FEATURES OF FORECASTING THE STATE OF STRESS AND DEFORMATION OF A COAL-ROCK MASSIVE

Nataliia Vergelska[1], Victoriia Vergelska[2]
[1]State Institution «Scientific Center of Mining Geology, Geoecology and Infrastructure Development of the National Academy of Sciences of Ukraine», 34 b Akademika Vernadskoho Blvd, Kyiv, Ukraine, 03142, e-mail:vnata09@meta.ua
[2]State Institution "Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine", 34a, Akademika Palladina av., Kyiv, Ukraine, 03142, e-mail:vvika10@meta.ua

ABSTRACT
Due to the fact that coal reserves are produced in relatively shallow horizons, Ukraine's coal basins are intensively developing deep horizons and mining reserves near the technical boundaries of coal mining enterprises. As mining operations deepen in coal seams, rock pressure increases and the risk of various dynamic phenomena increases. The influence of paleo-disturbance on the intensity of modern vertical and horizontal movements can be determined by comparing geological data on tectonic deformations and displacements by faulting in different areas of Donbas with the results of direct measurements of the stress state in the rock mass and data on vertical surface movements. At the same time, gas mixtures closed in the pores of the coal and rock massif change the quality characteristics due to diffusion between the gas and rocks. In other words, hydrocarbon gases starting from C_5H_{10} will predominate in gas mixtures from areas with a stress-strain state.
Prediction of the stress-strain state of a coal massif makes it possible to prevent gas-dynamic phenomena in coal workings. It is advisable to use geophysical methods of research to predict stress-strain areas from the surface, and to monitor the workings using acoustic and gas-geochemical methods.

Introduction.

In connection with the development of coal reserves in relatively shallow horizons, intensive development of deep horizons and development of reserves near the technical limits of coal mining enterprises takes place in the coal basins of Ukraine. As mining operations deepen in coal seams, rock pressure increases and the risk of various dynamic phenomena increases. During the preparation and operation of deep horizons, one of the most important mining and geological factors affecting the sinking of mine workings and their explosion hazard is the stress-strain state of the massif [10].

The diversity of views, ambiguity in the interpretation of experimental data, and different theoretical ideas about the nature of the stress state of a coal bed mantle indicate the complexity of the issue and the relevance of further research.

Previous studies carried out by different equipment and different organisations have proved the existence of horizontal displacements in coal seams. It is worth noting that horizontal movements have been studied insufficiently, with data available only for certain, limited areas, and their nature is practically unknown.

Materials and methods of the study.

The article analyses and generalises previous studies of the stress-strain state of coal-bearing massifs of the Donets basin. The peculiarities of high-quality gas mixtures in the stress-strain areas of the coal bed mantle are determined. The most informative methods for studying the stress-strain state of a coal bed massif to prevent gas-dynamic phenomena have been established.

Presentation of the main material.

In the postinversion period, the coal seam of the basin was in a state of regional compression, as indicated by the predominance of thrusts in the modern structural plan of the folded part of Donbas. The resulting stresses could be partially or completely relaxed by plastic deformation, rock fractures, and secondary mineral formation. Currently, there is no direct evidence of residual tectonic stresses in the Donets Basin. However, given the lithological heterogeneity of the coal seams, which have different physical, mechanical and rheological properties under comprehensive compression, it is reasonable to assume that complete relaxation may not have occurred. Taking into account the data from other coal basins, the opinion about complete relaxation of ancient tectonic stresses is refuted.

To date, there are authors who do not exclude the role of gravitational forces in the occurrence of areas of increased stress in the coal bed and associate them with residual tectonic stresses that are stored in the rocks and are able to accumulate elastic potential energy or stresses arising from modern tectonic movements [4]. On the other hand, the stress state is determined by the geostatic pressure and gas pressure in the rock pores.

According to the author [7], pressure can occur when temperature and pressure change due to the difference in elastic properties of minerals and inclusions in them and persist for at least about 10^{-3} thousand years. His experiments and the theory he proposed do not deny the possible mechanisms of pressure formation that exceed the lithostatic load in the Earth's crust. That is, the movement of Alpine orogeny in the Neogene, and especially in the Holocene, could have influenced the current tense state of Donbas.

Numerous studies [2, 3, 6, 8, 9] have obtained derived data on the natural stress state of the lithosphere. It has been experimentally established that the stress state of rocks is heterogeneous in terms of the magnitude, propagation and spatial orientation of the main components of the stress tensor. In the presence of general trends in the formation of regional stress fields (predominance of horizontal compressive stresses and close to linear growth with depth of the vertical component, approximately corresponding to the calculated gravity load above the overlying rocks), the ratio and direction of horizontal components are quite different. This made it possible to formulate a generalised geodynamic model of the lithosphere stress state, according to which the formation of the natural stress field occurs as a result of the interaction of gravitational forces and latent stresses caused by the lithological and petrographic composition of rocks, tectonic, hydrodynamic, thermal and other force fields.

