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THE UPPER SILESIAN COAL BASIN FAULT ZONE AS A REGION OF HIGH-RISK OPERATIONS

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ABSTRACT
This paper presents the results of investigations on changes of the parameters of coal and surrounding rocks in the fault zones in the Upper Silesia Coal Basin. It has been shown that these zones, in relation to the undisturbed coal seams, reveal an enrichment with some substances that pose a threat to the natural environment and that they also show a deterioration in the strength parameter values of rocks which threaten the safety of the operation. The greatest threat for the environment constituted sulphur and the ash. In the zone of the fault, it was observed that sulphur behaved in two ways. In the first case, the total sulphur and pyritic sulphur increased significantly by 192.3 and 823.5 %, respectively, and a small quantity of sulphate sulphur was found here, whereas in the other case, the total sulphur and pyritic sulphur decreased by 31.6 and 35.3 %, respectively, and sulphate sulphur increased considerably and reached up to 600 %. The mean content of ash increased by 171.8 %.
The mechanical strenght of the rocks under uniaxial compressive strength in the fault zones decreased by 67 %, the microhardness of coal decreased to zero, and the intensity of cracks in coal grains increased by 359.1 %.

KEYWORDS: epigenetic changes of coal, fault zones, strength parameter values of rocks

1. INTRODUCTION

The area of the Upper Silesian Coal Basin is cut by a dense network of faults. Their major systems show the course of W-E, NW-SE and NE-SW (Buła et al., 1997; Teper, 1998). The fault zones are seismically active, and the coal beds in their vicinity are enriched with the ingredients that pose a threat to the environment (Zuberek et al., 1997). The propagation of the fault affects the cohesion of the rock mass, causing the reduction in its strength, which is a threat to the safety in the mine (Ćmiel and Idziak, 1999).

The factor of the environmental risk is the change of the coal parameters related to its weathering. As the studies have shown, not in all fault zones coal quality changes are recorded, but in all the examined ones the reduction of rock strength parameters was observed. Degradation changes of the coal quality in the seams of the region were found in about 30 % of the faults of the Upper Silesian Coal Basin, while the aggradation ones in about 12 % (Ćmiel, 2009; Ćmiel and Dziurowicz, 2011).

2. METHODOLOGY AND THE STUDY AREA

The investigations included the area of the main anticline and the Bytom-Kazimierz syncline (Fig. 1). The observations of the quality of coal in the seams was carried out in 11, and the uniaxial compressive strength in 6 mines. The axis of research was the Kłodnica fault, the coal seam 405 and the Załęże beds.

The investigations was conducted in five areas in the vicinity of the following faults and coal seams: Bytom – seam 507, Radzionków – seam 503 (area 1), Klimontów – seam 409, Jakub – seam 510, Wojkowice-Będzin – seam 501 (area 2), Susanna – seam 364, Wesoła – seam 405, Mysłowice – seam 405 (area 3), Środkowy – seam 405, Arkona – seam 404, Wojciech – seam 405 (area 4), Kłodnica – seam 405, Halemba – seam 402 (area 5).

The measurements of the coal quality parameters: moisture, ash, calorific value, density, total sulphur, pyrite sulphur and sulphate sulphur were made in the fault breccia at the distance of 0–10 m from the fault plane. Out of the coal strength parameters, microhardness and fracture intensity were determined with the Vickers method. However, in the surrounding rocks the uniaxial compressive strength was determined along the section of 0–20 m from the fault plane. The level of the changes has been shown with the value of the variation coefficient and variability in relation to the average for the area not involved tectonically.

3. RESULTS

The variability of uniaxial compressive of rock surrounding the coal seams as a function of distance from the fault plane is shown in semi-variogram in Figure 2.

In all cases the strength of rocks increases with the distance from the fault, regardless of the fault wall in which the measurements were performed. Compressive strength values ranged from 6 MPa to 42 MPa, and were lower for mudstones than sandstones. The volume growth of the tested parameter with the distance from the fault varies and ranges from 62 % to 487 %. The semi-variogram

