PALEOENVIRONMENT, MIRES, INDICES OF THE FACIES OF BULGARIAN BASINS

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***Abstract*- Nine Bulgarian coal basins were sampled and investigated for their petrography and mineralogy. The origin of three of the coal basins was determined to be ombrotrophic bogs (Kyustendil basin, Oranovo-Simitli basin, Dobrudja basin). Three other coal basins were determined to be mesotrophic bog forests (Sofia basin, Katrishte deposit, Pernik basin), and an additional three as ombrotrophic bog forests (Chukurovo basin, Balkan basin, Svoge basin). There is no established relationship between the rank of the coals, the lithology of the coal-bearing layers, and type of the peat bogs. Three of the basins have a similar origin, without any relation between the location, lithology of the coal-bearing layers, type of the peat bog, or the coal rank. The Pernik, Oranovo, Chukurovo and Svoge basins originated in forested peatlands (telmatic swamps) when relatively high in coal ash and/or interbedded with mineral partings; and in forested, continuously wet raised bogs when low in ash. The Sofia, Kyustendil and Balkan basins are originated in intermittently dry forested swamps when high in ash, or in forested raised bogs when coal ash is low or moderate. The Dobrudja basin and Katrishte deposits originated in slowly subsiding, intermittently dry swamps from aerobically decomposed autochtonous plants, which were redistributed as subaqueous sediment or in slowly subsiding, relatively dry raised bogs.**

***Key words:* paleoenvironment, paleoecology, organic petrology, facies, mires.**

I. Introduction

Bulgaria has forty five coal basins (Siskov, 1997) and nine of them (1/5 part of all Bulgarian coal basins) were sampled and petrographically analysed for the present study. These basins were the Kyustendil lignite basin, the Sofia lignite basin, the Katrishte lignite deposit, the Oranovo lignite basin, the Chukurovo lignite basin, the Pernik sub-bituminous basin, Dobrudja bituminous basin, and Svoge anthracite basin. Every basin was sampled by a different scheme and for different tasks. The main purpose of the study is to summarize the petrographic data for the above-mentioned basins and relate coal facies to basin location.

Geological setting

1. *Sofia lignite basin*

The Sofia basin is located in a large area (~1000 km^2) around the city of Sofia and belongs to the Sofia coal province (Fig. 1) (Siskov, 1997). The age of the coal-bearing strata (the Sofia group) is Pliocene. Strata are mainly composed of sand, gravel and silt with a thickness of about 200 m. Other strata are mainly composed of clay, and younger layers are mainly composed of sandstone and sand (Fig. 2) (Kortenski, 2002). Rank of this coal is lignite.

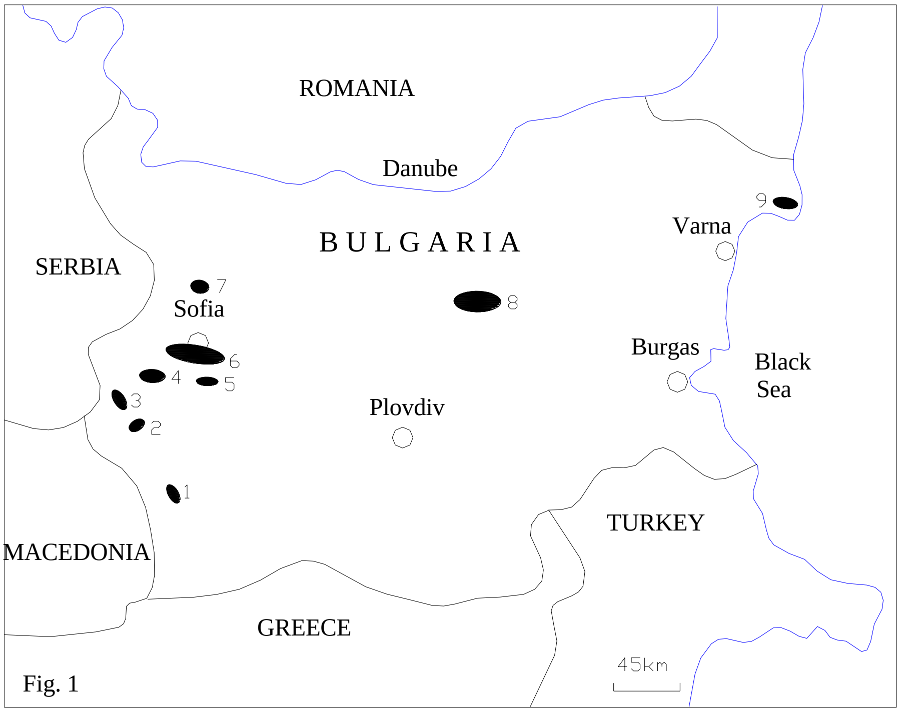


Fig. 1 Location of the studied coal basins: 1-Oranovo; 2-Katrishte; 3-Kyustendil; 4-Pernik; 5-Chukurovo; 6- Sofia; 7-Svoge; 8-Balkan; 9-Dobrudja.

2. Kyustendil lignite basin

The Kyustendil basin is situated in western Bulgaria about 70 km southwest of the capital city of Sofia (Fig. 1) and belongs to the Struma-Mesta coal province. Coal-bearing strata are about 100 m thick, and are primarily Upper Miocene clay. The age of the sediments was determined by Bakalov (Nikolov, 1974). Older strata are quartz sandstone and younger layers are composed of conglomerate and gravel (Fig. 2) (Kamenov, 1954). The rank of this coal is lignite.

