verge of the interfluve or Horodło Grzęda plateau grains are coarse, Mz magnitude is from 4.1 phi in the floor to 5 phi in the roof of this loess. In the other profiles Mz is usually in the interval 5.2—6.2 phi. The finest grains occur on the west peripheries of the studied area in the initial phase of loess accumulation in the profiles at Nieledew and Janki I (6.25—

6.31 phi). The most stabile loess accumulation occurs in the range 29—24 ka BP, Mz values in the compared profiles differ slightly. In the roof LMg layer, about 6 m above their floor, the grain diameter shows a distinct tendency to increase on the interfluve; this must have been a period of intestified eolian processes in the final part of glaciation.

Index σ_I ranges from 1.2 to 2.0 in most profiles, which account for a weak grain sorting, particularly on the peripheries of the loess patch. At Poraj σ_I magnitude is even as big as 2.06.

Sk_I indices in the studied LMg profiles are bigger than 0.3 and point to very skew positive distributions. An exception here is the profile at Horodło, where Sk_I ranges from 0.13 to 0.24, as well as the lower fragments of the profiles at Szpikołosy, Hrebenne, Janki I, Kułakowice I and Poraj.

K_G indices are usually in the range of the mesokurtic interval (0.9—1.0) on the meso- and leptokurtic borderline (1.0—1.5), however, this does not concern the profiles situated in the west part of the area studied, where K_G indices are in the domain of platykurtic systems.

In spatial conditions of LMg sedimentation apparent changes occurred in comparison with the conditions of LMs sedimentation; this is illustrated by Fig. 8. The loess dust transport directions from the NW and N sectors must have predominated then. Such a situation is especially evident in the NE part of the Horodło Grzęda plateau, where the direction of loess dust transport must have been congruent with the direction of the valley axis of the Bug river, and in the southern part of the plateau the transport direction was running along the lower Huczwa river valley. This accounts for a big role of the land relief in the course of the main routes of loess dust transport.

CONCLUSIONS

1. The diagrams of the graining indices are very complicated and one cannot mechanically draw conclusions from them. The granulometric features of loess changed in space and time. The recurrence of some features in concrete stratigraphic horizons can be utilized for diagnostic purposes. These features can be utilized in stratigraphic studies on a regional scale, particularly when using archival geological documentation in which the results of analyses of the mechanical composition are recorded.

Lower younger loess is characterized by the following indices: Mz from 5.79 to 7.07 phi, Md ranges from 5.8 to 7 phi, σ_I is in the range 1.35—2.0, Sk_I varies greatly from symmetrical systems in valley loesses to positively skew ones on the interfluves. Kurtosis shows platykurtic distributions.

Middle younger loess is characterized by the following magnitudes of indices: Mz from 4.5 to 7.3, Md from 4.5 to 6.5 (phi), σ_I from 1.2 to 2.1, Sk_I in the lower part shows distributions positively skew passing upwards into positively very skew ones. K_G points to platy- and mesokurtic distributions with characteristic oscillations towards lepto- and very leptocurtic distributions.

Upper younger loess is characterized by the following indices: Mz from 4.5 to 6.2 phi, Md in the range 4.5—6.6 phi, σ_I from 1 to 2, Sk_I positively very skew, K_G within the range of mesokurtic distribution or on the borderline of meso- and leptokurtic distribution.

2. In the Vistulian loess the grain diameter and graining degree at a relatively little variable skewness index increase towards the profile roof. The graphical kurtosis changes one-way from platykurtic distribution in LMd to mesokurtic in LMg. A distinct spatial variability of graining is also observed. The coarsest grains occur on the peripheries of the loess patch, particularly in the vicinity of the valleys. The finest grains are found in loesses of the central part of the interfluve.

3. The results of studies seem to indicate that dust deposits from the direct neighbourhood underwent deflation. They were transferred at short distances and deposited on slopes and interfluves. The directions of loess dust transport were differentiated in successive Vistulian periods. During sedimentation LMd material must have come from river valleys and blown away sediments from the highest elevations of land relief. The transport directions in those days were variable and it is difficult to say which one predominated. During accumulation of LMs, NE and E directions predominated in the spatial system, whereas NW and N directions rather during LMg sedimentation.

