UDC 552.574.12.08:550.85 DOI: https://doi.org/10.15407/geotm2022.163.089

IMPACT OF PETROGRAPHIC COMPOSITION ON DISTURBANCE OF COALS

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Abstract. Evaluating the disturbance of coal beds is important both in terms of conditions of their working out and in predicting such features as methane capacity, outburst hazard and spontaneous combustion. One of the methods for evaluating coal disturbance is its research using optical microscopy. Coal consists of petrographic microcomponents (macerals) distinguished by optical properties and, most importantly, strength properties. This heterogeneity of the coal matter largely determines the nature of coal disturbance. This paper shows the impact of the macerals of the inertinite and liptinite groups on the development of disjunctive and plicative coal disturbance.

The purpose of the paper is to establish the features in the formation of plicative and disjunctive disturbance of coal depending on its petrographic composition. The research is carried out with the help of a video-optical complex: MBI-11, HB 200, and Scope photo software. It is noted that the more diverse the petrographic composition of coals is, the less developed fracturing under equal other conditions coals have. The petrographic composition affects the disturbance of coals not only at the level of lithotypes but also at the level of macerals. Liptinite and inertinite prevent the development of endogenous fracturing. Liptinite and inertinite contribute to the development of exogenous fracturing. An increase in the total density of coal at high stages of metamorphism levels out the effect of the petrographic composition. Coals of low stages of metamorphism are characterized by the greatest diversity of composition. With the growth of metamorphism, the difference in strength and optical properties of the macerals is gradually leveled and coals of the C-coke, F-fat marks (CF) are characterized by the greatest fracturing. To the L mark, the composition becomes even more homogenous (features of vitrinite and liptinite fully become the same) but the overall density of coal increases, and the fracturing decreases. As long as differences remain in the strength properties of macerals (low and middle stages of metamorphism) the presence of liptinite and inertinite prevents the development of fracturing. Examples of suppression of fractures by macrospores and fusinite are given in the form of microphotographs. There are cases of interlayer slipping and slickenlines. The importance of petrographic research in evaluating both rupture and plicative disturbance of coals is emphasized.

Keywords: coal, petrographic research, optical microscopy, macerals, disturbance.

1. Introduction

Interest in studying the disturbance of coal beds has been noted since the 19th century, with the beginning of coal mining by hand, and then by mechanized methods. Identification of the spatial arrangement of cracks in coal contributed to the efficiency of its extraction since it was easier to chip away coal from the massif through cracks [1].

At the beginning and middle of the 20th century, the focus shifted to the analysis of the system of cracks in coals in terms of the safety of mining operations, namely in connection with gas outbursts, sudden coal and gas outbursts, and spontaneous combustion of coals. Here, two fundamental works of Ivanov G.A. [2] and Ammosov I.I. [3], as well as a number of foreign authors should be noted [4, 5].

At present, the research tools have significantly progressed (electron microscopy, tomography, etc.) and more attention is paid to the system of disturbance in the extraction of methane from the coal-bearing stratum, CO_2 utilization, choosing the direction of hydraulic fracturing shock, since the target of this method is to connect the main system of fractures (face cleat) with gas well [6-9].

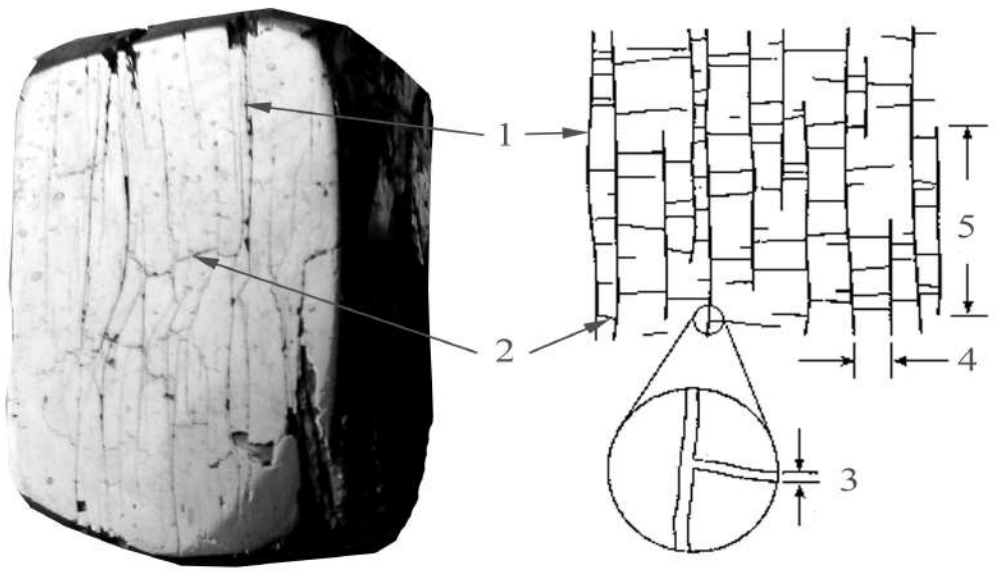
The main modern ideas about the system of coal disturbances can be summarized as follows:

- Disturbance can be either without disruption of discontinuity of a bed (plicative dislocation - bendings, bulgings) or with disruption (disjunctive dislocation - cracks);

- Disturbance can be either without disruption of discontinuity of a bed (plicative dislocation - bendings, bulgings) or with disruption (disjunctive dislocation - cracks);
- Cracks, according to the reasons for their occurrence, are divided into endogenous or cleat (dehydration, shrinkage) and exogenous (tectonic activity);
- Cleat is inherent in all marks of coal to varying degrees, but it is most pronounced at the middle stages of coalification (FC) in claren and vitren lithotypes. It is the main artery of gas migration in coal beds, especially the interlayer direction;
- Exogenous cracks disrupt the existing endogenous system and contribute to the emergence of gas traps and the manifestation of gas-dynamic phenomena.

The cleat system consists of cracks located in three mutually perpendicular directions, one of which is interlayer, and the other two are called the main (face cleats) and secondary (butt cleats) cleavage.

To characterize the fracture network, a number of indicators are proposed (Fig. 1): the distance between cracks (spacing), the length of cracks, and their opening amplitude (aperture).



A B

1 – face cleat; 2 - butt cleat; 3 - opening amplitude (aperture);
4 – the distance between cracks (spacing); 5 – crack length

Figure 1 – Characteristics of the fracture network: A) – lump section, O.F. Zasiadko mine, bed m_3, mark “F”, B) illustration from Laubach S.E. et al. [4]

It is not a problem to distinguish between the face and butt cleats due to the length of the cracks, despite the fact that the measurements are carried out in the laboratory, and not in natural conditions. As for the aperture, the indicator is very controversial, since the laboratory preparation goes through the “relaxation” period and it is unknown whether or not it corresponds to the observed crack opening to the natural one, although the relative trend should continue. With regard to the causes of endogenous and exogenous cracks, at least the spatial orientation of endogenous cracks is controlled by tectonic processes.

The impact of the petrographic composition on the fracturing of coals is noted in the literature at the level of lithotypes, and there are practically no works evaluating the contribution of individual microcomponents (macerals).

The purpose of the work is to establish the features of the formation of plicative and disjunctive disturbance of coals depending on their petrographic composition.

2. Methods

The authors used the method of primary examination of coal samples and, according to the prepared coal petrographic preparations (lump sections with the polishing of two planes – bedding and cut), carried out the research using optical microscopy (video-optical complex: MBI-11, HB 200, software – Scope photo [10].

3. Results and discussion

During the primary examination of coal samples and coal petrographic preparations made from them, cracks in the face and butt cleats were easily diagnosed on medium marks of coals (Fig. 2), at low stages of coalification and in anthracites, it is extremely problematic to do this using coal samples.