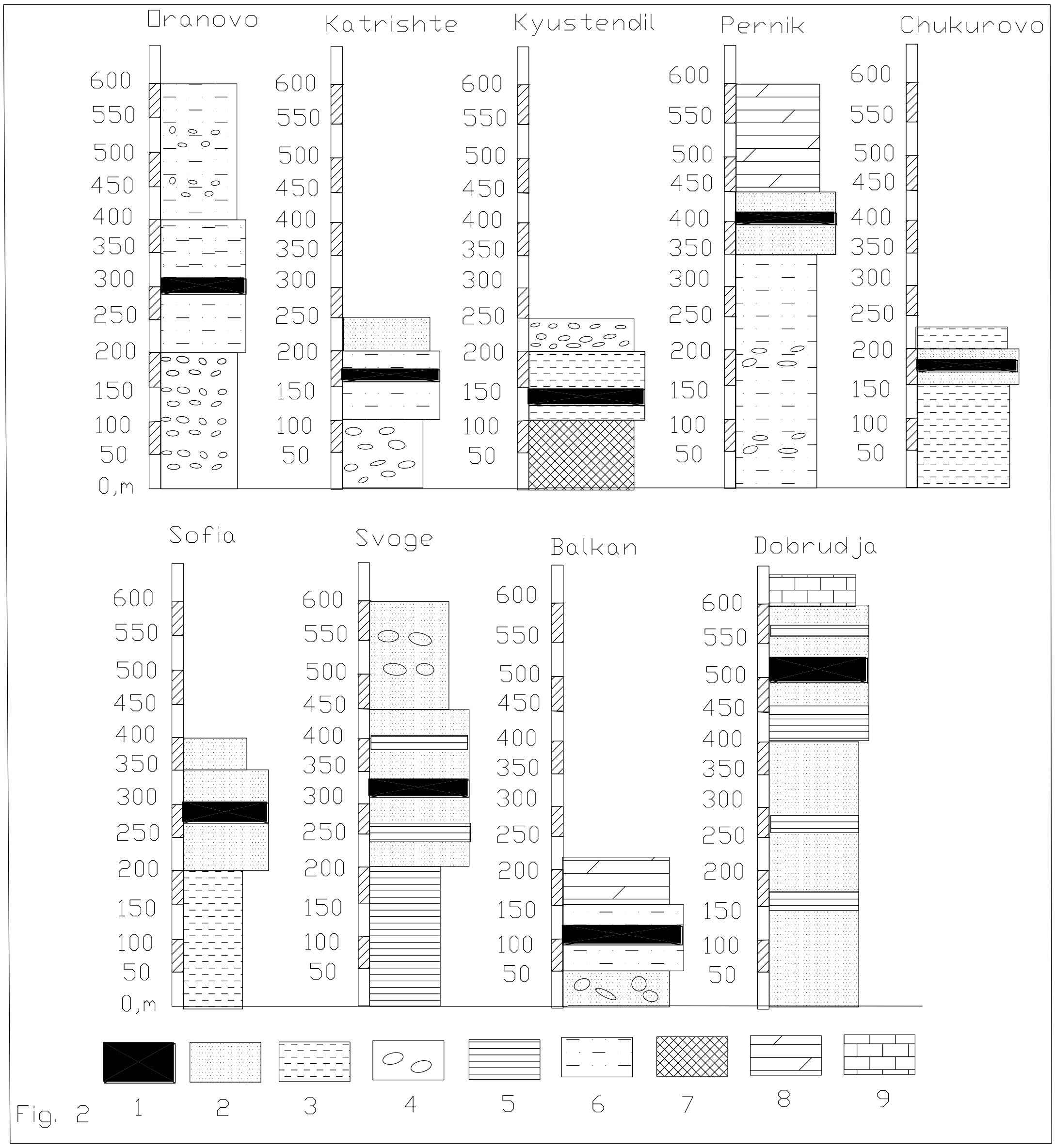


Fig. 2 Summary lithological profiles of the under layer, coal-bearing and covering layers of the studied basins: 1-coal; 2-sandstone; 3-clay; 4-conglomerate; 5-silt; 6-sandy clay; 7-crystalline rocks; 8-marlstone; 9-limestone.

3. Katrishte lignite basin

The Katrishte deposit is located in western Bulgaria, about 80 km southwest from the city of Sofia (Fig. 1), and is a part of the Stuma-Mesta coal province. The coal-bearing interval is about 100 m thick, and is composed of Badenian-Sarmatian sandy clay, silt and sandstone. The interval is underlain by conglomerate and overlain by sandstone, sand and gravel (Fig.2) (Vacev and Bonev, 1994). The coal of the basin is lignite.

4. Oranovo-Simitli lignite basin

The Oranovo-Simitli basin (Oranovo basin) is situated in southwest Bulgaria, about 100 km south of the city of Sofia (Fig. 1), and also belongs belongs to the Struma-Mesta coal province (Siskov, 1997). Coal bearing strata occurs in the 200 m thick - Middle Miocene Oranovo formation, which is composed of alternating sandy clay, silt and sandstone (Fig. 2). The interval is underlain by conglomerate and overlain by clay with some conglomerate particles (Vacev, 1991). The rank of this coal is lignite.

5. Chukurovo lignite basin

The Chukurovo basin is located about 40 km southeast from the city of Sofia (Fig. 1), and belongs to the Sofia coal province (Siskov, 1997). The age of the coal-bearing sediments is Helvetian, according to Palamarev (1964). Bounding strata are composed mainly of clay and sandy clay (Fig. 2), according to Kackov and Iliev (1993). The rank of this coal is lignite.

6. Pernik sub-bituminous basin
The Pernik basin is located about 30 km southwest of the city of Sofia (Fig.1), and belongs to the Pernik coal province (Siskov, 1997). The age of the basin is Late Oligocene-Early Miocene. Coal-bearing sediments are about 100 m thick, and are composed of sandstone. Older rocks are composed of sandy clay with conglomeratic clasts, while younger rocks are composed of marlstone (Fig. 2) (Marinova and Zagorchev, 1994). The coal of the basin is sub-bituminous-B.

7. Dobrudja bituminous basin
The Dobrudja basin is situated in Northeast Bulgaria, about 40 km North from the city of Varna. Part of it is located under the Black Sea (Fig. 1). It belongs to the Dobrudja coal province (Siskov, 1997). The age of this coal-bearing formation is Pennsylvanian (Westphalian), and consists of about 200 m of alternating silt and sandstone. Older strata are composed of the same alternation of silt and sandstone, while younger strata are composed of limestone (Nikolov et al., 1988). The rank of the coal in this basin is high volatile bituminous-A.

