Estimation of the Error in the Calculation of Mineral Reserves Taking into Account the Heterogeneity of the Geological Space

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Abstract. For effective application of the method of analogy in the geometrization and prediction of indicators, it is necessary to observe the principle of similarity of the field being studied to the field-analog developed by the development. Under the conditions of similarity, it can be assumed that the nature and intensity of deformation of rocks in the conduct of mining operations will be about the same. When choosing a mine-analogue should be based on the coincidence of the degree of metamorphism of coal and rock epigenesis, tectonic structure of the sites, the lithological and material composition of rocks and their physical and mechanical properties, power and depth of the coal seam, hydrogeological conditions. Homogeneous areas of the deposit can be distinguished by various methods of cluster analysis. The quality of the classification is assessed by comparing the average values of indicators in individual clusters (homogeneous areas) with their average values throughout the place.

1. Introduction

In this paper, as an object of study will be considered a rock mass (coal seam and its host rocks of the roof and soil), which are characterized by the general conditions of formation, geological features and certain physical and technical parameters. The coal deposit can be represented as a set of interrelated indicators characterizing its structure, properties and conditions of formation.

In [1-10] it is indicated that the sources of errors in determining the geological factors of the deposit are the discrepancy between the system of development of the features of the geological structure of the deposit; errors of geological observations and their interpretation; errors of generalization; low resolution of the means and methods of geological exploration. Errors in the exploration system lead to insufficient exploration of the coal seam in some parts of the mine field. Error geological observations due to inaccuracies in the determination of formation parameters in separate points and in the description of the revealed exploration workings intervals of coal-bearing strata. Error of generalization include improper alignment of layers and disjunction, the wrong selection of the calculation blocks, errors in interpolation and extrapolation of data exploration.

Probabilistic methods are absolutely necessary to determine the reliability of various data and indicators in the calculations associated with most of the tasks of designing a mining enterprise. They are used to assess the accuracy of the calculation of reserves, the justification of the optimal value (standards) of the opened, prepared and ready for the seizure of reserves, optimization of the heating...
plan for the construction and operation of the coal mine, determining the production capacity of the enterprise.

In [11-15] to improve the validity and reliability of the outcome of the framework design of the mining enterprise proposed to account for the predictive nature of the materials of geological reports during the elaboration of design documentation by the appropriate redundant elements of the technological schemes. A promising area of research in this area is the further improvement of processing and interpretation of exploration data in geological reports.

The concept of the reliability of the geological information used in the design is usually not given a quantitative expression. It is advisable to link the concept of reliability of reserves with the value of the error of calculation and its detail. The understanding of the nature of error propagation and how to account for them is contained in the theory of probability and mathematical statistics. In the processing of exploration data, this is not sufficient because of the presence of correlations between the individual indicators whose analysis requires the use of geostatistics methods of analysis errors [16-23].

2. Problem’s statement and methods of its solution

Increasing the reliability of the geometrization of the deposit indicators is based on the division of the rock mass into areas with mathematical models of the indicator placement, characteristic only for these areas. Clustering of the coal deposit (division into homogeneous areas) will be carried out by the method (k-means). The number k is given by the researcher and reflects the estimated number of sites within which various models of the indicators are expected to be available.

The criterion for the optimality of the number of clusters (sites of coal birth) will be the statistical homogeneity (constancy of average values, dispersions or, in general, the laws of distribution) of geological indicators in the selected areas. The features of modeling the correlation relationships between the indicators of the coal deposit were considered. The authors propose to consider the regression equation as an integral statistical characteristic of a geologically homogeneous area of a coal deposit. The regression equation coefficients that reflect the correlation between the indicators must remain stable (constant) for any set of test points that are included in the test site.

On the basis of multivariate statistical analysis of the data, the null hypothesis of equality of regression coefficients, i.e. equality of mathematical models of interrelations between the coal deposit parameters for different sets of testing points within a homogeneous area, is put forward. This approach in statistics is called the Chow test. It consists in the construction of a regression equation for the combined data, which are individually used to calculate the coefficients of the two compared models.

The increase in the reliability of the geometrization of mining and geological indicators is achieved through the use of a set of mathematical models for the placement of indicators for each site, as opposed to the creation of a single model for the entire coal field. An approach to the search for the boundaries of the plots based on linear discriminant analysis was proposed. In order to improve the quality of allocation of geologically homogeneous areas of the coal deposit, the authors propose to use only informative and independent separating indicators in the linear discriminant function. Step-by-step inclusion of indicators in the linear discriminant function is carried out by the method of the group account of arguments.

3. Discussion

As an example, consider the mining and geological conditions for the development of coal seam (mine "Rostovskaya"). According to the method of facies-phase analysis, the indicators within the carbohydrate-containing rhythm are in paragenetic relationship. As a quantitative statistical characteristic of this dependence, we will use the regression equation. The presence of a high coefficient of determination will be a confirmation of the existence of paragenetic (correlation) relationship in the carbohydrate rhythm.

As indicators, the power of the coal seam and its host layers of sand shale (direct roof) and (direct soil) were used. The proposed approach to the allocation of geologically homogeneous areas for
mining and geological conditions of coal seam mining on the example of the mine "Rostovskaya" allowed to identify six subtypes, which are homogeneous in terms of the paragenetic relationship between the reservoir capacity. Further clustering these subtypes is not possible to distinguish within them a new homogenous areas place of birth.

For the geometrization of spatial fields of indicators within homogeneous areas, it is proposed to use the geostatistical kriging method, taking into account the spatial variability of the indicator by means of an experimental semivariogram. On the example of modeling the reservoir capacity of the mine "Sadkinskaya" it is found that the advantage of kriging with the optimal model of the semivariogram is large prognostic possibilities due to the refinement of the semivariogram as the development of mining. Other mathematical methods of interpolation do not allow to use continuously replenished surveying information about the actual placement of indicators in the depths. For the mine "Sadkinskaya" the accuracy of the prediction of small-amplitude tectonic disturbances for the south – eastern part of the mine field is 70-85 %.

4. Conclusions

The allocation of geologically homogeneous areas of the coal deposit is necessary to improve the reliability of the geometrization of indicators in the geological space. With multi-dimensional geometrization, it is not always possible to build a single mathematical model with good prognostic properties for the entire field at once. In this case, for each geologically homogeneous area, an optimal mathematical model of the indicator placement is selected.

Sequential separation of coal deposits into homogeneous areas is carried out by cluster analysis. The criterion of the homogeneity of the site and the stop of the clustering procedure is to achieve the stability of the parameters of the regression equation, reflecting the paragenetic relationships of the indicators at the points of testing. Adjacent in space geologically homogeneous areas have a common border. For expression of such boundary in mathematical form the linear discriminant function of indicators at the points of testing. Adjacent in space geologic

5. References

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