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Coalification degree of the No. 116/2 seam in the Janina coal mine (Upper Silesian Coal Basin) based on vitrinite reflectance

Introduction

The Libiąż Beds (Westphalian D) are considered to be the youngest coal-forming episode of the productive coal-formation of the Upper Silesian Coal Basin. They occur in the eastern part of the basin, and the full profile of these layers is known in the mining area exploited by the Janina coal mine, where they form the roof part of the so-called Cracow Sandstone Series. The Libiąż Beds contain several indexed coal seams numbered 116 to 119.

The coal from these seams is of great interest to researchers and technologists due to the lowest coal rank in the whole basin. Generally considered as a transitional form between lignite and bituminous coal, it can be used as interesting research material for the study of

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early catagenesis processes, the broad geotectonics of this part of the basin and its influence on the depth of sediment deposition and the associated paleothermal history of the sediments, as well as the post-genetic erosion of younger sediments (Botor 2014). Additionally, technologists are interested in the possibility of the chemical processing of this low-rank coal through gasification to produce clean liquid and gaseous fuels, because relatively high sulfur content is unfavorable for direct combustion.

Recently, several initiatives have been finalized in international forums (International Committee for Coal and Organic Petrology, United Nations Economic Commission for Europe, International Organization for Standardization) to create a modern classification of coal, which at present forms a unified classification system based on the latest research achievements and at the same time shows the possibilities for the so-called "non-energy" use of low-rank coal (e.g. the classification contained in the UN-ECE 1998 document and the complementary ISO 11760 2018 standard). An important part of the discussed coal classification is the formalized assessment of the degree of coalification using coal reflectance and, in addition to technical tests, petrographic analysis. These methods are to be used in the future to assess the perspectives for the industrial use of coal.

1. The current state of knowledge regarding the degree of coalification of coal from the Libiąż Beds in the eastern part of the USCB

The coal of the Cracow Sandstone Series in the eastern part of the GZW has been examined for many years. The coal from the Łaziskie and Libiąż Beds layers was identified as bituminous coal type 31 and 32 (e.g., Gabzyl 1978, Laskowski and Panuś 1951; Mielecki 1961). Thereafter, major research interest was focused on the degree of coalification of coal from the "Janina", "Siersza" and "Jaworzno" coal mines in the eastern part of the USCB. This issue was first addressed by Gabzdyl and Hanak (1982, 1984), who, on the basis of detailed petrographic and technological studies, concluded that coal from seams No. 116, 117, 118, and 119 from the Janina coal mine and 207 and 301 from the Siersza coal mine correspond to subbituminous coal. This hypothesis was mainly based on the lower average mean reflectance of vitrinite than was established internationally ($R_{o\ mean}$ = 0.50%), while coal from the studied seams often showed a lower value of this parameter. It is also reflected in the lower values of the technical parameters and some details of the petrographic structure of the coal. The coal studied was generally considered to be lignite (Gabzdyl and Hanak 1982). This view was later partially revised – the coal from seams No. 207 and 301 of the Siersza coal mine is similar to bright subbituminous coal – one of the lowest rank coals in the USCB (Gabzdyl and Hanak 1984). These studies were continued by Hanak and Komorek (1987) and Hanak (1993), and the subject of the study was coal from the entire Cracow Sandstone Series of the eastern part of the basin. The degree of coalification of the Janina coal mine was also investigated by Kidawa and Jasieńko (1989) and Święch and Kwiecińska (2003). The former indicated an average reflectance of 0.45% in seams No. 116 and 119 and 0.51%

in seam No. 118. The authors explain such a low average reflectance by a poor degree of aromatization and ordering of the structure, which was confirmed by X-ray studies. The low reflectance of the coal correlated with the carbon content being lower than 76%. However, the authors considered the tested coal to be type 31 bituminous coal. Święch and Kwiecińska (2003) found the average reflectance of vitrinite in the No. 118 seam to be 0.42%, while in the No. 201 seam, it was 0.44%. Jelonek and Smieja-Król (2005) and Jelonek and Smółka-Danielewska (2006) investigated the petrographic structure and provided an evaluation of the rank of coal from the Cracow Sandstone series from seams No. 207 and 209 from the Jaworzno coal mine. In the No. 209 seam, the mean reflectance of vitrinite was 0.46%, which was the reason for the recognition of this coal as subbituminous coal.

2. Locality and geology of the research area

The Janina bituminous coal basin is located in the eastern part of the Upper Silesian Coal Basin (Fig. 1). With regard to the geological structure of the "Janina" mine deposit, exploratory drilling (up to a depth of 1,000 m) confirmed the occurrence of Carboniferous, Triassic, Neogene, and Quaternary deposits. The total thickness of the overburden varies and reaches 252 m.

The Łaziska Beds (Westphalian B and C) are the lower boundary of the Cracow Sandstone Series. It is a complex of coarse-grained rocks (sandstones and conglomerates) and layers of claystone and mudstone sediments. Their lower boundary overlaps the lower boundary of the Cracow Sandstone Series and is represented by facies change from clay formations belonging to the mudstone series to clastic formations (mainly sandstones) of the Cracow Sandstone Series. This change takes place between the No. 218 seam, belonging to the Łaziska Beds, and the No. 301 seam from the group of Orzesze Beds. The upper boundary of these layers is determined by the sandstone roof layer located under the clay-mudstone interlayers underlying the No. 119 seam belonging to the Libiąż Beds (Dembowski 1967).

