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LITHOLOGIC SEQUENCES IN THE UPPER SILESIA COAL-MEASURES (UPPER CARBONIFEROUS, POLAND)

(4 Figs.)

Sekwencje litologiczne w utworach Górnośląskiego Zagłębia Węglowego

(4 fig.)

Abstract: Vertical lithologic variability of the three chosen coal-bearing lithostratigraphic units was investigated using Markov chain analysis on the data from six deep boreholes. The relatively coarsest deposits appear randomly and initiate the sequences in path diagrams in all three units. In the Mudstone Series (deposits of an alluvial plain of meandering rivers) all lithologies are connected by transition paths and constitute one sequence. In the Poruba Beds (deposits of an alluvial plain and subordinately of mixed continental-marine environments) and in the Łaziska Beds (dominated by deposits of braided-rivers alluvial plain) also structureless fine-grained deposits appear randomly and have upwards transitions into rooty layers and coal. Thus two independent subsequences are distinguishable in these units: the „barren" (fining-upwards) and the „coal-bearing" ones.

The position of the relatively coarsest clastics in the paths diagrams is interpreted chiefly as a result of river channel shifting and is related to intrabasinal factors. The occurrence of independent coal-bearing subsequences is attributed to the intervention of extrabasinal factors.

INTRODUCTION

Traditionally, the investigations of lithologic sequences in coal-bearing deposits dealt primarily with problems of cyclic sedimentation. The base of the cycle was usually chosen arbitrarily taking into account practical purposes or a genetical hipothesis accepted. The application of the

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Markov chain analysis to this problem made the analysis of sedimentary sequences more objective and revealed some relationships which could not be detected earlier (see, Read 1969; Doveton 1971; Casshyap 1975).

The sequence of lithologies in the coal-bearing deposits of the Upper Silesia was discussed in most earlier works only incidentally and descriptively. Statistical methods were used for cyclicity analysis only by Dembowski & Unrug (1970) and Śliwa (1975) concerning the Łaziska Beds and the Upper Silesia Sandstone Series respectively. The authors mentioned have placed the base of the cycle at the base of a coal seam.

The present authors, within the scope of a more extensive sedimentological research, attempted to study the sequence of lithologies in selected lithostratigraphic units using the Markov chain analysis. The purpose of the work was the construction of path diagrams in order to obtain informations useful for environmental interpretation of the deposits.

GEOLOGICAL SETTING

The coal-bearing deposits in the Upper Silesia Coal Basin are of the Namurian and Westphalian age. They occur over an area of some 6.500 sq. km. The total thickness of all lithostratigraphic units approaches 7.000 m (Dembowski, 1972).

Table 1

		Local stratigraphy			
Westphalian	D	Cracow Sandstone Series	Libiąż Beds		WP43 MB61 MB43
	C		Łaziska Beds		
	B	Mudstone Series	Orzesze Beds		
	A		Załęże Beds		
Namurian	C	Upper Silesia Sandstone Series	Ruda Beds		
	B		Anticlinal Beds		M12 M16 Ig2
	A	Paralic Series	Poruba Beds	marine fauna horizons: I, II, III, IV, V	
			Jaklovec Beds		

The present-day lithostratigraphic division of these deposits is informal. Individual units bear traditional names, which neither follow international standards nor the Polish project of the stratigraphic code.

The deposits dealt with are divided into four main lithostratigraphic units traditionally called „series" (corresponding to formal subgroups) and smaller units named „beds" (corresponding to formations). In ascending order these are (cf. Stopa 1967; Bojkowski *et al.* in Dembowski, 1972): Paralic Series (with the Poruba Beds as the uppermost part), Upper Silesian Sandstone Series (Anticlinal Beds and Ruda Beds), Mudstone Series (Załęże Beds and Orzesze Beds) and the Cracow Sandstone Series (Łaziska Beds and Libiąż Beds) — compare Table 1.

Several horizons with marine fauna appear in the Paralic Series marking successive marine ingresions over an area of predominantly continental sedimentation. The upper lithostratigraphic units contain deposits laid down exclusively in continental environments.

Sandstones and/or mudstones predominate throughout the coal-bearing deposits. Claystones, conglomerates and coal seams occur only subordinately. The only carbonate rocks are clayey siderites forming either lenses of incosiderable lateral extent or, more frequent, dispersed siderite concretions.

MATERIAL AND METHODS OF INVESTIGATION

The investigated sequences were examined in drill cores derived from completely cored boreholes which penetrated relatively long sections of Paralic, Mudstone and Cracow Series (Tables 1, 2). For the purpose of the present work the data presented in the original core logs (cf. Fig. 1) were somewhat generalized by grouping the deposits in the following lithologic divisions (lithologies):

Z — conglomerates and intraformational conglomerates,
S — sandstones with large-scale cross-stratification and structureless sandstones,
R — sandstones with small-scale cross-stratification,
P — horizontally laminated sandstones,
M — horizontally laminated mudstones,
L — mudstones with lenticular and wavy stratification,
F — muddy sandstones with flaser bedding,
H — mudstones and claystones devoid of depositional structures,
X — rooty layers,
Q — coal seams,

Taking into account the specific character of the investigated material (core), individual layers were considered as basic elements of sequences. A layer is understood as such an accumulation of deposit corresponding to one of the divisions enumerated above, which can be distinguished in a core. The layers less then 5 cm in thickness were omitted.

