Polish Geological Institute Special Papers, 7 (2002): 51–62
Proceedings of the IV European Coal Conference

SELECTED PARAMETERS OF COAL QUALITY IN FAULT ZONES OF THE UPPER SILESIAN COAL BASIN (POLAND)

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A b s t r a c t . The paper presents the changes of coal seams quality near fault zones. Three types of relations have been found. The first one shows an increase of coal quality at the 0.2 m distance from fault surface, as a result of increase of coalification degree. It is assumed that, this type was caused by heat of friction which was rising during faulting. It is revealed as an increase of such parameters as: caking properties, vitrinite reflectance, calorific value and carbon content, as well as the decrease of oxygen, ash, and moisture content.

The second type presents differed degree of coal quality decrease. This type was produced due to hypergenic processes. The author found four subtypes of oxidation-type changes of coal quality parameters in fault zones. The first one shows the highest level of hypergenic processes in a coal seam about 1 m off a fault plane. The second presents minor degree of oxidation processes in the coal seam at a smaller distance from the fault. The third one demonstrates minimum oxidation changes of coal quality at a distance of 0.2 m from the fault. The fourth subtype of the oxidation changes of coal quality has been observed only in tectonic breccia and not in the coal seams itself.

The third types demonstrates faults which do not show any impact on changes of coal quality parameters. To this type belong faults from SW part of USCB and faults with downthrown up to 20 m.

K e y w o r d s : fault zones, coal quality parameters, Upper Silesian Coal Basin.

INTRODUCTION

The differentiation of coal quality parameters as well as geomechanical properties of coal seams and accompanying rocks in the fault zones has not been explained satisfactorily yet. It makes a problem for effective exploitation of coal seams. The research for it was carried out in the Upper Silesian Coal Basin (USCB). In the USCB the disjunctive structures reflect a crystalline basement block movements during geological history and in the majority, they have a nature of secondary faults (Kotas, 1985). There is a characteristic displacements range from tenth part of metre to hundreds of metres for a dense fault network.

The investigated samples were taken out from coal seam no. 405 in two areas in the USCB. The first area was situated in north part near the Klodnica fault system zone and the second one was in southwestern part and included Krzyżowice fault zone (Fig. 1).

The Klodnica fault is the main disjunctive structure of the structural sub-unit called “main anticline”. It is a normal fault with the throw of several hundreds metres dipping southward. The Krzyżowice fault is also a normal fault with the

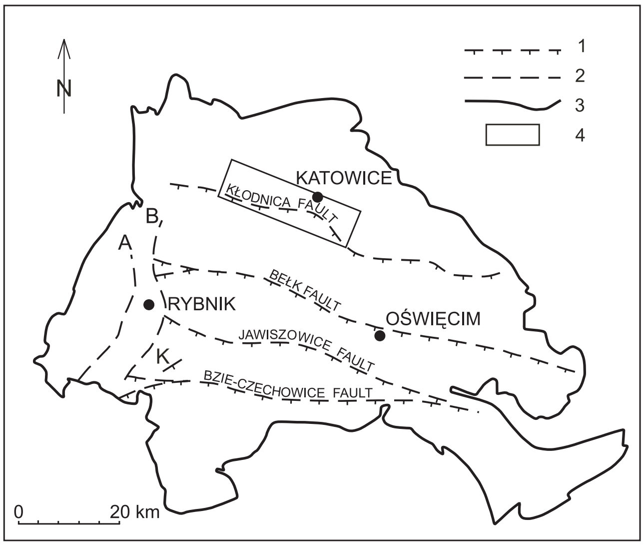

Fig. 1. Sketch of the research area in the USCB

1 — faults, *2* — overthrusts, *3* — border of USCB, *4* — research area; A — Michalkovice–Rybnik overthrust, B — Orlová overthrust, K — Krzyżowice fault

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throw of 30 metres dipping northward. The coal from faulted seams and from breccia filling fault fissures were analysed. Samples were taken at a distance of 0; 0.2; 0.4; 0.6; 0.8; 1.0; 2.0; 5.0; 8.0 and 10 m from a fault plane. An elementary chemical analysis was carried out for collected samples. Contents of C, H, O, N, and S were determined. Technological coal parameters such as ash, volatile matter contents, moisture, calorific value, and also coking properties such as Roga's index, swelling index, contraction as well as physical parameters such as vitrinite reflectance and coal density were measured.

Maximum, minimum and mean values, standard deviation and coefficient of variability of the measured parameters were accounted for disturbed zone and for undisturbed coal seams as well. The results are presented in six tables. The dependence of selected coal quality parameters according to the distance from fault plane for groups and types of changes of coal quality is presented in the diagrams.

EXPERIMENTAL

The study of geomechanical parameters of coal seams and rock layers showed that they decreased regularly towards a fault plane (Ćmiel, Idziak, 1999). The dependence of coal quality parameters was not explained yet satisfactorily. The previous study allowed to establish three types of the dependence (Ćmiel, 1995, 2000). Coal quality may rise or fall in a fault zone. In the vicinity of some faults, coal quality is the same as in undisturbed coal seam. It is assumed that changes of coal quality could be caused by heat convection through cracks present in a fault zone. Fractures facilitated degassing of organic mater during a coalification process (Ćmiel, 1988, 1997; Nieć, 1993; Probierz, 1986). Heat generated by friction on a fault plane could also augment degree of coalification locally (Teichmuller, Teichmuller, 1966). Similar effect was observed when coal was milled in a ball grinder (Jungten, Karweil, 1962). Changes of coal quality connected with pinching out of coal seams in an outcrop zones were studied particularly for the USCB area (Gabzdyl, Skoczowska-Górka, 1996; Kowalski, 1977; Lipiarski, 1997; Probierz, 1989). Obtained results point to three types of variability of coal quality in a fault zone.