The Libiąż Beds (Westphalian D) constitute the upper boundary of the Cracow Sandstone Series, and they close the sedimentation of the productive series in the USCB (Dembowski 1967; Zdanowski and Żakowa 1995). The lower boundary of the Libiąż Beds is a layer of clay formations, located below the No.119 seam, which separates them from the Łaziska Beds. This limit was determined based on paleontological criteria (Dembowski 1967). The upper boundary of these layers is assumed above the No. 110 seam, where coal layers or plant debris are no longer present, or where there is a change in the color of the formations from gray to red (Dembowski 1967).

The overburden of the coal series consists of Triassic, Neogene, and Pleistocene sediments.

The Janina mining area (Fig. 1) and the southeast branch of the main basin share a similar tectonic architecture. The Carboniferous layers generally dip at angles from 3º to 10º to the north and east. The analyzed mining area is characterized by a block-type geolog-

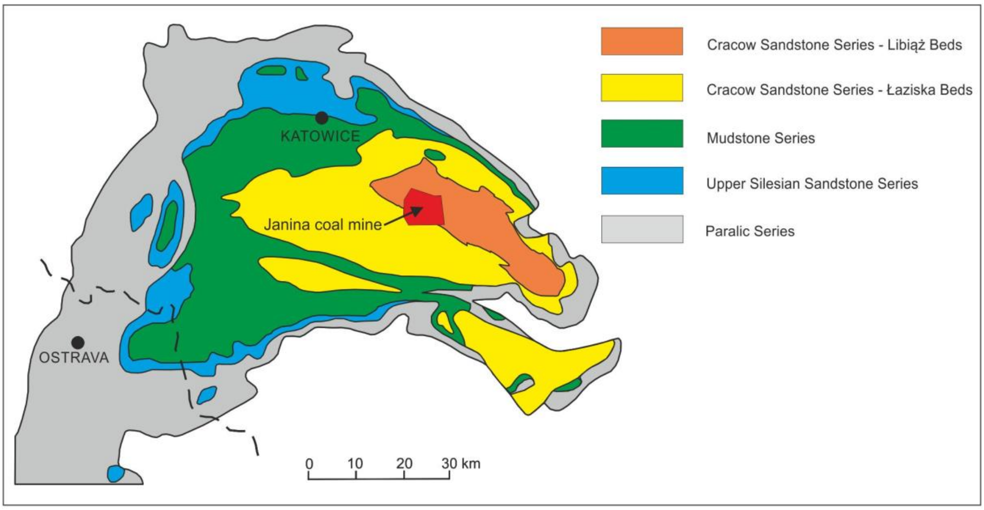

Fig. 1. Location of the research area in the USCB (after Jureczka et al. 1995)

Rys. 1. Lokalizacja rejonu badań na terenie GZW

ical structure. Within the boundaries of the analyzed mining area, there are numerous faults with throws ranging from 1.0 to 260 m; their course is highly variable (Documentation 2000).

3. Research material and methodology

The examined core obtained from the No. 116/2 seam, with a length of 1.67 m, was divided into sections with a length of several centimeters. A petrographic analysis of the coal was carried out in reflected and blue light using a Zeiss Axioskop polarization microscope. A 50× magnification lens was used for the observation. A petrographic examination was performed in both reflected white and blue light using a microscope in accordance with the standard. Maceral nomenclature for the vitrinite and inertinite maceral groups was based on the guidelines of the International Committee for Coal and Organic Petrology (ICCP 1998, 2001; Stach et al. 1982). Maceral nomenclature for the liptinite group was based on (Pickel et al. 2017). Samples were analyzed for vitrinite reflectance (%R_{oil}) (mean random reflectance) on telovitrinite. Numerical values, such as the frequency of macerals and GI (Diesel 1982) facies index were also determined (Gelification Index) GI = (vitrinite + macrinite)/(fusinite + semifusinite + inertodetrinite).

4. Assessment of the degree of coalification of coal from the No. 116/2 seam

4.1. Lithology of the coal seam

The coal seam indexed as the No. 116/2 in the Janina coal mine is a single-layer coal seam (thickness – 1.67 m), with a distinct shale roof and sandstone bottom. The general lithology of the No. 116/2 seam can be assessed as clarain – quantitatively, the predominant variety of this coal is semi-dull coal – durain-clarine (BD), accounting for 42.3%, and durain- dull coal (D) which accounts for 34.3% and forms, like durain-clarine, distinctive layers up to 8 cm thick. By contrast, semi-bright coal – vitrain-clarine (BB) is less commonly found in the seam (9.0%). Interbedded bright coal layers (B) are uncommon (1.8%) and reach a thickness of up to 3 cm; they are more often found in vitroclarain, forming layers with a thickness of up to 1 cm. The following share of maceral groups was found in the examined seam: vitrinite – 53.7%, inertinite – 34.2%, liptinite –12.1%.

4.2. Interpretation of vitrinite reflectograms

Reflectograms of the samples, taking into account all the vitrinite group macerals present in the coal, were recorded for R_o close to the standard deviation (0.02–0.03 R_o) and in the standard range (ΔR_o – 0.05%). More accurate recording in terms of absolute measurement error (e.g., Kwiecińska and Wagner 2001) was aimed at accurately presenting the differences in the average reflectance of macerals of this group and their statistical contribution (number of counts) to the evaluation of the average reflectance of the tested samples.

