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Optical anisotropy of coal from the Jastrzębie Fold (Upper Silesian Coal Basin)

Reflectance (R_{max} and R_{mean}) of vitrinite occurring in coal from the Jastrzębie Fold, as well as its optical anisotropy (R_{bi}) increase from the east to the west, what indicates an increase of coalification in this direction. The highest k-values were found in the marginal parts of the studied area, what proves, that the influence of tectonic stress on the coalification process was higher in the anticline limbs than in its axial part. Increase of the reflectance toward the north with simultaneous decrease of the k and R_{st} values in this direction indicate the presence of a heat source in the SW part of the area, which caused thermic metamorphism of coal.

INTRODUCTION

Vitrinites of coals behave like optically anisotropic substances (from $\overline{R}_o \approx 0.70\%$). Taking into account the optical character of vitrinite, coals divide to uniaxial optical negative and biaxial optical negative and positive. Changes of the vitrinite reflectance are described by the triaxial ellipsoid (indicatrix), whose axis in any direction is proportional to the reflectance (V. Hevia, J. M. Virgos, 1977). On the basis indicatrix shape (optical character of vitrinite), one may make conclusions concerning the tectonic history of the coal basin during the coalification process. Measurements of the reflectance of vitrinite, as well as the studies of its optical properties, may be useful methods of recognition of the manifestations of a tectonic stress even in the deposits that were weakly tectonically deformed (I. J. Stone, A. C. Cook, 1979).

The determination of the optical anisotropy of coals from the SW region of the Upper Silesian Coal Basin (Fig. 1) and an attempt of the elucidation of its reason, i.e. the influence of the metamorphism factors, were the aim of the present studies. The area under study consisted of the mining fields of the Jastrzębie and Zofiówka mines, which occur within the limits of the Jastrzębie Fold (Fig. 2).

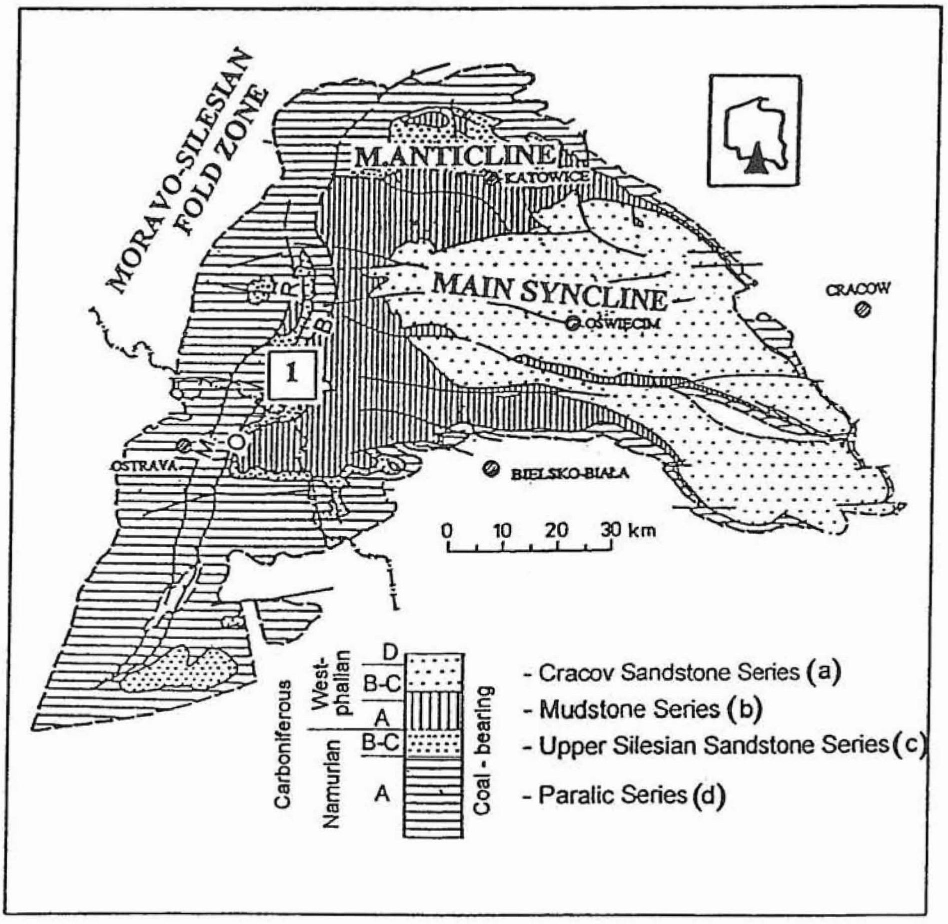

Fig. 1. Investigation area against the background of the major geological structures and lithostratigraphy of the Upper Silesian Coal Basin (after A. Kotas, 1994)

O–B — Orłowa - Boguszowice Overthrust; M–R — Michałkowice - Rybnik Overthrust; 1 — Jastrzębie Fold area

