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Uncertainty of propogation models in mineral resources evaluation studies and analysis

Yanying Ma[1,2], Jizhang Fan[1], Xue Wang[*]
[1]Institute of Mineral Resources Prediction of Synthetic Information, Jilin University, 130026, (CHINA)
[2]Jilin Teachers' Institute of Engineering and Technology, Jilin, 130052, (CHINA)
[3]Mathematics and Finice School, Fuyang Teachers College, Fuyang, 236041, (CHINA)

ABSTRACT

The prediction and evaluation of mineral resources is a systematic process, which is composed of multiple stages including data collection, data collation, information extraction, information synthesis and utilization, and prediction and evaluation of mineral resources from the information integration, thus to the ultimate results. It is because of the complexity and diverse changes of geology and the incompleteness of human knowledge and backward cognition that makes the prediction and evaluation of mineral resources with large uncertainties in each stage. And these uncertainties is very likely to result from the former period. All these lead to inaccuraries and errors in mineral resource prediction, and also cause quite a lot of uncertainty accumulation and propagation. At present, with more and more difficulties to find mineral resources and the increasing economic risks of mining industries, we have the urgent need for a better understanding of uncertainties in mineral prediction and evaluation. This research focuses on the the sources of uncertainties in the mineral resources prediction to offer the propagation model and algorithm accordingly.

KEYWORDS

Mineral resources prediction and evaluation; Uncertainty; Propagation model.

INTRODUCTION

Due to different geological structures, varied types and complex genesis of ore deposit types, plus elusive mineral factors, the prediction of mineralization is with great uncertainty. As the prospecting becomes more and more difficult with hidden uncertain factors, the risk is intensifying. Prediction and evaluation of mineral resources is to formulate an optimal decision under uncertainties, that is, to combine quantitative expression with the technical feasibility related to mineral resources, to predict quantities of undiscovered mineral resources in an uncertain way, then to base on the feasibility of this technology to develop optimal strategies.

China possesses abundant mineral resources. Mineral resources is defined as the minerals formed by geology, buried in the ground or poke aboveground, which have the exploitable and useful minerals and synthetics of useful elements with utilization value in industry. Mineral resources are important natural resources and an important material basis for the social production and development. Besides, they are non renewable resources with limited reserves. According to the characteristics and purposes, we usually divide them into three categories of metal minerals, non-metallic minerals and energy mineral resources.

The mineral resource is an important material basis for mining industry. The varieties, distribution and reserves all together determine the development of mining industry. Regional combination features of mineral resources affects regional economic development and industrial structures. Mineral resources and industrial value and productivity development level plus the technical and economic conditions are closely linked together. At present, with the progress of geological exploration, mining and processing technology, the utilization of mineral resources has been deepening and expanding. Mineral resources in China shows the following Figure 1 distribution:

Figure 1 : The distribution of mineral resources in China

Mineral resources in China have the following characteristics:

(1) Mineral resources are complete in varieties with ideal facilities. Of the reserves having been found but not yet proven, have been put into exploitation considerably. China's mineral resources distribution is in intensive range and has complete varieties.

(2) Although China boasts abundant mineral resources, it has dispersive potential values due to large population but less per capita hold.

(3) The poor quality of the mineral resources lead to less top-grade minerals, lower metal mineral grade, more lean ore, thus add difficulty to mining and cause a low rate of resources utilization.

(4) Deposit mainly ranges from small and medium-sized with less large minerals and comprehensive symbiotic minerals, which causes low efficiency of utilization.

To sum up, China is rich in mineral resources and mineral content. As the mineral content varies from region to region, the mining difficulty is also different, so we should strengthen the prediction and evaluation of mineral resources to promote the rational exploitation and utilization of mineral resources.

