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Organic petrology as a tool for peat-forming environmental reconstructions: insights from Suhostrel and Bobov Dol coals, SW Bulgaria

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Органичната петрология като инструмент за реконструкция на торфообразуващата среда на примера на въглищата от Сухострелското и Бобовдолското находище, Югозападна България

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Резюме. Петрографският състав на проби от въглищни находища Сухострел и Бобов дол е изследван с помощта на оптична микроскопия. Процентните съдържания на установените мацерали са използвани за изчисляване на мацерални съотношения, които са интерпретирани по отношение на условията на торфообразуващата среда. Петрографският състав на сухострелските въглища е съвместим с наличните данни за геохимичната характеристика на органичното вещество и подсказва за торфонатрупване в рамките на оводнено, топогенно, мезо- до реотрофно торфено блато, залесено с преобладаващо нискостеблена сухоземна и водна растителност и единични дървесни видове. Диаграмите на въглищния фациес за въглищата от Бобов дол обаче не предоставят възможност за еднозначна интерпретация на торфообразуващата среда, поради което не са подходящи за самостоятелно използване при реконструкциите на условията на образуване.

Ключови думи: ЮЗ България, Сухострелско и Бобовдолско въглищни находища, органична петрология, въглищен фациес.

Abstract. The petrographic composition of samples from Suhostrel and Bobov Dol coal deposits was studied using optical microscopy. The maceral contents were further used to calculate maceral ratios which were interpreted in terms of environmental condition during peat deposition. Petrographic data of Suhostrel coal is compatible with its organic geochemical characteristics and indicate peat formation under inundated topogenous, meso- to rheotropic, sparsely forested marsh- or fen-type environment. Coal facies diagrams for Bobov Dol coal, however, provide contradictory depositional settings and therefore cannot be used alone for environmental reconstruction.

Keywords: SW Bulgaria, Suhostrel and Bobov Dol coal deposits, organic petrology, coal facies.

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Introduction

Organic petrographic data of coals of various age and coalification rank are widely used worldwide to denote the relative contribution from different plant groups (i.e., woody vs. non-woody plants) or for evaluation of the environmental settings during peat formation. Numerous indices based on the concept of facies-critical macerals (Diessel, 1986), are applied in coal studies for the above purposes and their comparison with coals of known depositional environments provides a way to deduce the conditions of peat-formation.

In this short note, we used the coal facies concepts devised by Diessel (1986), Calder et al. (1991), and Mukhopadhyay (1989) for two coal deposits (i.e., Bobov Dol and Suhostrel coals) from SW Bulgaria in order to evaluate the environmental conditions during peat formation.

Geological settings

The Suhostrel deposit is a small bituminous coal deposit of Early–Mid Eocene age, located within a small area along the southern margin of the Padesh Graben. The deposit comprises three 0.2–0.6 m thick coal seams (seams I to III from bottom to top) with highly varying thickness and spatial distribution, representing seam splits from a locally up to 1.8 m thick coal seam.

The Bobov Dol deposit is the largest sub-bituminous coal deposit in SW Bulgaria. The Late Oligocene coal-bearing Bobov Dol Fm. is up to 100 m thick and contains up to 14 coal seams, among which only 6 (numbered I to VI from base to top) were considered economically significant. Seam I^a located beneath the first widespread coal seam (I) was also locally mined despite the poor quality of the coal.

Methods

Eighty-three sub-bituminous coal and 5 carbonaceous shale samples representing seams I^a, I, II^{a+b}, III, IV, and V from the Bobov Dol Basin, together with 19 bituminous coal samples representing seams I, II and III in the Suhostrel deposit, and ten additional samples with uncertain seam assignment from the same deposit, were characterized petrographically under reflected white and blue excitation light using Leica DM 2500 P microscope. Maceral percentages were used to calculate the Tissue preservation index (TPI), Gelification index (GI), Vegetation index (VI), Ground-water index (GWI), and parameters A, B and C, using the following formulas:

$$TPI = \frac{telohuminite/telovitrinite + corpohuminite/corpogelinite + fusinite + semifusinite}{detrohuminite/detrovitrinite + gelinite + macrinite}$$