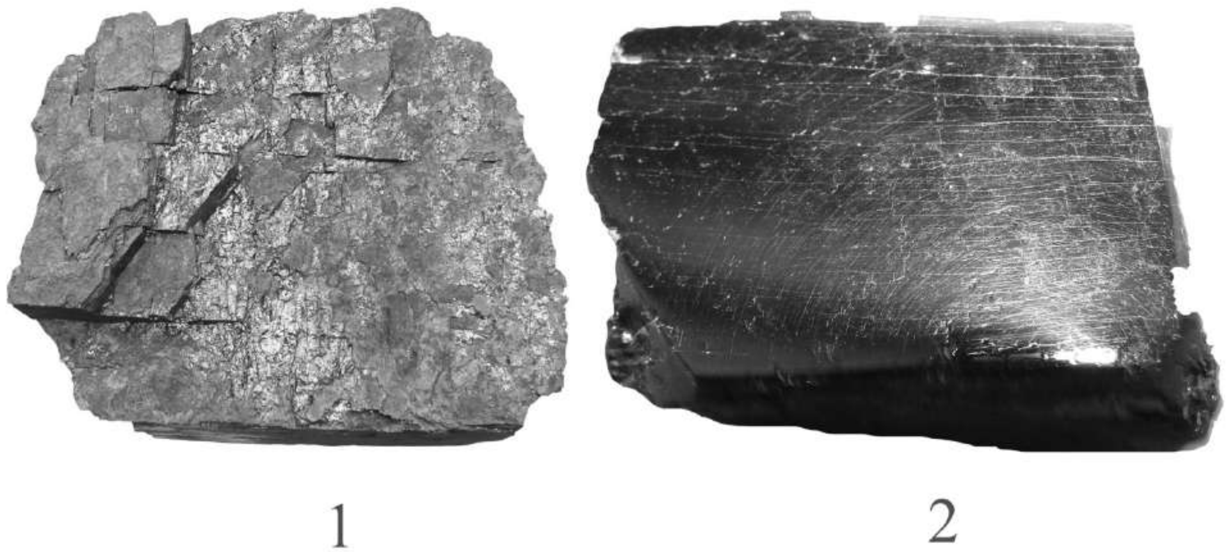


Figure 2 – Endogenous fracturing, diagnosed with the naked eye in a coal sample (1) and lump section (2)

In lump sections under a microscope, along lines located perpendicular to the strike of the face cleat, the distances between cracks (spacing) and the aperture of all intersected cracks (aperture) were measured. Between the cracks of the face cleat visible on the preparation with the naked eye, another 1 to 50 cracks are diagnosed under a microscope, located at a distance of 20–800 µm from each other. A fragment of the data of such studies (about 500 measurements per 2 cm of a line on the preparation) is given in Table 1.

Table 1 – Characteristics of cleat by lump sections

Measuring number	Spacing (µm)	Aperture (µm)
1	63	2
2	42	4
3	50	7
4	120	20
5	100	24
6	457	612
7	320	32
8	62	14
9	43	2
10	40	4
11	26	3

Graphical interpretation of the data in Table (Fig. 3) allows us to conclude that the formation of endogenous cracks has wave-like nature.

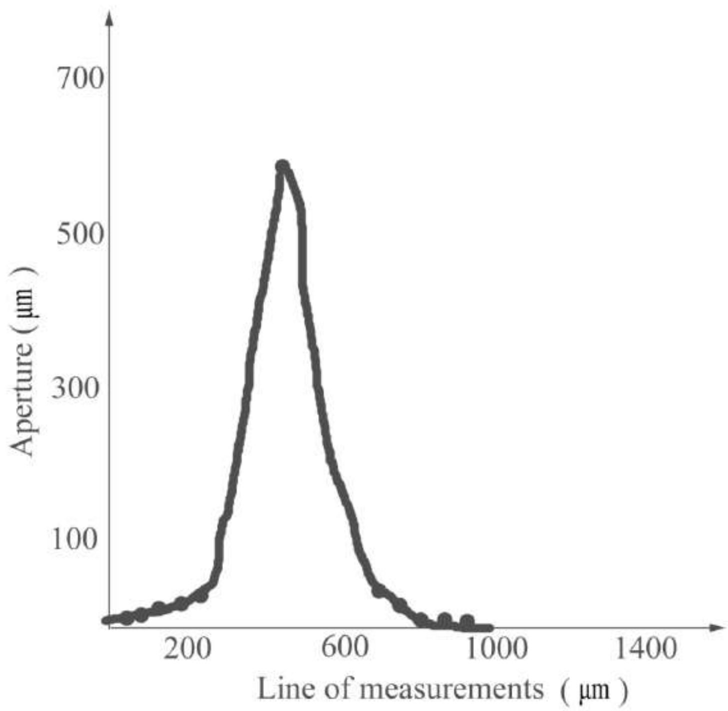
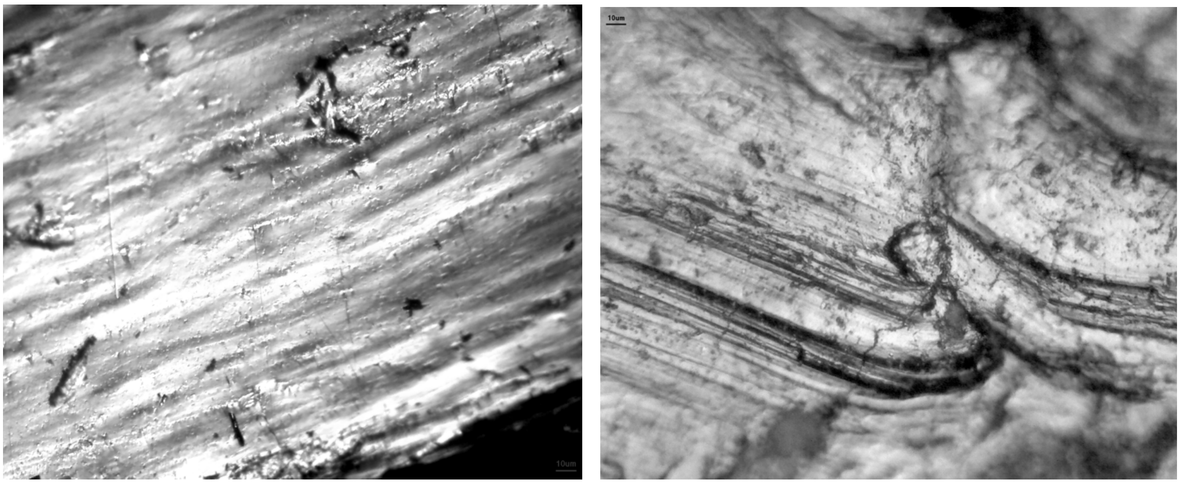


