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# SPECIFIC TYPES OF COAL MACERALS FROM ORZESZE AND RUDA BEDS FROM "PNIÓWEK" COAL MINE (UPPER SILESIAN COAL BASIN – POLAND) AS A MANIFESTATION OF THERMAL METAMORPHISM

# SPECYFICZNE ODMIANY MACERAŁÓW Z WĘGLA WARSTW ORZESKICH I RUDZKICH KWK „PNIÓWEK" (GÓRNOŚLĄSKIE ZAGŁĘBIE WĘGLOWE – POLSKA) PRZEJAWEM METAMORFIZMU TERMALNEGO

Subject of the research were coal samples from the seams of Orzesze and Ruda beds from "Pniówek" coal mine. All samples represent methabituminous coal B, which present high vitrinite content ($V^{mmf} > 60\%$). Optical character of vitrinite from all analyzed coal samples is biaxial negative and it is characterized by low differentiation of bireflectance.

The experiments have shown that the coal rank of investigated samples is generally decreasing with increasing both depth of coal seams and the distance between sampling point and the Carboniferous roof. It may suggests inversion of coalification.

Specific types of macerals, typical for thermally metamorphosed coals have been found for all analysed coal samples.

It was found, presence of such components like: fluorescing bituminous substance (FBS) filling of cellular spaces in semifusinite, fusinite, and funginite; pseudomorphs after megaspores exhibiting strong bireflectance, and anisotropic semifusinite. Petrographic components with a structure similar to structure of coke and pyrolytic carbon were observed rarely. Presence of colotelinite grains which are visible darker, impregnated with bituminous substance and exhibiting weak fluorescence may be related with influence of temperature on coal. Carbonates occur as filling of cellular spaces in semifusinite, in examined coal samples and there are the effect of thermal alteration of coal.

**Keywords:** coal macerals, Ruda beds, Orzesze beds, Upper Silesian Coal Basin, vitrinite reflectance

Przedmiotem badań były próbki węgla z pokładów warstw orzeskich i rudzkich KWK Pniówek. Badane próbki reprezentują węgiel średniouwęglony typu B (metabitumiczny), wysokowitrynitowy. Stwierdzono, że witrynit z badanych próbek ma dwuosiowy ujemny charakter optyczny i wykazuje małe zróżnicowanie w wartościach dwójodbicia.

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Przeprowadzone badania wykazały, że stopień uwęglenia badanych próbek generalnie maleje wraz ze wzrostem głębokości występowania pokładów węgla oraz ze wzrostem odległości miejsca opróbowania od stropu karbonu co może wskazywać na inwersję uwęglenia.

We wszystkich analizowanych próbkach węgla stwierdzono występowanie specyficznych odmian macerałów typowych dla węgli zmetamorfizowanych termicznie.

W próbkach stwierdzono obecność takich składników jak: fluoryzująca substancja bitumiczna (FBS) wypełniająca przestrzenie komórkowe w semifuzynicie, fuzynicie i funginicie; pseudomorfozy po makrosporach wykazujące silne dwójodbicie oraz anizotropowy semifuzynit. Rzadziej obserwowano składniki petrograficzne o strukturze wykazującej podobieństwo do struktury koksu i węgiel pirolityczny. Z oddziaływaniem temperatury na badany węgiel można wiązać także obecność w analizowanych próbkach wyraźnie ciemniejszych, przesyconych substancją bitumiczną, wykazujących słabą fluorescencję ziaren kolotelinitu. Przejawem przemian termicznych obserwowanych w badanych próbkach węgla może być także obecność węglanów najczęściej wypełniających przestrzenie komórkowe w semifuzynicie.

**Słowa kluczowe:** macerały, warstwy rudzkie, warstwy orzeskie, Górnośląskie Zagłębie Węglowe, refleksyjność witrynitu

# 1. Introduction

Coal mine "Pniówek" belongs to the JSW Group. The coal deposit of the "Pniówek" coal mine has been located in the south-west part of the Upper Silesia Coal Basin (USCB), eastward from the Jatrzębie saddle. In this geological structure take a part following lithostratigraphic units: Quaternary (Holocene, Pleistocene), Tertiary (Miocene) and Upper Carbon (Westphal B and A).

Quaternary and Tertiary formations represent overburden of the coal-bearing series of Carbon, which thickness varies from about 220 m in the northern part of the deposit up to maximally 1000 m in the southern part.

Carboniferous formations are represented by Orzesze and Ruda beds. Orzesze beds occurred on the almost total mining area of "Pniówek" coal mine except its southern part, where on the surface of Carboniferous roof their outcrops can be found. Maximal thickness of Orzesze beds is amount to 600 m. Within these beds 19 coal seams have been documented, numbered from 340/2 up to 363. In the lithological profile of Orzesze beds dominate claystones and mudstones. Coal seams occur most frequently between claystones and are characterised by highly differentiated thickness and quality.

Ruda beds occur on the whole mining area. Their thickness from 401 to 501 coal seams is amount to maximally 700 m. Upper part of the profile of Ruda beds is formed in clayey-mudstone facies, within which coal seams of numbers from 401 to 407 have been documented. Bottom part of Ruda beds profile is formed in sandstone facies with interlayers claystones, mudstones, and numerous coal seams.

It should be mentioned that in the mining area of "Pniówek" coal mine, occurrence of red beds has been identified (Kowalski, 1977). These formations appear in the Carboniferous roof, both in the Czech part of USCB – in the area of Karvina and Ostrava, and in its Polish part, in the area of Jastrzębie (Dopita, 1994; Klika & Kraussova, 1993; Kowalski, 1977). They do not correlate with any specific lithostratigraphic unit. Genesis of the red beds may relates to the zones of thermal and metasomatic influence of igneous intrusions (Gabzdyl & Probierz, 1987; Probierz 1989) and also to the processes of weathering, redeposition, and sedimentation of rock material, which occurred in regional scale (Dopita, 1994; Klika & Kraussova, 1993; Kowalski, 1977).

In the area of occurrence of the red beds, presence of new kinds of macerals, as anisotropic semifusinite, low-reflectance fusinite and fluorescing bituminous substance (FBS), is being frequently observed (Probierz, 1989; Komorek et. al., 2010). The anomalies of coal rank and new kinds of macerals has been already noticed in the earlier research on coals from the Saddle beds of "Jas-Mos" coal mine – mining area "Moszczenica" and "Morcinek" coal mines, and also in coal seams of Orzesze and Ruda beds in "Zofiówka" coal mine (Gabzdyl & Probierz, 1991; Probierz, 1986, 1989; Komorek et. al., 2010). Probably similar phenomena may be observed in the mining area of "Pniówek" coal mine, where presence of red beds in the Carboniferous roof has been found.