$$GI = \frac{ulminite(collotelinite) + densinite(collodetrinite) + corpohuminite(corpogelinite) + macrinite}{textinite(telinite) + attrinite(vitrodetrinite) + fusinite + semifusinite + inertodetrinite}$$

$$VI = \frac{telohuminite(telovitrinite) + resinite + suberinite}{detrohuminite(detrovitrinite) + (inerto + lipto)detrinite + sporinite + cutinite + fluorinite + alginite}$$

$$GWI = \frac{gelohuminite(gelovitrinite) + densinite(collodetrinite) + terrigenous\ mineral\ mater}{telohuminite(telovitrinite) + attrinite(vitrodetrinite)}$$

$$A = telohuminite(telovitrinite) + corpohuminite(corpogelinite) + sporinite + cutinite + resinite + suberinite + fluorinite$$

$$B = detrohuminite(detrovitrinite) + gelinite + liptodetrinite + alginite$$

$$C = inertinite$$

Results and discussion

Detailed petrographic data of Suhostrel and Bobov Dol coals is presented in Figure 1.

The coals from both deposits are humic and are predominantly composed of huminite/vitrinite macerals (avg. 95.7 vol.% and 86.5 vol.%; mineral matter-free, mmf), followed by liptinite (avg. 4.2 vol.% and 11.9 vol.%, mmf) and very low inertinite (avg. 0.1 vol.% and 1.5 vol.%, mmf for Suhostrel and Bobov Dol coals respectively; Fig. 1). In both coals telohuminite/telovitrinite (avg. 38.0 vol. % and 36.3 vol. %) and detrohuminite/detrovitrinite (avg. 56.7 vol.% and 37.2 vol.%, mmf) predominate, although proportions vary significantly between individual samples. Gelohuminite/gelovitrinite, represented almost exclusively by corpohuminite/corpogelinite (avg. 1.0 vol.% and 4.6 vol.%, mmf) and minor porigelinite in Bobov Dol coal (avg. 0.8 vol.%, mmf), is present in subordinate amounts. Based on the morphology and local association with cutinite, collotelinite in Suhostrel coal can mostly be linked to leaf-derived tissues (phyllovitrinite). Similar phyllohuminite remains were also detected in many samples from Bobov Dol deposit (avg. 7.5 vol.%, mmf) but are especially abundant (up to 29 vol.%, mmf) in samples from seams I[a], I, and III. Wood-derived tissues, mostly represented by ulminite with various degrees of impregnation by resinous substances, are also typical for Bobov Dol coal but are extremely rare in Suhostrel coal. Among the detrohuminite/detrovitrinite sub-group, both attrinite/vitrodetrinite and densinite/collodetrinite are abundant in the studied samples, but proportions mostly depend on the contents of the mineral matter.

Liptinite macerals in Suhostrel coal are mostly represented by microsporinite, cutinite, locally resinite and liptodetrinite, whereas in Bobov Dol coal cutinite, often in association with fluorinite in phyllohuminite, and resinite and exsudatinite occurring as cell infillings, are the most abundant macerals. In both deposits alginite is rare.

Macerals from the inertinite group, mostly represented by funginite and locally inertodetrinite, occur sporadically. Only in two samples from seams I and III in Bobov Dol deposit, inertinite is more abundant (up to 13.6 vol.%, mmf), but in both cases the macerals are of allochtonous origin, as evidenced by their association with mineral-rich partings.

The mineral matter in both deposits is dominated by terrigenous clay minerals and locally quartz (avg. 16.5 vol.% and 16.1 vol.% for Suhostrel and Bobov Dol coals respectively), typically finely dispersed within the organic groundmass or forming micrometer-sized mineral-rich bands. Framboidal and euhedral diagenetic pyrite (1.9 vol.%) are commonly detected in Bobov Dol coal, whereas in Suhostrel samples pyrite commonly associates with minor siderite and is partly of epigenetic origin.

