

Forming peculiarities and manifestation of tectonic faults in soft rocks

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One of the important geological factors that influence the efficiency of underground works is a fault disturbance of the coal deposit. About 10% prepared for extraction of coal in conditions of mines in Western Donbass coal basin are affected by tectonic fractures. Some extraction panels, such as at “Dneprovskaya” mine and mine named after Heroev Kosmosa, have violated zones for half the length of extraction pillars.

The main part of the Western Donbass coalfield represents one of the major blocks of the southern edge of the Dnieper-Donetsk cavity [1]. This block is bounded on three sides by large faults: Mikhailovskiy, Karabinovskiy and Krivorozhsko-Pavlovskiy (Fig. 1). Southern boundary of the blocks is the edge of the Ukrainian Precambrian crystalline shield.

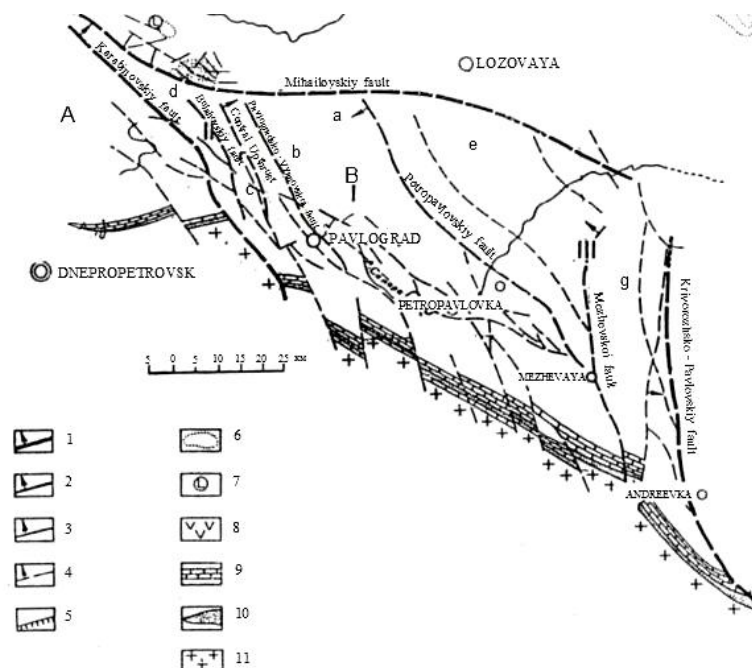


Fig. 1 Tectonic scheme of the Western Donbass.

1st order blocks: A - Dnieper block, B - Samara block; 2nd order blocks: I - Central, II - Western, III - Eastern; 3rd order blocks: a) - Average b) - Samarskiy, c) - Pavlogradskiy, d - Bulakhovskiy, e) - Karabinovskiy, f - Petro-pavlovskiy, g - Mezhevskiy. Faults: 1 - the first order faults, 2 - the second order faults, 3 - the third-order faults, 4 - the fourth order faults, 5 - thrusts, 6 - domes, 7 - the sources of salt, 8 - volcanic rocks, 9 - limestone, 10 - Devo, 11 - Precambrian.

A characteristic feature of the structural construction of this geological and industrial district is the location of sedimentary strata with the greatest capacity on the crystalline basement. It is assumed that the nature of the tectonics of the region is determined by the movement of the foundation blocks [1,2].

Because of unequal multi-dipping of crystalline basement of Samara lump the horst-and-graben structure was formed. It consists of three large blocks which broke the lump on narrow blocks (Fig. 2) [3].