The aim of this work was demonstrate of occurrence in coal from Orzesze and Ruda beds from "Pniówek" coal mine, specific types of macerals, like anisotropic intertinite and fluorescing bituminous substance FBS, which are probably indication of thermal alteration observed in coal seams and adjacent rocks, occurring nearly the red beds.

## 2. Sampling

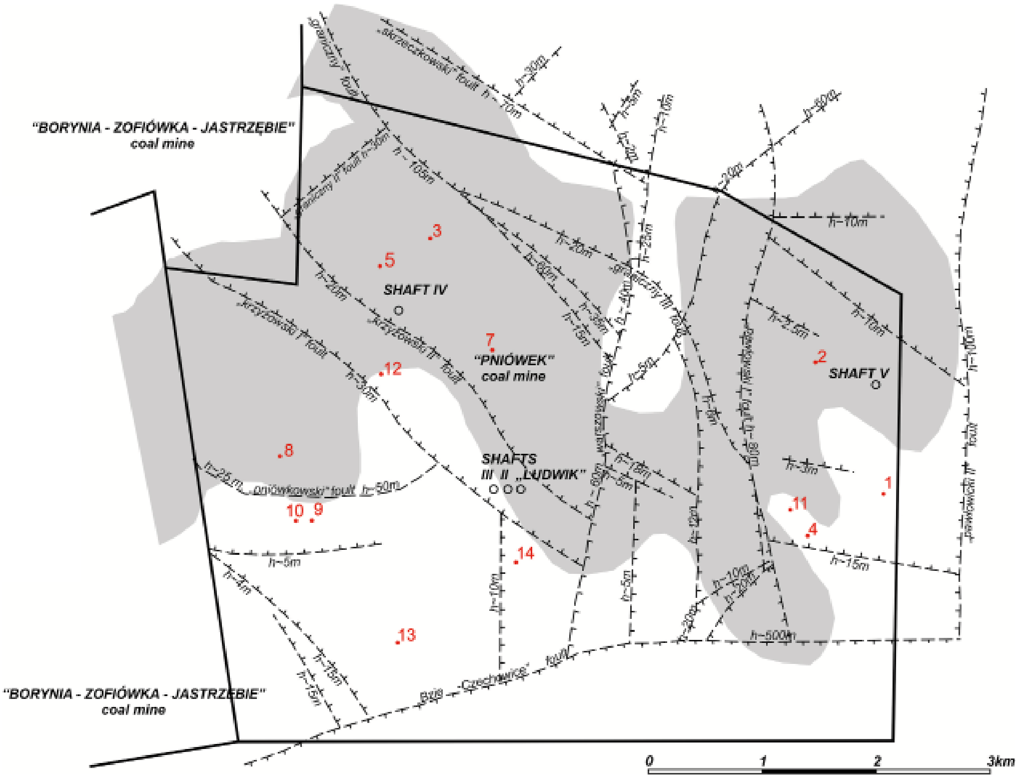
Subject of the work were coal samples from 360/1, 361, 362/1, 401/1. 403/1, 404/1 and 404/2 coal seams from "Pniówek" coal mine. A channel sample of coal has been collected from each one of the mentioned coal seams.

Sampling of the seams has been performed in different tectonic blocks of the deposit, considering the both areas located closely to the red beds as well as in large distance from them. Samples have been taken in different excavation – inclines, galleries, cross-cuts, and longwalls – (Fig. 1). Sampling points ranged the depth from (–478) to (–710) m below the sea level and were placed 140÷691 m away from the Carboniferous roof (Table 1).

TABLE 1

Location of sampling places in the vertical profile

| **Sample** | **Coal seam** | **Depth of sampling** [m b. s. l.] | **Distance from the Carboniferous roof** [m] |
|---|---|---|---|
| 1 | 360/1 | -667 | 477 |
| 2 | 361 | -681 | 691 |
| 3 | 361 | -615 | 495 |
| 4 | 361 | -598 | 368 |
| 5 | 362/1 | -605 | 510 |
| 6 | 362/1 | -605 | 510 |
| 7 | 401/1 | -625 | 655 |
| 8 | 403/1 | -496 | 516 |
| 9 | 403/1 | -485 | 365 |
| 10 | 403/1 | -478 | 318 |
| 11 | 404/1 | -710 | 560 |
| 12 | 404/1 | -646 | 676 |
| 13 | 404/2 | -510 | 140 |
| 14 | 404/2 | -579 | 449 |




Explanations:

•1 – location of sampling places and their numbers

– the range of red beds occurrence, according to Kowalski W. (1977)

Fig. 1. Tectonic sketch of the „Pniówek" coal mine and location of sampling places (geological documentation of „Pniówek" coal mine)

## 3. Methods

The channel samples were subjected to microscopic examination. Microscopic examination were made in the laboratory of Institute of Applied Geology at the Silesian University of Technology in Gliwice. For the microscopic tests samples were reduced and grinded to grain-size < 1 mm. They were used for preparation of polished grain mounts for microscopic examination in reflected light according to PN-ISO 7404-2 standard. To reach the goal of the study the measurement of random reflectance $R_r$ well as apparent maximum $R'_{max}$ and minimum $R'_{min}$ reflectance of vitrinite were carried out according to ISO 7404-5 PN-ISO.

The results of measurements of apparent maximum and minimum reflectance of vitrinite have been used for determination of the true maximum ($R_{max}$), the intermediate ($R_{int}$), and the minimum ($R_{min}$) reflectance of vitrinite using Kilby's method and computer programme (Kilby, 1988, 1991). The coefficient values of $R_{st}$ and $R_{am}$ have been determined by the same computer programme.

Coefficient $R_{st}$ describes reflectance Indicating Surface (RIS) shape. The $R_{st}$ value range from (–30) to (+30). Dependently RIS shape is described as:

$R_{st}$ = (–30) uniaxial negative
$R_{st}$ = (+30) uniaxial positive.
$R_{st}$ = (–30) – (0) biaxial negative
$R_{st}$ = (0) – (+30) biaxial positive
$R_{st}$ = (0) biaxial positive-negative (Kilby, 1988, 1991).

