UDC 551.24:553.9:553.41 DOI: https://doi.org/10.1051/e3sconf/201910900128

APPLICATION OF THE METHOD OF OBSERVING THE NATURAL IMPULSE ELECTROMAGNETIC FIELD OF THE EARTH TO TRACE WATERED FAULTS ON THE EXAMPLE OF YERISTOVO QUARRY

[1]Zmiievska K.O., [2]Tubaltsev O.V., [3]Zmiievskyi A.S.

[1]Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine, [2] "FERREXPO AG" Yeristovo Mining, [3] LLC "Epiroc Ukraine"

ЗАСТОСУВАННЯ МЕТОДУ СПОСТЕРЕЖЕННЯ ПРИРОДНОГО ІМПУЛЬСНОГО ЕЛЕКТРОМАГНІТНОГО ПОЛЯ ЗЕМЛІ ДЛЯ ВИДІЛЕННЯ ОБВОДНЕНИХ РОЗРИВНИХ ПОРУШЕНЬ НА ПРИКЛАДІ ЄРИСТІВСЬКОГО КАР'ЄРА

[1]Змієвська К.О., [2]Тубальцев О.В., [3]Змієвський А.С.

[1]Інститут геотехнічної механіки ім. М.С. Полякова НАН України, [2] "FERREXPO AG" ТОВ «Єристівський ГЗК», [3]ТОВ «Епірок Україна»

ПРИМЕНЕНИЕ МЕТОДА НАБЛЮДЕНИЯ ЕСТЕСТВЕННОГО ИМПУЛЬСНОГО ЭЛЕКТРОМАГНИТНОГО ПОЛЯ ЗЕМЛИ ДЛЯ ВЫДЕЛЕНИЯ ОБВОДНЕННЫХ РАЗРЫВНЫХ НАРУШЕНИЙ НА ПРИМЕРЕ ЕРИСТОВСКОГО КАРЬЕРА

[1]Змиевская К.О., [2]Тубальцев А.В., [3]Змиевский А.С.

[1]Институт геотехнической механики им. Н.С. Полякова НАН Украины, [2] "FERREXPO AG" ООО «Еристовский ГОК», [3]ООО «Эпирок Украина»

Abstract. Purpose. Determination of the possibility of applying the method of observing the natural impulse electromagnetic field of the Earth to isolate watering faults with the subsequent laying of water water-interception wells. Methods. The method of the natural impulse electromagnetic field of the Earth was used to isolate flooded faults in the studied areas. Findings. The development of deposits of minerals by the open method is often hampered by abundant water inflows into the quarry of groundwater's as a result of disturbance of the natural hydrogeological conditions of the site of work. To solve such problems, the article shows the possibility of using the method of the natural impulse electromagnetic field of the Earth in order to isolate watered disruptive disturbances on the territory of the Yeristovo quarry. The tectonic disturbances identified by us are characterized by the submeridional orientation of the structures of the natural impulse electromagnetic field of the Earth. Based on the studies performed, it can be concluded that it is advisable to perform the inception of water-interception wells within the minimum values of the natural impulse electromagnetic field of the Earth - in the southern parts of the sites. Originality. For the first time, using the method of observing the natural impulse electromagnetic field of the Earth, the natural impulse electromagnetic field of the Earth flux density maps were constructed in areas adjacent to the Yeristovo career, which made it possible to single out the positions of watering faults. Their strike azimuths coincide with the main ones - the Main and Yeristovo faults. Practical implications. Based on the studies performed, it is possible to recommend the laying of water-interception wells, which should be carried out within the zones with the minimum values of the natural impulse electromagnetic field of the Earth in the southern parts of the research sites. For the first time, three-dimensional models of distinguished tectonic structures were constructed, according to which it is possible to trace the elements of shear deformation, as well as the anticlinal fold structure.

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

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/hr. 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 [1].

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.

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 (RWISSS) (RWISSS AXI 2.026.001) [2]. 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 [3].

Results and discussion. Yeristovo iron ore deposit is located in the Kremenchuk district of the Poltava region, in the left bank of the Middle Dnipro. It is a part of a complexly constructed Kryvorizka-Kremenchutska suture zone, within which the deposits of the Kryvorizko-Kremenchutskyi iron-ore basin, which is divided into the Kryvorizkyi and Kremenchukskyi iron-ore regions, are concentrated. Yeristovo field is bordered on the Lavrykivske field, in the north, with the Bilanivske field. The deposit covers an area of about 3 km^2.

