ГЕОЛОГІЯ

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TECTONOPHYSICAL ASPECTS OF THE DEVELOPMENT OF GEOLOGICAL STRUCTURE OF THE WESTERN CLOSURE OF THE HORLIVKA ANTICLINE OF THE DONBAS

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ТЕКТОНОФІЗИЧНІ АСПЕКТИ РОЗВИТКУ ГЕОЛОГІЧНОЇ СТРУКТУРИ ЗАХІДНОГО ЗМИКАННЯ ГОРЛІВСЬКОЇ АНТИКЛІНАЛІ ДОНБАСУ

Purpose. The present study focuses on the analysis of the geological structure, stress and strain fields of the western closure of the Horlivka anticline to present a general development mechanism with regard to tectonophysical features, and to determine whether the structural complexity of the study area is consistent with a single regional stress field or not.

Methodology. The kinematic and structural data available for the study zone have been studied. Further, fault data, including both the fault plane and slickenline orientations, and the sense of movement have been studied by the kinematic analysis method of O. Gushchenko to estimate characteristics of the mesoregional stress field and the total strain field. Local stress data have been processed by the method for determination of general stress fields to provide for reconstruction of principal normal stresses which are arbitrarily considered as regional stresses. Relative age chronology and staging of tectonic stresses have been processed by the stress monitoring method.

Findings. NW-trending dextral and NE and N–S-trending sinistral strike-slip faults prevail among other faults. Mesoregional stress field characterized by subhorizontal NW–SE maximum (σ_3) and NE–SW minimum (σ_1) principal axes, and apparently originated in Laramide time of Alpine orogeny is strike-slip faulting type and the youngest for the Donets Basin. Extension axis (ε_1) of the strain ellipsoid is NW and N–S oriented, and shortening axis (ε_3) is NE oriented nearly orthogonal to the anticline axis. Strike-slip faulting type of total strain field was determined for the most part of the western closure of the Horlivka anticline area, and according to the Lode–Nadai coefficient ($\mu_\varepsilon = \pm1$), deformations on the study area had been going mainly under shear conditions. The pattern of a single structural paragenesis of deformation elements of the study area, including a conjugate strike-slip fault system, dome-shaped fold and longitudinal thrusts in its limbs, was developed due to the right-lateral displacements along the longitudinal strike-slip fault system within the Main anticline paraxial part.

Originality. Strike-slip faults and large shear zone are revealed in the geological structure of the study area, and their morphology, development, and interaction of structural elements are characterized. The primary characteristics of the stress fields of local and mesoregional level, including its relative age chronology and staging, and of the total strain field are reconstructed.

Practical value. Taking importance of the results obtained by the kinematic method into account, applying of new forecasting methods based on reconstruction of primary tectonophysical characteristics and reconstruction of deformation mechanisms appears to be needed.

Keywords: *kinematic method, stress and strain fields, Lode–Nadai coefficient, slickenlines, strike-slip fault, shear zone, structural paragenesis*

Introduction. Understanding the regularities, development mechanisms, and spatial distribution of tectonic dislocations plays an important role in both academia and industry, where it may be used for both elaborating the physical theory of the development of deformation processes in the Earth's crust, and in forecasting, prospecting, and exploration of mineral deposits, mining at deeper levels in more difficult geological conditions.

Any kinds of geological forecast on various stages of mining sequence should be based on explanation of deformation mechanisms and history of the crust part development. Key issues concerning its reconstruction are: 1) what were the main directions of active tectonic forces under which the geological structure at different stages over geological time was formed; 2) which stress fields were active while the geological structure was forming; 3) what deformation and dislocation distributions within the structure are?

Tectonophysical study is one of the effective ways to objectively estimate it by determination of regularities of the stress distribution and development of tectonic deformation, appearing within the crust. In spite of having various kinds of modeling to solve tectonophysical problems now, field tectonophysics data may make an essential addition to the final results. Furthermore, the surface and underground mining used in layered sedimentary deposits creates very favorable conditions for that. For instance, application of the longwall mining method in thick coal seams, along with geological mapping and documentation of underground workings in detail, allows studying geological structures on a true scale, and to record morphology changes both all over the planar surface and cross section.

Analysis of the recent research. The Main anticline of the Donets Basin is of great interest as a subject of tectonophysical study not only because of its structural complexity and development mechanism, but also due to their effect on the safe high-efficient exploitation of coal.

As one of the major segments of the Main anticline, the Horlivka anticline is known, first and foremost, for Nikitovka ore field occurred in the crest part of the fold. Structures of Nikitovka ore field have been investigated and mapped in detail for a long time. Various massif deformation elements were geometrized there, its morphology and kinematics were determined, and stress fields for many localities, mine fields, deposits and the region as a whole were reconstructed.

The stress field reconstructed for Nikitovka ore field is characterized by a subhorizontal NW-plunging (330°) maximum principal stress axis σ_3 (maximum compression) and a subhorizontal SW-plunging (245°) minimum principal stress axis σ_1 (maximum tension) [1–3]. The stress field axes are oriented in directions diagonal to the Horlivka anticline, a major ore-controlling structure, and symmetric to second-order dome-shaped folds complicating the crest of the Horlivka anticline. Moreover, a σ_3 axis is invariably perpendicular to the dome-shaped fold axes. The ore field structure was developed under conditions of a special pulsating type of the massif stress state, changing from uniaxial compression to uniaxial tension and vice versa. This stress field that apparently originated in Laramide time of Alpine orogeny is the youngest for the Donets Basin.