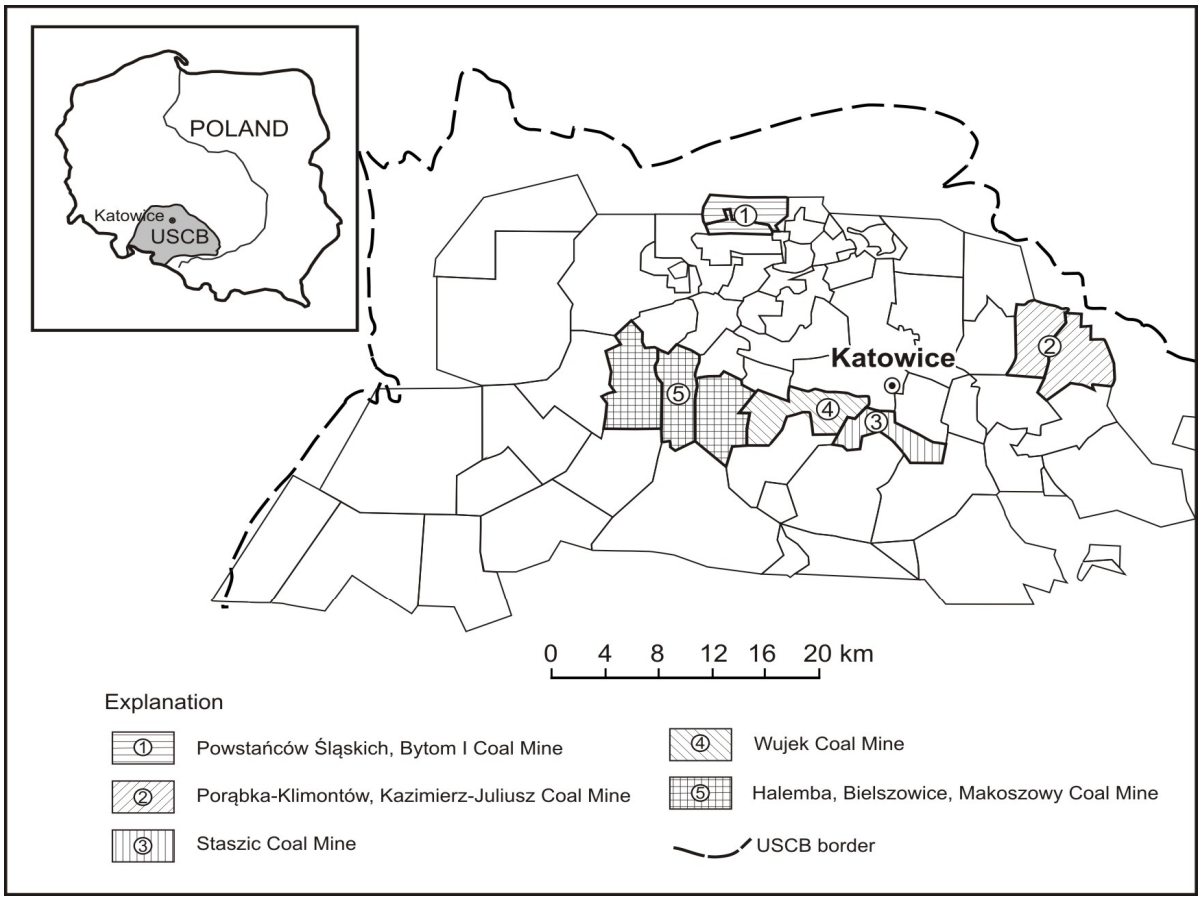

Fig. 1 Investigation area.

shows that in three cases, the compressive strength of rock increase abruptly at the distance of 3 m, 4 m, and 11 m from the fault plane, while in other cases it increases linearly. In the area of the Klimontów fault (line 2) mechanical strength of rocks varies from 7.6 MPa to 24 MPa. At 11 m distance from the fault the resistance value is the lowest and is fixed at 8.7 MPa. Further than 11 m it increase abruptly to 14.8 MPa and then increases linearly to 18.8 MPa. The jumps of value is 316 %.

Similar values of the mechanical strength of rocks are reached at the faults of Bytom (line 1a) and Kłodnica (line 3). The increase in the strength values is, respectively, 486 % and 384 % and is linear. The value jump occurs at the distance of, respectively, 4 m and 3 m from the fault plane. In the vicinity of the faults of Wojkowice-Będzin (line 2a) and Radzionków (line 1 and 1b) the increase in the strength values is linear and amounts to 64 %, 62 % and 335 %, respectively.

The investigation of coal quality parameters in the fault zones indicate, due to their intensity, two types of degradation (weathering) hypergenic changes. These changes were observed over a distance of 2 m from the fault plane and they were referred to the average value of the parameter for the zone not covered by the changes.

In the case of intense changes in coal (Table 1) the increase in the value of some parameters was reported, including: moisture by 52.3 %, ash by 143.1 %, density by 10.5 %, the number of cracks by 359.1 %, sulphate sulphur by 600 %, while the decrease was reported for the following: calorific value by 26 %, total sulphur by 31.6 %, pyrite sulphur by 35.3 % and the hardness by 60.7 %. The average value of the variation coefficient was 48.3 %.

In the vicinity of faults of low intensity of weathering changes in coal (Table 2) an increase in the values of some parameters was recorded, such as ash by 172 %, total sulphur content by 192 %, pyrite sulphur by 823 %, sulphate sulphur by 600 %, moisture by 10 % and cracks by about 122 %, while the decrease was recorded for the following: calorific value by 5 % and microhardness by 35 %.

