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TRENDS OF TEXTURAL AND STRUCTURAL VARIATION IN TURBIDITE SANDSTONES: THE CERGOWA SANDSTONE (OLIGOCENE, OUTER CARPATHIANS)

(Pl. I—II and 7 Figs.)

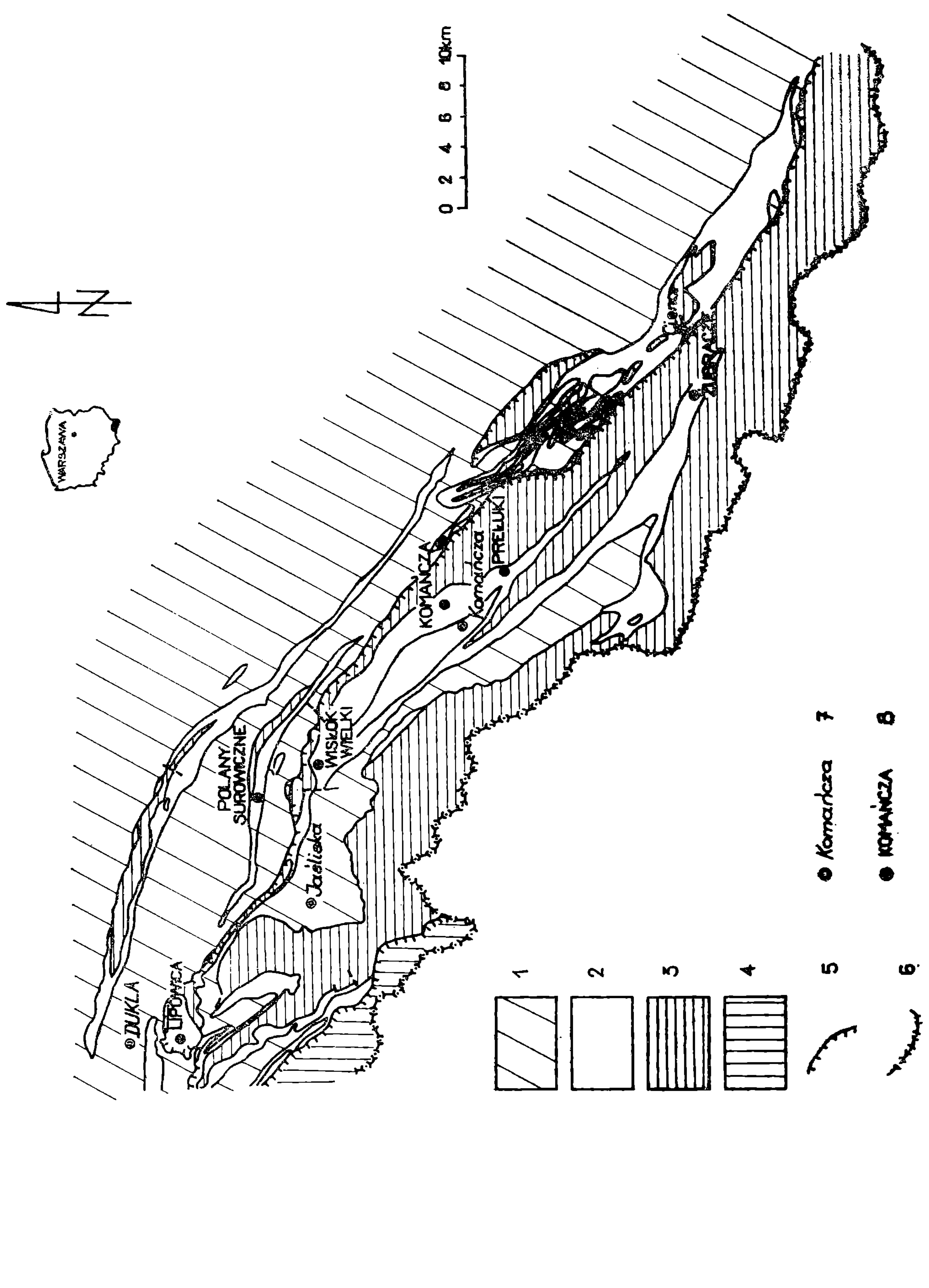
Zmienność cech teksturalnych i strukturalnych w piaskowcach turbiditowych: piaskowce cergowskie (oligocen, Karpaty Zewnętrzne)

(tabl. I—II i 7 fig.)

Abstract: Trends of variation determined quantitatively for bed thickness, stratification structures, grain size, and qualitatively for miscellaneous sedimentary structures, are discussed in relation to lithosome shape and inferred basin geometry. Besides downcurrent gradients of textural and structural features, there exist gradients across paleocurrent direction. In the elongated lithosome of the Cergowa sandstone marginal near-source and axial far-downcurrent zones have the same textural and structural characters.

INTRODUCTION

Turbidite sandstones usually show distinct trends of textural and structural variation. In most cases these trends are parallel to paleocurrent direction. Generally, grain size and bed thickness decrease, while the proportion of laminated and cross-laminated sandstone beds, and the proportion of pelitic material increase in the direction of paleotransport. These features were used by many authors (e. g. Dżułyński, Książkiewicz and Kuenen, 1959; Wood and Smith, 1959) as qualitative indicators of proximal and distal regions in sedimentary basins of turbidite series. Walker (1965, 1967) attempted to quantify the notions of proximality and distality, interpreting the standard sequence of stratification structures in turbidite deposits described by Bouma (1962) in terms of flow regime. Walker proposed a „proximality index" based on the proportion of beds beginning with various divisions of stratification structures, and suggested, that the value of this index changes sys-


WARSZAWA
0 2 4 6 8 10km
DUKLA
LIPOWICA
POLANY SUROWICZNE
Jaśliska
WISŁOK WIELKI
KOMAŃCZA
Komańcza
PREŁUKI
Cisna
ZUBRACZE
1
2
3
4
5
6
Komańcza 7
KOMAŃCZA 8

tematically in a turbidite basin, as the depositing turbidity currents passed from the upper flow regime in the proximal part of the basin to the lower flow regime in the distal part. The sedimentary structures were thus regarded by Walker (l. cit.) as responding primarily to conditions of transport in a turbidity current.

Walton (1967) pointed out in an important paper, that the formation of sedimentary structures in a granular sediment is controlled primarily by conditions of deposition. These conditions are depending on the deceleration of the transporting current. In case of rapid deceleration the load carried in suspension by the current is dropped rapidly, and sedimentary structures associated with bed forms are not produced. This idea was confirmed by experiments (Middleton, 1966). The beds deposited under conditions of rapid deceleration are either structurally homogenous or graded.

It seems therefore, that trends of variation of sedimentary structures and of textural features of turbidite sandstones within a sedimentary basin can be interpreted in terms of regional and local variation of conditions of deposition. These conditions are controlled by:

— initial hydrodynamic parameters of turbidity currents entering the area of deposition;

— hydraulic jumps associated with breaks in slope steepness;

— decay of turbulence along the distance travelled by the current.

All the above dynamic controls of conditions of deposition are depending upon basin geometry. Therefore a systematic study of textural features and sedimentary structures is an important factor in paleogeographic analysis. However, there are still very little quantitative data published on these problems, and generalizations are premature.