8. Balkan bituminous basin
The Balkan basin is situated in Central Bulgaria in the area of the Stara Planina Mountain (Fig. 1), and belongs to Balkan coal province (Siskov, 1997). According to Kanchev (1962), Nikolov (1979) and Petrov (1983), the coal-bearing sediments are Cenomanian in age. The coal-bearing interval is about 100 m thick, and is composed of sandy clay (Fig. 2) (Kanchev et al., 1995). Older rocks are mainly conglomerate and younger rocks are marlstone. The rank of the coal in this basin is high volatile bituminous-A.

9. Svoge anthracite basin
The Svoge basin is situated about 30 km North from the city of Sofia (Fig. 1), and belongs to the Svoge coal province (Siskov, 1997). The Westphalian coal-bearing interval is about 250 m thick, and is composed of alternating sandstone, silt and conglomerate (Fig. 2). The unit rests on silt, and is overlain by conglomerate (Kortenski, 2002). The rank of this coal is anthracite and meta-anthracite.

II. Materials and Methods

The main economic seams from each basin were sampled. A total of 458 samples were analyzed. Of these, 253 are from the Sofia basin, 20 are from the Kyustendil basin, 43 are from the Katrishte basin, 137 are from the Oranovo-Simitli basin, 20 are from the Chukurovo basin, 30 are from the Pernik basin, 20 are from the Dobrudja basin, 15 are from the Balkan basin, and 20 are from the Svoge basin. The samples were crushed to grain sizes between 1 mm and 3 mm. A representative part of each sample was mounted in epoxy resin and polished for petrographic study. Between 400 and 700 points in each sample were counted on a Leica microscope using reflected white (λ=546 nm) and fluorescent light under 50x/0.85 and 100x/0.25 objectives for maceral analyses. A computer program, "Leica mpv_meas", was also used. The relative amount of each maceral group and their subgroups in each sample were calculated using the Stopes-Heerlen System (Taylor et al., 1998; ICCP 1971, 1975, 1985). At least 50 points for vitrinite reflectance were measured on every sample using the methodology of Stach et al. (1987). An yttrium–aluminium granate with a reflectance of 0.899% was used as a standard for determination of the vitrinite reflectance. Random vitrinite reflectance $R_r=(R_{max}+R_{min})/2$ was used for the determination of coal rank. The standard deviation was generally low (<10% of the mean value).
An electron microprobe (EMP) – ARL-SEMQ 30 with a Spectrometer 4, EDS – Link AN 10/25S, and a computer program, "Jamiwin", were used for identification of some minerals through x-ray diffractometry. Debye-Scherer X-ray Method, differential-thermal analysis (DTA), binocular microscopy on a Zeiss Jena, and Scanning Electron Microscopy (SEM) were also used to help determine mineral content.
Reference data were used to characterize the ash contents for most of the studied coals. The ash content was determined for the Oranovo and Katrishte coals through standard ashing of the samples at 810ºC on a dry basis.
The maceral ratios of Calder et al. (1991), and Diessel (1986) were used for characterizing the coal facies. Diessel's (1992) table for the relationship between coal facies indices and conditions of coal formation was used to establish the origin of the ancient peat bogs.

I. Maceral ratios for calculation of coal facies indices for high rank coal.

Ground Water Index (GWI) (Calder et al., 1991)

$$GWI = \frac{gelocollinite+corpocollinite+syngenetic\ mineral\ matter}{telinite+telocollinite+desmocollinite} \quad (1)$$

Vegetation Index (VI) (Calder et al., 1991)

$$VI = \frac{telinite+telocollinite+fusinite+semifusinite+suberinite+resinite}{desmocollinite+inertodetrinite+alginite+liptodetrinite+sporinite+cutinite} \quad (2)$$

Tissue Preservation Index (TPI) (Diessel, 1986)

$$TPI = \frac{telinite+telocollinite+fusinite+semifusinite+rootletvitrinite+phylovitrinite}{desmocollinite+macrinite+semimacrinite+inertodetrinite} \quad (3)$$

Gelification Index (GI) (Diessel, 1986)

$$GI = \frac{vitrinite+macrinite+semimacrinite}{fusinite+semifusinite+inertodetrinite} \quad (4)$$

II. Maceral ratios for calculation of the coal facies indices for low rank coal.

Ground Water Index (GWI) (Calder et al., 1991)

$$GWI = \frac{gelinite+corpohuminite+syngenetic\ mineral\ matter}{textinite+ulminite+densinite} \quad (5)$$

Vegetation Index (VI) (Calder et al., 1991)

$$VI = \frac{textinite+ulminite+fusinite+suberinite+resinite}{densinite+inertodetrinite+alginite+liptodetrinite+sporinite+cutinite} \quad (6)$$

Tissue Preservation Index(TPI) (Diessel, 1986)

$$TPI = \frac{textinite+ulminite+fusinite+rootletvitrinite+phylovitrinite}{densinite+macrinite+inertodetrinite} \quad (7)$$

Gelification Index (GI) (Diessel, 1986)

$$GI = \frac{huminite+macrinite}{fusinite+inertodetrinite} \quad (8)$$

III. Results and discussion

1. Sofia basin

The random vitrinite (huminite) reflectance of the Sofia lignite is R_r=0.23% (average of all measured samples), and the ash content is A^d=18. 30% (Kortenski, 1989). The petrographic data for the studied basins, ordered in increasing values of vitrinite reflectance, is shown in Table 1,2,3, and 4. The macerals from the huminite (vitrinite) group are about 69%. The prevailing maceral from this group is ulminite, about 35% (volume percent) (texto-ulminite 15% and eu-ulminite 20%) (Table 1). Table 2 shows the percentage of the macerals, calculated on basis of the organic matter. The macerals from the liptinite group are about 15% (volume percent) as most abundant macerals are sporinite, resinite and liptodetrinite. The macerals from the inertinite group are about 3% (Table 1, 2). Mineral matter, counted on the microscope, is about 13%. The minerals identified in the coal are reported in Table 5. The GWI=0.70, VI=4.80, TPI=7.13 and GI=11.15. According to the GWI and VI of Calder et al. (1991), this type of peat bog was determined as a mesotrophic bog forest. According to the TPI and GI of Diessel (1986), the peat bog probably developed as a forested raised bog, when coal ash is low or moderate (Diessel, 1992).