Coefficient $R_{am}$ shows optical anisotropy. Isotropic constituent of coal is characterized by $R_{am}$ = 0. The higher the coefficient value means the stronger optical anisotropy.

Optical anisotropy has been also characterized by bireflectance value $R_{bi}$ according to a formula $R_{bi} = R_{\max} - R_{\min}$.

The analysis of maceral groups (according to PN-ISO 7404-3) was done for determination of petrographic composition of analysed coal samples.

The content of following macerals was determined within the intertinite group:

– non reactive (fusinite, sclerotinite, secretinite),
– partly reactive (semifusinite, micrinite).

The content of inertodetrinite, macrinite and anisotropic semifusinite was determined too.

During the research, the content of macerals of liptynite group was determinated with detailing the FBS.

Results of maceral groups analysis have been presented in accordance with PN-ISO standards with precision of integer. However, content of macerals of liptinite and inertinite group have been presented with precision to first decimal place.

Petrographic composition and reflectance measurement were done with use of Zeiss microscope Axioscope, in immersion oil ($n_0$ = 1,518 at 23°C) and light wave length $l$ = 546 nm.

# 4. Results

## 4.1. Vitrinite reflectancen analysis

It was found that vitrinite from examined coal seams is characterised by the mean random reflectance in the range from $R_r$ = 1.00% (sample 2, 361 coal seam) to $R_r$ = 1.16% (sample 13, 404/2 coal seam), with standard deviation $s_r$ = (0,03 – 0,05)% (Table 2). Reflectograms of all analysed samples are characterised by a one peak, without gaps. Their shapes are similar to the Gaussian distribution. Peaks bases ranges from 2 to 3 V stages.

On the bases of results was found that analysed samples are characterised by a similar coal rank. Tested samples represent metabituminous coal B (ECE-Geneva 1998)

The Kilby's program was used to determine the true maximum $R_{\max}$, intermediate $R_{\text{int}}$, and minimum $R_{\min}$ values of reflectance. These values vary within the ranges: $R_{\max}$ = (1,09 – 1,26)%, $R_{\text{int}}$ = (1,00 – 1,16)%, $R_{\min}$ = (0,90 – 1,06)%.

The bireflectance $R_{bi}$ values changes to a small range $R_{bi}$ = (0,18 – 0,23)%, like $R_{am}$ coefficient value $R_{am}$ = (0,03 – 0,04). The values of $R_{st}$ coefficient are always negative, what means that vitrinite in analysed samples has biaxial negative optical character (Table 2).

TABLE 2

Optical properties of vitrinite

| Sample | Coal seam | $R_r$ [%] | $s$ [%] | $R_{max}$ [%] | $R_{int}$ [%] | $R_{min}$ [%] | $R_{st}$ | $R_{am}$ | $R_{bi}$ [%] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 360/1 | 1,05 | 0,03 | 1,13 | 1,05 | 0,95 | –3,67 | 0,03 | 0,18 |
| 2 | 361 | 1,00 | 0,03 | 1,09 | 1,00 | 0,90 | –0,89 | 0,04 | 0,19 |
| 3 | 361 | 1,03 | 0,04 | 1,13 | 1,03 | 0,93 | –1,65 | 0,04 | 0,20 |
| 4 | 361 | 1,06 | 0,04 | 1,15 | 1,07 | 0,97 | –1,84 | 0,03 | 0,18 |
| 5 | 362/1 | 1,07 | 0,04 | 1,16 | 1,07 | 0,97 | –1,74 | 0,03 | 0,19 |
| 6 | 362/1 | 1,06 | 0,04 | 1,14 | 1,05 | 0,95 | –1,74 | 0,04 | 0,19 |
| 7 | 401/1 | 1,10 | 0,04 | 1,19 | 1,11 | 1,01 | –1,83 | 0,03 | 0,18 |
| 8 | 403/1 | 1,10 | 0,04 | 1,19 | 1,10 | 0,98 | –4,71 | 0,04 | 0,21 |
| 9 | 403/1 | 1,13 | 0,04 | 1,21 | 1,12 | 1,02 | –1,74 | 0,03 | 0,19 |
| 10 | 403/1 | 1,11 | 0,04 | 1,22 | 1,12 | 1,00 | –3,84 | 0,04 | 0,22 |
| 11 | 404/1 | 1,11 | 0,04 | 1,22 | 1,11 | 0,99 | –0,74 | 0,04 | 0,23 |
| 12 | 404/1 | 1,14 | 0,04 | 1,23 | 1,14 | 1,04 | –2,54 | 0,03 | 0,20 |
| 13 | 404/2 | 1,16 | 0,04 | 1,26 | 1,16 | 1,06 | –0,81 | 0,03 | 0,21 |
| 14 | 404/2 | 1,15 | 0,05 | 1,25 | 1,15 | 1,02 | –4,30 | 0,04 | 0,23 |

Explanations: $R_r$ – random reflectance, $s$ – standard deviation of random reflectance value, $R_{max}$ – true maximum reflectance, $R_{int}$ – true intermediate reflectance, $R_{min}$ – true minimum reflectance, $R_{st}$ – Reflectance Indicating Surface (RIS) style, $R_{am}$ – reflectance anisotropy coefficient, $R_{bi}$ – bireflectance

Coal samples have been collected from different tectonic blocks of the "Pniówek" deposit (Fig. 1), divided by the faults. It was found that coal rank of the examined samples generally decrease (Fig. 2A) with increase of depth of the coal seams. It can be assumed that the contemporary depth of coal samples occurrence are different than their original burial depth. Probably this is a result of vertical displacements of particular tectonic blocks. Determination of vertical coal rank gradient was difficult, because even samples collected from one coal seam (i.e. 404/1 – sample 11 and 12) are located in different tectonic blocks which are vertical dislocated.