ANALYSIS OF UNCERTAINTIES OF MINERAL RESOURCES PREDICTION

In the prediction and evaluation of mineral resources, the uncertainties of geological body and characteristics and geological process lead to errors in the prediction of geological anomalies and mineralization, while the uncertainties of geological data and geological measurement inaccuracy and inaccurate expression of measurement results can also cause errors in geological forecast data. For final procedure, inaccurate dereferrncing, screening and improper handling in the process of research and prediction are among the major factors leading to inaccuracy. Chinese scholar Zhao Dapeng also points out that such uncertainties exisit in the whole process of prediction and research work.

The main uncertainty also originates from the uncertainties and inaccuracy of forecasting data, while low precision of geological measurement and the expression of the results are also the major causes. Especially in not high-degree work areas, improper selection is also an important cause of uncertainty. In the process of research, evaluation and forecast process, improper handling can also lead to uncertainties.

The current mineral resources prediction and evaluation, based on the comprehensive analysis of physical and chemical conditions of Geology and earth as well as remote sensing data, is to search factors of mineralization and ore controlling and to obtain direction of existing address, scale of deposit and quality information of minerals. The current main mineral resources prediction and evaluation is based on geological information, and these information includes a large amount of geological data we have collected and technology we have adopted to deal with these data. Both exist or have a certain uncertainty. We analyze the main sources of uncertainties in the prediction and evaluation of mineral resources first. Source of uncertainties in prediction of mineral resources, shown as TABLE 1.

TABLE 1 : Source of uncertainties in prediction of mineral resources

Source of uncertainties	Characteristics
Human Factors	Geological processes need geological observation,sampling and engineering construction, and all these are supposed to be in line with certain scale and standard. But human’s subjective awareness accounts for a large proportion, which causes a certain degree of uncertainty in the geological work.
Geological Condition	The formation of natural minerals is complex. The grey characteristics of different geological conditions and the multible information in the course of prospecting can lead to uncertainty,which is the inherent attribute of geological process.
Effect of precision of instrument	Interference of some measuring instruments used in geological work and limits of the surrounding environmental factors can cause inaccurate geological data in the acquisition process. Mineral prediction process need extraction, synthesis, evaluation and expression of information. This series of process can lead to amplification and accumulation of uncertainties, all these together are the uncertain factors in the prediction of mineral resources.
Subjective Factors	When the subject analyze the received information, it can remodel object from concept and rules and form a variety of rusults of evaluation and prediction based on the existing knowledge. In this process, generally,people's subjective consciousness maintains dominance so that the information obtained distorted and has uncertainty in different degrees.

Mineral resources is of great value, the space available is also extending. Therefore, we should correctly understand the sources of uncertainties and learn how to estimate them.

There are a lot of methods to predict and evaluate the uncertainties of minerals resources, such as probability theory, geometry method and geostatistics method of which the geological geometry is mainly based on relationships of samples, while geostatistics is based on the random function and spatial relationships, but it is not suitable for the evaluation of small of the ore grade. We put forward the fuzzy mathematics as a method to solve the uncertainties. The biggest difference between fuzzy mathematics and other uncertainty evaluation method is that it can express any probability under uncertainty in a transparent manner, and can use the fuzzy membership function to replace the missing data in the prediction and evaluation of mineral, thus can reduce the uncertainties. Fuzzy set is qualitative evaluation based on the mathematical membership theory with clear and systematic results.

As for the uncertainty methods of the prediction and evaluation of mineral, studies both at home and abroad emerge one after another. Fodor and other scholars put forward the main methods to evaluate the geological uncertainty, including probability theory, geostatistics and geological geometry. Tutrnez summaries uncertainty methods that evaluate the grade of deposits mainly geological in grade geometry and geostatistics. Prade and Dubios point out a better way of dealing with uncertainty which is fuzzy sets. Cheng and other scholars point out that one of the main sources of uncertainty is the missing of data in the prediction and evaluation of mineral region which can make use of fuzzy membership function instead of missing data in order to reduce uncertainties. Still some others use interval neutrosophic set and neural network to predict its spatial position of mineral resources and use uncertain function to express uncertainty of the uncertainty of mineral resources

In terms of evaluation of the uncertainty in the number of undiscovered deposit, USGS uses fixed percentile and subjective estimates the undiscovered mineral deposit, which will produce large errors. In order to accurately estimate the number of undiscovered deposits, the US scholars also propose the use of density model to estimate the number of deposits, come up with undiscovered deposits and predict the area function of prospects through a linear regression.