The Kremenchuk 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-Plavninska 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-verkhovtsevska series of the Archean and the Kryvyi Rih 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 clay 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, Kyiv and Kharkiv 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.

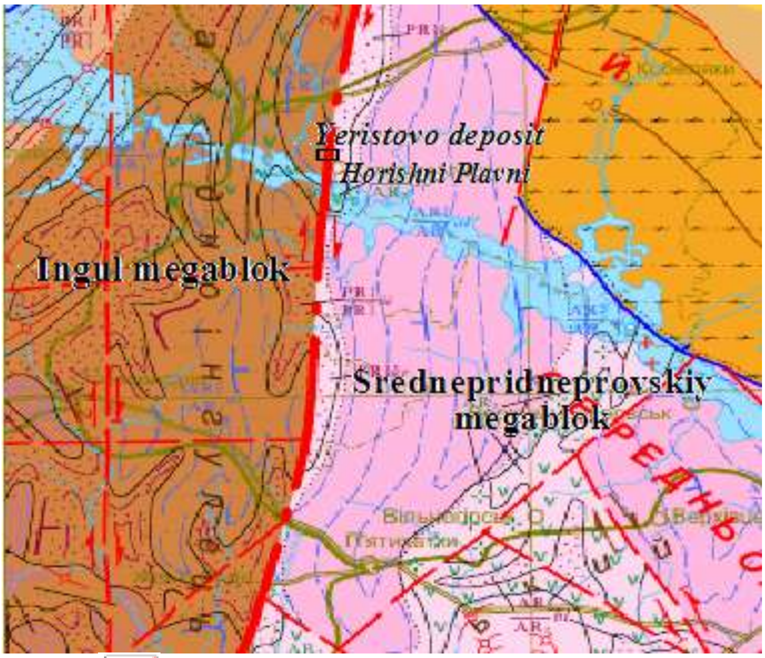
The Yeristovo fault zone can be traced in the form of a narrow strip of intensely fractured rocks, 20-40 m thick. [4].

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/hr.

At the initial stage of studying water-borne tectonic disturbances, we reviewed the position of the Yeristovo deposit on the tectonic map of Ukraine [5].

