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MORPHODYNAMIC PROCESSES IN THE LIGHT OF AN ANALYSIS OF DIFFERENTAGE ALLUVIAL DEPOSITS IN THE VISTULA VALLEY NEAR PŁOCK*

Comprehensive investigations carried out since 1981 resulted in the presentation of the valley morphogenesis along that section in the late Vistulian and the Holocene (E. Florek et al. 1987). The stages of the valley bottom formation have been presented an a geomorphologic map (Fig. 1). In order to determine structural and textural features, deposits accessible in outcrops were examined and a number of shallow borings were executed, mainly within abandoned channels. The results thus obtained concerned mainly the features of deposits from ceiling series (A. Cichosz-Kostecka et al. 1986). Fig. 2 shows the results. Seven features were considered characterizing three alluvial series: of the late Vistulian the Holocene, and of the present millennium as well as outwash deposits forming the northern slope of the valley.

Feature 1 concerns the dispersion of directions of lamine dip within river sediments of different ages. It indicates the character of the river channel (meandering or braided). And so the outwash deposits the same as river deposits of the late Vistulian and of the latest millennium, were formed by a braided river while Holecene deposits by a meandering river.

Feature 2 concerns the depth of channels preserved on the particular terrace surfaces as well as the degree of their sinuosity. Within the late-Viistulan terrace and in the area formed during the latest millennium those channels are shallow and considerably straightened. The immediate connection with the system of river channels can be observed (Feature 7). Within the Holocene horizon sinuous and deep channels occur. They are accompanied within higher and older terrace levels by straight and shallow overflow channels (of spate waters) dated 5000 years B.P. and less.

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F e a t u r e 3 concerns the lithology of fill in palaeochannels. On the late-Vistulian terrace palaeochannels are filled with gyttja (with accumulations of malacofauna) and a peat cover in the ceiling. Deep Holocene palaeochannels are filled with peat only. Holocene shallow and straight overflow channels lying on higher terrace levels are filled with mineral deposits with an admixture of peat. Similarly filled are also channels preserved on the floodplain formed during the latest millennium (TH-2, Fig. 1).

F e a t u r e 4 shows differences in the degree of rounding of quartz grains of two sand fractions (0.5—0.8 mm and 0.8—1.0 mm) within alluvial series of different ages. The direct influence of acolian processes is reflected here: they were very active in the late Vistulian and brought grains of generally high abrasion into river channels. The concerns particularly the thicker of the two fractions. In the Holocene a supply of better abraded grains of the finer fraction prevails which may mean lower dynamics of aeolian processes (R. Kamińska et al 1986). The transitory period between those two periods was characterized by a quantitative balance of the percentage of best abraded grains in both examined fractions.

F e a t u r e s 5 concerns the composition of heavy minerals in the vertical profiles of channel deposits. Both in outwash deposits and in river deposits sedimented in the late Vistulian there occur great differences in the content of heavy minerals.

This is different in deposits filling Holocene palechannels: going upwards a visible increase of the percentage of minerals resistant to abrasion can be observed and a decrease of non-resistant minerals. This can be best seen while comparing the content of garnets and amphiboles. The fact may be explained by the repeated processing of alluvia in the meandering Holocene river where the situation of the channel is relatively