According to the reconstructed stress field characteristics, fault kinematics and orientation of structural deformation elements, Korchemagin interprets the Main anticline as over-fault fold, developed in the Carboniferous ductile sedimentary series due to the right-lateral displacements along the zone of the Central Donets deep-seated fault, that also resulted in the development of the structure of the crest of the Horlivka anticline and Nikitovka ore field [1]. Reflection of the Central Donets fault in present geological structure of the study area is the Osevoy thrust, traced along the whole length of the Main anticline axis. Those studies have shown that all known deformation elements of the ore field, such as morphology and kinematics of the faults, position and orientation of the dome-shaped folds, systems of transverse fissured veins, straightness of segments of the longitudinal Sekuschaya fault, are parts of the structural paragenesis for right-lateral faulting, and are consistent with a single regional stress field.

Objectives of the article. Although the problems of deformation element structural paragenesis, stress fields of local and regional level, and also the mechanism of the development of the Main anticline western part were well studied, it should be pointed out that area of the western periclinal closure of the Horlivka anticline is not studied as well as Nikitovka ore field. Now it seems to be possible to do because of new facts of the regional geological structure, fault kinematics and stress field characteristics, obtained through the structural and tectonophysical works within Novodzerzhynska coal mine field.

The present study focuses on the analysis of geological structure and stress and strain fields of the western closure of the Horlivka anticline to present a general development mechanism, and to determine whether the structural complexity of the study area is consistent with a single regional stress field or not.

The tasks necessary to reach these objectives are: 1) to study kinematics, morphology, and age relations of the faults; 2) to define structural pattern of the massif deformation elements, and determine a mechanism of its development; 3) to reconstruct main characteristics of stress and strain fields of local and mesoregional level; 4) to analyse an interaction between geological factors and various tectonic structures, and basic characteristics of stress-and-strain fields.

Methodology. Tectonic stresses have been studied by the kinematic method [4]. The method used principles of plasticity mechanics, in particular, the Batdorf–Budiansky's plasticity theory, and postulated the coincidence of the fault side slip direction with the shear stress direction on the fracture plane. Graphic algorithm for calculating the principal stresses and evaluating the Lode–Nadai coefficient (or ratio coefficient), determining the shape of the stress ellipsoid and the ratio of deviatoric components of principal stresses were developed on this assumption. The input for the study was field-measured orientation data for faults and slickenlines from mine workings within the Novodzerzhynska mine field (more over than 900 measurements), consisting of the orientations of the fault planes and slickenlines, including the sense of movement. Mesoregional level stress field characteristics have been reconstructed by statistical processing of local stereographical solutions. Local stress data processed by the method for determination of general stress fields provide for reconstruction of main normal stresses which are arbitrarily considered as regional stresses [5]. Relative age chronology and staging of tectonic stresses have been studied by the stress monitoring method devised by O. Gushchenko and A. Mostrukov on the base of the kinematic method. It insures a possibility of space-time monitoring of tectonic fields of stresses and strains on the base of geological data, which allows us to solve the problem of age chronology of paleostresses [4]. Characteristics of the principal axes of the total strain field have been processed by means of specialized software GEOS developed by O. Gushchenko and upgraded by V. Korchemagin.

Presentation of the main research. *Geological structure.* The Main anticline, a major WNW–ESE-trending (290–305°) symmetrical fold, extends 300 km throughout the Donets Basin. Towards the west of the Nagolny Ridge, it divides into three right-stepping en echelon fold segments: Olkhovatka–Volyntsevo and Horlivka anticlines, Druzhkivka–Konstantinovka brachyanticline. Both limbs of the fold dip generally steeply (60–65°), and the crest of the fold, wide in the west and narrow in the east, is faulted by reverse and strike-slip faults, trend parallel to the fold axis. The Horlivka anticline is the most studied segment of the Main anticline where lots of coal mines and Nikitovka ore field are situated. Nikitovka ore field is related to five similar dome-shaped folds, 1 km length and 0.4 km width, exposed in roughly equal intervals (1.4 km) within the crest of the anticline. The fold axes appear rotated at an acute angle, typically 15–30° anticlockwise towards the Horlivka anticline axis. Longitudinal faults of the Osevoy thrust system separate these folds to the north and south of the anticline crest part. Four larger dome-shaped folds expose in roughly equal intervals (3–3.5 km) to the east and to the west of fold set of Nikitovka ore field.

As the object of the field tectonophysical studies, the Novodzerzhynska coal mine is the westernmost one in the area of the western periclinal closure of the Horlivka anticline. The Middle Carboniferous (suites *K* to *M*) seams over the mine field have been basically mined. In the study area, the beds dip away from the crest of the anticline at an angle of 30–35° on the periphery, which decreases to 10–15° near the crest. In strike, they vary from a little west through a little north to south of east. The whole region is traversed by an immense number of small-scale faults. Their strikes have such varying directions, but the great number appears to follow the three trends of sublatitudinal, submeridional, and northwest. Two major faults divide mine field from the anticline limbs: Almazny fault, NW-trending high-angle fault with dip to the north, in the north, and Glavny thrust, latitudinal fault with moderate southward dip, in the south. Both of the faults show displacements with a strong component of right-lateral strike-slip.

In view of the observed structural complexity, the study area was divided into two domains along the Osevoy thrust: the first (D_1), to the north, and the second (D_2), to the southwest (Fig. 1). The geological structure of D_2 domain is relatively simple. Beds dip to the southwest, and the amount of the displacement or deformation is comparatively insignificant. In strike, the beds are bounded by the Osevoy and Hlavny thrust planes in the west–northwest and south, respectively.

