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Lithology of the Late Pleistocene sands for stratigraphic and palaeogeographic correlation in Muszaki area, southwestern Mazury Lakeland

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Detailed geologic studies in the Muszaki region enabled testing of lithologic analysis of sandy series for stratigraphic and palaeogeographic correlation. Significant variation in grain size, content of heavy minerals and roundness of quartz grains was found for sands of the plateau, erosive outliers and erosive terraces of the Middle Polish Glaciations (Saalian), as well as for outwash terraces of the Vistulian Glaciation.

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Key words: Mazury Lakeland, Pleistocene, lithology, sands, outwash, erosive outliers.

INTRODUCTION

The Nidzica Plateau is a forefield of the maximum ice sheet limit of the Vistulian Glaciation in the southwestern Mazury Lakeland (after S. Z. Różycki, 1972) and developed during the Mława Stadial of the Wartanian Glaciation (W. Morawski, 1999, in print *a*, *b*). The northeastern part of this plateau near Muszaki, to the north and east of Nidzica (Fig. 1), is dissected into numerous erosive outliers. Some of them, e.g. near Orłowo and the one named Jastrzębia Góra (Fig. 1), have been previously accepted as end moraines of the last glaciation (A. Mańkowska, W. Słowański, 1978, 1980). According to W. Morawski (*op. cit.*), they are depositional features (presumably end moraines) of the Mława Stadial of the Wartanian Glaciation, and acted as a significant obstacle for the advancing ice sheet of the Vistulian Glaciation. The area between a compact plateau and the outliers, around the latter, as well as to the north and east of them, are occupied by outwash terraces which have been formed during successive ice sheet retreat of the Vistulian Glaciation.

Seven research boreholes were done (W. Morawski, in print *a*): Grabowo (7) on the Nidzica Plateau, borehole 6 on the outlier Złote Góry, borehole 4 on the outlier Jastrzębia Góra, the boreholes Nowy Las (3), Zimna Woda (8), Wały (5) and Zachy (9) on outwash terraces (Figs. 1 and 2). Upper parts of these geologic sections are composed almost exclusively from thick sandy-gravel series of the Late Pleistocene. They are undoubtedly of different derivation and age, but look very similar to one another. This fact made several dozen further drillings to depth of 10–25 m necessary and samples were collected at every 1 m in each core. The collected 655 samples were widely examined (1299 laboratory analyses; K. Kenig, 1994)). Sands were analyzed to compare lithology of successive beds in every section and between the sections. Great genetic and stratigraphic diversity of different sand series, occurring in very distinct landforms, were subjected to detailed examination and combined with an exceptional detailed geologic-stratigraphic recognition. This procedure enabled to test lithologic methods of sands, applied for stratigraphic and palaeogeographic purposes.

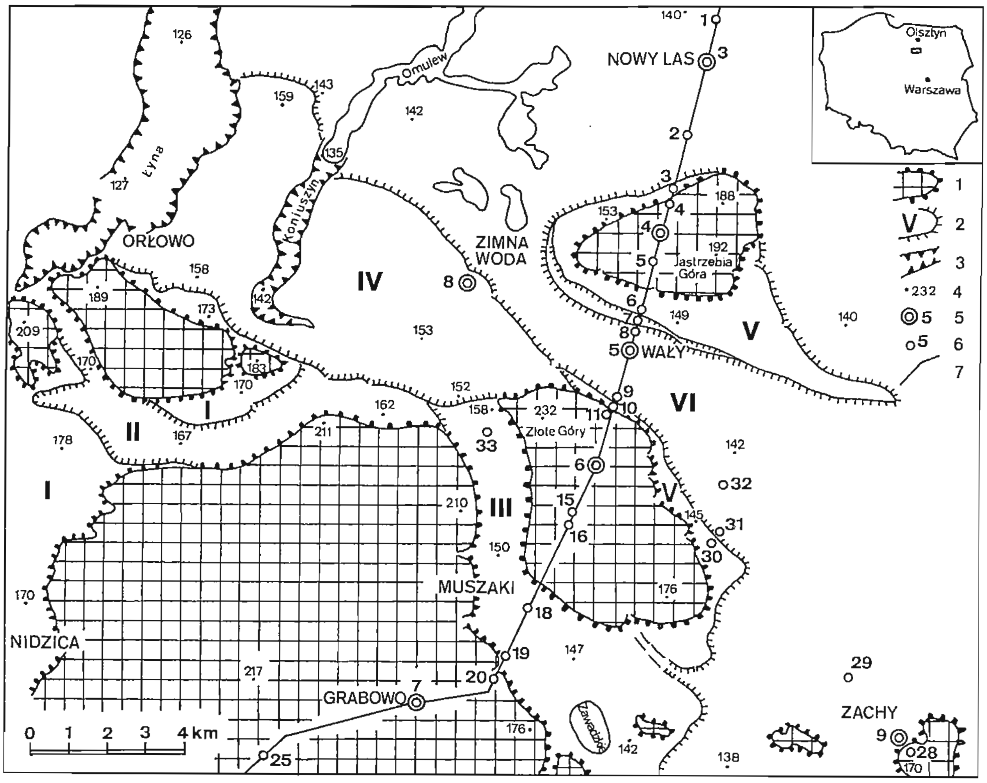


Fig. 1. Geomorphologic sketch of the Muszaki area, southwestern Mazury Lakeland

1 — Nidzica Plateau and its erosive outliers (Mława Stadial of the Wartanian Glaciation), 2 — outwash terraces (partly erosive socles) with their numbers (Vistulian Glaciation), 3 — main glacial channels, 4 — altitude, 5 — boreholes (with original number), 6 — drillings, 7 — geologic section (*cf.* Fig. 2)

GEOLOGY

Until a half of the nineties the study area was a military restricted zone and therefore, no geologic data were available. Research boreholes and geophysical sounding (W. Morawski, in print *a*) reached a top of the Tertiary sediments, composed of the Lower Pliocene clays and silts, and the Upper Miocene clays with brown coal inserts (B. Słodkowska, 1994). The Quaternary substrate is very diversified, presumably both due to glacial and glaciofluvial erosion.