Obszar badań na tle głównych struktur i litostratygrafii Górnośląskiego Zagłębia Węglowego (według A. Kotasa, 1994)

O–B — nasunięcie orłowsko-boguszowickie; M–R — nasunięcie michałkowicko-rybnickie; 1 — obszar fałdu Jastrzębia; a — krakowska seria piaskowcowa; b — seria mułowcowa; c — górnośląska seria piaskowcowa; d — seria paraliczna

Four areas of different features are distinguishable in the tectonic structure of the Jastrzębie Fold, though they are closely connected one with another, namely: the area of the folds of the subvertical beds (the region of the Mszana I Overthrust) connected with the Orłowo – Boguszowice Overthrust, the area of the Jastrzębie Syncline, the area of the Jastrzębie Anticline and the area of the Zofiówka Monocline (the easternmost part of the studied area).

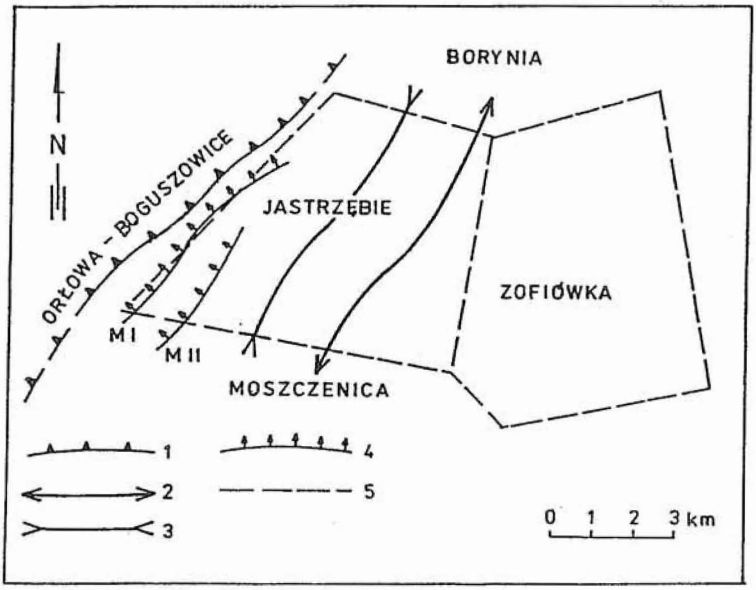

Fig. 2. Major tectonic structure of the study area

1 — Orłowa - Boguszowice Overthrust; 2 — Jastrzębie Anticline axis; 3 — Jastrzębie Syncline axis; 4 — reverse fault; 5 — Jastrzębie and Zofiówka coal mine area; M I, M II — Mszana I and II Overthrusts

Główne struktury tektoniczne obszaru badań

1 — nasunięcie orłowsko-boguszowickie; 2 — oś antykliny Jastrzębia; 3 — oś synkliny Jastrzębia; 4 — uskok odwrócony; 5 — obszar górniczy kopalń Jastrzębie i Zofiówka; M I, M II — nasunięcie mszańskie I i II

In the region of the Jastrzębie Fold, which was strongly tectonically affected, one observed anomalies of the coalification grade, caused by heat, the main factor of the thermic metamorphism (B. Hanak *et al.*, 1993; K. Probierz, 1989). In this context, the area was evaluated as appropriate for the performing the planned studies, because there the signs of the various kinds of metamorphism (regional, thermic and dynamic) overlapped one another.

INVESTIGATION METHODS

The optical characteristics of coals was performed by means of the reflected light polarization microscope *Axioskop* produced by *Zeiss* company, equipped with micro-photometer. An immersion liquid of the refractive index $n_o = 1.5176$ at the temperature of 297K for light of the wavelength $\lambda = 546$ nm. Measurements of the optical anisotropy were performed for granular polished sections (briquettes), prepared with use of a standard technique from averaged furrow samples crushed to the grain class < 1 mm. The mean reflectance ($\overline{R}_0$), measured for moderate- to high-metamorphosed coals, may display large

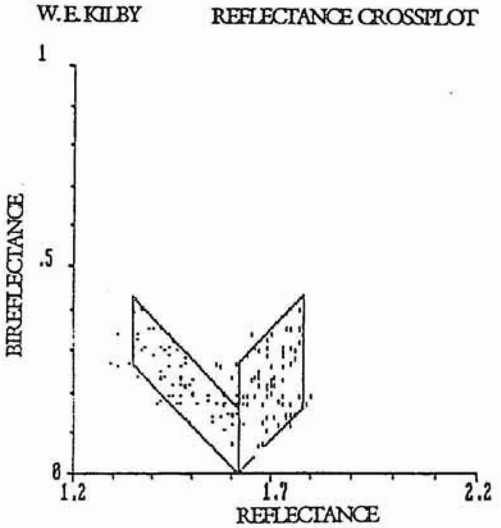

Fig. 3. Example of the reflectance crossplot
Przykład wykresu krzyżowego

variations and, depending on the orientation of grains in the briquette, approaches either the true minimum or maximum reflectance. In the polarized light, a grain of vitrinite shows an incidental maximum (R'_{max}) and minimum (R'_{min}) value of reflectance, recorded in about 50 measurement points of each coal sample. Lengths of the three main axes of the indicatrix, refering to the maximum (R_{max}), intermediate (R_{int}) and minimum (R_{min}) reflectance, were evaluated on the basis of the cross plots of the reflectance, determined by use of a computer program (W. E. Kilby, 1988*b*, 1991). An example of the reflectance crossplot is shown in Figure 3.