A careful analysis of vitrinite reflectograms reveals the presence of 3 or 4 distinguished peaks (Table 1, Fig. 2, 3). These maxima were separated into four ranges of average reflectance and are characterized by inflection points corresponding to modal values. The inflection points of the highlighted peaks occur in the following ranges R_o: from 0.31 to 0.36%, on average about 0.34% in the tested samples (peak No. 1); from 0.37 to 0.43%, on average about 0.41% (peak No. 2); from 0.41 to 0.48%, on average about 0.46% (peak No. 3); from 0.47 to 0.54%, on average about 0.51% (peak No. 4). However, in the standard recording range consistent with the ICCP recommendations (Stach et al. 1982) (0.05 and 0.1% ΔR_o, here 0.05%), all reflectograms are unimodal with variable skewness and kurtosis.

When assessing the degree of coalification, only the main maximum, peak No. 4, was considered to be significant. It was assumed that the other distinguished modal parameters of the reflectograms may affect the final value of the average reflectance, and thus the final evaluation of the rank of coal.

The easiest to interpret seems to be the peak marked above as the No. 1 peak. It is present on the majority of vitrinite reflectograms (Table 1) and should be interpreted as the maximum average reflectance of collodetrinite. This maceral is a finely dispersed mixture of small particles of gelinite, vitrodetrinite, probably also bituminite, and clay minerals, closely homogenized. Measurements were performed on separable colloidal particles with a diameter close to 10 μm (a measurement gap of 2 μm was used) and with optical characteristics being similar to gelinite. According to ICCP 1998 and Stach et al. 1982, the average reflectance of collodetrinite for this degree of coalification should be lower than that of collotelinite (peak No. 4) by an average of 0.05 to 0.10%. In the tested samples, this difference ranges from 0.08 to 0.13% (Table 1). In addition, the above identification is confirmed by reflectograms of collodetrinite measured on larger homogeneous surfaces of this maceral in samples 9 and 16. The decrease in average reflectance is related to the presence of bituminite, clay minerals, and other low-reflectance particles, both organic and inorganic, in the collodetrinite.

Table 1. Maximum values of the average reflectance of vitrinite from the No. 116 seam from the Janina coal mine

Tabela 1. Zestawienie maksimów średniej refleksyjności witrynitu węgla pokładu 116 z KWK Janina

	Maximum values					Vitrinite layers > 1 mm	Gelification Index
Sample no.	1	2	3	4	$R_o\,c$	$R_o\,c$	GI
3	0.37	0.42	0.48	0.53	0.47	0.53	1.5
4	0.31	0.37	0.41	0.47	0.42	0.47	1.0
7	0.36	0.41	0.46	0.49	0.42	0.49	4.5
9	0.36	0.43	0.48	0.51	0.49	0.5	20.1
10	0.32	0.42	0.46	0.52	0.47	0.52	3.1
16	0.35	0.40	0.46	0.51	0.45	0.5	2.2
27	0.35	0.40	0.44	0.49	0.46	0.5	8.4
30	0.32	0.41	0.47	0.52	0.43	0.51	0.2
32	0.34	0.40	0.45	0.48	0.43	0.5	6.0
35	0.38	0.38	0.43	0.52	0.45	0.5	10.0
Average	0,.4	0.40	0.45	0.51	0.45	0.5	Not determined

Explanations: 1, 2, 3, 4 – highlighted reflectogram maxima, n – number of counts, $R_o\,c$ – vitrinite average reflectance, GI – Gelification Index.

The vitrinite peak isolated and marked as No. 2 reveals modal values ranging from 0.37 to 0.43%, with an average of 0.40% in the tested samples (Table 1, Fig. 2, 3). Measurements were made on the surfaces of gelinite, and thin laminae most often found within durite, clarite, and clarodurite. Gelinite, mostly filling non-tectonic fissures in semi-fusinite and fusinite and impregnating these macerals, has a slightly higher average reflectance (0.42–0.43%) than thin (average 0.1–0.3 mm) laminar clusters of texturally homogeneous colloidal material. The average reflectance of these laminaes ranges from 0.36 to 0.41%, i.e., it is noticeably significantly lower, even visually, than the gelinite clusters. Moreover, the standard regulations included in the ICCP lexicon (Stach et al. 1982) specify a slightly higher average reflectance of gelinite than other accompanying macerals of the vitrinite group, i.e., collodetrinite, sometimes corpogelinite.

