Geophysical techniques for modeling mine structure and tectonic disturbances

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Abstract. This article presents the results of modeling the structural structure of a rock mass during underground mining operations. The research was carried out at one of the largest mining and processing plants in the Republic of Kazakhstan – Donskoy GOK. The spectral seismic profiling method, which has proven itself well for working in underground conditions, based on the seismoacoustic properties of the rock mass, was chosen as a tool for diagnosing the array. The purpose of the research was to diagnose the structural structure of the mine field in order to select the locations of drainage wells intended for drainage of mine workings and ore body. As a result of the research carried out, a structural model of each horizon and the mine as a whole was built, which allows us to determine with sufficient reliability the most promising sites for drainage work. In addition, the results obtained will be used to design vertical mine workings within the studied area. The results obtained were confirmed by verification drilling and proved their effectiveness and reliability.

1 Introduction

Mining operations at the underground method of field development are always associated with the solution of objectives of mine workings drainage and especially important objective is to reduce the water cut of ore during cleaning works. There are numerous ways of mine drainage - well water intakes, drainage ring underground workings around the deposit with a network of spillway wells, etc. Such measures are usually sufficient for safe mining operations, but they usually do not protect ore bodies from water saturation. Wet ore means not only additional material and time costs for drying, but also difficulties with its transfer through vertical mine workings to the lower horizons for transportation to the place of lifting to the surface, i.e. to the skip shafts. In this paper we would like to focus on one of the examples of solving the objectives of dewatering of mine workings and ore bodies with the help of unloading aquifers by drilling unloading wells.

Drilling of unloading and bypass wells is not new, but a common way to reduce the water cut of mine workings during underground mining operations, but the points of placement of these wells are usually selected only by analytical data, taking into account visual observations of the areas of water inflow and the direction of development of treatment works. This approach is in principle logically justified and cannot be criticized by

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specialists. In this case, as a rule, it justifies itself, although the volume of water obtained during drilling works is often minimal, or even the wells may turn out to be dry.

To increase the productivity of such wells, in addition to the above-mentioned parameters when selecting drilling points, it is necessary to take into account the parameters of fracturing of the rock massif, because water in rock massifs containing ore bodies goes exactly along the fractures. Knowing the spatial location of fractured zones, it is possible to set the location, required depth and azimuths of drilling with a high probability of obtaining maximum water yield of wells.

Unfortunately, traditional geophysical methods in most cases cannot be used in mine conditions, because there are various obstacles that prevent the measurements, such as concrete support, metal structures, backfill mesh and, of course, the small size of the mine workings themselves.

The method of spectral seismic profiling (SSP), developed at one time by SPF "Geofizprognoz" in St. Petersburg [1], has proven itself for solving the objectives of mapping structural disturbances in the conditions of underground mine workings. This method has been successfully used for more than twenty years by the specialists of the Geomechanics Department of the Institute of Geomechanics of the Ural Branch of the Russian Academy of Sciences in solving such objectives, both in underground mining and on the ground [2-8]. One of the examples of using the SCP method in modeling the structural structure of the rock massif of a mine to select the embedment points of unloading hydrogeological wells is given in this paper.

2 Research prerequisites

As mentioned above, the geophysical method of spectral seismic profiling makes it possible to quickly and accurately identify areas of increased fracturing, which are the main channel of groundwater filtration [9, 10]. Information on the location of these fractures can make it possible to drill drainage wells in the most promising points, ensuring their maximum productivity.

The rock massif of the Donskoy GOK mines (Republic of Kazakhstan), where the works were carried out, is highly disturbed and fractured. The main rocks composing the rock massif are serpentinite, dunite, gabbro and other rocks (Figure 1).

These rocks without fracturing are practically water-retaining, but high disturbance turns them into a highly productive water-bearing complex. This in turn causes numerous problems in mining these deposits.

In the field of the Kazakhstan Decade of Independence Mine (KDIM), where the dewatering works presented in this paper were carried out, there are widely developed discontinuities of predominantly sublatitudinal, northeastern, northwestern and to a lesser extent submeridional directions. Most of them are post-mining in age, often dissecting ore bodies into specific blocks and displacing them relative to each other.