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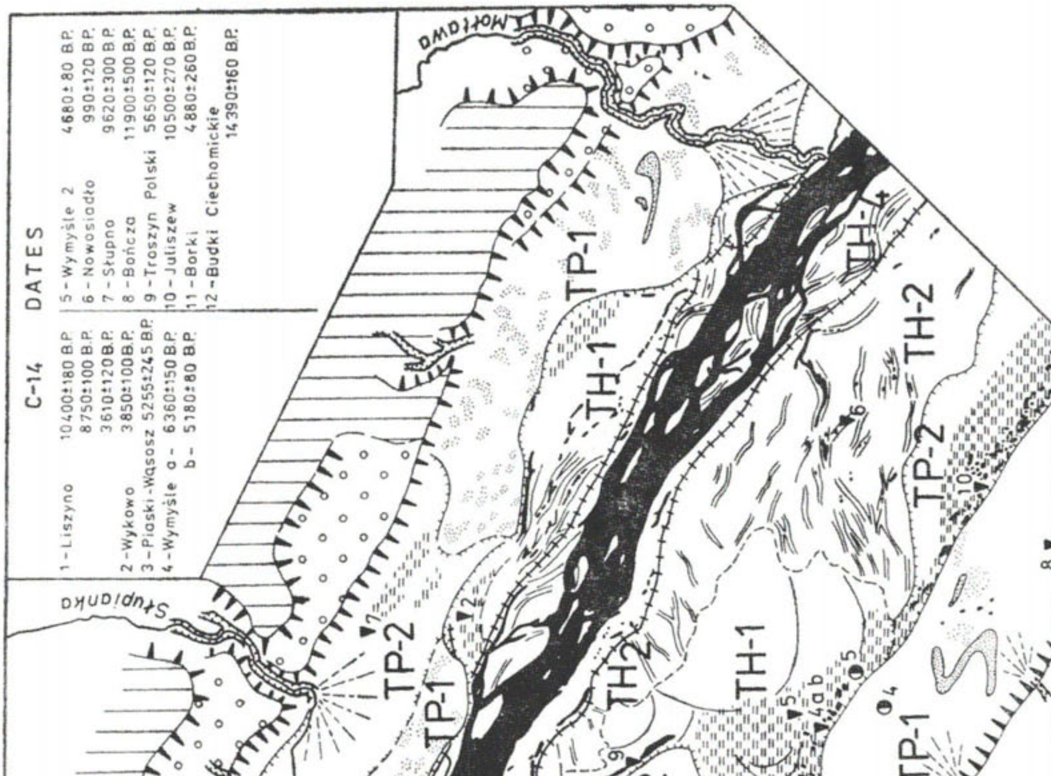
Fig. 1. Situation of the investigated area and geomorphologic map of the Vistula valley from Kępa Polska to Płock (radiocarbon dating nos 2 and 3 after E. Wiśniewski 1985); 1 — morainic plateau, 2 — glacifluvial level, 3 — edges of higher morphologic levels, 4 — esker, 5 — cuts in the valley edge and alluvial cones, 6 — distinct and indistinct edges of terrace levels, 7 — dunes, 8 — aeolian cover sands and irregular dune forms, 9 — traces of crevasse channels, 10 — present-day hydrographic system, 11 — abandoned palaeochannels with present--day peat bog accumulation, 12 — traces of palaeomeanders, 13 — flood banks; TP-0 — oldest Pleistocene terrace, TP-1 — older Pleistocene terrace, TP-2 — younger Pleistocene terrace, TH-1 oldest Holocene terrace, TH-2 — channels and crevasse cones overlaying terrace TP-2 and TH-1, TH-3 — part of Holocene terrace formed during a flood at the beginning of the 20th century, TH-4 — youngest part of Holocene terrace with the activity of the present-day river.


C-14 DATES
1 - Liszyno 10400±180 B.P.
8750±100 B.P.
3610±120 B.P.
2 - Wykowo 3850±100 B.P.
3 - Piaski-Wąsosz 5255±245 B.P.
4 - Wymyśle a - 6360±150 B.P.
b - 5180±80 B.P.
5 - Wymyśle 2 4680±80 B.P.
6 - Nowosiadło 990±120 B.P.
7 - Słupno 9620±300 B.P.
8 - Bończa 11900±500 B.P.
9 - Troszyn Polski 5650±120 B.P.
10 - Juliszew 10500±270 B.P.
11 - Borki 4880±260 B.P.
12 - Budki Ciechomickie 14390±160 B.P.
VISTULA
Słupianka
TH-3
TP-1
TP-2
TH-1
TH-2
0 1 2 km