On the contrary, the structural pattern of D_1 domain is more complex, characterized by the plicative dislocation structure severely complicated by the faults. In their orientation, faults follow the three trends of the northwest, west–northwest, and longitudinal (N–S). NW– and N–S-trending high-angle (75–80°) faults with dip to the northeast and west, respectively, while the dip of WNW-trending faults is about 40° to the south–southwest (Fig. 2, *a*).

To form a better view of the structural pattern of D_1 domain it was also subdivided into two subdomains: the eastern (D_{1E}), and western (D_{1W}). The most important fault system in the D_{1E} subdomain is the large shear zone 300 m width, a NW-trending set of faults consisting of several parallel high-angle (70–80°) fault planes with dip to the northeast that can be followed for 500–800 m over the domain area (Fig. 3). It is traced to the east into the crest of the Horlivka anticline where it merges into the Osevoy thrust. The en echelon NW faults are composed of right-stepping segments that imply a right sense of movement. The segment set has regular spacing of 100–150 m. The

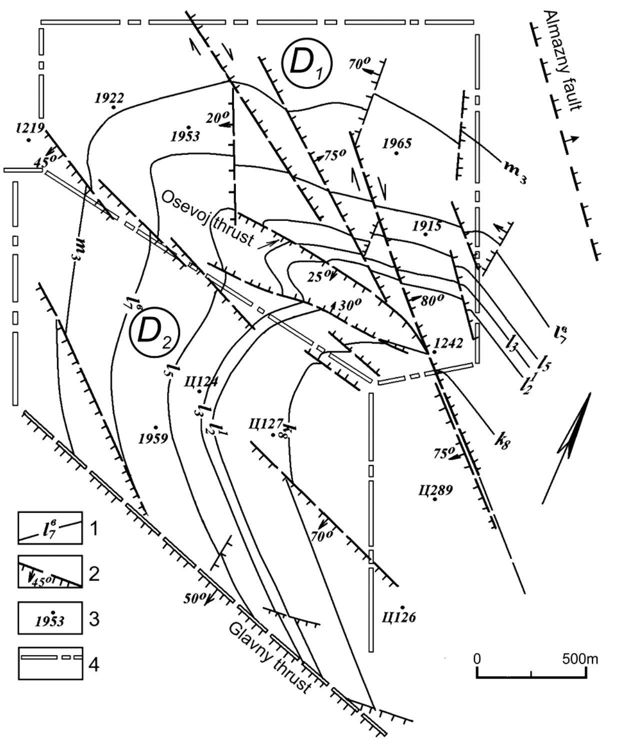


Fig. 1. Simplified geological and structural map of Novodzerzhynska mine field (plan of level –502 m):

1 – major coal seams; 2 – faults with attitude of dip; 3 – prospecting drills; 4 – structural domain boundaries

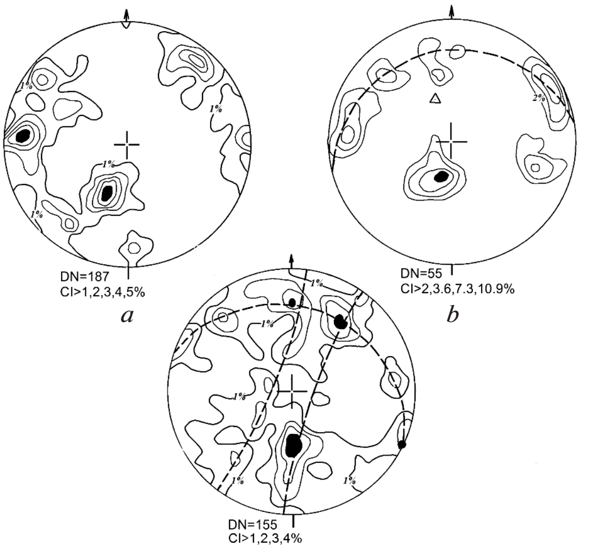


Fig. 2. A structural pattern of D_1 domain (all stereographic plots in this paper are upper-hemisphere projections):

a – contouring of poles to faults. Osevoy thrust zone: b – contouring of poles to faults; c – contouring of poles to slickenlines and grooves. Arcs of great and small circles are shown by dashed lines. Poles to those circles are shown by solid circles. DN, data number; C_1, contouring interval

slickenlines plunge gently to the southeast, giving predominantly dextral-normal oblique-slip faults.

The area between the NW-trending faults is traversed by the NNE-trending set of sinistral-normal oblique-slip faults consisting of several parallel high-angle fault planes with 5–7 m of stratigraphic throw. In strike, they can be followed for 400 m, and are commonly bounded by the former fault planes.

From kinematic and structural standpoints, these two fault sets, NW (dextral normal-oblique) and NE (sinistral-normal oblique), may be inferred as a conjugate strike-slip fault system.