RESULTS OF THE STUDIES

The true values of the reflectance R_{max}, R_{int} and R_{min} vary within broad limits: R_{max} — from 1.11 to 2.95%, R_{int} — from 1.02 to 2.71% and R_{min} — from 0.91 to 2.43% (Tab. 1). The values of the maximum, intermediate and minimum reflectance, correlated with the R_{mean} value (Fig. 4), calculated from the equation:

$$R_{mean} = (R_{max} + R_{int} + R_{min})/3$$

display a general tendency to an increase with the coalification grade. The relations $R_{max} = f(R_{mean})$, $R_{int} = f(R_{mean})$ and $R_{min} = f(R_{mean})$ are of a straight-line type. The coefficients of the gradients of the lines are equal a_{max} = 1.077, a_{int} = 1.008 and a_{min} = 0.888, respectively. Thus, the increase of R_{max} is proportionally larger than that of R_{min}, when related to the increase of R_{mean}. For this reason the optical anisotropy, as defined by the equation:

$$R_{bi} = R_{max} - R_{min}$$

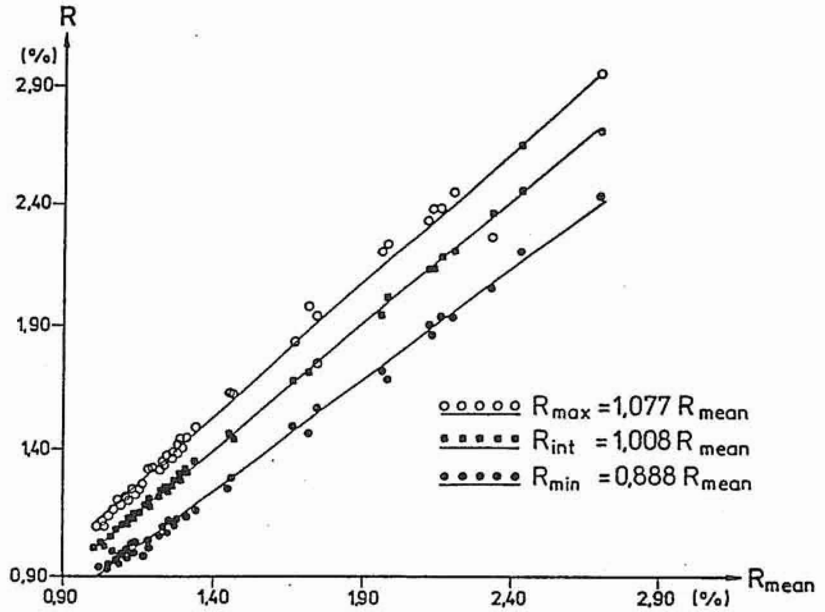

Fig. 4. Reflectance magnitudes R_{max}, R_{int}, and R_{min} versus rank for samples from the study area

R_{max} — maximum reflectance, R_{min} — minimum reflectance, R_{int} — intermediate reflectance, R_{mean} — mean reflectance

Wartości refleksyjności R_{max}, R_{int} i R_{min} próbek z obszaru badań w funkcji uwęglenia

R_{max} — refleksyjność maksymalna, R_{min} — refleksyjność minimalna, R_{int} — refleksyjność pośrednia, R_{mean} — refleksyjność średnia

increases systematically with the increment of R_{mean} within the ranges R_{bi} from 0.16 to 0.52% (Tab. 1 and Fig. 5).

The shape of the reflectance indicatrix of vitrinite permits to determine the kind of the geological factors during metamorphism and their influence on coal. The shape of the indicatrix was described by the axial ratio diagrams (J. R. Levine, A. Davis, 1989) $a = f(b)$, where: $a = R_{max}/R_{int}$, and $b = R_{int}/R_{min}$ (Fig. 6).

The gradient k of the straight line, connecting any point of the diagram with the point (1,1) of the coordinate system, calculated according to the equation (J. R. Levine, A. Davis, 1989):

$$k = (a-1)/(b-1)$$

is a very useful parametre of classification of the indicatrix shape.

