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TONSTEINS AND THEIR ROLE IN THE FORMATION OF THE PETROGRAPHIC COMPOSITION OF COALS

The tonsteins were found in the coal seams of all divisions of the Carboniferous deposits of the Donbas. They are thin clay interlayers of kaolinite composition and, according to most researchers, are of volcanic origin. The object of this study is the tonsteins of the Lower Carboniferous deposits of the Western Donbas. Analysis of the chemical composition of the tonsteins indicates their predominantly kaolinite composition. The aluminosilicate modulus (Al_2O_3/SiO_2 ratio) for tonsteins from a number of mines of the Western Donbas is close to the kaolinite norm (0.85). The titanium modulus (TiO_2/Al_2O_3 ratio) indicates that the tonsteins of the c_{11} seam were formed from volcanic ash of intermediate composition (titanium modulus 0.02-0.08). The tonsteins of all the other underlying layers studied (from c_1 to c_8^{low}) were formed from acid volcanic pyroclastics (titanium modulus less than 0.02). In order to establish the role of the tonsteins in the formation of the petrographic composition of the coals adjacent to them, the coal seam c_{11} is considered. Comparison of the weighted average contents of vitrinite (in %) for the coal patches located under and above the tonsteins showed the absence of any regularity in the distribution of microcomponents in the coal. Reconstruction of the conditions of peat accumulation of coals according to their microcomponent composition confirmed that the role of tonsteins in the formation of the petrographic composition of the coals of certain deposits should be assessed taking into account the specific conditions of the accumulation of paleo-peat bogs.

Keywords: *peat accumulation; coal; tonsteins; microcomponents; petrographic types of coals.*

Introduction

Tonsteins are thin clay interlayers of predominantly kaolinite composition, which are enclosed in coal seams and are often traced over a large area. The generally accepted postulate is that they are volcanogenic in nature. Tonsteins have been recorded not only in most Paleozoic basins, but also in Mesozoic and Cenozoic coal-bearing formations (Burger, 1979, 2007; Dai et al., 2017; Timofeev, Admakin, 2002 et al.). As noted by P.P. Timofeev and L.A. Admakin, tonsteins are as typical as the dominant rocks of coal-bearing deposits, although quantitatively they play a subordinate role.

The study of tonsteins is important for solving a number of problems of coal geology, in particular, their use as stratigraphic benchmarks, in the study of the morphology of coal seams, for the restoration of paleogeographic and paleotectonic conditions of their formation. When predicting the quality of coal, it is very important to solve the

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problem of the role of tonsteins in the formation of the material-petrographic composition of coals and their geochemical features.

The publication (Crowley et al., 1989) is devoted to elucidating these issues. Result, received by S.S. Crowley, namely the predominance of vitrinite microcomponents in coal above the tonstein interlayer and inertinite microcomponents under it, was used by Ya.E. Yudovich (Yudovich, Ketris, 2015) to substantiate the universal nature of its manifestation.

The purpose of this study is to establish the role of tonsteins in the formation of stable features of the petrographic composition of the coals adjacent to them on the example of the Lower Carboniferous deposits of the Western Donbas.

Coal samples from seam c_{11} were studied in wells located in the Heroyiv Kosmosu mine field. From interlayers of coal lithotypes with a thickness of 0.05 to 0.3 m, macroscopically identified by T.O. Krivega ("Pivdenukrgeology"), samples were taken for the manufacture of transparent bilaterally polished sections. As a result of studying 50 sections in transmitted polarized light on an MBI-6 microscope, microcomponents of coals were diagnosed and counted by L.B. Zaitseva. Based on the data of the thickness of the selected layers and the content of vitrinite in them, the authors calculated the weighted average content of vitrinite (in %) for coal patches located under and above the tonsteins.

To characterize the tonsteins and confirm their volcanic origin, chemical analyzes of the tonsteins were used according to the data (Bushak, 2005; Leskevich, Savchuk, 1961).

A part of the material of this article were presented at the conference "From Mineralogy and Geognostics to Geochemistry, Petrology, Geology and Geophysics: Fundamental and Applied Trends of the 21st Century" and published in the form of conference paper (Ivanova, Zaitseva, 2021).

The history of the study of Donbas tonsteins

The study of tonsteins in the Donbas has been carried out since the middle of the 20th century by mineralogical-petrographic and chemical methods. Tonsteins in the coal seams of the Carboniferous deposits are found in the deposits of the lower, middle and upper sections of the Carboniferous. In the Lower Carboniferous deposits, they were found in strata c_1, c_6^{low}, c_6, c_7, c_8^{low}, c_8^{up}, c_9^1, c_{11}^{low}, c_{11} (Western Donbas) (Bushak, 2005; Zaritskiy, 1977; Leskevich, Savchuk, 1961; Uziyuk, 2016; Chernovyants, 1992). In the Middle Carboniferous sediments, tonsteins are found practically throughout the entire territory of Donbas. They were found in strata g_1^4, g_2, h_{11} of the Baskirian Stage and k_3, k_5^1, k_5^2, k_8^1, l_1, l_3, l_8^1, m_3, m_5 of the Moscovian Stage (Zaritskiy, 2012; Uziyuk, 2016; Uziyuk, Prokhorov, 1970; Chernovyants, 1992 et al.). In the Upper Carboniferous deposits, the tonsteins were found in stratum n_1 (Uziyuk, 2016; Uziyuk, Prokhorov, 1970). The thickness of the tonstein layers usually does not exceed 2-3 cm.

Tonsteins have a predominantly kaolinite composition with an admixture of hydromicas and mixed-layer formations. The clastic part of the interlayers is represented by biotite, quartz, feldspars and decomposed volcanic glass (Chernovyants, 1992). According to P.V. Zaritskiy (Zaritskiy, 2012), the tonsteins contain accessory minerals, the leading of which are zircon and apatite.

