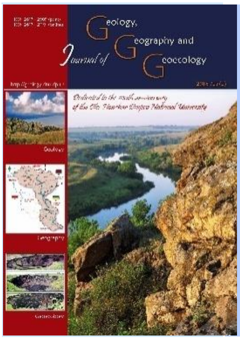

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Possibility of application of the method of observing the natural impulse electromagnetic field of the earth for allocation of watered faults on the example of Yeristovo quarry

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Abstract. One of the important tasks of operating the Yeristovo iron ore deposit is to reduce the level of water inflows, which complicate its development. The article presents the results of applying the express method of observing the natural impulse electromagnetic field of the Earth to isolate flooded faults in areas adjacent to the Yeristovo quarry. The features of the geological and tectonic structure of the territory of the Yeristovo field are considered. According to the tectonic map of Ukraine, the main deep faults characteristic of Srednepridneprovsky and Ingulsky megablocks of the Ukrainian shield in the area of study sites are highlighted. A method for conducting field studies by observing the natural impulse electromagnetic field of the Earth is presented. The studies were performed using equipment such as a radio wave indicator of the stress-strain state of rocks according to a previously developed technique. According to the results of the field studies, for the first time, maps of the density of the natural impulse electromagnetic field of the Earth flux were constructed for this area, which made it possible to isolate and trace the positions of watering faults. In addition, to visualize the most difficult fragments of the structure of the plots, three-dimensional models were built. Four zones of reduced values of the natural impulse electromagnetic field of the Earth (less than 3 conventional units) were identified on the studied areas. They are characterized by: the western tectonic disturbance - has a width of about 60 m and a strike azimuth of 3-5˚. The tectonic disturbance following it to the east is about 50 m wide and the strike azimuth is also 3-5˚. It is followed by an insignificant tectonic disturbance, which inherits the direction of the Krivyi Rih-Kremenchug break and has a width of about 20 m. In the east of the studied sites, there is a tectonic disturbance with a strike azimuth of 3-5˚, about 20 m wide. Since the azimuths of the strike of the identified tectonic disturbances coincide with the Main and Yeristovo faults characteristic of this territory, the identified faults are their feathering. On the basis of the conducted research, it is possible to recommend the use of water catching wells using a reasonably economical and reliable method of observing the natural impulse electromagnetic field of the Earth. It is advisable to lay them in the zones of minimum values of the natural impulse electromagnetic field of the Earth, within the southern parts of the research sites. The use of advanced observations will avoid unproductive costs when drilling water-reducing wells.

Keywords: natural impulse electromagnetic field of the Earth, tectonic disturbance, water inflow, Yeristovo fault, Main fault.

Можливість застосування методу спостереження природного імпульсного електромагнітного поля Землі для виділення обводнених розривних порушень на прикладі Єристівського кар'єра

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Анотація. В статті наведені результати застосування експрес методу спостереження природного імпульсного електромагнітного поля Землі для виділення обводнених розривних порушень на дільниках, що прилягають до Єристівського кар'єру. Розглянуто особливості геолого-тектонічної будови території Єристівського родовища. За даними тектонічної карти України виділені основні глибинні розломи, які характерні для Середньопридніпровського та Інгульського мегаблоків Українського щита в районі ділянок дослідження. Наведено методику проведення польових досліджень методом спостереження природного імпульсного електромагнітного поля Землі. За результатами проведення польових досліджень вперше для даного району побудовані карти-схеми щільності потоку ПІЕМПЗ, які дозволили виділити та трасувати положення обводнених розривних порушень. Крім того, для візуалізації найбільш складних фрагментів будови ділянок, були побудовані тривимірні моделі. На ділянках, що досліджувались виділені чотири зони знижених значень природного імпульсного електромагнітного поля Землі (менше 3 у.о.). Вони характеризуються (із заходу на схід): західне порушення має ширину близько 60 м та азимут простягання 3-5˚. Наступне за ним порушення шириною близько 50 м з азимутом простягання також 3-5˚. За ним слідує незначне за розмірами порушення, що успадковує напрямок Криворізько-Кременчуцького розлому, шириною близько 20 м. На сході ділянок, що досліджувались простежується порушення з азимутом простягання 3-5˚, шириною також близько 20 м. Оскільки азимути простягання виділених розривних порушень збігаються з Головним та Єристівським розломами, які характерні для даної території, то виділені розривні порушення є їх оперячими. На підставі проведених досліджень надається можливість, використовуючи досить економічний та достовірний метод спостереження природного імпульсного електромагнітного поля Землі, рекомендувати закладення водоперехоплюючих свердловин. Їх закладення доцільно проводити у зонах мінімальних значень природного імпульсного електромагнітного поля Землі, у межах південних частин площадок дослідження.

Ключові слова: природне імпульсне електромагнітне поле Землі, тектонічне порушення, водоприток, Єристівський розлом, Головний розлом.