The value of the variation coefficient, on average, changed by 61.3 %.

4. DISCUSSION

In the area of fault zones of the Upper Silesian Coal Basin both coal and the surrounding rocks undergo destructive changes. The strength of rocks to uniaxial compression lowers by an average of 211 %. The largest throw in the value of the parameter is observed over a distance up to 5 m, and the general

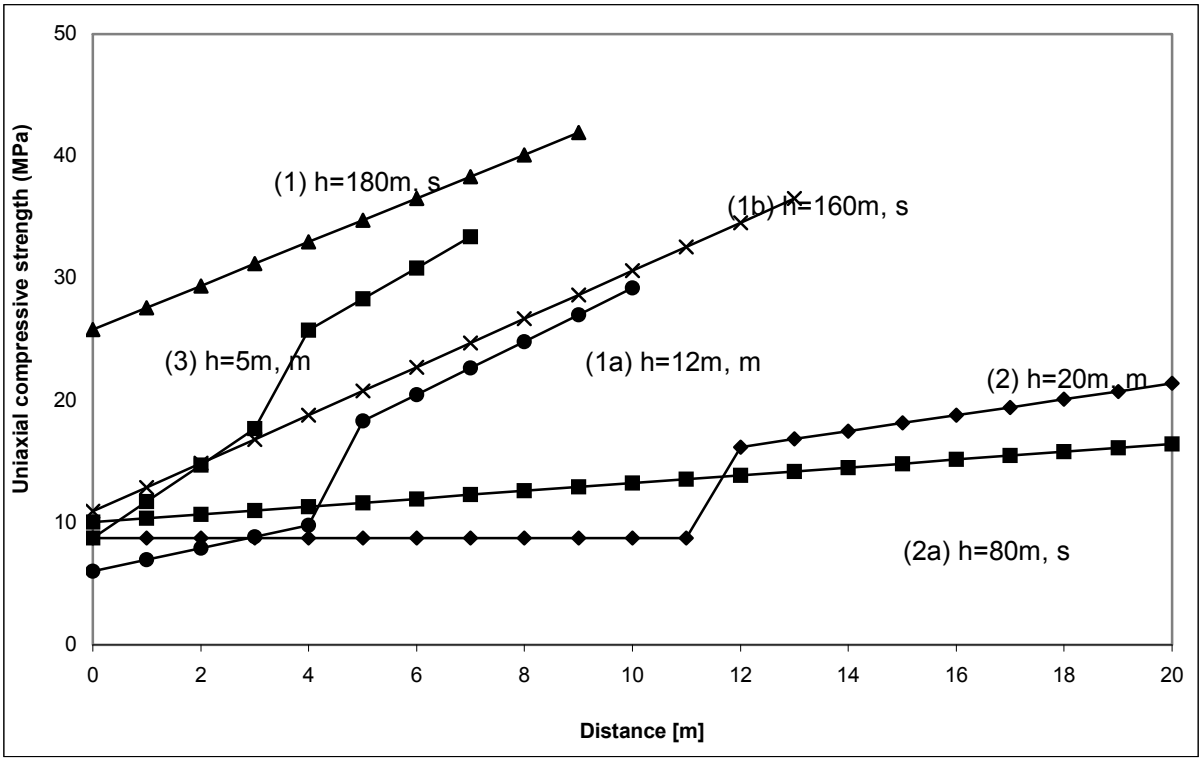

Fig. 2 Variability of strength to uniaxial compression of rocks surrounding coal beds as a function of distance from the fault (after Ćmiel and Idziak, 1999, modified).
Explanation: s – sandstone, m – mudstone, h – fault throw

Table 1 The example of variability of coal parameters in the area of faults with a strong degradation character (Coal Mine "Wujek", the central fault, the throw of 40 m, seam 405).

Distance [m]	0	0.2	0.4	0.6	0.8	1	2	5	8	10	A (%)	B (%)	C (%)	D (%)
M^a (%)	6.89	6.02	4.83	5.47	5.04	4.74	3.83	4.17	3.49	4.25	21.3	39.6	19.6	52.3
A^a (%)	34.8	30.8	28.3	27.7	19.9	13.5	9.1	11.3	10.6	9.4	51.3	156.8	64.3	143.1
CV_s^{daf} (MJ/kg)	23.8	23.9	24.8	24.2	25.4	27.5	33.4	33.5	34.2	33.6	16.3	–25.97	16.1	–26.0
S_t^a (%)	0.39	0.54	0.76	0.69	0.91	0.88	1.17	0.89	1.06	0.80	28.5	–28.57	27.4	–31.6
S_p^a (%)	0.21	0.30	0.35	0.05	0.28	0.21	0.28	0 24	0.62	0.13	56.5	–28.13	46.1	–35.3
S_{so4}^a (%)	0.09	0.08	0.06	0.06	0.03	0.05	0.02	0.01	0.02	0.00	72.6	500.0	125.0	600.0
d_r (Mg/m^3)	1.79	1.64	1.68	1.55	1.51	1.51	1.40	1.39	1.29	1.42	10.0	16.7	8.5	10.5
HV_{50} (10^7Pa)	0	0	10	20	32	36	38	42	42	41	65.9	–59.93	62.7	–60.7
Cracks (%)	93	91	92	85	62	52	33	19	12	5	64.8	359.0	64.8	359.1