1. The first type is characterised by a poor coal quality near a fault plane. In comparison to undisturbed coal seam, the biggest changes were noticed for a breccia filling a fault fissure and for an interval up to 0.2 m from the fault plane. Four groups of faults can be distinguished in accordance with maximum radius of disturbance.

1a. For the first group, disturbed zone range over a distance of 0.6–2.0 m from the fault plane. In the zone, oxygen and nitrogen contents, ash and volatile matter contents, coal density and moisture were enhanced significantly. On the contrary, content of carbon, hydrogen, total sulphur, vitrinite reflectance, calorific value, and H/C ratio declined. There is a lack of coking strength. The share of ash sulphur and sulphate sulphur in the total sulphur contents reached 30.2%. Main coefficient of variability equals from 3.2 to 110%. Results for the group are presented in Table 1a and in diagrams in Figure 2.

1b. For the second group, coal density, moisture, ash, volatile matter, oxygen content, and O/C ratio were bigger than in undisturbed coal seam. Nitrogen content was almost the same. Another parameters had lower value and showed the coking strength disappearance. Disturbances were observed at the distance up to 0.4–0.8 m from the fault plane. Main coefficient of variability equals 27.5%, from 3.4 to 90%. Results for the group are presented in Table 1b and in diagrams in Figure 3.

1c. Third group of faults is characterised by inconsiderable changes of majority of the parameters. Content of ash (41%), total sulphur (8%), and coal density (1.79 Mg/m^3) rose significantly. The share of ash sulphur in total sulphur content surpasses 80% but sulphate sulphur content was below 8%. Disturbances were observed mainly in breccia. Somewhere the influenced zone had a radius of 0.6 m. Main coefficient of variability equals 20.1%, from 1.3 to 86.6%. Results for the group are presented in Table 1c and in diagrams in Figure 4.

1d. For the fourth group, disturbed zone was limited to the nearest vicinity of the fault plane. The decrease of carbon and hydrogen content was noticed. The share of ash sulphur was reduced to 50–60% of total sulphur content. For this group, little changes of volatile matter content, vitrinite reflectance, and total sulphur content are characteristic. Main coefficient of variability equals 19.2%, from 2.5 to 71%. Results for the group are presented in Table 1d and in diagrams in Figure 5.

2. In fault zones with the second type of variability, coal quality increased in a narrow interval of 0.2 m from the fault plane, and somewhere in fissure's breccia, too. Coal quality increased in the some interval. Content of carbon and hydrogen, calorific value, contraction, Roga's index, and swelling index of coal were bigger than these for the coal seam. Volatile matter content diminished significantly. There was a lack of sulphate sulphur. For two investigated faults, coal quality in a breccia was lower than in undisturbed seam but in the nearest vicinity of the fault plane, coal quality parameters were bigger. Main coefficient of variability equals 21.8%, from 1.6 to 62.5%. Results for the group are presented in Table 2 and in diagrams in Figure 6.

3. The third type of variability is characterised by small, random changes of parameters values in the vicinity of faults; no trend of changes was observed. The big difference between maximum and minimum values of parameters was measured, and it is a result of high degree of coalification of coal samples taken from SW part of USCB. Main coefficient of variability equals 21.1%, from 1.4 to 74%. Results for the group are presented in Table 3 and in diagrams in Figure 7.

Table 1

Results of coal quality parameters measurements; 1a–d type of variability group of faults