Most researchers believe that, the wide distribution of tonsteins over the basin area with constant layer thickness, the synchronicity of their formation with the formation of peat bogs, the constancy and consistency of geochemical and mineralogical-petrographic features over large areas, including the idiomorphism of zircon and biotite crystals, indicate their volcanic origin (Zaritskiy, 2012; Uziyuk, Prokhorov, 1970, Chernovyants, 1992 et al.). The idiomorphism of zircon crystals, according to P.V. Zaritskiy (Zaritskiy, 2012), indicates a one-act transfer of pyroclastic material transformed in situ into kaolinite in the acidic environment of the peat bog. The enrichment of a number of interlayers with the lightest mi-caceous minerals (up to 20-30%), as well as the poor spectrum and an insignificant amount of the heavy minerals fraction indicate a significant distance from the centers of the eruption (Chernovyants, 1992).

No centers of volcanic activity were recorded on the territory of Ukraine in the Carboniferous, which could serve as a source of ash material (Goyzhevsky et al., 1977). Volcanic ash was apparently transported from the North Caucasus. The presence of powerful volcanism in the Early and Middle Carboniferous is confirmed by the wide development of volcanogenic rocks in the Carboniferous deposits of the Caucasus Fore Range (Andrushchuk et al., 1968; Chernovyants, 1992). Ac-

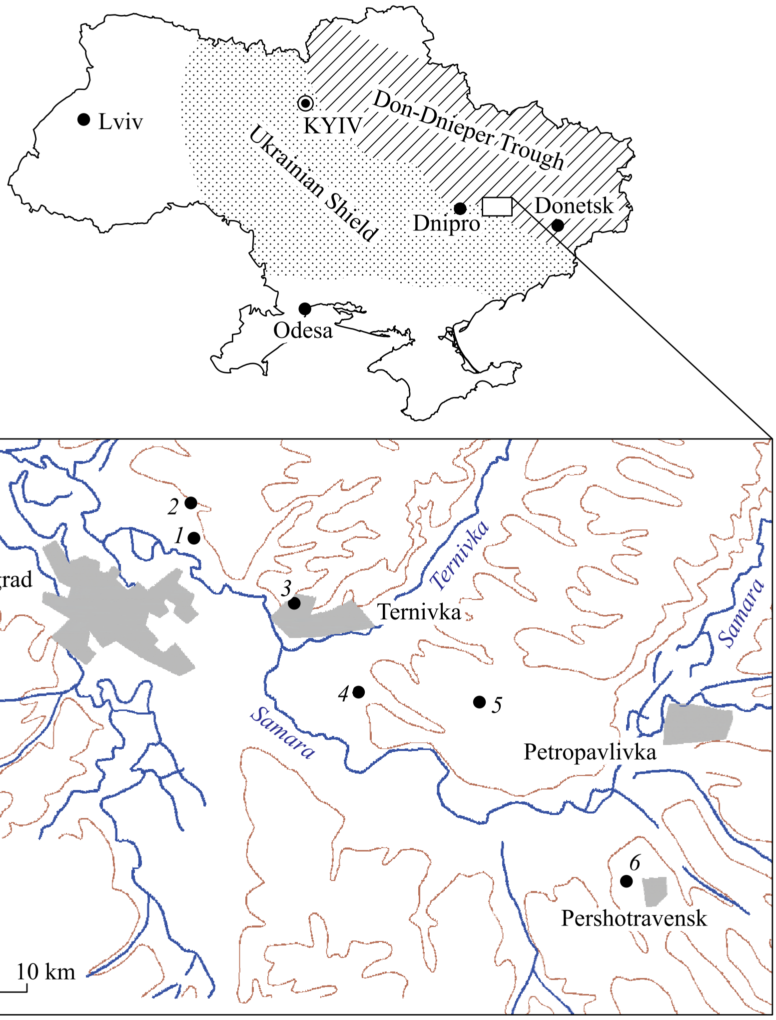

Fig. 1. The factual material map. Mines: *1* — Blagodatna, *2* — Heroyiv Kosmosu, *3* — Ternivska, *4* — Samarska, *5* — Dniprovska, *6* — Pershotravneva

cording to (Kuznetsov, 1951), the Central Formation of the Lower Carboniferous deposits of the Front Range contains effusives of acidic and intermediate composition.

Analysis of previous studies of the role of tonsteins in the formation of coal maceral composition

The question of the influence of tonsteins on the petrographic composition of coal patches in contact with them was considered by Ya.E. Yudovich (Yudovich, Ketris, 2015) according to S.S. Crowley et al. (Crowley et al., 1989). S.S. Crowley et al. studied the effect of tonsteins on the maceral and chemical composition of the C coal seam of the Late Cretaceous Emery deposit in the central Utah. The coal-bearing formations of the deposit were formed under delta conditions on the western coast of the Late Cretaceous inland sea and were subsequently deformed by faults into the Laramian phase of Alpine tectogenesis. The coal-bearing rocks hosting five coal seams are represented by sandstones, shales and siltstones with a total thickness of up to 55 m. The coal seam C contains 4 layers of tonsteins with the thickness of 10 (“Lower” parting), 3 (closely spaced pair of partings referred to as the “Doublet”) and 30-40 cm (“Upper” parting), maintained in thickness throughout the formation. Tonstein consists mainly of kaolinite and some (small) amount of smectite. The clastic part is represented by quartz, magnetite and zircon. The mineral composition, wide distribution, relative consistency in thickness, as well as sharp upper and lower contacts indicate their volcanic origin. In addition, the “Upper” tonstein contains