A CASE STUDY: THE CERGOWA SANDSTONE TURBIDITES

Geological setting, lithosome geometry and facial changes

The Cergowa sandstone of Early Oligocene age occurs in the central part of the Polish Carpathians (only a small part of its area of occurrence lies in the territory of Czechoslovakia). The Cergowa sandstone is

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Fig. 1. Geological map of the area of occurrence of the Cergowa sandstone in the Polish Carpathians. 1 — formations younger than the Menilite beds; 2 — Menilite beds, including the Cergowa sandstone member; 3 — formations older than the Menilite beds (1—3 Silesian unit and Dukla unit); 4 — Magura nappe; 5 — overthrusts; 6 — Polish-Czechoslovakian boundary; 7 — localities; 8 — sections studied

Fig. 1. Mapa geologiczna obszaru występowania piaskowców cergowskich w Karpatach polskich. 1 — utwory młodsze od warstw menilitowych; 2 — warstwy menilitowe z piaskowcem cergowskim; 3 — utwory starsze od warstw menilitowych (1—3 seria śląska i seria dukielska); 4 — płaszczowina magurska; 5 — nasunięcia; 6 — granica polsko-czechosłowacka; 7 — miejscowości; 8 — badane przekroje

forming part of the lithostratigraphic succession of two structural and facial units: the Dukla unit in the south-west and the Silesian unit in the north-east (Fig. 1).

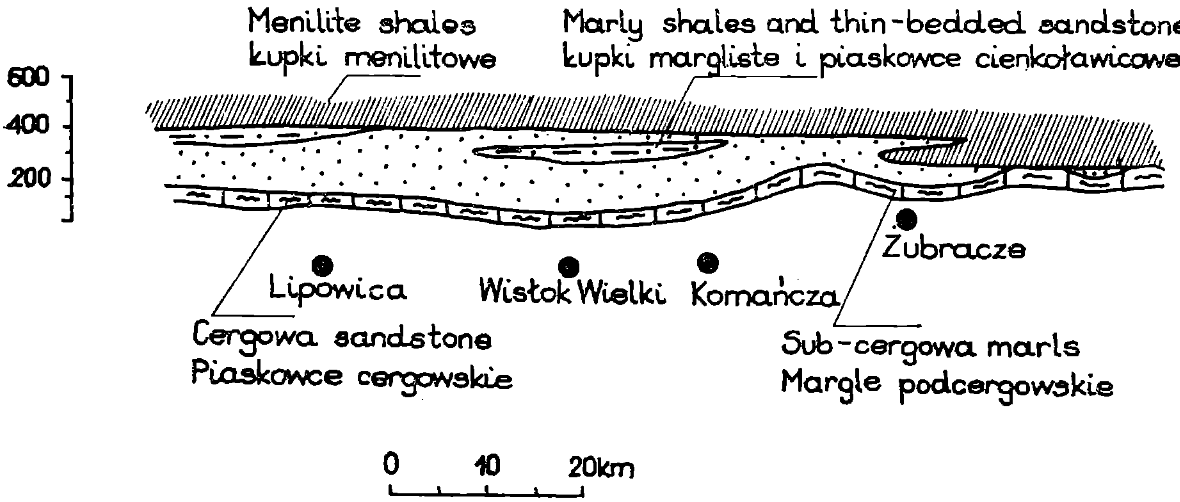

Fig. 2. Schematic cross-section showing the relation of the Cergowa sandstone member to the underlying and overlying members of the Menilite beds

Fig. 2. Schematyczny przekrój przedstawiający stosunek ogniwa piaskowców cergowskich do niżejległych i wyżejległych ogniw warstw menilitowych

The sandstone beds are generally thick, medium- and fine-grained (with rare coarse grained intercalations), mezomictic, more rarely oligomictic, poorly sorted. Their composition includes: quartz (23—43 per cent), feldspars (up to 10 per cent), sparry calcite grains (12—40 per cent), crystalline rock fragments (up to 5 per cent), rare sedimentary rock

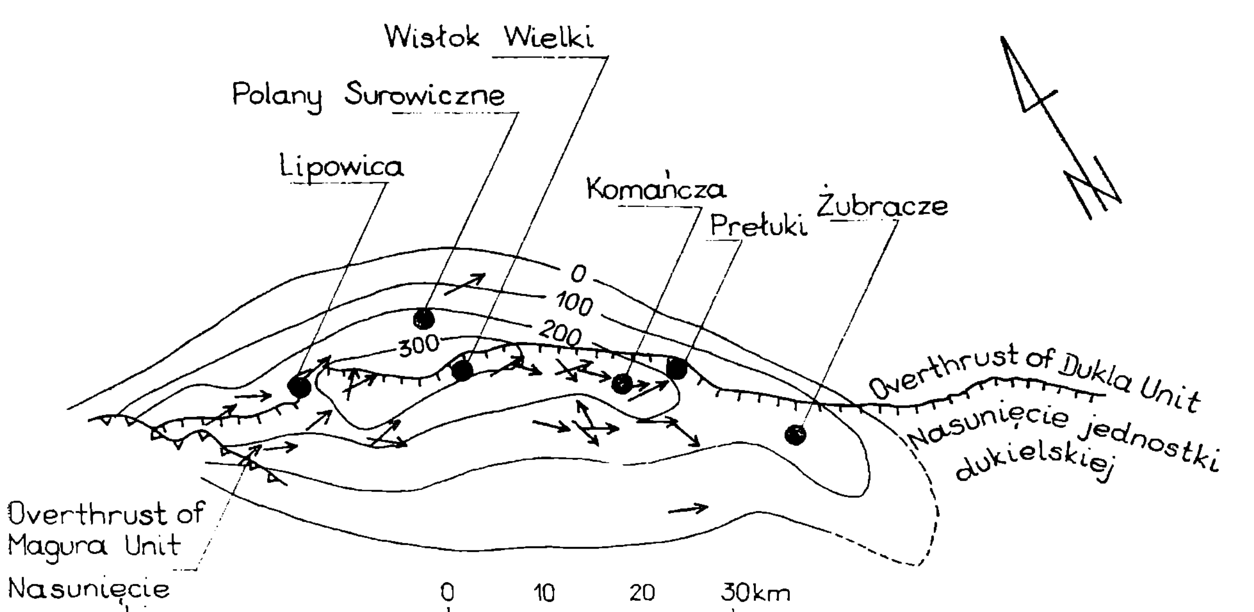

Fig. 3. Isopachytes of the Cergowa sandstone and paleocurrent directions

Fig. 3. Mapa miąższości piaskowców cergowskich i kierunki paleoprądów

fragments (zoogenic limestones, quartzitic sandstone) and carbonate skeletal grains. Mixed clay-carbonate matrix forms up to 28 per cent of the rock.

The sandstone beds are alternating with grey marly shales. Intercalations of sequences consisting of alternating marly shales and thin-bedded, very fine-grained micaceous sandstones are present locally. Such sequences range in thickness from 0.5 m to several metres. Their number increases in the marginal parts of the Cergowa sandstone lithosome.

The Cergowa sandstone forms a member of the informal lithostratigraphic unit of Menilite beds. It is underlain by Sub-Cergowa marls, and covered by Menilite shales (Fig. 2). The Cergowa sandstone lithosome has a lenticular outline in plan (Fig. 3), with maximum thickness — c. 350 m — in the central part, gradually wedging out towards the margins. The thickness changes across the long axis of the lithosome are rapid. To the north and east the Cergowa sandstone is wedging out in black-coloured clayey Menilite shales, while to the south it is wedging out among grey marly shales and thin-bedded very fine-grained sandstones, similar to those forming sequences intercalated among the thick-bedded Cergowa sandstones.