Parameters	M^a [%]	A^a [%]	N^{daf} [%]	O^{daf} [%]	S^{daf} [%]	S^a_a [%]	$S^a_{SO_4}$ [%]	C^{daf} [%]	H^{daf} [%]	O/C	H/C	V^{daf} [%]	CV^{daf} [MJ/kg]	R^m [%]RI	RI	SI	a [%]	d_r [Mg/m^3]
1a type																		
Maximum value	5.89	34.80	1.74	27.60	1.89	0.58	0.2	84.37	6.15	0.40	0.403	44.7	34.36	0.84	23.00	2.00	38.00	1.79
Minimum value	2.83	4.56	1.42	7.80	0.19	0.05	0	68.82	1.59	0.11	0.02	30.73	23.43	0.68	0.00	0.00	2.00	1.29
Mean value 0–10 m	4.14	14.03	1.53	15.13	0.76	0.24	0.038	78.80	3.98	0.194	0.15	35.61	31.18	0.79	7.26	0.49	16.70	1.41
Standard deviation	0.87	6.74	0.06	5.46	0.024	0.12	0.042	4.25	1.00	0.073	0.017	2.79	2.38	0.03	7.47	0.54	8.41	0.12
Variability coefficient	21	48	3.92	36.09	3.16	50	110.5	5.39	25.10	37.60	11.30	7.83	7.63	3.80	103.00	110.00	50.40	8.51
Mean value 0.6–10 m	3.55	8.99	1.52	11.04	0.91	0.20	0.009	82.01	4.63	0.134	0.06	27.11	32.81	0.81	12.00	0.93	21.94	1.33
1b type																		
Maximum value	6.02	41.80	1.78	25.09	1.69	1.11	0.14	84.02	6.23	0.36	0.075	42.96	34.15	0.83	27.00	2.00	36.00	1.79
Minimum value	2.81	5.70	1.39	7.45	0.38	0.02	0.00	69.25	2.28	0.09	0.030	32.09	26.24	0.67	0.00	0.00	2.00	1.29
Mean value 0–10 m	3.96	11.69	1.53	13.40	0.88	0.259	0.024	79.53	4.56	0.172	0.057	35.63	31.13	0.76	8.82	0.60	13.98	1.41
Standard deviation	0.72	4.58	0.06	4.41	0.29	0.149	0.024	3.68	0.82	0.066	0.009	2.51	2.15	0.026	7.94	0.47	11.01	0.09
Variability coefficient	18.20	39.20	3.92	32.91	32.95	57.53	100	4.63	18	38.4	15.8	7.04	6.91	3.42	90	78.30	78.80	6.38
Mean value 0.6–10m	2.93	8.71	1.51	10.37	0.93	0.154	0.00	82.04	5.05	0.127	0.061	34.58	32.66	0.77	13.78	0.78	14.44	1.36
1c type																		
Maximum value	3.89	27.96	1.56	14.44	8.25	6.94	0.51	84.26	6.24	0.191	0.085	39.96	33.97	0.80	31.00	1.00	46.20	1.79
Minimum value	1.88	3.66	1.40	8.12	0.46	0.03	0.00	73.22	3.79	0.097	0.052	31.52	29.60	0.72	0.00	0.00	2.10	1.26
Mean value 0–10 m	2.83	9.36	1.48	9.84	1.27	0.65	0.032	81.85	5.23	0.122	0.065	34.31	32.58	0.76	13.24	0.78	16.58	1.36
Standard deviation	0.33	5.24	0.04	1.53	1.10	1.02	0.072	2.68	0.46	0.023	0.005	1.52	0.90	0.015	6.92	0.01	6.45	0.11
Variability coefficient	11.70	56.00	2.70	15.55	86.61	156.90	225	3.27	8.80	18.90	7.69	4.43	2.76	1.97	52.30	1.28	28.90	8.09
Mean value 0.6–10 m	2.69	7.11	1.48	9.14	0.81	0.17	0.00	83.14	5.33	0.11	0.063	34.50	32.92	0.76	15.49	0.60	17.90	1.31
1d type																		
Maximum value	4.39	16.54	1.67	18.75	1.72	0.65	0.06	85.04	6.29	0.251	0.08	43.02	33.97	0.81	38.00	1.00	46.00	1.57
Minimum value	1.88	4.09	1.40	7.30	0.42	0.042	0.00	74.60	3.94	0.09	0.05	29.74	28.92	0.69	0.00	0.00	3.70	1.34
Mean value 0–10 m	2.98	9.09	1.49	11.53	0.82	0.24	0.006	82.47	5.19	0.12	0.06	34.61	32.69	0.76	15.28	0.56	16.10	1.34
Standard deviation	0.37	1.62	0.05	2.31	0.19	0.01	0.012	2.09	0.44	0.033	0.005	1.73	1.09	0.02	7.90	0.40	7.00	0.04
Variability coefficient	12.40	17.80	3.36	20.03	23.17	4.17	200	2.53	8.48	27.50	8.33	5.00	3.33	2.63	51.70	71.40	43.50	2.98
Mean value 0.6–10 m	2.92	8.59	1.48	9.10	0.48	0.23	0.00	83.19	5.26	0.11	0.06	34.77	33.03	0.77	16.74	0.64	16.56	1.34

