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COMPOSITION AND PROPERTIES OF CZECH BROWN COALS

Summary. The petrological and chemical characteristics of low rank coal from Czech Tertiary basins were studied from the geological, technological and ecological points of views. We discussed the rank, maceral composition, gelification of huminite macerals and chemical parameters of brown coals from the North Bohemian Basin, Sokolov Basin, South Moravian Lignite Coalfield, České Budějovice Basin and Višňová locality in North Bohemia.

Introduction

Brown coal is a suitable feedstock for gasification, liquefaction and/or processing of coal with the oil fractions, plastic materials and biomaterials in the Czech Republic. Geological structure of Czech Tertiary coal deposits, petrographic and chemical characteristics of Czech brown coal were published by Havlena [1], Bouška [2], Dopita et al. [3], Honěk [4, 5], Kříbek et al. [6], Mach et al.[7], Malán [8, 9], Pešek [10], Svoboda [11], Včelák [12], Zelenka [13, 14], Žáková [15], Černý et al. [16], Rojík [17, 18], Sýkorová et al. [19, 20]. Most of these characteristics were tested as parameters of the international codification and classification system of low rank coals [21, 22].

Methods

The coal petrographic analysis includes huminite (eu-ulminite) light reflectance (R_r), and maceral and mineral composition according to Stach et al. [23] and Taylor et al. [24]. Microscopic and microphotometric measurements were performed using the UMSP 30 Petro microscope-microphotometer (Zeiss-Opton) in oil immersion (n = 1.518) and reflected light at a wavelength (λ = 546nm). The total magnification was 450x and 720x. Fluorescence analysis of liptinite macerals was carried out using a halogen discharge lamp and F1 09 filter

set. Mathematical relations based on the maceral composition of huminite and inertrinite were used to express the geligication index (GI) and the tissue preservation index (TPI) [25].

The proximate and ultimate analysies of coal samples were performed according to national standards.

^{13}C CP/MAS NMR spectra were measured using a Bruker DSX 200 spectrometer operating at 50.32Mhz. Aromaticity f_a was estimated as the ratio of the integrated area of aromatic carbons (about 90 - 165ppm) to the integrated area of all carbons in the spectrum.

Results and Discussion

The study includes data regarding coals from currently mined deposits and also from already shut down seams and deposits. Samples are representing the main seams in the North Bohemian Basin, Sokolov Basin, Cheb Basin, South Moravian Lignite Coalfield, České Budějovice Basin and Višňová locality.

The North Bohemian Basin is the most important brown coal basin in the Czech Republic. It is situated south-east of the Krušné Hory Mountains and has an area approximately 1400 km^2. The only mineable seam in the basin is the main coal seam with an average thickness of 30 m and maximal thickness of 60 m. It mainly consists of xylodetritic and semidetritic coal. Less frequent are pure xylitic, detritic and sapropelic coals. The overall composition and properties of North Bohemian coals depend slightly on their geological position in the basin (Tables 1 and 2). The mineral content increases from the north to the south. Data in Table 1 show that a coal with high ash content, between 20 % and 44 %, occurs in the western and central part of the basin. Most abundant are clay minerals, quartz, and pelosiderites; carbonates, feldspars are less frequent. Iron disulfides are stable mineral components in the basin. The lowest total sulfur content up to 0.40 % S_t^d (see Table 1) was found close to Chabařovice in the eastern part of the basin.

Studied coal samples were hard brown coal with parameters: W_t^r = 26 – 55%. Metatype brown coal (W_t^r = 18.3 – 26.0%) was formed in the deepest areas (Hrdlovka, Osek, Dřínov) in the central part. The samples examined were huminitic coals with variable reflectance from 0.31% to 0.45% R_r. Huminite concentration varies from 19% to 95%. The macerals, ulminite and densinite contribute to the high huminite content (Table 2). The concentration of attrinite and textinite is substantially lower, i.e. 3 – 19%. Humogelinite (gelinite and corpohuminite) content does not exceed 30%. The sample collection consists of nearly pure gelinite [26] with random reflectance R_r = 0.40% and aromaticity f_a = 0.58.