Because of the predominance of detrovitrinite in most Suhostrel samples, both tissue preservation index (TPI) and vegetation index (VI) are generally low, with values ranging from 0.1 to 3.2 (avg. TPI and VI = 0.8), indicating enhanced humification of the plant tissues and/or contribution from plant remains with poor preservation potential. The gelification index (GI) is >1 for most of the samples (0.3–141.0; avg. 11.7), whereas the groundwater index (GWI) is generally low (0.3–7.2; avg. 1.4). On the TPI vs. GI (Fig. 2a) and VI vs. GWI (Fig. 2c) facies diagrams, most Suhostrel samples are concentrated in the areas of limnic to limno-telmatic environments, indicating likely peat formation under inundated topogenous, meso- to rheotropic marsh- or fen-type environment. Only three samples with higher contents of woody tissues fall within the area of the wet forest swamp environment (Fig. 2a), thus suggesting that the mire might have been sparsely forested. Similar conclusions can also be drawn using the ABC triangular facies diagram (Fig. 2e; Mukhopadhyay, 1989). Such environmental interpretation of the peat-forming conditions within the Suhostrel deposit is compatible with the recent organic geochemical data (Zdravkov et al., 2023), which denote major contribution from aquatic macrophytes and angiospermous plants, deposited under reducing marginal-aquatic settings.

In Bobov Dol coal, the highly varying proportions of telohuminite and detrohuminite result in significant scatter of TPI (0.1–210.0; avg. 4.6), VI (0.1–254.0; avg. 5.5) and GI (0.3–241.0; avg. 9.2). The scatter is well presented on the TPI-GI diagram with ~36 % of the samples falling within the area of the forested swamps, ~18 % of the samples plot under inundated marsh-/fen-type environment, and ~46% of the samples plot within the limno-telmatic but less inundated environment (Fig. 2b). Because of the low amounts of terrigenous mineral matter, the GWI is very low for most of the samples (0.1–0.9; avg. 0.3) and result in plotting of almost all samples within the area of oligo- to mesotrophic mires (Fig. 2d). In combination with the relatively

