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EVIDENCE OF STRONG AEOLIAN ABRASION IN FLUVIAL DEPOSITS IMMEDIATELY BEFORE THE ODRIAN ICE SHEET ADVANCE IN AN AREA OF THE MIDDLE VISTULA RIVER

Abstract

In Central Poland, in addition to earlier investigated two series of fluvioperiglacial deposits preceding the Wartian (Saalian II) and Vistulian (Weichselian) ice sheet advance, the third series accumulated before the Odrian (Saalian I) ice sheet transgression has been identified. Its stratigraphic position is best recognized in the middle Vistula River valley. This valley section was situated in the area covered by the Odrian ice sheet, and then behind the Wartian ice sheet extent. Here, fluvial deposits underlying Odrian tills were studied at sites: Dębno, Puławy-Włostowice and Zwoleń. These are characterized by the very high content (up to 80–90%) of round mat grains. This testifies that grains were transported long term by the wind which afterwards supplied them to valleys in severe, continental periglacial environment. Thus, in the formation of fluvioperiglacial deposits preceding three succeeding transgressions of Scandinavian ice sheets (Odrian, Wartian, Vistulian) aeolian processes played a particularly important role.

INTRODUCTION

In Central Poland, under periglacial conditions, aeolian processes played a significant role in the formation of relief and deposits (CAILLEUX, 1942; DYLIKOWA, 1967; DYLIK, 1969; MARUSZCZAK, 1968, 1995; MANIKOWSKA, 1966, 1985; GOŹDZIK, 1981, 1991). Their effects have been recognized most fully for the last glacial cycle (= Vistulian), especially as typical aeolian forms – dunes, and as deposits – loesses, dune sands and cover sands. Quartz grains of the sand fraction, as they travelled in the wind, became distinctly rounded and matted (CAILLEUX, 1942). In Central Poland, such grains are dominant in aeolian deposits (DYLIKOWA, 1967; DYLIK, 1969; GOŹDZIK, 1981, 1991, MANIKOWSKA, 1985). They however are also present in deposits of other genesis, e.g. in fluvial. Thus examinations of such grains are of great importance in determining the phases of intense aeolian activity during the Pleistocene

Loess deposits with soil horizons in between have been considered a source of information about the phases of Pleistocene aeolian activity in cycles over a long time (MARUSZCZAK, 1995). Unlike loess, aeolian sandy

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deposits rarely form covers which represent different glacial cycles. That deposited during one cycle material was often eroded while its grains – incorporated in deposits of other provenance. Thus the occurrence of aeolian sandy deposits older than the Vistulian is relatively uncommon (GOŹDZIK, 1992).

In a periglacial realm, aeolian processes often interfinger with fluvial processes (e.g. GOOD, BRYANT, 1985; VAN HUISTEDEN, 1990; GOŹDZIK, 1991; ASHLEY, HAMILTON, 1993). During intensive wind action, the large amount of sand reaches river channels and undergoes fluvial transportation and deposition. Alluvium of such periods contains quartz grains with well preserved shape and texture of wind-abraded surfaces (Goździk, 1980, 1991, 1995a) because the changes of these features in fluvial environments are exceptionally slow (CAILLEUX, 1942; KUENEN, 1960; LINDE, MYCIELSKA-DOWGIAŁŁO, 1980). Due to this, layers in alluvia with the significantly larger amount of round mat grains point to intense aeolian processes, which can be synchronous with alluvial sedimentation. Such alluvium, collected in deeper valleys, survives better than covers of aeolian sands situated hypsometrically higher.