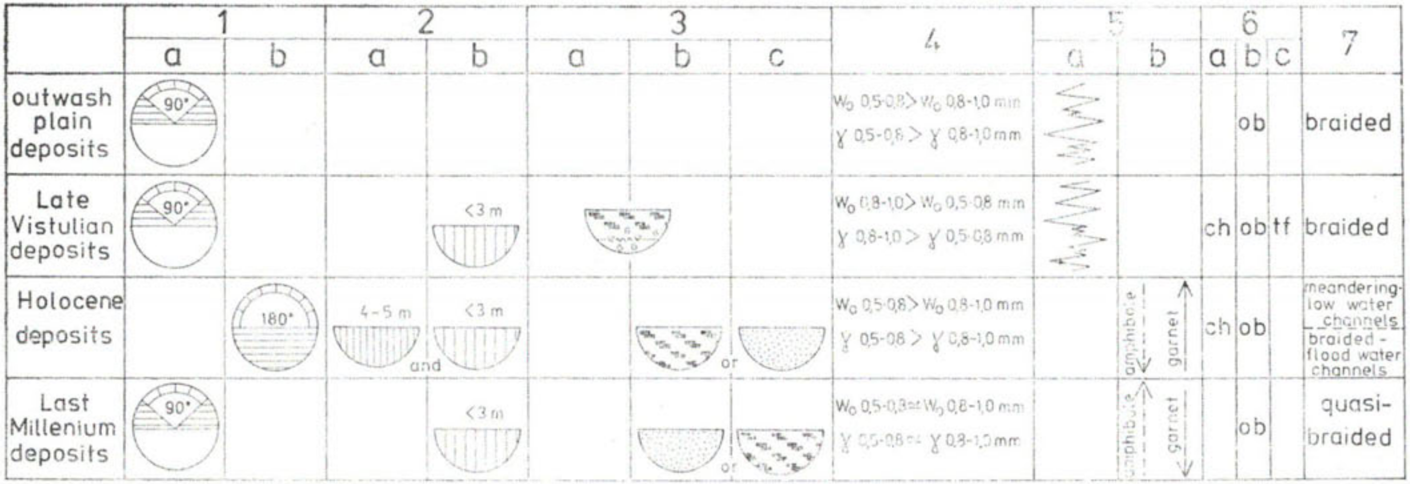


Fig. 2. Slected structural and textural features of deposits in terraces of different ages 1 a — dispersion of directions of lamine dip in the whole series of deposits within the interval $\leqslant 180°$ concentration of directions (60%), interval $\leqslant 90°$, 1b — dispersion of directions of lamine dip—interval $\leqslant 360°$, directions concentration (60%) in the interval of $\leqslant 180°$, 2a — depth of palaeomeanders filled (4—5 m) and 2b — overflow channel (below 3 m), 3a — palaeochannels filled with gyttja containing malacofauna, 3bc — palaeochannels filled with peat or mineral deposit (sand, silt or clay), 4 — abrasion degree of quartz grains (in fractions 0.5—0.75, 0.75—1.0 mm); index of abrasion (W_0 and content of γ group grains, 5a — differences in the mineral and petrographic composition of the sand fractions of channel deposits 5b — direction and character of changes of heavy minerals content (growth or drop in content of resistant minerals--garnets or non-resistant—amphiboles), 6 — prevailing facies of deposits (a — channel, b — extra-channel, c — of palaeochannel fills, d — in alluvial cones of the Vistula affluents, e — prevailing channel system: braided, meandering etc

stable. Such a river acted selectively removing from the sediment minerals less resistant to mechanical abrasion (amphiboles) and enriched it in more resistant minerals (garnets). In a braided river with an unstable channel system there was no repeated processing of alluvia and no mineral selection of deposits.

Feature 6 describes the type of facies recognized in the selected alluvial deposits.

Feature 7 defines the river channel system responsible for the formation of deposits.

In order to complete the above results five borings were executed reaching the floor of alluvial deposits and getting into the ceiling of the underlying Tertiary clays (Fig. 3). The first question to which an answer was sought concerned the relation of the Holocene terrace to the Pleistocene one. Borings carried on where terrace surfaces of different ages contacted showed that the Holocene terrace is an erosive-accumulative form particularly deeply cut in its older part (TH-1, Fig. 1) under the south-west edge of the Pleistocene terrace. During its development the meandering channel of the Holocene river moved to the north-west reducing its depth at the same time. In this part of the valley bottom the floor of alluvial deposits both of the Pleistocene and the Holocene terrace is situated on the same level.

The next question which was to be answered concerned the features of alluvial deposits and their changes in the vertical section. The geological profiles executed were examined in every respect from the point of view of textural features of the deposits. Samples were collected at spaces of 1 m The features of granulation were characterized on the basis of frequency curves and indices of granulation (M_z, δ_1, Sk_1) after R. L. Folk and W. C. Ward (1957). The degree of abrasion of quartz grains was determined in two fractions (0.5—0.8 and 0.8—1.0 mm) using two types of graniformameter (standared and automatic) (see: B. Krygowski 1964) ant Cailleux's method in the version modified by J. Goździk (1980) to determine the degree of matting of quartz grains. Besides, the content of heavy minerals in the fine-sand fraction (0.1—0.2 mm) was also determined and the content of leading minerals has been presented in diagrams. The last of the diagrams shows the percentage of quartz in two fractions (0.5—0.8 and 0.8—1.0 mm).

All results obtained have been presented in diagrams (Fig. 4). As the size of the present paper is limited the text deals only with more important connections and dependence occurring among the results obtained with the use of different methods.