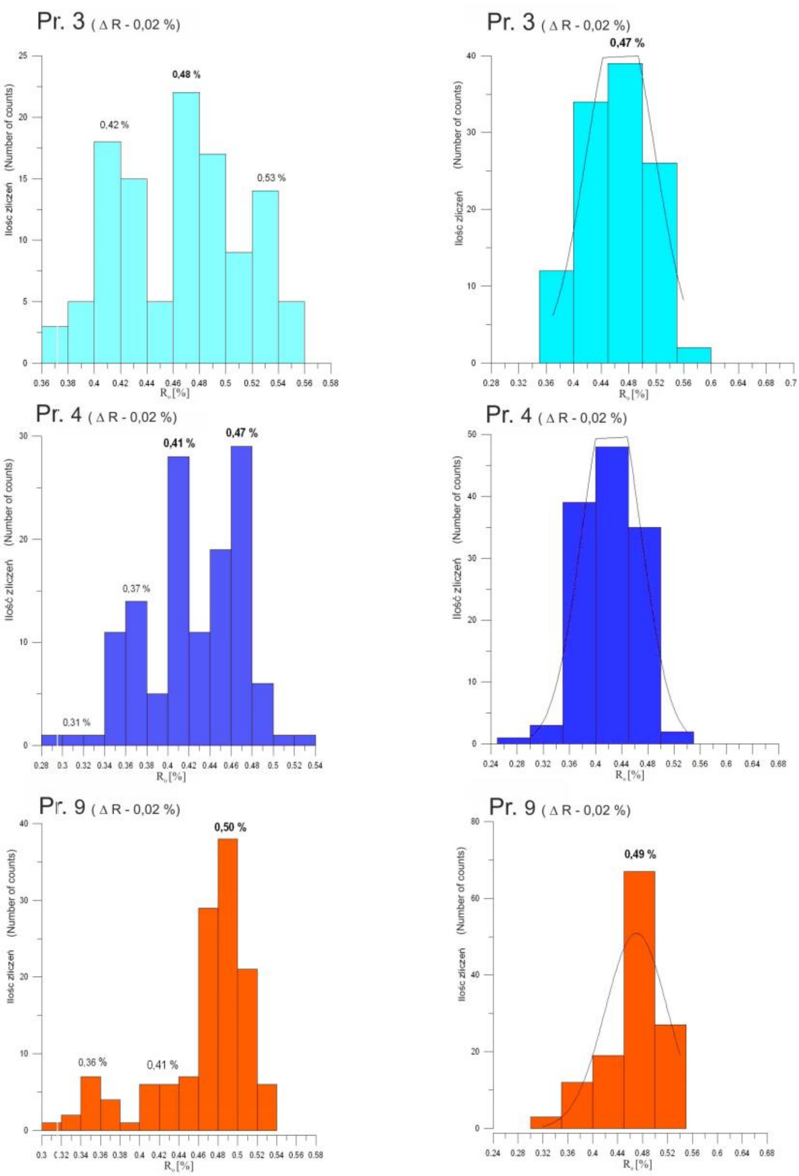

Fig. 2. Vitrinite reflectograms from the No. 116/2 seam from the Libiąż Beds

Rys. 2. Zestawienie reflektogramów witrynitu z węgla pokładu 116/2 warstw libiąskich

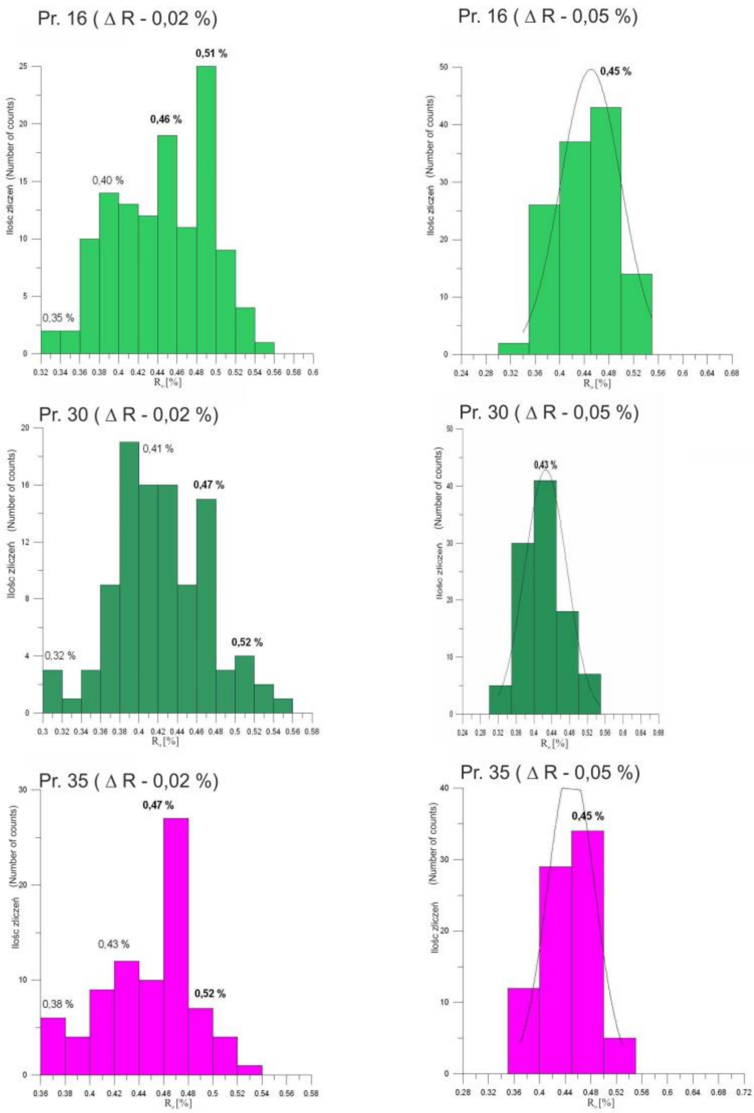

Fig. 3. Vitrinite reflectograms from the No. 116/2 seam from the Libiąż Beds R_o [%]

Rys. 3. Zestawienie reflektogramów witrynitu z węgla pokładu 116/2 warstw libiąskich R_o [%]

The morphology of these laminae is difficult to classify unequivocally as microcrack fillings: they are certainly not fractures of tectonic origin, associated with diagenetic compaction, or primary porosity associated with sedimentation of plant material.

It should be assumed that these are small particles of phytogenic detritus (fractions of tree twigs or their small roots, fragments of herbaceous vegetation stems, etc.), sedimented in the peat bog, as indicated by their clear and relatively even surfaces, oriented generally parallel to the lateral extension of the laminae made of other macerals, and thus the entire rock, which clearly distinguishes them from irregular, fissure clusters of gelinite.