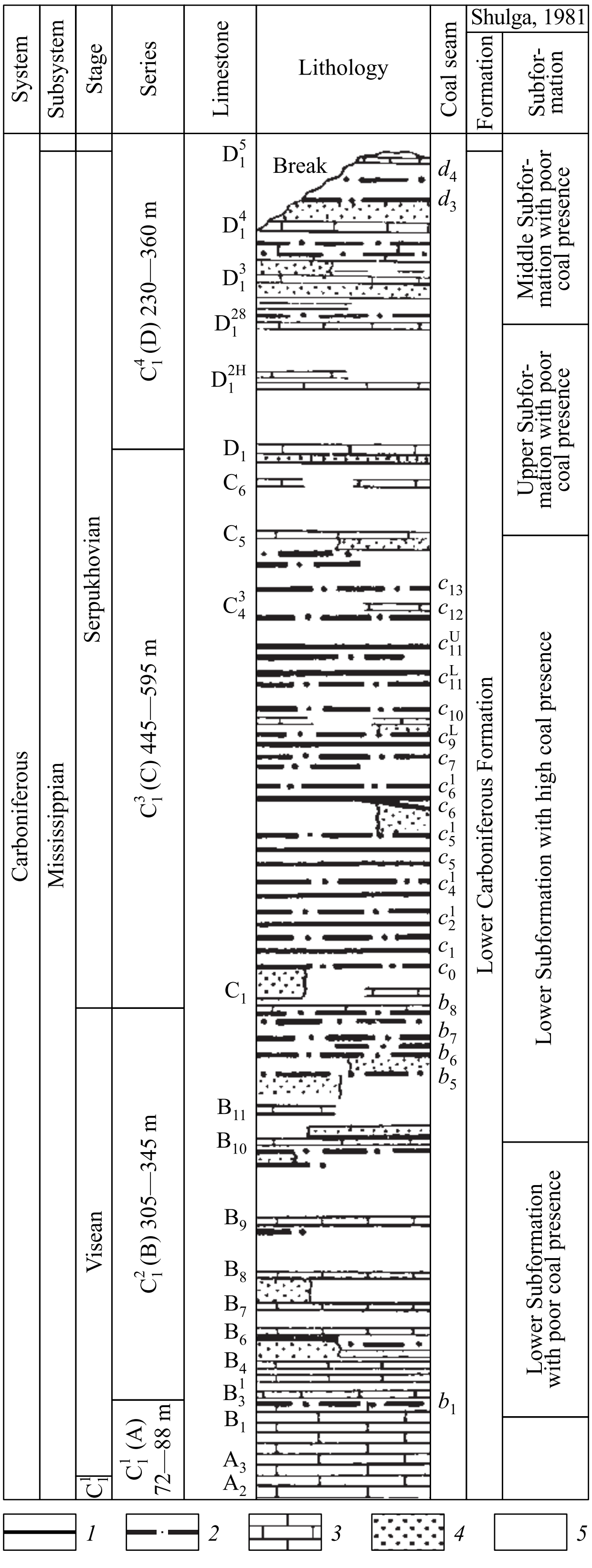

Fig. 2. The section of Lower Carboniferous coal-bearing formation (Shulga, 1981): *1* — working coal bed; *2* — unworkable coal bed; *3* — limestones; *4* — sandstones; *5* — mudstones, siltstones

accretionary lapilli, which are commonly considered products of volcanic eruptions (Crowley et al., 1988, 1989; Stracher et al., 2005; Quick et al., 2004; Triplehorn, Bohor, 1981).

The coal samples of the Emery deposit taken above and below the tonstein layers are characterized by the constancy and stability of the distribution of the main maceral groups. Inertinite maceral is are generally more abundant in coal below the tonsteins. The inertinites are composed primarily of semifusinite (presumably degradofusinite), with less abundant inertodetrinite and fusinite. Vitrinite macerals are more common in samples from coal patches overlying the tonstein layers. Desmocollinite is the most abundant vitrinite maceral, followed by telinite and detrocollinite. Unlike vitrinites and inertinites, the content of liptinites does not depend on the position of coal in relation to the tonstein interlayer (Crowley et al., 1989).

This distribution of microcomponents is explained by S.S. Crowley with co-authors, and afterwards by Ya.E. Yudovich (Crowley et al., 1989; Yudovich, Ketris, 2015) as follows. The high content of inertinite in the coals below the tonstein layer is probably related to the conditions of poorly watered well-drained bogs that existed before the fallout of volcanic ash. After the fallout of ash material into the peat bog, which played the role of an aquiclude, the peat bog above the tonstein turned out to be more waterlogged, which led to its enrichment with gelified material. In addition, according to S.S. Crowley, other factors that may have contributed to the distribution of macerals found near tonsteins in the C coal seam are related to changes in pH and plant communities induced by the volcanic ash falls.

Study objects

To clarify the influence of tonsteins on the petrographic composition of the coal patches in contact with them, we examined the Lower Carboniferous deposits of the Western Donbas, which is the extreme southwestern part of the Donetsk coal basin (Fig. 1). The main coal content of Western Donbas is associated with the Samara Formation C_1^3. Seams c_1, c_4-c_{11} with an average thickness of 0.7-0.8 m are of industrial importance. Most of the layers are classified as thin with the thickness of 0.45-0.6 m and are characterized by constant distribution over