The Pleistocene sequence is considerably reduced in comparision with NE Poland, and oscillate from 50 m (Piotrowice, SW to Grabowo) to 224 m (Jastrzębia Góra) thick (Fig. 2). It comprises 7 tills (W. Morawski, in print *a*) but only the four older ones are of univocal stratigraphic location. Their regional correlations is based mainly on simplified petrograhic analysis of clasts (K. Kenig, 1994, 1998). These tills represent the Nidanian Glaciation (presumably two beds at Jastrzębia Góra and Wały, together over 78 m thick) but the Sanian Glaciation (lower and upper stadials: at Grabowo and Zimna Woda). The other three tills are ascribed to the Middle Polish Glaciation, two older ones form commonly thin inserts and lag concentrates within thick glaciofluvial and glaciolacustrine sediments. A till of the Odranian Glaciation is distinct in the borehole Zachy (9) in the south-east where it is over 10 m thick and directly overlain by outwash deposits of the Vistulian Glaciation. There are two tills of the Wartanian Glaciation. The older till, of the Wkra Stadial, forms a thin bed (several to a dozen metres thick) and occurs almost in the whole plateau and the erosive outliers, also at a land surface or under a thin cover of outwash sediments of the erosive socles-terraces IV and V (Fig. 2). The youngest till, of the Mława Stadial, forms patches at the Nidzica Plateau. It is several metres thick and gets thinner, passing into residual boulders what suggests that the till has primarily covered the whole plateau (W. Morawski, 1999, in print *a, b*). There are vast depositional landforms at the northern edge of the Nidzica Plateau and partly also in the erosive outliers. They are presumably the end moraines, composed of sands, gravels, boulders and inserts of flow tills, in total over 80 m thick. They are to be connected with the Mława Stadial (*op. cit.*).

In the studied area there are no glacial sediments of the Vistulian Glaciation. Numerous dry valleys form a complex drainage pattern on the Nidzica Plateau and are partly filled with colluvial and biogenic deposits of the Eemian Interglacial (W. Morawski *et al.*, 1999). Most northern and eastern part of the area is occupied by outwash terraces, formed during a ice sheet retreat of the Vistulian Glaciation (Fig. 1).

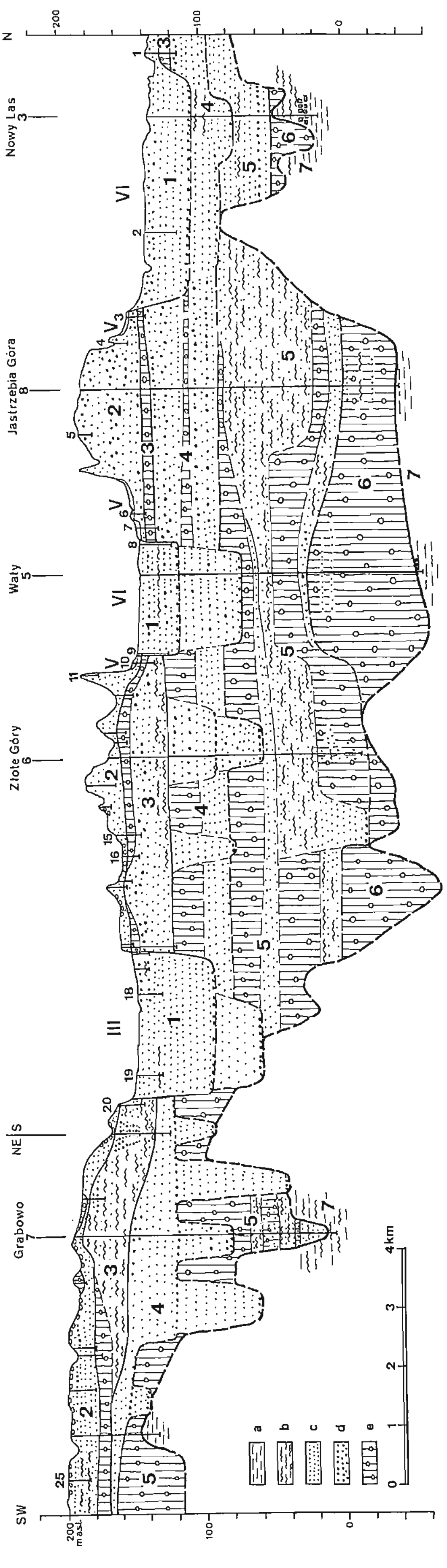


Fig. 2. Geologic section

1 — Vistulian Glaciation; Wartanian Glaciation: 2 — Mława Stadial, 3 — Wkra Stadial; 4 — Odranian Glaciation; 5 — Sanian Glaciation; 6 — Nidanian Glaciation; 7 — Tertiary; roman numbers are outwash terraces (in fragments erosive socles; *cf.* Fig. 1); arabian numbers are boreholes and drillings (*cf.* Fig. 1); lithology: a — clays, b — silts, c — sands, d — gravel, e — till