Embedded count matrices of upwards transitions (ij) were constructed to determine interrelations between the individual layers. The null hypothesis assuming that the layers occurring recurrently in a vertical sec-

Investigated drill-cores
Opracowane wiercenia

Table 2

	Poruba Beds warstwy porębskie				Mudstone Series seria mułowcowa			Łaziska Beds warstwy łaziskie		
bore hole wiercenie	M16	M12	Ig2	total razem	MB61	WP43	total razem	MB43	MB61	total razem
core m. rdzeń m.b.	730	746	784	2260	348	609	975	792	627	1419
number of layers ilość warstw	505	593	698	1777	271	593	864	391	264	555

tion form a sequence of random events independent one from another, was verrified using the Chi-square test. The Chi-square statistics was computed from difference between the observed and expected (if the null hypothesis was true) frequency of the ij pairs. The expected frequences were computed using the following formula (Doveton in Read, 1969):

$$n_e = \frac{r_i c_j}{(N - c_i)}$$

where r_i = sum of row i, c_i — sum of column i, c_j = sum of column j, N = number of all transitions in a set.

The Chi-square test was used for a matrix as a whole and for its individual rows, considering the rows as matrices $n \times 1$ (Potter & Blakely, 1967). In both cases the Chi-square values are higher on the significance level of 0.05 than the critical values for the corresponding number of degrees of freedom. Thus the null hypothesis may be rejected for the whole set as well as for the individual rows of the matrix (i.e. for the particular lithologies).

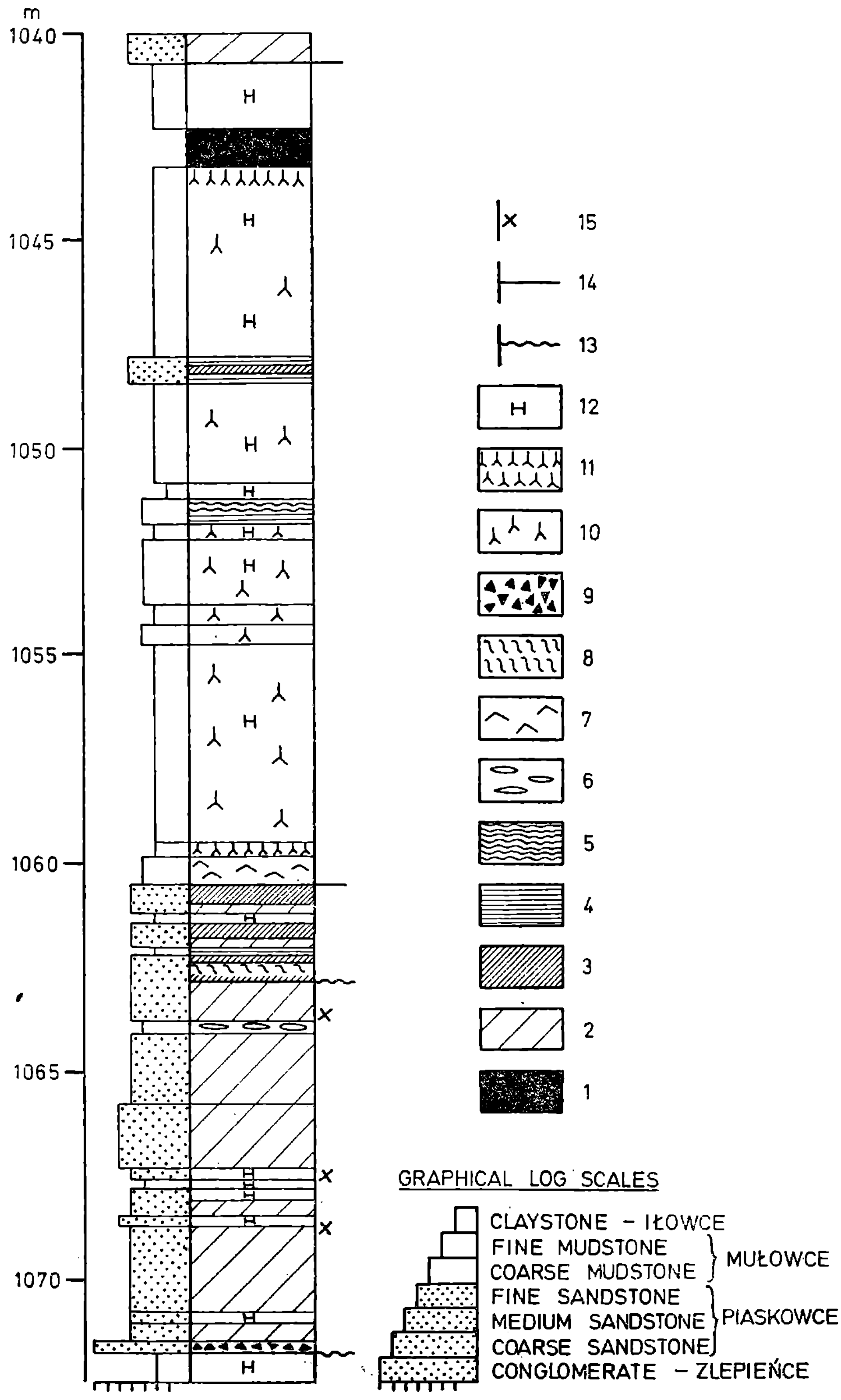
It means that lithology of a layer (j) is related to the lithology of the underlying layer (i). In other words, every j has a „memory" of

Fig. 1. Example of a core log. 1 — coal seam; 2 — large-scale cross-stratification; 3 — small-scale cross-stratification; 4 — horizontal lamination; 5 — wavy lamination; 6 — lenticular stratification; 7 — small-scale cross-stratification and horizontal lamination; 8 — deformational structures; 9 — introformational conglomerate; 10 — rare root traces; 11 — rooty layer; 12 — sediments devoid of depositional structures; 13 — erosional surface; 14 — sharp contact; 15 — plant fragments