At present, many scholars are devoted to many discussions and studies about uncertain resources, classification as well as the methods of evaluation. But due to the complex structures and its varieties of geology, so far, many methods and systematical frame to predict and evaluate mineral resource are not practical. Therefore, the study on the uncertainty of mineral resource is still researching.

ALGORITHM OF THE UNCERTAIN EVALUATION IN THE PREDICTION OF MINERAL RESOURCE

Information processing method based-on the uncertainty of the fuzzy set statistics

Fuzzy set means the uncertainty of the object of study which can be expressed by membership grade. Fuzzy set function can be decided by the shapes of the left function (L) and the right function(R), which can be expressed as M=（M1，M2，a，b）. M1 and M2 are all belong to the positive and negative infinity, while a and b are greater or equal to zero. The common membership functions of the fuzzy set are the bell, the uplifted and the drop shape, as follows Figure 2.

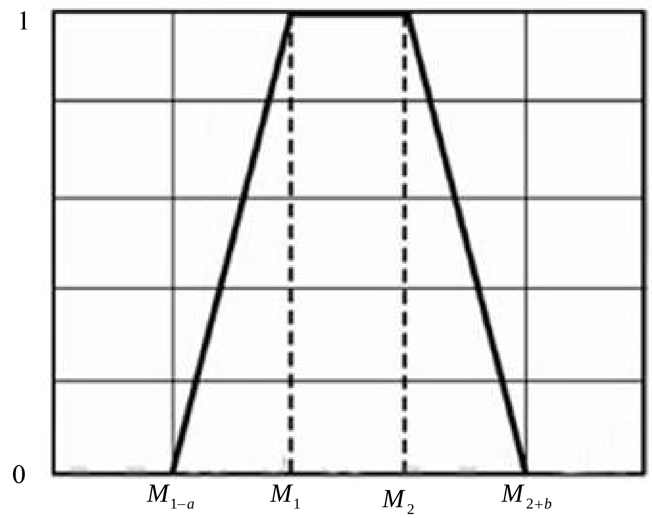

Figure 2 : Trapezium fuzzy set function

Regarding the establishment of a general method for the calculation of the above-mentioned sources of uncertainty, the uncertainty information of these parameters can be characterized and expressed systematically.

Any of uncertainty information is assumed to be X, and the scope of activities of the parameter is defined as the interval $[A_i, B_i]$, And ($i = 1,2,3\ldots n$), namely X has in the case of n possible values. According to the statistical theory of fuzzy sets of values, uncertain parameters X can be used to represent the membership function, and it is referred to as a, there

$$\alpha = \mu(x) = \frac{1}{k}\sum_{t=1}^{k} F_{[a_i, b_j]}^{(x)} \quad \textbf{(1)}$$

Among them:

$$F_{[a_t, b_t]}^{(x)} = \begin{cases} 1, x \in [a_t, b_t] \\ 0, x \ | [a_t, b_t] \end{cases} \quad \textbf{(2)}$$

Known as the characteristic function of [a, b].

We can take advantage of the density of mineral deposits to estimate the number of undiscovered ore deposits and specifically express the uncertainty of the number of undiscovered ore deposits as well as express the type of ore deposits, and the mineral equivalent can be introduced to predict the size of deposits. First of all, mineral equivalent can be drawn based on the number of mineral equivalent rights law, and different sizes of mineral deposits can be converted into the equivalent number of small-scale deposits. The density of mineral equivalent can express a high degree of exploration of mineral equivalents per unit area. According to the studies of previous experts, they judge the proportion of large, medium and small deposits in the prediction region is 1: 7:50, which can be used to estimate the ratio of equivalents of the mineral and replaced by the number of ore deposits. This method can not only be used to estimate the number of undiscovered ore deposits, but also express the uncertainty of the number of undiscovered ore deposits as well as predict different sizes of ore deposits and the probability. Through the use of fuzzy sets to predict mineral, prospecting areas can be represented by the following Figure 3.