The direction of paleotransport determined on the basis of sedimentary structures (sole markings, cross-lamination) is from the north-west to the south-east, corresponding with the long axis of the lithosome (Ś l ą c z k a, 1959). The clastic sedimentary material was derived from the Silesian Cordillera, an intra-geosynclinal tectonic land. The Cergowa sandstone lithosome may be regarded as the sedimentary fill of an elongated furrow on the floor of the sedimentary basin of the Menilite beds. Characteristically the shales deposited on the two sides of this furrow are facially different, as stated above.

These differences were probably controlled by basin geometry and submarine topography at the time of deposition. The thin-bedded, very fine-grained sandstones and marly shales occurring along the south-western margin of the Cergowa sandstone lithosome and forming intercalations in it, are not representing a distal facies of the Cergowa sandstone, as their occurrence is not related to the distance of the source area of clastic material. The discussed facies is almost entirely lacking along the north-eastern margin of the Cergowa sandstone lithosome, where thick-bedded sandstones are wedging out among black clayey shales. The exact nature of the topographic control of the described facies distribution remains obscure, although it may the assumed, by analogy to Recent deep-sea turbidite sands, that the thick-bedded sandstones were deposited in a topographic depression, acting as a conduit for turbidity currents.

Besides the main lithosome of Cergowa sandstone, there are two occurrences of lithologically and stratigraphically equivalent beds. One is situated on the western prolongation of the axis of the main lithosome, in the Klęczany—Librantowa tectonic window. Because of tectonic complications and poor exposures this sandstone was not studied facially. However there is no doubt that the Klęczany—Librantowa occurrence of Cergowa-type sandstone is separated from the main lithosome of Cergowa sandstone.

Another occurrence of Cergowa sandstone forms a small lense, a few hundred metres long, situated on the south-eastern prolongation of the axis of the main lithosome (Fig. 2). Again, this lense is separated from the main lithosome.

The discussed geometric relations of the individual lenticular lithosomes of Cergowa sandstone are tentatively regarded as indicating the possibility of by-passing of transverse knolls by turbidity currents. Such knolls formed areas of non-deposition.

All the following discussion pertains to the middle lense of Cergowa Sandstone, called here the main lithosome of Cergowa sandstone.

Sections studied

Six section of the Cergowa sandstone studied quantitatively are situated in various parts of the main lithosome. Exposures comprise both quarries and stream-beds. As the completeness of the sections and the accesibility of exposures varies among the localities studied, all quantitative conclusions are verified by statistical tests.

Four sections were selected along the axial part of the lithosome: at Lipowica (quarry — Plate I), at Wisłok Wielki (stream-bed), at Komańcza (quarry) and at Żubracze (quarry). Two sections are situated outside the axial part, closer to the margins of the lithosome: at Polany Surowiczne (stream-bed) and at Preluki (quarry — Plate II). The localization of the sections are shown in Fig. 1 and Fig. 3.

Bed thickness

Histograms of bed thickness distribution for sandstones and shales (Fig. 4) were prepared with the use of a logarithmic scale, comprising five thickness classes:

thin beds	up to 5 cm
medium beds	6— 25 cm
thick beds	26—125 cm
very thick beds	126—625 cm
extremely thick beds	more than 625 cm.

In the axial part of the Cergowa sandstone lithosome there is no change in bed thickness distribution on a distance of 34 km between the sections at Lipowica and at Komańcza. The general shape of the histograms for these sections are identical, with modes in the thick beds class, and the proportion of very thick beds exceeding 10 per cent.

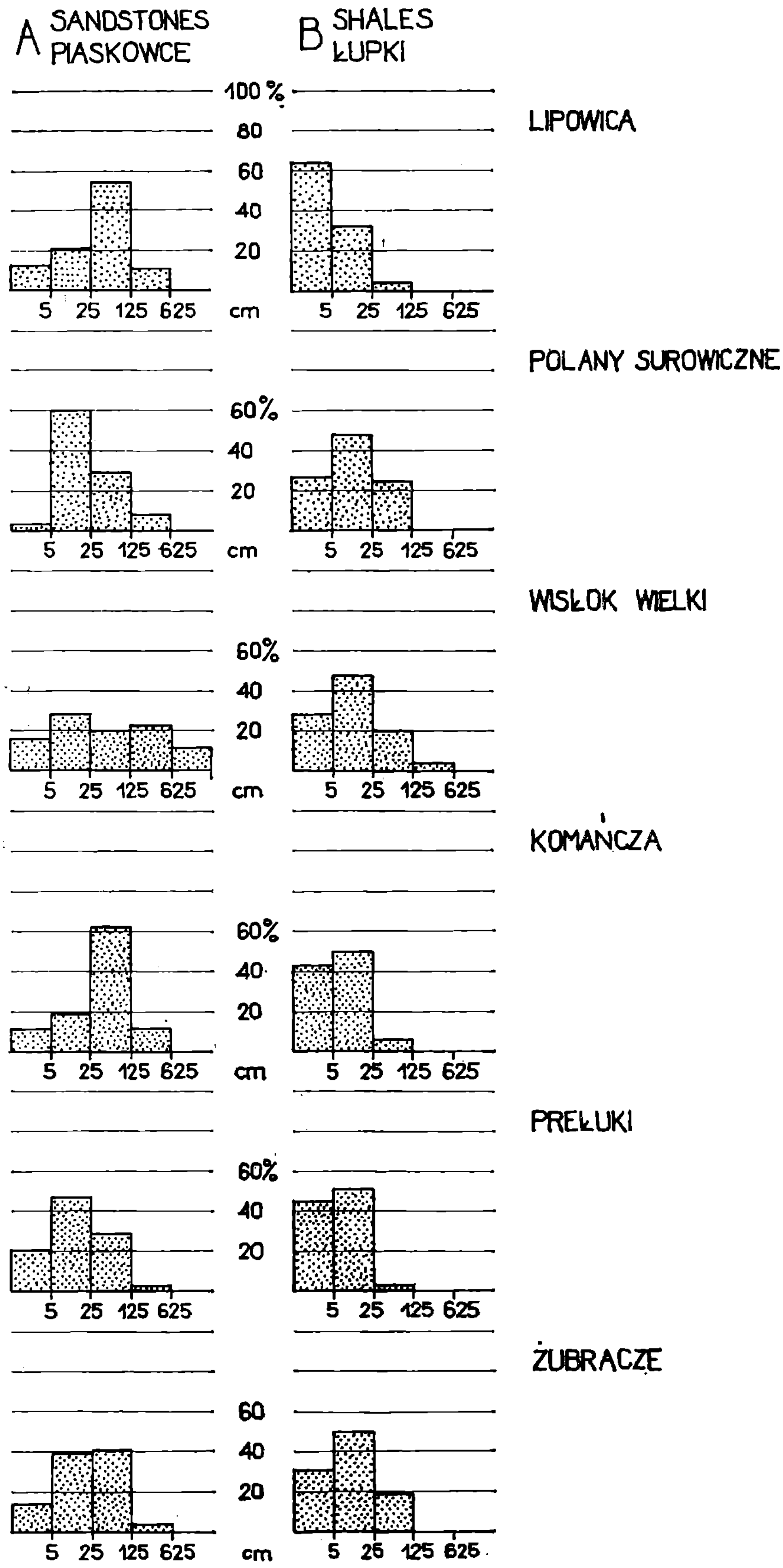

Fig. 4. Histograms showing the thickness distribution of sandstone and shale beds in the Cergowa sandstone member

Fig. 4. Histogramy miąższości ławic piaskowców i łupków w ogniwie piaskowców cergowskich

In the section at Wisłok Wielki situated midway between Lipowica and Komańcza the bed thickness distribution is different, with unconspicuous modes in the medium beds and very thick beds classes, and more than 10 per cent of extremely thick beds.