Dome-shaped fold is an important point in the context of geological structure of the D_{1W} domain which is not observed on the present topography and becomes readily apparent at more than 450 m depth below the surface. Periclinal closure and the north limb of the fold are best exposed on the current mining level and its south limb is cut by set of low-angle faults of the Osevoy thrust system (Fig. 4). The fold has gently plunging (20°) hinge-line which plunges to the west and south-dipping nearly upright (82°) axial plane. The south limb of the fold dips 18° to the west, and the

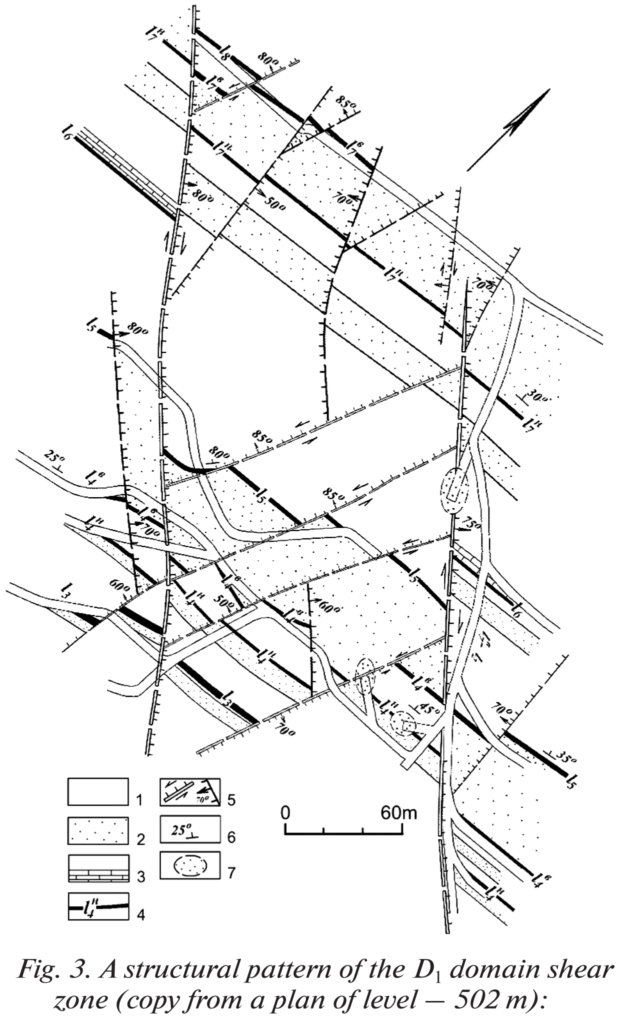


Fig. 3. A structural pattern of the D_1 domain shear zone (copy from a plan of level – 502 m):

1 – argillites and aleurolites; 2 – sandstones; 3 – limestones; 4 – coal seams; 5 – faults with sense of slip, dip direction and dip angle of the fault; 6 – attitude of bedding; 7 – inrushes

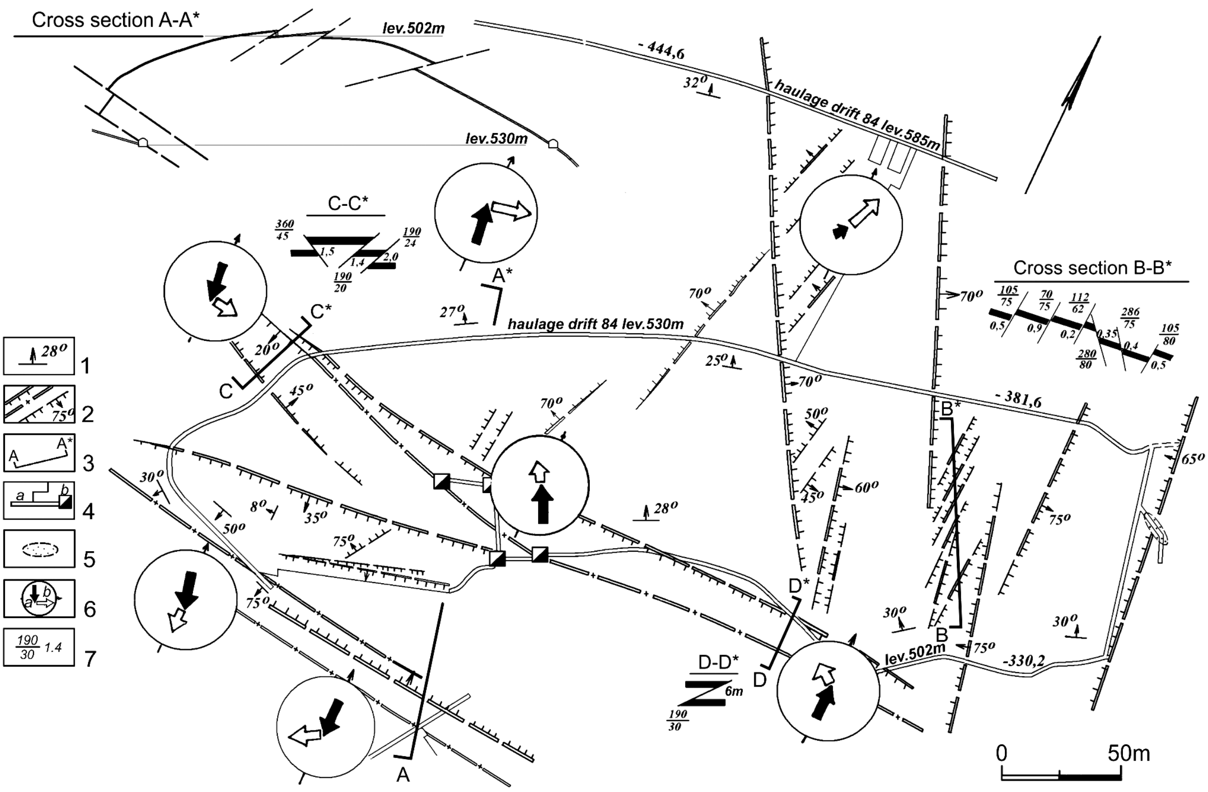


Fig. 4. Geological structure and stress fields of the Osevoy thrust zone (a copy of l_2^1 *coal seam mining plan):*