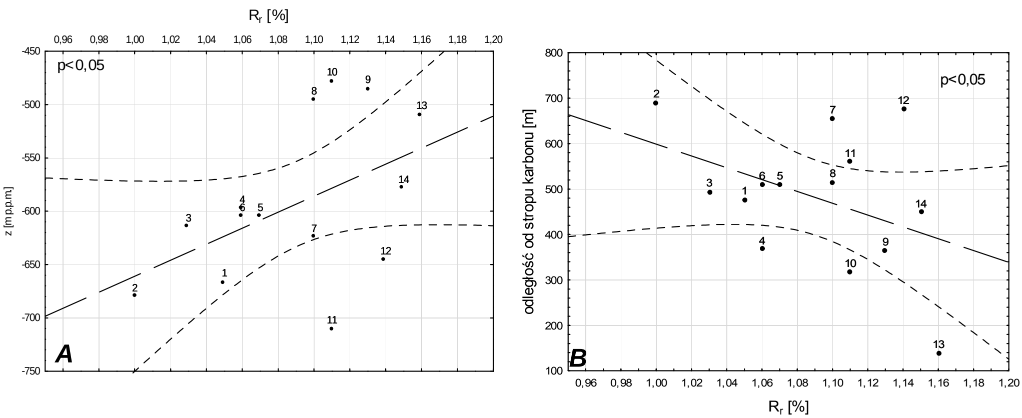



Fig. 2. Relationship between coal rank and:
*A* – the depth of sampling, *B* – the distance from the Carboniferous roof

The relation between coal rank and vertical distance of sampling points from the Carboniferous roof (Fig. 2B) shows that the reflectance of vitrinite slightly decrease with increase the distance between sampling points and the Carboniferous roof. This shows a slight inversion of the coal rank, although variability of coal rank of examined samples is small. This phenomena probably has connection with the red beds presence in the Carboniferous roof. Coal samples situated in the places located nearly Carboniferous roof (Fig. 2B, Table 2), are characterised by higher coal rank than the samples, which originate from further distances from it. The obtained results may suggest that slight inversion of coal rank confirmes about influence of an additional heat source, which contributed to the creation of red beds.

## 4.2. Maceral analysis

The studies have determined the content of maceral groups and mineral matter in coal samples (Table 3).

It was found that vitrinite content ($V^{mmf}$) is always above 60% in all samples (Table 3, Fig. 4). In three samples (samples 2, 6, 9) vitrinite content ($V^{mmf}$) is very high and exceeding 80%. Therefore examined coal samples represent high vitrinite content coal (ECE Geneva 1998). Vitrinite content (in the state with mineral matter) ranges from 58% to 89% (Fig. 3). Among vitrinite macerals the most often colodetrinite and colotelinite was observed. Telinite was observed rarely. Except typical vinitrinite macerals, visible darker grains of colotelinite (the reflectance was not measured for them), which exhibit a weak fluorescence was observed. These grains are probably impregnated with bituminous substance. The occurrence of bituminous substance may be related with influence of temperature from magmatic intrusion on coal (Gabzdyl & Probierz, 1987; Probierz, 1989).

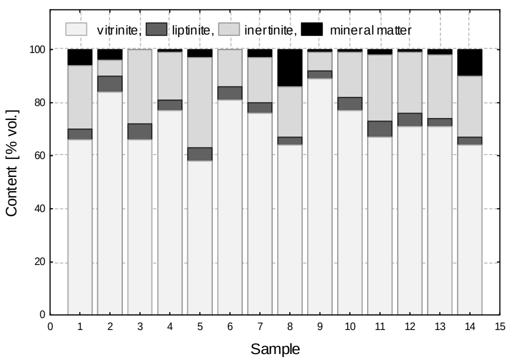



Fig. 3. Content of maceral groups and mineral matter in examined coal samples

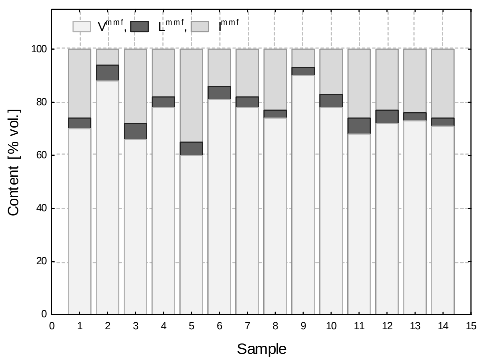



Fig. 4. Content of maceral groups (in mineral matter free state) in examined coal samples

Liptinite content ($L^{mmf}$) is changing in a small range $L^{mmf}$ = (3 – 6)% in examined coal samples (Table 3, Fig. 4). Liptinite content (in the state with mineral matter) is changing in the same range (fig. 3). Among liptinite macerals the most often sporinite (1,2 – 4,7)% was observed. Sporinite was represented by micro- and megaspores which demonstrates fluorescence in orange colours. Except sporinite, resinite (0,3 – 2,3)%, which is present in a form of lenses in clarite, durite and trimacerite was observed. Resinite in a form of FBS (exudatinite) fills of cellular spaces in semifusinite, fusinite, and funginite (0,0 – 0,8)%. Fluorescing bituminous substance demonstrated strong fluorescence in colours from yellow to orange (Fig. 9). FBS is probably derived from the bituminous substances "melted" under heat. The same substance probably impregnates some vitrinite grains, what resulted in their darker colouration and weak fluorescence. Cutinite (0,0 – 0,7)% and liptodetrinite (0,0 – 0,8)% in the analysed samples was observed rarely (Fig. 5, 6). All macerals from liptinite group demonstrated fluorescence in orange colours but its intensity is lower than fluorescence of FBS.

In some samples pseudomorphs after megaspores, which show a strong bireflectance was observed (Fig. 10 a-f). Usually they are present in coal samples characterised by higher vitrinite reflectance value (samples 6, 8, 10-12). Their presence may be considered as untypical and being a symptom of high temperatures impact on the coal.

The inertinite content varies in a wide range $I^{mmf}$ = (6 – 35)% (Table 3, Fig. 3). Almost all analysed samples are characterised by inertinite content $I^{mmf} \leq 30\%$, except sample 5 from 362/1 coal seam, which contains 35% of inertinite. Inertinite content (in the state with mineral matter), varies in a range I = (6 – 34%) (Table 3, Fig. 4). The inertinite group is represented mainly by inertodetrinite (3,9 – 17,2)%, semifusinite (1,3 – 13,2)% and macrinite (0,3 – 3,7)% (Fig. 7). The other macerals, like fusinite (0,0 – 1,6)%, micrinite (0,0 – 0,8)%, funginite (0,0 – 0,6)%, and secretinite (0,0 – 0,3)% was observed rarely (Fig. 7). Based on the research it was found that of semifusinite (0,4 – 9,2)% shows anisotropy (Fig. 8, Fig. 11).

In the analysed coal samples have been also observed thermally altered components with a structure similar to structure of coke (samples 1, 11, 12; Fig. 10 g-h). Occurrence in coal components with a structure similar to porous structure of coke may be interpreted as a result of degassing of organic matter, which took place at temperature above 300°C (Taylor et al., 1998).