The comparison of granulation frequency curves of alluvial deposits

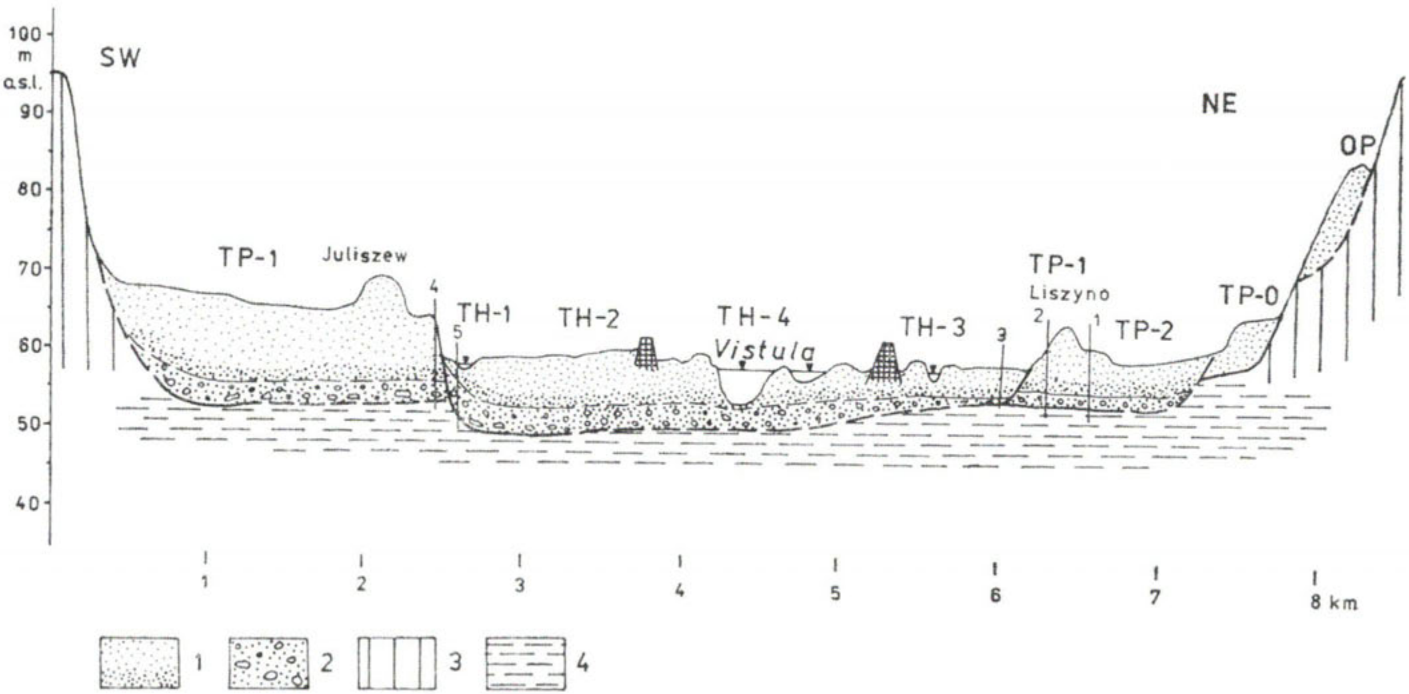


Fig. 3. Simplified geologic cross-section through the deposits of the Vistula valley south of Płock; 1 — sand, 2 — with gravls and pebbles, 3 — clay, 4 — boulder clay.

in the Pleistocene and Holocene terrace has not shown any essential differences. In both cases the structure of curves is multimodal and much the same (Fig. 4).

Instead, we can observe a considerable change of values of granulation indices calculated after R. L. Folk and W. C. Ward's formulas (1957) for the deposits of the Pleistocene terrace (boring n° 4) and the deposits of the Holocene terrace (boring n° 5). In the Pleistocene deposits great differences of granulation features in the vertical profile can be observed. In the Holocene profile (boring n° 5) only below 8 m of depth negative values of the mean diameter of grains (M_z) prevail indicating the coarse grain of the series, high values of standard deviation (δ_1), meaning very poor sorting of deposits in this series, and negative values of the skewness (Sk_1).

The picture of granulation features in alluvial deposits on the north--east side of the Vistula valley (borings nos 1, 2 and 3) is quite different. We can observe here, in the ceiling of deposits forming the Pleistocene terrace, a considerable admixture of aeolian grains (in the secondary deposit). It is the decisive reason why the deposits of the series are fine--grained, well-sorted and have a positively skew particle distribution. The fine-grained deposits are underlaid only by a 2—3 m thick series of channel deposits which are coarse-grained, poorly sorted and have a negatively skew particle distribution. The features of deposits forming the Holocene terrace are similar, the only difference being that negative skewness occurs in the whole vertical profile.

The degree of abrasion of quartz grains was determined within two sand fractions (0.5—0.8 and 0.8—1.0 mm) with the use of two types of graniformameters: standard and automatic. The additional aim of using both types was to state the degree of conformability of results obtained using different types of graniformameters. The results were highly conformable but in both fractions the values of the abrasion index (W_o) are somewhat lower when the automatic graniformameter is used (by 17—32 units on the average) while the content of grains of group γ, the best abraded, is, in that case, higher (averagely 2—3%).

The degree of abrasion determined using the graniformameter should be considered together with the results of the analysis of the abrasion and matting degree executed according to Cailleux's method modified by J. Goździk (1980). The higher degree of grain abrasion and matting in fraction 0.5—0.8 mm in Pleistocene alluvia is particularly well visible on the south-west side of the Vistula valley. At the same time, we can observe in the whole profile (boring n° 4) a great part of non-obraded grains, which is particularly strongly marked in the roof of the deposits. The content of amphiboles increases considerably in this part of the profile while the content of garnets decreases.

