Forecasting of geological hazards based on the reconstruction of tectonic stress fields within the Krivoy Rog ore region

O. Plotnikov *(Kryvyi Rih National University),* ***M. Kurylo*** *(Taras Shevchenko National University of Kyiv),* ***V. Stapay*** *(Kryvyi Rih National University)*

SUMMARY

Tectonic-physical studies were carried out within large territory of Kryvyi Rih region, covering all age rocks complexes and areas with different types of structures. Reconstructions of tectonic stress fields of the local level were carried out within the study areas. The initial data were the results of a field study of sliding mirrors, cracks, cleavage planes, layering, microstructural orientations of minerals, which were combined into separate groups according to age and structural features. The reconstructed stress field characterizes the next stage of the structure formation of the Kryvyi Rih ore region, which is compression. The characteristics of this stress field correlate well with the axes of fold deformation of the Cypriot series transverse compression, which means that it is folded. The latest stress field is reliably reconstructed according to the youngest cleavage cracks and discontinuities that cut all the age complexes of the Kryvyi Rih ore region. It is characterized by the strongest variability of the orientations of the local stress axes distribution. On the summary stereograms, 45-degree conical regions corresponding to the minima of the distribution of the axes σ1 and σ3 are confidently determined, which make it possible to determine the stress axes direction of the regional level.

Прогнозування небезпечних геологічних явищ на основі реконструкції полів тектонічних напружень у Криворізькому рудному районі

О. Плотніков *(Криворізький національний університет),* ***М. Курило*** *(Київський національний університет імені Тараса Шевченка),* ***В. Стапай*** *(Криворізький національний університет)*

РЕЗЮМЕ

Тектоніко-фізичні дослідження проводилися на великій території Криворіжжя, охоплюючи всі вікові комплекси порід і ділянки з різним типом будови. У межах досліджуваних територій проводилися реконструкції полів тектонічних напружень локального рівня. Вихідними даними були результати польових досліджень дзеркал ковзання, тріщин, площин спайності, шаруватість, мікроструктурна орієнтація мінералів, які були об'єднані в окремі групи за віковими та структурними особливостями. Відтворене поле напруг характеризує наступний етап структуроутворення Криворізького рудного району - стиснення. Характеристики цього поля напруг добре корелюються з осями деформацій складчастості поперечного стиснення кріворізької серії, що говорить про те, що воно є спів-складчатим.

Introduction

Kryvyi Rih ore region is the main iron ore base in Ukraine. The largest BIF deposits and rich iron ores deposits are located within it, exploration and mining of which has been going on more than a hundred years. Recently, the mining and geological conditions for the deposits development have worsened because of stopes deepening, the appearance of voids in the depths, and an increase in water inflows. There were problems with the development of geological hazard: sinkholes, landslides, man-made earthquakes.

In order to forecast development of geological hazard and related problems mining operation for Kryvyi Rih deposits, the authors applied the methods of field tectonophysics.

Tectonic-physical studies were carried out within large territory of Kryvyi Rih region, covering all age rocks complexes and areas with different types of structures (Fig. 1). Reconstructions of tectonic stress fields of the local level were carried out within the study areas. The initial data were the results of a field study of sliding mirrors, cracks, cleavage planes, layering, microstructural orientations of minerals, which were combined into separate groups according to age and structural features. The combining technique is described in detail in (Gzovsky, 1975; Gushchenko and Kuznetsov, 1979; Turner and Weiss, 1963).

Research results

Statistical processing of the tectonic-physical research results was carried out on a personal computer using the GEOSTAT software package. In the course of statistical processing, more than 200 individual stereograms were compiled for each site, characterizing the levels of local stress fields. The obtained stereograms were taken out on geological-structural maps, scale 1 : 2000, compiled as a result of structural-geological mapping of the studied areas with an instrumental linking of elements of folded and discontinuous disturbances to the geodetic network. The estimation of regional stress fields parameters was carried out according to the summary stereograms, in which the local stress fields the stereograms were combined according to the structural and age characteristics. This approach made it possible to determine the general spatial characteristics of the stress fields of the Kryvyi Rih region.