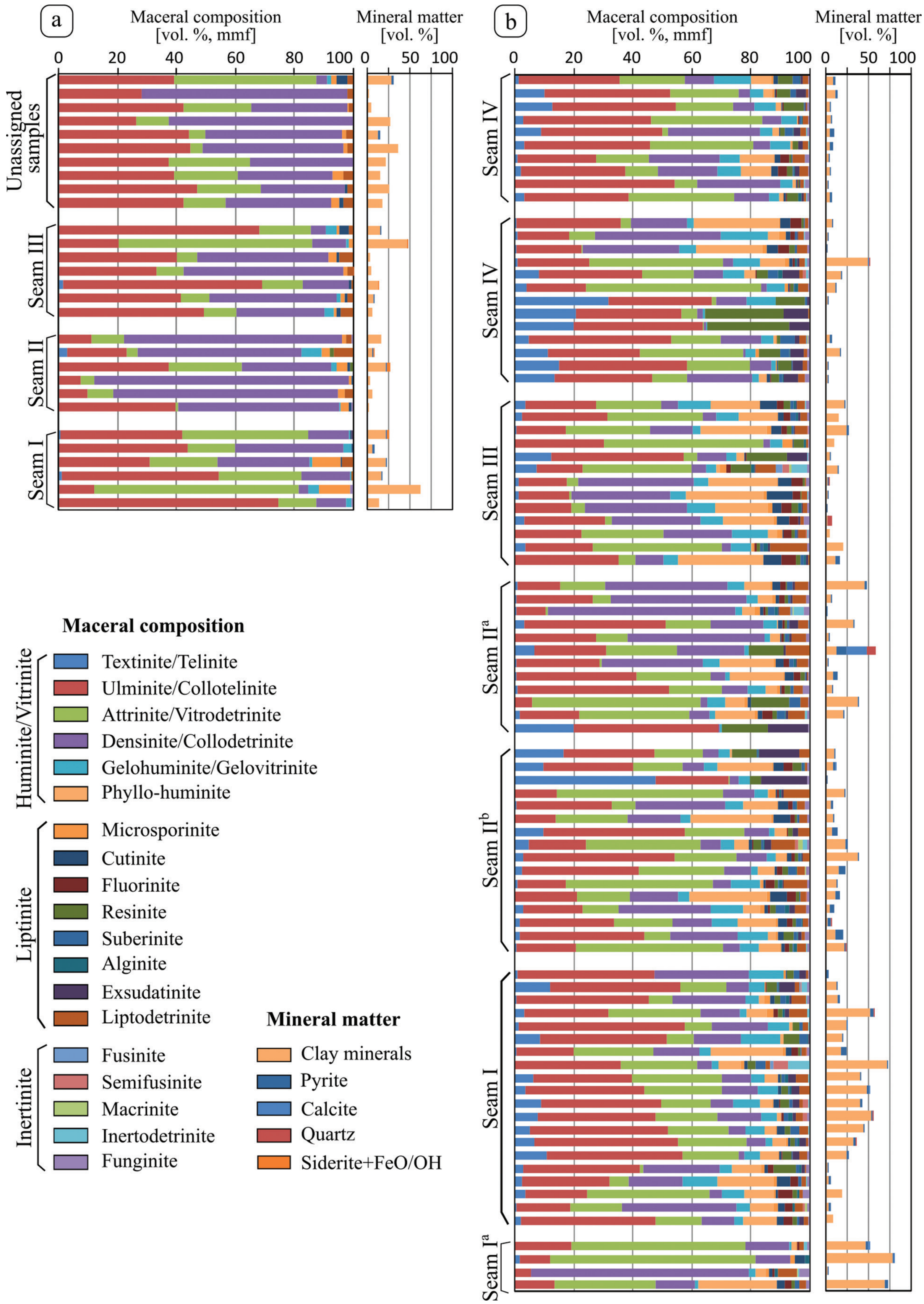

Fig. 1. Maceral composition (mineral matter-free, mmf) and mineral matter content of Suhostrel (a) and Bobov Dol (b) coals

Фиг. 1. Мацерален състав (на база суха безпепелна маса) и съдържание на минерални примеси във въглищата от Сухострелското и Бобовдолското находище