The sections at Polany Surowiczne and at Prełuki both situated outside the axial zone of the lithosome, at various distances downcurrent from the proximal section at Lipowica, have again similar distributions of sandstone bed thickness, with modes in the medium bed class, and decreasing proportions of thicker beds classes.

The most distal section in the axial zone of the lithosome at Żubracze, has still another shape of the histogram of bed thickness distribution, with medium and thick beds present in nearly equal proportions.

The sandstone bed thickness distributions were tested in pairs for homogenity, with the use of the Kolmogoroff-Smirnoff test (the values of bed thickness were grouped in classes 20 cm wide). No significant differences were found between the bed thickness distributions in the sections at Lipowica, Wisłok Wielki and Komańcza, which are regarded as a homogenous group. The bed thickness distribution in these three sections differ significantly from the distributions in the remaining sections, with the exception of the section at Polany Surowiczne showing some affinities with the Section at Wisłok Wielki. The distance between these two sections is small.

The sections at Polany Surowiczne, at Prełuki and at Żubracze form another homogenous group, with no significant differences in bed thickness distribution between them (see Table 1).

Therefore, considering sandstone bed thickness as a measure of intensity of deposition, two zones may be distinguished within the Cergowa sandstone lithosome: the inner zone, comprising the proximal axial part of the lithosome (sections at Lipowica, Wisłok Wielki and Komańcza), and the outer zone, comprising the marginal and distal axial part of the lithosome (sections at Polany Surowiczne, Prełuki and Żubracze).

Histograms showing the bed thickness distribution for shales are shown in Fig. 4. The thickness distribution of shale beds is generally very similar over the major part of the Cergowa Sandstone lithosome, with modes of c. 50 per cent in the medium beds class. The proportion of thin and thick beds vary, and a small percentage of very thick beds is present in the section at Wisłok Wielki. The only exception to this general picture is formed by the proximal section at Lipowica, where a very pronounced mode is present in the thin beds class, with decreasing percentages of thicker beds.

The thickness distribution of shale beds divides therefore the Cergowa sandstone lithosome into two unequal parts: the proximal part — with predominance of thin shale beds comprising the section at Lipowica, and the remaining part of the lithosome with predominance of medium shale beds.

Table 1

Tabela 1

Kolmogoroff - Smirnoff test for homogenous distribution of sandstone bed thickness in the Cergowa Sandstone

Test Kołmogorowa - Smirnowa dla weryfikacji jednorodności rozkładów miąższości ławic piaskowców cergowskich

Section Przekrój	n	Lipowica	Polany Surowiczne	Wisłok Wielki	Komańcza	Prełuki	Żubracze
		maximum vertical distance between cumulative bed thickness distribution for pairs of sections największy rozstęp kumulowanego rozkładu miąższości ławic dla par przekrojów					
Lipowica	25	X	0,434	0,222	0,116	0,580	0,516
Polany Surowiczne	65	1,84 S	X	0,265	0,372	0,056	0,056
Wisłok Wielki	35	0,848 NS	1,264 NS*	X	0,205	0,327	0,296
Komańcza	33	0,438 NS	1,741 S	0,8446 NS	X	0,418	0,354
Prełuki	40	2,27 S	0,278 NS	1,413 S	1,781 S	X	0,064
Żubracze	69	2,20 S	0,323 NS	1,426 S	1,671 S	0,333 NS	X

values of Kolmogoroff - Smirnoff λ for pairs of sections

wartości statystyki λ Kołmogorowa - Smirnowa dla par przekrojów

n - number of beds
- liczba ławic

$\alpha = 0,05$

$\lambda_{\alpha} = 1,36$

* at $\alpha = 0,10$

$\lambda_{\alpha} = 1,235$

$\lambda = 1,264$ S

S - significant
- istotne

NS - not significant
- nie istotne

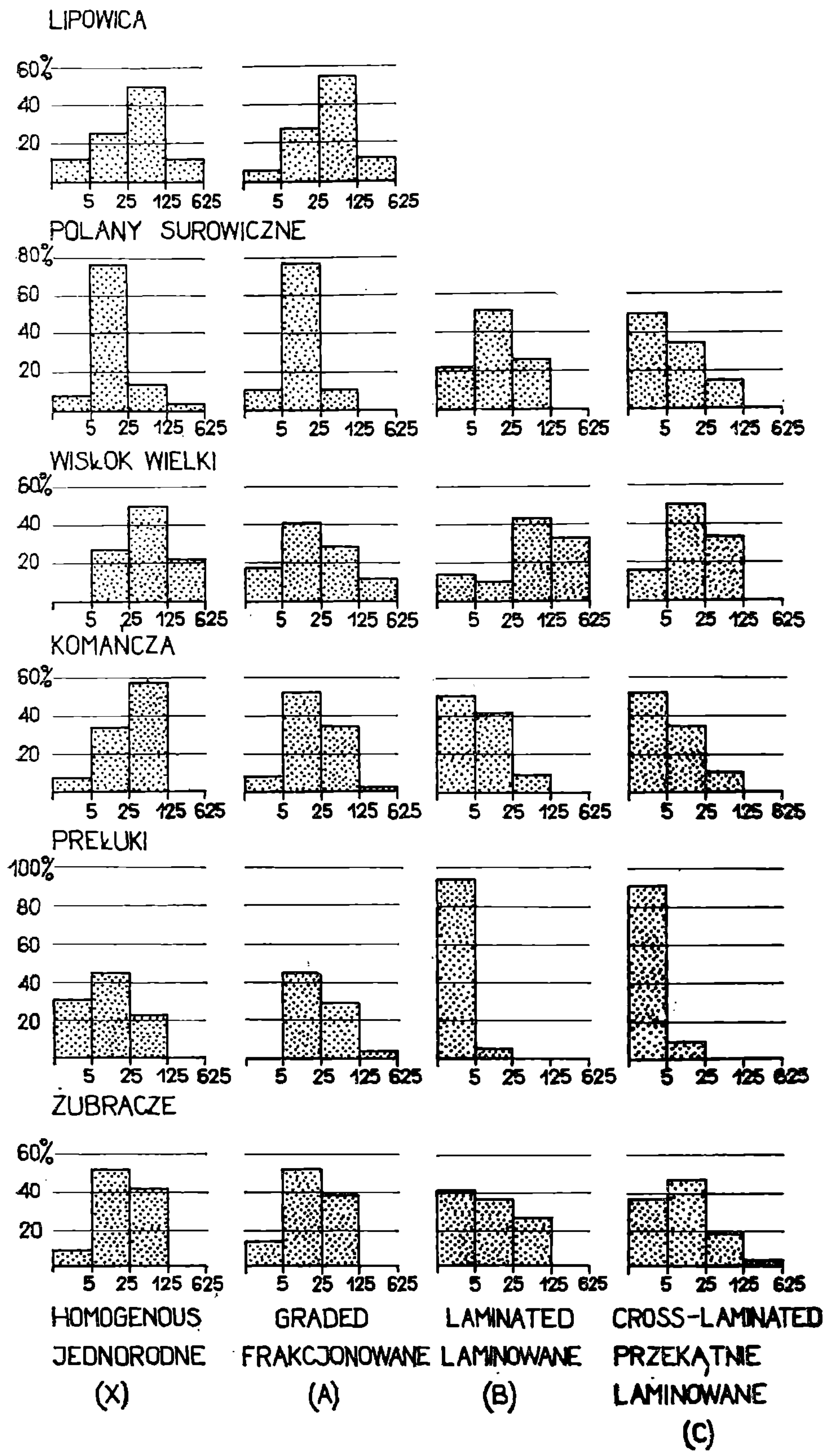

Fig. 5. Histograms showing the thickness distribution of sandstone divisions with various stratification structures