The research results allow us to quite definitely speak about the presence of several different-age stress fields of the regional level. The earliest stress field is restored according to the study results of fault tectonics for granites and migmatites of Dnipropetrovsk complex (Archean age). The fault tectonics of these rocks in the zone of the Krivorizsko-Kremenchugsky deep fault is represented by faulting of several generations, traced in mines.

Fracture tectonics stereograms comparison of granites and migmatites of the Archean age and rocks of the Krivorizhska series made it possible to distinguish several systems of cracks, characterizing the stress field that existed before and during the accumulation of ferruginous rocks. Judging by the distribution of the local axes $\sigma 1$ and $\sigma 3$ on the composite stereogram (Fig. 2 a), the direction of the axis of the algebraically minimal principal normal stresses ($\sigma 3$ of the regional level) corresponds to an azimuth of 23° and an angle of 12°. The axis of the algebraically maximum principal normal stresses has an azimuth of 113° and an angle of 16°.

Thus, it can be assumed that the foundation and initial development of the Kryvyi Rih ore region took place under conditions of stretching of the earth's crust, and the general structure was a graben-synclinorium, at least until the deposition of gdantsevska suite rocks. This can also be confirmed by the presence of talc shale horizons in the sections of the Krivorizska series (skelevatskaya and

saksaganskaya suites), which, according to many researchers, are metamorphosed products of underwater effusive rocks.