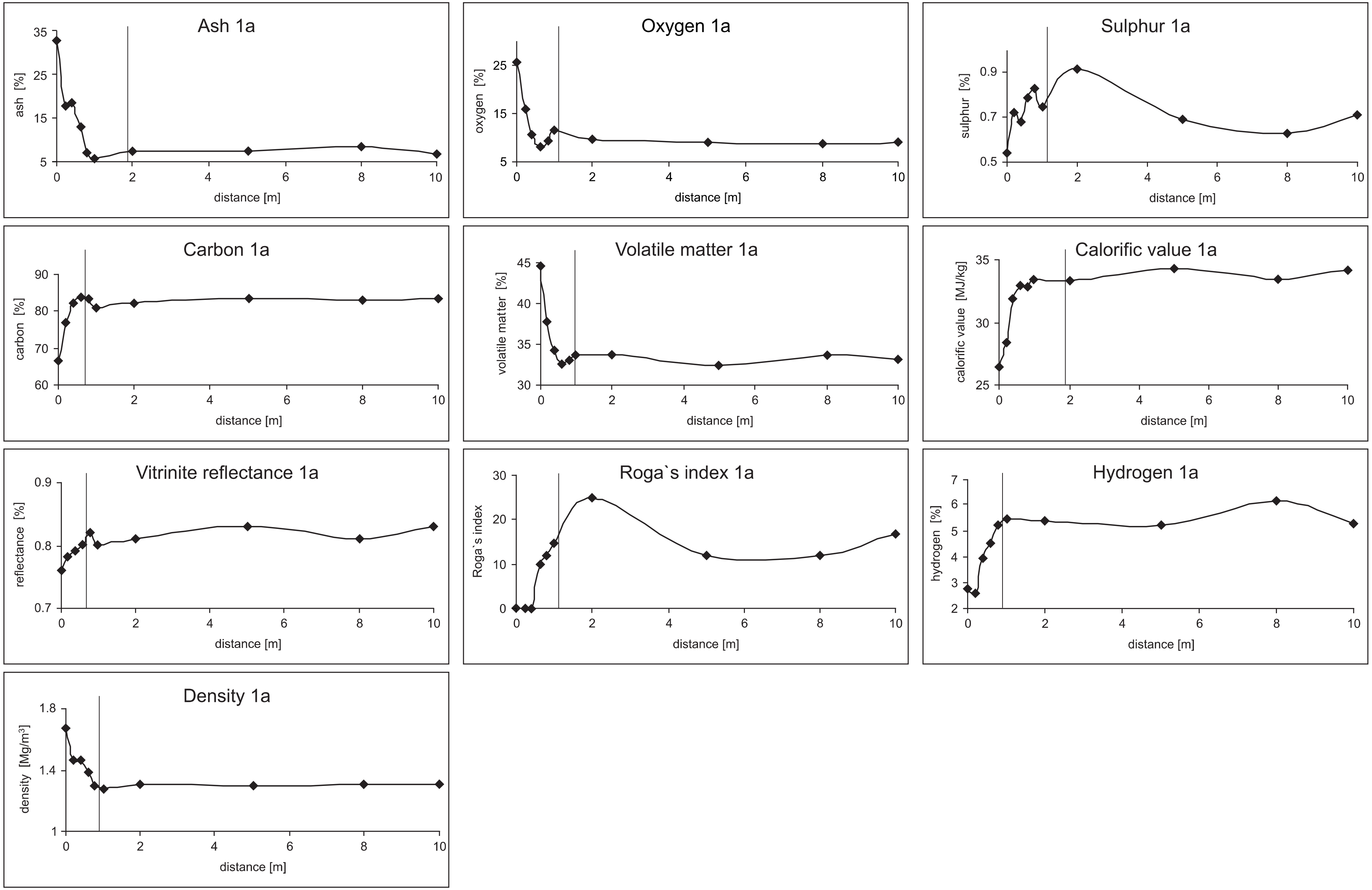

Fig. 2. Changes of coal quality parameters with distance from fault plane for 1a type of variability group of faults

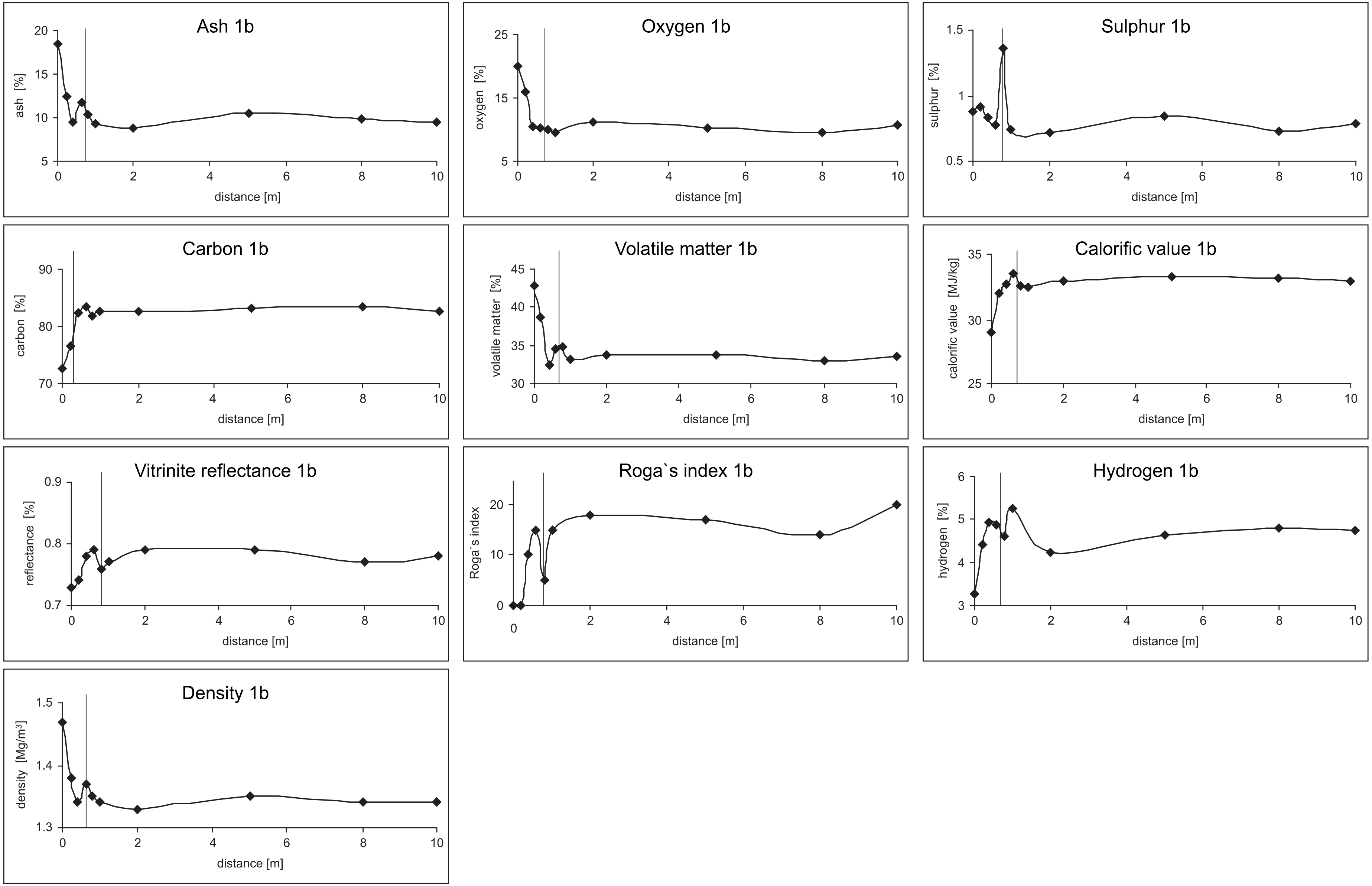

Fig. 3. Changes of coal quality parameters with distance from fault plane for 1b type of variability group of faults