The value of the parametre a, determined for all the samples, ranges from 1.07 to 1.12, whereas b may vary from 1.09 to 1.20. The gradient k for majority of the samples has values lesser than 1 (Tab. 1). The samples no. 9, 18, 27A and 28A are exceptions, which for the gradient $k = 1$. As it is apparent from the diagram $a = f(b)$ (Fig. 6), the indicatrix shape for the majority of the samples is typical of the optically biaxial negative substances ($k < 1$).

Table 1

Optical properties of examined coals

Sample number	Seam	R_{st}	R_{am}	B_K	R_{max} [%]	R_{int} [%]	R_{min}[%]	R_{mean} [%]	R_{bi} [%]	*a*	*b*	*k*	B_F
1		–4.13	0.0299	B(–)	1.11	1.04	0.95	1.03	0.16	1.07	1.09	0.77	B(–)
2	362	4.05E-7	0.0370	B(±)	1.14	1.04	0.94	1.04	0.20	1.10	1.11	0.91	B(–)
3		–3.00	0.0380	B(–)	1.11	1.11	0.91	1.01	0.20	1.09	1.12	0.75	B(–)
4		–3.00	0.0399	B(–)	1.17	1.07	0.95	1.06	0.22	1.09	1.13	0.69	B(–)
5	363	3.10E-5	0.0363	B(–)	1.16	1.06	0.96	1.06	0.20	1.09	1.10	0.90	B(–)
6		–1.95	0.0319	B(–)	1.11	1.03	0.94	1.03	0.17	1.08	1.10	0.80	B(–)
7		–2.27	0.0427	B(–)	1.20	1.09	0.96	1.08	0.24	1.10	1.14	0.71	B(–)
8	403/1	–3.00	0.0368	B(–)	1.26	1.16	1.04	1.15	0.22	1.09	1.14	0.71	B(–)
9		1.74	0.0322	B(+)	1.20	1.10	1.01	1.10	0.19	1.09	1.09	1.00	B(±)
10		–3.00	0.0400	B(–)	1.24	1.14	1.02	1.13	0.22	1.09	1.12	0.75	B(–)
11	404/2	3.57E-5	0.0350	B(±)	1.20	1.10	1.00	1.10	0.20	1.09	1.10	0.90	B(–)
12		3.65E-5	0.0344	B(±)	1.22	1.12	1.02	1.12	0.20	1.09	1.10	0.90	B(–)
13		4.38E-5	0.0365	B(±)	1.18	1.08	0.98	1.08	0.22	1.09	1.14	0.71	B(–)
14		–5.08	0.0442	B(–)	1.26	1.15	1.00	1.14	0.26	1.10	1.15	0.66	B(–)
15		–5.50	0.0401	B(–)	1.27	1.17	1.03	1.16	0.24	1.09	1.14	0.71	B(–)
16	404/4	–1.22	0.0465	B(–)	1.25	1.12	0.98	1.12	0.27	1.12	1.14	0.86	B(–)
17		–5.08	0.0400	B(–)	1.24	1.13	0.98	1.12	0.26	1.10	1.15	0.67	B(–)
31		–4.40	0.0472	B(–)	1.37	1.24	1.07	1.23	0.30	1.10	1.16	0.63	B(–)
32		–5.32	0.0502	B(–)	1.34	1.21	1.03	1.19	0.31	1.11	1.17	0.59	B(–)
18		0.89	0.0406	B(+)	1.94	1.75	1.57	1.75	0.40	1.11	1.11	1.00	B(±)
19	501/1/2	–3.67	0.0304	B(–)	1.23	1.15	1.05	1.14	0.18	1.07	1.10	0.70	B(–)
20		–3.96	0.0438	B(–)	1.22	1.11	0.97	1.10	0.25	1.10	1.14	0.71	B(–)
21		–6.83	0.0518	B(–)	2.23	2.02	1.70	1.98	0.53	1.10	1.19	0.52	B(–)
22	502/1	–4.71	0.0434	B(–)	1.38	1.26	1.10	1.25	0.28	1.10	1.15	0.66	B(–)
23		–1.32	0.0416	B(–)	1.28	1.16	1.03	1.16	0.25	1.10	1.13	0.77	B(–)
24A		2.48E-5	0.0398	B(±)	2.35	2.13	1.91	2.13	0.44	1.10	1.12	0.83	B(–)
24B	503/1	–3.00	0.0391	B(–)	2.38	2.18	1.94	2.16	0.44	1.09	1.12	0.75	B(–)
25A		–1.95	0.0446	B(–)	2.45	2.21	1.94	2.20	0.51	1.11	1.14	0.79	B(–)
25B		–6.59	0.0416	B(–)	2.56	2.36	2.06	2.33	0.50	1.08	1.14	0.57	B(–)