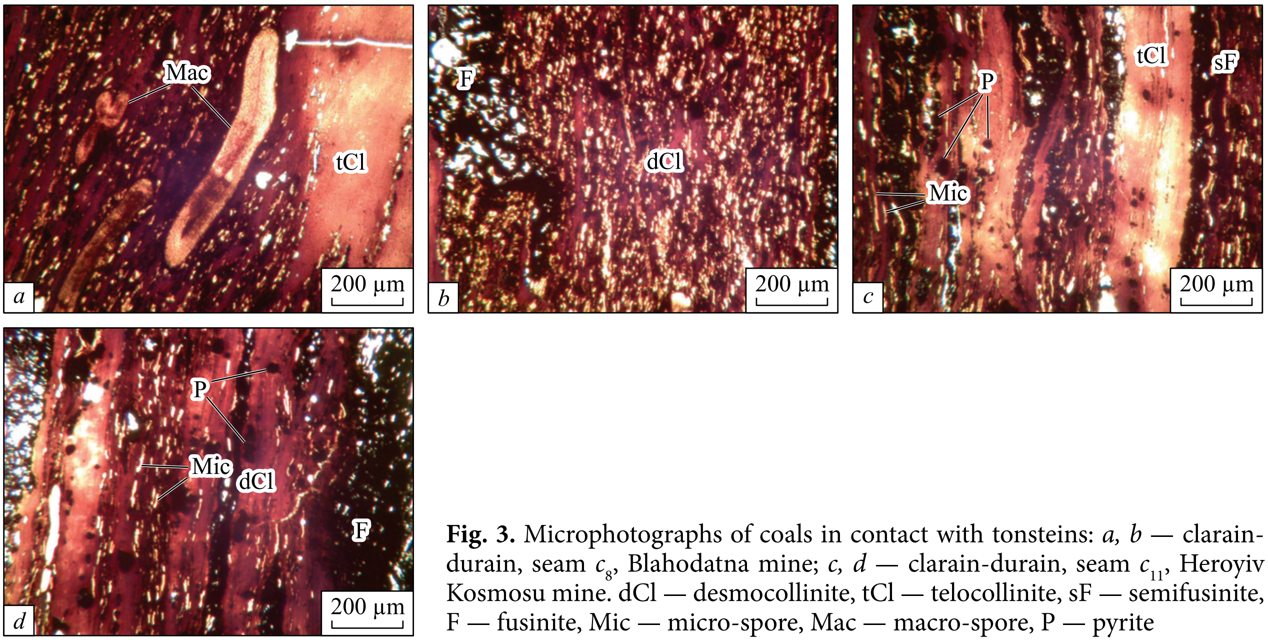

Fig. 3. Microphotographs of coals in contact with tonsteins: *a, b* — clarain-durain, seam c_8, Blahodatna mine; *c, d* — clarain-durain, seam c_{11}, Heroyiv Kosmosu mine. dCl — desmocollinite, tCl — telocollinite, sF — semifusinite, F — fusinite, Mic — micro-spore, Mac — macro-spore, P — pyrite

the area. The top and bottom of the strata are mainly represented by mudstones and siltstones. The layers contain interlayers of mudstones (from 3-5 to 20 cm) and tonsteins up to 2-3 cm thick, which serve as marker horizons (Ivanova et al., 2018).

The stratigraphic section of the Lower Carboniferous of the study area is shown in Fig. 2.

The petrographic composition of coal seams c_4, c_5, c_6, c_7^{low}, c_8^{low}, c_{11} of mines of the Western Donbas (Heroyiv Kosmosu, Blagodatna, Ternivska, Samarska, Dniprovska, Pershotravneva mines) was determined by studying 260 transparent sections in transmitted light (Ivanova et al., 2018).

Results

The organic matter of coal is represented by three groups of microcomponents: vitrinite, inertinite, and liptinite. The content of microcomponents of the vitrinite group is on average 52-58%. Vitrified microcomponents of the c_{11} seam are mainly represented by desmocollinite and telocollinite. The content of fusainized micro-components is on average 20-30%. They are more often represented by semifusinite, fusinite and inertodetrinite. The average content of microcomponents of the liptinite group is 18-23%. The main role is played by sporinite, represented by micro- and macro-spores. According to the content of vitrinite, the following microlithotypes of coal are distinguished (ISO 11760: 2005): clarain — coal with a high content of vitrinite (>80%), durain-clarain — with a moderately high content of vitrinite (60-80%), clarain-durain — with an average content of vitrinite (40-60%), durain — with a low content of vitrinite (<40%). In the studied coal, clarain-durain and durain predominate, and to a lesser extent, durain-clarain and clarain occur. Vitrinite reflectance is 0.75-0.84% (Ivanova et al., 2018). The figure (Fig. 3) shows micrographs of coals in contact with the tonsteins.

The considered tonsteins usually have clear contacts with their enclosing coals (Fig. 4, *a*). In c_{11} seam, abundant pyritization is observed at the contact of organic material with the tonstein, represented by pseudomorphs after organic residues and spherulites. In c_8 seam, the tonstein is in contact with the clarain-durain without sharp transitions (Fig. 4, *b*). According to the mineral composition, the tonsteins are predominantly kaolinite. The kaolinites of the c_{11} seam are represented by rounded and angular grains in a clayey-carbonaceous matrix. In the underlying seam c_8, which contains more metamorphosed coal, crystals of a curved, columnar, worm-like shape are enclosed in a carbonaceous matrix. According to petrographic features, the tonstein of c_{11} seam is granular (see Fig. 4, *a*), and the tonstein of c_8 seam is crystalline (see Fig. 4, *c*) (Burger, 1979, 1980; Chernovyants, 1992). According to L.A. Admakin (Admakin, 2002), the original mineral matter of the tonsteins is transformed as it is lithified (maxi-

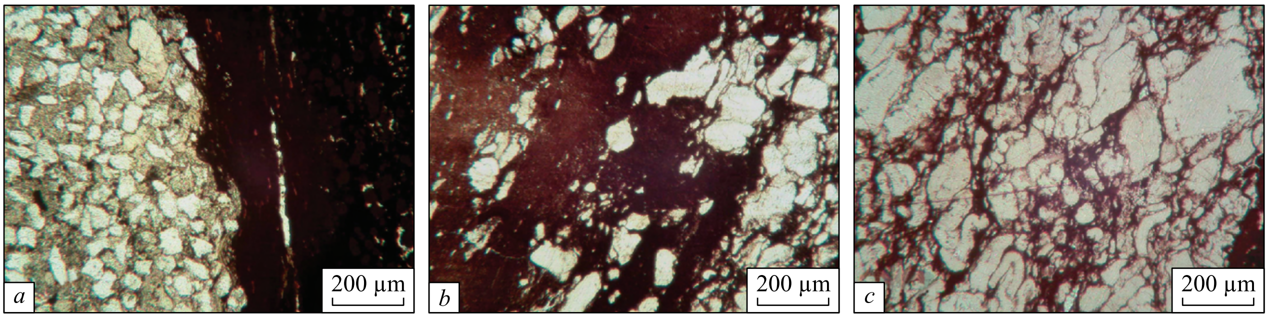

Fig. 4. Tonstein structure and nature of contact with coal: *a* — granular tonstein, sharp contact of the tonstein with coal, c_{11} seam, Heroyiv Kosmosu mine; *b* — crystalline tonstein, fuzzy contact of tonstein with coal, c_8 seam, Blahodatna mine; *c* — crystalline tonstein, c_8 seam, Blahodatna mine

mum kaolinization at the stage of diagenesis and subsequent vermiculization at the middle substages of metacatagenesis).