TABLE 3

Content of maceral groups and mineral matter in examined coal samples

| Sample | Coal seam | Content [% vol.] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *V* | *L* | *I* | *SM* | $V^{mmf}$ | $L^{mmf}$ | $I^{mmf}$ |
| 1 | 360/1 | 66 | 4 | 24 | 6 | 70 | 4 | 26 |
| 2 | 361 | 84 | 6 | 6 | 4 | 88 | 6 | 6 |
| 3 | 361 | 66 | 6 | 28 | śl. | 66 | 6 | 28 |
| 4 | 361 | 77 | 4 | 18 | 1 | 78 | 4 | 18 |
| 5 | 362/1 | 58 | 5 | 34 | 3 | 60 | 5 | 35 |
| 6 | 362/1 | 81 | 5 | 14 | śl. | 81 | 5 | 14 |
| 7 | 401/1 | 76 | 4 | 17 | 3 | 78 | 4 | 18 |
| 8 | 403/1 | 64 | 3 | 19 | 14 | 74 | 3 | 23 |
| 9 | 403/1 | 89 | 3 | 7 | 1 | 90 | 3 | 7 |
| 10 | 403/1 | 77 | 5 | 17 | 1 | 78 | 5 | 17 |
| 11 | 404/1 | 67 | 6 | 25 | 2 | 68 | 6 | 26 |
| 12 | 404/1 | 71 | 5 | 23 | 1 | 72 | 5 | 23 |
| 13 | 404/2 | 71 | 3 | 24 | 2 | 73 | 3 | 24 |
| 14 | 404/2 | 64 | 3 | 23 | 10 | 71 | 3 | 26 |

Explanation: *V* – vitrinite content, *L* – liptinite content, *I* – inertinite content, *SM* – mineral matter, $V^{mmf}$, $L^{mmf}$, $I^{mmf}$ vitrinite, liptinite, inertinite content in mineral matter free state, śl. – trace amounts < 0.5%

Furthermore, in examined coal samples pyrolytic carbon was observed rarely. It shows a strong anisotropy and Brewster crosses which remains stationary on rotation of the microscope stage at crossed polars (Fig. 11 g-h). Pyrolytic carbon is a product of thermal alteration of organic matter, which took place at temperatures above 500°C (Taylor et al., 1998). Therefore its occurrence in analysed samples indicates influence of temperature on the coal from examined seams.

| | Content [% vol.] | | | |
|---|---|---|---|---|
| **Sample** | **Sporinite** | **Cutinite** | **Resinite** | **Liptode-trinite** |
| 1 | 2.2 | 0.7 | 0.8 | 0.4 |
| 2 | 4.0 | 0.2 | 1.3 | 0.0 |
| 3 | 4.7 | 0.0 | 0.4 | 0.6 |
| 4 | 2.5 | 0.6 | 0.3 | 0.3 |
| 5 | 2.3 | 0.0 | 2.0 | 0.4 |
| 6 | 2.3 | 0.0 | 1.9 | 0.5 |
| 7 | 2.3 | 0.2 | 1.8 | 0.0 |
| 8 | 1.2 | 0.2 | 1.4 | 0.2 |
| 9 | 1.4 | 0.0 | 0.8 | 0.3 |
| 10 | 2.9 | 0.5 | 1.4 | 0.4 |
| 11 | 2.8 | 0.4 | 2.3 | 0.8 |
| 12 | 2.9 | 0.2 | 0.9 | 0.5 |
| 13 | 2.3 | 0.0 | 0.7 | 0.4 |
| 14 | 2.0 | 0.0 | 0.5 | 0.6 |

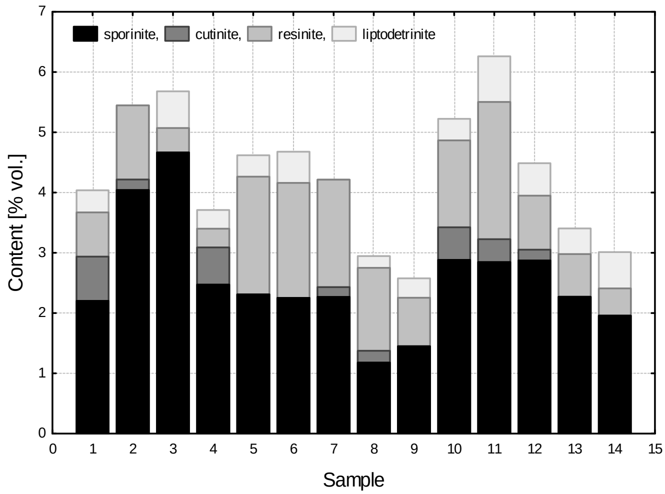



Fig. 5. Content of liptinite group macerals in examined coal samples

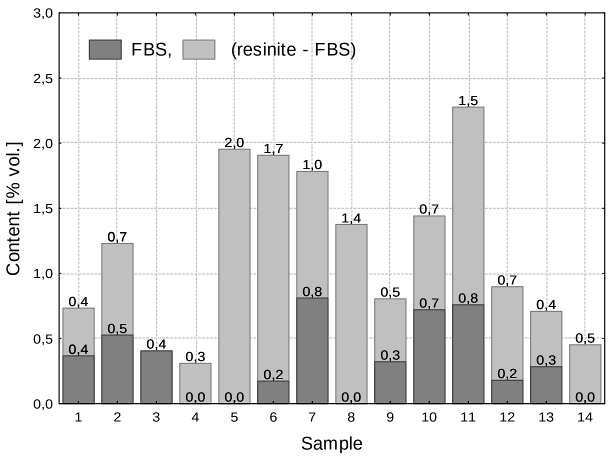



Fig. 6. Content of FBS and resinite without FBS (resinite – FBS) in examined coal samples