At the outcrops of the Bełchatów opencast mine, within over 200 m thick Quaternary deposits, two series of river deposits about 30 m thick clearly reveal the upwards increasing number of round mat grains (RM) and the decrease of polish abraded grains (EL). The first cycle of the changes in grain properties, related to the growing intensity of aeolian processes, directly preceded the Wartian ice sheet advance, the second cycle took place in the Upper Plenivistulian period. The content of round mat grains in fluvial deposits, especially in their middle and upper members, is appreciably higher than in all glacial and glaciofluvial deposits in the mine, thus their main source deposits. The changes in the content of particular grains in river deposits coincide with the changes of other lithologic properties. Both features have provided some basis for the conclusion that the aggradation of alluvium took place under conditions of the increasing continentality of a periglacial climate and the growing role of aeolian processes (GOŹDZIK, 1980, 1991, 1995a, b).

The regularities like in Bełchatów also appear in Central Poland within the range of the Wartian ice sheet. However only occasionally the whole profile of fluvial series was sampled, which allowed to investigate the growth of aeolian processes throughout a cycle. More often were available only samples from upper sections of series, from the period of the maximum concentration of round mat grains, thus from the period of the well pronounced differences between grains of river deposits and glacial and glaciofluvial deposits (GOŹDZIK, 1995a).

A study of glacial and glaciofluvial deposits from succeeding glaciations, in the area of Central Poland, beyond the Wartian ice sheet range, shows the content of RM grains from 25 to 40%, exceptionally to 55%,

while EL grains – 15 to 30%, exceptionally to 40% (GOŹDZIK, 1986, 1991; BARCICKI *et al.* 1991 and own unpublished data).

Recent research conducted beyond the Wartian ice sheet extent, in the middle part of the Vistula drainage basin, shows that river deposits contain distinctly more wind-abraded grains than glacial deposits. The findings provide new essential data for the determination of palaeogeographical conditions under which the glacial cycle in Central Poland developed as well as enable verification of previous views on the origin and stratigraphy of sandy deposits known from geological cross-sections to be made. The higher content of wind-abraded grains in fluvioperiglacial deposits is a feature which differs them not only from fluvioglacial but also from fluvial deposits of interglacial periods.

AN APPROACH TO THE GRAIN SHAPE STUDY

Outlines of quartz grains produced in natural conditions are generally far from regular geometric figures. Thus there can be difficulty in describing them with one definition. Usually three aspects of a shape are considered: 1) surface texture, 2) roundness, 3) sphericity. It may be added that some distinguish also a form (BLATT, MIDDLETON, MURRAY, 1980). Geologically, the first two properties are important, and will be discussed in the present work. Various methods have been used to determine surface texture and roundness of grains. In choosing a method, we have used the criterion of frequency of application, and therefore possibility of comparying the results.

The quartz grains of the 0.8–1.0 mm fraction, from samples taken in the field, were analysed using three methods: 1) the morphoscopic A. CAILLEUX method (1942) modified by J. GOŹDZIK (1980); 2) the determination of the roundness index after W. C. KRUMBEIN (1941); 3) the graniformametric method after B. KRYGOWSKI (1964). Since no mentioned method fully characterizes roundness and surface texture, we regard them as being complementary (GOŹDZIK 1995b).

The idea of the A. CAILLEUX method modification is that: a) into the RM (round mat) group – distinctly wind-abraded grains – have been fitted only those whose roundness index by the KRUMBEIN scale is ≥ 0.7; b) the NU (non used) and EL (polish abraded – modelled in water environment) groups have remained unchanged; c) an additional EL (abraded transitive) group – abraded but being neither typical RM nor EL grains – has been introduced.

Recently, in determining the roundness index, by comparison with a visual chart, the M. C. POWERS method (1953) is more common than the W. C. KRUMBEIN method (1941). Nevertheless the later has been applied because it allows to make a better distinction between more rounded

grains, frequent in aeolian and river deposits of Central Poland. Tables and figures present only mean values, calculated for about 100 grains. The increase of the index within the range of 0.1 to 0.9 indicates the higher degree of roundness.

Among the grains studied on the B. KRYGOWSKI'S graniformameter, mainly the γ class (well-abraded grains), which shows the high degree of roundness, was analysed.