1 — attitude of bedding; 2 — faults with dip direction and dip angle of the fault plane (for low-angle faults — layer crop lines in the hanging and footwalls); 3 — cross section lines; 4 — mining workings: (a) horizontal (drift), (b) vertical (rise); 5 — inrushes; 6 — points of stress fields reconstruction: (a) σ_3 *upper-hemisphere projection, (b)* σ_1 *upper-hemisphere projection; 7 — fault attitude: dip direction (numerator), dip angle (denominator), and stratigraphic throw*

north limb dips steeper (35°) than the south one to the north–northwest. According to dimensions, geometry and spatial orientation, the observed fold is similar to those of Nikitovka ore field.

In contrast to the shear zone, the faulting style of D_{1E} domain is mainly defined by WNW-trending faults of the Osevoy thrust system, parallel to the dome-shaped fold axis. Two sets of WNW-trending, N- and SSW-dipping, low-angle (20–30°) thrust faults with the stratigraphic throw of up to 20 m on some of them have been observed there. Slickenlines are elongated parallel to the dip direction. In addition to the low-angle thrusts, network of numerous secondary high-angle faults is developed on both the hanging and footwalls of the thrusts. Relatively large and extensive ones of those are: NW-trending high-angle (75°) faults with 3–4 m of stratigraphic throw. Two sets of small high-angle (55–70°) faults with the stratigraphic throws of a few decimeters to a couple of meters are mainly developed within the footwalls of the main NW-trending faults. In strike, they appear to follow the two trends of N–S and NE. These faults of comparatively small extent in strike, developing as fractures a few decimeters to a couple of meters away from the plane of the main fault, reach maximum stratigraphic throw in some meters, and then attenuate completely in 20–30 m in strike. Although these thrust-related faults have different kinematics, one with normal movement and the other with a strike–slip movement, along NW- and NE-trending faults, lateral displacement prevails, and right-lateral slip along the former faults and left-lateral slip along the latter is the rule.

On equal-area plot, as shown in Fig. 2, *b*, poles to the fault planes, clustering around several distinct maxima, distribute along a great circle which corresponds to the Osevoy thrust plane. A slickenline analysis also shows the symmetry of the linear elements relatively to the Osevoy thrust plane (Fig. 2, *c*). There are three circles on equal-area plot, where one, a great circle, corresponds to the trace of the main fault plane, and two other, small circles, have a common axis, lying in the thrust plane.

According to the foregoing data, movements on all of these faults at the D_{1E} domain most likely have appeared due to general displacement of the massif along the main fault plane.

Stress fields. Tectonic stresses in the massif localities have been studied by the kinematic method [4]. The input for the study was field-measured orientation data for faults and slickenlines from mine workings within Novodzerzhynska mine field consisting of the orientations of the fault planes and slickenlines, including the sense of movement. Mesoregional level stress field characteristics have been reconstructed by statistical processing of local stereographical solutions. Local stress data processed by the method for determination of general stress fields provide for reconstruction of principal normal stresses which are arbitrarily considered as regional stresses [5].

It has been determined that maximum stress axes are concentrated in the upper left (NW) and in the diagonally opposite (SE) sector of the stereogram, while minimum stress axes, on the contrary, are concentrated in the upper right (NE) and lower left (SW) sectors (Fig. 5). At mesoregional level, the reconstructed stress field is strike-slip faulting type and characterized by a NW–SE, 320–330° and 140–150°, subhorizontal principal compression axis and subhorizontal NE–SW, 50–60 and 230°–240°, principal extension axis.

However, despite the persistent general orientation of the principal stress axes, some differences in its orientation within the domains have been revealed. For example, in the D_2 domain, as shown in Fig. 5, *c*, σ_1 plunges at a low angle southwestward (232°/30°) and σ_3 is southeast and horizontal (140°/5°), lying at average bedding plane of this domain. In the D_{1W} subdomain, σ_1 and σ_3 plunge moderately to the northeast (65°/24°) and northwest (330°/20°), respectively, also lying at nearly average bedding plane of this subdomain (Fig. 5, *a*). In the D_{1E} subdomain, σ_1 and σ_3 plunge moderately to the southwest (230°/28° SW) and northwest (330°/18° NW), respectively, but the σ_3 axis is located near to bedding plane and σ_1 is lying at the plane of the Osevoy thrust fault (Fig. 5, *b*).

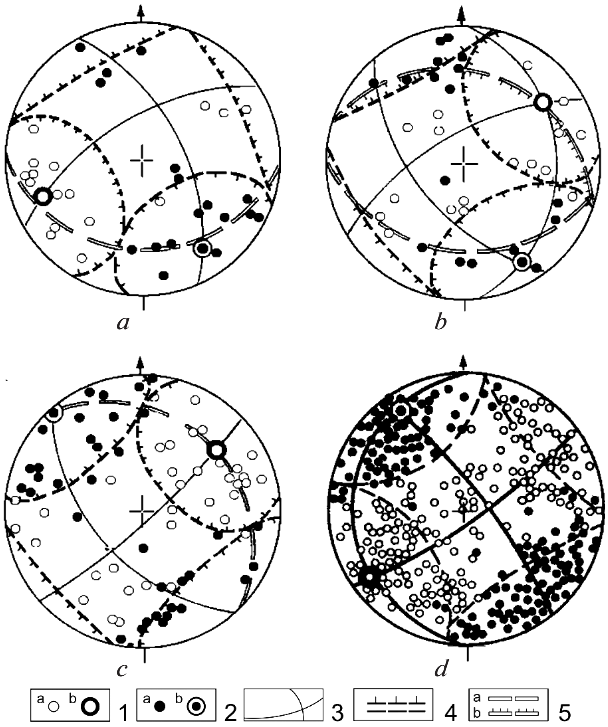


Fig. 5. Stress fields of Novodzerzhynska mine (a to c) and Nikitovka ore field (d):

