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Studies of the coal facies in Eastern Ukraine

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Abstract

This article is a short review concerning the knowledge of petrographic compositions and origins of the diverse age coals in the eastern Ukraine regions, i.e. the Carboniferous age coals of the Dnieper–Donets Basin and the same age coals of the Donets Basin one as well as the Paleogene coals of Dnieper Brown Coal Basin. It was concluded that the coal-forming conditions depend on the geotectonic situations of the above basins.

Keywords: Coal; Carboniferous; Paleogene; Neogene; Petrography; Genesis

1. The Donets Coal Basin

The Donets Coal Basin, part of the Paleozoic Don-Dnieper Depression, is located at the southern margin of the East-European Platform. The basin contains thick Paleozoic, Mesozoic and Cenozoic sedimentary rocks unconformably overlying the Precambrian igneous and metamorphic rocks. The Middle Carboniferous (Pennsylvanian) deposits contain numerous economic coal seams.

The first geological studies started in the beginning of 19th century. The first critical contributions to investigations of coals were presented by Zhenzhurist (1884), Zalessky (1914) and Meffert and Krym (1926). In succeeding years, Mayer (1930), Sverdel and Zhemchuzhnikov (1935) and Pogrebitsky (1937) continued the studies of coals. Yergolskaya (1937) discovered the relation between the degree of metamorphism and structural features of coals. Zhemchuzhnikov (1934) subdivided coals into two types—the lustrous and the semi-lustrous clarain coals.

"The geological–chemical map of the Donbas" was published in 1941. This book contains the results of petrographic studies and chemical features of coal and X-ray mineralogy. Shkurenko (1941) noted in this paper that coal seams of Donbas are clarains, with less common transitions to durain. Fux and Zaitseva (1941) showed that coal seams were formed in uniform autochthonous environments.

Vidavsky and Ryabokoneva (1941) introduced the term "reduction" to explain the variation of chemical, physical and petrographical features of equally metamorphosed coals. The term "reduced" may correspond to the notion of bituminization due to nature of change of organic matter to a higher concentration of carbonaceous compounds. A process of formation of different "reducted" coals is

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linked with different facies conditions of peat accumulation rather than the bituminization, that is part of coalification.

The coals of the Donets Basin were subdivided into five types by reduction ratio. Reduction ratio of coals was investigated by petrographic, geo-genetic, paleobotanical and chemical aspects. Bogolyubova and Yablokov (1951) were the first to show that more "reduced" coals are xylite-vitrain coals. Zhemchuzhnikov (1965) and Sarbeeva (1970, 1975) stated that coals of all rank contain all types of coal by reduction ratio. The "reduced" coals are characterized by xylo-vitrain structure and orange–red color of vitrinite in transmitted light. Timofeev (1952) explained the formation of more "reduced" coals by subsidence of peat-bogs. Zhemchuzhnikov et al. (1960) noted that marine water is responsible for the antiseptic environments. Zhemchuzhnikov (1965) determined the relation between the "reduced" and original plant material.

In the post-war period, many systematic and synthetic works were performed. They summarized the results obtained from an intensive borehole exploration program and huge amount of previously derived data. The most important and interesting results are published by Bogolyubova and Yablokov (1951), Samoylovich et al. (1954), Timofeev (1952), Botvinkina and Zhemchuzhnikov (1956) and Usacheva and Samoylovich (1954).

Valts et al.'s (1952) investigation of coals in thin doubly polished sections in transmitted light made it possible to study coals of different levels of coal metamorphism up to anthracites.

Bogolyubova and Yablokov (1951) and Bogolyubova (1956) separated the clarain coals into two categories: (1) coals with xylite-vitrinite gelified plant matter; (2) coals with homogeneous gelified plant matter. Timofeev (1952) explained the formation of different coal types in coal seams by conditions of sedimentary deposition.

The "Atlas of coal microstructure of the Donets Basin" (Yablokov et al., 1955) was the result of investigation of many years and a huge amount of data.

In 1956, a new classification of coal types and terminology of microcomponents of humic coals was proposed by Valts (1956). This classification took into account the preservation, rank, structure and genesis of coals.

The discovery of the coal deposits in the Lower Carboniferous (Mississippian) in the Southern Donbas is a success in geological investigations. The results of long-standing petrographical investigation of Lower (Mississippian) and Middle (Pennsylvanian) Carboniferous coals were reviewed in the 1950s and 1960s (Berdyukova et al., 1964; Inosova, 1963; Yablokov et al., 1955; Feofilova and Levenshtein, 1963). These papers presented the coals petrographic composition, the comparison between the condition of coal accumulation during Lower Carboniferous (Mississippian) and the condition of coal accumulation during Middle Carboniferous (Pennsylvanian).