OUTWASH TERRACES

Six outwash terraces developed during ice sheet retreat of the Vistulian Glaciation in the vicinity of Nidzica and Muszaki (W. Morawski, in print *a*, *b*; Fig. 1). They are separated from the Nidzica Plateau and the erosive outliers by steep escarps, locally over 50 m high. The edges between the terraces are commonly distinct and several to a dozen metres high. Terrace surfaces are inclined generally southwards or south-eastwards. The terraces I–III and V are almost flat, with small elevations to 2 m high. On the other hand, the terrace IV is cut by glacial channels of the Łyna and the Koniuszyn Rivers (Fig. 1) to depth of over 20 m. Within this terrace there are also numerous kettle holes of a pitted outwash. Similar is a northern part of the terrace VI, but with numerous lakes, the Lake Omulew included (Fig. 1). In the middle, i.e. between Zimna Woda and Wały, and further to the south, this terrace is flat and shallow depressions are filled with the Holocene peats, whereas thin aeolian covers form gentle hummocks. In the south the terraces III and VI join together without any edge, and small erosive outliers emerge from its surface; they are probably the end moraines of the Mława Stadial. A peculiar feature of this vast outwash plain is the Zawadzkie Lake on the terrace III, to the south of Muszaki (Fig. 1), about 8 km southwards from the maximum ice sheet limit of the Vistulian Glaciation (W. Morawski, 1999). This lake is over 1 km wide and generally to 2 m deep, but its central part is occupied by the channel, about 200 m wide and to 12 m deep. Origin of this depression is enigmatic: it could be formed by melting of icing, but an outwash valley of the terrace III and especially the lake basin itself, could be eroded by an ice stream.

The terraces indicate directions of meltwater runoff, concentrated locally in distinct and deep valleys, particularly distinct at the terraces II, III and VI. The terrace VI encircles the outlier of Jastrzęba Góra with two valleys (northern and southern) that join together eastwards (Fig. 1). The terraces I–III and partly VI are the accumulative ones, with their outwash sands over 30 m thick (Fig. 2). On the other hand the terraces IV, V and partly VI are the erosive-accumulational ones, and in small areas their erosive socles are completely devoid of outwash sediments. Delimiting of these socles is

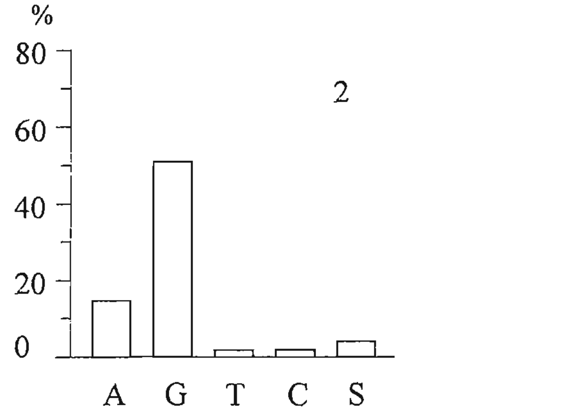
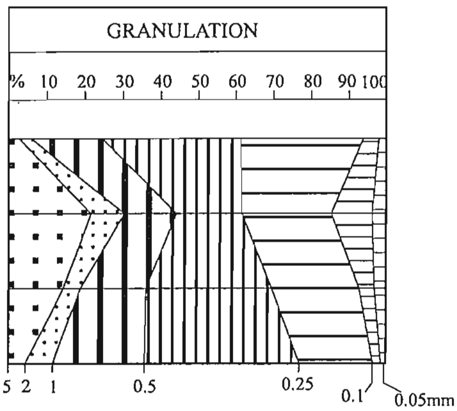


Fig. 3. Main heavy minerals in sediments of the terrace VI in drilling 2

A — amphibole, G — garnet, T — tourmaline, C — zircon, S — staurolite



Mz	δ_1	Sk_1	K_G
1,71	1,07	-0,03	1,08
1,07	2,11	-0,16	0,81
1,14	1,70	-0,21	1,29
0,30	1,12	-0,08	1,25

Fig. 4. Grain size composition and parameters of outwash sediments of the terrace VI in the borehole Wały (5)

Mz — mean grain diameter, δ_I — standard deviation, Sk_I — skewness, K_G — curtosis

univocal in case of occurrence of a till of the Wkra Stadial at a land surface or its residual boulders. However, most commonly a surface of the terrace socle is composed of glaciofluvial sands from under a till of the Wkra Stadial, and they are similar to outwash sands which were deposited in a thin layer on the erosive socles during ice sheet retreat of the Vistulian Glaciation (Fig. 2).

Research drillings were done not only on the plateau and erosive outliers, but also on each terrace (Figs. 1 and 2), what makes mutual comparison of sands of all these landforms possible.

LITHOLOGY

Samples of sands, sands with gravel and occasionally silts, collected from research boreholes and drillings, were then subjected to the following examination:

Grain size by pippette and non-aspiration analysis modified by S. Rząsa for aleurites, and sieve analysis for sands and gravels. Results were then calculated to determine centiles and grain size parameters after R. L. Folk and W. C. Ward (1957) in phi scale, in which Mz is a mean grain diameter, δ_I is a standard deviation, Sk_I is a skewness, and K_G — curtosis.

Heavy minerals content (grain size 0.25–0.1 mm), in which transparent minerals are equal to 100%.

Roundness of quartz grains (grain size 1.0–0.5 mm) by photographic method. Distinguished roundness classes, i.e. angular (K), rounded (O) and partly rounded (CO), were used to calculate the roundness coefficient $R = (K + 1/2\ CO) : (O + 1/2CO)$.

Calcium carbonate content by volumetric method with Scheiblers apparatus (grain size below 0.1 mm).