1 – minimum principal stress axis of local (a) and mesoregional (b) level; 2 – maximum principal stress axis of local (a) and mesoregional (b) level; 3 – planes of principal stress axes; 4 – boundaries of compression and extension cones; 5 – planes of bedding (a) and Osevoy thrust (b)

There is such a feature of the structure of the reconstructed stress field in distribution of local stress fields as regular bending of trajectories of the principal stress axes near the large faults, where the axes tend to be oriented either perpendicularly or parallel to the fault plane. These parts interchange each other along the fault plane (Fig. 4).

The close agreement of the stress field reconstructed for the study area and Nikitovka ore field strongly suggests one origin and one stress field that resulted in present-day structural pattern, as can be seen in Fig. 5, *d*. This stress field that apparently originated in Laramide time of Alpine orogeny is the youngest for the Donets Basin.

Series of six stress fields (*F* to *A*) resulting in the development of the geological structure of the western closure of the Horlivka anticline has been defined and reconstructed [6]. Directed and inherited character of changing of the tectonic loading conditions of the geological structure of the study area is characterized by consecutive change of the stress field type from the oldest (*F*), normal faulting type, to the youngest (*A*), strike-slip faulting one. The main characteristics of the stress fields are given in Table 1. There is no possibility to define absolute time lags of the action of the stress fields exactly, nevertheless the youngest stress field *A* is synchronized with the youngest one reconstructed for the Donbas and Priazovie.

Strain fields. Strain field is heterogeneous for the western closure of the Horlivka anticline area. Orientation of axes of total strain field and type of strain field are changing both all over the study area and within the large geological structures.

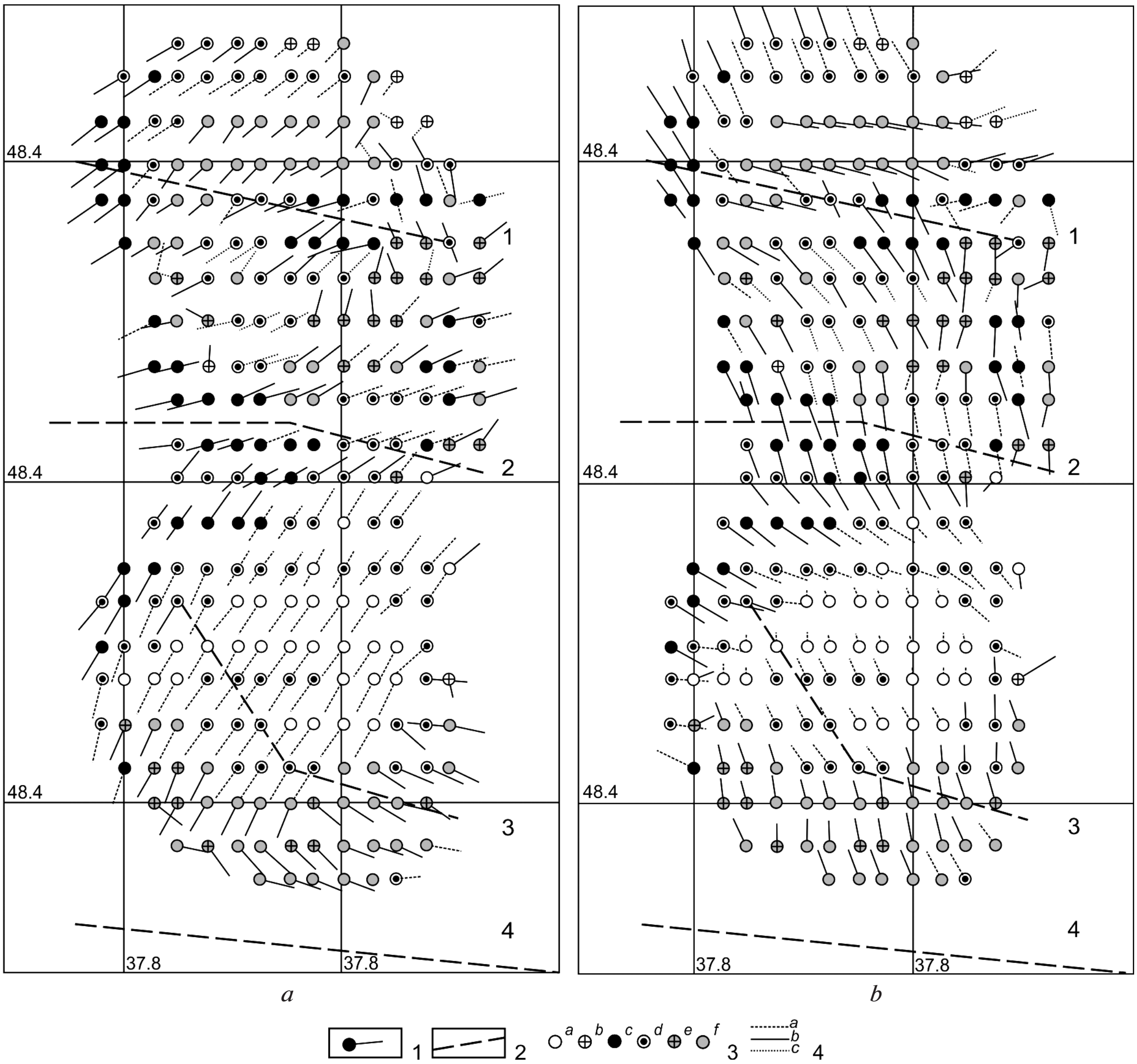
Maximum extension axis ε_1 is the most invariable and characterized by mainly gently plunging to the southwest nearly all study area. However, as it is apparent from Fig. 6, *a*, some divergence of ε_1 axis orientation is observed within the large faults, for instance,