The study of original plant material and the coal petrographical investigations were simultaneous. Zalessky (1914) discovered the existence of exinite vessel and the wood fragment in coals. Snigirevskaya (1958, 1964) studied the morphology of mineralized tissue remains from coal ball. Inosova (1963, 1969), Lapo (1970) and Novik (1968) described the plant tissues of different botanical origin in the coal of Lower (Mississippian) and Middle (Pennsylvanian) Carboniferous, and the remains of fructification organs dominant in the composition of the Lower Carboniferous (Mississippian) coals. Uziyuk (1969, 1970, 1990) described microstructures of vitrinised tissues from the cortex of Bothrodendron, Sigillaria and Lycopsids. These investigations made it possible to use the original plant material of coals for coal seams correlation.

Identification and properties of plant tissues in small fragments of vitrinite, classification were published by Lapo (1976). Drozdova et al. (1971), Vyrvich (1967) and Vyrvich and Lapo (1970) recognised a wide variety of anthracites, and identified a relationship between the structure of the original plant material and the chemical and physical properties of coals. The Carboniferous flora consists of lycopsids, pteridosperms and arthrophytes (Inosova, 1979). Uziyuk and Ignatchenko (1985) generalised the results of identification of plant material of Lower (Mississippian) and Middle (Pennsylvanian) Carboniferous coals. They also described microstructures of vitrinite.

Zhemchuzhnikov (1934) and Naumova (1937) started the investigation of miospores from the coal-bearing strata. Inosova (1969, 1979) described the detailed fructification organs and distinguished

them by their morphologic features. Inosova et al. (1979) published an atlas of miospores and pollen of the Upper (Pennsylvanian) Carboniferous, currently used for correlation of stratigraphic sections of the Carboniferous.

Lately a comparative analysis of facies conditions and corresponding petrographic types of coal was made for some coal-bearing basin of Ukraine (Ivanova and Zaitseva, 1997; Ivanova et al., 1999a,b, 2001).

2. The Dnieper–Donets Depression

The Dnieper–Donets Depression (DDD) together with the Western Donbas, which is located on its southeastern side, is the great regional structure (subgeosyncline) in the southern part of the East-European Platform. It is situated between the folded Donbas in southeast and the Pripyat River in the northwest. The sedimentary rocks range in age from Devonian through Quaternary. The Devonian, Carboniferous, Mesozoic and Cenozoic coal seams are of commercial thickness.

Stepanov (1932) demonstrated that the coal-bearing strata of the Donets Basin expand to the West beyond the old industrial Donbas. This idea is based on the Karpinsky's concept of the paleogeography and tectonics of the southern part of the East-European Platform. The Western Donbas was studied first because the coal seams of economic thickness had been discovered there in the Lower (Mississippian) Carboniferous strata. The first period (1950–1965) included the investigations of the petrographical, chemical, and technological properties of coals, which favoured more thorough research of coal properties and elucidation of coal genesis and metamorphism. The results of these re-evaluations were summarized in two monographs (Alymov et al., 1963; Berdyukova et al., 1964). The condition of the formation of the coal-bearing strata, the structure of coal seams, chemical and technological properties, original plant matter, microcomponent composition of coals, the structure of coal seams and the properties depending on initial conditions of coal formation were determined.

Feofilova and Levenshtein (1963) indicated that the Lower (Mississippian) and Middle (Pennsylvanian) Carboniferous coal-bearing deposits are part of different coal-bearing formations. The Lower Carboniferous Formation was part of the platform development, as demonstrated by the quartz composition of rocks, presence of kaolin and by the fines grain sizes of deposits, etc. During the Middle Carboniferous (Pennsylvanian), this territory was a huge alluvial plain with well -developed river valleys and a distant source of sediments. Alluvial sandstones and marine, terrigenous and carbonate rocks are common here. Since 1965, the studies have been connected with geological-prospecting surveying for coal measures in the Western Donbas. During the first period, petrographic, chemical and technological properties of coals were studied. Volkova and Stsepinskaya (1972) established the connection between the petrographical and chemical composition of coals and conditions of their formation. Uziyuk (1981) made detailed description of stratification and sample-by-sample correlation of the coal seams by the geological–petrographical method. Teteryuk (1984, 1988) investigated the condition of the peat accumulation by the palynological method. Ivanova and Krivega (1985) studied salt coals, including their quality and conditions of formation on the basis of analysis of the chemical and geological data. She proved that the salting took place during the diagenesis stage. Shulga (1981) determined the facies and the genetic types of the Lower Carboniferous deposits by the method of the formation analysis.