26		–0.65	0.0462	B(–)	2.38	2.13	1.87	2,13	0.51	1.12	1.14	0.51	B(–)
27A		3.00	0.0436	B(+)	1.63	1.45	1.30	1.46	0.33	1.12	1.12	1.00	B(±)
27B		9.03E-6	0.0569	B(±)	1.98	1.72	1.47	1.72	0.51	1.15	1.18	0.51	B(–)
28A	503/1	2.11	0.0462	B(+)	2.20	1.95	1.73	1.96	0.47	1.13	1.13	1.00	B(±)
28B		–2.54	0.0371	B(–)	2.95	2.71	2.43	2.70	0.52	1.09	1.12	0.75	B(–)
29A		–4.46	0.0491	B(–)	1.63	1.47	1.26	1.45	0.37	1.11	1.17	0.64	B(–)
29B		–1.95	0.0391	B(–)	1.84	1.68	1.50	1.67	0.34	1.09	1.12	0.75	B(–)
30	504	–6.36	0.0448	B(–)	1.37	1.25	1.08	1.23	0.29	1.10	1.16	0.63	B()
33		–1.14	0.0431	B(–)	1.44	1.30	1.15	1.29	0.29	1.10	1.13	0.77	B(–)
34		–7.10	0.0403	B(–)	1.35	1.25	1.09	1.23	0.26	1.08	1.15	0.53	B(–)
35		–5.00	0.0493	B(–)	1.45	1.31	1.12	1.29	0.33	1.11	1.17	0.65	B(–)
36		–2.13	0.0467	B(–)	1.43	1.29	1.12	1.28	0.31	1.11	1.15	0.73	B(–)
37		–2.07	0.0480	B(–)	1.44	1.29	1.12	1.28	0.32	1.12	1.15	0.80	B(–)
38		–5.68	0.0455	B(–)	1.37	1.25	1.08	1.23	0.29	1.10	1.16	0.63	B(–)
39		–5.81	0.0557	B(–)	1.34	1.20	1.00	1.18	0.34	1.12	1.20	0.60	B(–)
40		–7.43	0.0479	B(–)	1.40	1.28	1.09	1.26	0.31	1.09	1.17	0.53	B(–)
41		–4.40	0.0450	B(–)	1.43	1.30	1.13	1.29	0.30	1.10	1.15	0.67	B(–)
42		–3.67	0.0400	B(–)	1.40	1.28	1.13	1.27	0.27	1.09	1.13	0.69	B(–)
43	505/1	–5.08	0.0416	B(–)	1.33	1.22	1.07	1.22	0.26	1.09	1.14	0.64	B(–)
44		2.24E-5	0.0435	B(±)	1.38	1.24	1.10	1.24	0.28	1.11	1.13	0.85	B(–)
45		1.96E-5	0.0462	B(±)	1.40	1.25	1.10	1.25	0.30	1.12	1.14	0.86	B(–)
46		–6.59	0.0458	B(–)	1.41	1.29	1.11	1.27	0.30	1.09	1.16	0.56	B(–)
47		1.32	0.0387	B(+)	1.37	1.24	1.12	1.24	0.25	1.10	1.11	0.91	B(–)
48		–3.67	0.0417	B(–)	1.38	1.26	1.11	1.25	0.27	1.10	1.14	0.71	B(–)
49		–5.08	0.0393	B(–)	1.40	1.29	1.14	1.28	0.20	1.09	1.13	0.69	B(–)
50		–2.75	0.0360	B(–)	1.38	1.27	1.14	1.26	0.24	1.09	1.11	0.82	B(–)
51		–5.68	0.0427	B(–)	1.45	1.33	1.16	1.31	0.29	1.09	1.15	0.60	B(–)
52		–6.18	0.0462	B(–)	1.49	1.36	1.17	1.34	0.32	1.10	1.16	0.63	B(–)
53		–4.40	0.0443	B(–)	1.45	1.32	1.15	1.31	0.30	1.10	1.15	0.67	B(–)

B_K — optical character indicate by Kilby method; B_F — optical character indicate by Flinn's axial ratio diagram method; optical character: B(–) — biaxial negative, B(+) — biaxial positive, B(±) biaxial positive-negative; seam: 362, 363, 403/1, 404/2, 404/4 — Zofiówka mine area; seam: 501//1/2, 502/1, 503/1, 504, 505/1 — Jastrzębie mine area; samples no. 24A–29A — upper bed of seam 503/1; samples no. 24B–29B — lower bed of seam 503/1; R_{st} — style; R_{am} — anisotropy magnitude; R_{max} — maximum reflectance; R_{int} — intermediate reflectance; R_{min} — minimum reflectance; R_{mean} — mean reflectance; R_{bi} — optical anisotropy; other explanations in the text