| | Content [% vol.] | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample | Semifusinite | Fusinite | Inertodetrinite | Funginite | Secretinite | Macrinite | Micrinite |
| 1 | 12.1 | 0.7 | 9.4 | 0.2 | 0.0 | 1.7 | 0.0 |
| 2 | 1.3 | 0.0 | 4.2 | 0.2 | 0.0 | 0.5 | 0.2 |
| 3 | 11.3 | 0.0 | 14.4 | 0.0 | 0.0 | 2.4 | 0.0 |
| 4 | 6.5 | 0.2 | 9.3 | 0.3 | 0.0 | 1.2 | 0.8 |
| 5 | 12.4 | 0.9 | 17.2 | 0.0 | 0.0 | 3.7 | 0.0 |
| 6 | 5.4 | 0.2 | 7.5 | 0.2 | 0.0 | 0.9 | 0.2 |
| 7 | 7.8 | 0.5 | 7.6 | 0.0 | 0.3 | 0.8 | 0.0 |
| 8 | 6.6 | 1.2 | 8.6 | 0.6 | 0.2 | 1.6 | 0.4 |
| 9 | 3.2 | 0.0 | 3.9 | 0.0 | 0.0 | 0.3 | 0.0 |
| 10 | 5.4 | 1.6 | 7.7 | 0.4 | 0.0 | 1.1 | 0.4 |
| 11 | 6.8 | 0.6 | 13.9 | 0.4 | 0.0 | 3.0 | 0.2 |
| 12 | 6.7 | 0.5 | 13.1 | 0.2 | 0.2 | 2.5 | 0.2 |
| 13 | 13.2 | 0.7 | 8.1 | 0.3 | 0.0 | 0.7 | 0.6 |
| 14 | 7.1 | 1.1 | 12.5 | 0.2 | 0.0 | 1.5 | 0.3 |

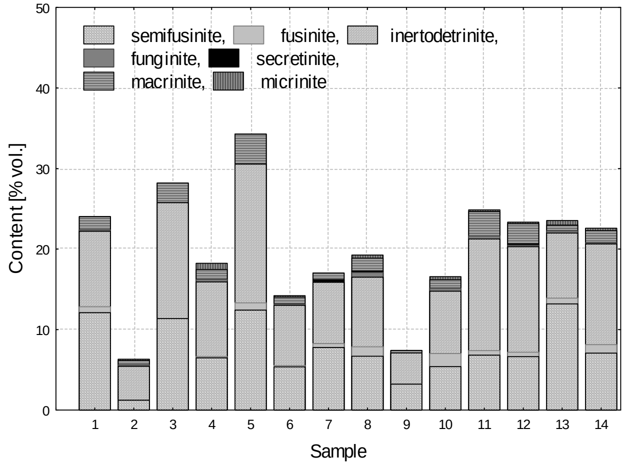



Fig. 7. Content of inertinite group macerals in examined coal samples

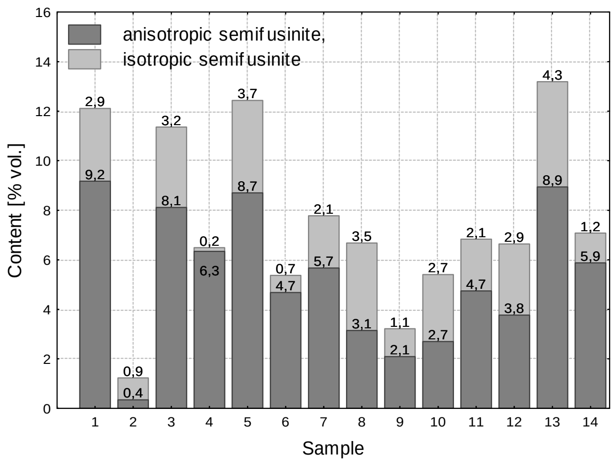



Fig. 8. Content of isotropic and anisotropic semifusinite in examined coal samples