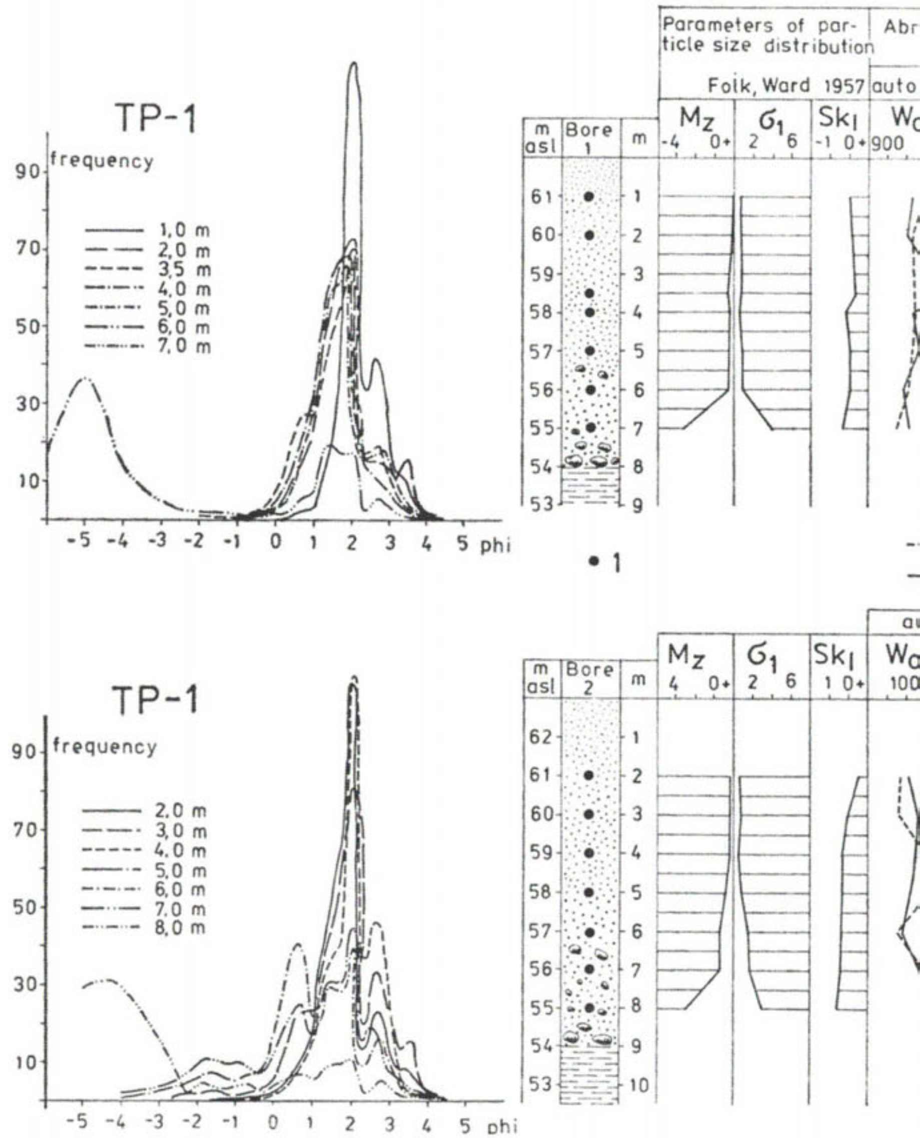
The results presented prove that a great part of quartz grains in the alluvia of the Pleistocene terrace underwent earlier aeolian abrasion (especially fraction 0.8—1.0 mm) and also that there was a considerable inflow of fresh waste material from glacial covers forming the West edge of the valley. In the profile under investigation the supply of this material is particularly well visible in the ceiling of the series.

Within the oldest part of the Holocene terrace-TH-1 (Fig. 1 and 4) boring n° 5 was executed. The profile of deposits and the results of analyses reveal three levels with different features of quartz grain abrasion, of their surface matting and heavy minerals contents. The coarse-grain floor series (6—10 m) contains more abraded grains in fraction 0.8—1.0 mm than in fraction 0.5—0.8 mm (both in values of the abrasion index W_0 and in the content of γ-type grains) while the part of mat grains (RM and EM) is small and smoothed polished grains (EL) prevails. In this series, too, numerous non-abraded grains occur and among heavy minerals the content of amphiboles is higher.