To characterize the tonsteins the chemical analysis data presented in (Bushak, 2005; Leskevich, Savchuk, 1961) were used. Based on them, the authors of the present study constructed a diagram of the chemical composition of tonsteins and determined the aluminosilicate (Al_2O_3/SiO_2 ratio) and titanium (TiO_2/Al_2O_3 ratio) modulus with the construction of appropriate graphs. Fig. 5 shows a diagram of the chemical composition of the tonsteins. It indicates that their main constituents are silica and alumina, which are the basic components of kaolinite.

Fig. 6 shows a graph of the distribution of samples depending on their aluminosilicate modulus. The aluminosilicate modulus for classical kaolinite is 0.85 (Dai et al., 2017). The given graph shows that this modulus for most of the tonsteins is close to the kaolinite norm. The lower modulus values in the two coal samples from c_{11} seam indicate an excess of silica, apparently represented by clastogenic quartz.

The titanium modulus is used to identify sources of volcanic ash from which the tonsteins formed (Dai et al., 2017). Fig. 7 shows a graph of the distribution of samples by titanium modulus, which indicates the composition of the initial ash material, which became the source of the formation of tonsteins. It indicates that the tonsteins of c_{11} seam (according to 5 samples) were formed from volcanic ash of intermediate composition (titanium modulus 0.02-0.08). The tonsteins of all the other underlying seams studied (from c_1 to c_8^{low}) were formed from acid volcanic pyroclastics (titanium modulus less than 0.02). This is rather curious circumstance. Such a clear distribution of seams according to the composition of the original material of the tonsteins indicates their volcanic origin. All the mentioned seams belong, according to V.F. Shulga (Shulga, 1981) to the same high coal-bearing subformation, and the paleogeographic setting did not fundamentally change during their formation (see Fig. 2).

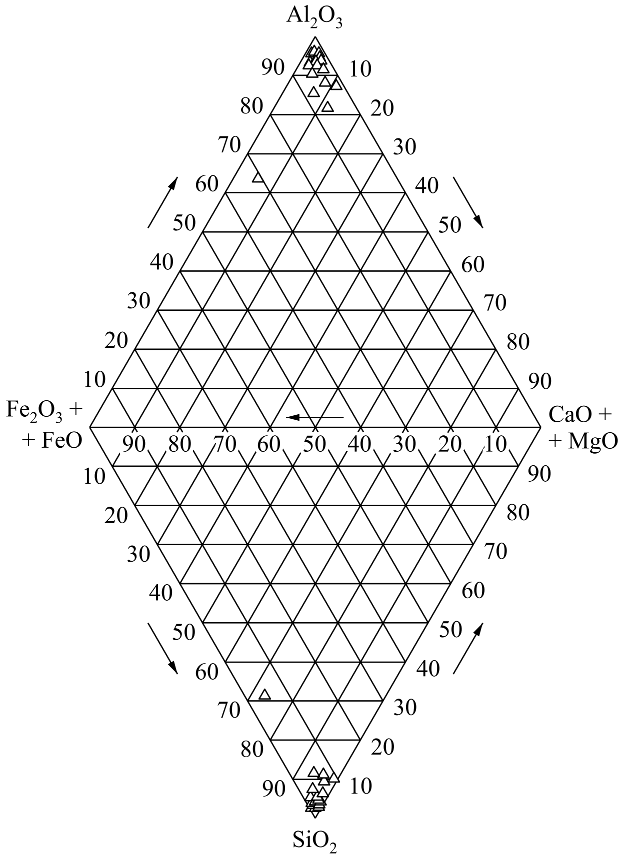

Fig. 5. Diagram of the chemical composition of tonsteins

In order to establish the role of tonsteins in the formation of the petrographic composition of the coal adjacent to them the materials of layer-by-layer description of coals of c_{11} seam were involved from 6 wells located in the Heroyiv Kos-

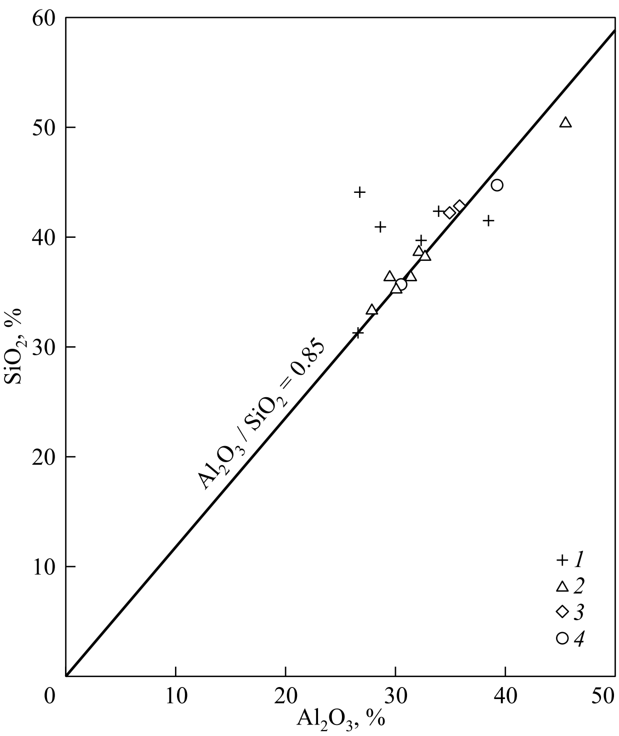

Fig. 6. Distribution of samples according to the aluminosilicon modulus: *1* — c_{11} seam, *2* — c_8 seam, *3* — c_6 seam, *4* — c_1 seam