Fig. 1. Przykład graficznego opisu profilu. 1 — pokład węgla; 2 — warstwowanie przekątne o dużej skali; 3 — warstwowanie przekątne o małej skali; 4 — laminacja pozioma; 5 — laminacja falista; 6— warstwowanie soczewkowe; 7 — warstwowanie przekątne o małej skali i laminacja pozioma; 8 — struktury deformacyjne; 9 — zlepieńce śródformacyjne; 10 — rzadkie ślady podziemnych pędów; 11 — ziemia stigmariowa; 12 — osady pozbawione struktur depozycyjnych; 13 — powierzchnie erozja; 14 — ostry kontakt; 15 — fragmenty roślin

a preceding event i in this sense that the probability of occurrence of a determined j over i is significantly higher (or smaller) then if the null hypothesis was true.

Usually for the construction of the path diagrams these transitions are used for which the difference between te observed (p_{ij}) and expected (e_{ij}) probability is positive. However, as p_{ij} and e_{ij} depend on the fre-



Poruba Beds - Difference count matrix
Warstwy porębskie - macierz różnicowa

Table 3

	Z	S	R	P	M	L	H	F	X	Q	n_i
Z	-	+34.55	-10.07	+2.00	-10.32	-2.51	-2.75	-3.70	-3.39	-3.80	55
S	+33.95	-	+36.52	+8.94	-26.43	-3.11	-25.14	-5.88	-4.59	-14.26	202
R	-14.86	+15.42	-	+9.60	+30.73	+9.28	+0.97	-2.34	-16.64	-32.51	378
P	-0.07	+10.72	+4.89	-	-7.04	+0.86	-8.30	+6.52	-1.92	-6.65	94
M	-10.22	-6.87	+36.06	-9.88	-	-8.44	-4.87	+17.23	+0.46	-13.44	323
L	-2.63	-5.33	+11.06	-2.20	-2.31	-	+0.92	+7.35	+1.99	-6.85	110
H	-2.03	+4.17	+0.09	-11.14	+5.12	-3.05	-	-13.15	+15.68	+4.31	274
F	-3.84	-3.11	+1.60	+3.44	+19.44	+2.32	-8.14	-	-3.40	-8.31	116
X	-3.49	-9.81	-23.98	-4.96	-10.49	-19.49	-7.38	-6.36	-	+72.45	106
Q	-3.59	-2.50	-25.13	-5.75	+3.82	-2.90	+41.33	-8.33	+2.39	-	119

Poruba Beds - Test "z" values
Warstwy porębskie - wartości statystyki "z"

Table 4

	Z	S	R	P	M	L	H	F	X	Q
Z	-	14.48	....	1.18	....	....	....	....	....	....
S	12.79	-	6.02	2.65	....	....	....	....	....	....
R	....	2.26	-	1.97	3.75	1.77	0.11	....	....	....
P	....	3.40	1.21	-	....	0.46	....	3.65	....	....
M	....	....	4.57	....	-	....	....	3.54	....	....
L	....	....	2.57	....	....	-	0.24	2.75	0.78	....
H	....	0.74	....	....	0.75	....	-	....	3.70	0.97
F	....	....	0.23	1.38	4.56	0.86	....	-	....	....
X	....	....	....	....	....	....	....	....	-	27.36
Q	....	....	....	....	0.88	....	10.19	....	0.89	-

Mudstone series - Difference count matrix
Seria mułowcowa - macierz różnicowa

Table 5

	Z	S	R	P	M	L	H	X	Q	n_i
Z	-	+5.45	-0.10	+0.89	-1.11	-1.18	-1.45	-1.15	-1.28	12
S	+2.25	-	+8.62	+15.89	-4.52	+3.75	-2.74	-9.96	-13.27	110
R	-1.19	-2.92	-	-0.24	+7.16	+5.67	+5.69	-6.14	-8.03	78
P	-0.27	+21.31	+4.71	-	-5.39	-3.93	-2.04	-4.71	-9.67	83
M	-1.21	-2.07	+4.15	-2.35	-	+8.55	+8.34	-7.25	-8.16	79
L	-1.29	+3.15	-0.40	-2.94	+6.49	-	+10.62	-5.83	-9.80	84
H	-1.75	-8.54	+10.13	-5.85	-0.27	-1.25	-	+22.55	-15.02	245
X	-0.26	-10.53	-5.12	-5.70	-4.28	-8.81	-14.69	-	+49.46	82
Q	+1.59	-8.95	-9.18	-6.77	-5.30	-8.89	+23.16	+14.35	-	91

Mudstone series - Test "z" values
Seria mułowcowa - wartości statystyki "z"

Table 6

	Z	S	R	P	M	L	H	X	Q
Z	-	4.69	....	0.81	....	....	....	....	....
S	1.71	-	2.70	4.84	....	1.13	....	....	....
R	....	....	-	....	2.70	2.14	1.39	....	....
P	....	6.72	1.72	-	....	....	....	....	....
M	....	....	1.56	....	-	3.11	2.02	....	....
L	....	0.99	....	....	2.35	-	2.49	....	....
H	....	....	1.95	....	....	....	-	4.23	....
X	....	....	....	....	....	....	....	-	17.03
Q	1.34	....	....	....	....	....	5.22	4.88	-