Fig. 5. Histogramy miąższości warstw (oddziałów) w ławicach piaskowców o różnych strukturach warstwowania. Ogniwo piaskowców cergowskich

Table 2

Tabela 2

Distribution of stratification divisions in the sections studied, Cergowa Sandstone

Rozkład struktur warstwowania w piaskowcach cergowskich

Section / Przekrój	Frequency of stratification structures per cent / Częstość struktur warstwowania w %				
	No bed forms / Bez form dna			Bed forms / Z formami dna	
	Homogenous / Jednorodne X	Graded / Frakcjonowane A	Total / Razem X + A	Laminated / Laminowane B	Cross laminated / Przekątnie laminowane C
Lipowica	28,0	72,0	100,0	-	-
Polany Surowiczne	29,3	17,1	46,4	27,3	26,3
Wisłok Wielki	25,0	30,4	55,4	37,5	7,1
Komańcza	14,0	39,5	53,5	14,0	32,5
Prełuki	16,2	35,1	51,3	20,0	28,7
Żubracze	32,0	26,0	58,0	17,0	25,0

For the sections / dla przekrojów /:
Polany Surowiczne, Komańcza, Prełuki and Żubracze

$$\chi^2 = 8{,}951 \text{ NS}$$

$$\alpha = 0{,}05$$

$$\chi^2_{\alpha}/\text{DF6}/ = 12{,}592$$

Stratification structures in sandstone beds

The range of stratification divisions recorded in sandstone beds comprise the following types:

— homogenous (macroscopically structureless) — symbol X,
— graded — symbol A,
— laminated — symbol B,
— cross-laminated — symbol C.

The frequency of these stratification divisions in the individual sections is presented in Table 2. The thickness distribution of stratification divisions within the individual sections is presented in Fig. 5.

The proximal section at Lipowica is characterized by the absence of laminated and cross-laminated divisions in the thick-bedded sandstones. All four divisions are present in various proportions in the remaining sections. At Lipowica all divisions represent rapid deposition without formation of bed forms. In all remaining sections such divisions (i.e. division X and division A) form c. 50 per cent of the total number of divisions recorded. Laminated divisions deposited under conditions of the upper flow regime represent 14.0—27.3 per cent of the total number of divisions, with the exception of the section at Wisłok Wielki, where their proportion amounts to 37.5 per cent. Cross-laminated divisions formed under conditions of lower flow regime form 25.0—32.3 per cent of the total number of divisions recorded, again with the exception of the section at Wisłok Wielki, where their proportion amounts to 7.1 per cent only.

The sections at Polany Surowiczne, Komańcza, Prełuki and Żubracze form a homogenous group, and the differences in frequencies of stratification divisions between them are statistically not significant (see Table 2).

Thus, in the proximal section at Lipowica all sandstones were deposited under conditions of rapid deceleration. The next section downcurrent in the axial zone — at Wisłok Wielki — has the highest proportion of divisions deposited under conditions of the upper flow regime. The remaining sections — the proximal marginal section at Polany Surowiczne and the sections distal with regard to Wisłok Wielki have a statistically uniform frequency distribution of stratification divisions, with proportions of cross-laminated structures, formed under conditions of lower flow regime in the range of 25—30 per cent.

Other sedimentary features

Field observations indicate, that several other sedimentary features of the Cergowa sandstone are changing systematically along and across the lithosome. Yet, the nature of these features and the conditions of observations cause that a quantitative analysis of their occurrence and frequency would be burdened by a large observational error. A semiquantitative discussion is therefore preferred.

Scours and erosional channels

In the proximal section at Lipowica numerous scours and erosional channels up to 1.5 m deep are present. These scours are undoubtedly reducing the thickness of the shale beds separating the sandstone beds. Only few shallow scours were observed in the remaining sections.

Sole markings

The occurrence of sole markings on sandstone beds show a distinct pattern. In the axial zone of the Cergowa sandstone lithosome there are a few flute marks in the proximal section at Lipowica; their number increases downcurrent at Komańcza and Prełuki, where they are accompanied by prod marks and brush marks. In the most distal section at Żubracze flute marks are absent, while drag marks and longitudinal ridges appear, accompanied by prod marks and brush marks. In the marginal section at Polany Surowiczne drag marks are the most common type of sole markings, similarly as at Żubracze. Thus, an axial distal section and a proximal marginal section have the same predominant component of the sole markings assemblage.

Convolution

Convolution is common only in the cross-laminated divisions of sandstone beds in the distal section at Żubracze.

Top surfaces of sandstone beds

Sharp top surfaces of sandstone beds predominate in the proximal part of the Cergowa sandstone lithosome, both in the axial zone sections, and in the marginal section at Polany Surowiczne. Farther downcurrent, beds with continuous transition from the sandstone division to the pelitic division become more abundant. At Prełuki sharp and gradual transitions are nearly equally frequent, while at Żubracze the gradual transitions are distinctly more frequent that the sharp ones.

Intrabasinal shale clasts

Intrabasinal clasts of greenish and grey marly shales are occurring along the whole axial zone of the Cergowa sandstone lithosome. They are most frequent at Wisłok Wielki.

Carbonized plant detritus

In the proximal section at Lipowica carbonized plant detritus forms layers up to 20 cm thick situated in the upper part of the pelitic divisions. However there is no plant detritus dispersed within the sandstones. Farther downcurrent carbonized plant detritus appears dispersed in the sandstone beds. At Żubracze, plant detritus becomes again abundant in the pelitic divisions separating the sandstone beds.

Grain size

The coarsest grade present in each bed, or in a division in a bed individualized by its stratification structures, was noted during field work. Five grades, viz. very coarse, coarse, medium, fine and very fine grains were distinguished by comparison with a standard. The general distributions of grain size in the various sections of the Cergowa sandstone lithosome are presented in Fig. 6.