Introduction. The development of deposits by the open method, as a rule, is complicated by the water inflows, which are formed mainly due to the opened aquifers, as well as powerful zones of water-borne faults. Hydrogeological conditions of mining of iron ore deposits are determined by the nature of the permeability of fractured karst reservoirs, which in natural conditions contain groundwater reserves.

In this case, the flooded rocks have a negative impact on all technological processes. As the quarry becomes a drain, the conditions of surface and underground runoff are violated, as a result of which a zone of filtration deformations is formed. Under the influence of watering, surface erosion occurs, suffosion and landslide deformations of boards and heaps occur, and the presence of water-flooded rocks worsens excavation conditions and reduces the performance of mining equipment.

Drainage (protection) of the quarry field from groundwater of various origins makes it possible to minimize the occurrence of negative mining and geological conditions, which ensures efficient and safe mining operations.

Under the conditions of high rates of mining at the Yeristovo field, a surface drainage method was previously proposed for opening the quarry, which included drilling of water-lowering wells equipped with filters and located along the pit walls - 51 wells per quaternary aquifer; 50 wells in the Buchaksky aquifer and 4 drainage trenches located at the bottom of the pit. The distance between the wells is 100 m, the flow rate of one well is approximately 100 m^3/hour. The inner contour is represented by horizontal drains and quarry drainage. The depth of drains from the surface is more than 20 m, the length is 600-700 m. Drainage water is discharged into the bypass channel (Volkov, Zhdanova, 2015).

However, in practice, the proposed method of drainage is not sufficiently effective, since the positions of powerful water-boring faults were not taken into account when laying down the system of water-lowering wells.

Materials and methods. Watered discontinuous faults were isolated using an operational geophysical express-method for observing the natural impulse electromagnetic field of the Earth (NIEMFE) with a radio-wave indicator of a stress-strain state of rocks (РВИНДС АХИ 2.026.001) (Passport of the radio-wave indicator of the stress-strain state of the rocks, 1984). The carrying out of reference points and observation profiles of research sites on the surface of the plots were performed using geodesic GNSS receiver Leica Geosystems Viva GS08 plus. The observation data of NIEMFE were processed using a personal computer, then they were used to construct maps of the density of the NIEMFE. Rock Fractures were distinguished using previously developed methods. (Tyapkin K., Gontarenko V. 1990).

Main part. Yeristovo iron ore deposit is located in the Kremenchug district of the Poltava region, in the left bank of the Middle Dnieper. It is a part of a complexly constructed Krivorozhsko-Kremenchug suture zone, within which the deposits of the Krivorozhsko-Kremenchugsk iron-ore basin, which is divided into the Krivorozhskiy and Kremenchugskiy iron-ore regions, are concentrated. Yeristovo field is bordered on the Lavrikovskoye field, in the north, with the Belanovo field. The deposit covers an area of about 3 km^2.

The Kremenchug magnetic anomaly area belongs to the region of the northeastern slope of the Ukrainian crystalline shield, with a clearly pronounced immersion of its surface in the northeastern direction, in the direction of the Dnieper-Donets depression. The territory of the Yeristovo field is located within the eastern wing of the Horishna-Plavninskaya syncline.

Precambrian metamorphic and igneous rocks of the crystalline basement, covered with a continuous sedimentary cover, take part in the geological structure of the area.

Among the oldest crystalline rocks within the deposit, metamorphic formations of the konksko-verkhovtsev series of the Archean and the Krivoy Rog Proterozoic series, as well as the complexes of granitoids corresponding to them in age are common.

Within the deposit, the weathering crust of crystalline rocks of Paleozoic-Mesozoic age, with a thickness of from 20 to 60 m. It is represented by brown iron ores, aluminous and ferruginous laterites, variegated and white kaolins and other clay formations. A particularly powerful linear weathering crust has formed in the zones of faults, where it forms depressions up to 115 m deep.

The crystalline basement of the Yeristovo deposit is covered with a continuous cover of thick sedimentary deposits, represented by Paleogene and Quaternary sediments. Cenozoic deposits occur almost horizontally, with an immersion to the northeast of only 1 m per 1 km. In the composition of the Paleogene stand out deposits Buchak, Kiev and Kharkov suites.

The complex of Precambrian rocks has a very complicated fold-block structure due to the presence in the region of a number of large anticlinal and dividing synclinal structures of submeridional strike. From the west, the deposit is limited to the Main fault.

The zone of the Main fault is traced in the form of a wide strip (40-80 m thick) of intensely fragmented, milonitized rocks. It is accompanied by intensive crushing of rocks, development of carbonation, sericitization, chloritization and pyritization of rocks.