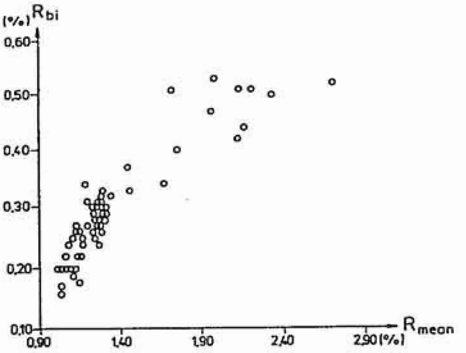

Fig. 5

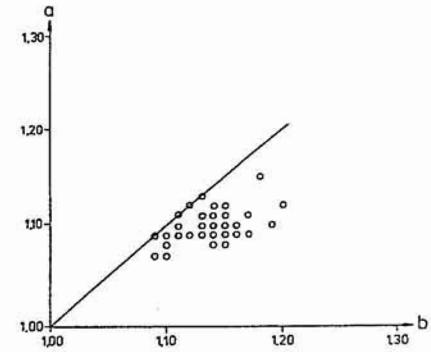

Fig. 6

Fig. 5. Bireflectance R_{bi} versus R_{mean}
Dwójodbicie R_{bi} w funkcji R_{mean}
Fig. 6. Axial ratio diagram of vitrinite reflectance anisotropy
Wykres stosunków osiowych refleksyjności witrynitu

Indicatrix of coals with $k = 1$ has shape typical of the optically biaxial positive-negative substances. These results indicate the influence of the tectonic stress on the coalification process of the studied coals.

The biaxial negative and positive-negative optical character of the studied coals are confirmed by the values of additional parametres R_{am} and R_{st} applied to the characteristics of the indicatrix, introduced by W. E. Kilby (1985, 1988*a*, 1991). The first of the parametres, R_{am} (*am* — anisotropy magnitude), determines the magnitude of the optical anisotropy. For the isotropic substances $R_{am} = 0$, whereas $R_{am} > 0$ for anisotropic substances describes their deviation from the isotropic state. $R_{am} = 0.1$ means very strong anisotropy (W. E. Kilby, 1988*a*, 1991). On the basis of the index R_{am}, which ranges from 0.0299 to 0.0569, one stated, that all the studied coals are anisotropic (Tab. 1).

The second of the parametres, R_{st} (*st* — style), describes the indicatrix shape, thus also the optical character of coal and it may have the values from –30 to 30. When $R_{st} = -30$, the optical character is uniaxial negative, and when $R_{st} = 30$, the optical character is uniaxial

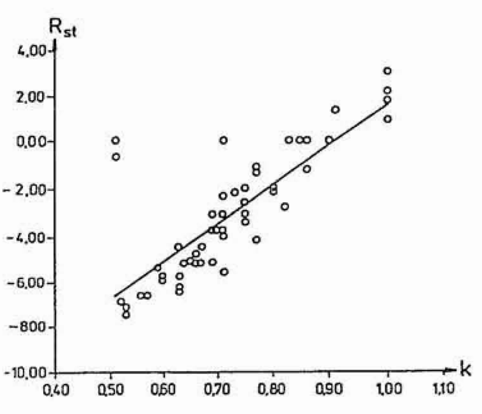

Fig. 7. Development of the R_{st} in relation of k
Zmienność parametru R_{st} w zależności od k

positive.The values of R_{st} between –30 and 30 mean the optically biaxial character of the coal, and the sign of the parametre indicates positive or negative optical character.

The value of the parametre R_{st} for all the studied coals range from –6.83 to 3.00 (Tab. 1). Optical character of vitrinite in the studied samples (except of the samples no. 9, 18, 27A, 28A and 47) is biaxial negative or positive-negative, what correlates well with the values of the parametre *k* (Fig. 7).

INTERPRETATION OF THE RESULTS

Distributions of the reflectance and optical anisotropy measurements are shown in maps, prepared by use of the computer program SURFER with application of the procedure of kriging for interpolation. To maintain the obtained image legible, the points of sampling (total 58) were not spotted in the map. In the western part of the investigation area the seam 503/1, from which came the samples located to the west of the Mszana II Overthrust, consists of the upper and lower part, separated with several-tens-centimetre-thick intergrowth of the barren rock (clayey shale). For preparation of the maps of the optical parametres distribution one used the results of the measurements, performed for the samples, collected in the upper part of the seam. The courses of the isolines in the lower part of the seam are presented in the map inserts. One should indicate as well, that the seam 503/1 extincts in the SW part of the area of the studies.

CONCLUSIONS

On the basis of the obtained results the following conclusions may be given:

1. Reflectance of vitrinite (both R_{max} and R_{mean}) increases distinctly westward, indicating the increase of coalification (Figs. 8 and 9).

2. The magnitude of the optical anisotropy (R_{bi}) increases similarly in the western direction (Fig. 10). In the area of the Zofiówka Monocline it ranges from 0.20 to 0.25%, in the Jastrzębie Anticline it is close to 0.30%, whereas in the region of the Mszana II Overthrust it increases to 0.35-0.45%. The course of the R_{am} isolines is slightly different, especially in the western part of the area, where the R_{am} values decrease to the west (Fig. 11).