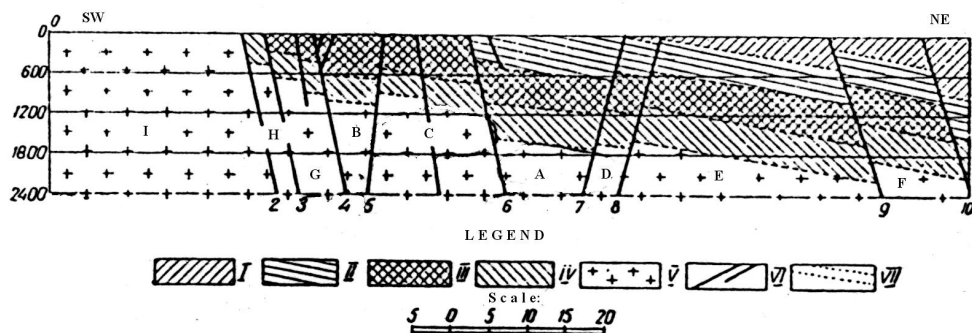


Fig. 2 Schematic geological and structural section of the Western Donbass

I - Middle Carboniferous sediments; II - Namur deposits; III - Samara Formation (coal-bearing); IV - carbonless entourage, nizhnevizeyskie and turnayskie deposits; V - Precambrian crystalline basement rocks; VI - faults; VII - geological boundaries. T The structural elements of Zapadnodonetsk graben: A - Central Graben, B - Pavlogradskiy graben, C - Samara horst, D - Petropavloasky block, E - Bykovskii block, F - Slavyanki block, G - Bulakhovskiy block, and - Karabinovskiy block, H - Novomoskovskaya stove. The principal faults: 2 - Karabinovskiy fault 3 - Bulakhovskiy fault, 4 - Central fault, 5 - Pavlograd-Viazovskoi fault, 6 - Bogdanovskiy fault 7 - Shevchenkovskiy fault, 8 - Prtopavlovskiy fault, 9 - Mezhevskiy thrust, 10 - Krivorozhsko-Pavlovskiy fault.

Mines of DTEK "Pavlogradugol" company (Western-Donbass coal basin) are located in the central block of 30-40 km wide and elongated in a north-west direction for 90 km. This block represents the stage structure of three blocks: Medium, Pavlogradskiy graben and Samarskiy horst. Fault planes of this tectonic fissures fall in opposite directions at an angle of 55° - 70° [1]. It considered that these faults were formed during sedimentation (Bulakhovskiy, Central, Bogdanovkiy), and Pavlogradsko-Viazovskoi and Petopavlovkiy faults were formed during the inversion of vertical movements [4].

Tectonic disturbances are divided into five groups:

I - The largest faults of region with vertical amplitude of up to 2000 m;

II - Faults inside blocks with vertical displacement of 80 - 250 m;

III - Faults inside blocks with a vertical amplitude of up to 70 - 200 m;

IV - off shooting faults which are characterized by displacement amplitude of 20-30 m and have negligible depth.

V - micro-faults with an amplitude of up to 2-3 m and affect one or more seams.

The main feature of geological tectonics of the Western Donbass industrial region is the prevalence of tectonic fractures in the form of faults. Small-amplitude violations of IV and V groups are usually found within strata of small thickness and have a minor extent [5]. Thus, it is observed that small-amplitude folded and disjunctive dislocations are the result of a single process, but it is impossible to set it on the geological data.

The manifestation of faults of IV and V groups in the Western Donbass was considered to establish the nature of its formation. The research of these manifestations is based on the principles of fixing major morphological signs of violations that need to be related to the nature of formation and of course do not depend on the production human activity.

The direction and value of faults wings movement can be determined by a slide mirrors, which is the fault plane [6]. Considering that, in accordance with the theory of Mohr, failure occurs under the action of shear stresses, sliding track can be some of the geometric parameters of the formation of normal stresses principal axes [7]. In the condition of weak rock walls, such as siltstones and mudstones in the Western Donbass, these displacement tracks in the form of lines and furrows are not fixed by the Geological Survey of mines because of their inability to establish them visually. This complicates the solution of the problem.