Analysis of the examined sediments resulted in ranking evaluation of lithologic and lithodynamic features of sediments of the outwash terraces, as well as erosive outliers and socles. This evaluation is a quantitative or qualitative deter-

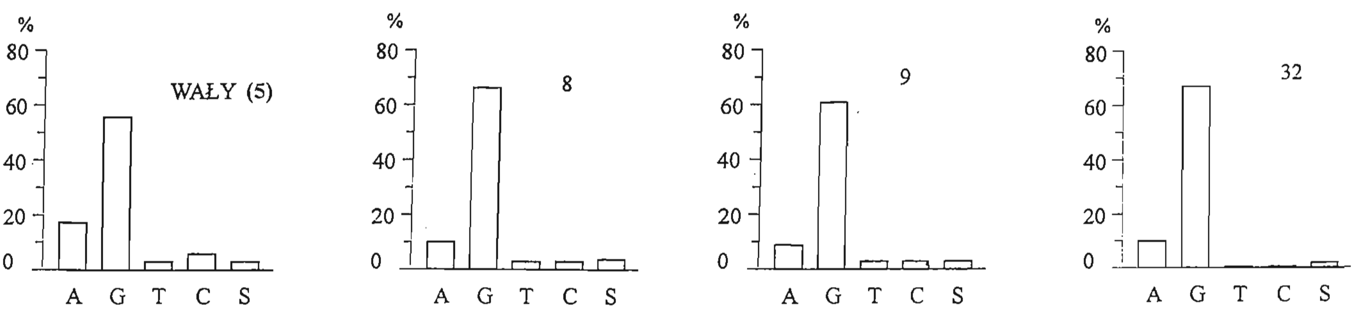
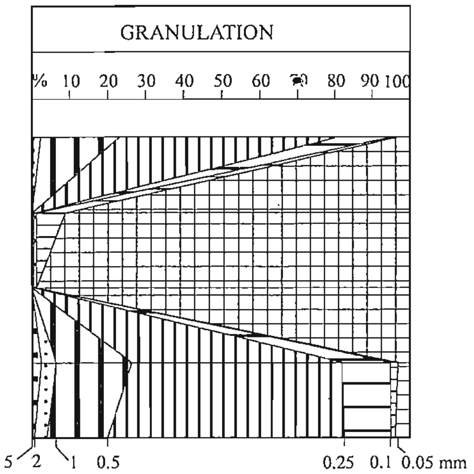


Fig. 5. Main heavy minerals in sediments of the terrace VI in the borehole Wały (5) and drillings 8, 9 and 32

For explanations see Fig. 3



Mz	δ_I	Sk_I	K_G
1,48	0,80	0,13	1,46
6,62	1,42	-0,26	0,82
6,40	1,61	-0,35	0,72
1,36	0,93	0,01	1,71
1,46	0,79	0,07	1,72

Fig. 6. Grain size composition and parameters of outwash sediments (flood facies) of the terrace III in drilling 33

For explanations see Fig. 4

mination of the environment, based on selected lithological features (R. Racinowski, T. Szczypek, 1985).

OUTWASH TERRACES

Geological structure of the **northern valley train of the terrace VI**, which contacts directly to north with a morainic plateau of the Vistulian Glaciation, is presented by the borehole Nowy Las (3) and the drillings 1 and 2 (Figs. 1 and 2). In the drilling 1 there are coarse-grained sediments (to depth 8.5 m) with varied grain size parametres. They are vari-grained sands with varied predominance of coarse or medium fraction or even of gravels. Therefore, the parameter Mz is equal from 1.52 to 0.22 phi. These sediments are medium or poorly sorted (0.94–1.84). Similarly varied is also the curve of grain size distribution (from platycurtic, through mesocurtic to leptocurtic one). Roundness of quartz grains is exceptionally poor, with predominance of angular grains, so the coefficient R is equal to over 1. Heavy minerals contain more garnets (34–49%) than amphiboles (11–16%). These sediments were deposited by flowing water with significantly energetic environment, indicating typical strong glaciofluvial conditions.

Similar deposits were described from the drilling 2 (Figs. 1 and 2). They are vari-grained sands of a glaciofluvial environment with intensive hydrologic regime but with commonly varied intensity of flow. Predominant are medium-, coarse- or fine-grained sands with slight admixture of silt. Mz is equal from 0.40 to 2.56 phi. Sorting is medium or poor. Grain size curve is usually leptocurtic, what indicates high transport dynamics. Among quartz grains there are mostly partly rounded, with varying contents of rounded and angular ones (R is equal to 0.85–1.03). Heavy minerals are mainly garnets (41–69%, mean 51%) and amphiboles (12–17%, mean 15%) (Fig. 3).

Sediments of the **southern valley train of the terrace VI**, which separates erosive outliers of Złote Góry and Jastrzębia Góra, are known from the borehole Wały (5) and the drillings 8 and 9 (Figs. 1 and 2). In the borehole Wały (5) there is a single sedimentary sequence, about 30 m thick, with Mz increasing upwards from 3.12 to 2.49 phi (Fig. 4). Sorting is varied, from poor to quite a good one. Sediments in the drilling 8 are considerably varied facially, with coarse-grained channel deposits (Mz equal to 0.67 phi) and silty floodplain ones (Mz to 4.52 phi). Slightly less varied are sediments in the drilling 9 which are mostly vari-grained sands, with Mz equal from 1.02 to 1.78 phi, and only occasionally lower. Sorting is usually medium, seldom poor, and grain size curve is leptocurtic.

Considerable grain size variation of these sediments is also reflected in varied contents of rounded (23–33%), angular (16–23%), and partly rounded grains (44–57%). Heavy minerals are predominated by garnets and amphiboles, with low and varied contents of amphibole (8–19%) and frequent peaks of garnet, a mean content of which is equal to over 60% (generally from 47 to 65%). Other resistant minerals play secondary role (Fig. 5).