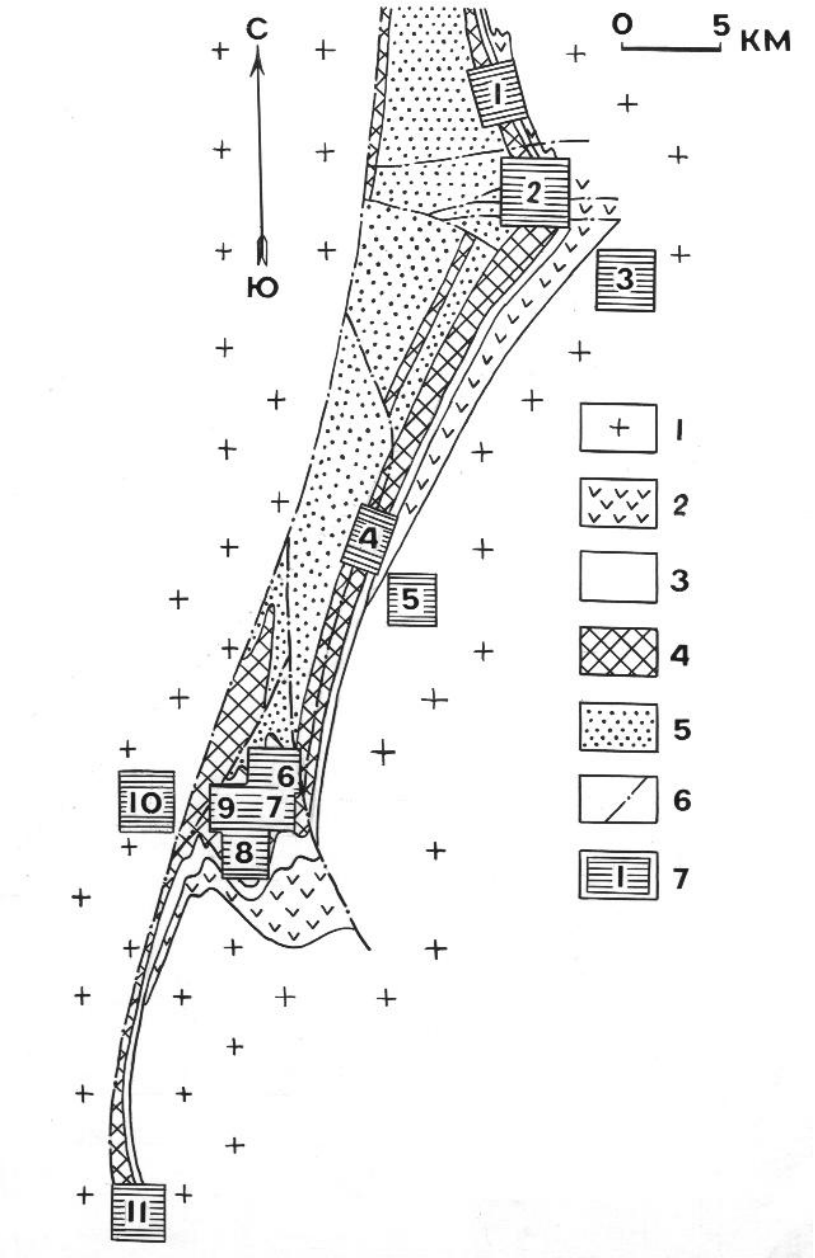

Figure 1 *Areas of instrumental geological-structural mapping and tectonophysical research. Legend: 1- granites and migmatites; 2-5 - suites of the Kryvyi Rih series: 2 – novokryvorizka, 3- skelevatska; 4- saksaganskaya; 5- gdantsevska and gleyevatska; 6- faults; 7- areas for instrumental geological-structural mapping and tectonophysical study.*
Deposits by numbers: 1- Hannivske; 2- Pershotravneve; 3- Kolomoytsevske; 4- Velyka Gleevatka; 5- Octyabrske; 6- Novokryvorizhske; 7 - Ingulets anticline deposit; 8- Skelevatske Magnetite; 9- Valyavkinske deposit of oxidized and Valyavkinske deposit of unoxidized ferruginous quartzites; 10- Karachunivske; 11- Inguletske.