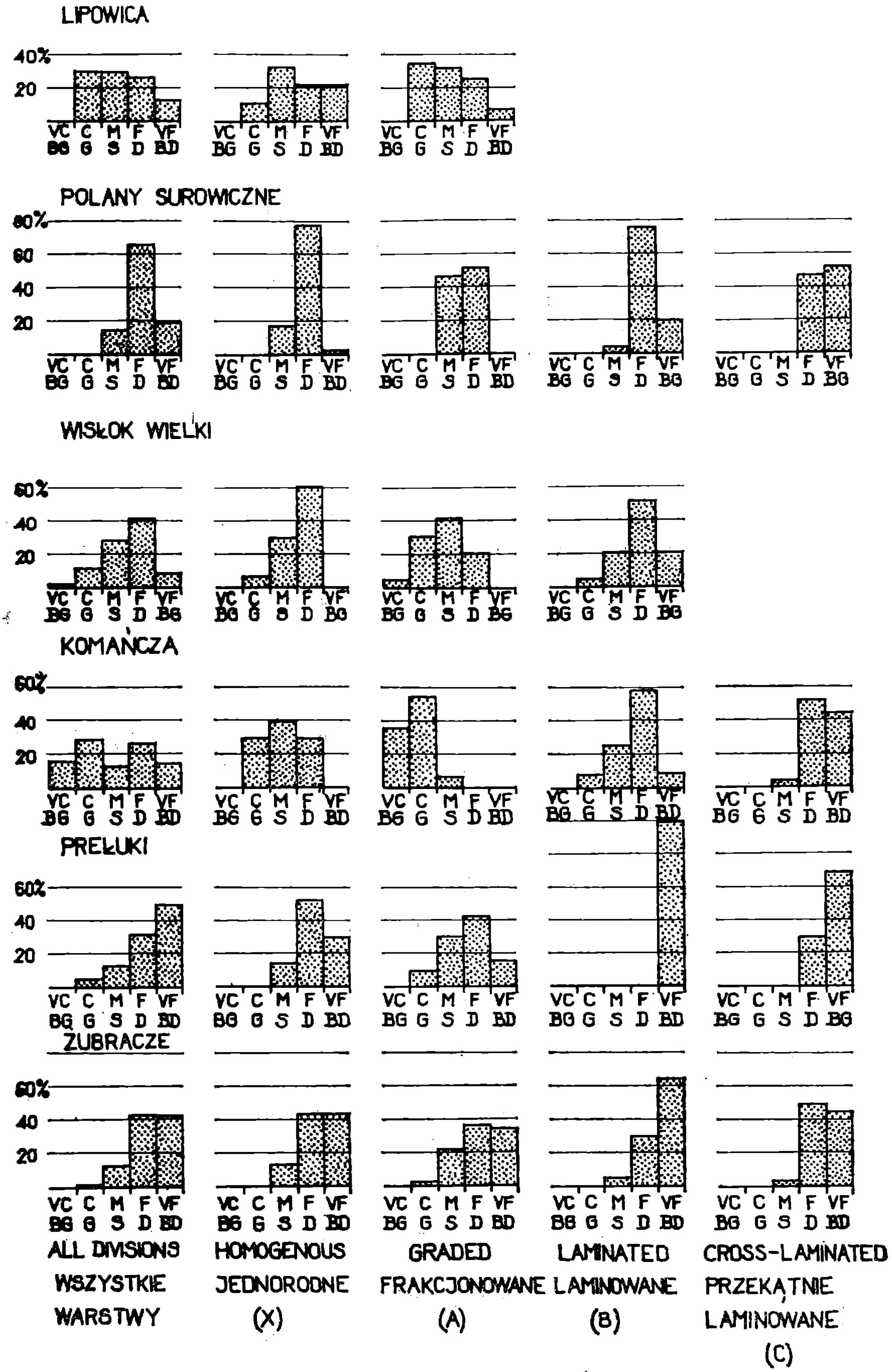

Fig. 6. Histograms showing grain-size distribution in sandstone divisions with various stratification structures. VC — very coarse; C — coarse; M — medium; F — fine; VF — very fine

Fig. 6. Histogramy rozkładu wielkości ziarna w oddziałach ławic piaskowców o różnych strukturach warstwowania. BG — ziarno bardzo grube; G — grube; S — średnie; D — drobne; BD — bardzo drobne

Table 3
Tabela 3

Observed /O/ and expected /E/ frequencies of coarsest grain size classes, Cergowa Sandstone

Obserwowane /O/ i oczekiwane /E/ częstości najgrubszego ziarna w piaskowcach cergowskich

Section Przekrój	grain size - wielkość ziarna					
	Very fine B. drobne	Fine Drobne	Medium Srednie	Coarse Grube	Very coarse B. grube	$\sum$ O
Lipowica	O 5,00 E 9,46 O-E -4,46	9,00 14,21 -5,21	10,0 5,50 +4,50	10,0 3,66 +6,34	0,00 1,15 -1,15	34
Polany Surowiczne	O 19,00 E 27,87 O-E -8,87	66,00 41,80 +24,20	15,00 16,18 -1,18	0,00 10,77 -10,77	0,00 3,37 -3,37	100
Wisłok Wielki	O 4,00 E 12,54 O-E -8,54	19,00 18,81 +0,19	13,00 7,28 +5,72	8,00 4,85 +3,15	1,00 1,52 -0,52	45
Komańcza	O 13,00 E 23,96 O-E-10,96	23,00 35,95 -12,95	11,00 13,91 -2,91	25,00 9,28 +15,72	14,00 2,90 +11,10	86
Prełuki	O 40,00 E 22,29 O-E+17,71	26,00 33,44 +7,44	10,00 12,94 -2,94	4,00 8,63 -4,63	0,00 2,70 - 2,70	80
Żubracze	O 43,00 E 27,87 O-E+15,13	43,00 41,80 +1,20	13,00 16,18 -3,80	1,00 10,77 -9,77	0,00 3,37 -3,37	100
$\sum$ O	124	186	72	48	15	445

For sections / dla przekrojów/ : Lipowica and Wisłok Wielki

$\alpha = 0,05$; χ^2_{α}/DF4/=9,488; χ^2 = 8,532 NS

For sections / dla przekrojów/ : Prełuki and Zubracze

$\alpha = 0,05$; χ^2_{α}/DF3/=7,815; χ^2 = 4,31 NS

Generally the grain size decreases downcurrent and outside the axial zone of the lithosome, as indicated by the modal grades in the individual sections. Two areas with uniform grain-size distribution can be distinguished within the Cergowa sandstone lithosome (see Table 3). The proximal area comprises the sections at Lipowica and at Wisłok Wielki. The distal area comprises the sections at Prełuki and at Żubracze. Between these two areas lies the section at Komańcza with the coarsest grain present. The section at Polany Surowiczne situated in the marginal