Table 1 Petrographic data for the studied low rank coal, calculated on the basis of all matter

Table 1 Low rank coal (all atter)

Average, %	Sofia	Kyustendil	Katrishte	Oranovo	Chukurovo	Pernik
Number samples	253	20	43	137	20	30
Rank	Lignite	Lignite	Lignite	Lignite	Lignite	Sub-bituminous-B
Rr	0.23	0.30*	0.31	0.33	0.37	0.48
Rmin	0.20	0.24*	0.24	0.30	0.32	0.39
Rmax	0.25	0.36*	0.38	0.04	0.39	0.56
Ash	18.30***	36.00****	32.00	8.84	n.d.	16.8**
Textinite	10.00	5.00	0.01	0.00	16.51	4.00
Texto-ulminite	15.00	15.00	7.00	10.00	36.50	30.00
Eu-ulminite	20.00	35.00	13.00	30.24	20.24	39.95
Attrinite	10.00	13.00	7.00	13.50	3.33	5.00
Densinite	9.00	12.00	48.00	13.50	0.80	5.00
Gelinite	1.00	1.00	0.01	4.00	0.00	1.00
Phlobaphinite	3.00	2.00	1.00	2.00	4.79	1.00
Pseudo-phlobaphinite	1.00	1.00	1.00	1.00	0.70	0.00
Sporinite	4.00	2.50	2.00	3.00	0.13	1.00
Cutinite	1.00	0.01	0.01	0.01	0.13	0.01
Resinite	3.00	1.00	1.00	2.00	10.39	2.00
Suberinite	3.00	0.01	0.00	1.00	1.86	0.00
Alginite	1.00	0.47	0.01	7.00	0.13	0.01
Liptodetrinite	3.00	1.00	2.00	1.00	1.60	1.00
Fluorinite	0.00	0.00	1.00	0.75	0.00	0.00
Chlorophyllinite	0.00	0.00	0.00	0.00	0.01	0.00
Bituminite	0.00	0.00	3.00	0.00	0.00	1.00
Fusinite	1.00	1.00	1.00	0.00	0.01	0.01
Semifusinite	0.00	0.00	0.00	0.00	0.00	0.01
Macrinite	0.00	0.00	0.00	0.00	0.00	0.00
Sclerotinite	1.00	0.01	0.01	1.00	0.13	0.01
Inertodetrinite	1.00	2.00	3.00	1.00	0.13	1.00
Vitrinite group	69.00	81.50	77.02	74.24	66.49	85.95
Liptinite group	15.00	4.99	9.02	14.76	14.12	5.02

Inertinite group	3.00	3.01	4.01	2.00	0.27	1.03
Mineral matter	13.00	8.00	10.00	9.00	3.06	8.00
GWI	0.70	0.42	0.80	0.30	0.10	0.07
VI	4.80	2.42	9.80	1.77	22.35	9.90
TPI	7.13	2.80	0.38	3.14	78.76	9.12
GI	11.15	19.53	19.67	78.00	634.15	95.17
Mire	Mesotrophic bog forest	Ombrotrophic bog	Mesotrophic bog forest	Ombrotrophic bog	Ombrotrophic bog forest	Mesotrophic bog forest

*Minchev et al. (1974) ***Kortenski (1989) n.d.-no data
**Kostova et al. (1996) ****Pesheva-Sachkova (1979)

2. Kyustendil basin

The coal from Kyustendil basin is lignite. The vitrinite (huminite) reflectance (average from all measured samples) is R_r=0.30%. Average ash yield is A^d=36% (Pesheva-Sachkova, 1979). The macerals from the huminite group are about 81.50% (volume percent) ulminite is most abundant maceral (about 50%); texto-ulminite is ~15% and eu-ulminite is ~35% (Table 1, 2). Macerals from the liptinite group are about 5%; sporinite is 2.50% of this total. Macerals from the inertinite group are 3% (volume percent). Mineral matter is about 8%, and identified minerals are given in Table 5. According to the GWI=0.42 and VI=2.42, the peat bog was determined as ombrotrophic bog. With a TPI of 2.80, GI of 19.53 and high ash content, the peat bog probably originated in an intermittently dry forested swamp.

Table 2 Petrographic data for the studied low rank coal, calculated on the basis of organic matter.