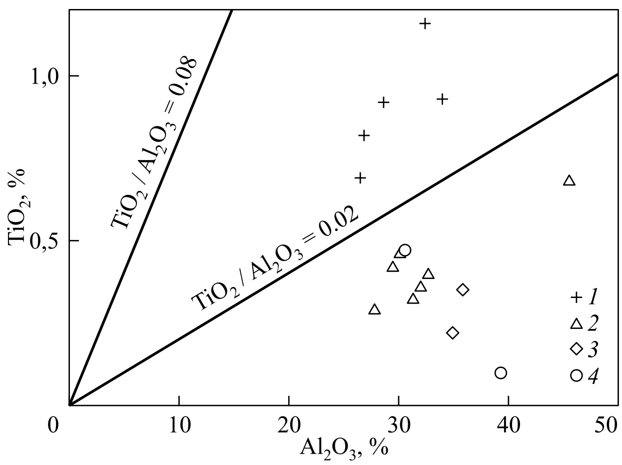

Fig. 7. Distribution of samples according to the titanium modulus: *1* — c_{11} seam, *2* — c_8 seam, *3* — c_6 seam, *4* — c_1 seam

mosu mine field (see Fig. 1), and petrographic analysis was carried out in 50 transparent sections characterizing each selected coal lithotype (see Introduction). In the coal seam with the thickness of 0.73 to 0.90 m, lying at the depth of 362 to 522 m, 5-7 layers of coal microlithotypes with the thickness of 0.04 to 0.30 m were identified. Based on the data on the thickness of the selected layers and on the content of vitrinite in them, we calculated the weighted average content of vitrinite (in %) for the coal patches located under and above the tonstein layers in each well. The formation contains two tonstein layers 2-3 cm thick (Fig. 8). The absence of the second tonstein interlayer in 21624 well is most likely associated with local processes.

The content of vitrinite is taken as a key indicator of the influence of tonsteins on the coal petrographic composition, since the contents of inertinite and liptinite in the coals of the Western Donbas are close by most estimates. The distribution of the weighted average contents of the groups of microcomponents is shown in Fig. 9.

Discussion

A pattern identified by S.S. Crowley, that is, an increase in the content of vitrinite in the coal above the tonsteins, is confirmed for the coal patches ad-

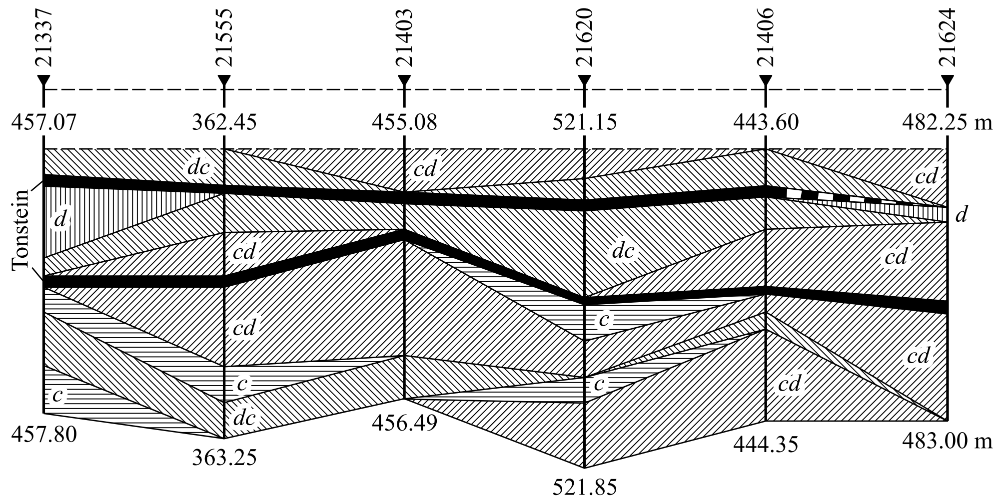

Fig. 8. Distribution of lithotypes in coal seam c_{11}: *c* — clarain, *dc* — durain-clarain, *cd* — clarain-durain, *d* — durain

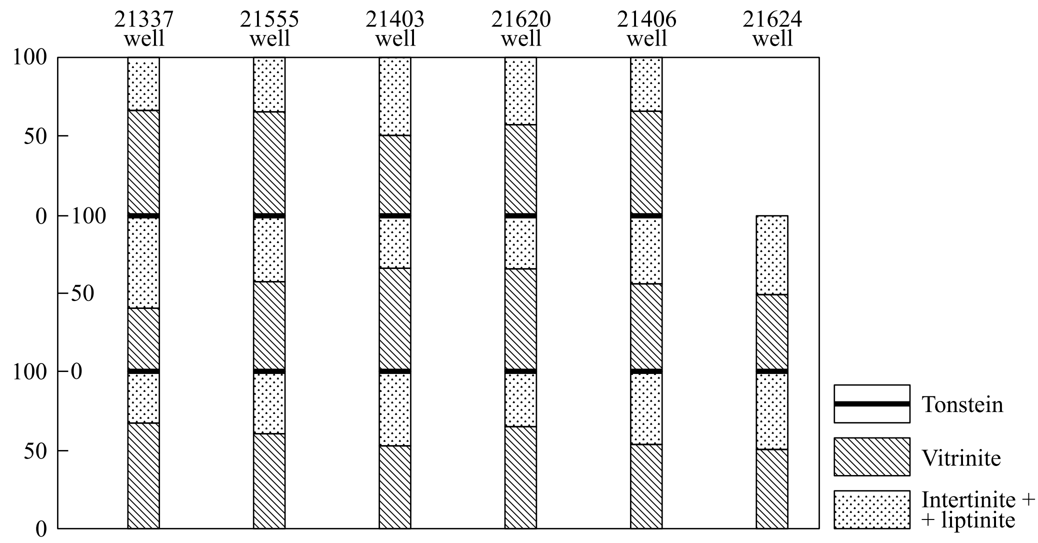

Fig. 9. Percentage ratio of groups of microcomponents in coal of c_{11} seam above and below the tonstein interlayers

jacent to the upper tonstein in 21337, 21555, 21406 wells. The same pattern is preserved for the lower tonstein in 21403 well. In other cases, a decrease in the content of vitrinite is observed above the tonstein (21620 well, upper tonstein; 21337 well, lower tonstein) or its content above and below the tonstein is practically the same (21555, 21620, 21624, 21406 wells, lower tonstein).