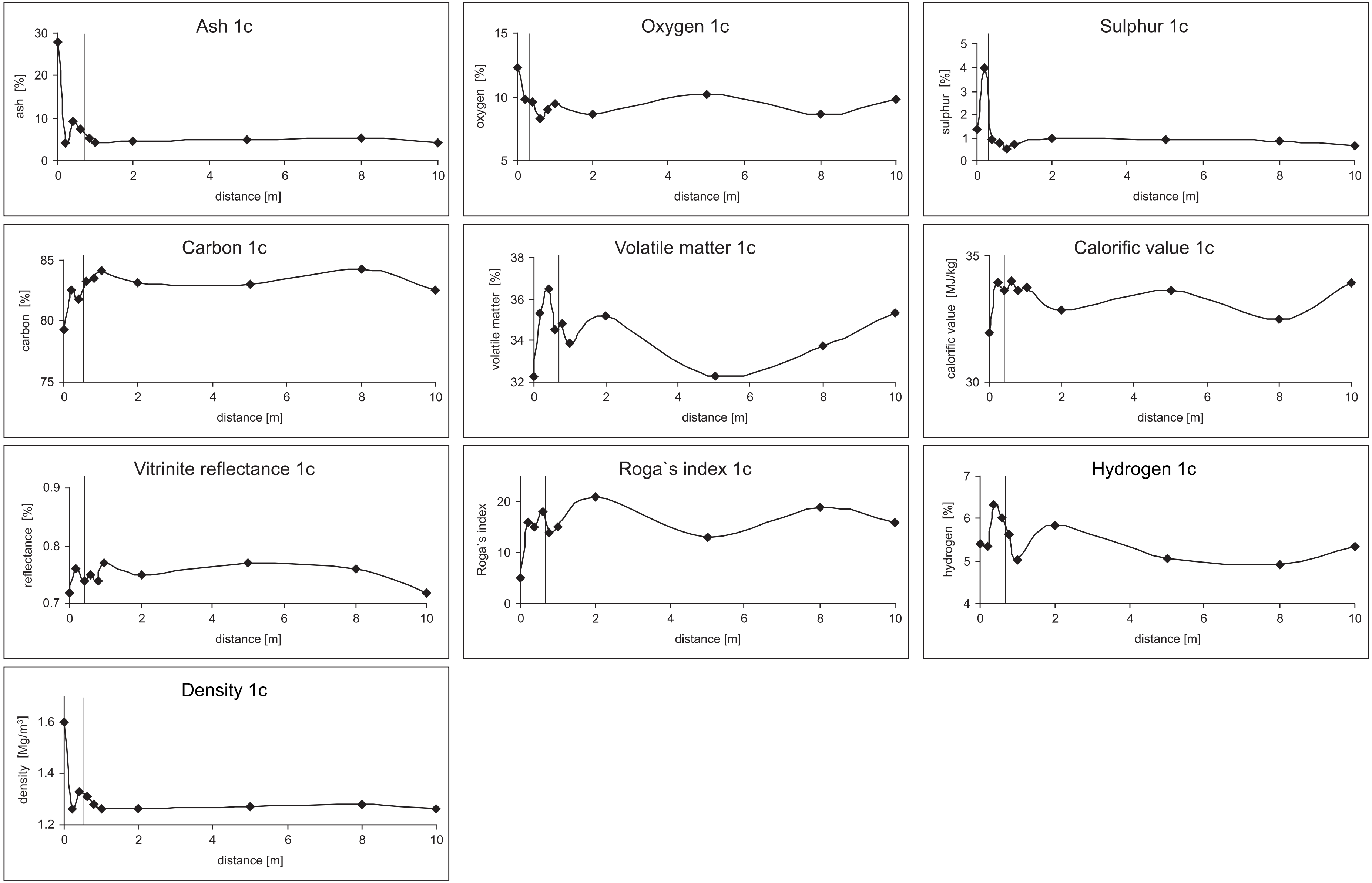

Fig. 4. Changes of coal quality parameters with distance from fault plane for 1c type of variability group of faults