STUDY AREA AND ANALYSED SITES

As yet, in Poland, well pronounced aeolian marks on quartz grain surfaces of fluvioperiglacial deposits have been recorded in layers preceding the advance of the last (Vistulian) ice sheet (GOŹDZIK, 1981, 1991; STANKOWSKI, KRZYSZKOWSKI, 1991), and of the one before last i.e. Wartian (GOŹDZIK, 1980, 1992; KRZYSZKOWSKI, 1990). It thus seemed worth carring out similar studies for fluvioperiglacial deposits of the previous ice advance which in Central Europe reached a maximum limit in the Odra valley. However the latest results of investigations in the Odra drainage basin show that extents of Middle Polish ice sheets (Saalian) – i.e. Wartian and Odrian – accepted so far, will probably require revision, at least within the Trzebnica Hills. The authors of newly published sheets of the Detailed Geological Map of Poland 1:50 000 suggest that glaciotectonic deformations of the Trzebnica Hills date back to South Polish glaciations (Elsterian) and overlying tills are of Odrian age (WINNICKI, 1990, 1997; WINNICKI, SKOMPSKI, 1991). Others are of the opinion that it is an area where besides Odrian moraines occur those of Wartian age (KRZYSZKOWSKI, 1993; CZERWONKA, KRZYSZKOWSKI, 1997).

In that respect, the situation in the middle Vistula valley is surely more clear. From the latest chronostratigraphic study it follows that the Odrian ice sheet reached here the San mouth near Sandomierz, and the Wartian ice sheet – the Wieprz mouth near Dęblin (vide POŻARYSKI, MARUSZCZAK, LINDNER, 1994, 1995). This is in full agreement with geological and geomorphological analyses of the occurrence of Pleistocene deposits in the uplands eastwards and westwards of the middle Vistula valley. The valley itself contains the thick series of river deposits that date back to the period prior to the last ice advance in this area, i.e. the Odrian ice sheet (vide Fig. 1).

At first we chose three well known sites from the middle Vistula valley (POŻARYSKI *et al.* 1994) to study – Sandomierz, Dębno and Puławy-Włostowice (Fig. 1). Fluvial deposits beneath Odrian till at the Sandomierz site appeared however too poor in a sandy fraction; they did not have sufficient grains of the 1.0–0.8 fraction to study. To two sites that satisfied

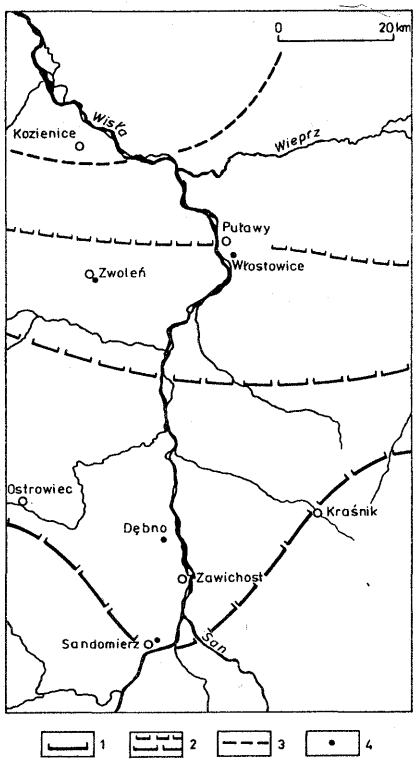

Fig. 1. Location map of studied sites against the extents of Odrian and Wartian ice sheets in the middle Vistula drainage basin; the extents after POŻARYSKI, MARUSZCZAK, LINDNER (1995)

1. maximum Odrian stadial; 2. two post-maximum Odrian stadials; 3. maximum Wartian stadial; 4. sites studied and discussed in the text

our requirements we thus added the archaeological locality "Zwoleń" (SCHILD, 1988) at which fluvial deposits rest immediately beneath Odrian till.