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

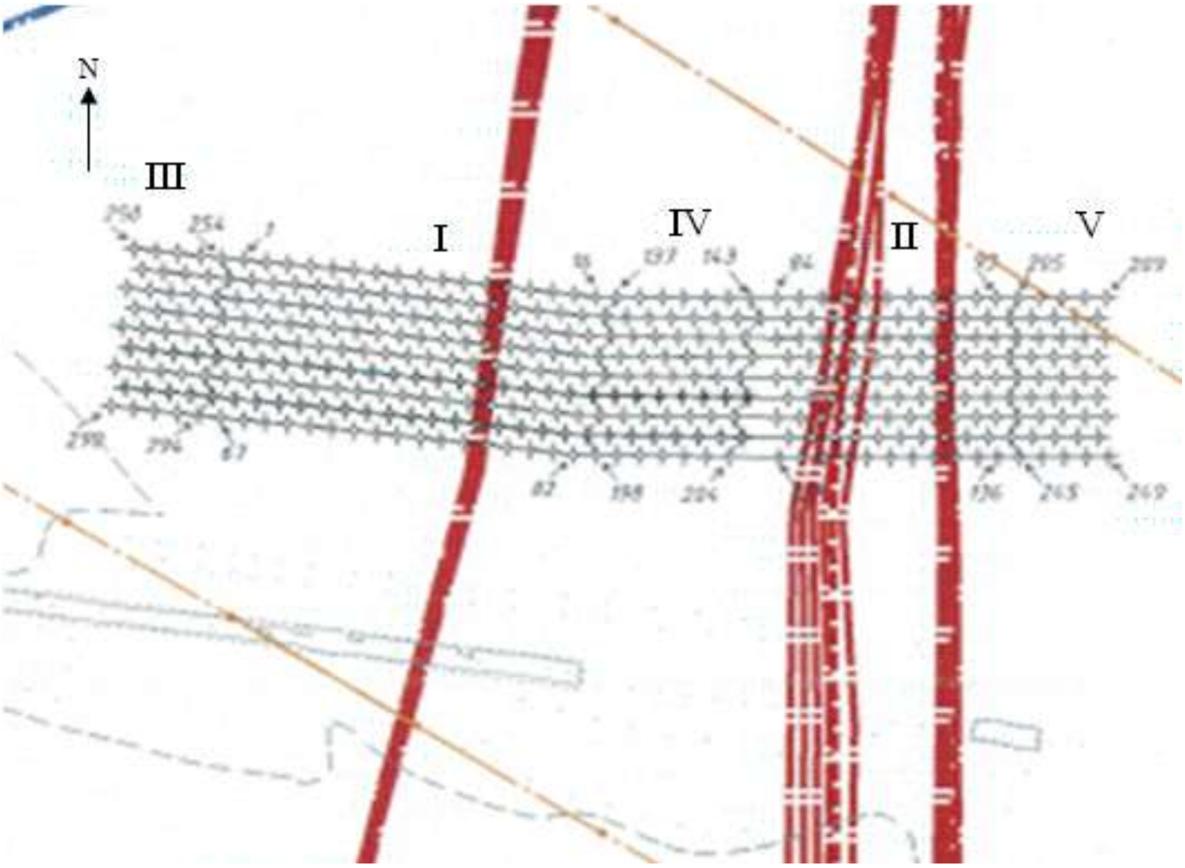


Kryvorizko-Kremenchutskyi deep fault
faults of higher orders
second order faults second order faults

Figure 1 - Fragment of a tectonic map of the Serednopridniprovskyi and Ingulskyi megablocks of the Ukrainian shield Scale 1:1 000 000

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. [6], 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.



254 – observation point number

tectonic disturbance

observation point

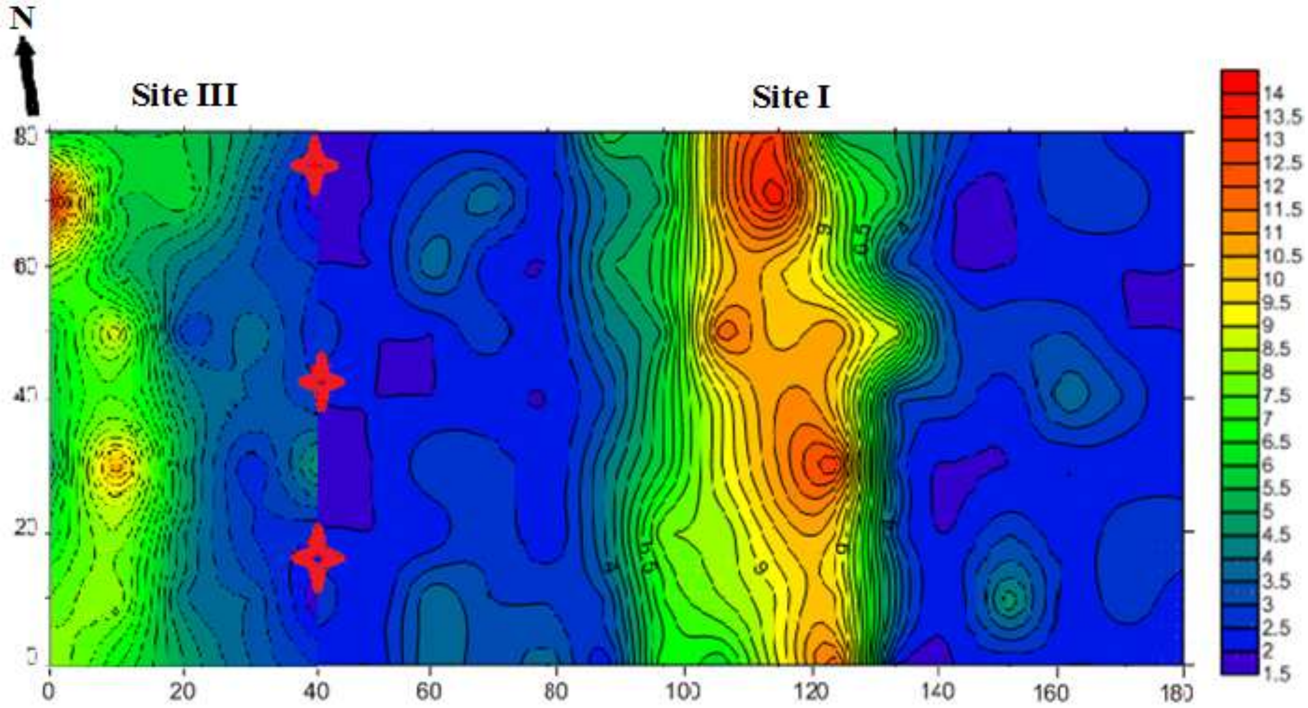
Figure 2 - Position of NIEMFE study sites No. I, II, III, IV, V and rendered point numbers in the quarry zone

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.