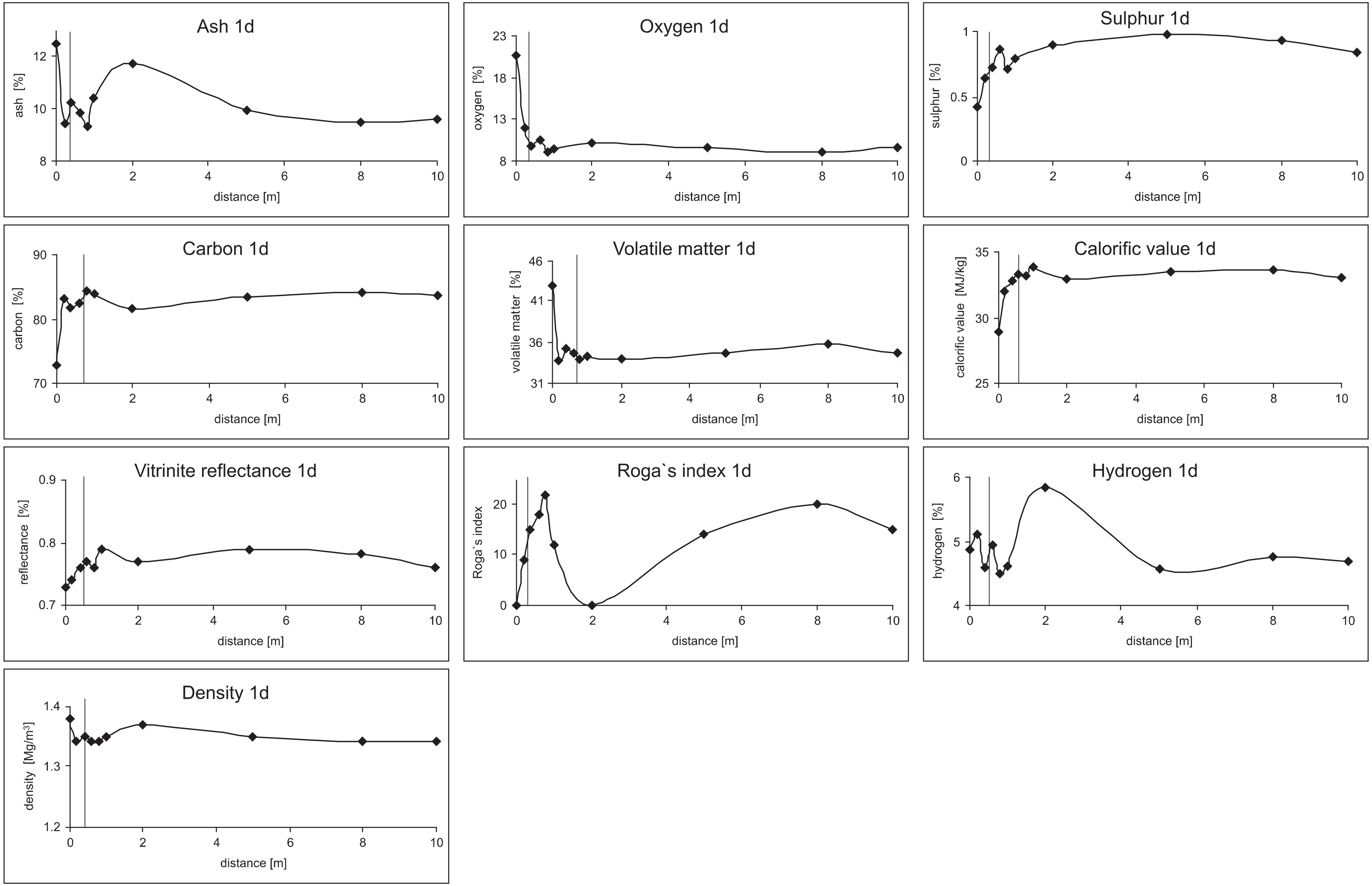

Fig. 5. Changes of coal quality parameters with distance from fault plane for 1d type of variability group of faults

Table 2

Results of coal quality parameters measurements; second type of variability group of faults

Parameters	M^a [%]	A^a [%]	N^{daf} [%]	O^{daf} [%]	S^{daf} [%]	S^a_a [%]	$S^a_{SO_4}$ [%]	C^{daf} [%]	H^{daf} [%]	O/C	H/C	V^{daf} [%]	CV^{daf} [MJ/kg]	R^m [%]RI	RI	SI	a [%]	d_r [Mg/m^3]
Maximum value	4.37	16.40	1.58	15.05	2.09	1.66	0.33	86.73	6.35	0.15	0.08	42.96	34.61	0.84	31.00	2.00	72.00	1.54
Minimum value	1.95	3.90	1.27	6.31	0.42	0.05	0.00	77.04	4.22	0.09	0.06	28.40	27.96	0.71	0.00	0.00	21.00	1.26
Mean value 0–10 m	3.09	7.45	1.44	9.96	0.76	0.25	0.00	82.41	5.22	0.121	0.064	33.92	31.81	0.77	13.16	0.70	16.58	1.36
Standard deviation	0.45	1.35	0.06	1.32	0.22	0.145	0.00	1.30	0.33	0.018	0.04	2.34	0.99	0.03	7.79	0.39	8.42	0.06
Variability coefficient	14.60	18.10	4.17	13.25	28.95	58.00	0.00	1.58	6.32	14.90	62.5	6.90	3.11	3.90	59.20	55.70	50.80	4.41
Mean value 0.6–10 m	3.17	7.43	1.45	10.40	0.82	0.20	0.00	81.98	5.25	0.13	0.06	34.70	31.57	0.76	10.94	0.61	13.30	1.36

Table 3

Results of coal quality parameters measurements; third type of variability group of faults

Parameters	M^a [%]	A^a [%]	N^{daf} [%]	O^{daf} [%]	S^{daf} [%]	S^a_a [%]	$S^a_{SO_4}$ [%]	C^{daf} [%]	H^{daf} [%]	O/C	H/C	V^{daf} [%]	CV^{daf} [MJ/kg]	R^m [%]RI	RI	SI	a [%]	d_r [Mg/m^3]
Maximum value	5.12	13.70	1.58	15.21	3.96	1.19	0.21	90.00	6.11	0.19	0.077	38.15	36.60	1.24	71.00	2.00	40.00	1.52
Minimum value	0.71	2.40	1.18	3.31	0.29	0.06	0.00	78.92	3.89	0.07	0.049	23.70	30.18	0.69	0.00	0.00	2.00	1.24
Mean value 0–10 m	3.37	7.96	1.43	10.60	0.92	0.29	0.00	82.00	5.03	0.129	0.062	34.53	32.65	0.76	12.64	0.58	15.56	1.36
Standard deviation	0.45	1.99	0.04	1.01	0.56	0.20	0.00	1.16	0.45	0.014	0.006	1.28	0.81	0.02	6.62	0.43	8.49	0.056
Variability coefficient	13.40	25.00	2.80	9.53	60.87	68.97	0.00	1.41	8.95	10.90	9.680	3.71	2.48	2.63	52.40	74.10	54.60	4.12
Mean value 0.6–10 m	3.31	7.74	1.43	10.46	0.89	0.24	0.00	82.16	5.11	0.127	0.062	34.23	32.59	0.76	12.30	0.57	14.59	1.35