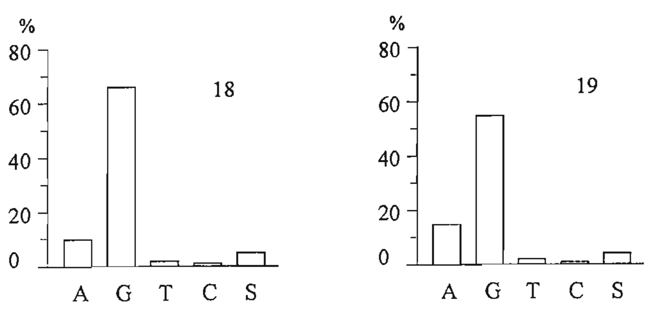
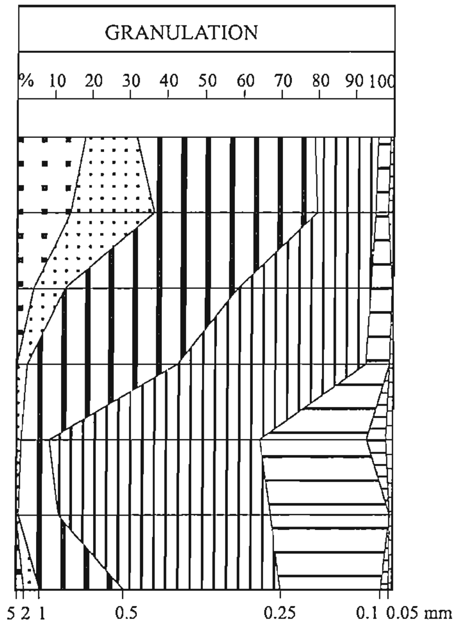


Fig. 7. Main heavy minerals in sediments of the terrace III in drillings 18 and 19

For explanations see Fig. 3



Mz	δ_1	Sk_1	K_G
0,16	1,23	-0,25	1,23
0,20	1,12	-0,14	1,22
0,84	0,81	-0,08	1,22
1,11	0,61	0,03	1,05
1,91	0,82	0,25	1,23
1,74	0,64	0,03	1,07
1,51	0,96	-0,03	1,07

Fig. 8. Grain size composition and parameters of sediments in the upper part of the borehole Jastrzębia Góra (4)

For explanations see Fig. 4

This outwash deposition is indicated further to the east in the drillings 29, 31 and 32, as well as the borehole Zachy (9) (Fig. 1). Lithology of outwash sediments in these drillings indicates their facial variation. Although there is no morphogenetic boundary (escarp) in the field, several outwash zones can be distinguished. One of them is represented by sediments in the drilling 32, typical for a long-distance transport (Fig. 5). The second outwash zone represents sediments from the drillings 29 and 31. Heavy minerals are predominated by garnets (67%), what indicates a long alluvial transport. This fact cannot be neglected by varied predominance of rounded and angular grains. Grain size composition is predominated by medium- and coarse-grained sands.

On the other hand, sands from a top part of the borehole Zachy (9) (to 6.0 m) represent another sedimentary environment if their heavy minerals (garnet 41%, amphibole 33%), and quartz grains roundness (R = 0.94) are concerned. Most probably, it is due to redeposition of older sediments from the denuded outliers of the plateau (Fig. 1).

The outwash **terrace III** was examined in the drilling 33 in the north and the drillings 18 and 19 in the south (Fig. 1). In these drillings there are typical long-distance transport sediments, with quite intensive but similar hydrologic regime, and occasional flood episodes. Such is the evidence from the drillings 19 and 33, in which vari-grained sands (mainly fine- and medium-grained) contain silty-clayey interbeddings (Fig. 6). Grain size parameters are varied, especially for the sediments from low ones to about 5 phi. This conclusion is also supported by a content of heavy minerals, among which garnet prevails (Fig. 7). Additional information is given by roundness of quartz grains: rounded (to 40%) prevail over angular ones (9–23%), and content of partly rounded is equal

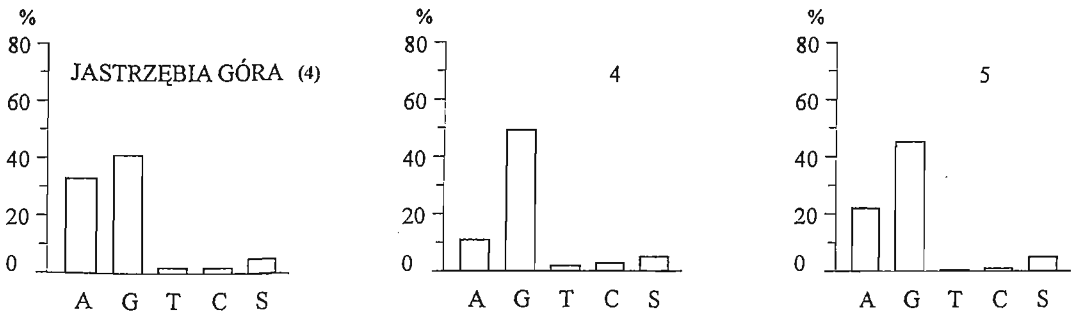
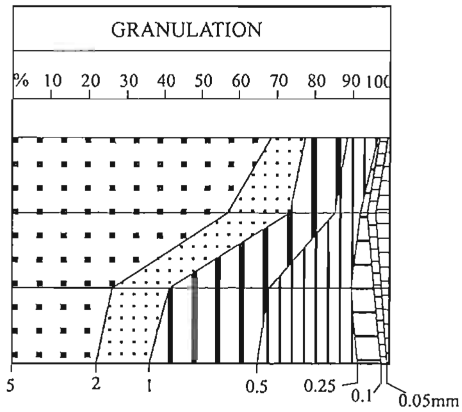


Fig. 9. Main heavy minerals in sediments of the upper part of the borehole Jastrzębia Góra (4) and in drillings 4 and 5

For explanations see Fig. 3



Mz	δ_1	Sk_1	K_G
-1,19	1,61	0,31	1,03
-1,01	1,50	0,20	0,97
1,16	1,66	-0,09	0,98
0,29	1,52	-0,17	1,04

Fig. 10. Grain size composition and parameters of sediments in drilling 5

For explanations see Fig. 4

to 39–61%. Vari-grained sands from the drilling 19 indicate other contents of quartz grains in different roundness classes, because there are more angular ones. They can represent another facies of a braided river.