Dębno site. At this site, the thick series of fluvial deposits underlies two rather thin till horizons that W. POŻARYSKI (1953) related to two ice sheet advances different in age. The latest chronostratigraphic study as well as lithologic-sedimentologic analyses of melt-out tills and sandy deposits separating them have shown that both of them represent one glacial cycle (vide Fig. 2). A fuller discussion of the stratigraphic interpretation and the description of the site are given in POŻARYSKI *et al.* (1994, p. 23–25).

At the bottom of the Dębno profile (Fig. 2) there are sandy-gravelly fluvial deposits that used to be dated back to the Zbójno interglacial (POŻARYSKI, MARUSZCZAK, LINDNER, 1994). Our investigations have shown

that the deposits contain the very large amount of round mat grains (ca 80%). That fact testifies to intense aeolian processes synchronous with accumulation of these river deposits. The lack of organic intercalations is also the case for severe periglacial conditions of the accumulation; thus the discussed deposits were produced immediately before the Odrian ice sheet advance. Stratigraphically, one should include them to the Odrian glacial cycle.

Two till horizons at the Dębno site (Fig. 2) are related to subsequent, stadial or phasal, Odrian ice sheet advances. The sandy-silty series between these has been perhaps due to fluvioperiglacial sedimentation of

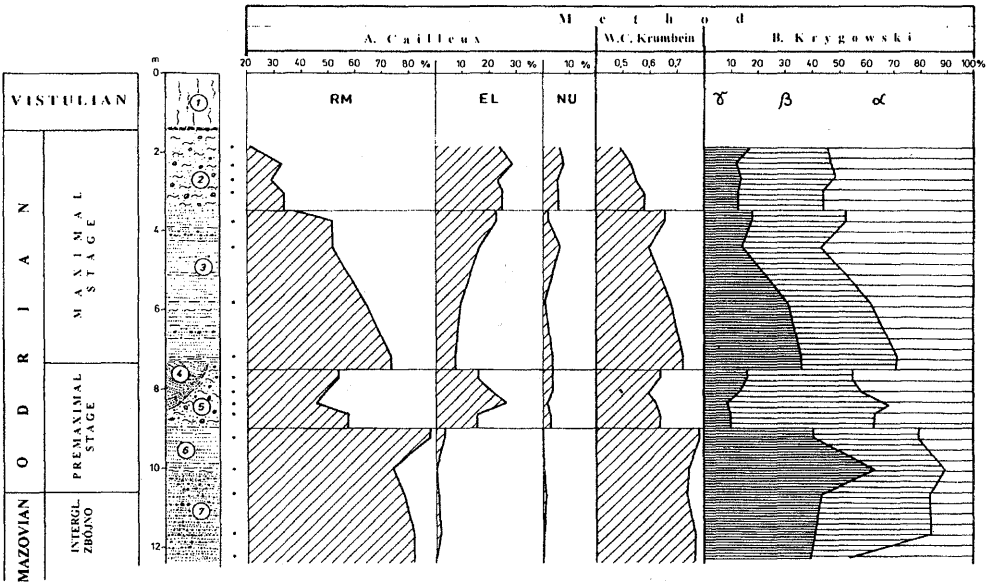

Fig. 2. Quartz grain shape and surface texture in deposits of the Dębno site. Lithological profile after H. MARUSZCZAK (POŻARYSKI , MARUSZCZAK, LINDNER, 1994, p. 24)

1. loess; 2. upper melt out till; 3. sands, silty sands and sands with gravels; 4. sands and sands with gravels with foreset stratification; 5. lower melt out till; 6. sands and silty sands, sands with gravels

material produced by erosion of the underlying alluvia, which would explain the very high content of RM grains at the bottom. Gradually, however, as the ice sheet recurred, the supply of glacial material was greater, and the content of EL grains distinctly increased. It is characteristic that there are significantly more round mat grains in the lower till horizon contacting directly fluvioperiglacial deposits. Whereas the upper till horizon, isolated from strongly wind-abraded grains of alluvia with deposits poorer in them, contains less – almost by a half – RM grains than the lower horizon.