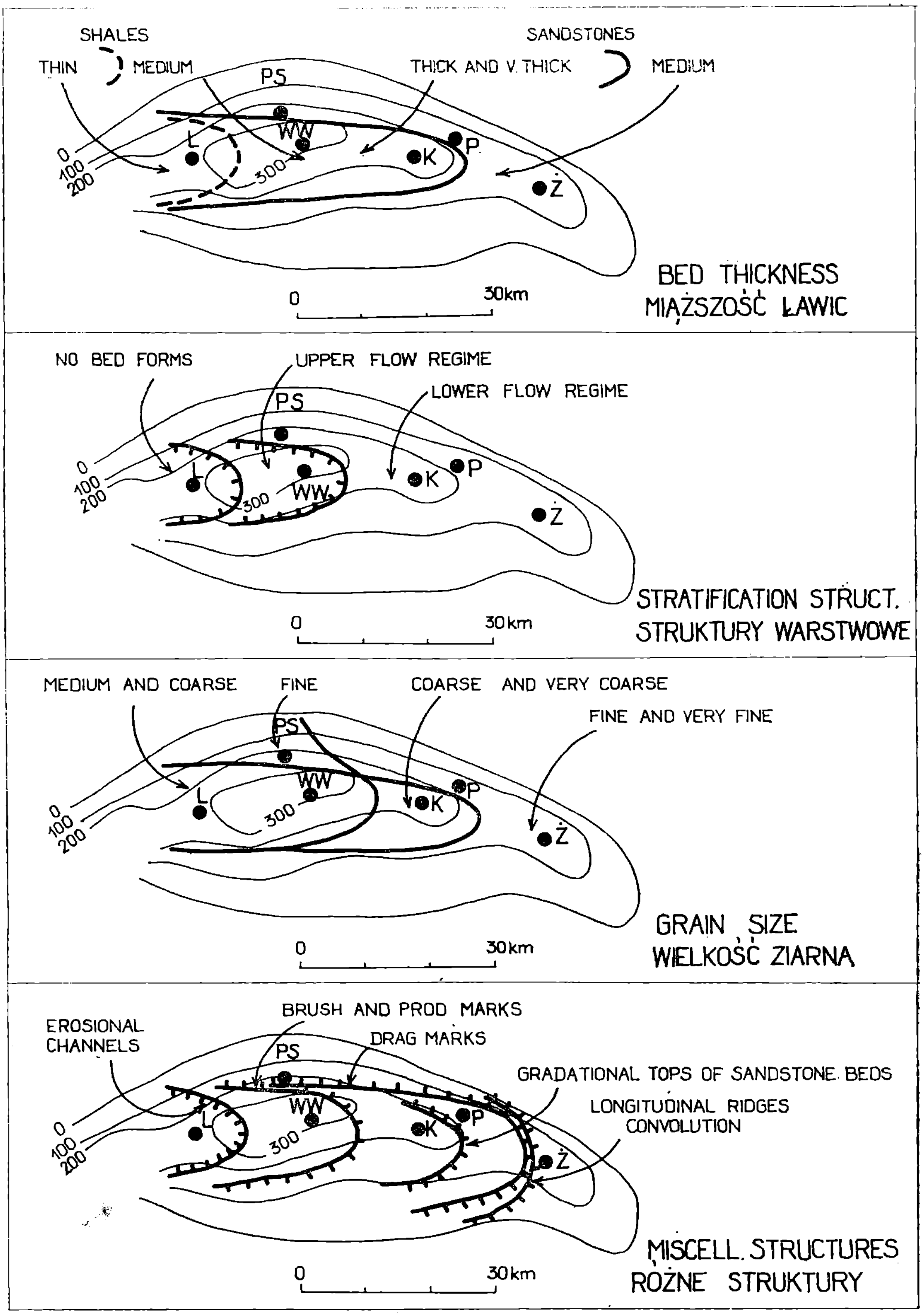

Fig. 7. Gradients of textural and structural features in the Cergowa sandstone lithosome. For bed thickness, stratification structures and grain size the heavy lines are delimiting statistically homogenous areas. Thin lines show isopachytes of the Cergowa sandstone

Fig. 7. Gradienty cech teksturalnych i strukturalnych w litosomie piaskowców cergowskich. Dla miąższości ławic, struktur warstwowania i wielkości ziarna grube linie rozgraniczają obszary statystycznie jednorodne. Cienkie linie są izoliniami miąższości piaskowców cergowskich

part of the lithosome has a grain size distribution differing from all other sections.

The grain size and the stratification structures are correlated, the coarsest grain in each section being present in graded divisions. The list of divisions arranged from coarser to finer grain is: graded, homogenous, laminated and cross-laminated. Coarse and very coarse grain is relatively rare with the exception of the section at Komańcza, where 36 per cent of graded divisions are very coarse-grained, while 55 per cent of graded divisions and 30 per cent of homogenous divisions are coarse-grained. Field relations suggest that these coarse-grained beds are filling a channel eroded into the underlying deposits.

The distribution of grain size and of bed thickness and lithosome thickness suggest that the proximal end of the area of deposition of the Cergowa sandstone was by-passed both by the major part of the volume of sedimentary material and by the coarsest grain.

CONCLUSIONS

The changes of textural and structural parameters in the Cergowa sandstone lithosome described above are presented in Fig. 7, in relation to lithosome geometry. Two regions can be clearly distinguished within the lithosome. The first, axial region comprising the zone of maximum thickness, and characterized by distinct downcurrent gradients of textural and structural features. The second — marginal region, comprising the zone of decreasing thickness of the lithosome, is characterized by few weak downcurrent gradients of textural and structural features. This difference between the axial region and the marginal region is clearly visible in the following list.

Region:	Downcurrent gradients:
1. axial region	
shale thickness:	thin to medium
sandstone thickness:	thick to medium
sandstone stratification structures:	no bed forms — to upper flow regime — to lower flow regime
sandstone grain size:	medium and coarse — to coarse and very coarse — to fine and very fine
sandstone tops:	sharp — to gradational
sandstone sole marks:	brush and prod marks — to drag marks — to longitudinal ridges
2. marginal region:	
shale thickness:	medium (no gradient)
sandstone thickness:	medium (no gradient)
sandstone stratification structures:	lower flow regime (no gradient)
sandstone grain size:	fine — to fine and very fine
sandstone tops:	sharp — to gradational
sandstone sole marks:	brush, prod and drag marks (no gradient)

The features of the marginal region are in general similar to those present at the downcurrent — distal end of the axial region. It is concluded therefore, that longitudinal downcurrent gradients of textural and structural features present in the axial region are accompanied by steeper lateral gradients across the paleocurrent direction. The gradients of textural and structural features are reflecting changes in hydraulic conditions of transport and deposition, which are controlled by basin geometry. From the above it follows, that this geometric control is more pronounced in the direction transverse to paleocurrent, than in the direction parallel to paleocurrent. This supports strongly the hypothesis that elongated lithosome shape in turbidite sandstones is indicative of deposition in a submarine valley (see discussion by Stanley and Unrug, 1972).

The existence of the two types of gradients of structural and textural features leads to the conclusion that the notion of „proximality" in the sense of Walker (1965, 1967) should be used with care, and specifically that the so called „ABC indexes" can not be used to estimate the distance travelled by turbidity currents from the source area.

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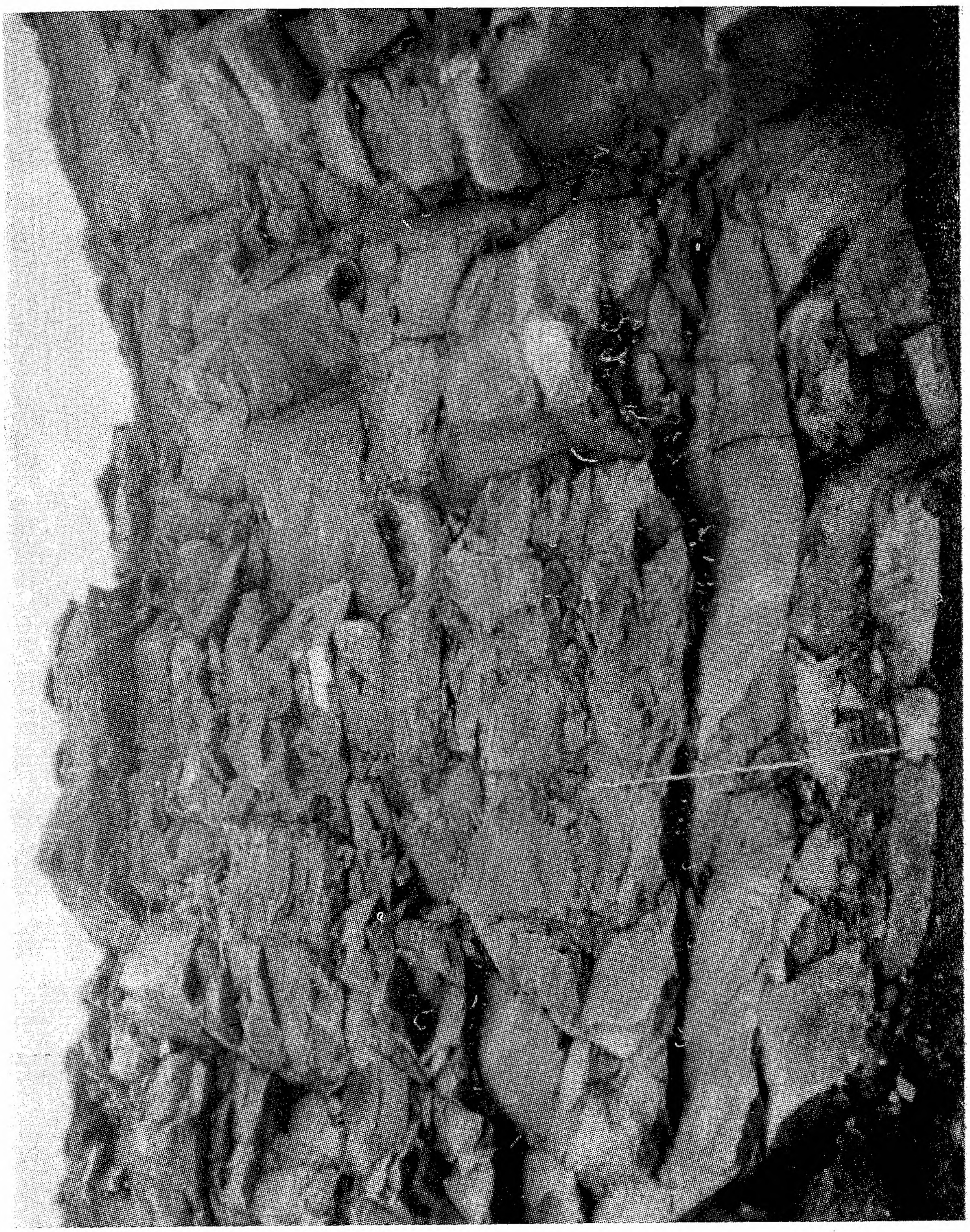