The western part of the zone of the Main fault passes through granitoids, the eastern - through the detrital rocks of the upper suite. The Yeristovo fault of the submeridional strike passes through the center. The amplitude of the displacement of rocks along the Main fault reaches hundreds of meters. Granitoids in the fault zone are heavily crushed, broken up by numerous cracks in which sericitization is observed. Barren quartzites and meta sandstones of the upper suite in the fracture zone are mainly brecciated and fragmented into small fragments (crushed stone), intensively carbonated, with multiple sliding mirrors.

The Yeristovo fault is also a major fault fracture of a fault-displacement nature, which is observed to the east of the Main fault and has an almost parallel strike with it. The fall of the Yeristovo fault plane is western, at an angle of 75-85º. The amplitude of displacement of rocks along the fault is measured in dozens, in some places by the first hundreds of meters.

The Yeristovo fault zone can be traced in the form of a narrow strip of intensely fractured rocks, 20–40 m thick. (Lyisenko, Mega, Zhuzhoma, 2015).

Within the deposit, groundwater is widespread, enclosed in sediments of the Quaternary system, the Kharkov and Buchak formations of the Paleogene, as well as in the cracked zone of Precambrian crystalline rocks. The water abundance of the aquifer of the Precambrian crystalline rocks is determined by the degree of fracturing of the rocks, the condition of the cracks, the conditions of feeding. The thickness of the upper, most water-rich zone of active fracturing is 100-150 m, increasing in places up to 200 m and more. In zones of tectonic disturbances fracture extends much deeper. Exploratory wells encountered water-bearing cracks containing high-pressure salt water at depths of more than 800 m. The highest water abundance is characterized by the upper zone of active fracturing within the areas where there is a direct hydraulic connection with the aquifer of the Buchak suite.

The water inflows into the quarry of the Yeristovo deposit reach 2464 m^3/h.

At the initial stage of studying water-borne tectonic disturbances, we reviewed the position of the Yeristovo deposit on the tectonic map of Ukraine(Gursky, Kruglov, 2007).

The research area is located on the border of two tectonic blocks - Srednepridneprovsky and Ingulsky (Fig. 1). The dominant directions of development of deep tectonic disturbances according to the tectonic map of Ukraine are: 0º; 7-10º; 85-90º.

The observations of NIEMFE were carried out at five research sites proposed by the management of "Yeristovo Mining" in accordance with the methodology developed and protected by the patent. (Zmiievska, 2015), on profiles which attached to the reference coordinate points. Flow density is measured in c.u. (conditional units – number of impulses per unit time). Registration of flux density of NIEMFE is carried out according to the indicator.

The position of observation points, observation profiles and the profile directions is shown in Figure 2.

Observations were made at 381 points. The number of observation profiles is 43. The observation profiles were located submeridionally. The density of the observation grid on research areas was 10×10 meters. The volume of field work amounted to 3860 linear meters.

Fragments of the observed NIEMFE were considered in detail on separate sections. Since the survey was performed in several stages, the boundary profiles were combined.

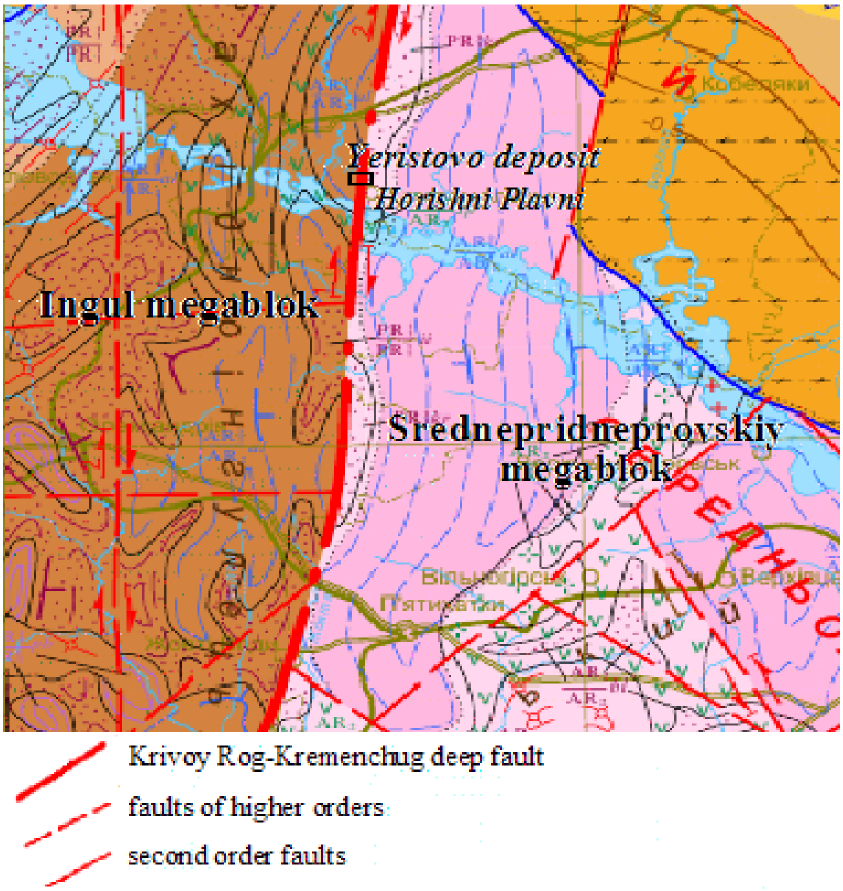

Fig. 1. Fragment of a tectonic map of the Srednepridneprovsky and Ingulsky megablocks of the Ukrainian shield Scale 1:1 000 000