The results of the study showed that the distribution of microcomponents in the coal above and below the tonstein interlayers does not follow a certain pattern.

To assess the reconstruction of the paleoenvironment of peat formation by the microcomponent composition of coals according to the S.F.K. Diessel method (Diessel, 1986, 1992) tissue preservation index (TPI) and gelification index (GI) were used, where TPI = (telinite + telocollinit + + semifusinite + fusinite)/(desmocollinite + + macrinite + inertodetrinite) and GI = (total vitrinite + macrinite)/(semifsinite + fusinite + inertodetrinite). The resulting diagram shows that the formation of the c_{11} seam took place in overgrown lakes, reed mars, and in forest swamp from flooded to dry (Fig. 10).

It should be assumed that, in the general case, the fallout of volcanic ash on the surface of a flooded peat bog and, accordingly, an increase in the pH of bog water contributed to the biochemical decomposition of organic matter and intensified gelation in the paleo-peat environment. This process led to the result that is observed in the Emery deposit.

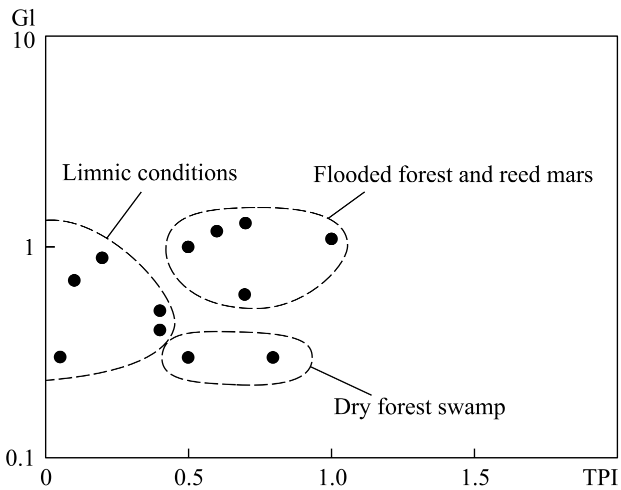

Fig. 10. Diagram of peat accumulation conditions of c_{11} seam

The absence of a definite regularity in the distribution of vitrinite in coal above and below the tonstein interlayers within the same mine field in the Western Donbas may be due to variations in landscape conditions (microrelief), which determine the level of groundwater and the general watering of the swamp, the nature of the vegetation cover, as well as the distance to forest communities.

Conclusions

The volcanic origin of the tonsteins is confirmed by the distribution of titanium modulus values in accordance with the sequence of formation of coal seams. The source for the formation of tonsteins was the pyroclastics of acidic (from c_1 to c_8^{low} seams) and intermediate (c_{11} seam) composition.

The study of coal samples from the c_{11} seam, taken above and below the interlayers of tonsteins, demonstrated the lack of uniformity in the distribution of groups of microcomponents. The weighted average content of vitrinite from the coal patches in contact with the tonsteins does not obey simple regularity. Observed by S.S. Crowley et al. uniformity in the distribution of groups of microcomponents in the studied deposit reflects the peat accumulation conditions characteristic of this deposit and cannot be considered as a common pattern. The role of tonsteins in the formation of the petrographic composition of the coals of various deposits should be assessed with careful consideration of the specific paleogeographic conditions of paleo-peat accumulation, which were determined by the geotectonic regime.

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REFERENCES

Admakin L.A. 2002. Accumulation and Post-Sedimentary Diagenesis of Tonsteins. *Lithology and Mineral Resources*, 37 (1): 60-67. https://doi.org/10.1023/A:1013687506268

Andrushchuk V.L., Dubinsky A.Ya., Hain V.E. (Eds.). 1968. Geology of the USSR. Geological description, 9 (1)1. North Caucasus. Moscow: Nedra (in Russian).

Burger K. 1979. Vorkommen und Stratigraphische Verteilung der Kaolin-Kohlentosteine in den Kohlenrevieren der Erde. *VIII Int. Cong. on Carboniferous Stratigraphy and Geology.* (pp. 21-31). Moscow: Nauka (in Russian).

Burger K. 1980. Kaolin-Kohlentonsteine im flözführenden Oberkarbon des Niederrheinisch-Westfälischen Steinkohlenreviers. *Geologische Rundschau*, 69 (2): 488-531. https://doi.org/10.1007/BF02104551

Burger K., Rabitz A. 2007. Petrographie des Kaolin-Kohlentonsteins l_3^1 bei Lutugino (Ukraine, Mittleres Moskovium) und seines $^{40}Ar/^{39}Ar$-datierten Sanidins mit Ausblick auf Erweiterung der Altersbestimmungen im Donez-Becken. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, 158 (2): 213-224. https://doi.org/10.1127/1860-1804/2007/0158-0213

Bushak S.M. 2005. Application of tonsteins to coal seams correlation in Western Donbas. *Tectonics and stratigraphy*, 34: 87-92 (in Ukrainian).

Chernovyants M.G. 1992. The tonshteins and its use for coal formation study. Moscow: Nedra (in Russian).

Crowley S.S., Simon F.O., Stanton R.W. 1988. *Selected chemical composition of the C coal bed, Emery coal field, Utah.* U.S. Geol. Survey open-file rep. 88-526. https://doi.org/10.3133/ofr88526

Crowley S.S., Stanton R.W., Ryer T.A. 1989. The effects of volcanic ash on the maceral and chemical composition of the C coal bed, Emery Coal Field, Utah. *Org. Geochem*., 14 (3): 315-331. https://doi.org/10.1016/0146-6380-(89)90059-4

Dai S., Ward C.R., Graham I.T., French D., Hower J.C., Zhao L., Wang X. 2017. Altered volcanic ashes in coal and coal bearing sequences: a review of their nature and significance. *Earth Science Reviews*, 175: 44-74. https://doi.org/10.1016/j.earscirev.2017.10.005

Diessel C.F.K. 1986. The correlation between coal facies and depositional environments. Advances in the study of the Sydney Basin. *Proceedings of 20th Symposium of University of Newcastle*. (pp. 19-22). Univ. Newcastle.