Łaziska Beds - Difference count matrix
Warstwy łaziskie - macierz różnicowa

Table 7

	Z	S	R	P	M	L	H	X	Q	n_i
Z	-	+25.98	-5.52	-3.80	-2.41	-3.04	-5.95	-2.66	-2.61	39
S	+16.89	-	+24.64	+17.30	-5.71	-6.36	-14.00	-14.91	-18.62	174
R	-5.28	+1.53	-	-5.20	+5.91	+7.04	+3.46	-2.16	-9.64	103
P	-1.93	+25.45	-5.39	-	-1.83	-4.84	-2.48	-4.24	-4.75	60
M	-1.40	-3.72	+3.66	-0.70	-	+5.04	+1.21	-1.59	-2.51	38
L	-3.08	-2.76	-2.86	-1.74	+6.00	-	-0.43	+0.68	-1.51	48
H	-4.53	-3.16	-6.26	-2.05	-2.37	+2.04	-	+14.96	+1.45	94
X	-2.35	-8.48	-6.21	-3.62	-1.29	-1.89	-4.66	-	+33.57	42
Q	-2.72	-1.59	-5.82	-5.72	-3.62	-2.58	+22.04	0.00	-	57

Łaziska Beds - Test "z" values
Warstwy łaziskie - wartości statystyki "z"

Table 8

	Z	S	R	P	M	L	H	X	Q
Z	-	9.22	....	....	....	....	....	....	....
S	4.69	-	4.56	3.96	....	....	....	....	....
R	....	0.32	-	....	2.30	2.46	0.90	....	....
P	....	7.21	....	-	....	....	....	....	....
M	....	....	1.59	....	-	3.05	0.54	....	....
L	....	....	....	....	3.57	-	....	0.39	....
H	....	....	....	....	....	0.75	-	6.19	0.49
X	....	....	....	....	....	....	....	-	18.90
Q	....	....	....	....	....	....	8.03	....	-

quency of the individual j in a set, the absolute value of the $p_{ij} - e_{ij}$ difference is not determinant for the significance level of the relation between i and j. The same is valid when differences between the observed and expected frequencies are considered.

As a test of a statistical significance of this difference (Tables 3, 5, 7) the authors accepted the statistics used to verify mean values[3]:

$$z = \frac{n_o - n_e}{\sqrt{n_e(1 - e_{ij})}}$$

where: $e_{ij} = \dfrac{c_j}{N - r_i}$, n_o = observed frequency of transitions, n_e = expected frequency of transitions.

The z statistics served for the construction of path diagrams reflecting general trends in sedimentary processes operating in the depositional environments of the investigated lithostratigraphic units. Transitions were considered as significant in the case of a positive sign of $n_o - n_e$ and when $z > 1.64$ (cf Tables 4, 6, 8), which means that the null hypothesis may be rejected at a confidence level of 0.05. Other transitions were considered as being random events.

The path diagram was constructed by joining the successive lithological divisions which fulfill the above mentioned conditions. Placed at the start of the sequence were the lithologies which randomly appeared above the others ($z < 1.64$); the sequence terminates with a lithology which does not reveal significant transitions to lithologies other than those which have appeared earlier within the sequence.

ANALYSIS OF PATH DIAGRAMS

The „ideal" sequences of lithologies in the Poruba Beds, Mudstone Series and Łaziska Beds are ilustrated by path diagrams in Fig. 2.

In the Poruba and Łaziska Beds two subsequences are distinguishable which are statistically independent of each other, lacking any significant mutual transitions. The first one consists of conglomerates, sand-size sediments and stratified fine-grained sediments. The second one is made up of structureless fine-grained sediments (H), rooty layers and coal. For the sake of brevity the first subsequence will be referred in the following text as a „barren" and the second one as a „coal-bearing" subsequence. Their statistical separation suggests that their deposition has taken place in different sedimentation regimes and that change of these regimes occurred randomly.

[3] After this paper was submitted to the Editor the authors had found that a similar method was employed by Hobsday et al. (1975).