In light of these observations, it seems that regular laminar aggregates of phytogenic gelified material may be identified as so-called dark vitrinite (Newman and Newman 1982; Teichmüller 1989), a hitherto poorly recognized coal microcomponent. Sometimes dark vitrinite is associated with so-called degradinite, massively distinguished in coals of lower rank in Japan (e.g., Suzuki and Fujii 1996), also identified with collodetrinite in domestic bituminous coal (Gabzdyl 1978). However, the latter view is not commonly accepted in the literature and is justified only by the lower average reflectance, which is not supported by facies analysis of vitrinite occurrence.

An important petrographic diagnostic feature of dark vitrinite is its laminar formation and unstructured texture, which is due to the far-reaching bituminization of the mainly cellulosic starting organic material, which is characterized by a strong colloidal dispersion, presumably up to the particle size typical of real solutions. These solutions coagulate, inter alia, in the outer parts of the collotelinite clusters, creating thin envelopes around the collotelinite consistent with the direction of solution diffusion. This is revealed by the presence of laminae or blurred zones with lower reflectance on the outside of the collotelinite.

To sum up, it was assumed that in the No. 116/2 seam from the Janina coal mine, in addition to gelinite (eugelinite by analogy to lignite), there is also a variety of dark collotelinite (dark vitrinite) with an average reflectance slightly lower than typical gelinite (about 0.05% on average) but also significantly lower than typical collotelinite (Stach et al. 1982). The average reflectance of this coal micro component is also clearly higher than the binder (matrix) of collodetrinite (peak No. 1). The presence of a mixture of gelinite and also in coal from Jaworzno coal mine (Fig. 2, 3). This peak represents the average reflectance factor measured on collotelinite surfaces with very weak impregnations with gelinite (no fluorescence) or presumably resinite (barely noticeable streaky fluorescent “glow”). These submicroscopic impregnations, in the form of faded streaks or small flattened objects, are poorly visible on collotelinite surfaces. Impregnations may also be formed by bituminite (sometimes with micrinite) or clay minerals, which are often visible in the outermost parts of collotelinite bands, and can be identified as relatively strongly gelified telinite. These impregnations reduce the average reflectance value of collotelinite from 0.03 to 0.06% (Table 1).

Measurements of average reflectance on clean collotelinite surfaces, which did not contain visible streaks, show values from 0.47 to 0.52%, on average about 0.51%; in individual measurements, the values range from 0.46 to 0.57% (Fig. 2, 3). In detailed reflectograms, this is usually the dominant peak of average reflectance.

Measurements of the average reflectance of collotelinite were also performed only on the vitrinite surfaces with a thickness of more than 1 mm on the same samples. The detailed reflectograms revealed only two maxima: one between 0.43 and 0.49% (about 0.47% on average) and the other between 0.47 and 0.53% (about 0.51% on average) (Table 1, Fig. 2, 3).

Dark vitrinite in the tested coal is significant (Fig. 2, 3), sometimes dominant (e.g., sample No. 30), but this strongly depends on the type of facies highlighted in the coal seam.

Medium reflectance measurements on collotelinite (telocollinite) surfaces also formed two maxima marked as No. 3 and No. 4. The lower-value peaks range from 0.41 to 0.48% (Table 1) have an average value of 0.45%. In several coal samples, they are dominant, grouping the highest frequency of individual measurements (e.g. in samples No. 3, 4 and 30b).

These maxima correlate with the peaks marked as No. 3 and 4 in the sample reflectograms taking into account all the vitrinite group macerals. At the same time, they seem to confirm the diagnosis that peak No. 1 represents the average reflectance for collodetrinite, while peak No. 2 represents the values for gelinite and (or) dark vitrinite. The comparison of the results and reflectograms also shows that pure collotelinite (i.e., without visible impregnations) has a slightly higher average reflectance in the thickest layers. This phenomenon is known in bituminous coal and is mainly associated with moderate bituminization of thin vitrain laminae and external parts of thicker layers in permanently flooded peat bogs of that time.

Based on measurements of the average reflectance of vitrinite, the average values were calculated for the tested samples. These range from 0.48 to 0.53%. These results are similar to those obtained for selected coal seams of the Libiąż Beds from the eastern part of the USCB by many researchers, including Gabzdyl and Hanak 1982, 1984; Hanak 1993; Hanak and Komorek 1987; Święch and Kwiecińska 2003. These values do not exceed 0.50%, which was the basis for the cautious inference of the occurrence of meta-lignite and subbituminous coal in addition to bituminous coal in the highest stratigraphic series of the Cracow Sandstone Series of the USCB.

However, from the summary of the above results, it can be seen that the conclusions about the degree of coalification on the example of the No. 116/2 seam from the Janina coal mine strongly depend on the adopted methodology – the coefficients of average vitrinite reflectance, i.e. all macerals of this group occurring in the tested sample are generally low, below 0.50% – i.e. below the adopted formal limit for bituminous coal, depending on the content of collodetrinite and gelinite, including telinite and other macerals of the vitrinite group with R_o values lower than those of pure collotelinite. The same conclusions were obtained by Gabzdyl and Hanak (1982, 1984). Measurements of the average reflectance performed only on collotelinite surfaces (this methodology is recommended by the ICCP for assessing the rank of coal) usually range from 0.50 to 0.53%, only occasionally slightly lower (0.48–0.49%), which may signal the presence of bituminous coal, assuming a formal limit of 0.50% between subbituminous coal and bituminous coal.