Outwash sediments contain very little calcium carbonate, e.g. about 1% in the borehole Wały (5), and they are decalcified in the borehole Zachy (9).

EROSIVE OUTLIERS AND SOCLES

Sediments of the **outlier Jastrzębia Góra** are known from the borehole Jastrzębia Góra (4) and the drillings 4 and 5 (Figs. 1 and 2). In the borehole Jastrzębia Góra (4) there are vari-grained sands to depth of 45 m. In these sediments, a grain size diameter is larger upwards (Mz changes gradually from 1.91 to 0.16 phi). Sorting is generally medium but worse upwards (Fig. 8). The whole series contains much amphibole (maximum 55%, and mean slightly over 30%) and relatively low content of garnet (mean below 50%, minimum about 10%) (Fig. 9). The whole series comprises two sedimentary cycles at depths 0–24 and 24–45 m, connected with a varying hydrological regime. The upper cycle contains a coarser clastic material and worse sorting upwards — typical for transport environment with varied dynamics and considerably varying hydrological regime, corresponding most frequently to fluvial channel facies.

There are similar sediments in the drillings 4 and 5. In the drilling 5 there are mainly vari-grained sands with gravel interbeddings, which are more common upwards (Fig. 10). Mean grain diameter is 0.29–1.19 phi and sorting is poor. The drilling 4 is located in a lower area (Fig. 2) but grain size composition is generally similar, although represents a slightly different sedimentary zone. Weaker flow resulted in lower content of coarse fraction (Fig. 11) and therefore, Mz gets gradually higher (from 0.53 to 1.15 phi), and irregular sorting becomes better.

Contents of heavy minerals in coarse-grained sediments from the borehole Jastrzębia Góra (4) and from the drilling 5 are similar (Fig. 9). There is 39–50% (mean 44%) of garnet, and 20–32% of amphibole. There is a low content of resistant minerals, usually 3–5%. In the drilling 4 there is, however, more garnet.

This comparison indicates that elevation of the outlier of Jastrzębia Góra represents a single sedimentary basin, whereas the lower part seems to be a fragment of another lithodynamic series what is also supported in grain size composition by finer grains. In all the sections from the outlier of Jastrzębia Góra, there are more angular than rounded quartz grains (Fig. 12).

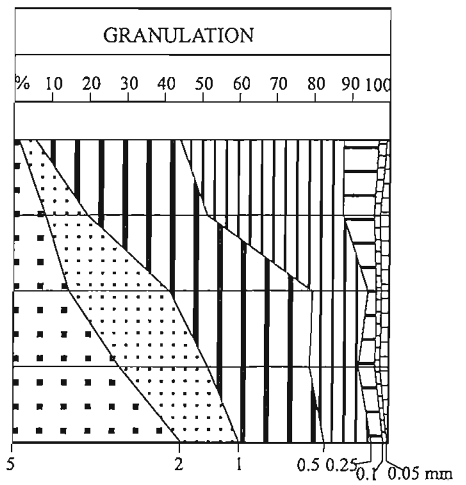
Sediments from the drillings 3 and 6, located at foot of the outlier on the erosive terrace V (Figs. 1 and 2), are distinctly similar in their lithology and especially a mineral composition. There are the same contents of garnets (mean 45%), amphibole (9–22%) and staurolite (2–3%). Similar mineral content is indicated in the drilling 7, located on a slightly lower socle of the terrace V (Figs. 1 and 2), and it is close to the one in sediments of the outlier Jastrzębia Góra.

The erosive **outlier Złote Góry** was examined in the borehole Złote Góry (6) and the drillings 11, 15 and 16 (Figs. 1 and 2). The narrow terrace V forms an erosive socle at its foot, and is examined by the drilling 10 (Figs. 1 and 2). Generally speaking, sediments of this landforms indicate varying deposition, with frequent vertical grain size changes.

Table 1

Main heavy minerals and roundness coefficients of quartz in sediments of the outlier Złote Góry

Main heavy minerals [%]	Profiles				
	borehole Złote Góry (6)	drillings			
		10	11	15	16
Garnet Amphibole Staurolite	24 22 –	41–59 11–17 2–9	42–56 5–17 4–7	53–58 14–26 2–5	55–60 9–17 2–3
Roundness coefficient R	1.69	1.13–1.22	0.87–1.30	1.21	1.25–1.34 (2.01)



Mz	δ_1	Sk_1	K_G
1,15	0,89	0,17	1,33
0,83	1,22	-0,13	1,36
0,12	1,13	-0,10	1,17
-0,12	1,55	0,01	1,12
-0,53	1,59	0,09	0,90

Fig. 11. Grain size composition and parameters of sediments in drilling 4

For explanations see Fig. 4

They are usually sand-gravel deposits with alternate predominance of the main grain sizes (Mz is from below 1.0 to almost 2 phi). Sorting of these sediments is also varied but they are usually typical for a mean state. There are also similar relations of the main heavy minerals, i.e. garnet and amphibole, with significant content of staurolite. Roundness of quartz grains is poor and irregular vertically, R being commonly over 1.0 due to distinct predominance of angular over rounded grains (Table 1).