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STRESZCZENIE

Badania granulometryczne lessów prowadzono na Grzędzie Horodelskiej oraz w obrębie teras plejstoceńskich Bugu i Huczwy. Szczegółowo zbadano 18 profili lessów Vistulianu. Różnowiekowe warstwy tych lessów wyodrębniono według schematu stratygraficznego H. Maruszczaka (1976, 1980, 1985). Obliczono wskaźniki uziarnienia wg R. L. Folka i W. C. Warda (1957): Mz (średnie ziarno), σ_I (odchylenie standardowe od średniej), Sk_I (skośność), K_G (kurtoza graficzna) oraz dodatkowo Md (mediana). Stwierdzono, że wskaźniki granulometryczne mogą stanowić podstawę wydzielania głównych jednostek stratygraficznych lessów w skali regionalnej.

Less młodszy dolny (LMd) cechują wskaźniki: Mz od 5,79 do 7,07 phi; Md od 5,8 do 7 phi; σ_I od 1,35 do 2; Sk_I od układów symetrycznych w obrębie dolin do bardzo skośnych dodatnio na wierzchowinach; K_G o rozkładach platykurtycznych. Less młodszy środkowy (LMs): Mz 4,5—7,3 phi; Md 4,5—6,5 phi; σ_I 1,2—2,1; Sk_I od rozkładów dodatnio skośnych w dolnej części pokładów do bardzo skośnych dodatnio w stropie; K_G ma rozkłady platy- i mezokurtyczne z wahnieniami do rozkładów lepto- i bardzo leptokurtycznych. Less młodszy górny (LMg): Mz 4,5—6,2 phi; Md 4,5—6,6 phi; σ_I 1—2; Sk_I bardzo skośny dodatnio; K_G w granicach rozkładów mezokurtycznych bądź na pograniczu mezo- i leptokurtycznych.

W Vistulianie ulegały deflacji osady z bezpośredniego sąsiedztwa badanych profili, głównie z den dolinnych. Podczas akumulacji LMd nie zarysował się dominujący kierunek przenoszenia pyłów. Podczas sedymentacji LMs zdawały się przeważać kierunki NE i E, natomiast podczas akumulacji LMg — kierunki NW i W.

РЕЗЮМЕ

Исследования проводились на Городельской граде и по террасам рек Буг и Гучва. Детально изучено 18 разрезов лёсса из времени последнего, значит вислинского оледенения. Разновозрастные слои этих лёссов выделялись по стратиграфической схеме X. Марущака (1976, 1980, 1985). Вычислялись показатели гранулометрического состава по Р. И. Фольку и В. Ц. Уерду (1957) : Mz (мера среднего зерна), σ_I (графическое стандартное отклонение), Sk_I (мера асимметрии), K_G (графический эксцесс), а кроме того Md (медяное зерно). Констатировано, что на основе показателей гранулометрического состава можно определять главные стратиграфические единицы лёссового покрова в региональном масштабе.

Лёсс младший нижний (LMd) отличается показателями: Mz от 5,79 до 7,07 ф; Md от 5,8 до 7,0 ф; σ_I от 1,35 до 2,0; Sk_I от симметричного распределения в до-

линах до очень косого положительного на междуречьях; K_G — распределение платикуртичное (индекс 3). Лёсс молодой средний (LMs): Mz 4,5—7,3 ф; Md 4,5—6,5 ф; σ_1 1,2—2,1; Sk_I от распределений положительно косых в нижней части горизонта до очень косых положительно в верхней; K_G — распределения платикуртичные и мезокуртичные с отклонениями к лепто и очень лептокуртичным. Лёсс молодой верхний (LMg): Mz 4,5—6,2 ф; Md 4,5—6,6 ф; σ_1 1,0—2,0; Sk_I очень косы положительно; K_G — в пределах распределений мезоруртичных или на рубеже мезо- и лептокуртичных.

На основании показателей гранулометрического состава сделано попытку определения некоторых динамических условий накопливания лёсса. В период вислинского оледенения лёссовая пыль переносилась из непосредственного соседства исследованных разрезов, главным образом из долинных днищ. Во время накопления LMd не отличались преобладающие направления переноса лёссовой пыли. Для времени образования LMs как преобладающие кажутся направления СВ и В, а для времени LMg направления СЗ и З.