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 Figure 3.



– isolines of flux density of NIEMFE, c.u. – conditional boundary of research sites № I, III

Figure 3 - Combined map-scheme of NIEMFE flux density at sites № I, III with tectonic disturbance

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.

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

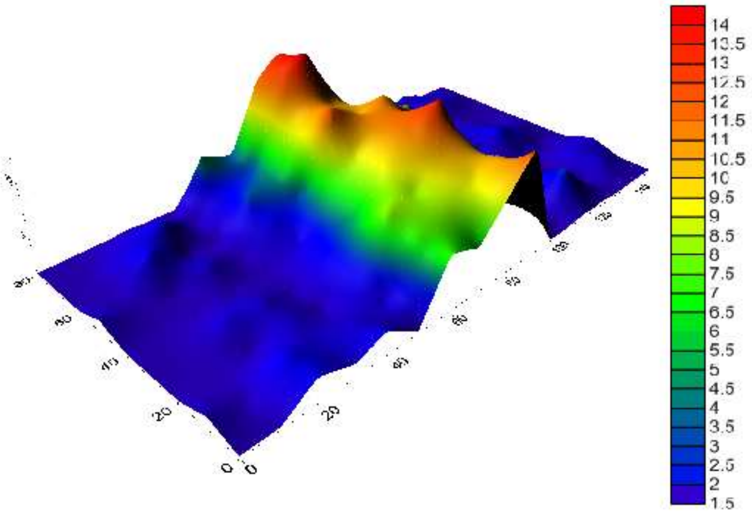
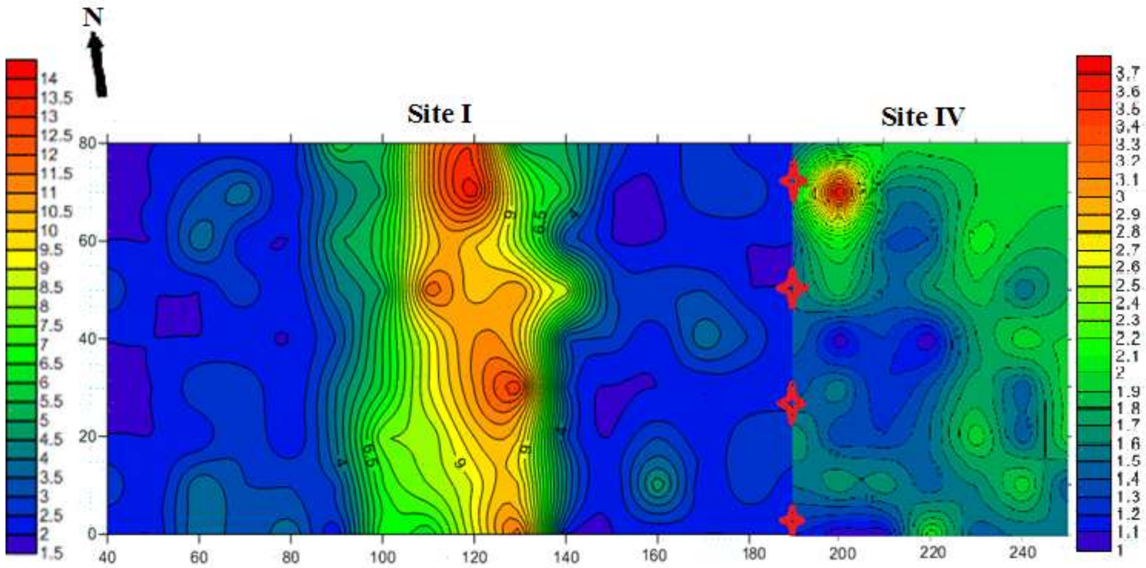


Figure 4 - Three-dimensional model of selected tectonic structures research site № I

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.