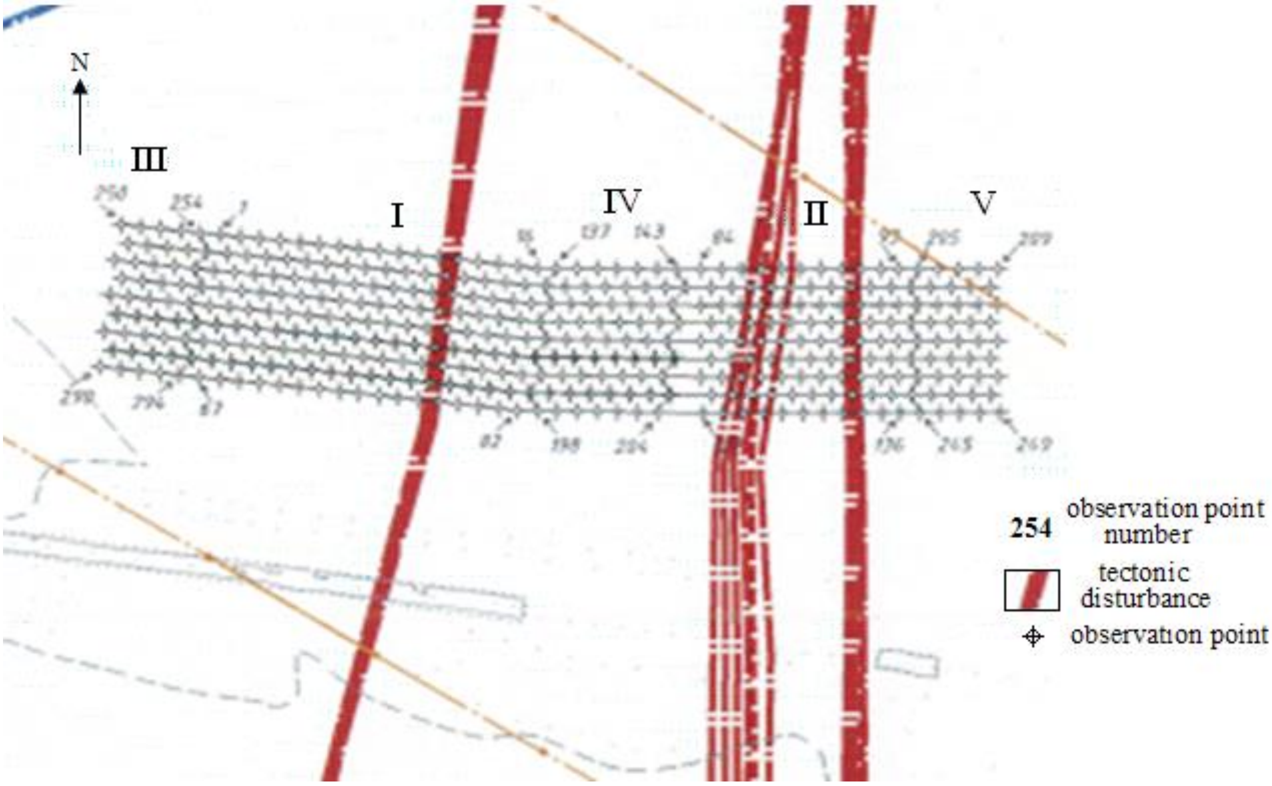

Fig. 2. Position of NIEMFE study sites No. I, II, III, IV, V and rendered point numbers in the quarry zone

According to the observations, maps of the density of the NIEMFE flux at the sites where the zones of potentially flooded tectonic disturbances were identified were constructed. (Fig. 3, 5, 6).

The combined map-scheme of the NIEMFE flux density of the sites № I and III is shown in Fig. 3. The flow density of NIEMFE at sites № I, III varies from 1 to 14 c.u. When considering the obtained map-scheme of the site № I, the submeridional orientation of the selected field structures attracts attention. This is explained by the fact that the research site is located in the zone of influence of the submeridional Main fault. Its branch fault component is located in the east of this research site.

In the western part of site PK (picket) 40-85 m (along the X axis), a zone of lower values is also observed, which is characterized by a flux density level of 1,5-3,5 c.u., which may indicate the presence of another submeridional fault.