The condition of the coal-bearing massif within the Donets basin is characterised by tectonic faulting, which was formed in a layered heterogeneous environment under the influence of multidirectional forces and in different tectonic phases, which is not always taken into account in the interpretation.

The concentration of stresses arising in a heterogeneous coal mass (in the coal and in the host rocks) during the process of mining workings may cause "local" brittle fractures. Depending on the nature and magnitude of the stresses acting in the rock mass at the time of sinking, the fractures can either be localised or develop into a massive process that may involve several mine workings. The quantitative assessment of stress changes based on the measured strain is carried out using the formulas of the theory of elasticity or by means of preliminary laboratory calibration of the installed stress strain gauges. However, during the study, the continuity of the massif is disturbed by drilled wells, which does not allow to assess its fracture rate, which should also be taken into account.

Increased deformations and stresses in the near-horizontal plane were also observed in other mines in the region. When conducting observations in zones of geological disturbances at the Budenovsky mine complex (fields of the Mushketovska, No. 9 Kapitalna, Gluboka mines), it was established that at some distance (4-5 m) from the fault planes of small-amplitude disturbances, horizontal deformations and stresses exceed vertical ones in 2-3 times. Near the displacements, deformations in the subvertical plane predominate [12].

Most observations are fragmentary; they provide a clear idea of the nature of the tectonic stresses currently operating in the coal-bearing strata. The orientation of the stress axes of this field can be judged only by indirect signs. Tectonic stresses in the coal-bearing strata of the region are still active today. They are

inherited from Alpine tectonic movements and are characterized by the same orientation of the axes of the main normal stresses (fig. 1).

Electrometric methods for determining the stress state and fracture rate of rocks have an error of 20-30 % or more. The results are complicated by taking into account many factors [1, 5, 11]: external electric and electromagnetic fields, rock moisture content in the study areas, the type of rock pore space filler and the degree of mineralisation, the presence of metal reinforcement in the study area, etc.

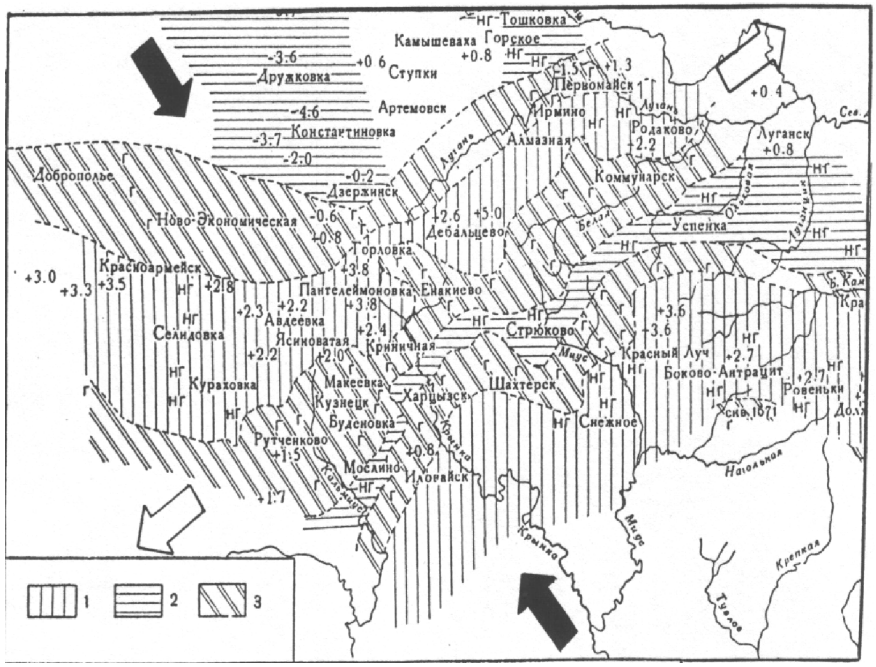

Fig. 1. Zones of modern tectonic movements of Donbass and distribution of gas content of coal seams (Konkov G.A., 1962)

Legend: 1. Zones of modern uplifts (non-gas-bearing and weakly gas-bearing), 2. Zones of modern relative subsidence (gas-bearing or weakly gas-bearing), 3. Zones of modern contrasting movements (gas-dynamic).

In rocks, when the stress increases, it is believed that pores and microcracks close, the number of elastic contacts between individual grains increases and the area of their contact increases. As a result, the decrease in porosity and fracture of rocks leads to an increase in the elastic modulus (Young's modulus).

At the same time, gas mixtures closed in the pores of the coal and rock massif change the quality characteristics due to diffusion between the gas and rocks. In other words, hydrocarbon gases starting from C_5H_{10} will predominate in gas mixtures from areas with a stress-strain state, and unsaturated hydrocarbons may be added in the extreme parts of fractures.

The issue of the nature of the horizontal components of the stress field has not been resolved, as data on them are available only for certain areas and are of a point nature. Taking into account the fact that the coal massif has certain tectonic features, which are expressed by both horizontal and vertical movements. The influence of the type of dislocations and their intensity on the stress state of Donbas rocks has not been studied so far.