3. Table 2 Low rank coal (organic matter)

Average, %	Sofia	Kyustendil	Katrishte	Oranovo	Chukurovo	Pernik
Rank	Lignite	Lignite	Lignite	Lignite	Lignite	Sub-bituminous-B
Rr	0.23	0.30	0.31	0.33	0.37	0.48
Textinite	11.49	5.43	0.01	0.00	16.95	4.35
Texto-ulminite	17.24	16.30	7.77	10.99	37.33	32.61
Eu-ulminite	22.83	38.00	14.41	33.23	20.70	43.42
Attrinite	11.49	14.13	7.77	14.83	3.45	5.43
Densinite	10.34	13.04	54.00	14.83	0.80	5.43
Gelinite	1.15	1.09	0.01	4.40	0.00	1.09
Phlobaphinite	3.49	2.17	1.10	2.20	4.90	1.09
Pseudo-phlobaphinite	1.15	1.09	1.10	1.10	0.72	0.00
Sporinite	4.60	2.78	2.22	3.30	0.13	1.09
Cutinite	1.15	0.01	0.01	0.01	0.13	0.01
Resinite	3.49	1.09	1.10	2.20	10.93	2.17
Suberinite	3.49	0.01	0.00	1.10	1.90	0.00
Alginite	1.15	0.50	0.01	7.69	0.13	0.01
Liptodetrinite	3.49	1.09	2.22	1.10	1.65	1.09
Fluorinite	0.00	0.00	1.10	0.82	0.00	0.00
Chlorophyllinite	0.00	0.00	0.00	0.00	0.01	0.00
Bituminite	0.00	0.00	3.03	0.00	0.00	1.09
Fusinite	1.15	1.09	1.10	0.00	0.01	0.01
Semifusinite	0.00	0.00	0.00	0.00	0.00	0.01
Macrinite	0.00	0.00	0.00	0.00	0.00	0.00
Sclerotinite	1.15	0.01	0.01	1.10	0.13	0.01
Inertodetrinite	1.15	2.17	3.03	1.10	0.13	1.09
Vitrinite group	79.18	91.25	86.17	81.58	84.85	93.42
Liptinite group	17.37	5.48	9.69	16.22	14.88	5.46
Inertinite group	3.45	3.27	4.14	2.20	0.27	1.12
Mire	Mesotrophic bog forest	Ombrotrophic bog	Mesotrophic bog forest	Ombrotrophic bog	Ombrotrophic bog forest	Mesotrophic bog forest

Katrishte basin

The coal from Katrishte basin is lignite. The vitrinite (huminite) reflectance is R_r=0.31%. Average ash content of the coal is A^d=32%. The macerals from the huminite group are about 77%, and densinite is the prevailing maceral, ~48% (Tabl. 1, 2). Macerals from the Liptinite group are about 9%, and bituminite is the prevailing maceral (3%). Fluorinite is about 1%, and it is associated with cutinite (Fig. 4). Inertinite macerals are 4% volume percents. Mineral matter is about 10%, and the list of minerals is given in Table 5. According to the GWI=0.80 and VI=9.80, the peat bog was determined as mesotrophic bog forest. According to the TPI=0.38 and GI=19.67, the origin of the peat bog was probably in slowly subsiding intermittently dry swamp from aerobically decomposed autochthonous plants or in redistributed as subaqueous sediment or in slowly subsiding relatively dry raised bog.

4. Oranovo-Simitli basin

The coal from the Oranovo-Simitli basin is lignite (Stach et al. 1982). The vitrinite (huminite) reflectance is R_r=0.33% and the average ash content is A^d=8.84%. The macerals from the huminite group are about 74.24%, liptinite group is 14.76% and Inertinite group is 2% (volume percent) (Table 1, 2). The maceral eu-ulminite is the most abundant maceral of the huminite group ~40%, with eu-ulminite predominating (~30%). Alginite is the most common maceral of the liptinite group (7%) (Fig. 3). Sporinite and resinite are very frequently observed macerals of that group (Fig. 3). The coal is very poor in inertinite macerals (nearly full absence of fusinite). The mineral matter, counted on the microscopic, is about 9% (Table 1). Fig. 3 shows framboidal pyrite, which is the prevailing type in the Oranovo coal.

The minerals found with other methods are listed in Table 5. According to the calculated maceral ratios of Calder et al. (1991) GWI=0.30 and VI=1.77, the type of the peat bog was determined as ombrotrophic bog. According to the TPI=3.14 and GI=78, the peat bog was probably originated in a forested, continuously wet raised bog, when low in ash (Diessel, 1992).

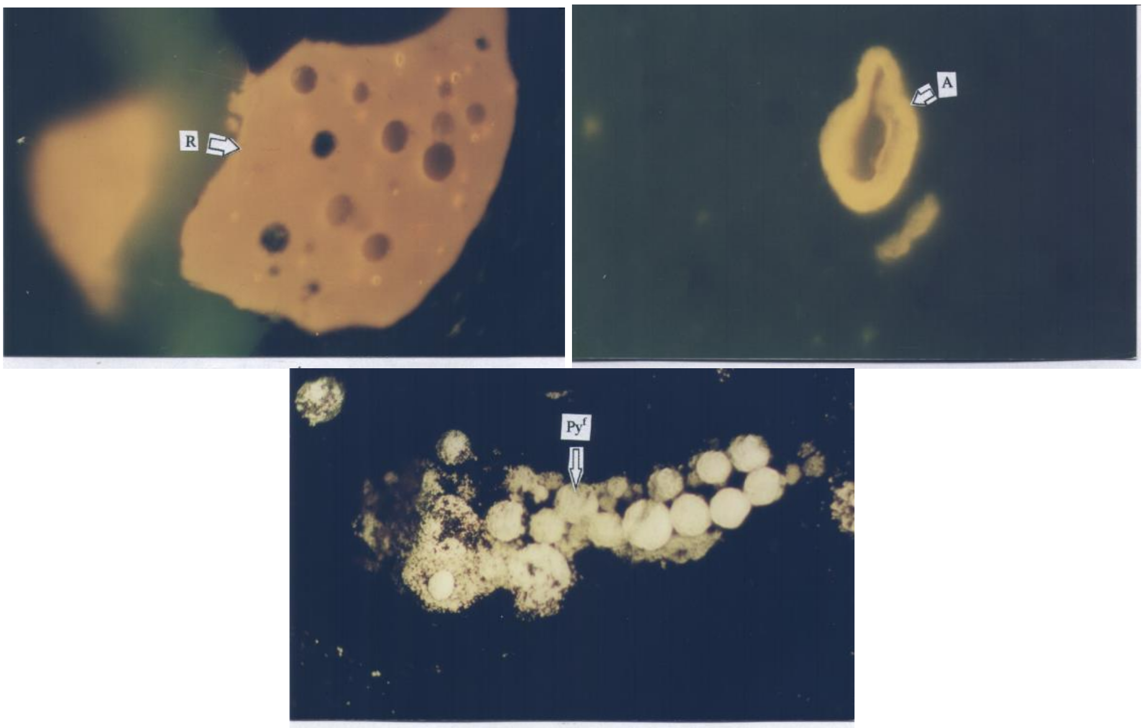
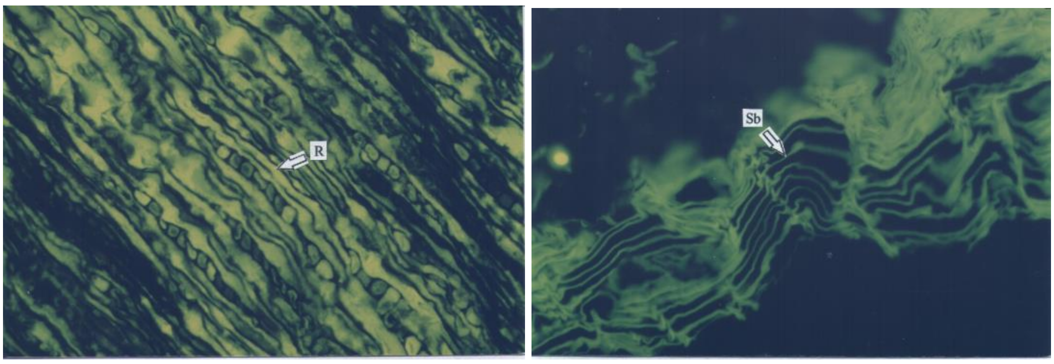