A detailed analysis of the obtained results indicates that not only macerals of the vitrinite group, such as collodetrinite and gelinite, reduce the R value; this also applies to submicroscopic impregnations in collotelinite with a darker material (Table 1, Fig. 4). Unfortunately, they are not always clearly visible in the preparations, and the differences between peaks 3 and 4 range from 0.03 to 0.06%; although they are smaller than or equal to the permissible measurement error, they underestimate the values of average reflectance.

Individual results for peaks 3 and 4, expressed as a total maximum, partially confirm a hypothesis based on the analysis of peak No. 4 (0.44–0.50%, 0.48% on average). In view

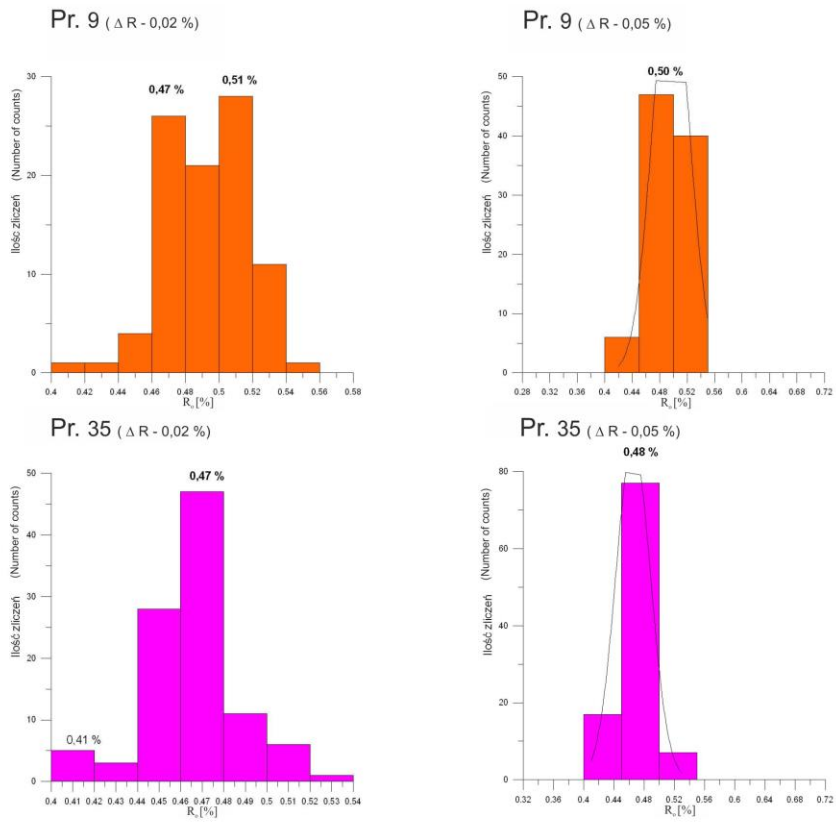

Fig. 4. Selected collotelinite reflectograms in vitrinite layers with a thickness >1 mm, coal seam No. 116/2, KWK Janina coal mine

Rys. 4. Zestawienie wybranych reflektogramów kolotelinitu w warstwach witrynu o grubości większej od 1 mm, Pokład 116/2, KWK Janina

of this, the only reliable way to isolate the diagnostic peak (No. 4) is to present the results in the form of a reflectogram in the range ΔR_o equal to or close to the value of the obtained standard deviation.

4.3. Assessment of the degree of coalification based on chemical and technical characteristics

The average reflectance of collotelinite, currently considered to be the strongest measure of the degree of coalification, should be related to other measures on the principle that as the coalification of fossil organic material increases, other characteristics of coal that shape its petrographic and geochemical character etc. also change. Usually, these comparisons involve vitrinite (bright coal), because it is believed that this variety of coal shows proportional changes in many measures considered to be significant parameters in this process as the rank of coal increases (e.g. Stach et al. 1975).

The most important factors, in addition to the average reflectance, are the carbon content and the gross calorific value, while the volatile matter content is of less importance.

The C^{daf} content in the tested coal from the Janina coal mine ranges from 75.9 to 77.5 wt%, while for vitrain it is 71.1 to 75.5 wt%. Comparing the values of this parameter with the reference data, one can see their high compatibility with respect to bituminous coal, the lower limit value of which is usually assumed to be 76%. The carbon content in vitrain is lower, which has been confirmed in many works, including the analysis for the Siersza coal mine from the No. 207 and 301 seams, where this value ranged from 73.4 to 74.8 wt% (Gabzdyl and Hanak 1982), with the average reflectance close to 0.5%.

The carbon content in vitrain is associated with a strong correlation with the average reflectance (Fig. 5).

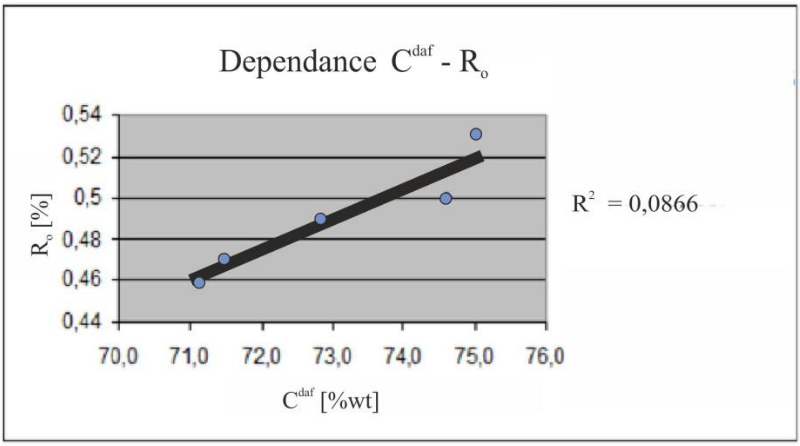

Fig. 5. Correlative relationship between the carbon content and the average reflectance of vitrain interlayers in coal from the No. 116/2 seam of the Janina coal mine

Rys. 5. Korelacyjna zależność zawartości pierwiastka C i średniej refleksyjności wkładek witrynu w węglu z pokładu 116/2 KWK Janina

The relationship is an exponential regression with a correlation coefficient of $r = 0.95$, which can be approximated by a linear correlation of $r = 0.94$. The statistical significance of this correlation, despite the small sample size, refers to the general correlation known from the entire coal series.