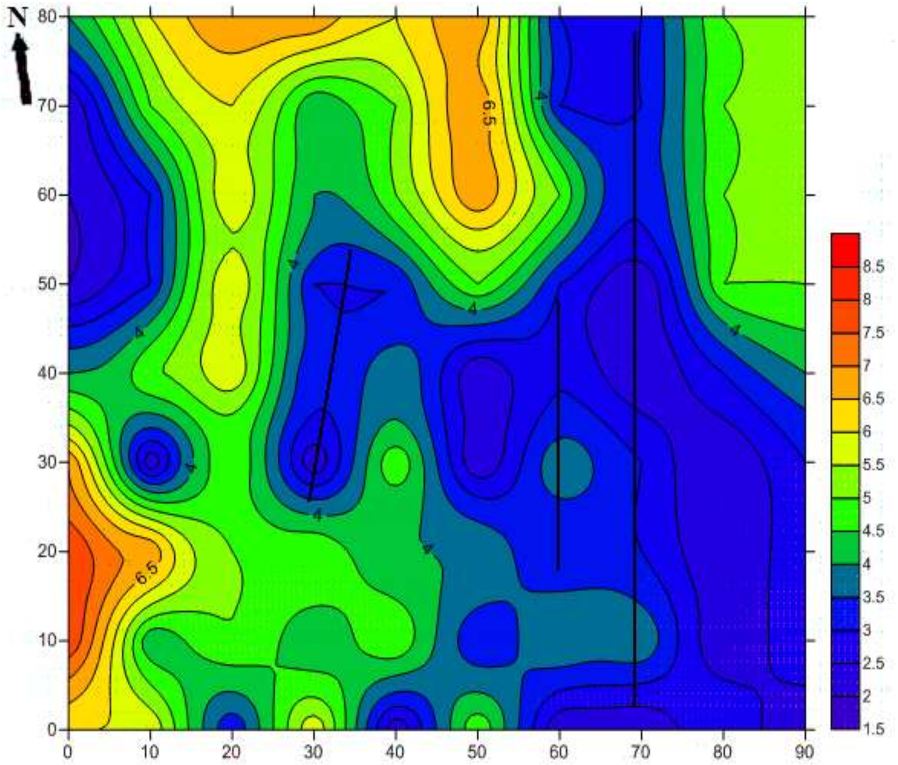
– isolines of flux density of NIEMFE, c.u. – conditional boundary of research sites № I, IV

Figure 5 - Combined map-scheme of NIEMFE flux density at sites № I, IV with tectonic disturbance

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 Kryvyi Rih-Kremenchuk 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).

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).



- isolines of flux density of NIEMFE, c.u; - axes of detected tectonic disturbances

Figure 6 - Combined map-scheme of NIEMFE flux density at site № II with tectonic disturbance

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 Krivyi Rih-Kremenchuk 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.

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).

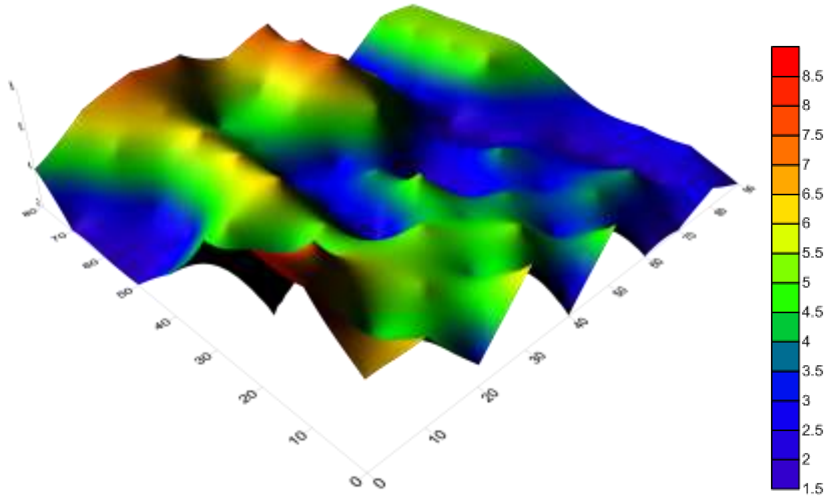


Figure 7 - Three-dimensional model of selected tectonic structures at the research site № II

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.