The presence of several differently oriented systems of faults creates uncertainty of their determination. The intersection of one fault by another should indicate a younger age of first one. On the geological maps of the Western Donbass multidirectional fissures are shown as contiguity (jamming) of smaller discontinuity to the larger one. Smaller discontinuities are called "apophyse" [8]. It was found that in the place of jamming of one violation to another the amplitude of smaller one is zero at transition of faults by the mechanized complexes in Western Donbass (Fig. 3) [9]. Disturbed areas represent the combination of individual fault planes located subparallel to each other or elongated in chain.

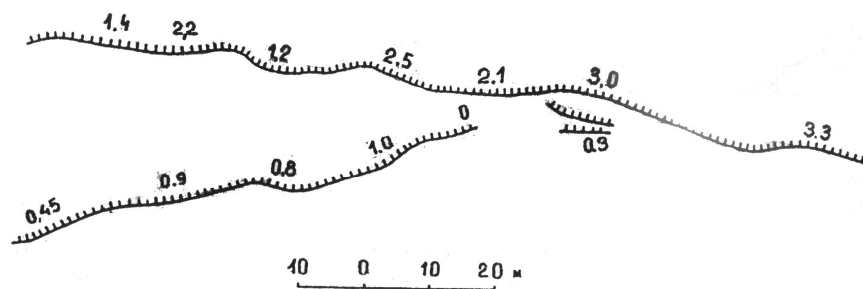


Fig. 3 "Jamming" of faults in the lava, mine "Dneprovskaya"

There were cases when contouring of the excavation field did not give information about the presence of faults (Fig. 4). These facts confirm elements of the phase formation of faults by the theory of M.V.Gzovsky in closed volumes [10].

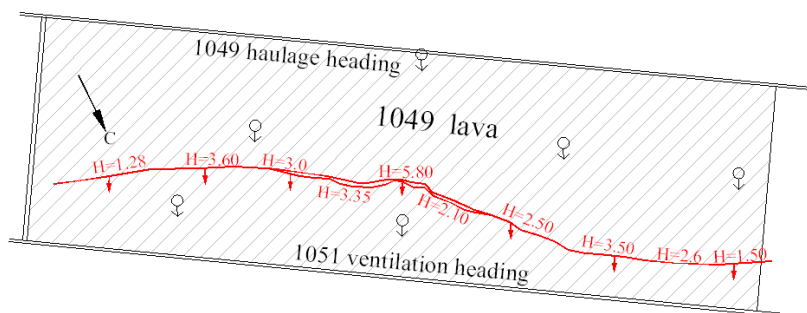


Fig. 4 Extract of mine plan, the mine "Dneprovskaya"

On rose diagrams analysis of shear zones of faults in "Pavlogradskaya" mine established that chips are oriented at an angle of 15-20 ° to the zone of the main displacement and authors carried them to the Riedel chipping [12]. It should be noted that the impact angle of small violations with larger one is also approximately equal to 25 ° (Fig. 3).

In the transition of tectonic violations by the mechanized complexes staggering of faults are found (Fig. 5) [9], which generally corresponds to the shape of the stepped arrangement of faults in horizontal shifts with a simple chips [13].