The central part of the study site PK 85-145 m (along the X axis) is characterized by a zone of elevated values of NIEMFE of 5,5-14 c.u., the contours are formed in the form of an anticlinal fold structure. Its individual fragments indicate the presence of shear deformations (PK 40-60 m along the Y axis; PK 150-180 m along the X axis), which are characterized by lower values of the NIEMFE flux density – 1,5-4,5 c.u.

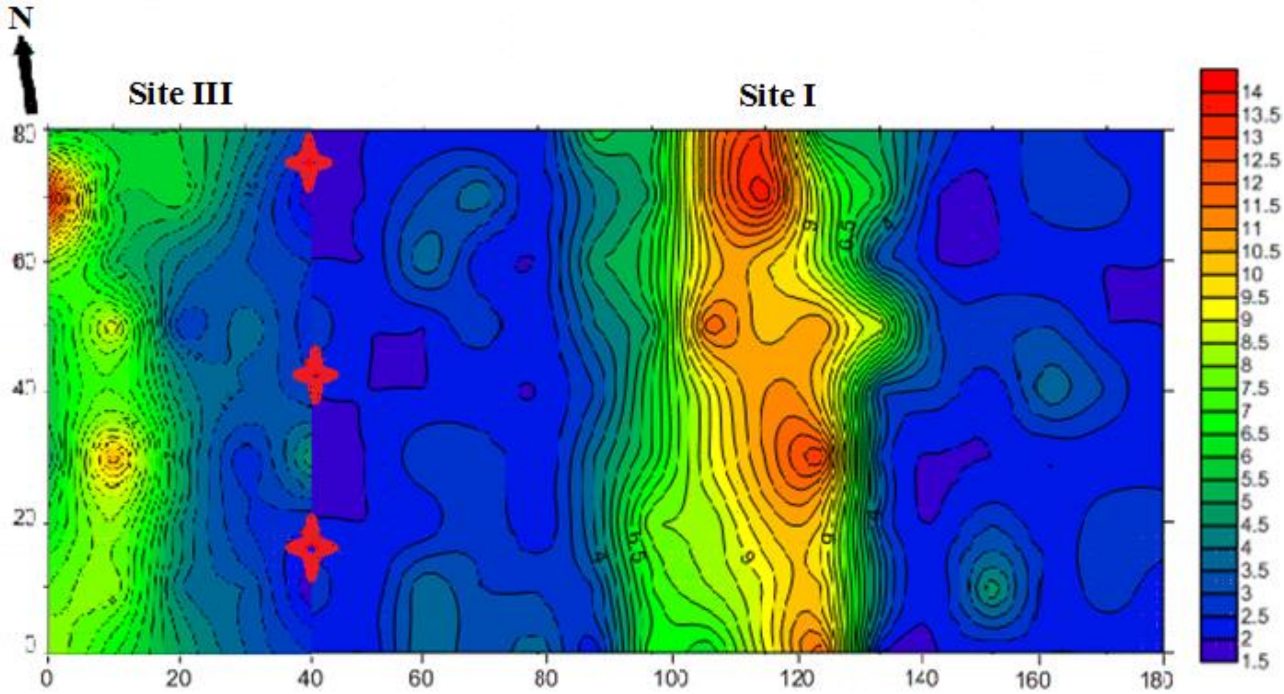

Fig. 3. Combined map-scheme of NIEMFE flux density at sites № I, III with tectonic disturbance.
– isolines of flux density of NIEMFE, c.u.
– conditional boundary of research sites № I, III

The constructed three-dimensional model of the selected tectonic structures at research site № I is shown in Fig. 4.

When considering the received map-scheme of site № III, the submeridional direction of the structures also attracts attention. This is explained by the fact that the research site is in the zone of influence of the Main Fault. Its feathering component is located in the eastern part of the site. In the area of PK 25-40 m along the X axis, a zone of lower values is observed, which is characterized by values of the flux density of NIEMFE of 1-1,5 c.u.

The central and western parts of the research site № III (PK 0-25 along the X axis) are characterized by zones of stable, higher field values up to 4 c.u. In addition, it is possible to determine the width of the submeridional fault structure, which is about 60-70 m from the values of the NIEMFE flux density.

Thus, according to the results of the research, submeridional faults were identified, in zones where the maximum water inflow is expected. They are located in the intervals of PK 40-80 m and PK 145-180 m along the X axis, in the contours of the isolines of the minimum values of NIEMFE, less than 3 c.u.

Figure 5 shows a combined map-scheme of the flux density of plots № I, IV.

The flux density of NIEMFE at site № IV varies from 1 to 3.7 c.u.