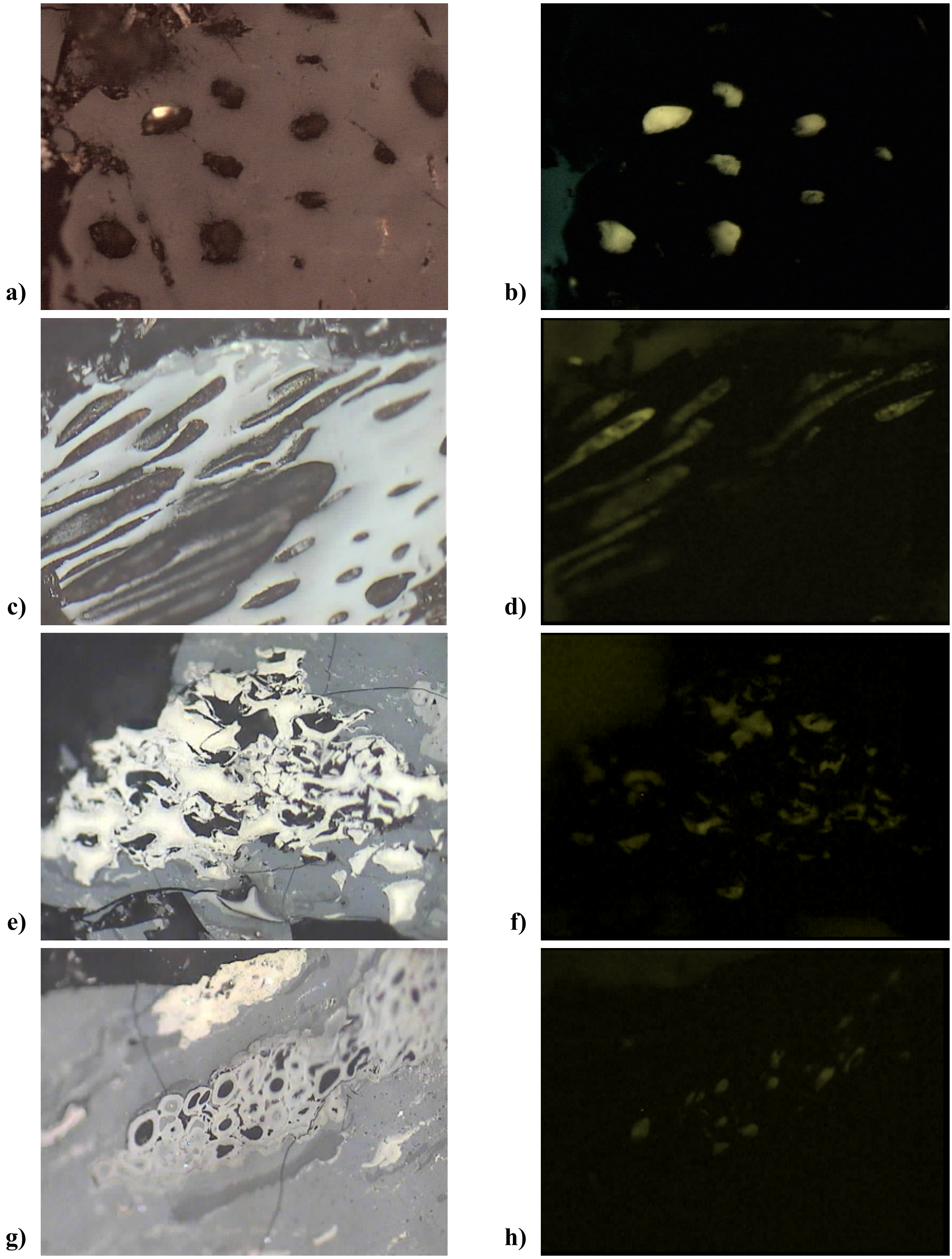



Fig. 9. Microphotographs: **a)** semifusinite filled in with FBS – s. 360/1, 500×; **b)** same field as phot. a – under uv light irradiation; **c)** semifusinite filled in with FBS – s. 404/2, 500×; **d)** same field as phot. c – under uv light irradiation; **e)** semifusinite filled in with FBS – s. 362/1, 500×; **f)** same field as phot. e – under uv light irradation; **g)** funginite filled in with FBS – s. 362/1, 500×; **h)** same field as phot. g – under uv light irradation

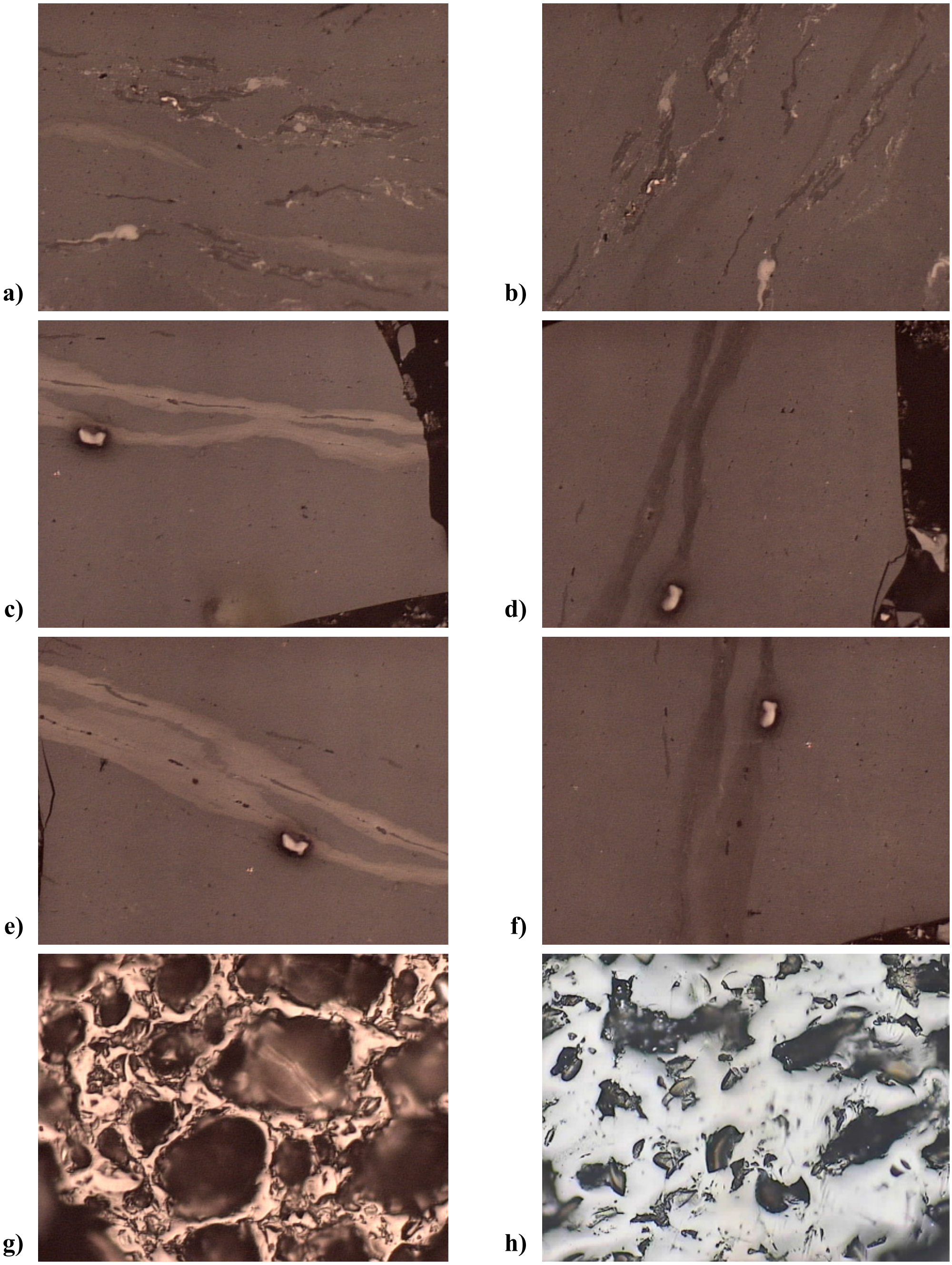



Fig. 10. Microphotographs: **a)** pseudomorph after sporinite – s. 362/1, ||N 500×; **b)** same field as phot. a turn through an angle of 90°; **c)** pseudomorph after sporinite – s. 403/1, ||N, 500×; **d)** same field as phot. c turn through an angle of 90°; **e)** pseudomorph after sporinite – s. 403/1, ||N, 500×; **f)** same field as phot. e turn through an angle of 90°; **g)** heat-altered coal – coke structure is visible – s. 404/1, ||N, 500×; **h)** heat-altered coal – coke structure is visible – p. 361, ||N, 500×