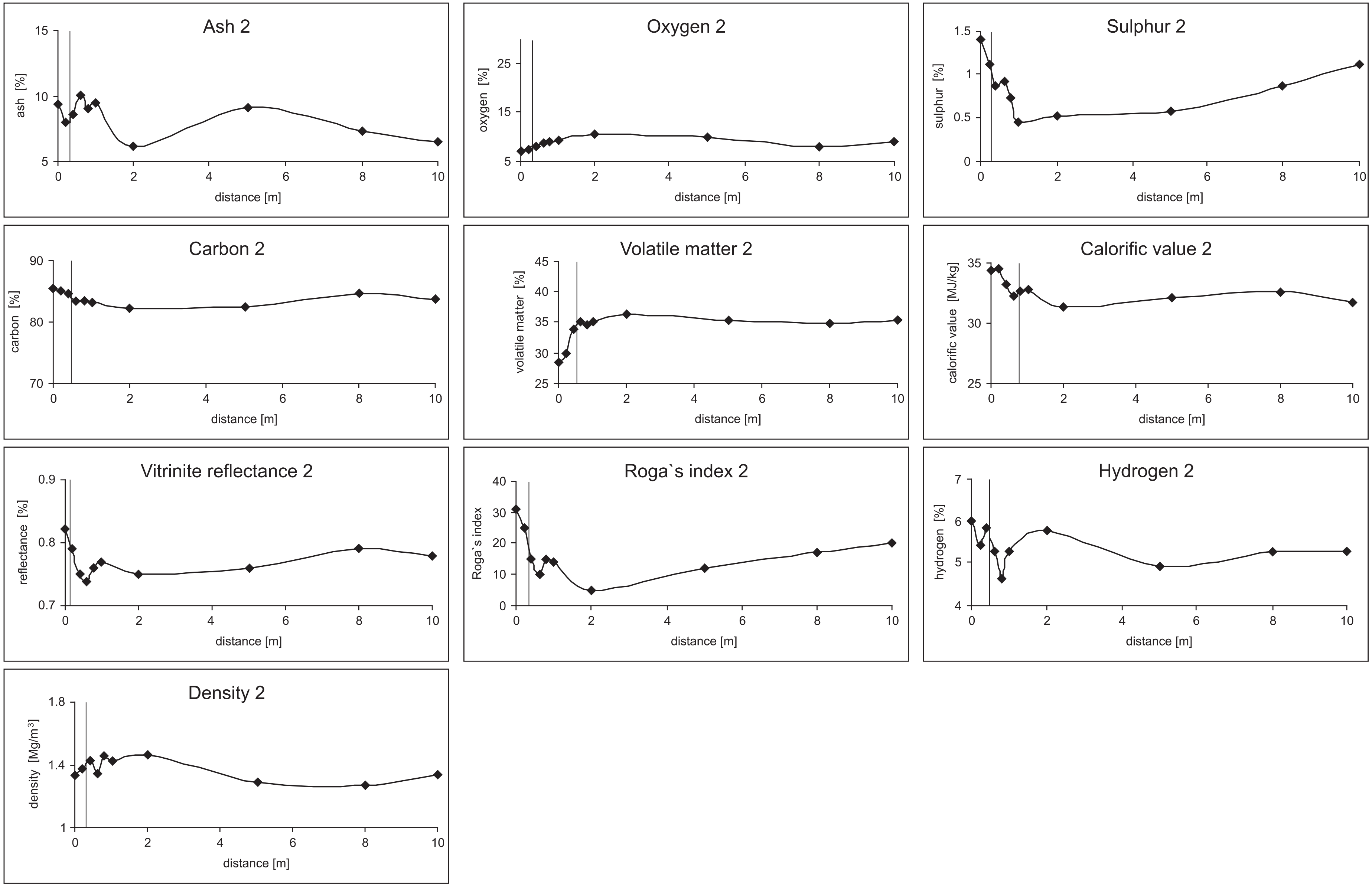

Fig. 6. Changes of coal quality parameters with distance from fault plane for second type of variability group of faults