In these areas, a predominance of the submeridional direction is also observed. An insignificant diagonal structure with a strike azimuth of 10-12° is located along the X axis in the range of PK 200-210 m. It is characterized by the values of NIEMFE 1-1.6 c.u. This suggests that the formation of this anomalous zone occurred under the influence of the Krivoy Rog-Kremenchug fault. In addition, in the southern part, the sublatitudinal structure of PK 190-240 m can be traced, which is possibly a continuation of the sublatitudinal tectonic disturbance which located within the Ingul megablock (Fig. 1).

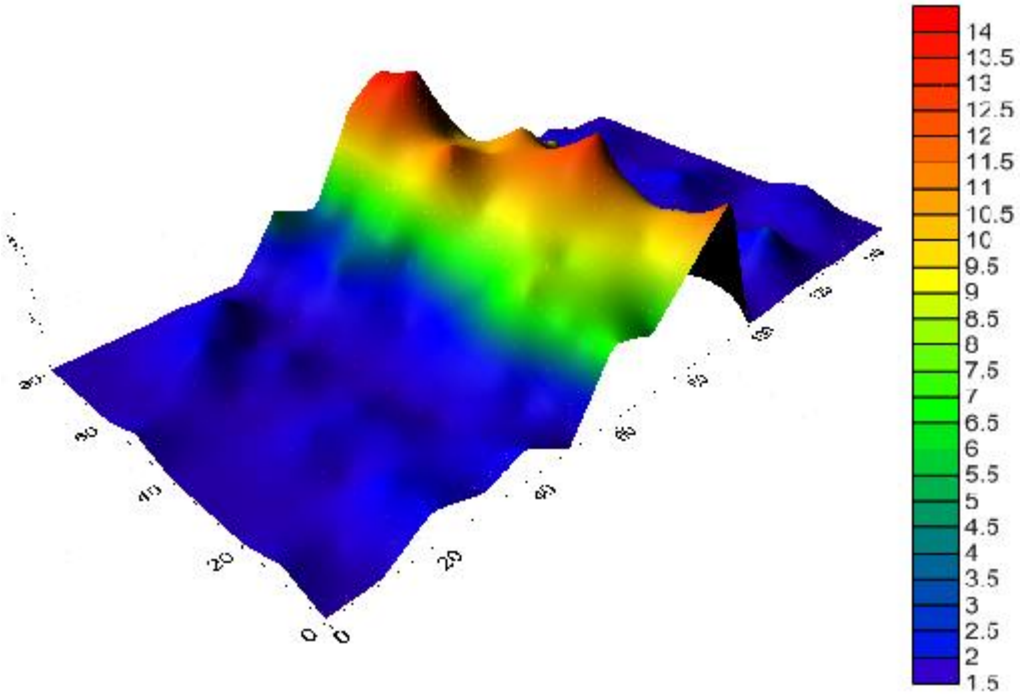

Fig. 4. Three-dimensional model of selected tectonic structures research site № I