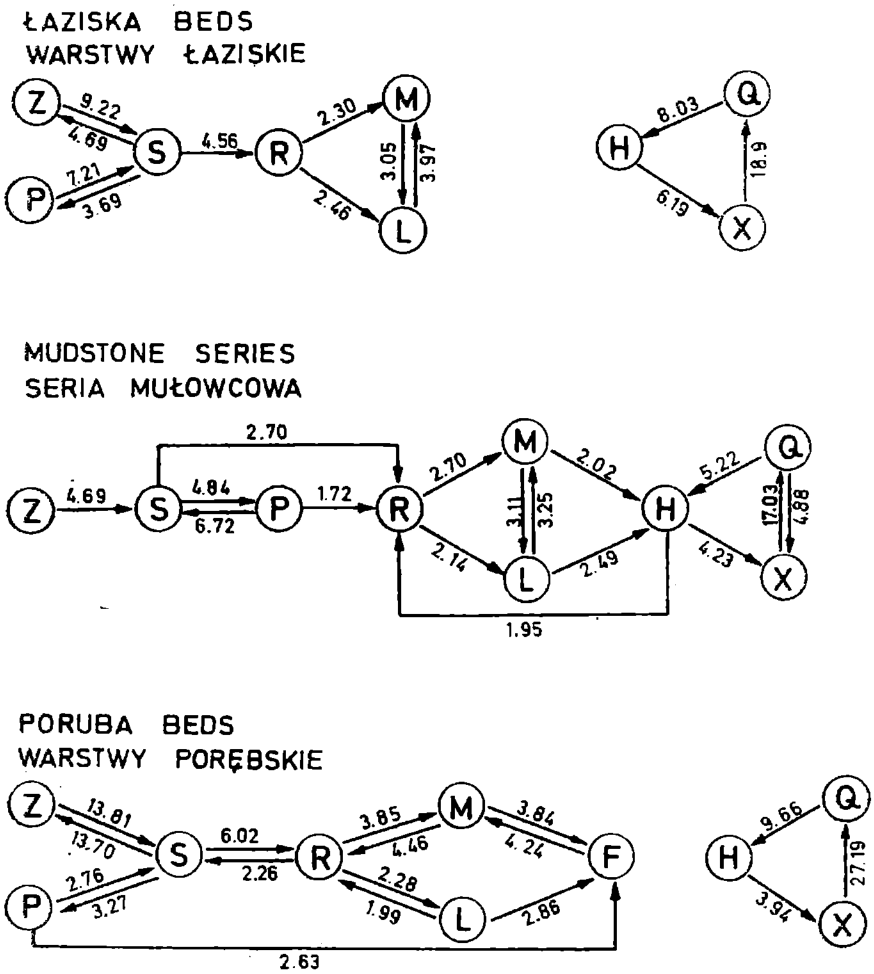


Fig. 2. Path diagrams of lithologies
Fig. 2. Sekwencje typów litologicznych

In the path diagram of the Mudstone Series the barren and coal-bearing subsequences are connected to one run by statistically significant transition. Thus it may be concluded that during the deposition of this series only the conditions leading to the deposition of the coarsest sediments appeared randomly.

The barren subsequences in the Poruba and Łaziska Beds and the corresponding elements in the diagram of the Mudstone Series display a generally similar sequence of lithologies and an upward decrease in the grain size as well as in the amplitude of sedimentary structures. In this respect the discussed sequences strongly resemble the sequences occurring in recent and fossil fluvial deposits (cf. Allen 1965a, 1965b; Miall, 1973, 1977) as well as the sequences arising from the sedimentation models of these deposits (cf. Potter & Blakely, 1967; Allen, 1970; Beerbower, 1964; Visher, 1965, 1972). Similar sequences are also characteristic of the alluvial deposits of deltaic plains (cf. Coleman & Gagliano, 1964, 1965; Elliott, 1974). It should be remembered however, that deposits of other environments may have some features in common with the discussed ones, especially those of tidal channel deposits (see, Van Straaten, 1964; Reineck 1972; Reineck & Singh, 1973).

The fact that the deposits of the Mudstone Series and of the Łaziska Beds are of exclusively continental origin as well as the above mentioned features of the sequence both suggest that the sand-size and stratified fine-grained rocks of these lithostratigraphic units are fluvial deposits. The Poruba Beds may have been deposited partly in a fluvial (including fluvial deposits of a deltaic plain) and partly in a mixed, continental-marine environment.

The flaser bedding encountered in the Poruba Beds deserves a special attention. It has reversible transitions with the laminated mudstones and appears in a statistically significant manner above the mudstones with lenticular bedding (L) and horizontally laminated sandstones (P). The flaser bedding is a sedimentary structure especially common in a tidal flat environment (Reineck, 1972), moreover it is associated there with the same lithologies as it as ascertained in the Poruba Beds. It should be noted also that lithology F appears in the investigated cores in a form of relatively thick layers of a mean thickness 0.59 m and attaining a maximum thickness 4.6 m. It was also found that this lithology usually occurs in strict association with marine fauna-bearing horizons, or its stratigraphic position corresponds to such horizons found in the neighbouring boreholes.

The data presented above suggest that in the Poruba Beds the lithology F, and probably also the muddy deposits associated with them (M and L), were deposited in tidal flats during the successive marine ingresions. The sandy deposits (P) frequently underlying the lithology F may be interpreted as beach deposits. The sets of flat, slightly inclined laminae separated by similarly inclined set boundaries predominate in recent beach deposits (see, Thompson, 1937; Logvinenko & Remizov, 1964). The small inclinations of the laminae and of the set boundaries can be hardly recognized in the cores, thus it is probable that some sandstones included into the lithology P are actually cross-stratified.

Those parts of the cores from the Poruba Beds where the flaser bedding is associated with other lithologies (P, M, L, R, S) are interpreted by the authors as deposits of continental-marine environments (i. e. tidal channels, tidal flats, beaches, barriers etc.).

In the coal-bearing subsequences of the Poruba and Łaziska Beds the lithologies H, X, Q are connected to the circular closed sets. A sequence of the higher elements in the path diagram of the Mudstone Series is similar, but in addition a reversible linkage between X and Q is present there. The individual lithologies may be in a very general way related to the following subenvironments: H — with bodies of standing water (lakes or swamps), X — with densly vegetated areas, Q — with swamps where a phytogenic sedimentation occurred.

The observations of the cores from the Poruba and Łaziska Beds indicate that the structureless mudstones and claystones (H) usually display no traces of roots.. This suggests that the majority of these deposits were laid down in lake-like basins where water depth was relatively small but sufficient to inhibit the growth of plants rooted in the bottom.

In the Mudstone Series most of the H deposits reveal relatively abundant root traces. This suggests that these deposits were mostly laid down in vegetated areas, probably wet and seasonally flooded. The plant remains decayed or remained preserved only fragmentarily as a subordinate component of the fine-grained deposits. A phytogenic sedimentation leading to the accumulation of coal beds periodically occurred in these areas. This sedimentation was stopped usually by the death of the vegetation caused by asignificant rise of the water level (cf. Bouroz, 1958) suggested by the lack of roots in the H mudstones directly overlying the coal seams.