3. Distribution of the parametre *k* (Fig. 12), which indicates the optical character of coals, thus suggesting the type of the metamorphism factors, is more variable. Relatively high *k* values were found for the samples from the marginal parts (both western and eastern) of the studies area. This may indicate, that the influence of the tectonic stress on the coalification process was more prominent at the anticline limbs than its axial part. The decrease of the *k* value in the NW part of the studied area toward the seam extinction is apparent. The courses of the isolines of R_{st} are similar (Fig. 13).

4. As it was mentioned earlier, seam 503/1 was sampled in the western part of the studied area. The upper and lower parts of this seam contain coal, that displays different coalification grade (Tab. 1). The presented map inserts (Fig. 14) indicate the increase of the reflectance

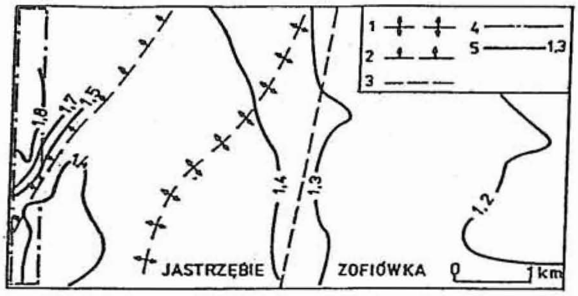

Fig. 8. Distribution of R_{max} in the study area

1 — Jastrzębie Anticline axis; 2 — Mszana II Overthrust; 3 — Jastrzębie and Zofiówka coal mine area; 4 — investigation area of the lower bed of coal seam 503/1; 5 — R_{max} isolines

Rozkład wartości R_{max} na obszarze badań

1 — oś antykliny Jastrzębia; 2 — nasunięcie mszańskie II; 3 — obszar górniczy kopalń Jastrzębie i Zofiówka; 4 — obszar badań ławy dolnej pokładu 503/1; 5 — izolinie R_{max}

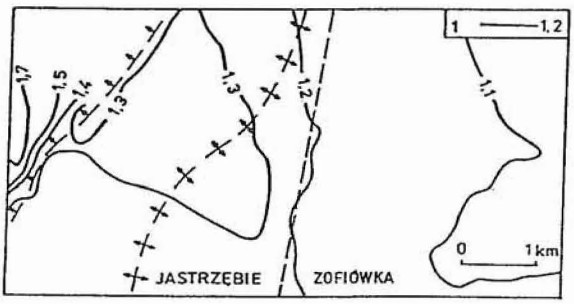

Fig. 9. Distribution of R_{mean} in the study area

1 — R_{mean} isolines; other explanations see Fig. 8

Rozkład wartości R_{mean} na obszarze badań

1 — izolinie R_{mean} ; pozostałe objaśnienia jak na fig. 8

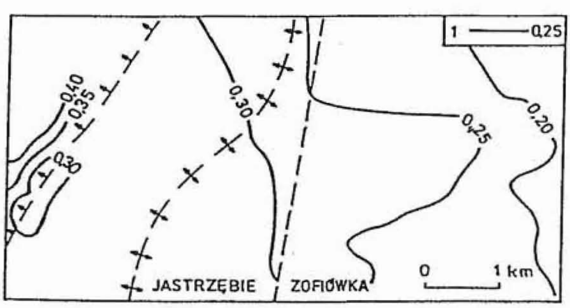

Fig. 10. Distribution of R_{bi} in the study area

1 — R_{bi} isolines; other explanations see Fig. 8

Rozkład wartości R_{bi} na obszarze badań

1 — izolinie R_{bi}; pozostałe objaśnienia jak na fig. 8

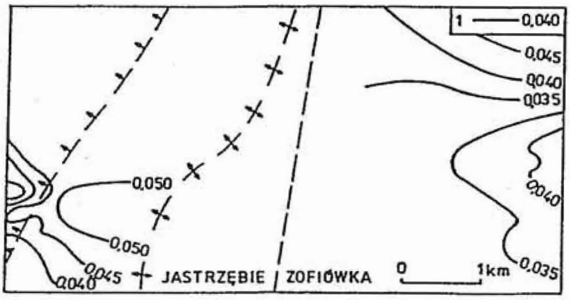

Fig. 11. Distribution of R_{am} in the study area
1 — R_{am} isolines; other explanations see Fig. 8
Rozkład wartości R_{am} na obszarze badań
1 — izolinie R_{am}; pozostałe objaśnienia jak na fig. 8

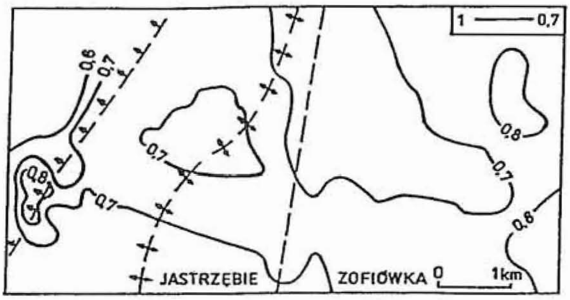

Fig. 12. Distribution of k in the study area
1 — k isolines; other explanations see Fig. 8
Rozkład wartości k na obszarze badań
1 — izolinie k ; pozostałe objaśnienia jak na fig. 8