In sediments from the drilling 30 on the terrace V (Fig. 1), there are very small differences in contents of heavy minerals and grain size composition, if compared with sediments of the drilling 31 (terrace VI). They are, however, considerably different if compared with sediments of outliers and erosive socles. Thus, an erosive socle of the terrace V seems to drop down in the drilling 30, and its core is composed of the underlying outwash deposits.

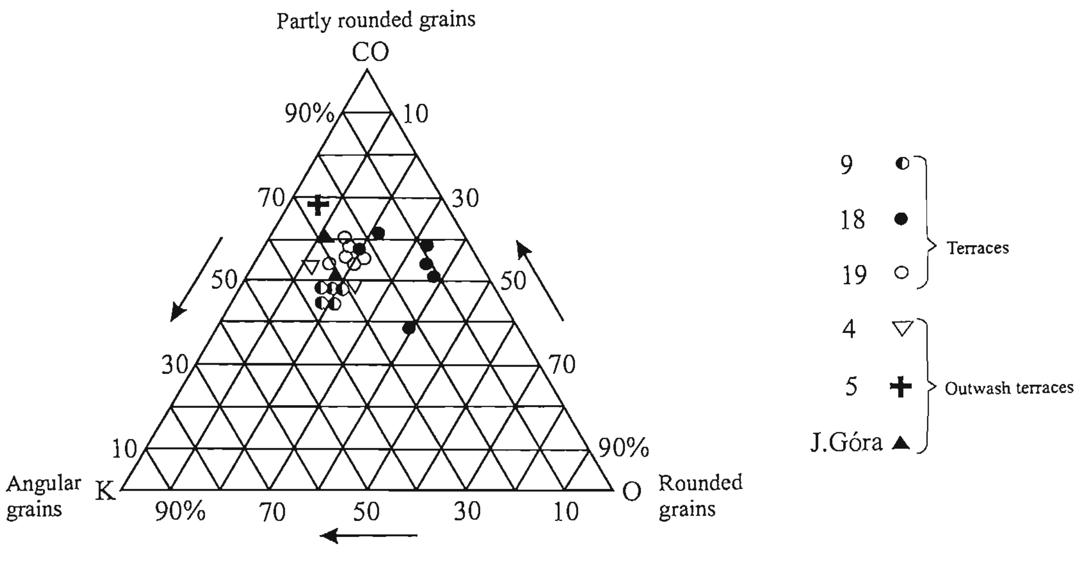


Fig. 12. Roundness of quartz grains of the 1–0.5 mm fraction from sediments, a triangular projection

4, 5, 9, 18, 19 — drillings; J. Góra — borehole Jastrzębia Góra (4)

Contents of carbonates in sediments of erosive outliers and socles is greater than in outwash sediments, reaching 4% (mean 2%) in the borehole Jastrzębia Góra (4) and 2–6% in the borehole Złote Góry (6).

RECAPITULATION OF LABORATORY ANALYSES

Spatial lithologic quantitative analysis indicates relationship as well as distinction of sandy deposits from different landforms in the vicinity of Muszaki.

Sediments of outwash terraces are vari-grained sands with alternate predominance of medium, fine or coarse fraction. Common facial variation of sediments that contact sharply with one another is typical both for the Pleistocene outwash plains as well as for the present braided rivers, e.g. from Iceland (M. Bogacki, 1976; K. Klimek, 1972; K. Kenig, unpubl.). In the vicinity of Muszaki these sediments are predominated by garnet (about or even over 60%), with admixture of amphibole (usually about 10%). Content of carbonates is insignificant. There is small prevalence of angular over rounded quartz grains, but there are mostly partly rounded ones. Varying lithology and their sequence allowed to distinguish secondary lithodynamic units (flow zones) within the terraces.

Sandy sediments of erosive outliers and socles are vari-grained, usually contain mostly coarse-grained and gravel fractions but with distinct participation of the finest one. Relation of the main heavy minerals indicates predominance of garnet (but below 50%) over amphibole (over 20%). Angular quartz grains are more common than rounded ones, and partly rounded ones are not so abundant as in sediments of the outwash terraces. Carbonate content is higher than in outwash sediments. In spite of varying lithology, sands of erosive outliers and the encircling terrace socles are distinctly similar. Their deposition is due to short glaciofluvial transport in intensive hydrological regime.

A roundness coefficient of quartz grains (R) does not play a decided diagnostic role. Complex lithologic characteristics, among them also contents of quartz grains in individual roundness classes, are the most significant in determination of a sedimentary environment. Such approach coincides with the most recent opinions (K. Kenig, 1997; E. Mycielska-Dowgiałło, 1995; R. Zabielski *et al.*, 1998), and the studies of the present fluvial sediments (K. Kenig *et al.*, 1976).

CONCLUSIONS

Comparative analysis of similar sandy sediments of different landforms in the vicinity of Muszaki confirmed their varying lithology and lithodynamic characteristics.

Lithology of sandy sediments of isolated erosive outliers and erosive terraces (socles) was similar, although with an inner facial diversity. Similar lithology was noted for outwash sediments of different terraces but outflow zones within individual terraces indicated various differences. Comparative lithologic analysis permitted to distinguish glaciofluvial sands of erosive socles from thin covering outwash sands.

Comparative analysis of lithology of sandy sediments can establish a significant secondary argument in stratigraphic and palaeogeographic studies. In this very case, close relationship of lithology of sandy sediments in outliers and the plateau was an extra evidence to find the Jastrzębia Góra to be a fragment of the Nidzica Plateau, formed during the Mława Stadial of the Wartanian Glaciation (instead of being the end moraine of the Vistulian Glaciation as considered previously). Such relationship of lithology is also true for sediments of the terraces that encircle the outliers, previously classified as outwash terraces of the Vistulian Glaciation, and now interpreted as erosive socles, only locally with thin outwash covers. Distinctly different lithology of sediments in outliers and socles, if referred to sediments in outwash valleys, was the extra argument to consider them for outwash terraces formed during ice sheet retreat of the Vistulian Glaciation.