Fig. 3 Maceral content of the studied coal, fluorescent light, oil immersion: Resinite (R) (Oranovo basin), magnification x3600; Alginite (A) (Oranovo basin), magnification x1800; Framboidal pyrite (Py^f), reflected light, (Oranovo basin), magnification x1800.

5. Chukurovo basin

The coal from the Chukurovo basin is lignite. The vitrinite (huminite) reflectance is R_r=0.37%. The macerals from the huminite group are about 66.50%, liptinite group is about 14% and the inertinite group is below 1% (volume percent) (Table 1,2). Ulminite is very abundant. Very high amount of resinite in textinite cells was also observed in the coal (Fig. 4). Suberinite is a very frequently observed maceral from the liptinite group (1.86%) (Fig. 4). The mineral matter counted is about 3% and the identified minerals are listed in Table 5. According to GWI=0.10 and VI=22.35, the type of the peat bog was determined as ombrotrophic bog forest. The TPI=78.76 and GI=634.15 suggest, that the peat bog was originated in a forested peatland (telmatic swamp), when relatively high in coal ash, or in a forested, continuously wet raised bog, when low in ash.



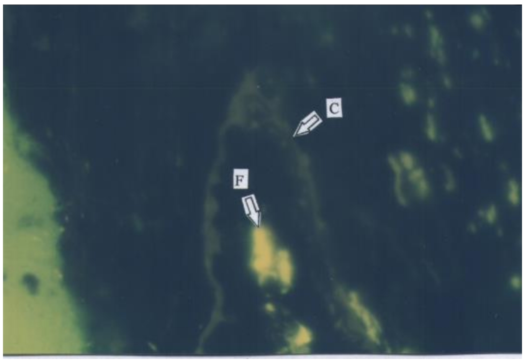


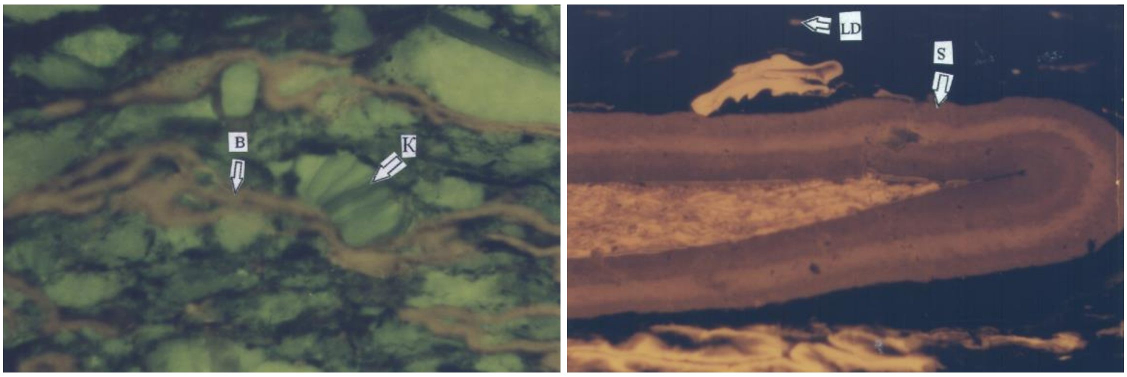
Fig. 4 Maceral content of the studied coal, fluorescent light, oil immersion: Resinite (R) into textinite lumens (Chukurovo basin), magnification x1800; Suberinite (Sb) (Chukurovo basin), magnification x1800; Cutinite (C), fluorinite (F) (Katrishte deposit), magnification x1800.

6. Pernik basin

The coal from Pernik basin is sub-bituminous-B, according to vitrinite (huminite) reflectance (R_r=0.48%). The average ash content is A^d=16.80% (Kostova et al., 1996). The macerals from the Huminite group are 85.95%, and ulminite (texto-ulminite+eu-ulminite) is nearly 70% (volume percent). Macerals from Liptinite group are about 5%, with resinite being the most abundant maceral (2%). Inertinite macerals average about 1%, represented mainly by inertodetrinite. Mineral matter, counted on the microscope, is about 8% and the minerals found in the coal are listed in Table 5. According to the GWI=0.07 and VI=9.90, the type of the peat bog was probably mesotrophic bog forest. According to the TPI=9.12 and GI=95.17, the peat bog was probably originated in a forested peatlands (telmatic swamp), when coal relatively rich in ash or in a forested continuously wet raised bog, when low in ash.