Table 1

Characteristics of the principal axes of the stress fields

Phase	Type	σ_1	σ_2	σ_3	μ_σ
		Dir./Pl.	Dir./Pl.	Dir./Pl.	
A	S	257/3	154/77	348/13	0.9
B	R	219/67	79/18	344/14	0.95
C	R	187/75	347/14	78/5	0.95
D	S	336/13	178/76	68/5	–0.95
E	N	350/15	260/1	166/75	–0.95
F	N	259/2	350/15	162/75	–0.9

Notes: Types of the stress field: N – normal; R – reverse; S – strike-slip; Dir. and Pl. – trends and plunges of principal stress axes in degrees; σ_1, σ_2, σ_3 *– minimum, intermediate, and maximum principal axes of the stress field;* μ_σ *– Lode–Nadai coefficient: uniaxial tension* (–1)*, uniaxial compression* (+1)



a *b*

Fig. 6. Projections to a horizontal plane of the principal strain axes and distribution of the Lode–Nadai coefficient values for the western closure of the Horlivka anticline:

a — extension axis ε_1*; b — shortening axis* ε_3*: 1 — horizontal projections of the strain axes (plunging is out from the circle; the length of the projection corresponds to the angle of plunge of the axis: shorter axis — steeply plunging, longer axis — gently plunging, centered point axis — (sub)horizontal); 2 — faults (shown sketched): 1 — Severny thrust, 2 — Osevoy thrust, 3 — Toretzky thrust, 4 — Glavny thrust; 3 — type of strain field (corresponding to the values of the Lode–Nadai coefficient): (a) normal, (b) reverse, (c) strike-slip, (d–e) transitional (oblique–slip), (f) octahedral; 4 — Lode–Nadai coefficient: (a) uniaxial extension (*$\mu = -1$*); (b) pure shear (*$\mu = 0$*); (c) uniaxial shortening (*$\mu = +1$*)*

within the Osevoy thrust and transition zone between Toretzky and Hlavny thrusts, where ε_1 axis tends to be oriented sublatitudinally (Table 2).

Maximum shortening axis ε_3 is less invariable both in strike — from meridional to sublatitudinal — and in an angle of plunging — from subhorizontal to subvertical (Fig. 6, *b*). Intermediate strain axis ε_2 is the least invariable, often in irregularly standing position from gently to steeply (or vertical) plunging, especially within the large faults.

Strike-slip faulting type of total strain field was determined for most part of the western closure of the Horlivka anticline area (Fig. 6). According to the Lode–Nadai coefficient (μ_ε) which is nearly equal to ±1 or varied in range from +0.5 to –0.5, deformations on the study area had been going under shear conditions. Axial part of the anticline within Osevoy thrust and paraxial part of the anticline southern limb within Toretzky thrust are characterized by normal faulting type of the total strain field, where deformations had been going under uniaxial extension conditions ($\mu_\varepsilon = -1$).

In the whole, it can be asserted that strike-slip faulting strain field type is characterized by NW and N–S-plunging maximum shortening axis and strain conditions which are similar to pure shear prevailing in

Table 2

Variability of orientation of the principal strain axes within the large faults of the study area

	ε_1	
	Dir.	Pl.
	227–238	27–60
Severny thrust	221–248; 335–346	11–55
	234–265; 51–79	11–29; 17–42
Osevoy thrust	255–257; 56–79	9–30; 11–19
	33–63; 207–217	0–20
Toretzky thrust	207–217; 95–125	16–30
	97–135; 198–215	22–43
	ε_3	
	334–342	11–18
Severny thrust	73–104; 138–189	11–55; 13–31
	136–173	34–46
Osevoy thrust	157–174	12–31
	115–144; 333–350	21–33; 57–74
Toretzky thrust	324–342	48–53
	338–359	33–47

Notes: ε_1 and ε_2 – extension and shortening axes of local strain fields; Dir. and Pl. – trends and plunges of principal strain axes in degrees

the western closure of the Horlivka anticline area of the Donets Basin. Extension axis ε_1 of the strain ellipsoid is oriented NW and N–S within the western closure of the Horlivka anticline, and shortening axis ε_3 is oriented NE nearly orthogonal to the anticline axis. Summing up the results, it can be concluded that the strain tensor forms an ellipsoid similar to the stress ellipsoid.

Thus, the western closure of the Horlivka anticline can be considered as the area of the extension in back part of right-lateral strike-slip fault.