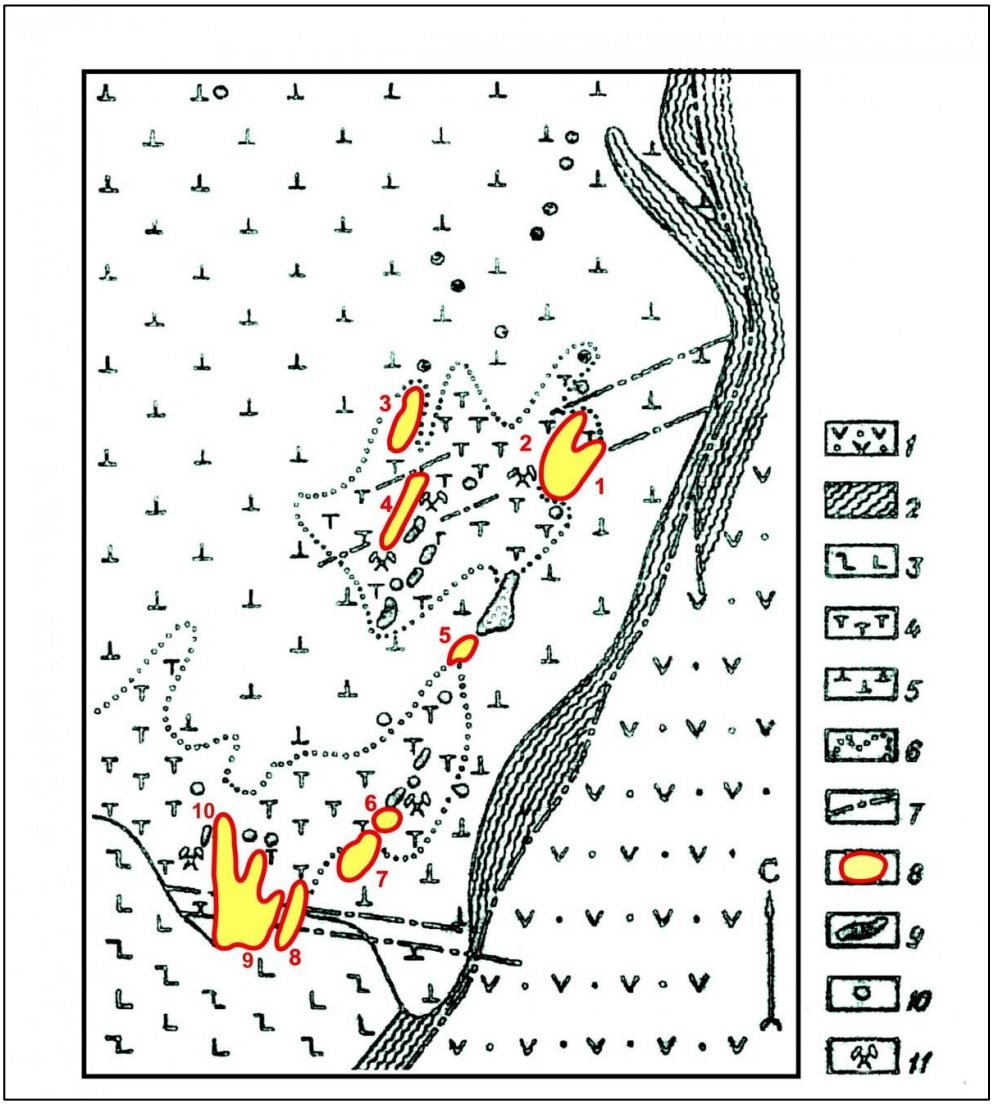

Fig. 1. Geologic scheme of South Kempirsay chromite deposits (by G.A.Elpashev): 1 - Paleozoic volcanogenic-sedimentary deposits; 2 - Proterozoic metamorphic rocks; 3 - gabbroamphibolites; 4 - serpentinites on dunites; 5 - serpentinites on peridotites; 6 - rock boundaries; 7 - discontinuities; 8 - large chromite deposits (1 - Molodezhnoye, 2 - 40 years of the Kazakh SSR, 3 - Geophysical XII, 4 - 20 years of the Kazakh SSR, 5 - Geophysical VI, 6 - Spornoye, 7 – No. 21, 8 - Pervomayskoye, Almaz-Zhemchuzhina, 10 - Milionnoye); 9 - medium and small deposits; ore occurrences; 11 - developed deposits.

The faults are represented by zones of intense serpentinization and crushing of rocks with numerous serpentinite veins containing an admixture of brucite. Specific disturbances are traced by low thickness dikes of gabbro-diabase.

The entire ore field is dissected by fractures of the above directions into blocks with a cross-section from 100 to 700 meters. Their length is 1-5 or more km, and their thickness varies from the first decimeters to tens of meters. Against the background of such a lattice of discontinuities, numerous higher-order fractures are manifested and, eventually, the entire massif of ore-bearing serpentinized hyperbasites is broken by a system of small

fractures of various directions into elementary blocks of 0.5-2.0 m in size, and near the discontinuities - up to 0.1 m.

During watering of the rock massif in the zones disturbed by structural fractures, rock delamination and rock outcropping are regularly observed (Figure 2).