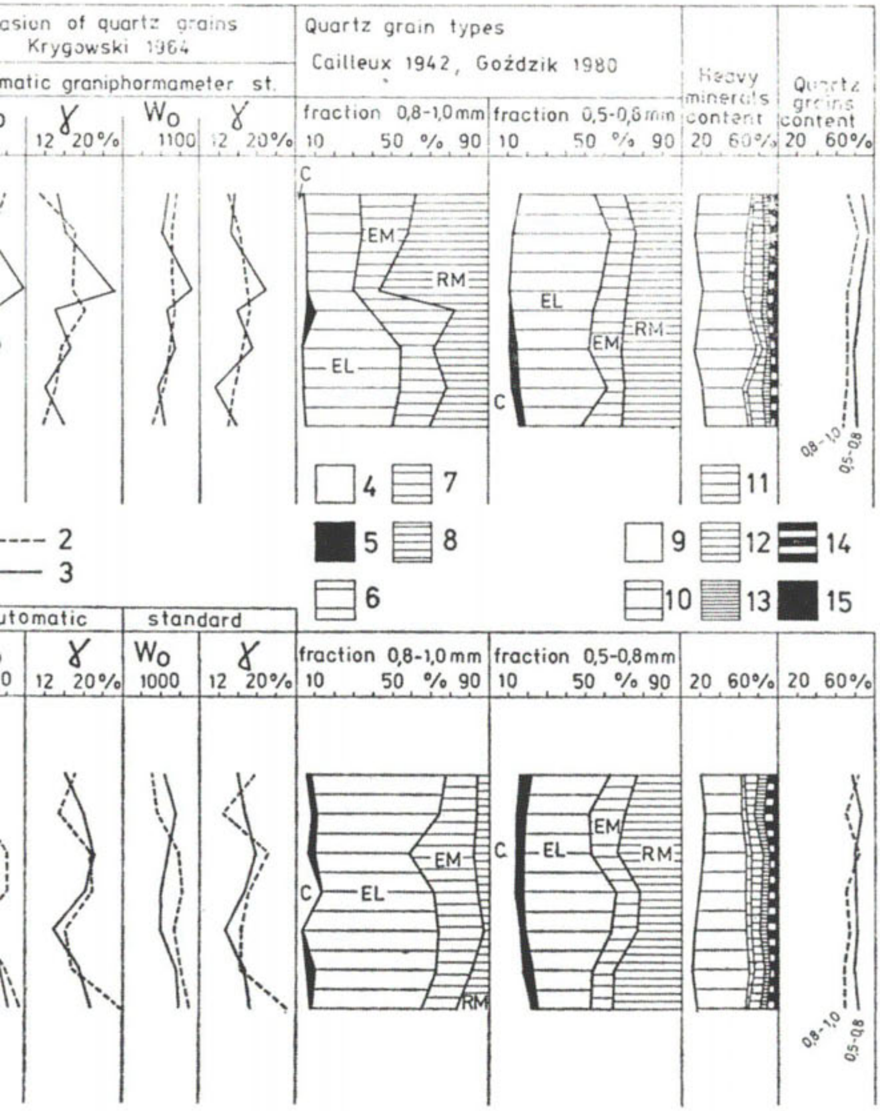
The comparison of those results seems to show that the Holocene lower sand-gravel-pebble series was formed both of the washed-away older alluvial series of the Pleistocene terrace (it can be proved, among others, by the petrographic composition of gravels and pebbles) and of the erosion of the Tertiary substractum. In this area Teritiary deposits have a reservoir origin and, as a rule, they are characterized by a predominance of rounded polished grains (EL) (J. Goździk, E. Mycielska-Dogiałło 1988). The gathered data seem to indicate that the lower series of the Holocene terrace was formed while bottom erosion of the substratum prevailed.

The middle series (4—6 m) is a typical alluvial deposit of a Holocene river of the channel bar facies. Fine-sand deposits prevail here, they are well sorted with better rounded grains in the finer fraction (0.5—0.8 mm) than in the coarser fraction (0.8—1.0 mm) and with a large content of mat grains (RM, EM) in the finer fraction which means an inflow of quartz grains with earlier acolian abrasion. The prevalence of the finer fraction indicates acolian processes in the Holocene period.

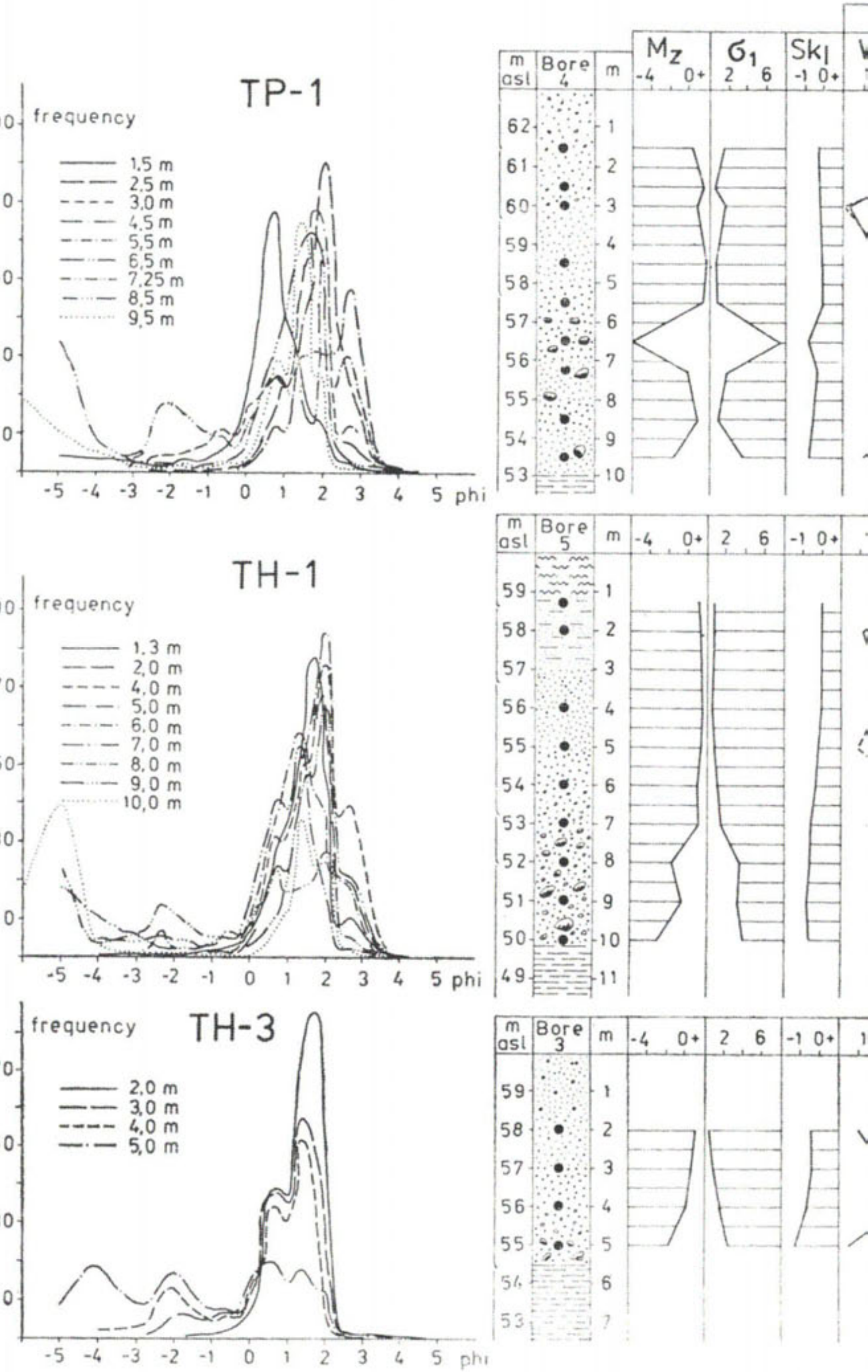
The ceiling series (1.2—2 m) is a series of the spate facies. It has a generally higher content of rounded and mat grains alternately in the coarser and finer fraction. The higher content of rounded mat grains at 2 m of depth is accompanied by a higher content of amphiboles. It