7. Dobrudja basin

The coal from the Dobrudja basin is high volatile A-bituminous, according to vitrinite reflectance R_r=0.79%. The ash content of the studied coal seam is A^d=21.40% (Nikolov, 1988). The macerals from the Vitrinite group are about 60.65% (volume percent) (Table 3,4) and desmocollinite is the predominant maceral (average 47.31%). Liptinite group macerals average are about 14.59% and tenui-sporinite is the most abundant maceral (average 12.39%) (Fig. 5). The macerals from the Inertinite group average 24.61% and degradofusinite is the prevailing maceral from that group. Mineral matter counted, is less 1%. The identified minerals are shown in Table 6. The calculated indices of the coal facies (GWI=0, VI=0.35, TPI=0.43, GI=2.55) suggest, that the type of the peat bog was determined as ombrotrophic bog and the peat bog was originated probably in a slowly subsiding, intermittently dry swamp from aerobically decomposed autochthonous plants or redistributed as subaqueous sediment or in slowly subsiding relatively dry raised bogs (Diessel, 1992).



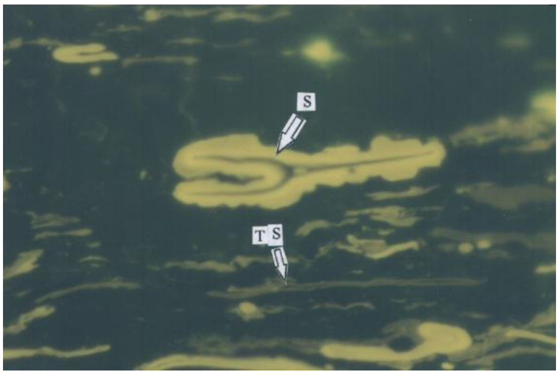


Fig. 5 Maceral content of the studied coal, fluorescent light, oil immersion: Migra-bitumen (B), kaolinite (K) (Dodrudja basin), magnification x1800; Macro-sporinite (S), liptodetrinite (LD) (Dobrudja basin), magnification x3600; Crassi-sporinite (S), tenui-sporinite (Dobrudja basin) (TS), magnification x 3600.

8. Balkan basin

The coal from Balkan basin is high volatile A-bituminous. The vitrinite reflectance is R_r=1.12% and the ash content is A^d=17.50% (Pesheva-Sachkova, 1979). The macerals from the vitrinite group average 71.57% (volume percent) and telocollinite is averages 46.80% (Table 3,4). Because of the very high coal rank, the macerals from the Liptinite group are about 1.83%, represented only by bituminite. Similar maceral distribution is reported by Sachsenhofer et al. (in review) for the coal of Barshanova mine – Donets basin (Ukraine). The macerals from the Inertinite group average 6.44% as pyrofusinite is prevailing (3.67%). The mineral matter is 20.16% (Table 6). The following values of the indices of the coal facies were calculated: GWI=0.38, VI=7.12, TPI=7.20 and GI=11.15. The type of the peat bog was probably ombrotrophic bog forest. The origin of the peat bog was in an intermittently dry forested swamp when high in ash or in a forested raised bog, when coal ash is low or moderate (Diessel, 1992).

Table 3 Petrographic data for the studied high rank coal, calculated on the basis of all matter.

Table 3 High rank coal (all matter)

Average, %	Dobrudja	Balkan	Svoge
Number samples	20	15	20
Rank	High volatile bituminous-A	High volatile bituminous-A	Anthracite/Meta-anthracite
Rr	0.79	1.12	4.89
Rmin	0.80	0.94	4.50
Rmax	0.83	1.29	5.64
Ash	21.40*	17.50**	27.50**
Tellinite	1.16	1.83	10.14
Telocollinite	12.12	46.80	81.04
Desmocollinite	47.31	4.59	0.00
Pseudo-Phlobaphinite	0.00	0.00	0.00
Vitrodetrinite	0.00	18.35	5.51
Phylovitrinite	0.05	0.00	0.00
Macro-sporinite	0.14	0.00	0.00
Tenui-sporinite	12.39	0.00	0.00
Crassi-sporinite	0.34	0.00	0.00
Cutinite	0.00	0.00	0.00
Liptodetrinite	1.67	0.00	0.00
Bituminite	0.00	1.83	0.00
Exsudatinite	0.05	0.00	0.00
Pyrofusinite	0.83	3.67	0.01
Semipyrofusinite	0.20	0.00	0.00
Degradofusinite	8.07	0.01	0.00
Semidegradofusinite	3.20	0.00	0.00
Macrinite	0.20	0.00	0.00
Semimacrinite	0.05	0.00	0.00
Sclerotinite	0.10	0.01	0.00
Sclerotinite-Plectenhiminite	0.39	0.00	0.00
Inertodetrinite	11.57	2.75	0.01
Vitrinite group	60.65	71.57	96.69
Liptinite group	14.59	1.83	0.00
Inertinite group	24.61	6.44	0.02
Mineral matter	0.15	20.16	3.29
GWI	0.00	0.38	0.02
VI	0.35	7.12	92.46
TPI	0.43	7.20	92.46
GI	2.55	11.15	97.97
Mire	Ombrotrophic bog	Ombrotrophic bog forest	Ombrotrophic bog forest

*Nikolov et al. (1988)
**Pesheva-Sachkova (1979)

Table 4 Petrographic data for the studied high rank coal, calculated on the basis of organic matter.

Table 4 High rank coal (organic matter)

Average, %	Dobrudja	Balkan	Svoge
Rank	High volatile bituminous-A	High volatile bituminous-A	Anthracite/Meta-anthracite
Rr	0.79	1.12	4.89
Tellinite	1.16	2.30	10.50
Telocollinite	12.12	58.59	82.00
Desmocollinite	47.46	5.75	0.00
Pseudo-Phlobaphinite	0.00	0.00	0.00
Vitrodetrinite	0.00	22.99	7.48
Phylovitrinite	0.05	0.00	0.00
Macro-sporinite	0.15	0.00	0.00
Tenui-sporinite	12.39	0.00	0.00
Crassi-sporinite	0.34	0.00	0.00
Cutinite	0.00	0.00	0.00
Liptodetrinite	1.67	0.00	0.00
Bituminite	0.00	2.30	0.00
Exsudatinite	0.05	0.00	0.00
Pyrofusinite	0.83	4.60	0.01
Semipyrofusinite	0.20	0.00	0.00
Degradofusinite	8.07	0.01	0.00
Semidegradofusinite	3.20	0.00	0.00
Macrinite	0.20	0.00	0.00
Semimacrinite	0.05	0.00	0.00
Sclerotinite	0.10	0.01	0.00
Sclerotinite-Plectenhiminite	0.39	0.00	0.00
Inertodetrinite	11.57	3.45	0.01
Vitrinite group	60.80	89.63	99.98
Liptinite group	14.59	2.30	0.00
Inertinite group	24.61	8.07	0.02
Mire	Ombrotrophic bog	Ombrotrophic bog forest	Ombrotrophic bog forest

Table 5 Mineral composition of the studied low rank coal.