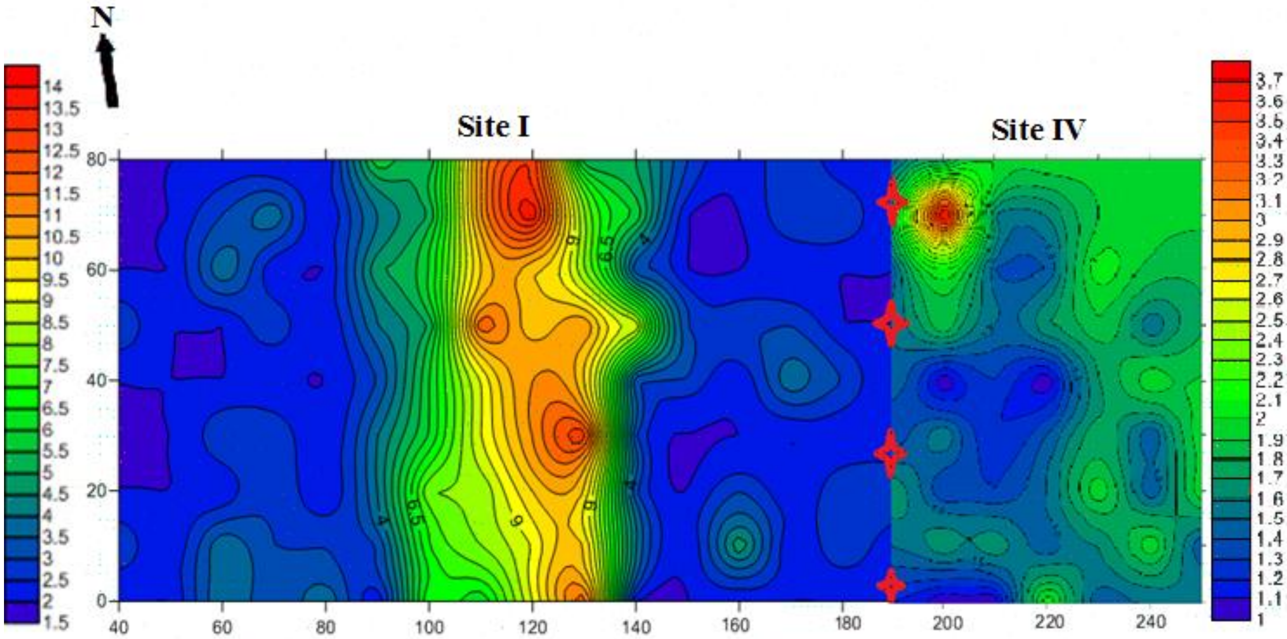

Fig. 5. Combined map-scheme of NIEMFE flux density at sites № I, IV with tectonic disturbance.
– isolines of flux density of NIEMFE, c.u.
– conditional boundary of research sites № I, IV

In the interval of the PK 240 m, an insignificant submeridional structure is traced along the X axis. According to the results of the research, another watered submeridional zone of tectonic disturbance been identified, which is located within PK 150-190 m (along the X axis), its width is approximately 40 m.

The flux density of NIEMFE at research site № II varies from 1,5 to 8,5 c.u. (Fig. 6). In this area, a more complex tectonics is observed - in addition to the submeridional structure, traced in the PK interval 60-75 m along the X axis, a fragment of the tectonic disturbance following the Krivoy Rog-Kremenchug direction - PK 25-40 m along the X axis is revealed. A complex anticline structure is traced in the north of the central part of the research site of PK 30-65 m along the X axis. It is characterized by values of the flux density of NIEMFE more than 5 c.u.

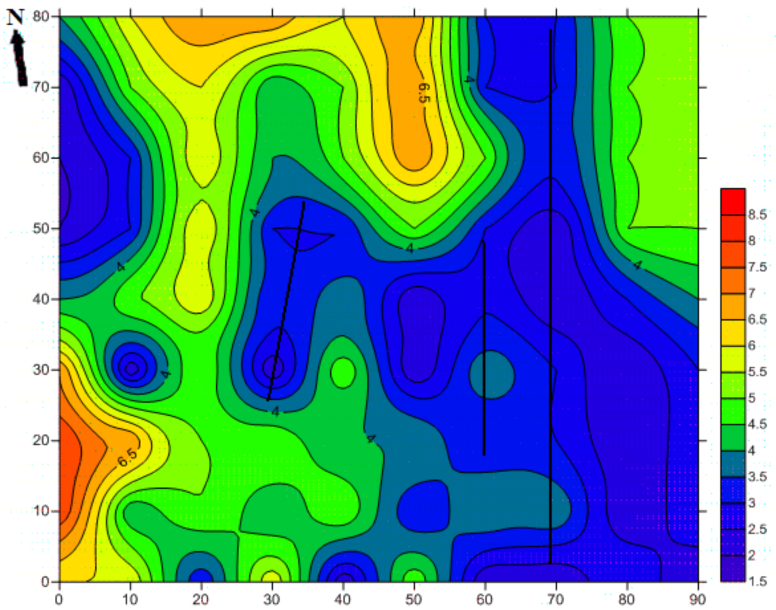

Fig. 6. Combined map-scheme of NIEMFE flux density at site № II with tectonic disturbance
isolines of flux density of NIEMFE, c.u.
axes of detected tectonic disturbances

A three-dimensional model was also built on this site, on which one we can trace the element of shear deformation that formed the branch fault of the Yeristovo fault (Fig 7).