The influence of paleo-disturbance on the intensity of modern vertical and horizontal movements can be determined by comparing geological data on tectonic deformations and displacements by faulting in different areas of Donbas with the results of direct measurements of the stress state in the rock mass and data on vertical surface movements.

The post-sedimentation dumps are permeable and, in the absence of gas impermeable cover deposits, contribute to degassing the coal seam along the dump planes. Consolidation dumps are impermeable, which creates favourable conditions for the formation of gas accumulations confined to the zones of associated fractures [2]. In cases where the dumps and transverse faults reach the surface, the

presence of such faults contributes to the demethanisation of coal seams; at greater depths, this type of fault can serve as gas reservoirs.

Shears, as the youngest and most active structures in the modern stress field, control the bulk of recorded emissions. In this case, gas-dynamic phenomena are confined not only to the zones themselves, but to a greater extent to the areas of development of layer-by-layer compensation dislocations (brittle and plicative) in their wings.

Abnormally high reservoir pressures (AHRP) in coal-bearing rocks are of particular interest, as they are associated with the safety of coal field development. One of the reasons for this may be the presence of fracture zones beneath the coal seam, which is a tyre for hydrocarbons. Hydrogen and hydrocarbons flow through the cracks from great depths under high pressure, accumulating and creating high reservoir pressures. When the workings approach such a zone, an explosive gas is bound to be released. Such zones, which cannot be isolated, can only be relieved by degassing explosive gases. Acoustic transmission methods are best suited for their identification, as these are zones of depressurisation with low elastic wave propagation velocities.

According to some researchers, methane is of pre-inversion origin. After the inversion, residual methane volumes were concentrated in structural and tectonic traps of anticline type due to the presence of lithological barriers, as well as in areas of local sandstone depression and non-anticline traps. In such zones, mixtures with methane content prevail.

Conclusion

The influence of paleo-disturbance on the intensity of modern vertical and horizontal movements can be determined by comparing geological data on tectonic deformations and displacements by faulting in different areas of Donbas with the results of direct measurements of the stress state in the rock mass and data on vertical surface movements. At the same time, gas mixtures closed in the pores of the coal and rock massif change the quality characteristics due to diffusion between the gas and rocks. In other words, hydrocarbon gases starting from C_5H_{10} will predominate in gas mixtures from areas with a stress-strain state.

Prediction of the stress-strain state of a coal massif makes it possible to prevent gas-dynamic phenomena in coal workings. It is advisable to use geophysical methods of research to predict stress-strain areas from the surface, and to monitor the workings using acoustic and gas-geochemical methods.

REFERENCES

1. Baklanov I.V. (1988). Deformation and destruction of rock masses. Moscow: Nedra. 190 p.
2. Batugin A.S., Batugina I.M. (1973). Changes in the stress state of an intact rock mass in space and time. Stressed state of the earth's crust. Moscow: Nauka. pp. 148-157.
3. Bulin N.L. (1971). Modern stress field in the upper horizons of the earth's crust. Geotectonics. No. 3. P. 3-15.
4. Bykov L.N. (1964). On the nature of sudden releases of minerals in mines. Safety issues in coal mines. Moscow: Nauka. 184 p.
5. Integration of geophysical methods in solving geological problems / Ed. V.E. Nikitsky, V.V. Brodovoy (1987). 2nd ed. reworked and additional Moscow: Nedra. 471 p.
6. Markov G.A., Savchenko S.N. (1984). Stressed state of rocks and rock pressure in mountainous relief structures. Leningrad: Nauka. 138 p.
7. Panova O.A. (1995). Patterns of influence of geological factors on displacement of the earth's surface in conditions of forgery (on the example of the Donetsk-Makiiv district of Donbass): 04.00.16. Abstract of the dissertation. ... candidate geol. of science Lviv. 25 p.
8. Pimonenko L., Vergelskaya N. (2022). Prediction dynamic phenomena in coal mines. Proceedings of the X International Geomechanics Conference, Varna, Bulgaria, 19 – 23 September, 2022. pp. 230-234.
9. Sherman S.I., Dneprovsky Yu.G. (1989). Stress fields of the earth's crust and geological and structural methods for its study. Novosibirsk: Science. Siberian branch. 155 p.

10. Skochinsky A.A., Lidin G.D. (1948). Classification of methane emissions in coal mines. Izv. USSR, ONT. No. 11. P. 1741 – 1751.
11. Zakharov V.N. (2002). Seismoacoustic forecasting and monitoring of the state and properties of rocks during the development of coal deposits. Moscow: Federal State Unitary Enterprise NSC GP – IGD named after A.A. Skochinsky. 172 p.
12. Zubarev Yu.P., Shestakov G.P. (1974). About increased stresses in zones of tectonic disturbances. Measurement of stresses in rock masses. Novosibirsk. P.125-127.