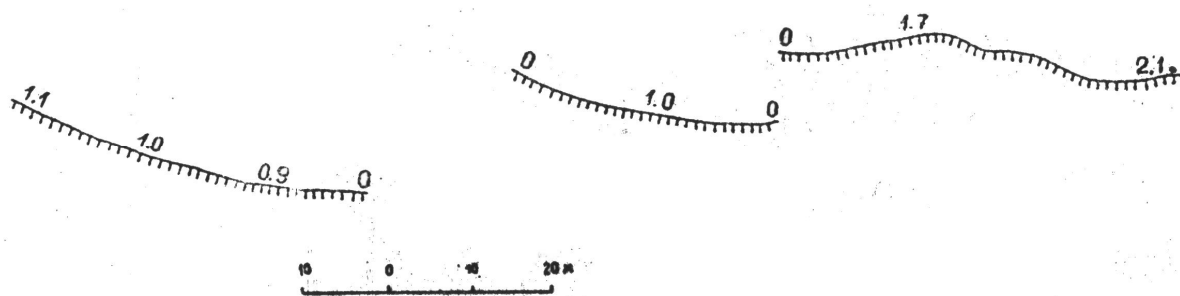


Fig. 5 Staggered faults

In gently dipping seams in Western Donbass coal region is convenient to use graphical representation of propagation of fault plane crossing lines with the seam in the form of rose-diagrams. 8 seams was examined in nine mines. Total amount of examined crossing lines is 304, the maximum amplitude is 20 m. Distribution of crossing lines of fault planes with the seam is characterized by two dominant directions (Fig. 6) with an angle between them about 60 °. One of the directions coincides with the direction of tectonic disturbances of the second group. All this confirms the generality of causes of their formation.

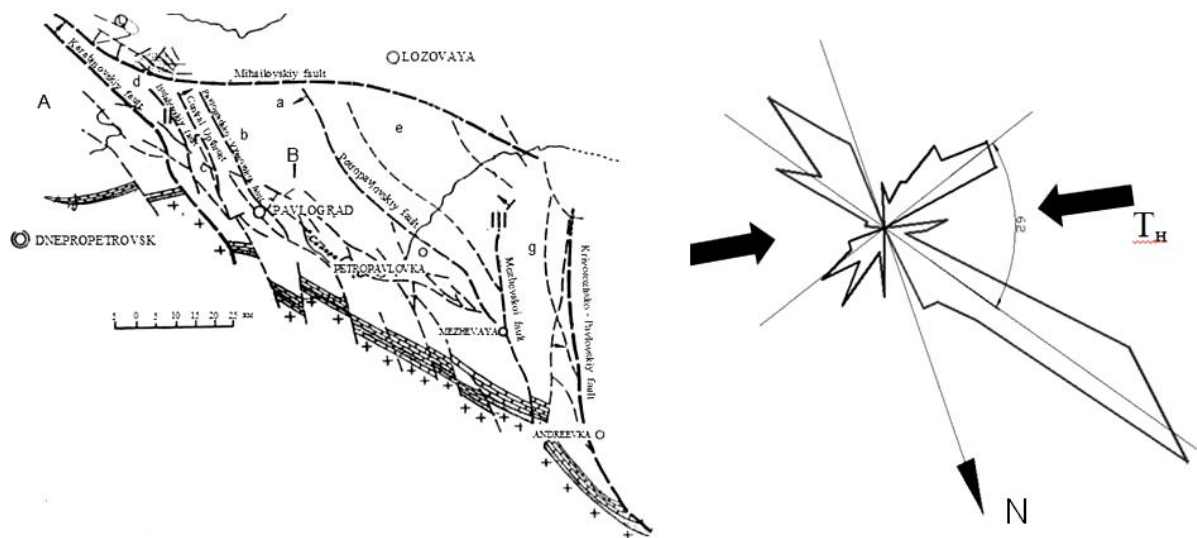


Fig. 6 The scheme of distribution of discontinuous tectonic disturbances in the Western Donbass.

If we assume that the horizontal tectonic tension and overall tension in this direction more than γH , then when reaching the maximum shear stress, shift must occur approximately vertically to the site AB at an angle α (Fig. 7).