The accumulation of information about the coal-bearing strata of DDD provided the results of the oil and gas prospects of the Western Donbas. Kovalev (1963) was the first to summarise these data on the DDD. Later, Ignatchenko et al. (1979) summarised the data on the coal-bearing Carboniferous formations. The first studies on the petrography and metamorphism of coals were done by the latter authors. All petrographical studies were made on thin and polished sections in transmitted light. The studies were the basis for the classification of coal components and coal types and led to the concept of the coal genesis for the Lower (Mississippian) and partly Middle (Pennsylvanian) Carboniferous.

Shyrokov and Savchuk (1983) represented the formational analysis of the coal-bearing Carboniferous deposits of the DDD. Shulga et al. (1987) characterised the lithogenetic types and facies of the

Lower Carboniferous (Mississippian) coal-bearing deposits of the Western Donbas. Original plant material was investigated with the phyteral method for the entire DDD. Later studies of chemical and petrographical composition of the Lower (Mississippian) and Middle (Pennsylvanian) Carboniferous coals are given in the papers of Ignatchenko et al. (1986) and Radzivill et al. (1990). Byk and Bartoshinskaya (1988) studied the chemical composition of inorganic matter, petrographic composition of coals and formation of coal seams at great depth.

The Paleogene and Neogene coal-bearing strata occur locally in the DDD and the northwestern Donbas. This region is known as the Dniepro-Donetsk Brown Coal Area. During the period of 1950–1970, the fundamental investigations of brown coals and features of their accumulation were conducted. Systematic studies of coal petrography have been conducted since 1965 (Mikhelis, 1971, 1984; Kiryukov, 1973; Ignatchenko and Zaitseva, 1980). The most complete summary of the coal petrographic studies was done by Ignatchenko and Zaitseva (1980). They worked out the classification of organic microcomponents, made petrographic characterizations, and identified the coal types. They characterised the initial plant matter and nature of its transformation in conditions of peat bogs and early diagenesis. The palynological studies of Mikhelis et al. (1970) and Mikhelis (1971) were used to understand the coal genesis and for the correlation of coal seams.

3. The Dnieper Brown Coal Basin

The Dnieper Brown Coal Basin is situated at the Southern margin of the East-European Platform within the limits of the Ukrainian Shield. In this area, the Mesozoic sedimentary rocks occur in a limited area and the Cenozoic rocks occur everywhere. The Buchak Formation of the Middle Eocene contains coal seams of industrial importance.

The Dnieper Brown Coal Basin was mentioned for the first time in the second half of the 19th century and was the object of intensive geological and geophysical investigations in 1930–1950. These investigations were accompanied by paleogeographical, paleobotanical, petrographical, chemical, and technological studies, which facilitated revealing features of coal accumulation conditions and contributed to the knowledge of coal origin and coal quality. Studying facies conditions of the Buchak Peat Formation was the main problem. According to most investigators (Chervinsky, 1939; Nagorny, 1970; Radzivill et al., 1987), the coal accumulation took place in the ancient river valleys and communicating lakes. Other authors considered that the formation of brown coal deposits was connected with depressions as lake basins in the crystalline basement (Syabryaj, 1959) or with swampy marine plains and depressions as river valleys in the crystalline basement (Nesterenko, 1956). In accordance with Slenzak (1946), Ignatchenko and Zaitseva (1981) stated that the peat accumulation occurred in the littoral zone. Valts and Chyrvinskaya (1940) studied the coal petrographic composition and coal genesis between 1934 and 1940. They proposed the first classification of brown coals. The petrographical, paleobotanical and palynological investigations of Rotman (1956), Agulov (1962), Kiryukov (1960) and Nesterenko (1952) have shown that initial coal material is represented mostly by arborescent vegetation. The types of phytocenos (plant community) were distinguished by combination of spore and pollen assemblages. The detailed macroscopic description of coals in transmitted light and classification of organic microcomponents were done by Syabryaj (1958, 1959), Agulov et al. (1960), Nesterenko (1963) and Radzivill et al. (1987). The quantitative ratio of lignin-cellulose and liptinite were used for the identification of two classes of coals: humite and humite-liptobiolite.

The coal types were determined taking into account structural–textural features and degree of gelification and dwarfing of plant tissue. The increased content of mineral salts was used for the identification of one more type of coal-ash coal.