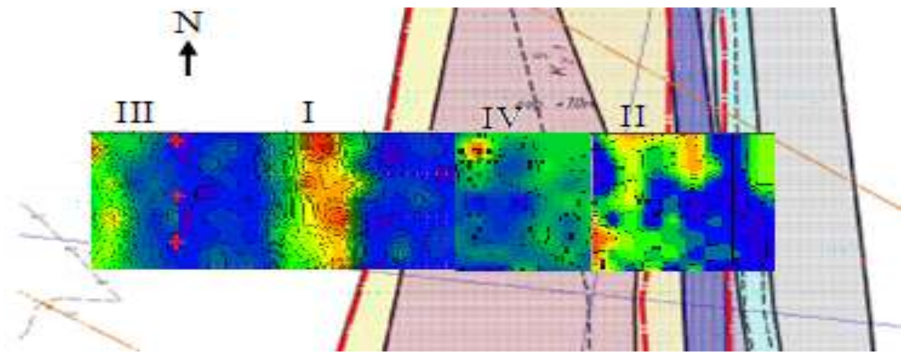


Figure 8 - Comparison of the initial exploration data with the results obtained using the NIEMFE method

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.).

Conclusions. 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.

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.

REFERENCES

1. Volkov Y.I., Zhdanova T.V. Application of geofiltration modeling in mining quarries of the Kremenchug magnetic anomaly, Moscow, Mining information analysis bulletin (of scientific and technical journal), Geology, 2015, 56, 356-367.
2. Passport of the radio-wave indicator of the stress-strain state of the rocks (RVINDS AHI 2.026.001 PS). Lviv Plant of Geophysical Equipment, 1984.
3. Tyapkin K.F., Gontarenko V.N. Fault systems of the Ukrainian shield, Kyiv, Naukova Dumka, 1990, 1-184.
4. Lyisenko A.A., Mega R.V., Zhuzhoma V.N. Studying of deposits at the stage of their operation, Kyiv, Mineral resources of Ukraine, 2015, 3, 3-8.
5. Gursky D.S, Kruglov S.S. Tectonic map of Ukraine S 1: 1000000, Kyiv: State Geological Service, UkrDGRI, 2007.
6. Zmiievska K.O. *A method for identifying tectonic disturbances in crystalline rocks* Patent № 99831, Ukraine, 2015.

СПИСОК ЛІТЕРАТУРИ

1. Волков Ю.И. Применение геофильтрационного модеирования при отработке карьеров Кременчугской магнитной аномалии / Ю.И. Волков, Т.В. Жданова // Горный информационно-аналитический бюллетень (научно-технический журнал). – М.: Геология. - 2015. - № 56. – С. 356-367.
2. Паспорт радио-волнового индикатора напряженно-деформированного состояния пород (РВИНДС АХИ 2.026.001 ПС). – Львовский завод геофизического оборудования, 1984.
3. Тяпкин К.Ф. Системы разломов Украинского щита / К.Ф. Тяпкин, В.Н. Гонтаренко // Киев: Наукова думка, 1990. – 184 с.
4. Лысенко А.А. Изучение месторождений на стадии их эксплуатации / А.А. Лысенко, Р.В. Мега, В.Н. Жужома // Минеральные ресурсы Украины. – Киев: УкрГГРИ, 2015. – № 3. – С. 3-8.
5. Гурский Д.С. Тектоническая карта Украины / Д.С. Гурский, С.С. Круглов // Киев: Государственная геологическая служба, УкрГГРИ, 2007.
6. Пат. № 99831 UA, МПК G 01V 3/00. Способ выявления разрывных нарушений в кристаллических породах / К.О. Змиевская. – u 2015 00013; заявл. 05.01.2015; опубл. 25.06.2015, Бюл. № 12. – 6 с.

About the autors

Zmiievska Kristina Olehivna, Candidate of Geological Sciences (Ph.D.), Researcher of the Department of technologies of underground mining of coal deposits, Institute of Gotechnical Mechanics named by N. Poljakov of National Academy of Science of Ukraine (IGTM, NAS of Ukraine), Dnipro, Ukaraine, zmievskaya@gmail.com

Tubaltsev Oleksandr Volodymyrovych, Master of Science, chief miner “FERREXPO AG” Yeristovo Mining, fym.office@mine.ferrexpo.com

Zmiievskyi Artur Stanislavovich, Master of Science, sales engineer RDT, LLC “Epiroc Ukraine”, www.epiroc.com

Про авторів

Змієвська Кристина Олегівна, кандидат геологічних наук, науковий співробітник відділу проблем технологій підземної розробки вугільних родовищ, Інститут геотехнічної механіки ім. М.С. Полякова Національної академії наук України,zmievskaya@gmail.com

Тубальцев Олександр Володимирович, магістр, головний гірник «Феррекспо Єристівський ГЗК», fym.office@mine.ferrexpo.com

Змієвський Артур Станіславович, магістр, інженер з продажу RDT, ТОВ «Епірок Україна»,www.epiroc.com

Анотація. Мета. Визначення можливості застосування методу спостереження природного імпульсного електромагнітного поля Землі для виділення обводнених розривних порушень з подальшим закладенням водоперехоплюючих свердловин.