Explanation: M^a – moisture, A^a – ash, CV_s^{daf} – calorific value, S_t^a – total sulphur, S_p^a – pyrite sulphur, S_{so4}^a – sulphate sulphur, d_r – density, HV_{50} – Vickers hardness, A – average at the segment of 0 – 0.8 m; A – variation coefficient = standard deviation / mean), B – variability = value at fault / to the mean from the unchanged zone, A, B values for the table, C – variation coefficient - for the entire of investigated population of samples, D – variability - for the entire of investigated population of samples,

Table 2 Variability of coal in the fault area at the absence or low-grade level of the degradation change. (Coal Mine "Staszic", the Mysłowice fault, the throw of 30 m, seam 405).

Distance [m]	0	0 .2	0 .4	0 .6	0 .8	1	2	5	8	10	A (%)	B (%)	C (%)	D (%)
M^a (%)	3.87	3.62	3.14	2.98	3.02	2.84	2.79	3.00	2.76	2.93	11.9	17.7	26.7	10.3
A^a (%)	29.7	25.3	12.5	12.7	10.2	10.1	9.8	9.6	10.0	9.6	52.2	102.8	43.6	171.8
CV_s^{daf} (MJ/kg)	28.5	31.3	33.3	32.3	32.9	33.5	32.1	32.8	33.1	33.5	4.6	–5.0	3.8	–5.4
S_t^a (%)	5.24	4.20	1.85	0.87	0.83	0.70	0.77	0.64	0.68	0.72	101.2	322.2	84.1	192.3
S_p^a (%)	5.05	3.96	1.37	0.56	0.39	0.29	0.27	0.23	0.25	0.49	135.7	756.3	157.5	823.5
S_{so4}^a (%)	0.07	0.05	0.05	0.00	0.02	0.00	0.00	0.00	0.01	0.00	150.0	300.0	166.7	600.0
d_r (Mg/m^3)	2.35	2.06	1.83	1.69	1.35	1.34	1.36	1.34	1.35	1.34	23.1	46.7	10.8	39.2
HV_{50} (10^7Pa)	15	20	24	36	39	45	41	39	43	43	31.2	–43.0	22.3	–35.3
Cracks (%)	47	37	39	31	27	17	13	18	11	14	49.7	131.0	40.1	121.6

For explanation see Table 1

weakening of the rocks – up to 20 m from the fault plane. A jump increase of the value is recorded at the smaller amplitudes of the fault throw and a lower strength of the rocks (Fig. 2 - mudstones).

The section between the fault plane and the place where there is a jump increase of the strength is the zone of the largest rocks crushing. At this section there was a complete discharge of the destruction energy. The zone of the lowered strength of the rocks reaches further and is continuous where the fault throw is greater and the strength of the rocks higher (Fig. 2 - sandstone).

In the fault area of intense degradation changes the increase of the degree of cracking of coal seams amounted to 359 %, while the hardness measured with the Vickers method decreased by 61 %. Micro-hardness of coal fell to zero over a distance of 0.6 m, and was decreasing up to 2 m from the fault plane. Continuity distortions in the coal beds reached 1.5 m deep into the bed.

In the fault zones with less destructive changes of the coal, the changes in the parameter values were lower, except that the total content of sulphur increased, and the increase in ash and pyrite sulphur content was significantly larger than in the case of intense coal weathering.

The propagation of faults in the Upper Silesian Coal Basin led to the lowering of the strength of the rock mass and microhardness of the coal as well as increase of its cracking, thus putting the mining staff in danger. Opening of fault cracks caused the streamlining of rocks for fluids, which resulted in oxidation of coal seams, rock waterlogging and gas hazards. Water and oxygen caused the activation of sulphur, which resulted in an increase in the contents of sulphate sulphur by 600 %.

Closing the fault fissures by precipitation of mineral substances (iron sulphides) from the solutions, at an early stage of weathering, was the reason for the increase of total sulphur and pyrite sulphur, and higher density and ash content, which also had a negative impact on the quality of coal. It resulted in a reduction of its energy values, increasing the amount of ash and sulphur emissions to the atmosphere.

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