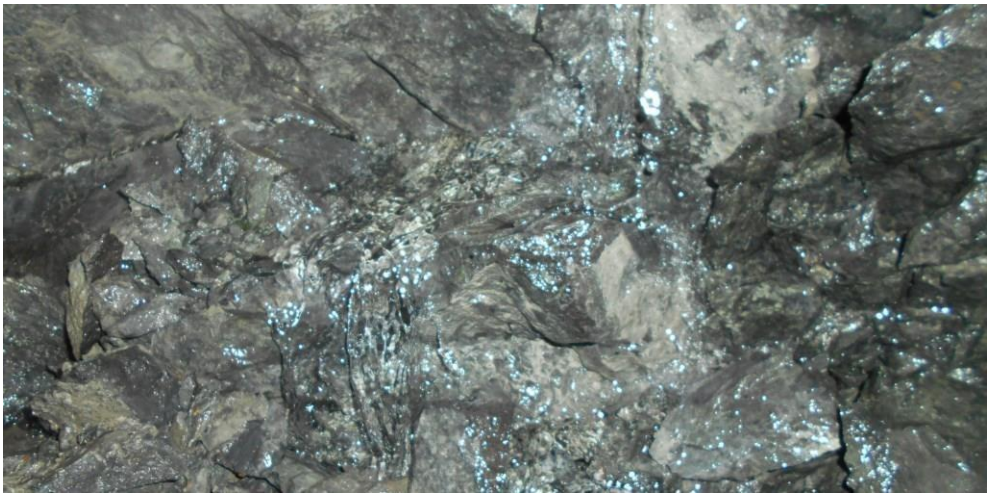

Fig. 2. Waterlogging and peeling of mine walls.

To combat the increased watering of mine workings, it was decided to use drainage wells, making it possible to discharge the aquifer in a timely manner, before the start of cleaning works in certain areas. At the same time, as already mentioned, without fractures the massif is practically waterless, so the question of how to choose the points and direction of drilling drainage wells became the main one for this method of drainage.

3 Research results

Geophysical research by spectral seismic profiling method has been carried out at this mining and processing plant for more than 15 years, both by specialists of the Geomechanics Department of IHD Ural Branch of the Russian Academy of Sciences together with IHD-Kazakhstan LLP, and by specialists of Donskoy GOK. In this regard, the method of determining the location of areas of increased fracturing was unambiguously chosen - the method of SCP.

Fixing of mine workings at the DNA mine is made by a small-sized metal grating with shoring. In this connection it was not possible to perform measurements in the walls or roof because it was not possible to fix the seismic receiver qualitatively for making measurements. It was decided to carry out research of the array into the soil of excavations. Taking into account that this method of measurements does not make it possible to view the state of the array in different directions, it was decided to perform research at all available horizons to obtain a volumetric model and the possibility of interpolating the identified disturbances at different depths and in space.

Figure 3 shows an example of the resulting cuts.

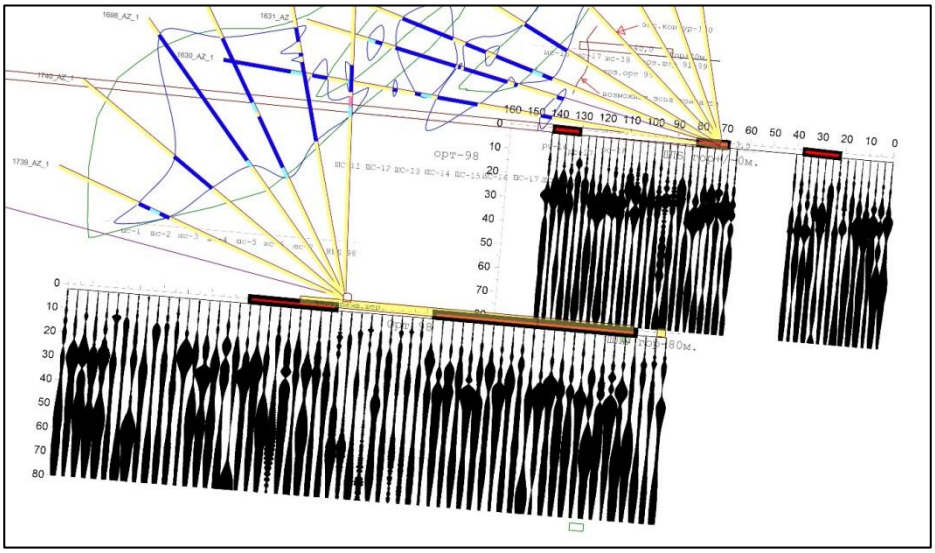

Fig. 3. Example of seismic sections obtained for two horizons.

All sections were carefully georeferenced and implemented into the structural model of the DNA mine.