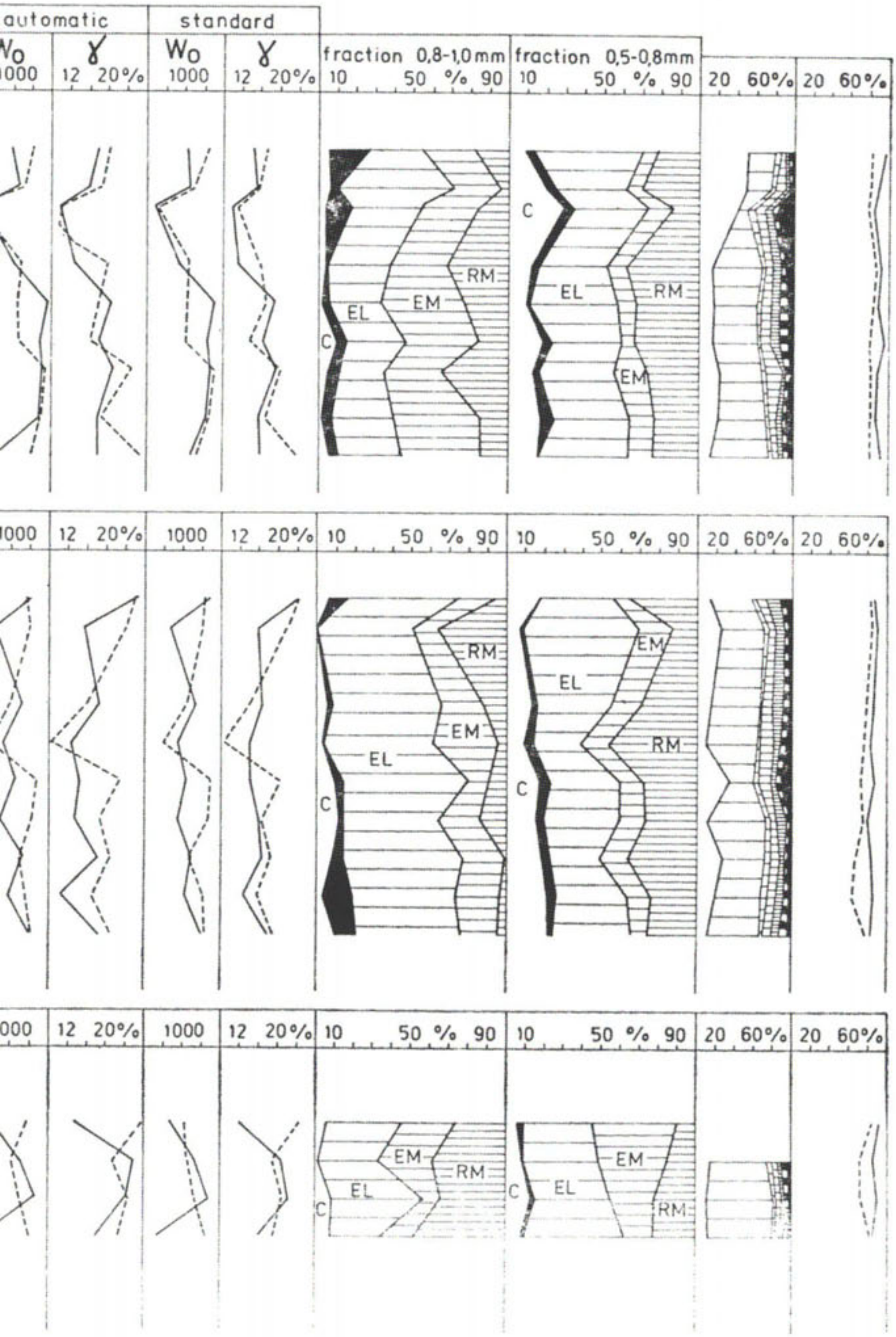


TP-1
frequency
1,0 m
2,0 m
3,5 m
4,0 m
5,0 m
6,0 m
7,0 m
phi
Parameters of particle size distribution
Folk, Ward 1957
m asl
Bore 1
m
M_Z
σ_1
Sk_I
• 1
TP-1
frequency
2,0 m
3,0 m
4,0 m
5,0 m
6,0 m
7,0 m
8,0 m
phi
Bore 2