The wrong tendency to relate the accumulation of almost all river deposits registered in the Pleistocene profiles of Polish Lowland to interglacial periods has been already stressed (GOŹDZIK, 1987). Observations in large excavations in Central Poland show that the series of river deposits accumulated mainly under periglacial conditions (GOŹDZIK, 1980, 1995a; KLATKOWA, ZAŁOBA, FORYSIAK, 1996). The Dębno case has raised the question whether it would not be wise to revise the criteria used to classify some alluvia, considered to be of an interglacial age, in the uplands of south Poland as well.

Puławy-Włostowice site. The thick series of fluvial deposits rests here directly below melt-out till (Fig. 3). Near the site this till is covered by classical glacial drift of the significant thickness (POŻARYSKI, MARUSZCZAK, LINDNER, 1994, p. 29, Fig. 10). The chronostratigraphic study of both this site and neighbouring ones – near Parchatka and in Puławy-Mokradki – has shown that the whole thick series of glacial deposits dates back to the Odrian ice sheet advance. Layers of fluvial deposits directly beneath contain a quite considerable admixture of dust fractions, as in Sandomierz. Therefore, a part of samples taken in 1993 was practically worthless for quartz grain analyses. More details on the site are given in the cited work (POŻARYSKI, MARUSZCZAK, LINDNER, 1994, p. 29–31). Fluvial deposits underlying Odrian till at the Puławy-Włostowice site are distinguished by – as at Dębno – the large content of wind abraded grains (RM), up to 80% (Fig. 3).

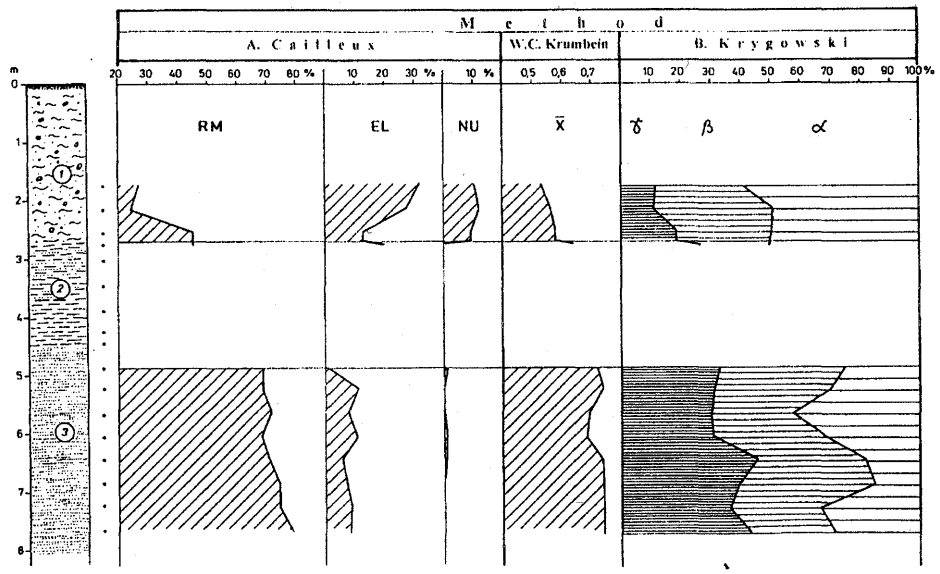

Fig. 3. Quartz grain shape and surface texture in deposits of the Puławy–Włostowice site. Lithological profile after H. MARUSZCZAK (POŻARYSKI , MARUSZCZAK, LINDNER, 1994, p. 24)

1. melt out till; 2. dammed silts with sandy intercalations; 3. sands and sands with gravel layers

The synchronousness of the discussed fluvial deposits – directly underlying Odrian till in Sandomierz, Dębno and Puławy-Włostowice – is confirmed not only by the chronostratigraphic data. It should be stressed that they represent one sedimentation cycle of the infilling of the Vistula valley caused by the ice sheet advancing from the north. This is clearly documented on the longitudinal profile of Pleistocene deposits of this valley (POŻARYSKI, MARUSZCZAK, LINDNER, 1994, Fig. 18, p. 42). Also, our findings give evidence of the same time of their formation. From the obtained results, it follows that in Dębno and Puławy-Włostowice, at least the upper layers of thick fluvial series underlying Odrian tills accumulated under severe periglacial conditions.