Table 1

The basic characteristics of coal samples from the North Bohemian Basin, Sokolov Basin and Cheb

Basin	Formations, Seams	Number of samples	Basic coal types	W_t^r (%)	A^d (%)	Sulfur content (%)			Q_s^{daf} (MJ/kg)	V^{daf} (%)
						S_t^d	S_p^d	S_{SO4}^d		
North Bohemian Basin	east part	10	XD, DX	30.1 - 35.9	11.5 - 25.3	0.2 – 0.4	0.0 - 0.3	0.01 – 0.2	25.3 - 29.1	48.3 – 56.0
	central part	150	XD,SD,DX, X	23.3 - 35.8 18.3 - 26.0	10.6 - 40.2 3.2 - 29.0	0.4 – 8.7 0.3 – 1.5	0.02 - 4.4 0.02 - 0.8	0.01 – 1.51 0.01	27.3 - 29.8 28.6 - 30.8	46.8 – 54.5 42.8 – 45.0
	west part	20	XD, DX, SD, cXD	26.0 - 55.0	21.5 - 44.0	0.5 – 6.0	0.3 - 2.3	0.01 – 2.11	24.9 - 30.6	46.2 – 54.1
Sokolov Basin	Cypris F.	15	OSH	-	78.0 - 89.0	0.2 - 2.7	0.0 - 1.5	-	-	-
	Antonín	250	XD,SD,DX, XLD, LDC, cLDC	34.9 - 45.7	3.1 - 42.0	0.1 – 1.5	0.4 – 1.1	0.01 – 0.12	29.5 – 33.3	48.4 – 63.5
	Anežka	5	XD,DX,SD, SC, cDC	38.0 - 40.5	8.0 - 36.5	0.8 – 2.5	0.4 – 0.6	0.01 – 0.51	24.9 – 27.4	51.8 – 62.3
	Josef	45	XD,DX,SD, SC, cDC	34.0 - 40.8	5.2 – 29.0	1.5 – 5.0	0.2 – 4.6	0.02 – 0.42	29.5 – 35.8	48.1 – 80.0
Cheb Basin	Antonín	15	XD,SD,DX, XLD, cDC	48.3 - 51.8	7.5 – 41.3	1.1 – 3.2	0.1 – 1.1	0.01 – 0.08	25.4 – 28.5	54.2 – 58.4

DX- detroxylitic coal, XD-xylodetritic coal, SD-semidetritic coal, cXD – clayey xylodetritic coal, cDC – clayey detritic coal, SC – sapropelic coal, XLD – xyloliptodetritic coal, LDC – liptodetritic coal, OSH – oil shale, X - xylite

Liptinite content varies between 1% and 15 %. Sporinite, cutinite and liptodetrinite are prevailing macerals in brown coals from Northern Bohemia. Inertinite content is below 10% in the studied coals. Sclerotinite, fusinite, inertodetrinite and macrinite are abundant inertinite macerals in the central part of the basin.

The greater part of the coal is utilized in power plants, domestic heating, and for gasification. In the past it was utilized in liquefaction and underground gasification, as well.

The Sokolov Basin is the second most important brown coal basin in the Czech Republic. The basin is located south of the Krušné Hory Mts. The medium hard brown coal (Table 1) mined in this basin is used for power industry (fluidized bed combustion, gasification and briquetting). The Tertiary coal bearing strata in the Sokolov Basin encloses three coal seam formations: Josef seam Formation (Oligocene age), Anežka and Antonín seam Formation (Miocene age). Thy Cypris Formation (Ottangian age) overlies the Antonín seam. The studied coals from the Antonín, Anežka and Josef seams are characterized by variable amount of mineral matter. Mineral matter consisted of clay minerals, with admixture of quartz, carbonate and feldspar. The majority of clays were finely dispersed through on the densinite and attrinite in samples from all seams. Ash content increases from 3 to 42 % (Table 1). Antonín seam is characterized by low total sulfur content (S_t^d = 0.3 – 1.5 %) especially by low iron disulfide amount (S_p^d = 0.4 – 1.1 %). However, coals from the Josef and Anežka seams have high sulfur content including both pyritic and organic sulfur (Table 1).