Методика. Для виділення обводнених розривних порушень на ділянках, що досліджувались, застосовувався метод природного імпульсного електромагнітного поля Землі.

Результати. Розробка родовищ корисних копалин відкритим способом часто ускладнюється рясними водопритоками в кар'єр підземних вод внаслідок порушення природних гідрогеологічних умов ділянки проведення робіт. Для вирішення таких проблем, у статті показана можливість застосування методу природного імпульсного електромагнітного поля Землі з метою виділення обводнених розривних порушень на території Єристівського кар'єра. Виділені нами тектонічні порушення характеризуються субмеридіональним напрямком структур природного імпульсного електромагнітного поля Землі. На підставі виконаних досліджень, можна зробити висновок, що закладення водоперехоплюючих свердловин доцільно виконувати у межах мінімальних значень природного імпульсного електромагнітного поля Землі - на південних частинах ділянок.

Наукова новизна. Вперше, з застосуванням методу спостереження природного імпульсного електромагнітного поля потоку Землі, побудовані карти-схеми щільності потоку природного імпульсного поля Землі на ділянках, прилеглих до Єристівського кар'єру, які дозволили виділити положення обводнених розривних порушень. Їх азимути простягання збігаються з основними - Головним і Єристівським розломами. Вперше побудовано тривимірні моделі виділених тектонічних структур, за якими можливо простежити елементи зсувної деформації, а також антиклінальну складку.

Практична значимість. На підставі виконаних досліджень, можна рекомендувати закладення водоперехоплюючих свердловин, яке доцільно виконувати у межах зон з мінімальними значеннями щільності потоку природного імпульсного електромагнітного поля потоку Землі на південних частинах майданчиків дослідження.

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

Аннотация. Цель. Определение возможности применения метода наблюдения естественного импульсного электромагнитного поля Земли для выделения обводненных разрывных нарушений с последующим заложением водоперехватывающих скважин.

Методика. Для выделения обводненных разрывных нарушений на исследуемых участках применялся метод естественного импульсного электромагнитного поля Земли.

Результаты. Разработка месторождений полезных ископаемых открытым способом часто затрудняется обильными водопритоками в карьер подземных вод вследствие нарушения естественных гидрогеологических условий участка проведения работ. Для решения таких проблем, в работе показана возможность применения метода естественного импульсного электромагнитного поля Земли с целью выделения обводненных разрывных нарушений на территории Еристовского карьера. Выделенные нами тектонические нарушения характеризуются субмеридиональным направлением структур естественного импульсного электромагнитного поля Земли. На основании выполненных исследований, можно сделать вывод, что заложение водоперехватывающих скважин целесообразно выполнять в пределах минимальных значений естественного импульсного электромагнитного поля Земли – на южных частях площадок.

Научная новизна. Впервые, с применением метода наблюдения естественного импульсного электромагнитного поля потока Земли, построены карты-схемы плотности потока естественного импульсного поля Земли на участках, прилегающих к Еристовскому карьеру, которые позволили выделить положения обводненных разрывных нарушений. Их азимуты простирания совпадают с основными – Главным и Еристовским разломами. Впервые построены трехмерные модели выделенных тектонических структур, по которым возможно проследить элементы сдвиговой деформации, а также антиклинальную складку.

Практическая значимость. На основании выполненных исследований, можно рекомендовать заложение водоперехватывающих скважин, которое целесообразно выполнять в пределах зон с минимальными значениями плотности потока природного импульсного электромагнитного поля потока Земли на южных частях площадок исследования.

Ключевые слова: естественное импульсное электромагнитное поле Земли, тектоническое нарушение, водоприток, Еристовский разлом, Главный разлом.

Стаття надійшла до редакції 19.08.2019
Рекомендовано до друку д-ром гнол. наук В.А. Барановим