The data above allow us to suggest the shear zone revealed in the D_{1W} subdomain is the direct extension of the regional right-lateral displacement within the Main anticline paraxial part. Conjugated strike-slip fault system was formed due to the right-lateral displacements that originated in final stages of Alpine orogeny. Horizontal displacements of the sediment masses to the west at the south limb of the anticline were accompanied by a compression in near-horizontal plane. It resulted in the longitudinal bending of the sediment masses accompanied by formation of the dome-shaped fold and sublatitudinal thrust faults developed at the limbs of the fold. Horizontal displacements at the walls of thrust faults resulted in formation of normal oblique-slip faults which might have developed as normal faults subsequently.

The findings of our research are quite convincing, and thus the following conclusion can be drawn: a structural pattern of the deformation elements of the Main anticline western closure may be interpreted as a single pattern of structural paragenesis developed due to the right-lateral displacements along the longitudinal strike-slip fault system within the Main anticline paraxial part.

Conclusions. NW-trending dextral and NE and N–S-trending sinistral strike-slip faults prevail among the other faults within the study area. Mesoregional stress field, characterized by subhorizontal position of NW–SE-oriented maximum principal stress axis (σ_3) and NE–SW-oriented minimum principal axis (σ_1) is shear type. This one that apparently originated in Laramide time of Alpine orogeny is the youngest for the Donets Basin. Extension axis (ε_1) of the strain ellipsoid is NW and N–S oriented within the western closure of the Horlivka anticline, and shortening axis (ε_3) is NE oriented nearly orthogonal to the anticline axis. Strike-slip faulting type of total strain field was determined for most part of the western closure of the Horlivka anticline area, and according to the Lode–Nadai coefficient ($\mu_\varepsilon = \pm 1$), deformations on the study area had been going mainly under shear conditions. The pattern of a single structural paragenesis of deformation elements of the study area, including a conjugate strike-slip fault system, dome-shaped fold and longitudinal thrusts in its limbs, was developed due to the right-lateral displacements along the longitudinal strike-slip fault system within the Main anticline paraxial part.

The present results which have just been explained briefly, may allow forecasting to be made of structural patterns of deformation structures that forms in right-lateral shear zones at deeper mine levels.

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Мета. Визначення умов та механізму розвитку геологічної структури західного змикання Горлівської антикліналі.

Методика. Детальне картування з елементами структурно-морфологічного аналізу всіх відомих тектонічних елементів району та тектонофізичні методи аналізу тріщинно-розривних структур.

Результати. Встановлено, що серед розривів різного структурного рівня домінують зсуви: північно-західні – праві, північно-східні та субмеридіональні – ліві. Виділено правозсувовий структурний парагенезис деформаційних елементів структури західного змикання Горлівської антикліналі, що містить у собі комплекс спряжених північно-західних та меридіональних розривів, брахіантиклінальну складку другого порядку, крила якої ускладнені насувами, що орієнтовані повздовж осі головної складчастої структури першого порядку. Встановлено, що за просторовою орієнтацією осі головних нормальних напружень, відновлене поле напружень є зсувовим та наймолодшим для Донецького басейну, датованим ларамійською фазою альпійського тектогенезу. Зсувовий тип поля сумарних деформацій є домінуючим на більшій частині зони західного змикання Горлівської антикліналі.

Наукова новизна. Виявлені зсуви та зсувові зони, охарактеризована їх морфологія, супутні деформації та механізм формування. Відновлені головні характеристики полів напружень та деформацій локального й мезорегіонального рівня.

Практична значимість. Впровадження у практику геологорозвідувальних та геолого-експлуатаційних робіт нових наукових методів прогнозу гірничо-геологічних умов, що засновані на реконструкції головних тектонофізичних параметрів і відтворенні механізмів деформаційного процесу.

Ключові слова: *кінематичний метод, поля напружень та деформацій, коефіцієнт Лоде–Надаі, штрихи ковзання, зсувна зона, зсув, структурний парагенезис*

Цель. Определение условий и механизма развития геологической структуры западного замыкания Горловской антиклинали.

Методика. Детальное картирование с элементами структурно-морфологического анализа всех известных тектонических элементов района и тектонофизические методы анализа трещинно-разрывных структур.

Результаты. Установлено, что среди разрывов различного структурного уровня здесь доминируют сдвиги: северо-западные – правые сдвиги, северо-восточные и субмеридиональные – левые. Выделен правосдвиговый структурный парагенезис деформационных элементов структуры западного периклинального замыкания Горловской антиклинали, включающий в себя комплекс сопряженных северо-западных и меридиональных разрывов, брахиантиклинальную структуру второго порядка, крылья которой осложнены надвиговыми структурами, ориентированными продольно оси главной складчатой структуры первого порядка. Установлено, что по пространственной ориентировке осей главных нормальных напряжений, восстановленное поле напряжений является сдвиговым и самым молодым для Донецкого бассейна, датирующимся ларамийской фазой альпийского тектогенеза. Сдвиговый тип поля суммарных деформаций является доминирующим на большей части площади западного замыкания Горловской антиклинали.

Научная новизна. Выделены в геологической структуре изучаемого района сдвиги и сдвиговые зоны, описана их морфология, сопутствующие деформации и механизм образования. Восстановлены основные характеристики полей напряжений и деформаций локального и мезорегионального уровня.

Практическая значимость. Внедрение в практику геологоразведочных и горно-эксплуатационных работ новых научных методов прогноза горно-геологических условий, основанных на реконструкции основных тектонофизических параметров и восстановлении механизмов деформационного процесса.

Ключевые слова: *кинематический метод, поля напряжений и деформаций, коэффициент Лоде–Надаи, зеркала скольжения, сдвиговая зона, сдвиг, структурный парагенезис*

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