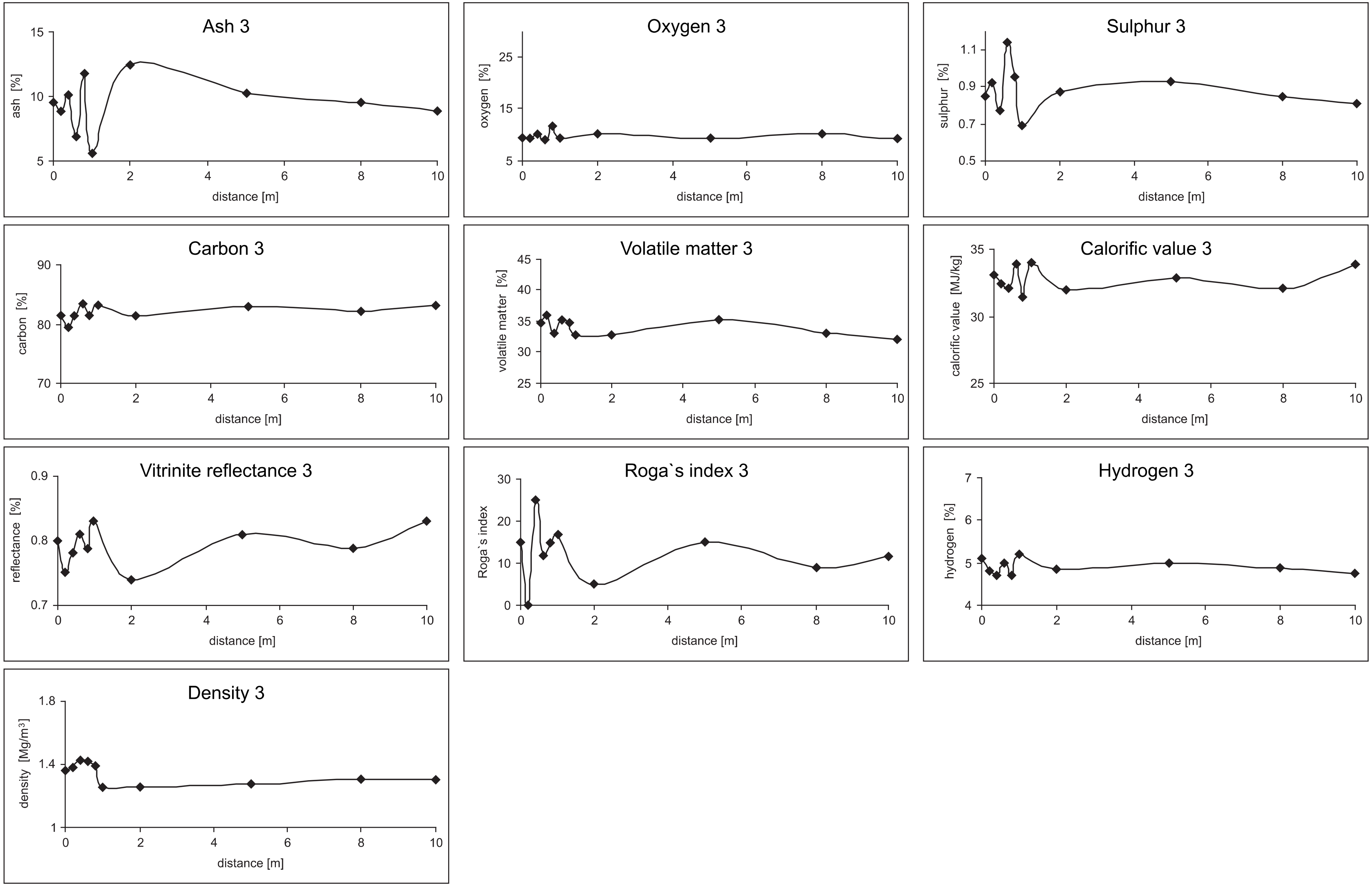

Fig. 7. Changes of coal quality parameters with distance from fault plane for third type of variability group of faults

CONCLUSIONS

The first type of variability is characteristic for faults where the decrease of coal quality is caused by oxidation of the matter. Major changes occur in fault fissures and its immediate vicinity. With growing distance from a fault plane, parameters tend to the average values calculated for undisturbed coal seam.

Oxidation of coal is advanced the most for the first group of faults. It manifests itself by rising of ash, moisture, volatile matter, and oxygen content as well as by diminishing of technological parameters values. Coking strength is decreasing up to zero. Contents of hydrogen, carbon, total sulphur, and calorific value are diminishing significantly. Changes of coking strength, swelling index, and calorific value occur up to 2.0 m from a fault plane. Other parameters are changed at the 0.0 to 0.8 m interval.

For the coal samples taken from oxidation zone, H/C ratio is lower and O/C ratio is bigger than for coal seam. Total sulphur content decreases, and this element is bound mostly to inorganic matter. Fissure's breccia is strongly watered and is laminated with a number of polycrystalline sulphates. Coal seam structure is delaminated at the 1.5 metre-long distance from a fault plane. The layers are internally displaced. Weathering is less intense, and coefficient of variability, and standard deviation value are lower in the second group of faults. The range of disturbance is shorter than in the first group. The material filling fissures is hard and compact, without visible mineralization. Coal seam structure is less disturbed and coal is drier.

For the third group of faults, the range of weathering was limited to the distance of 0.4 m from a fault plane. High density as well as ash and total sulphur content characterise coal in the zone of disturbances. High total sulphur content is connected with sulphide mineralization. Coal quality parameter values testify to small scale of coal alteration. Weathering degree of coal seam is low. High mineralization degree of coal seam in fault zones protects them against oxidation.

For the fourth group of faults, weathering occurs only in the fault's fissure and does not affect coal seams.

It seems that degree of coal oxidation in a fault zone depends on structural disturbance of coal seams occurred during faulting. Stratification of coal seam and displacement of created layers gave facilities for air diffusion from a fault fissure into the seam. Sulphide mineralization slows down the weathering of coal.

The rise of coalification of coal seams (the second type of variability) is strongly connected with the occurrence of lustrous fault planes. One can assume that coal was modified by heat generated when fracture was propagating in conditions of high normal stress. Decrease of quality of coal, which is filling the fissure of some faults, is a symptom of early stage of weathering.

Fault zones in which no changes of coal quality were observed are characteristic for faults with displacement limited to several metres and with fractures width less than several millimetres. Small fault size hinders diffusion of oxygen into coal seams and protects them against weathering.

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