Figure 3 – Graphical interpretation of the data in Table 1

Under external (tectonic) action, corrugation of interplanar surfaces occurs in terms of bedding and micro thrusts associated with this in terms of section (Fig. 4).

The role of individual macerals in the formation of fracturing can be divided depending on the nature of the process (endogenous or exogenous).

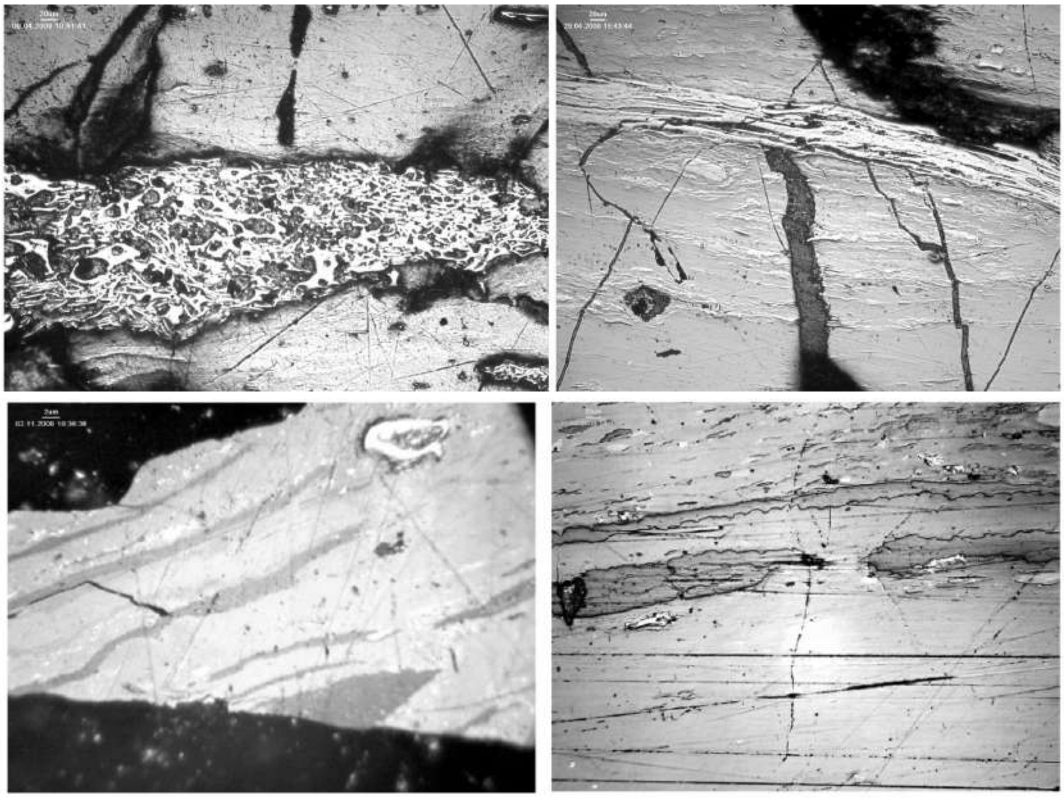
Endogenous fracturing (cleat). Macerals of the liptinite and inertinite groups, due to their greater plasticity or hardness in relation to vitrinite, prevent the development of cleat cracks (Fig. 5).