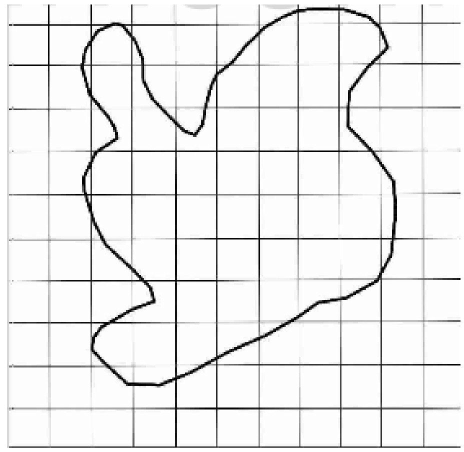

Figure 3 : prospecting areas

Get data and fuzzy sets of mineral equivalent based on forecast area, so as to determine the type and size of mineral resources.

Evaluation of the uncertainty in mineral resource assessment

In forecasting minerals, a variety of mineralization, ore and mineral indicators are needed to infer the results of mineral prediction and assessment. Because the results of mineral prediction and assessment are influenced by several factors, such as factors of resources, structural factors and the geophysical-geochemical anomaly factors, outcome indicators of prediction and evaluation are uncertain. Uncertainty parameter is represented by X, X = (Uncertainty, use uncertain parameters x to represent, and $x_0 = (x_1, x_2, x_3, \cdots x_m)$,

If each uncertainty parameter takes expectations, the final results of evaluation--the expression of Z can be expressed the following formula:

$$E(Z) = f(E(X_1), E(X_2), \cdots E(X_m), Y_0) \qquad \textbf{(3)}$$

$$R_Z = \prod_{t=1}^{m} R_i$$

Its corresponding reliability:

Wherein: R reflects the intensity of expectations.

From the above conclusions we can find that the impact of uncertainty on the evaluation results of X has the following conditions:

When the uncertainty parameter X increases, the results of evaluation becomes superior, then the parameter X becomes beneficial parameters of Z.

When the uncertainty parameter X increases, but the results of the evaluation was poor, then the parameter X becomes damaged parameters of Z.

The uncertain method of evaluation and prediction of mineral resources

We make use of the evaluation results of the expected value and the reliability of system and risk quantitative concept to describe the uncertainty of mineral prediction results, it also examine the validity of the prediction and evaluation results based on the valid data, with simple method and clear thinking in line with the general thinking of mathematical statistics and broad scope of applicablites, thus can be used to predict and evaluate all kinds of uncertain data and the corresponding calculation results. But this method still exists defects in a certain extent, because the whole process of prediction and evaluation is the process of a pure mathematics and lack of accurate expression of the uncertainty characteristics of geology. We have studied the source of such uncertainties through the quantified analysis and then develop a unique data type for the description of the information involved in forecast uncertainty of mineralization. We hope to combine the uncertainties of prediction and evaluation with those of economic evaluation that through the research and improvement of the continuous progress of technology to provide effective help for the current development of resource conditions and mining situation.

CONCLUSION

The main characteristics of the mineral resources prediction and evaluation are multi period and multisystem. Variables of the latter phase often need forecast and evaluation results of the former one, at this time, technology assessment results will serve as the basis for economic evaluation. So through continuous inputting uncertain variables from one procedure to next and repeating operation, a iterative algorithm will form then stop the operation in the final output results. The research on uncertain factors of mineral resources prediction and evaluation can provide effective clues for the further development of mining industry.

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