In Puławy-Włostowice, where the thickness of till resting on fluvioperiglacial deposits is larger than in Dębno, merely the bottom of the horizon is distinctly enriched in round mat grains (Fig. 3). This case is analogous to the regularity registered in profiles of the Bełchatów mine in Wartian till, whose immediate substratum are fluvioperiglacial deposits (GOŹDZIK, 1992; BARANIECKA, GOŹDZIK, ZIOMEK, 1994). The enrichment of the till bottom in grains similar to these reported from alluvia was considered to be due to the "collection", as an ice sheet advanced, of material from fluvioperiglacial deposits and its incorporation in a basal till.

Zwoleń site is located in the west of the middle Vistula valley (vide Fig. 1). We performed there the study in 1989 at the archaeological site investigated by a team led by Professor R. SCHILD, (SCHILD *et al.* 1988); our work was continued in 1993. The archaeological site is situated on the N exposed slope of the Zwolenka river valley, 1 km ESE of the Zwoleń town centre. Near the exposure with Palaeolithic artefacts, there are melt out till and fluvial sands beneath. Since no more detailed documentation of the site is available, we give a simplified version of the cross-section of the Zwolenka valley-side in the vicinity of the archaeological site, after the work by H. MARUSZCZAK (1992, Fig. 4).

Fluvial sands underlying Odrian tills in Zwoleń reveal the high content of round mat grains (to 80%), and the minimum content of polish abraded grains (Tab. I). Therefore our original view on their provenance, viz. being fluvioglacial deposits (vide Fig. 4, layers "2"), needs to be changed now. As with both the Dębno site and Puławy-Włostowice site, we thus can interpret them as fluvioperiglacial deposits.

It should be noted that in Zwoleń the content of round mat grains in Odrian alluvia is considerably higher than in Vistulian alluvia (Tab. I). However the differences seem to be a feature of the regional extent. Over the wast area, west of Zwoleń, the content of round mat grains at the top of Vistulian alluvia is higher than in Zwoleń and similar to this in pre-Wartian alluvia.