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STRESZCZENIE

Treść: Kierunki zmienności, określone ilościowo dla miąższości ławic, występowania struktur warstwowych i wielkości ziarna, oraz jakościowo dla występowania różnych struktur sedymentacyjnych, są związane z kształtem litosomu i geometrią basenu sedymentacyjnego. Oprócz zmienności cech strukturalnych i teksturalnych w kierunku paleotransportu występuje zmienność tych cech prostopadle do paleotransportu. W wydłużonym litosomie piaskowców cergowskich stwierdzono podobieństwo cech strukturalnych i teksturalnych w osiowej części basenu odległej od obszaru źródłowego materiału klastycznego i w brzeżnej części basenu w sąsiedztwie tego obszaru.

Osady powstałe w wyniku działalności prądów zawiesinowych charakteryzuje zmienność cech strukturalnych i teksturalnych zależna od regionalnych i lokalnych różnic w warunkach osadzania, na co w pierwszym rzędzie wpływa kształt basenu, a także odległość od obszaru źródłowego. Dlatego też systematyczne badania struktur i tekstur mają istotne znaczenie dla wszelkich analiz paleogeograficznych. Do tej pory prowadzone były głównie obserwacje jakościowe tych cech, brak natomiast było szerszych opracowań zmienności w ujęciu ilościowym dającym bardziej obiektywny obraz.

Celem uchwycenia w ujęciu ilościowym zmienności cech strukturalnych i teksturalnych w zależności od miejsca depozycji w obrębie basenu przeprowadzono badania jednego kompleksu piaszczystego osadzonego przez prądy zawiesinowe.

Badaniami tymi objęte zostały piaskowce cergowskie (niższy oligocen), które tworzą zwarty litosom w obrębie warstw menilitowych jednostki dukielskiej i południowo-wschodniej części jednostki śląskiej (fig. 1). Litosom ten ma kształt soczewki wydłużonej zgodnie z kierunkiem transportu (fig. 2 i 3). Do badań pobrany został materiał z 4 profili leżących mniej więcej wzdłuż osiowej części litosomu (Lipowica, Wisłok Wielki, Komańcza, Żubracze) oraz z 2 profili leżących w pobliżu NE brzegu litosomu (Polany Surowincze, Prełuki).

Przeanalizowano zmienność grubości ławic, wielkości ziarna oraz struktur warstwowania w ujęciu ilościowym (tab. 1—3). Niektóre pozostałe cechy — mechanoglify, charakter górnych powierzchni ławic piaskowców oraz występowanie detrytusu roślinnego rozpatrywane były półilościowo ze względu na brak dostatecznej ilości materiału do badań statystycznych.

Zmiany w badanych parametrach w zależności od kształtu litosomu przedstawione są na fig. 7. Na jej podstawie wyróżnić można dwa rejony. Pierwszy — osiowy o maksymalnej miąższości osadów, charakteryzuje wyraźna zmiana cech teksturalnych i strukturalnych przebiegająca zgodnie z kierunkiem transportu; drugi — obejmujący północną strefę brzeżną, charakteryzuje niewielka zmienność badanych cech wzdłuż kierunku transportu.

Różnice pomiędzy tymi dwoma rejonami przedstawione są poniżej:

Badane cechy	Przebieg zmian
1. Rejon osiowy	
Grubość ławic łupków	od cienkich do średnioławicowych
Grubość ławic piaskowców	od grubo- do średnioławicowych
Warstwowanie piaskowców	od bezwarstwowych do osadzonych w warunkach górnego, a potem dolnego reżimu przepływu
Wielkość ziarn	od średnich i grubych przez grube i bardzo grube do drobnych i bardzo drobnych
Górne powierzchnie ławic piaskowców	ostre do gradacyjnych
Mechanoglify	ślady uderzeniowe przez ślady wleczeniowe do podłużnych grzbietów prądowych
2. Rejon brzeżny	
Grubość ławic łupków	średnioławicowe (brak zmienności)
Grubość ławic piaskowców	średnioławicowe (brak zmienności)
Warstwowanie piaskowców	utworzone w warunkach dolnego reżimu przepływu (brak zmienności)
Wielkość ziarn	od drobnych do drobnych i bardzo drobnych
Górne powierzchnie ławic piaskowców	ostre do gradacyjnych
Mechanoglify	ślady uderzeń i ślady wleczenia (brak zmienności)

Przeprowadzone badania wykazały, że cechy rejonu brzeżnego zbliżone są do cech występujących w dystalnej części rejonu osiowego. Wskazuje to, że zmiany struktur i tekstur osadów występowały szybciej w poprzek niż wzdłuż kierunku prądów. Zmiany te są odbiciem gradientów warunków hydraulicznych panujących w czasie transportu i depozycji, a zależnych od kształtu basenu. Nasuwa się więc wniosek, że kształt basenu musiał zmieniać się szybciej prostopadle do stwierdzonego kierunku paleotransportu niż w kierunku paleotransportu. Świadczy to, że litosomy o wydłużonym kształcie osadzane były w podmorskich obniżeniach lub dolinach, których kształt kontrolował rozkład cech teksturalnych i strukturalnych.

Zmienność cech strukturalnych i teksturalnych w kierunku równoległym i prostopadłym do paleotransportu wskazuje, że pojęcie „proksymalności" Walkera (1960) powinno być używane z dużą dozą ostrożności, a szczególnie że tzw. „indeks ABC" nie może być używany bezpośrednio do określania odległości od obszaru źródłowego.

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EXPLANATION OF PLATES
OBJAŚNIENIA TABLIC

Plate — Tablica I

Cergowa sandstone, Lipowica quarry. Thick and very thick-bedded sandstones in proximal axial part of the sedimentary basin. Note the absence of shale intercalations
Piaskowce cergowskie, kamieniołom w Lipowicy. Grubo i bardzo gruboławicowe piaskowce w osiowej części basenu sedymentacyjnego, blisko obszaru źródłowego materiału klastycznego. Przeławicenia łupków nie występują

Plate — Tablica II

Cergowa sandstone, Prełuki quarry. Dominantly medium-bedded sandstones in marginal distal part of the sedimentary basin, alternating with shales
Piaskowce cergowskie, kamieniołom w Prełukach. Głównie średnioławicowe piaskowce w brzeżnej części basenu sedymentacyjnego dalekiej od obszaru źródłowego materiału klastycznego, przekładane łupkami