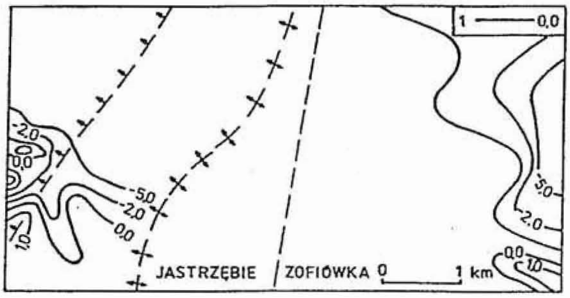

Fig. 13. Distribution of R_{st} in the study area
1 — R_{st} isolines; other explanations see Fig. 8
Rozkład wartości R_{st} na obszarze badań
1 — izolinie R_{st}; pozostałe objaśnienia jak na fig. 8

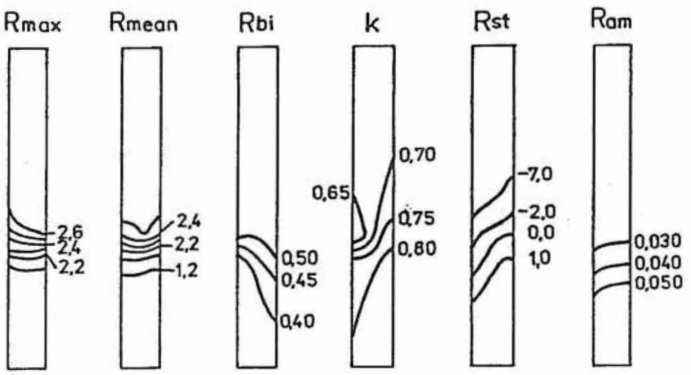

Fig. 14. Variation of coal optical properties (R_{max}, R_{mean}, R_{bi}, k, R_{st}, and R_{am}) in the lower bed of coal seam 503/1
Rozkład własności optycznych węgla (R_{max}, R_{mean}, R_{bi}, k, R_{st} i R_{am}) z ławy dolnej pokładu 503/1

toward the north with simultaneous decrease of k and R_{st} in the same direction. It proves the existence of the heat source, located in the SW part of the area (apparently below this seam), that caused the phenomenon of thermic metamorphism. That would confirm the earlier obtained results, concerning the reasons of the coalification anomaly in the region of Jastrzębie (K. Probierz, 1989).

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ANIZOTROPIA OPTYCZNA WĘGLA FAŁDU JASTRZĘBIA GZW

Streszczenie

Symetria (kształt) indykatrysy refleksyjności, decydująca o charakterze optycznym witrynitu w węglach kamiennych, jest uzależniona od czynników geologicznych oddziaływających na materię organiczną w procesie uwęglania. Badania obejmowały obszar fałdu Jastrzębia w południowo-zachodniej części niecki głównej Górnośląskiego Zagłębia Węglowego. Opróbowano pokłady warstw orzeskich i rudzkich (362, 363, 403/1, 404/2, 404/4 — na obszarze górniczym kopalni Zofiówka) oraz siodłowych (501/1–2, 502/1, 503/1, 504, 505/1 — na obszarze górniczym kopalni Jastrzębie), zawierające węgiel o zróżnicowanym stopniu uwęglenia, wyrażonym przez R_{mean} = 1,01–2,70%.

Rzeczywiste wielkości osi indykatrysy oszacowano z pomiarów maksymalnej (R_{max}) i minimalnej (R_{min}) refleksyjności, na szlifach ziarnowych (brykietach), na podstawie wykresów krzyżowych W. E. Kilby'ego. Rzeczywiste wartości refleksyjności (R_{max} = 1,11–2,95%, R_{int} = 1,02–2,71% i R_{min} = 0,91–2,43%) pozwoliły stwierdzić, że badane węgle są anizotropowe (R_{am} = 0,0299–0,0569, R_{bi} = 0,16–0,52%). Kształt indykatrysy, określony na podstawie wykresu stosunków osiowych (*axial ratio diagram*) oraz parametru R_{st}, jest charakterystyczny dla ciał o charakterze optycznym dwuosiowym ujemnym B(–), dodatnio-ujemnym B(±) i dodatnim B(+). Na podstawie rozkładu wartości refleksyjności i anizotropii optycznej na mapach stwierdzono, że naprężenia tektoniczne miały wpływ na stopień uwęglenia pokładów skrzydeł antykliny Jastrzębia, oraz zlokalizowano hipotetyczne źródło ciepła metamorfizmu termalnego.