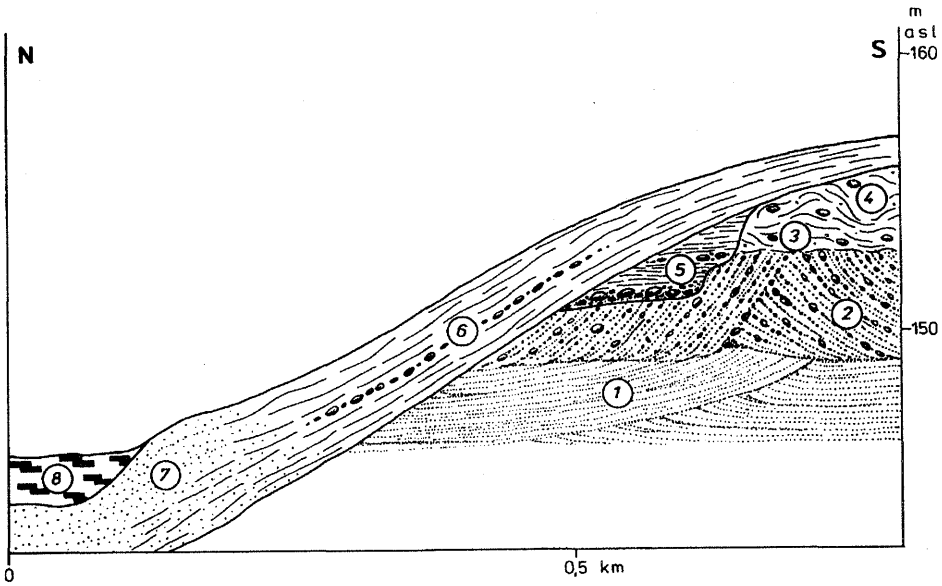

Fig. 4. Simplified geological section of the Zwolenka river valley-side in the vicinity of the archaeological site "Zwoleń" (after MARUSZCZAK 1992)

1–4. deposits of Odrian glaciation age: 1. fluvioperiglacial sands; 2. fluvioglacial sands; 3. flow till; 4. massive till; 5. deposits of Wartian glaciation age, different in origin; 6. Vistulian slope deposits; 7. Vistulian river deposits; 8. Holocene alluvia and organogenic deposits

Table I

Sediment	Method after							
	A. Cailleux				W.C.Krumbein	B. Krygowski		
	% RM	% EL	% NU	% ET	mean	% γ	% β	% α
Odrian till s. 1	43,4	28,3	9,1	19,2	0,60	26,3	40,4	33,3
„ s. 2	41,9	38,7	1,6	25,6	0,61	19,4	40,3	40,3
„ s. 3	48,6	26,2	4,6	20,6	0,63	20,6	32,8	46,6
„ s. 4	45,5	25,5	6,4	22,7	0,58	24,5	35,5	40,0
„ s. 5	36,9	25,4	5,7	32,0	0,56	13,9	69,7	16,4
„ s. 6	46,0	26,0	6,0	22,0	0,63	17,0	45,0	38,0
„ s. 7	37,1	32,5	4,0	27,4	0,57	22,6	30,6	46,8
Odrian alluvium s. 1	71,0	6,5	-	22,5	0,72	22,5	43,0	35,5
„ s. 2	80,3	2,2	-	17,5	0,75	17,6	40,0	42,4
„ s. 3	88,9	0,7	-	10,4	0,77	51,8	31,8	16,4
„ s. 4	81,2	2,9	-	15,9	0,75	46,4	27,5	26,1
Vistulian alluvium s. 1	62,4	7,1	-	30,5	0,68	24,7	24,1	48,2
„ s. 2	51,6	6,4	-	42,0	0,65	22,6	38,7	38,7
„ s. 3	53,0	3,0	-	44,0	0,64	14,4	35,6	55,0
„ s. 4	55,9	5,3	-	38,8	0,64	20,2	31,5	48,3