In the 1970s and 1980s, the studies of Dnieper Basin coals were rather intensive. Ignatchenko and Zaitseva (1978), Mikhelis and Drozdova (1979) and other authors studied the conditions of accumulation and formation of coals, and the processes of transformation of plant matter at the peat and brown coal stages. They characterized the coals by a combination of megascopic features, and also proposed advanced classifications of microcomponents and coal types. Ignatchenko and Zaitseva (1981, 1984)

Table 1
Eastern Ukrainian coal basins

Author	Method	Depositional environment	Age/area	ASTM rank
DDD and Western Donets Coal Basin (W. DONBAS)				
Savchuk (1955)	petrology, sedimentology		Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Berdyukova et al. (1964)	petrology, sedimentology, paleobotany, organic geochemistry	fluvial, marine	Lower Carboniferous (Mississippian)/ DDD, W. Donbas	subbit-lvb
Volkova and Stsepinskaya (1972)	petrology, sedimentology, organic geochemistry		Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Shulga (1981)	sedimentology	fluvial, marine influence	Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Uziyuk (1981)	petrology, paleobotany		Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Teteryuk (1984, 1988)	palynology, paleobotany, paleoecology	marine, fluvial	Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Shulga et al. (1987)	petrology, sedimentology, thyteral	marine, fluvial	Lower Carboniferous (Mississippian)/ DDD, W. Donbas	hvb
Byk and Bartoshinskaya (1988)	petrology, sedimentology		Lower Carboniferous (Mississippian)/ DDD	hvb
Alymov et al. (1963)	petrology, sedimentology, organic geochemistry	marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD, W. Donbas	subbit-hvb
Kovalev (1963)	sedimentology, organic geochemistry		Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD	subbit-hvb
Ignatchenko et al. (1979)	petrology, sedimentology, organic geochemistry	fluvial, marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD W. Donbas	subbit-san
Ivanova and Krivega (1985)	petrology, sedimentology,	marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD, W. Donbas	subbit-hvb
Ignatchenko et al. (1986)	petrology, organic geochemistry	fluvial, marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD	hvb
Ivanova et al. (1988)	petrology, sedimentology	fluvial, marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD W. Donbas	subbit-an
Ivanova and Zaitseva (1997)	petrology		Lower, Middle Carboniferous (Mississippian–Pennsylvanian)/DDD, W. Donbas	hvb-lvb
Donets Coal Basin (DONBAS)				
Feofilova and Levenshtein (1963)	petrology, sedimentology	fluvial, marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)	hvAb-san
Inosova (1963, 1969, 1979)	petrology, palynology, paleobotany	marine	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)	subbit-an
Novik (1968)	paleobotany		Lower, Middle Carboniferous (Mississippian–Pennsylvanian)	
Inosova et al. (1979)	petrology, paleobotany, palynology		Lower, Middle Carboniferous (Mississippian–Pennsylvanian)	hvCb-an
Ivanova et al. (1999a,b, 2001)	petrology, organic geochemistry, sedimentology	marine, limnic, fluvial	Lower, Middle Carboniferous (Mississippian–Pennsylvanian)	hvb-lvb
Yergolskaya (1937)	petrology	marine	Middle Carboniferous (Pennsylvanian)/ Almazno-Marievsk area	hvAb-mvb

(continued on next page)

Table 1 (*continued*)