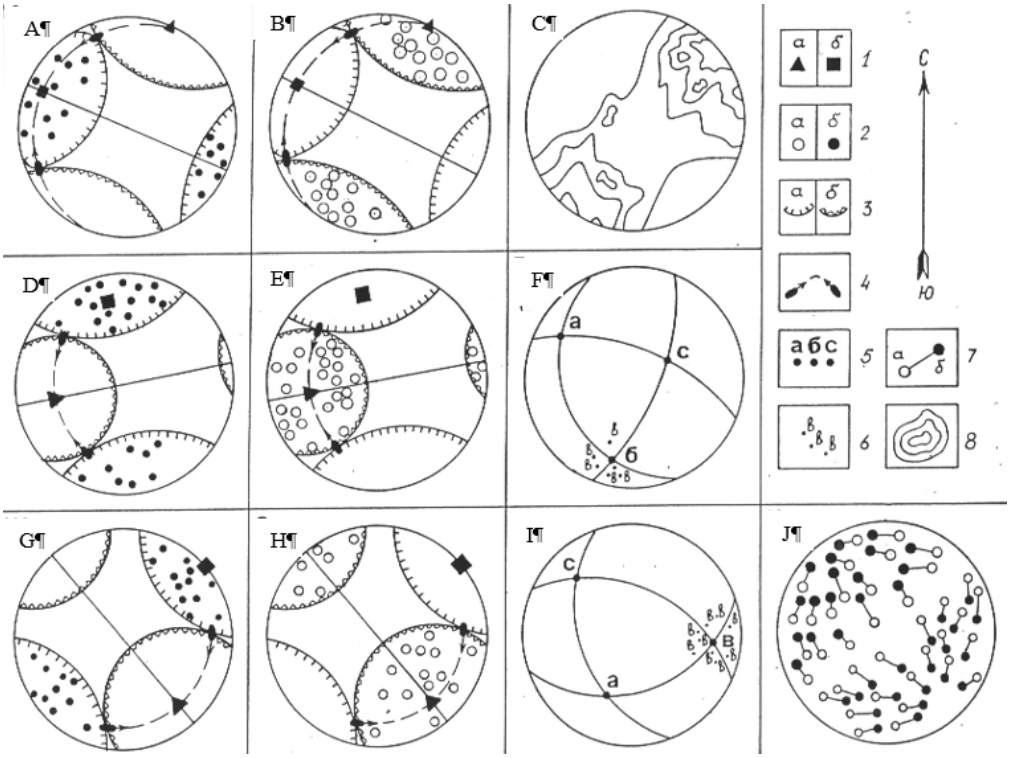

Figure 2 *Summary stereograms of stresses and deformations of the Krivorizsko-Kremenchugsky deep fault zone. Legend: 1-2- projections to the upper hemisphere: 1- stress axes of the regional level (a- σ3, b- σ1); 2- stress axes of the local level (a- σ3, b- σ1); 3- traces of conical surfaces, bounding the area of separate distribution of axes (a- σ1, b- σ3); 4- poles of areas of action of maximum tangential stresses; 5- axes of deformations A, B, and C; 6-folds axis; 7- optical orientations of quartz lamellas (open circles correspond to pre-kinematic orientation, filled - post-kinematic); 8- isolines of cracks poles densities of the first generation Dnipropetrovsk complex granitoids.*
A-C - fault tectonics stereograms of the first generation of granitoids of the Dnipropetrovsk complex (first stage of structure formation): A- stress distribution σ1 of the local level and B- stress distribution σ3 of the local level (after filtering by the sliding window method); C - rock structures of the first generation of granitoids of the Dnipropetrovsk complex.
D-F - stereograms of cracked-fractured and folded tectonics of the first generation for the Saksaganska suit and subsequent generations of granitoids of the Dnipropetrovsk complex: D-E - distribution of stresses σ1 and σ3 of the local level, respectively; F- orientation of the axes of deformations and folds axis.
G-J - stereograms of cracked-fracture, folded tectonics and microstructural orientation of minerals for late generations of the Saksaganska suit and granitoids of the Dnipropetrovsk complex: G-H – distribution of stresses σ1 and σ3 of the local level, respectively (after filtration with a cubic spline); I-axes of deformations, poles of quartz veins and folds axis; J- optical orientation of quartz lamellas

The next stress field is reconstructed according to the cracks and faults systems of the first generation of the Krivorizska series (mainly along the Saksaganska suit rocks) and later generations of the cracked-fracture tectonics of the Dnipropetrovsk complex granitoids. It is characterized by a large variability of the axes orientations of the main the local level normal stresses, which vary strongly even within the same area. Therefore, the determination of the regional stress field parameters was carried out by the absolute minimum of the distribution of local stress fields. In this case, the minimum of the local stresses distribution σ1 in the evaluation window with a radius of 45° corresponds to the axis orientation of regional stresses σ3, and the minimum of the concentration of the local stress axes 3 in the same calculation window corresponds to the axis orientation of the

regional stresses. The regional stress field parameters determined by this method correspond to: for σ3 - azimuth 42° and angle 8°, for σ1 - azimuth 132° and angle 72°.

Conclusion

Thus, the reconstructed stress field characterizes the next stage of the structure formation of the Kryvyi Rih ore region, which is compression. The characteristics of this stress field correlate well with the axes of fold deformation of the Krivorizska series transverse compression, which means that it is folded.

The latest stress field is reliably reconstructed according to the youngest cleavage cracks and discontinuities that cut all the age complexes of the Kryvyi Rih ore region. At the same time, it is characterized by the strongest variability of the orientations of the local stress axes distribution. However, on the summary stereograms, 45-degree conical regions corresponding to the minima of the distribution of the axes σ1 and σ3 (Fig. 2) are confidently determined, which make it possible to determine the stress axes direction of the regional level.

The axis direction of the algebraically minimal principal normal stresses of this field corresponds to an azimuth of 42° and an angle of 8°. The axis of the algebraically maximum principal normal stresses has an azimuth of 122° and an angle of 72°. With this orientation of the stress axes, the distribution character of the quartz veins poles and dikes, as well as the deformation axes orientation of the folds of the 1st order drawing of the Kryvyi Rih series, is well correlated. This field of stresses corresponds to a right-sided slip.

In the development of the Kryvyi Rih ore region, three stages of structural formation are distinguished. The first stage - pre-folding - is characterized by the formation of faults in the first system (Western, Tapakivskiy, Saksaganskiy, Eastern) in conditions of stretching of the earth's crust. At this stage, a general rag-shaped structure of the region was formed in which the rocks of the Krivorizska series were accumulated. The next stage - transverse compression - led to the formation of the scaly-thrust structure of the region. It was replaced by a right-sided slip, which led to the formation of breaks in the second system and a wide development of dragging folds. The development of the Kryvyi Rih ore region as a right lateral strike-slip continues at the present time.

References

Gzovsky, M.V. (1975). Foundations of tectonophysics. Nauka, 536 pp.

Gushchenko, O.I. and Kuznetsov, V.A. (1979). Determination of the orientation and ratio of the values of the main normal stresses by the set of directions of shear tectonic displacements. *Fields of stresses and deformations in the lithosphere*, 60-66.

Turner, F.J. and Weiss, L.E. (1963). Structural analysis of metamorphic tectonites. McGraw Hill Book Co., 554.