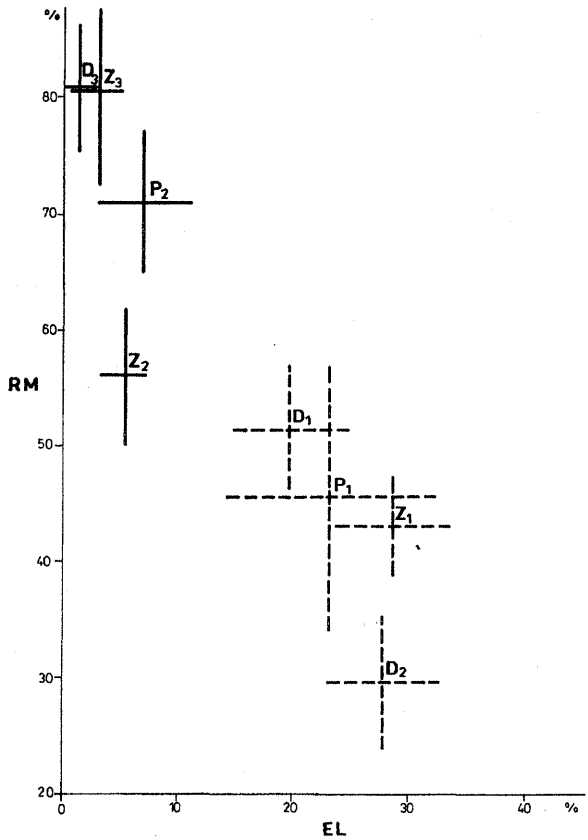

Fig. 5. Mean content of round mat (RM) and polish abraded (EL) grains – with standard deviation marked: a – in Odrian fluvioperiglacial deposits at: Dębno (D_3), Puławy-Włostowice (P_2), Zwoleń (Z_3); b – in Vistulian alluvia at Zwoleń (Z_2); c – in Odrian tills at: Dębno lower till (D_2), upper till (D_1), Puławy-Włostowice (P_1), Zwoleń (Z_1)

CONCLUSIONS

1. The study performed at three sites (Dębno, Puławy-Włostowice and Zwoleń) have indicated that the Odrian ice sheet advance (Saalian 1) was preceded by intensive fluvial accumulation. That developed under conditions of the more and more severe periglacial climatic regime which favoured the activation of aeolian processes. This is proved by the very large amount of round mat grains (RM) in alluvia (fluvioperiglacial deposits) accumulated then. In the middle Vistula valley (Fig. 5), the mean of RM grains in the alluvia is 76.0%, while in the till only 40.1%. The mean roundness index by the KRUMBEIN's scale in the alluvia is 0.737, in the till – 0.583; the percentage of well-abraded (γ) grains after the KRYGOWSKI's method is respectively 38.9 and 16.6.

2. The large content of strongly wind abraded grains is also characteristic for analogous fluvioperiglacial deposits accumulated before the advances of younger ice sheets. The results of investigations of the alluvia of the last three glaciations show that the largest content of RM grains occurs in the Odrian cycle. However more detailed analyses of Vistulian alluvia in Central Poland point to considerable regional changes in the content of such grains (GOŹDZIK, 1995a). Similar changes could have occurred in fluvioperiglacial deposits of earlier cold periods. Only examinations of many samples from fluvioperiglacial deposits of successive cold periods, from different sites in Poland, will enable the answer to the question whether the distinct tendency in the content of RM grains really exists.

3. Our findings indicate that the revision of the interpretation of geological sequences of alternating glacial (tills, fluvioglacial, limnoglacial) and interglacial fluvial deposits is necessary. This remark refers especially to the sequences reported, by means of borings, from deep buried or partly buried valleys. That has been shown in relation to one member of such sequences investigated in the middle Vistula valley. Such members are there more numerous (vide cross-section and longitudinal profile in POŻARYSKI, MARUSZCZAK, LINDNER, 1994). They were identified on the basis of borings, and assumig that thick fluvial series – divided by glacial horizons – represent first of all interglacial periods. Our investigations have shown that at least the upper layers of these fluvial "interglacial" deposits should relate to the glacial periods. The same rule as in the cited work on the chronostratigraphy of Vistula valley deposits was applied to distinguish the sequences of interglacial-glacial deposits earlier, e.g. in the monograph by RÓŻYCKI (1972), as well as on geological cross-sections of the newly published sheets of the Detailed Geological Map of Poland (e.g. ŻARSKI, 1991, 1996). The upper layers of "interglacial" series distinguished on these maps were probably deposited in the periglacial environment, thus in glacial periods.

4. In the analysed profiles, in tills covering fluvioperiglacial sands with strongly wind-abraded grains, the content of RM grains is relatively high – in the lower horizon in Dębno and at the bottom in Puławy-Włostowice. As at some other sites of central Poland where till rests on fluvioperiglacial deposits with wind-abraded grains – their enrichment in RM grains might have been due to the incorporation of alluvial deposits into basal till of the advancing ice sheet. However, the incorporation not always occurred; the profile from Zwoleń proves this. Perhaps differences in the intensity of the erosion of sub-glacial material were connected with dynamic conditions of the ice advance and its pressure.

Translated by D. Szafrańska

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