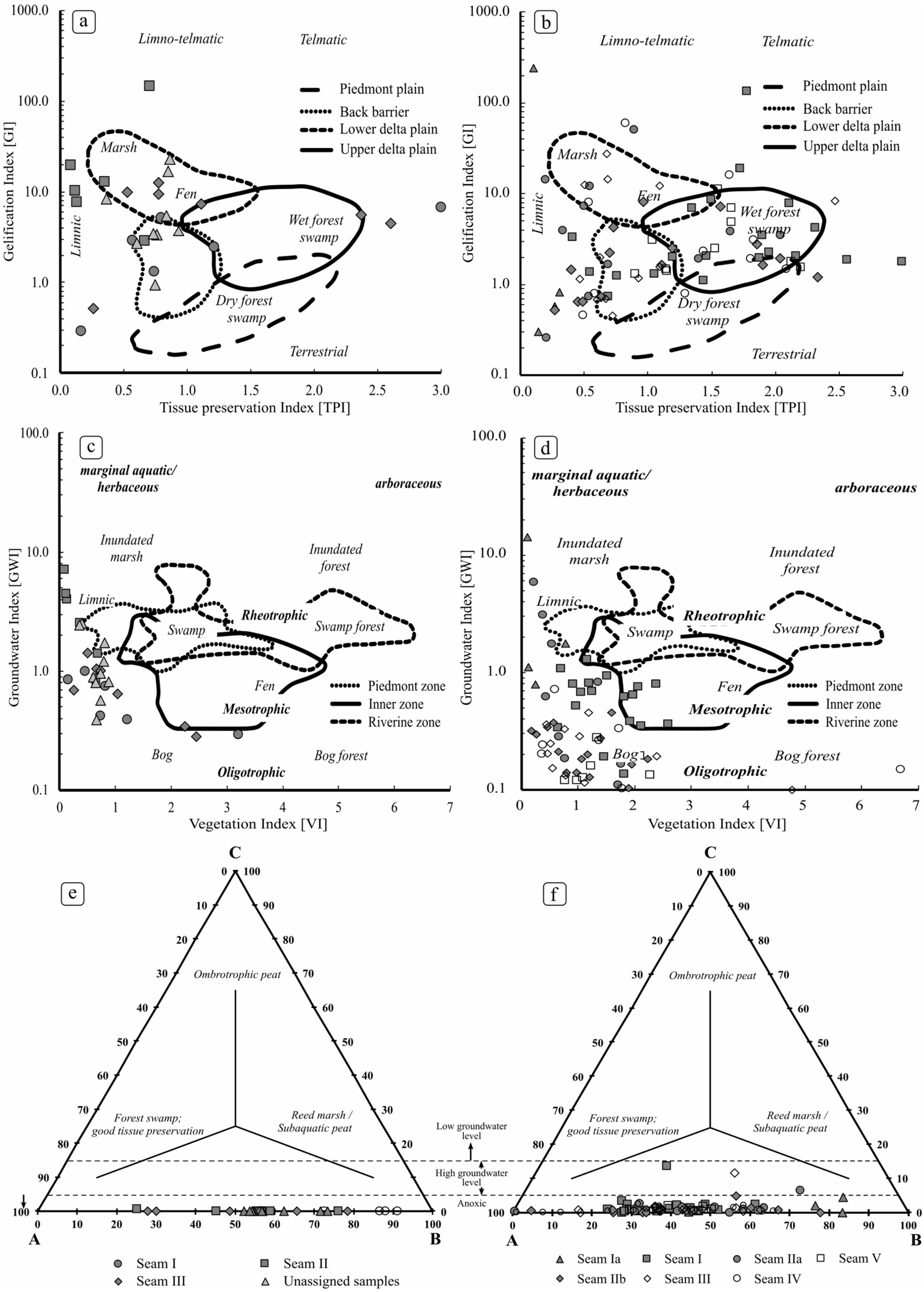

Fig. 2. Coal facies diagrams after Diessel (1986) (*a* and *b*), Calder et al. (1991) (*c* and *d*), and Mukhopadhyay (1989) (*e* and *f*) for Suhostrel and Bobov Dol coals respectively

Фиг. 2. Диаграми на въглищния фациес по Diessel (1986) (*a* и *b*), Calder et al. (1991) (*c* и *d*) и Mukhopadhyay (1989) (*e* и *f*) за въглищата от Сухострелското и Бобовдолското находище low VI values this indicates possible peat formation within a sparsely forested fen or marsh with rather limited nutrient supply. Such interpretation, however, is incompatible with the petrographic data, which indicate presence of wood-derived tissues in all studied samples. Moreover, both the ABC (Fig. 2f) and the TPI-GI (Fig. 2b) facies diagrams suggest a more probable environment characterized by the presence of tree islands within more or less inundated fen. This discrepancy is further emphasized if organic geochemical data is also accounted. Recent data (Zdravkov et al., 2023) indicate that the biomarker composition of Bobov Dol coal is almost completely dominated by gymnosperm-derived sesqui- and diterpenoids, whereas the angiosperm-derived biomarkers appear in very low amounts. It is, therefore, obvious that the facies interpretation based on the petrographic data alone fails to correctly identify the peat-forming environment. Considering both petrographic and organic geochemical data, it seems more likely that Bobov Dol coals deposited under densely forested habitats dominated by coniferous plants, with the low TPI and VI in many of the samples most probably resulting from enhanced humification of the woody tissues due to low burial rate and/or changes in the hydrological regime.

Conclusions

Organic petrographic data from coal samples from Suhostrel and Bobov Dol deposits is used to interpret the peat-forming depositional settings. The coal facies diagrams for Suhostrel deposit indicate peat deposition under inundated topogenous, meso- to rheotropic, sparsely forested marsh- or fen-type environment, which is compatible with the organic geochemical data for that coal. For Bobov Dol deposit, the facies diagrams provide contradicting environmental interpretation, which is further not supported by the organic geochemical data, thus indicating that petrographic data alone should be treated with caution.

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