CLASTIC SUCCESSIONS IN ALLUVIAL DEPOSITS

The following discussion deals with the analysis of the lithologic successions occurring in the deposits considered to be of fluvial origin. For this reason the deposits attributed to the mixed continental-marine environments (on the grounds of the associations of sedimentary structures or of the presence of marine or brackish fauna) as well as the part of the deposits forming the coal-bearing subsequences, are not taken into account in this discussion.

In this phase of investigation the detailed logs of the cores were used and further generalization of the lithologies earlier used was done. The generalization consisted in grouping together the sediment types (lithologies) laid down in similar conditions of transport and deposition as indicated by their grain size and sedimentary structures. In this way the following gross lithotypes were distinguished:

A — conglomerates (Z) and sandstones (P and S),
B — sandstones with small-scale cross-stratification (R),
C — stratified fine-grained deposits (M and L), sometimes with subordinate intercalations of the R sandstones,
D — fine-grained deposits devoid of depositional structures (H).

Taking into account the features of alluvial deposits (see, Allen, 1965a, 1965b; Miall, 1976; Visher, 1965, 1972) it may be generally assumed that gross lithotype A corresponds to the typical lower part of channel deposits, lithotype B — to the uppermost part of channel deposits and/or crevasse splay deposits, lithotype C — to overbank deposits, lithotype D — to the uppermost part of the overbank deposits laid down in flood basins and shallow lakes on the outer flood plain, and also fine-grained deposits of abandoned channels.

Taking the succession A — B — C — D as a model, 635 individual successions were distinguished in the investigated sections. The boundaries of every succession were placed in comparison with the model succession. If within a section of a core composed exclusively of the A lithotype sharp erosional contacts and/or conglomeratic layers with well defined lower boundaries were found, the succession boundaries were placed at these surfaces.

The individual succession types recognized in the investigated sections can be divided into 4 main groups:

I — A, AB,
II — ABC, ABCD,
III — ABD, AC, ACD, AD,
IV — BC, BCD, CD, C,

Thus, the groups II and III include successions consisting of both channel and overbank deposits, more or less complete, group I included successions made up exclusively of channel deposits, and to grup IV the

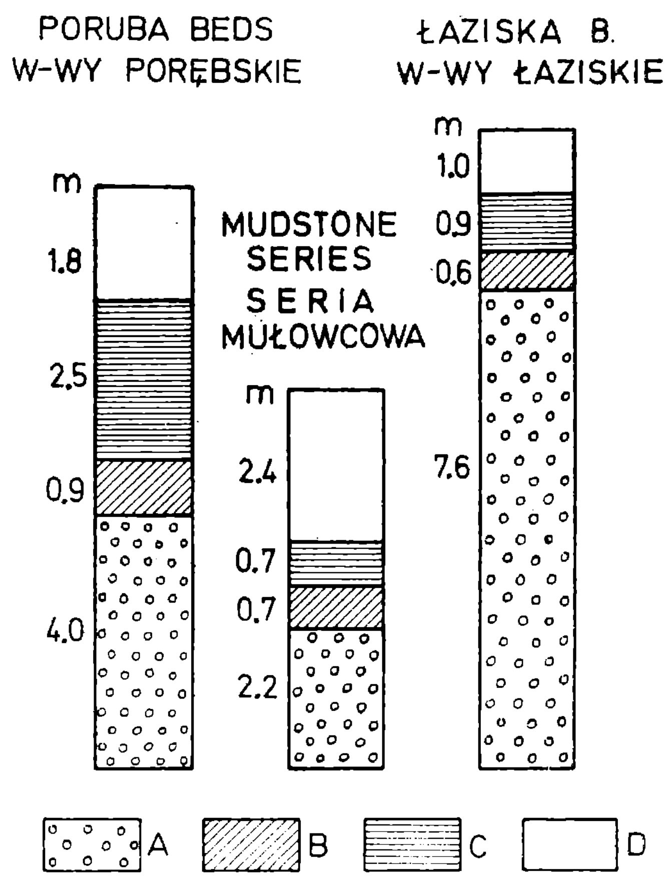


Fig. 3. Mean thickness of barren sequences, A, B, C, D — gross lithotypes (see text)

Fig. 3. Średnie miąższości sekwencji płonnych, A, B, C, D — główne typy litologiczne, wymienione w tekście

successions devoid of typical channel deposits and representing mostly or exclusively overbank deposits are attributed.

The possibility of accumulation and preservation of thick alluvial deposits, as in the case of the Upper Silesia coal-bearing deposits, depends on a prolonged aggradational trend, related first of all to the subsidence of the sedimentary basin. In these circumstances the development of the depositional succession depends largely on the type of the rivers shaping the alluvial plain (cf, Allen, 1965a; Miall, 1977).