Complex studies in the vicinity of Muszaki, supplied with lithologic description of sandy series of different origin and stratigraphy, brought much information to studies of sandy interbeddings in glacial sequences of the Pleistocene. Lithostratigraphic correlations in drilling cores find always such sandy series to be the most enigmatic material. Correct genetic interpretation, but also palaeogeographic and stratigraphic ones, can be easier if lithology of drilling cores is compared with results of methodical examination in the area with well known geological structure.

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ZASTOSOWANIE ANALIZY PORÓWNAWCZEJ PIASKÓW DLA STRATYGRAFII I PALEOGEOGRAFII PLEJSTOCENU W REJONIE MUSZAKÓW, POŁUDNIOWO-ZACHODNIE MAZURY

Streszczenie

W trakcie prac geologiczno-zdjęciowych dla opracowania arkusza Muszaki *Szczegółowej mapy geologicznej Polski* w skali 1:50 000, rozpoznano ostańce erozyjne wyodrębnione z Wysoczyzny Nidzickiej z okresu zlodowaceń środkowopolskich. Pomiędzy ostańcami a wysoczyzną oraz wokół ostańców wyróżniono 6 poziomów tarasów sandrowych z deglacjacji ostatniego zlodowacenia (fig. 1). Tarasy I–III i VI są tarasami akumulacyjnymi, natomiast tarasy IV i V stanowią cokoły erozyjne, przykryte jedynie cienką i nieciągłą pokrywą sandrową (fig. 2).

Zarówno ostańce erozyjne, jak i tarasy sandrowe są zbudowane z jednakowych makroskopowo piasków ze żwirami, o miąższości do ok. 80 m w ostańcach i do ponad 30 m na tarasach (fig. 2). Osady te zostały rozpoznane w profilach 7 wierceń badawczych (2 na ostańcach, 4 na tarasach i 1 na wysoczyźnie), gdzie zostały opróbowane, a próbki poddano badaniom laboratoryjnym. Dodatkowo wykonano kilkadziesiąt sond mechanicznych do głębokości 10–25 m (fig. 1 i 2), z których pobrano próbki piasków co 1 m.

Duża różnorodność genetyczna i stratygraficzna osadów piaszczystych w bezpośrednio ze sobą sąsiadujących bardzo dobrze czytelnych formach przy szczegółowym rozpoznaniu stratygraficznym dawała wyjątkową szansę przetestowania przydatności badań litologicznych osadów piaszczystych dla wnioskowania stratygraficznego i paleogeograficznego.

Dla 655 próbek z rozpoznanych serii piaszczystych zostały wykonane analizy uziarnienia, składu minerałów ciężkich, stopnia obtoczenia ziarn kwarcu oraz zawartości węglanu wapnia. Na podstawie badań litologicznych przeprowadzono analizę porównawczą serii piaszczystych w celu odróżnienia osadów budujących sąsiadujące ze sobą różne genetycznie i stratygraficznie formy. Celem tych badań było danie odpowiedzi na pytanie czy przy ogromnym zróżnicowaniu piaszczystych osadów plejstoceńskich jest możliwe uchwycenie przekonywających różnic lub podobieństwa.

Badania te dały wyniki pozytywne. Porównanie zespołu cech litologicznym w ujęciu ilościowym pozwoliło z jednej strony stwierdzić podobieństwo serii piaszczystych budujących wysoczyznę, ostańce erozyjne z niej wyodrębnione oraz cokoły erozyjne im towarzyszące. Z drugiej strony stwierdzono pokrewieństwo serii piasków sandrowych budujących poszczególne tarasy akumulacyjne. W szczególności analizy składu minerałów ciężkich i stopnia obtoczenia ziarn kwarcu pozwoliły odróżnić osady wodnolodowcowe, o krótszym transporcie i bliższym związku z lądolodem, budujące ostańce i cokoły erozyjne (tab. 1, fig. 9, 12), od osadów sandrowych, które podlegały dłuższemu transportowi (fig. 3, 5, 7, 12). Odmienność ta jest czytelna mimo zróżnicowania facjalnego w obrębie osadów budujących ostańce i cokoły erozyjne (fig. 8–11), mimo zróżnicowania osadów budujących poszczególne tarasy sandrowe, jak również zróżnicowania w obrębie tych samych tarasów (fig. 4–7), co pozwoliło na wyróżnienie kilku stref przepływu wód sandrowych.

Wyniki badań dostarczyły dodatkowych argumentów, które potwierdziły dokonane wcześniej ustalenia stratygraficzne i paleogeograficzne (W. Morawski, w druku *a*). Masyw Jastrzębiej Góry, dotychczas uważany za morenę czołową z okresu ostatniego zlodowacenia (A. Mańkowska, W. Słowański, 1978), został zinterpretowany jako ostaniec erozyjny, podobnie jak ostaniec Złotych Gór (fig. 1 i 2). Ostańce te to prawdopodobnie moreny czołowe powstałe w stadiale mławy zlodowacenia warty. Tarasy IV i V wokół ostańców, uważane dotychczas za tarasy akumulacyjne z recesji ostatniego zlodowacenia (*op. cit.*), są cokołami erozyjnymi wyciętymi w osadach ostańców, jedynie z cienką pokrywą sandrową.

Przedstawione wyniki badań mogą posłużyć do porównań ułatwiających interpretację paleogeograficzną i stratygraficzną piaszczystych poziomów międzymorenowych badanych w profilach wiertniczych.