Some revealing relationships were observed among different chemical properties of the Sokolov coal samples. Volatile matter V^{daf}, calorific value Q_s^{daf}, hydrogen content H^{daf}, carbon content C^{daf} and aromaticity f_a correlate directly with liptinite content and ash content for all coals (Tables 1 and 2). Samples of brown coal from the Sokolov basin are generally classified as humic coal, saprodetritic coal, sapropelic coal, liptodetritic coal and liptobioliths, based on the lithotype and maceral composition. The dark bands of the huminite-rich and inertinite-poor coal with liptinite content less than 15% were identified in the Antonín seam, and in central and upper parts of the Anežka and Josef seams. This coal is gelified, highly aromatic material with higher random reflectance (R_r = 0.32 – 0.42 %). It is apparent from the petrographic data that most significant differences occur within humotelinite and humodetrinite (Table 2).

Table 2

Petrological and chemical characteristics of coal samples from the North Bohemian Basin, Sokolov Basin, Cheb Basin

Seam, Formation	R_r(%)	Huminite (%)				Liptinite (%)	Inertinite (%)	Minera lmatter (%)	GI	TPI	C^{daf} (%)	H^{daf} (%)	fa
		ΣH	humotelinite	humodetrinite	humogelinite								
east part NBB	0.34 – 0.37	46 - 95	20 - 64	7 – 51	3 - 8	1 - 6	1 – 2	3 – 48	4 –19	0.7 – 3.6	68 - 72	4.7 – 5.6	0.51
central part NBB	0.33 – 0.38 0.38 – 0.45	42 - 90 61 – 89 (100)	17 - 69 20 - 55	4 – 48 13 – 30	3 – 10 3 – 30 (100)	2 – 15 2 - 15	1 – 10 1 - 5	8 – 54 3 – 30	1 – 33 4 – 44	0.5 – 4.1 0.3 – 2.4	67 - 74 71 - 81	4.9 – 6.3 5.3 – 6.1	0.50-0.58 0.55-0.62
west part NBB	0.31 – 0.37	19 - 85	3 - 60	5 – 45	1 – 16	1 - 8	1 - 5	8 - 40	2 - 18	0.7 – 4.4	64 - 73	4.9 - 5.7	0.50-0.55
Cypris F. SoB	0.22 – 0.26	< 1	<1	0	0	5 – 20	0 – 2	83 - 93	-	-	C^d = 2 – 8%	-	0.23
Antonín SoB	0.33 – 0.42 0.28 – 0.35 0.23 – 0.28	55 - 92 43 - 58 4 - 40	5 - 64 30 - 42 4 – 28	0 – 45 5 – 35 0 - 30	0 – 11 0 – 8 0 - 3	2 – 16 17 – 28 45 - 80	1 – 8 3 – 8 3 – 10	2 – 42 5 – 30 2 - 15	9 - 18 5 - 19 2 - 9	0.5 – 3.9 4.0 – 6.0 0.6 – 2.8	68 – 75 71 - 75 73 - 78	4.9 – 5.9 6.0 – 7.0 >7.0	0.45 – 0.53 0.28 – 0.47 0.23 – 0.25
Anežka SoB	0.34 – 0.36 0.25	60 – 66 1	24 – 37 1	5 - 30 0	0 – 8 0	6 – 16 84	2 – 3 10	20 –22 5	3 – 7 -	0.9–1.3	69 - 75 78	5.2 – 5.9 8.5	0.47 – 0.50 0.25
Josef SoB	0.32 – 0.42 0.28 – 0.33 0.22 – 0.28	50 – 85 42 – 71 4 - 13	4 – 55 10 – 25 4 - 10	0 – 50 21 – 42 0	1 – 12 2 – 6 0 - 3	5 – 17 18 – 32 42 - 83	1 – 8 1 – 6 6 - 8	4 – 45 3 – 30 3 - 12	7 – 13 2 – 6 0	0.5 – 3.2 0.5 – 1.4 4.0	69 – 75 70 –7 6 73 - 78	5.0 – 5.9 6.0 – 7.5 > 8.0	0.47 – 0.54 0.28 – 0.45 0.23 – 0.28
Antonin ChB	0.27 – 0.36	67 - 87	16 - 57	19 - 58	1 - 13	0 - 10	1 - 7	6 – 35	0 – 6	0.2 – 0.5	67 - 73	4 8 – 5.8	-