asion of quartz grains
Krygowski 1964
matic graniphormameter st.
Quartz grain types
Cailleux 1942, Goździk 1980
Heavy minerals content
Quartz grains content
fraction 0,8-1,0 mm
fraction 0,5-0,8 mm
Wo
γ
12 20%
1100
10 50 % 90
20 60%
C
EL
EM
RM
0,8-1,0
0,5-0,8
4
5
6
7
8
9
10
11
12
13
14
15
2
3
utomatic
standard
1000


TP-1
frequency
1,5 m
2,5 m
3,0 m
4,5 m
5,5 m
6,5 m
7,25 m
8,5 m
9,5 m
phi
TH-1
frequency
1,3 m
2,0 m
4,0 m
5,0 m
6,0 m
7,0 m
8,0 m
9,0 m
10,0 m
phi
TH-3
frequency
2,0 m
3,0 m
4,0 m
5,0 m
phi
m asl
Bore 4
m
Mz
σ1
Skl
Bore 5
Bore 3



automatic
standard
Wo
γ
1000
12 20%
fraction 0,8-1,0 mm
fraction 0,5-0,8 mm
10 50 % 90
20 60%
C
EL
EM
RM

cannot be excluded that it is the effect of side erosion of the Holocene channel and of the inflow of the alluvial material from the undercut Pleistocene terrace.

The varying percentage of quarts in aluvia (Fig. 4) seems to coincide with changes of the content of aeolically abraded grains. The increasing part of rounded mat grains coincides with the growth of the quartz content in a given fraction. At the same time, the content of quartz is lower in fraction 0.8—1.0 mm than in fraction 0.5—0.8 mm in all investigated profiles.

The results of analyses of alluvial deposits in the younger parts of the Pleistocene and the Holocene terrace surfaces on the right, north--eart side of the Vistula valley (borings nos 1, 2, 3) should be considered separately. The features of alluvial deposits in this part of the valley are due to outwash deposits forming the edge of the valley and to aeolian deposits overlaying the surface of the Pleistocene terrace. In boring n° 1 executed in the roof of the Pleistocene terrace (TP-1) a considerable admixture of aeolian material can be observed in the deposits down to the depth of 3.5 m. It concerns particularly fraction 0.8—1.0 mm. The increared content of round and rounded mat grains in this fraction means that during the accumulation of the investigated alluvial series there acted aeolian process caused by strong winds. Judging by the age of fossil soils occurring in the overlaging dune (R. Kamińska et al. 1986) we may suppose that the ceiling of the alluvial series, enriched in aeolian deposit, was formed in the older Dryas or in the preceding period.

Boring n° 2 executed near the edge of the Pleistocene terrace (Fig. 3) cuts through deposits which differ from those described above. The abrasion degree of quartz grains in fraction 0.8—1.0 mm (graniformametric analysis) is benerally higher and in almost the whole profile this fraction contains a very small quantity of mat grains and a large ammount of rounded polished grains. Instead mat grains are much more numerous in the finer fraction (0.5—0.8 mm). It cannot be excluded that it is a cross-section through a younger part of the Pleistocene terrace accreted laterally with the older terrace and formed between the close of the Vistulian and the Holocene. Investigations carried on in an overlaying dune at Liszyno (R. Kamińska et al. 1986) have shown that the dune series of that age are characterized by the approximately balanced quantity of group γ grains in both fractions (0.8—1.0 and 0.5—0.8 mm). It seems to prove that the dynamics of aeolian processes was decreasing from the close of the Vistulian to the Holocene.

Boring n° 3 was done directly at the foot of the Pleistocene terrace in the younger part of the Holocene terrace (TH-3). In both sandy fractions grains with earlier aeolian abrasion prevail (RM and EM grains). At the same time, garnet dominates ammong heavy minerals as it is most resistant to mechanical abrasion. The considerable likeness of features of alluvial deposits in the Holocene terrace and in the Pleistocene terrace lying higher seems to prove the great influence of lateral erosion processes and the participation of older alluvia in the formation of the younger alluvial cover.

The results of investigations presented above allow us to conclude that the features of alluvial deposits are influenced both by processes integrally connected with the river dynamics (bottom and lateral erosion, etc.) and by accompanying processes (aeolian weathering, slope processes, etc.). The effects of those processes overlap and only the use of a whole complex of investigative methods of the sphere of sedimentology can gives results permitting to form conclusions on processes prevailing in the period of accumulation of the particular depositional series. Indirectly it also makes possible the evaluation of climate and local conditions affecting the investigated alluvial deposits.

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