Sofia Basin	**Kyustendil Basin**	**Katrishte Deposit**
Clay minerals, quartz, organogenic calcite, chalcopyrite, marcasite, massive pyrite, framboidal pyrite, euhedral pyrite, anhedral pyrite, illite, kaolinite, halloyzite, dolomite, anorthite, amphibole, augite, siderite, witherite, gypsum, melanterite, jarosite.	Framboidal Pyrite, massive pyrite, euhedral pyrite, marcasite, quartz, calcite, feldspar, kaolinite, illite.	Caly minerals, epigenetic calcite, quartz, chalcopyrite, framboidal pyrite, euhedral pyrite, infiltration pyrite, massive pyrite, illite, kaolinite, glauconite, nontronite, halloysite, anorthite, amphibole, natrolite, stilbite, augite, hypersthene, scapolite, arsenopyrite, skorodite, gypsum, melanterite, argentojarosite, hexahydrite, siderite, dolomite, witherite, kutnahorite, Fe-spinel, pyrargyrite, galena.
Dobrudja Basin	**Balkan basin**	**Svoge Basin**
Infiltration pyrite, euhedral pyrite, massive pyrite, singenetic carbonates, epigenetic carbonates, clay minerals, kaolinite, quartz,	Framboidal pyrite, massive pyrite, euhedral pyrite, clay minerals.	Framboidal pyrite, euhedral pyrite, clay minerals, epigenetic calcite.

mica.		

Table 6 Mineral composition of the studied high rank coal.

Oranovo-Simitli Basin	**Chukurovo Basin**	**Pernik Basin**
Framboidal pyrite, euhedral pyrite, infiltration pyrite,massive pyrite, marcasite, chalcopyrite, galena, albite, anorthite, analcime, kaolinite, sericite, illite, kammererite, montmorillonite, epidote, titanite, calcite, siderite, aragonite, witherite, dolomite, hematite, braunite, rutile, gypsum, apatite.	Framboidal pyrite, massive pyrite, euhedral pyrite, epigenetic calcite, clay minerals.	Framboidal pyrite, euhedral pyrite, clay minerals, siderite, epigenetic calcite.

9. Svoge basin

The coal from Svoge basin is anthracite and meta-anthracite, according to vitrinite reflectance R_r=4.89%. The average ash content is A^d=27.50% (Pesheva-Sachkova, 1979). Macerals of the Vitrinite group average 96.69% and telocollinite is the prevailing maceral (average 81.04%) (Table 3,4). The macerals from the Liptinite group are not represented, because of the very high coalification of the coal (Taylor et al., 1998). Inertinite macerals are less then 1%. The mineral matter counted, is 3.29% and a list of the identified minerals is shown in Table 6. According to the GWI=0.02, VI=92.46, TPI=92.46 and GI=97.97. The type of the peat bog was probably ombrotrophic bog forest and the peat bog was probably originated in a forested peatland (telmatic swamp), when relatively high in coal ash (Diessel, 1992).

Conclusions

Nine Bulgarian coal basins and deposits were sampled and studied for their maceral and mineral content. The type of the peat bogs of three coal basins was determined as ombrotrophic bogs, three coal basins were mesotrophic bog forests and three of them were ombrotrophic bog forests. There is an interesting order between the location of the basin and the type of the peat bog: Figure 1 shows the location of the studied basins in West Bulgaria from South direction to North direction: 1-Oranovo-Simitli (ombrotrophic bog), 2-Katrishte (mesotrophic bog forest), 3-Kyustendil (ombrotrophic bog), 4-Pernik (mesotrophic bog forest), 5-Chukurovo (ombrotrophic bog forest), 6-Sofia (mesotrophic bog forest), 7-Svoge (ombrotrophic bog forest). All three studied basins in North Bulgaria were ombrotrophic bogs: 7-Svoge (ombrotrophic bog forest), 8-Balkan (ombrotrophic bog forest), 9-Dobrudja (ombrotrophic bog). According to Calder et al. (1991), the ombrotrophic mires are solely rain-fed, the rheotrophic mires receive recharge from both groundwater and rainfall and the mesotrophic mires are intermediate classification tending toward ombrotrophic conditions. West Bulgaria has very complicated and various lithology, tectonics and geomorphology with mosaic view and therefore similar distribution of the bog types was established. North Bulgaria has very similar and uniform lithology, tectonics, and geomorphology, and therefore the established bog types were also very similar. There is not established relation between the rank of the coals, age, lithology of the coal-bearing layers and the type of the peat bogs.

Three basins have similar origins, without any relation between the location, age, lithology of the coal-bearing layers, type of the peat bog, or coal rank. The Pernik, Oranovo, Chukurovo and Svoge basins al originated in forested peatlands (telmatic swamps), when relatively high in coal ash and/or interbedded with mineral bands, and in forested, continuously wet raised bogs, when low in ash. The Sofia, Kyustendil and Balkan basins originated in intermittently dry forested swamps when high in ash, or in forested raised bogs, when coal ash is low or moderate. The Dobrudja basin and Katrishte deposit are originated in slowly subsiding, intermittently dry swamps from aerobically decomposed autochthonous plants, redistributed as subaqueous sediment or in slowly subsiding relatively dry raised bogs.

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