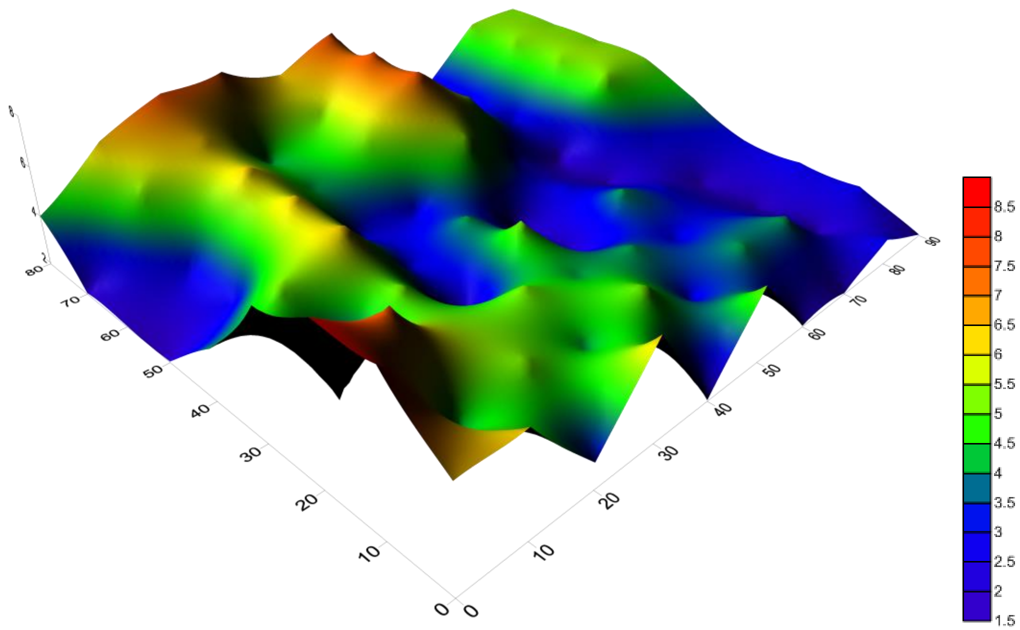

Fig. 7. Three-dimensional model of selected tectonic structures at the research site № II

Comparison of the initial exploration data of the research sites and the constructed NIEMFE map-scheme are shown in Figure 8. As follows from the data presented, the results of the studies carried out by the NIEMFE method supplement the data on the geological and tectonic conditions of the study area, allowing tracing faults to the west and east, as well as determining their probable width.

Thus, as can be seen from the presented materials, it is advisable to build water interceptor wells within the southern parts of research sites № I, III, IV, in areas with minimal values of the natural impulse electromagnetic field of the Earth (less than 3,5-2 c.u.).

Conclusion. Constructed according to the observation of natural impulse electromagnetic field of the Earth flux density maps-schemes by the NIEMFE made it possible to single out the positions of watering faults in areas adjacent to the Yeristovo quarry. Their strike azimuths coincide with the faults - the Main and Yeristovo.

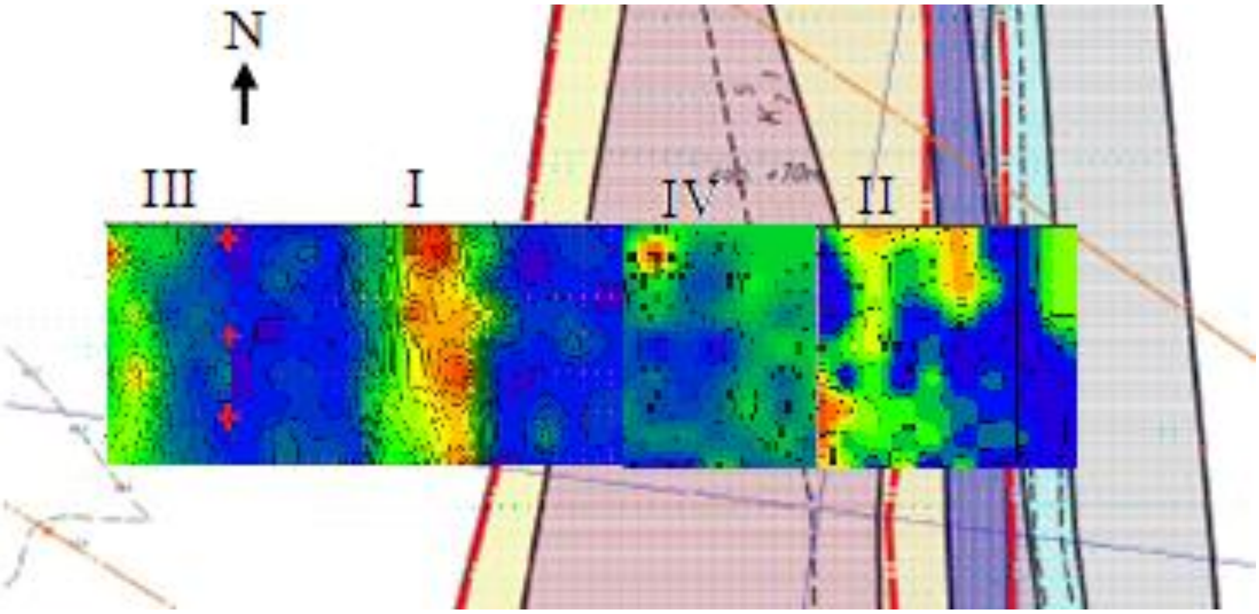

Fig. 8. Comparison of the initial exploration data with the results obtained using the NIEMFE method

In the western part of the research sites № I, III at their combination, the width of the discontinuous disturbance is determined, which is 50-60 m. The combination of sites № I, IV, allowed us to allocate another zone of tectonic disturbances with a width of about 40 m.

In the eastern part of the research sites, flooded tectonic disturbances are less pronounced, they are much smaller in width and are characterized by less contrasting values of NIEMFE level.

On the basis of the studies performed, it is possible to recommend the laying of water interceptor wells, which should be carried out within the zones with the minimum values of NIEMFE (less than 3,5-2 c.u.) in the southern parts of the sites № I, III, IV.

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