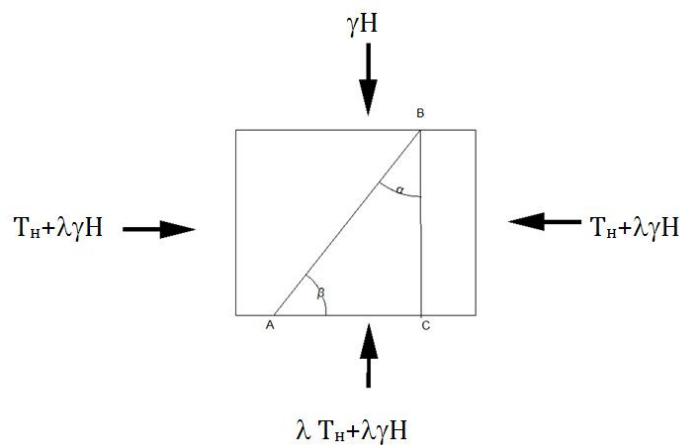


Fig. 7 Formation of shear planes, λ - coefficient of lateral thrust.

From the theory of strength it is known that the angle α depends on the internal friction angle ρ of material [14] and is equal:

$$\alpha = \pi/2 + \rho/2.$$

In turn, the angle BAC from the triangle ABC is equal to:

$$\beta = 90^\circ - (\pi/2 + \rho/2) = \pi/2 - \rho/2.$$

Taking the angle of internal friction for the rocks in Western Donbass equal to $\rho = 30^\circ$ [15], we obtain $\beta = 30^\circ$. Taking the Anderson model of horizontal shift formation in pure chips [13] it can be explained a lot of morphological manifestations of faults (Fig. 8). Under compressive tectonic forces T_n the chip is formed at an angle of 30° from the direction of the tectonic stress. Along the line I-I points 1 and 1' will have to take a new position 2 and 2', that is, the array should be reduced in this direction with the formation of rupture. When shifting rocks along the line I-I parallel to the stress T_n , the array should be expanded. When shifting perpendicular to the stress T_n the array should shrink. As deformation of array occurs in closed volume, points must be moved in horizontal and vertical directions. Taking into account the

anisotropy of array and other geological factors such as heterogeneity the same displacements may occur along line II-II. The total angle between the lines I-I, II-II and Tn is approximately 60°, which corresponds to rose diagram (Fig. 10)

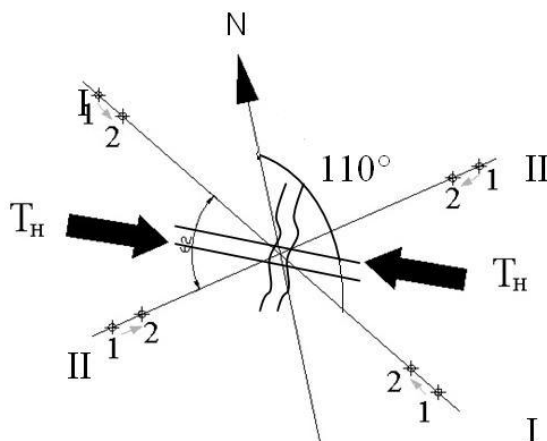


Fig. 8 Schematic of the formation of crossing lines of fault plane with the seam.

≈ - compression of the rock massif; = - expansion of the array rock massif.

Fault plane usually has a wavy surface, so sinusoidal crossing line is formed with its intersection with the seam (Fig. 3, 4). Random function of crossing line has a stationary character [11]. This line was graphically divided into straight lines of 3 m lengths. The distribution density of the angles between the line segments and the line of the fluctuations has uniform character and changes in the range of 1° to 25,5°. It can be seen that the stage of faults development is the simplest flow of smaller discontinuities formation, which combine into larger violations while expanding. The destruction of bridges between original discontinuities results in the sinusoidal form of crossing line between fault plane and coal seam. The standard deviation of uniformly distributed points on a crossing line from the fluctuation line, determined by 14 crossings of faults by mechanized complexes, is 2.46 m. Thus, the width of fluctuation zone between crossing line of the fault plane with the seam can be considered as 5.7 m with a probability of 0.68.

Amplitude variability in rock mass discontinuity occurs both vertically and horizontally. There are cases when the faults "damped" as the depth increases. Undercutting of fault at auxiliary shaft drivage at the mine "Pershotravneva" can be as an example (Fig. 9) [9].