1 2

Figure 4 – Plicative disturbances in terms of bedding (1) and section (2)

A



B

Figure 5 – Inertinitis (A) and liptinitis (B) prevent the cleat cracks propagation in the gelified substance

Thus, the more diverse the petrographic composition of coals is, the less endogenous fracturing is developed in them, all other conditions being equal. Coals of low stages of metamorphism are characterized by the greatest diversity of composition. With the growth of metamorphism, the difference in the strength and optical properties of macerals is gradually leveled out and the coals of the F-C marks are characterized by the greatest fracturing. To the L mark, the composition becomes, even more, homogenous (features of vitrinite and liptinite fully become the same), however, the total density of coal increases, and fracturing decreases.

Exogenous fracturing. Under an external (exogenous) action leading to corrugation of the interlayer surfaces, cracks in vitrinite appear at the contact boundary with other macerals that differ from it in strength properties (Fig. 6).

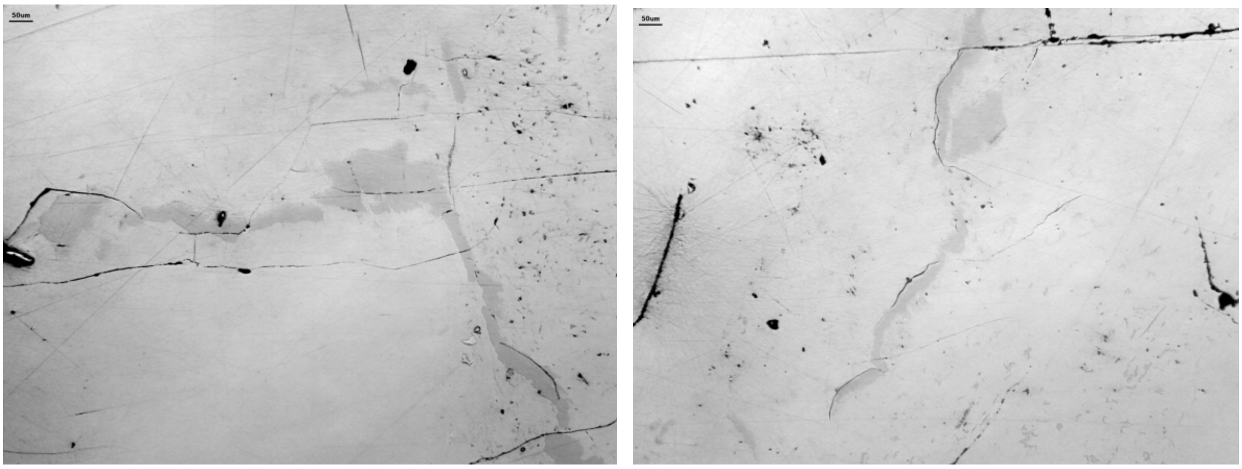


Figure 6 – The emergence of exogenous cracks at the vitrinite-liptinite contact

4. Conclusions

1. The petrographic composition affects the disturbance of coals not only at the level of lithotypes but also at the level of macerals.
2. Liptinite and inertinite prevent the development of endogenous fracturing.
3. Liptinite and inertinite contribute to the development of exogenous fracturing.
4. An increase in the total density of coal at high stages of metamorphism levels out the effect of the petrographic composition.

REFERENCES

1. Mammatt, Edward (1834), *A collection of Geological Facts and Practical Observations intended to elucidate the formation of the Ashby Coal-Field in the Parish of Ashby-de-la-Zouch and the neighbouring district: being the result of forty years experience and research : Illustrated by a Map and Profiles Plates Lawford*, W. Hextall, London, The United Kingdom of Great Britain and Ireland.

2. Ivanov, G. A. and Sarbeeva, L. I. (1940), Klivazh (otdelnosti) v uglyah i vmeshayushih porodah i puti ego prakticheskogo ispolzovaniya [Cleavage (separately) in corners and enclosing rocks and ways of its practical use], part 2, GONTI, Moscow, USSR.