NBB – North Bohemian Basin, SoB – Sokolov Basin, Cheb Basin, GI – gelification index, TPI – tissue preservation index

Pale coal from Upper part of the Antonín seam contains 28 – 80% of liptinite with the majority of liptodetrinite and bituminite. The remaining material is mainly composed of sporinite, suberinite, resinite and macerals of huminite and inertinite. This coal is highly aliphatic material with low aromaticity f_a = 0.23- 0.25, low reflectance values R_r = 0.22 – 0.28 % and hydrogen content H^{daf} higher than 7 %. In contrast to liptobioliths, the different liptinite macerals (liptodetrinite, sporinite, alginite, bituminite) are finally granular in dark sapropelic coals from the Josef and Anežka seams. Sapropelic coal has 32 – 83 % liptinite content, hydrogen content higher than 8 % and aromaticity f_a = 0.23 – 0.28. Significant differences in chemical parameters between sapropelic coal and liptobioliths from the Sokolov Basin have not been determined. The main differences between these coals were found in macroscopic characteristics and in liptinite composition. There are common brown and dark coals with liptinite content between 15 an 25 %, hydrogen content H^{daf} = 6 – 7% and aromaticity f_a = 0.28 – 0.47 in all seams. Good relation was determined in composition and properties of coal samples from Antonín seam (Sokolov Basin) and Antonín seam (Cheb Basin).

Sediment from Cypris Formation is formed by clay minerals with admixtures of organic matter and pyrite. The main components of organic matter (C^d = 2 – 8%) are alginite, bituminite and fragments of fusinite.

The least coalified and gelified are detroxylitic and xylodetritic coals from the South Moravian Lignite Coalfield, the České Budějovice Basin and from Višňová locality in North Bohemia, which are Miocene age. They are characterized by high water content W_t^r = 45 – 52 %, calorific values Q_s^{daf} = 24.5 – 27.8 MJ/kg, reflectance R_r = 0,18 – 0.30% and aromaticity f_a = 0.30 – 0,42 (Tables 3 and 4). From the petrographic point of view it is a coal with high content of dark variety of ulminite A and textinite A and with low liptinite and inertinite content.

The South Moravian Lignite Coalfield is situated in the northwestern margins of the Vienna Basin region. Coal of this basin is represented by autochtonous humites. Two extractable seams occur there (Miocene Kyjov seam and Pliocene Dubňany seam). Both deposits České Budějovice Basin and Višňová locality were closed in the first half of last century. The coal is used as fuel for households and power plants with fluidized bed combustion technology. Soft xylitic coal has been a suitable raw materials for adsorbens production [27, 28].