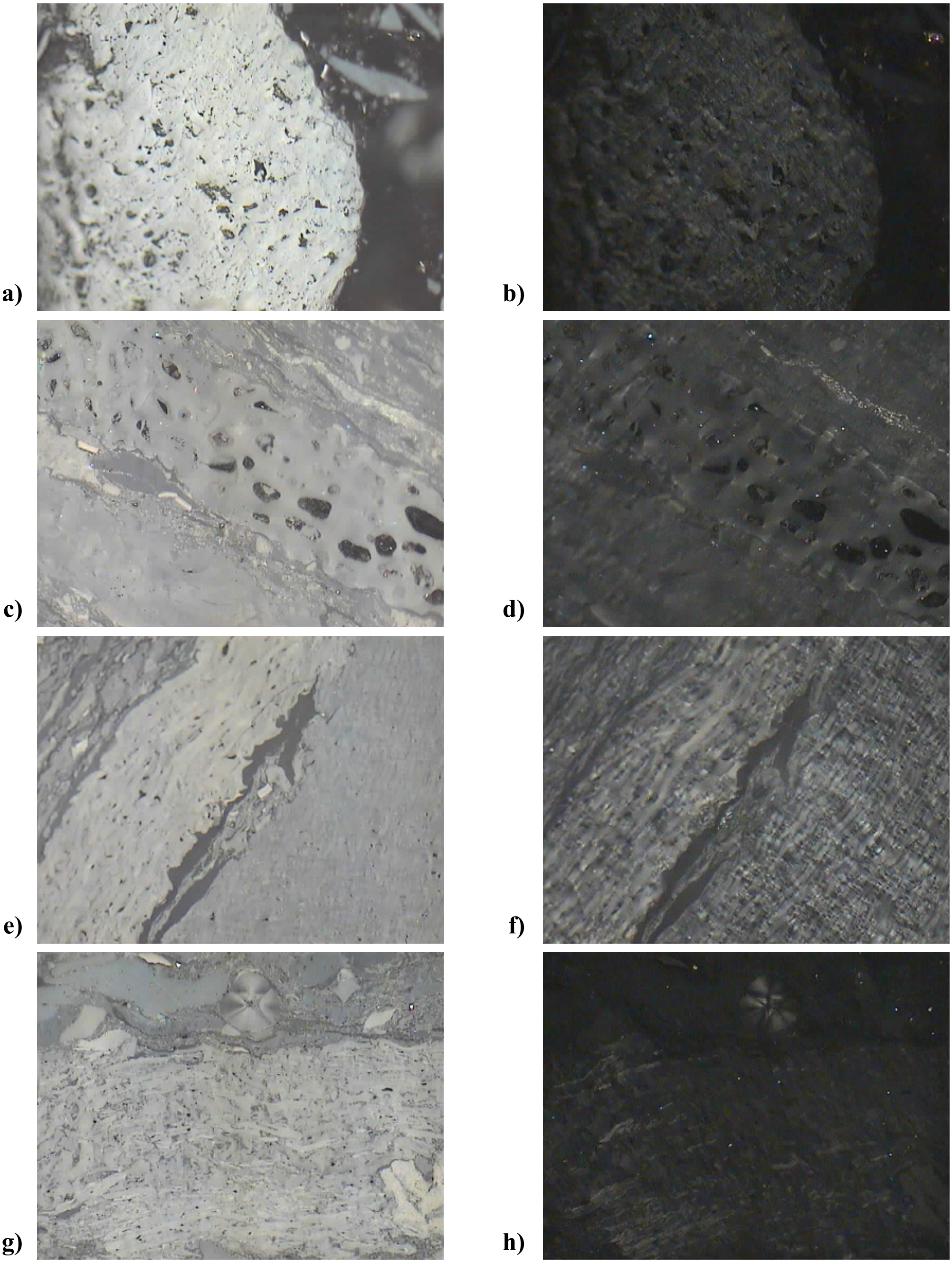


Fig. 11. Microphotographs: anisotropic semifusinite **a)** s. 403/1, ||N, 500×; **b)** same field as phot. a – ×N; **c)** s. 404/2, ||N, 500×; **d)** same field as phot. c – ×N; **e)** s. 404/2, ||N, 500×; **f)** same field as phot. e – ×N; **g)** anisotropic semifusinite and pirolitic carbon – s. 403/1, ||N, 500×; **h)** same field as phot. g – ×N

Content of semifusinite with cellular spaces which are filled by fluorescing bituminous substance, amounts to (0,2 – 2,7)%. Semifusinite observed in coal is most often anisotropic (Fig. 8, Fig. 11).

The content of mineral matter varies in range from trace content to 14%. Mineral matter in analysed samples is represented mainly by carbonate minerals and polymineral substance. Clay minerals and sulfides was observed rarely.

Carbonate minerals most often occurred the as filling of cellular spaces in semifusinite and as single grains rarely. Whereas polymineral substance occurred only as a single grains. Mineral components are often included in a substance which shows a weak fluorescence in yellow and orange colour (Table 3). This substance is probably composed of fine-crystalline carbonates minerals and/or bituminous substance. Carbonate minerals which filled cellular spaces in semifusinite, fusinite and funginite may be considered as the effect of thermal alteration of coal (Probierz, 1989; Taylor et.al., 1998; Komorek et.al., 2010).

## 5. Conclusion

Based on the results of research it can be concluded that examined coal samples from Orzesze and Ruda beds are characterised by a similar coal rank. Accordingly to the classification of in-seam coals (ECE- Geneva, 1998) tested samples represent high vitrinite content, metabituminous coal B.

Vitrinite from the analysed samples has biaxial negative optical character and shows small variation of the bireflectance values.

It was found that coal rank of the examined samples generally decreasing with increasing both depth of the coal seams and vertical distance between sampling point and the Carboniferous roof. It may suggests inversion of coalification.

Coal samples situated in the places located nearly red beds in Carboniferous roof, are characterised by higher coal rank than the samples, which originate from further distances from it. It may suggest on the existence of an additional heat source probably connected with the red beds occurring in the Carboniferous roof.

Besides of the typical macerals commonly occurring in coals from Orzesze and Ruda beds it was found petrographical components which could be related with thermal-impact zones of igneous intrusions.

In coal samples were observed following components: fluorescing bituminous substance (FBS), which filled cellular spaces in semifusinite, fusinite, and funginite; pseudomorphs after megaspores, which demonstrate strong bireflectance and anisotropic semifusinite. Petrographic components with a structure similar to structure of coke and pyrolytic carbon were observed rarely.

With the influence of temperature on the examined coal may be correlated the occurence in samples colotelinite grains which are visible darker, impregnated with bituminous substance and showing weak fluorescence.

The symptom of thermal alteration analysed coal samples may be also presence of carbonates minerals, which the most often fill cellular spaces in semifusinite.

The study confirmed that the phenomenon of thermal metamorphism described previously for the Saddle beds from "Moszczenica" coal mine (Probierz, 1989) and Ruda beds from "Zofiówka" coal mine (Komorek et al., 2010) may have considerably wider extent and is not only a local phenomenon.

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