3. Ammosov, I.I. and Eryomin, I.V. (1961), Treshinovatost uglej [Coal fracturing], Nauka, Moscow, Russia.

4. Laubach, S.E, Marrett, R.A., Olson, J.E. and Scott, A.R. (1998), "Characteristics and origins of coal cleat: a review", International Journal of Coal Geology, vol. 35, pp. 175-207. https://doi.org/10.1016/S0166-5162(97)00012-8

5. Solano-Acosta, W., Mastalerz, M. and Schimmelmann, A. (2007), Cleats and their relation to geologic lineaments and coalbed methane potential in Pennsylvanian coals in Indiana", International Journal of Coal Geology, vol. 72, pp. 187-208. https://doi.org/10.1016/j.coal.2007.02.004

6. Widera, Marek (2014), "What are cleats? Preliminary studies from the Konin lignite mine, Miocene of central Poland", Geologos, vol. 20, no. 1, pp. 3-12, https://doi.org/10.2478/logos-2014-0001

7. Xiaoqing, Wang and Fuqiang, Gao (2022), "Triaxial compression behavior of large-scale jointed coal: a numerical study", International Journal of Coal Science & Technology, vol. 9, no. 76, https://doi.org/10.1007/s40789-022-00534-9

8. Guangfu, Zhang, Shiming, He, Ming, Tang and Linghao, Kong (2022), "The mechanism and countermeasures of in-clined well wellbore instability in Dibei deep coal seam", Journal of Petroleum Exploration and Production Technology, vol. 12, pp. 2833-2848,: https://doi.org/10.1007/s13202-022-01483-4

9. Liu, Y., Xiong, Z. and Zhang, X. (2022), "Fracture network characterization of high-rank coal and its control mechanism on reservoir permeability. Earth Sci", https://doi.org/10.3389/feart.2022.995394

10. 10. Scope Photo Image Software (2009), available at: http://labx.narod.ru/documents/scope_photo_image_software.html

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ВПЛИВ ПЕТРОГРАФІЧНОГО СКЛАДУ НА ПОРУШЕНІСТЬ ВУГІЛЛЯ

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Анотація. Оцінка порушеності вугільних пластів важлива як в плані умов їх відпрацювання, так і при прогнозуванні таких особливостей як метаноємність, викидонебезпечність, самозаймання.Одним з методів оцінки порушеностівугілля є його дослідження задопомогою оптичної мікроскопії.Вугілля складається з петрографічних мікрокомпонентів (мацералів), що відрізняються оптичними, а головне міцнісними властивостями.Ця гетерогенність вугільної речовини багато в чому визначає характер порушеностівугілля.У цій роботі показаний вплив мацералів груп инертинітута липтиніту на розвиток диз'юнктивної та плікативноїпорушеності вугілля.

Мета роботи – встановити особливості формування пликативної та диз'юнктивної порушеності вугілля залежно від його петрографічного складу.

Дослідження проводилися за допомогою відеооптичного комплексу: МБІ - 11, HB 200, програмного забезпечення Scope photo. Відмічено що чим різноманітніше петрографічний склад вугілля, тим менш в них розвинена тріщинуватість за рівних інших умов. Петрографічний склад впливає на порушеність вугілля не лише на рівні літотипів, але і на рівні мацералів. Ліптиніт та інертиніт перешкоджають розвитку ендогенної тріщинуватості. Ліптинит та інертиніт сприяють розвитку екзогенної тріщинуватості. Підвищення загальної щільності вугілля на високих стадіях метаморфізму нівелює вплив петрографічного складу. Найбільшою різноманітністю складу характеризується вугілля низьких стадій метаморфізму. Із зростанням метаморфізму різниця в міцнісних та оптичних властивостях мацералів поступово нівелюється і вугілля марок Ж-К відрізняється найбільшою тріщинуватістю. До марки Т склад стає більш одноманітним (повністю вирівнюються властивості вітриніту та ліптиніту), проте збільшується загальна щільність вугілля та тріщинуватість.До тих пір, доки зберігаються відмінності в міцнісних властивостях мацералів (низькі та середні стадії метаморфізму), наявність ліптиніту та інертиніту перешкоджає розвитку тріщинуватості.У вигляді мікрофотографій наведені приклади гасіння тріщин макроспорами та фюзинітом. Відмічені випадки міжшарових просковзуваньта борозен ковзання. Наголошується важливість петрографічних досліджень при оцінці як розривної, так і плікативної порушеності вугілля.

Ключові слова: вугілля, петрографічні дослідження, оптична мікроскопія, мацерали, порушеність.