Figure 4 shows the results of embedding geophysical data on one of the mine horizons.

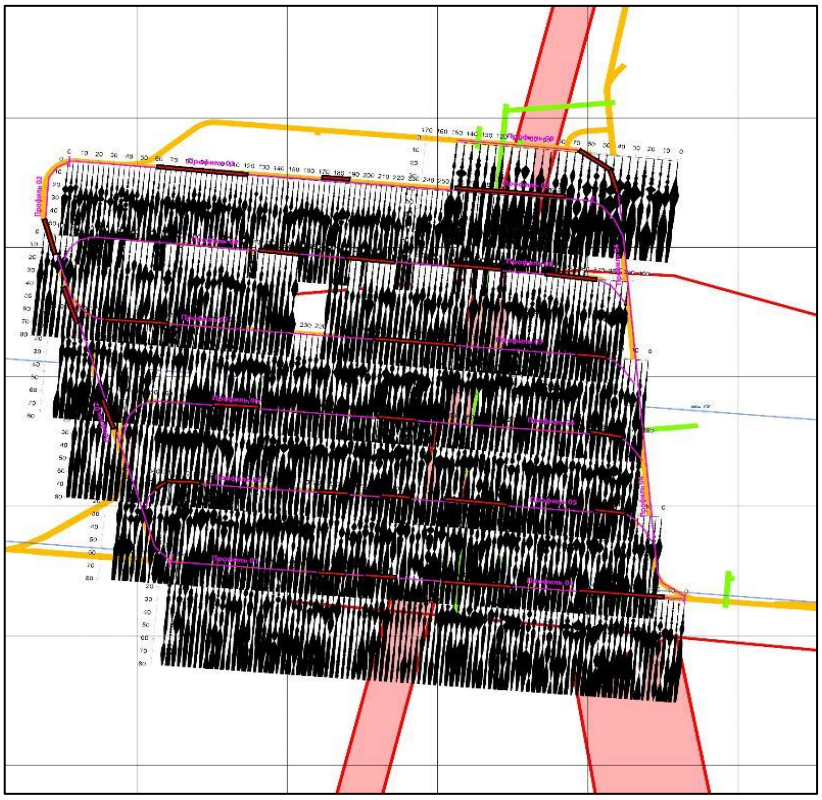

Fig. 4. Visual representation of research results.

Each section was interpreted separately to identify the most disturbed areas, and given that the massif at the site is already highly disturbed, oblique fractures, i.e., fresh fractures, were favored when identifying structures.

In addition, information from archival data on confirmed tectonic faults and water outcrops in the walls and roofs of the workings was transferred to each horizon. All information was thoroughly studied and compared, which made it possible to put on the plan of each horizon the areas recommended for drilling drainage wells. An example of data presentation is shown in Figure 5.

Fig. 5. Horizon zoning by degree of disturbance.

Based on the results of zoning, the drilling of borehole fans was carried out. For this purpose, drilling points and fan directions were selected jointly with the mine specialists. At the same time, the points were set both in the areas recommended for drilling and outside the selected areas, in order to compare the results obtained.

The first fan was drilled outside the selected area, the wells turned out to be dry and the array is quite stable according to the drillers' information.

The second and third fans were drilled taking into account the selected heterogeneities. In the second fan the water came out, though the flow rate was insignificant, in the third fan there was no water, but the whole massif also turned out to be strongly disturbed according to the information of the drilling foreman, the wellbores are strongly bent due to oblique fracturing.

It should be noted that drilling of the first three fans was carried out on practically dry lower horizon in the roof of workings, and as it was said before the disturbed areas were allocated by probing into the soil and interpolated on the rest of the array.

Further drilling on other horizons is to be done, but already now it can be concluded that the chosen research methodology was informative enough, and the results were confirmed by drilling, i.e., the results are reliable.

Research of the structural and tectonic structure of the rock massif during mining operations is a necessary objective not only for draining the rock massif, but also for ensuring the safety of mining operations, which is confirmed by many international studies [11-15].

4 Conclusions

The use of the spectral seismic profiling method for structural diagnostics of the rock massif containing the mine field has shown its effectiveness and reliability. In this case, research was conducted into the soil of the workings, however, with other methods of workings support, probing can be conducted into the walls and roof of the workings, which makes it possible to study the rock massif in different planes [16].

The results of research have been experimentally evaluated by drilling drainage wells, the structural model of the mine field built on the results of geophysical works will be used not only as information not only for draining the rock massif of the mine, but also in the preliminary selection of locations of vertical mine workings. Of course, during the final selection of the locations of uprising workings, additional geophysical research with more detailed probing (profile step of no more than 1 meter) should be carried out to obtain complete information, especially since there is already an example of such work at the mill [17].

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