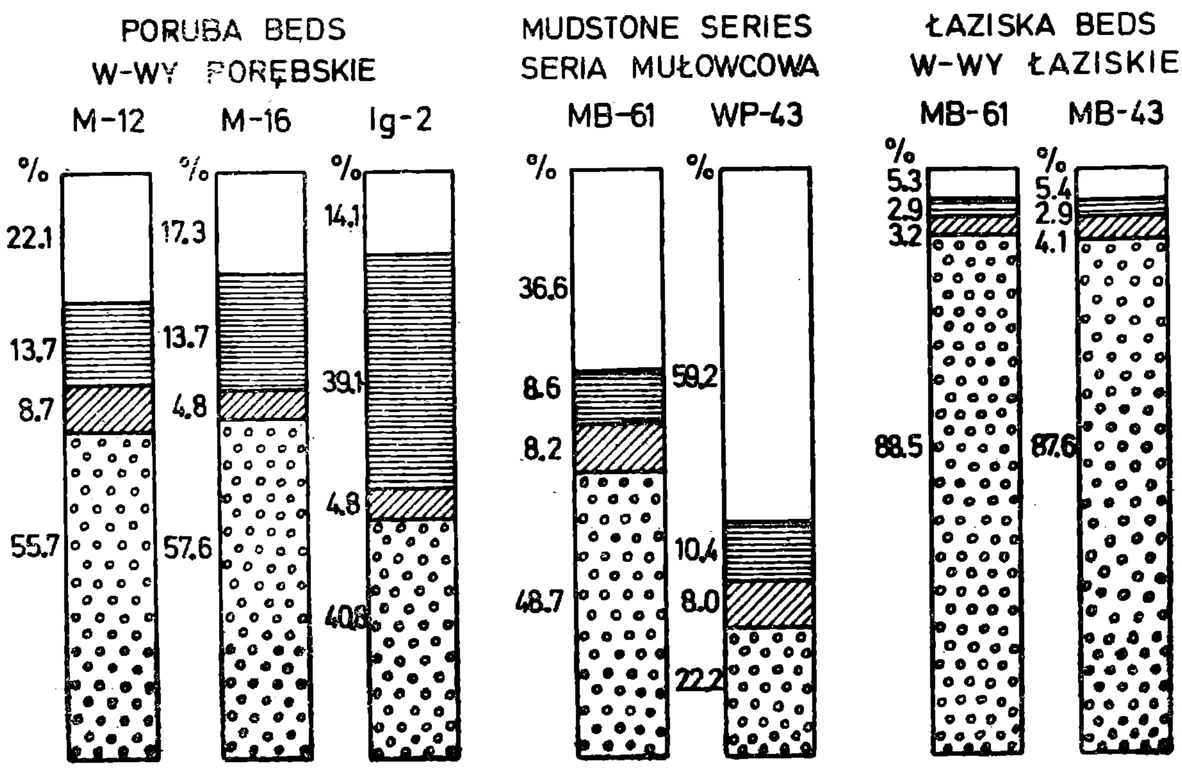


Fig. 4. Percentage of gross lithotypes in total thickness of barren sequences (for explanation see Fig. 3)

Fig. 4. Procentowy udział poszczególnych głównych typów litologicznych w całkowitej miąższości sekwencji płonnych (objaśnienia symboli na fig. 3)

In the thick sections of alluvial deposits of meandering rivers both channel and overbank deposits usually are well developed, the latter being volumetrically significant. Relatively regular migration of the channels leads to the development of more or less complete successions including both classes of deposits. The progradation of natural levees and crevasse splays may often lead to a development of successions devoid of typical channel deposits.

On the other hand, in alluvial successions deposited by braided rivers, channel deposits predominate. In general, irregular and rapid shifting of the channels accompanied by an intense deposition within the channels contribute to building up of successions which commonly consist exclusively of these deposits. They often build up thick multi-storey complexes, with the individual successions within them only poorly diferanciated. In the case of the deposits of great braided rivers (e.g. Brahmaputra, cf Coleman, 1969) additional numerous successions composed of channel and overbank deposits can be expected.

Relative frequency of successions /per cent/
Częstotliwość występowania sekwencji w procentach

Table 9

Gross-lithotype successions group		Poruba Beds				Mudstone Series			Łaziska Beds		
		M12	M16	Ig2	mean for group	MB61	WP43	mean for group	MB61	MB43	mean for group
I	A	8.3	15.4	10.5	25.2	2.0	-	4.6	22.8	21.3	43.6
	AB	12.9	14.5	12.6		4.0	3.8		14.0	25.9	
II	ABC	2.8	2.6	7.4	12.9	6.1	2.9	7.2	-	3.7	5.4
	ABCD	12.9	6.0	7.4		6.1	1.9		5.3	1.9	
III	ABD	-	4.2	5.2	26.5	10.2	7.7	43.8	12.3	11.1	37.6
	AC	6.4	5.1	6.4		4.0	5.8		5.3	12.0	
	ACD	5.5	6.0	7.4		10.2	7.7		1.7	3.7	
	AD	9.1	18.8	7.4		16.4	24.0		21.0	9.3	
IV	B	0.9	-	-	35.4	-	-	44.4	-	0.9	13.3
	BC	0.9	-	1.0		-	1.0		1.7	-	
	BCD	6.4	-	1.0		4.0	1.0		1.7	-	
	BD	17.4	2.6	1.0		16.4	3.8		3.5	5.6	
	C	8.3	11.9	15.8		-	2.9		-	1.9	
	CD	8.3	12.8	16.8		20.5	38.5		10.5	2.8	

Table 10

	Poruba Beds	Mudstone Series	Łaziska Beds
Total thickness of barren sequences	1626,5 m	594.7 m	1258.6 m
Percentage of thickness of barren sequences in total lenght of cores	72	62	89
Number of barren sequences	317	153	165
Mean thickness of barren sequences	5.1 m	3.9 m	7.6 m
Percentage of A+B in total thickness of barren sequences	58	39	92

The statistical results obtained using the subdivisions mentioned above (Table 9, 10, Figs 3, 4) indicate that the greatest differences exist between the deposits of the Łaziska Beds and the Mudstone Series, while the deposits of the Poruba Beds occupy and intermediate position.