The gross calorific value and volatile matter content are weaker measures of the degree of coalification due to their strong dependence on petrographic composition – macerals of other maceral groups show significant changes in these parameters in the same coal. This note also applies to the carbon content, but the content of this element in various macerals is lower. Nevertheless, it is important to compare the coal of the same global province (northern Euro-American), which has a similar (in the range of up to a dozen percent) petrographic composition.

The gross calorific value of the tested samples from the No. 116 seam of the Janina coal mine ranges from 6,661 to 6,943 kcal/kg, while for vitrain it is between 6,658 and 6,763 kcal/kg.

The data in Table 4 are sparse and divergent. However, assuming the value of 7,000 kcal/kg as the boundary between lignite and bituminous coal (Table 2), it can be seen that in several samples of the tested coal, such a value has been achieved. Others show slightly lower values, differing by approx. 300 kcal/kg from this limit. However, taking into account the significant influence of the petrographic composition on this parameter, it is impossible to make a precise diagnosis regarding the degree of coalification of the tested coal.

Table 2. Chemical and technical parameters of coal from the No. 116/2 seam of the Libiąż Beds

Tabela 2. Zestawienie parametrów chemiczno-technicznych węgla z pokładu 116/2 warstw libiąskich

Sample No.	W^a	A^{and}	C^a	V^a	Q_s^a	A^d	C^{daf}	V^{daf}	Q_s^{daf}
	[wt%]	[wt%]	[wt%]	[wt%]	[kcal/kg]	[wt%]	[wt%]	[wt%]	[kcal/kg]
3	5.2	8.2	67.1	28.5	6,001	8.6	77,5	32,9	6,930
3 vitrain	4.5	9.6	62.6	29.8	5,773	10.1	72.9	34.7	6,721
4	3.4	8.7	66.7	31.2	5,855	9.0	75.9	35.5	6,661
4 vitrain	3.1	9.2	64.4	31.5	5,874	9.5	73.4	35.9	6,698
9	4.2	10.6	64.8	29.6	5,726	11.1	76.1	34.7	6,721
9 vitrain	4.1	11.2	61.7	30.2	5,639	11.7	72.8	35.7	6,658
35	4.3	8.4	66.3	35.3	6,061	8.8	75.9	40.4	6,943
35 vitrain	6.3	9.2	60.1	34.2	5,715	9.8	71.1	40.5	6,763

Explanations: *W* – total moisture, *A* – coal ash content, *C* – carbon content, *V* – volatile matter, Q_s – gross calorific value, designations: *a* – analytical, *d* – dry, *daf* – dry and ash-free; analyses of the separated vitrain.

The content of volatile matter (V^{daf}) in the tested coal ranges from 32.9 to 40.4 wt%, while for vitrain, it ranges from 34.7 to 40.5 wt% (Table 2). In bituminous coal, according to the cited works (Table 4), the content of volatile matter is below 42–43%, while in glossy lignite it is, on average, above 43 wt%.

Taking into account the volatile matter content, the tested coal has the characteristics of bituminous coal; this also applies to vitrain, but one should not forget about the rather low significance of this measure of the degree of coalification.

The correlation strength between the volatile matter content and the coefficient of average reflectance in the vitrinite of the tested coal was also examined. The statistically significant correlation is strong, as expressed by the exponential correlation coefficient "r" being close to 0.99 (almost a functional relationship) and its linear approximation with a correlation coefficient value of $r = 0.98$ (R^2 is the so-called "correlation efficiency" expressing the statistical number of relationships in the regression determined by the equation – Fig. 6).

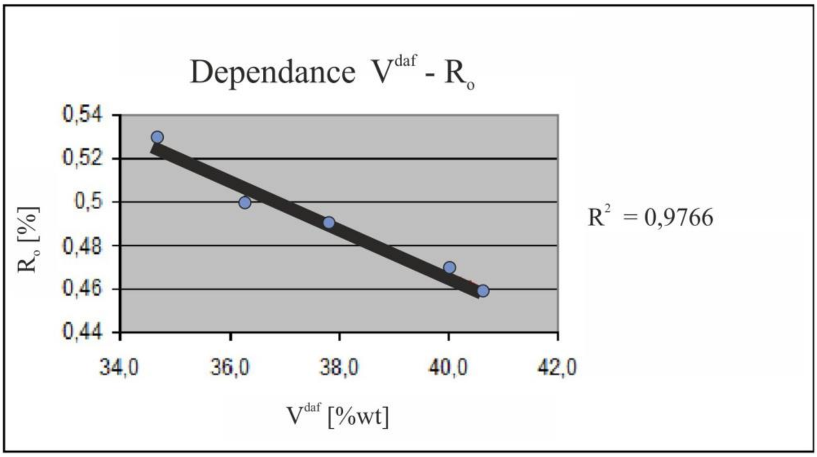

Fig. 6. Correlative relationship between volatile matter content and mean reflectance of collotelinite in vitrine from the No. 116/2 seam of the Janina coal mine