Author	Method	Depositional environment	Age/area	ASTM rank
Bogolyubova and Yablokov (1951)	petrology	marine	Middle Carboniferous (Pennsylvanian)/ Donbas South–West	hvb-hvAb
Ishchenko (1952, 1955)	petrology, sedimentology	marine	Carboniferous	mvb
Timofeev (1952, 1956)	petrology, sedimentology	marine	Middle Carboniferous (Pennsylvanian)	hvb-mvb
Yablokov et al. (1955)	petrology, paleobotany		Middle Carboniferous (Pennsylvanian)	subbit-san
Bogolyubova (1956)	petrology, organic geochemistry	tectonics controle	Middle Carboniferous (Pennsylvanian)	hvBb, hvAb
Botvinkina and Zhemchuzhnikov (1956)	petrology, sedimentology	marine	Middle Carboniferous (Pennsylvanian)	subbit-an
Snigirevskaya (1958, 1964, 1967)	paleobotany, coal balls		Middle Carboniferous (Pennsylvanian)/ Pervomaysk mine	subbit-an
Zhemchuzhnikov et al. (1959, 1960)	petrology, sedimentology, paleobotany	marine, fluvial	Middle Carboniferous (Pennsylvanian)	hvAb, mvb
Zhemchuzhnikov (1965)	sedimentology paleobotany, petrology	marine	Middle Carboniferous (Pennsylvanian)	subbit-san
Vyrvich (1967)	petrology, paleobotany		Middle Carboniferous (Pennsylvanian)	an
Uziyuk (1969, 1970, 1990)	petrology, organic geochemistry, paleobotanic		Middle Carboniferous (Pennsylvanian)/ Krasnoarmeysk, Donetsk-Makeevka areas	subbit-hvb
Lapo (1970)	petrology, paleobotany		Middle Carboniferous (Pennsylvanian)/ Severo-Donetsk area	subbit
Sarbeeva (1970, 1975)	petrology, sedimentology	marine	Middle Carboniferous (Pennsylvanian)	subbit-an
Vyrvich and Lapo (1970)	petrology, paleobotany		Middle Carboniferous (Pennsylvanian)	an
Ginzburg et al. (1972)	petrology		Middle Carboniferous	subbit-an
Lyuber (1972)	palynology		Middle Carboniferous	subbit
Matsenko (1984)	petrology		Middle Carboniferous	an
Uziyuk and Ignatchenko (1985)	petrology, paleobotany		Middle Carboniferous (Pennsylvanian)/ Donetsk-Makeevka, Krasnoarmeysk areas	hvb
Drozdova et al. (1971)	petrology, paleobotany		Upper Carboniferous (Pennsylvanian)	hvBb, hvCb
Inosova et al. (1979)	paleobotany		Upper Carboniferous (Pennsylvanian)	hvCb-an
Cainozoic Coal Basins, Dnieper Brown Coal Basin				
Chervinsky (1939)	petrology, sedimentology	fluvial and limnic	Paleogene (Eocene)	lig-subbit
Slenzak (1946)	petrology, sedimentology	fluvial and marine	Paleogene (Eocene)	lig-subbit
Nesterenko (1952, 1956, 1963)	paleobotany, palynology	fluvial and marine	Paleogene (Eocene)	lig-subbit
Rotman (1956)	palynology		Paleogene (Eocene)/Schesterinetsk	lig-subbit
Syabryaj (1958, 1959)	petrology, sedimentology, paleobotany, palynology, organic geochemistry	fluvial and limnic	Paleogene (Eocene)	lig-subbit
Agulov et al. (1960)	petrology, paleobotany, sedimentology		Paleogene (Eocene)	lig-subbit
Agulov et al. (1960)	palynology, paleobotany		Paleogene (Eocene)	lig-subbit
Kiryukov (1960, 1962)	petrology, sedimentology, paleobotany	limnic, tectonical control	Paleogene (Eocene)	lig-subbit
Bogdanova (1968)	petrology, organic geochemistry		Paleogene (Eocene)/Semenovsk-Golovkov section	lig-subbit
Valts (1937, 1968)	petrology, paleobotany		Paleogene (Eocene)/Alexandriya coal deposit	lig-subbit
Nagorny (1970)	sedimentology	fluvial, tectonical control	Paleogene (Eocene)/Zvenigorodka, Alexandriay	lig-subbit

Table 1 (*continued*)

Author	Method	Depositional environment	Age/area	ASTM rank
Ignatchenko and Zaitseva (1978, 1981, 1984)	petrology, sedimentology	fluvial and marine	Paleogene (Eocene)/Mironovka, Novomirgorod, Verghniednieprovsk, Oratovka-coal deposits	lig-subbit
Mikhelis and Drozdova (1979)	petrology, palynology		Paleogene (Eocene)	lig-subbit
Radzivill et al. (1987)	petrology, sedimentology	fluvial, marine influence, tectonical control	Paleogene (Eocene)	lig-subbit
DDD				
Mikhelis et al. (1970)	palynology		Paleogene–Neogene	lig
Mikhelis (1971)	petrology, palynology		Paleogene–Neogene	
Kiryukov (1973)	sedimentology	salt tectonics control	Paleogene–Neogene	lig
Ignatchenko and Zaitseva (1980)	petrology, palynology	salt tectonics control	Paleogene–Neogene	lig

described and determined as independent microcomponent bituminito-desmite for the first time. Valts (1968) and Bogdanova (1968) studied the diagenetic changes of plant matter at the peat and brown coal stages of coalification (for example, in the Dnieprobas) (Table 1).

4. Conclusions

On the base of own works as well as investigations carried out by another researchers, we can conclude the following:

- The Carboniferous age beds of the Dnieper-Donets Basin and the Donets Coal Basin contain coals of all the metamorphism stages from the brown coals up to anthracites.
- The above depends on the sufficiently high geodynamic–geothermal activity due to the geotectonic settings of regions mentioned above.
- In contrast, the Paleogene coals of the Dnieper Brown Coal Basin were generated under conditions of the Ukrainian Shield's ancient-consolidated basement and achieved only the brown-coal stage.

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