In the Łaziska Beds the successions included into group I (43.6%) and group III (37.0%) predominate, and channel deposits make up about 90%

of the total thickness of the successions taken into account. This indicates that these deposits were laid down mainly by braided rivers. The relatively large mean thickness of channel deposits (about 8 m) is due to the presence of the thick, multistorey accumulations of these deposits which could not be divided in the cores.

In the Mudstone Series the successions attributed to group III (43.8) and group IV (44.4%) predominate, while the successions of group I are scantily represented. The predominance of the overbank deposits (about 70%) over the channel ones is well marked. Thus, these deposits can be interpreted as laid down on an alluvial plain constructed by meandering rivers.

CONCLUDING REMARKS

The path diagrams of the three investigated lithostratigraphic units show a general similarity. In all units the relatively coarsest deposits appear randomly and are followed by other lithologies arranged in a fining-upward sequence or subsequence. In the Poruba and the Łaziska Beds also the non-stratified fine-grained deposits (H) occur randomly and have significant transitions to rooty layers and coal; in these units two subsequences may be distinguished, a „barren" and „coal-bearing" ones.

The analysis of sedimentary features, of the gross lithotype successions, and of quantitative contribution of these lithotypes indicate that the Mudstone Series is a deposit of an alluvial plain of meandering rivers, while the Łaziska Beds were laid down on an alluvial plain dominated by braided rivers. The Poruba Beds are interpreted as deposits of an alluvial plain constructed mainly by meandering rivers and of mixed continental-marine environments.

In the authors' opinion the random appearance of the coarsest clastics in all investigated units is controlled primarily by channel shifting typical for fluvial environment. Thus the accumulation of the Mudstone Series may be interpreted as a result of intrabasinal factors only, while in the other two lithostratigraphic units also a participation of extrabasinal factors, resulting in the distinction of the barren and coal-bearing subsequences, is highly probable.

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STRESZCZENIE

Materiał do badań stanowiły rdzenie z wybranych 6 wierceń (tabela 2). Na podstawie własnych opisów rdzenia, uwzględniających sedymentacyjne cechy osadów, zestawiony został dla każdego wiercenia profil graficzny, którego wycinek przedstawiony jest na fig. 1. Do celów niniejszej pracy dane z takich profilów zostały nieco zgeneralizowane, przy czym wydzielono następujące typy litologiczne: Z — zlepieńce i zlepieńce śródformacyjne; S — piaskowce z warstwowaniem przekątnym o dużej skali i piaskowce bezstrukturowe; R — piaskowce z warstwowaniem przekątnym o małej skali; P — piaskowce laminowane poziomo; M — mułowce laminowane poziomo; L — mułowce z warstwowaniem soczewkowym i/lub falistym; H — mułowce i iłowce pozbawione struktur depozycyjnych; X — ziemia stigmariowa; Q — pokłady węgla. Ze względu na specyficzny charakter materiału, jakim jest rdzeń wiertniczy, za podstawowy element sekwencji uznano „warstwę", określając tym terminem nagromadzenie osadu odpowiadające jednemu z wymienionych typów litologicznych.

W oparciu o takie wydzielenia zestawiono macierze przejść w górę między warstwami (Tabele 3, 5, i 7) przy pomocy testu *chi*^{2} sprawdzono hipotezę zerową. Istotność poszczególnych, pozytywnych różnic testowano przy pomocy statystyki z używanej do weryfikacji średnich. Diagramy przejść konstruowano łącząc ze sobą kolejno typy litologiczne powiązane przejściami, dla których przy dodatnim znaku różnicy między oczekiwaną a obserwowaną ilością przejść $z > 1{,}64$. Na początku sekwencji znalazły się typy litologiczne, które pojawiały się nad pozostałymi w sposób przypadkowy ($z < 1,64$).

Skonstruowane w ten sposób diagramy przejść (fig. 2) wykazują ogólne podobieństwo sekwencji typów litologicznych we wszystkich badanych jednostkach litostratygraficznych. Członem pojawiającym się losowo i wyznaczającym początek sekwencji są osady o stosunkowo najgrubszym ziarnie, ponad którymi występują o następstwie wykazującym cechy cyklu frakcjonowanego prostego. W warstwach porębskich i łaziskich losowo pojawiają się również bezstrukturowe osady drobnoziarniste, związane przejściami z ziemią stigmariową i węglem; w związku z tym w tych warstwach wyodrębniają się dwie subsekwencje, określone jako „płonna" i „węglowa".

Analiza cech sedymentacyjnych i procentowego udziału głównych typów litologicznych A, B, C, D (por. tabele 9, 10, Fig. 4, 5) pozwala wnosić, że seria mułowcowa reprezentuje osady równiny aluwialnej rzek meandrujących, warstwy łaziskie — równiny aluwialnej utworzonej głównie przez rzeki roztokowe, natomiast warstwy porębskie — osady nadbrzeżnej równiny oraz występujące podrzędnie osady środowisk mieszanych, lądowo-morskich.

Zdaniem autorów, losowe pojawianie się na diagramach osadów stosunkowo gruboziarnistych wiązać można przede wszystkim z procesami bocznej migracji koryt rzecznych. W związku z tym akumulacja serii mułowcowej może być tłumaczona wyłącznie jako rezultat działania czynników autocyklicznych. Natomiast w odniesieniu do dwóch pozostałych jednostek litostratygraficznych wysoce prawdopodobny jest ponadto współudział czynników allocyklicznych, czego rezultatem jest odrębność sekwencji płonnych i węglowych uwidaczniająca się na diagramach przejść.

Niniejsza praca wykonana została częściowo w ramach Międzyresortowego Planu MR I-16.