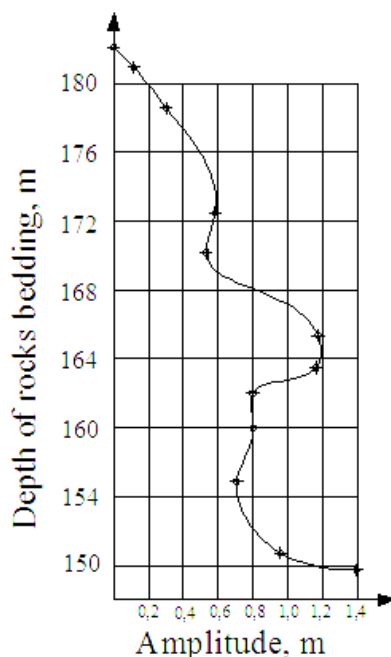


Fig. 9 Change of the faults amplitude during an auxiliary shaft drivage at mine "Pershotravneva"

Idealized fault plane can be represented as a set of closed systems of ellipsoidal shifts with amplitudes changing from minimal at the center to zero at the periphery [7]. These systems can have access to the surface of the Carbon. The amplitude of faults varies along the crossing lines for two reasons. First, it changes within the fault plane diagrams. And the correlation between stratigraphic amplitude displacement of fault wings and the distance to a point of zero amplitude is described by equation [9]:

$$A=0,02E,$$

A - stratigraphic amplitude at the observation point, m;

E - distance from the observation point to the wedging of fault plane, i.e. the violations damping, m.

After 30 years, these studies were repeated, but with a large number of data [15]:

$$A=0,016E.$$

By the instrumental survey of profiles Seam in pre-breaking zones it is found that in most cases the stratigraphic displacement amplitude of the faults wings is less than the stratigraphic amplitude in place of the discontinuity in the rock mass (Fig. 6). The origin of these bends cannot be explained by the presence of tectonic stresses stretching. The origin of these bends can be explained by the seam plicativity before breaking of its continuity.

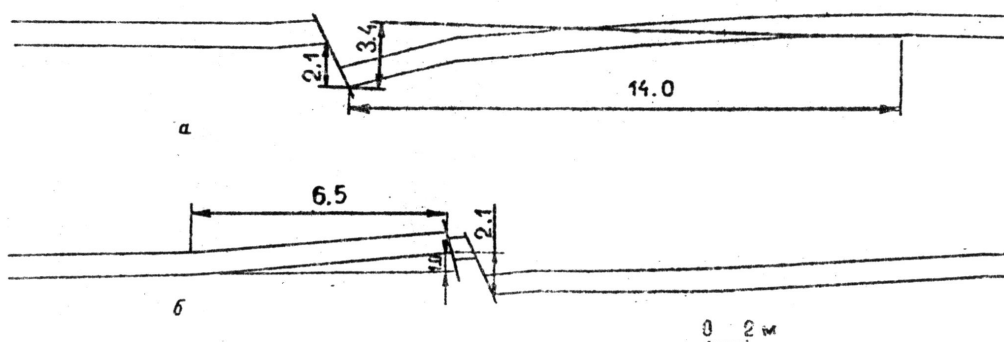


Fig. 10 Seam profile in lava at fault transition:
a) at the entrance of lava to the violated zone; b) after moving along the fault plane

Thus, the formation of faults in Western Donbass coal region was in an enclosure volumes of rocks during the action of horizontal tectonic stresses. Thus the long axes of the majority of violations are oriented according to the Anderson model of the discontinuities formation. Studying of features of the formation and propagation of discontinuous tectonic faults in weak rocks, such as undulation of crossing lines of fault plane with the seam and the damping of the amplitude, provides an efficient planning of mining operation in disturbed zones taking into account these characteristics.

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