Diessel C.F.K. 1992. Coal-Bearing Depositional Systems. Berlin: Springer-Verlag.

Goyzhevsky A.A., Naumenko V.V., Skarzhinsky V.I. 1977. Tectonic-magmatic activation of the regions of Ukraine. Kyiv: Naukova Dumka (in Russian).

International Standard Classification coals, ISO 11760:2005 (2005).

Ivanova A.V., Zaitseva L.B. 2021. Donbas volcanogenic tonsteins and their role in the formation of the petrographic composition of coals. *Proceedings of the All-Ukrainian Conf. “From Mineralogy and Geognostics to Geochemistry, Petrology, Geology and Geophysics: Fundamental and* Applied *Trends of the 21st Century” (MinGeoIntegration XXI).* Kyiv: Institute of Geology, Taras Shevchenko National University (in Ukranian).

Ivanova A.V., Zaitseva L.B., Spirina O.I. 2018. Geotectonic regime of formation of the coal-bearing deposits in the Western Donets Basin (Ukraine). *Geologičnij žurnal*, 1 (362): 66-79. https://doi.org/10.30836/igs.1025-6814.2018.1.126569

Kuznetsov I.G. 1951. Tectonics, volcanism and stages of formation of the structure of the Central Caucasus*: Proceedings of the IGS, No. 52, Geol. Series, Issue 131*. Moscow: Academy of Sciences of the USSR (in Russian).

Leskevich I.E., Savchuk S.V. 1961. Kaolinite in Lower Carboniferous coals of the Western Donbass. *Reports of the USSR Academy of Sciences,* 137 (5): 1206-1208 (in Russian).

Quick J.C., Tabet D.E., Hucka B.P., Wakefield S.I. 2004. The Available Coal Resources for Eight 7.5-Minute Quadrangles in the Southern Emery Coalfield, Emery and Sevier Counties, Utah. *Utah Geological Survey Special Study* 112.

Shulga V.F. 1981. Lower Carboniferous coal bearing formation of Donets Basin. Moscow: Nauka (in Russian).

Stracher G.B., Tabet D.E., Anderson P.B., Pone J.D.N. 2005. Utah's state rock and the Emery coalfield: Geology, mining history, and natural burning coal beds. In *Geological Society of America Field Guide, 6*: 199-210). https://doi.org/10.1130/2005.fld006(09)

Timofeev P.P., Admakin L.A. 2002. Overview of Studies and the Modern Knowledge of Tonsteins (on the Occasion of the 150th Anniversary since the Beginning of Their Investigation). *Lithology and Mineral Resources*, 37 (3): 228-238. https://doi.org/10.1023/A:1015482113658

Triplehorn D.M., Bohor B.F. 1981. Altered volcanic ash partings in the C coal bed, Ferron Sandstone Member of the Mancos Shale, Emery Country, Utah. *U.S. Geol. Survey open-file* rep. (pp. 81-775). https://doi.org/10.3133/ofr81775

Uziuk V.I. 2016. Correlation features of coal seams of Carboniferous system of the Donets and Lviv-Volyn basins. *Geology and geochemistry of combustible minerals*, 1-2 (168-169): 38-61 (in Ukrainian).

Uzyuk V.I., Prokhorov I.G. 1970. Possibility of using kaolin interlayers for stratigraphy and correlation of some coal layers in Krasnoarmeysky district of Donbass. *Geology and geochemistry of combustible minerals*, 22: 97-102 (in Ukrainian).

Yudovich Ya.E., Ketris M.P. 2015. Inorganic substance of coals. Moscow-Berlin: Direct-Media (in Russian).

Zaritsky P.V. 1977. Intercoal kaolinite interlayers (tonsteins) of the Lower Carboniferous of the western and southwestern Donbass. *Reports of the Academy of Sciences of the Ukrainian SSR. Serie B,* 10: 881-884 (in Russian).

Zaritskiy P.V. 2012. Intercoal interlayers (tonsteins, kaolin-kohlentonstein) are products of volcanic ash transformation in the process of coalification (on the example of Donbass). *Diagnosis of volcanic products in sedimentary strata.* (pp. 121-124). Syktyvkar: IG Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (in Russian).

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ТОНШТЕЙНИ ТА ЇХ РОЛЬ У ФОРМУВАННІ ПЕТРОГРАФІЧНОГО СКЛАДУ ВУГІЛЛЯ

У роботі констатується, що тонштейни виявлені у пластах вугілля всіх відділів кам'яновугільних відкладів Донбасу. Вони являють собою малопотужні глинисті прошарки каолінітового складу і, на думку більшості дослідників, мають вулканогенне походження. Об'єктом цього дослідження є тонштейни нижньокам'яновугільних відкладів Західного Донбасу. Аналіз хімічного складу тонштейнів свідчить про їхній переважно каолінітовий склад. Алюмокремнієвий модуль Al_2O_3/SiO_2 для тонштейнів із низки шахт Західного Донбасу є близьким до каолінітової норми (0,85). Титановий модуль TiO_2/Al_2O_3 свідчить, що тонштейни пласта c_{11} утворилися з вулканічного попелу середнього складу (титановий модуль 0,02—0,08). Тонштейни решти досліджених пластів, що залягають нижче (від c_1 до $c_8^н$), сформувалися з кислої вулканогенної пірокластики (титановий модуль менше 0,02). Для встановлення ролі тонштейнів у формуванні петрографічного складу прилеглого до них вугілля розглядається вугільний пласт c_{11}. Порівняння середньозважених вмістів вітриніту (в %) для пачок вугілля, розташованих під і над тонштейнами, показало відсутність будь-якої закономірності у розподілі мікрокомпонентів у вугіллі. Реконструкція умов торфонакопичення вугілля за їх мікрокомпонентним складом підтвердила, що роль тонштейнів у формуванні петрографічного складу вугілля тих чи інших родовищ повинна оцінюватися з урахуванням конкретних обстановок накопичення палеоторф'яників.

Ключові слова: *торфонакопичення; вугілля; тонштейни; мікрокомпоненти; петрографічні типи вугілля.*