Table 3

The basic characteristics of coal samples from Vienna Basin, České Budějovice Basin and Višňová locality

Basin	Seams	Number of samples	Mine coal type	W_t^r (%)	A^d (%)	Sulfur content (%)			Q_s^{daf} (MJ/kg)	V^{daf} (%)
						S_t^d	S_p^d	S_{SO4}^d		
České Budějovice	Mydlovary	5	DX,XD,cXD	48.7 – 55.3	12.0 – 25.9	1.5 – 2.8	0.6 – 0.9	0.1 – 0.2	24.2 – 26.3	57.8 – 63.3
north Bohemia	Višňová	5	DX,XD,cXD	45.0 - 51.3	14.0 – 25.0	1.5 – 2.5	0.5 - 2.5	0.3 - 0.8	24.1 – 26.0	52.2 – 62.5
Vienna - south Moravia	Dubňany	5	DX,XD,cXD	45.0 – 52.7	14.0 – 25.0	1.5 – 2.5	0.9 – 1.0	0.1 – 0.2	26.5 – 26.9	52.5 – 62.1
	Kyjov	5	DX,XD,cXD	45.0 – 50.2	15.0 – 29.0	1.5 – 3.5	0.9 – 1.1	0.0 – 0.2	25.8 – 26.7	58.0 – 61.9

DX- detroxylitic coal, XD-xylodetritic coal, cXD – clayey xylodetritic coal

Table 4

Petrological and chemical characteristics of coal samples from Vienna Basin, České Budějovice Basin and Višňová locality

Seam	R_r(%)	Huminite (%)				Liptinite (%)	Inertinite (%)	Mineral matter (%)	GI	TPI	C^{daf} (%)	H^{daf} (%)	fa
		ΣH	humotelinite	humodetrinite	humogelinite								
Mydlovary CBB	0.20 – 0.25	45 -73	13 - 65	3 - 45	7 - 16	3 - 14	5-16	17 - 37	0.7 – 4.3	0.8 –10.5	64 - 67	4.7 – 5.3	0.45
Višňová NBL	0.18 – 0.24	45 – 74	18 – 46	19 – 25	5 – 9	4 – 8	3 – 10	15 – 42	0.9 – 1.0	0.8 – 3.0	61 – 64	5.3 – 5.4	0.44
Dubňany VB	0.22 – 0.26	60 - 84	30 - 42	21 - 35	7 - 10	1 - 4	1 - 4	10 - 23	0.8 – 2.0	0.7 - 9.8	65 - 69	4.8 – 5.7	0.47
Kyjov VB	0.22 – 0.26	71 - 90	33 - 47	27 - 40	8 - 12	1 - 3	1 - 3	5 - 36	0.9 – 2.4	0.8 - 10.0	65 - 68	4.7 – 5.5	0.46

CBB – České Budějovice Basin, NBL – North Bohemian locality, VB – Vienna Basin, GI – gelification index, TPI – tissue preservation index

Conclusions

The overall composition and properties of Czech brown coals depend slightly on their geological age, and geological position in the basins.

It was found, that significant indicators of rank of Czech brown coals are moisture W_t^r and light reflectance R_r. In remaining rank parameters like carbon content (C^{daf}), calorific values (Q_s^{daf}) and aromaticity f_a there is evident influence of liptinite content and weathering stage.

The light reflectance expresses the degrees of coalification of studied Czech brown coal, which correspond to the international classification [30, 31].

Table 5

Coalification degree of Czech brown coals

Brown coal types [27]	ČSN 44 1395 [29]	UN-ECE [30, 31]	W_t^r (%)	C^{daf} (%)	Q_s^{maf} (MJ/kg)	Q_s^{daf} (MJ/kg)	R_r (%)
hemitype	lignite	ortho-lignite	> 40	< 68	< 15	< 28	0.18 – 0.29
orthotype	brown coal	meta -lignit	20 - 40	68 – 73	15 – 20	28 - 32	0.30 – 0.39
metatype	brown coal	subbituminous coal	< 20	> 73	20 - 24	< 32	0.40 – 0.45

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