Rys. 6. Korelacyjna zależność zawartości części lotnych i średniej refleksyjności kolotelinitu w witrynie węgla z pokładu 116/2 KWK Janina

Conclusions

A careful analysis of vitrinite reflectograms reveals the presence of 3 or 4 clearly distinguished peaks. When assessing the degree of coalification, only the main maximum, peak No. 4, was considered to be significant. Measurements of the average reflectance of collotelinite were made only on the vitrinite surfaces with a thickness of more than 1 mm. On reflectograms, they reveal two maxima. These maxima correlate with the peaks marked as No. 3 and 4 in the sample reflectograms taking into account all the vitrinite group macerals. The C^{daf} content in the tested coal from the Janina coal mine ranges from 75.9 to 77.5 wt%, while for vitrain, it ranges from 71.1 to 75.5 wt%. The relationship is an exponential regression with a correlation coefficient of r = 0.95, which can be approximated by a linear correlation of r = 0.94. The correlation strength between the volatile matter content and the coefficient of average reflectance in the vitrinite of the tested coal was also examined. The statistically significant correlation is strong, which is expressed by the exponential correlation coefficient "r" close to 0.99 and its linear approximation with the correlation coefficient r = 0.98. However, no correlation was found between the measured reflectance values and the GI coefficient calculated for the tested samples.

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COALIFICATION EEGREE OF THE NO. 116/2 SEAM IN THE JANINA COAL MINE (UPPER SILESIAN COAL BASIN) BASED ON VITRINITE REFLECTANCE

Keywords

coal, vitrinite reflectance, coalification

Abstract

The subject of the study was the No. 116/2 coal seam belonging to the Cracow Sandstone Series of the Upper Silesian Coal Basin. Reflectograms of the samples taking into account all the vitrinite group macerals present in the coal were recorded for ΔR^o close to the standard deviation and in the standard range. A careful analysis of vitrinite reflectograms reveals the presence of three or four clearly distinguished peaks. When assessing the rank of coal, only the main maximum, peak No. 4, was considered to be significant. Measurements of the average reflectance of collotelinite were made only on the vitrinite surfaces with a thickness of more than 1 mm. Only two maxima were revealed on detailed reflectograms. These maxima correlate with the peaks marked as No. 3 and 4 in the sample reflectograms taking into account all the vitrinite group macerals. The C^{daf} content in the tested coal from the Janina coal mine is between 75.9 and 77.5 wt%, while for vitrain, it ranges from 71.1 to 75.5 wt%. This relationship is an exponential regression with a correlation coefficient of r = 0.95h and can be approximated by a linear correlation of r = 0.94. The correlation strength between the volatile matter content and the coefficient of average reflectance in the vitrinite of the tested coal was also examined. The statistically significant correlation is strong, which is expressed by the exponential correlation coefficient "r" being close to 0.99 and its linear approximation with the correlation coefficient r = 0.98. However, no correlation was found between the measured reflectance values and the GI coefficient calculated for the examined samples.

OCENA STOPNIA UWĘGLENIA POKŁADU 116/2 W KOPALNI JANINA (GÓRNOŚLĄSKIE ZAGŁĘBIE WĘGLOWE) NA PODSTAWIE REFLEKSYJNOŚCI WITRYNITU

Słowa kluczowe

węgiel, refleksyjność witrynitu, uwęglenie

Streszczenie

Przedmiotem badań był pokład węgla 116/2 należący do krakowskiej serii piaskowcowej Górnośląskiego Zagłębia Węglowego. Reflektogramy próbek uwzględniające wszystkie występujące w węglu macerały grupy witrynitu, zarejestrowano w postaci reflektogramów przy stadium ΔR^o zbliżonego do odchylenia standardowego oraz w zakresie standardowym. Reflektogramy witrynitu dokładniej rejestrowane ujawniają obecność 3 lub 4 wyraźnie wyodrębnionych pików. Znaczenie w ocenie stopnia uwęglenia badanego węgla przypisano wyłącznie głównemu maksimum – pik nr 4. Wykonano także pomiary średniej refleksyjności kolotelinitu wyłącznie na powierzchniach warstewek witrynu o grubości większej od 1 mm. Na szczegółowych reflektogramach ujawniły się jedynie 2 maksima. Maksima te korelują z pikami oznaczonymi jako nr 3 i 4 w reflektogramach próbek uwzględniający wszystkie macerały grupy witrynitu. Zawartość pierwiastka C^{daf} w badanym węglu z KWK Janina zmienia się w przedziale od 75,9 do 77,5 %wt, natomiast w witrynie od 71,1 do 75,5 %wt. Zależność ta ma charakter regresji o charakterze wykładniczym o współczynniku korelacji r = 0,95, która może być przybliżona korelacją liniową o r = 0,94. Zbadano również siłę korelacyjną między zawartością części lotnych a współczynnikiem średniej refleksyjności w witrynitu badanego węgla. Statystycznie istotna korelacja jest silna, co wyraża współczynnik korelacji wykładniczej „r” bliski wartości 0,99 i liniowe jej przybliżenie o wartości współczynnika korelacji r = 0,98. Nie stwierdzono natomiast korelacji pomiędzy pomierzonymi wartościami refleksyjności a współczynnikiem GI obliczonym dla badanych próbek.