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Method for Determining Lower Limit of Soil Geochemical Anomaly and Its Advantages and Disadvantages

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Abstract: Based on the study of soil geochemical surveys in exploration geochemistry, this paper mainly discusses the method of determining the lower limit of anomalies. This paper introduces the basic principles and practical operation steps of the four commonly used methods of determining the lower limit of anomalies, such as the histogram method, traditional statistical method, EDA technology, and fractal theory, and then analyzes the advantages and disadvantages of various methods, to ensure that the anomalies of different geological characteristics and data characteristics can be judged more accurately, to lay the foundation for prospecting exploration and prospecting prediction.

1. Introduction

Exploration geochemistry, also known as geochemical prospecting, referred to as geochemical exploration, is a new branch of geology combined with geochemistry. It is mainly to determine the geochemical anomaly area of a certain element in a geological body and evaluate the anomaly in combination with the actual geological characteristics of the mining area, to achieve the purpose of deep prospecting prediction[1]. According to the different sampling media, geochemical exploration techniques can be divided into the following five categories: rock geochemical survey, soil geochemical survey, stream sediment geochemical survey, biogeochemical survey, water geochemical survey, etc[2]. The sampling object of the soil geochemical survey is soil. Through the systematic collection of soil samples, and according to the results of the content of some elements in the samples, the delineated geochemical anomalies are used as prospecting indicators. Through the practice of geochemical prospecting, it is found that soil geochemical survey is more successful in various geochemical prospecting methods, which provides a more favorable geochemical basis for the discovery of deposits.

Since the emergence of the term “geochemistry”, the delineation of anomalies has always been an important task in mineral exploration[4]. Soil geochemical survey is no exception. Because of its advantages of a simple test, accurate scale, and strong representativeness, soil geochemical survey has been widely used in prospecting[3]. Determining the lower limit of the anomaly is a essential step in soil geochemistry. This paper starts with the introduction of the lower limit of the anomaly of soil geochemistry and analyzes and compares the four basic methods of determining the lower limit of an anomaly: histogram method, traditional statistical method, EDA technology, and fractal theory. Clarify the basic principles and applicable characteristics of various methods, in order to make a reasonable judgment in the soil geochemical survey of the mining area for specific geological characteristics and specific geological development history, and better carry out deep metallogenic prediction.

2. Research Status at Home and Abroad

In 1798, the former Soviet scientist Severkin, first proposed the concept of 'mineral proximity'. In 1849, Bleissopte, Germany, found that minerals have the characteristics of symbiotic and associated assemblages. This theory provides a basis for speculating the possible mineralization of the cap and the lower part of the mineralized outcrop[8]. In the 1930 s, the former Soviet Union's Filesman et al. proposed the use of soil geochemical survey for prospecting, and on the basis of some major research results of predecessors in related fields, Emmons put forward the conclusion that there is a zoning phenomenon of mineral components around endogenous metal deposits, and then the soil geochemical survey was gradually developed. Subsequently, Weber, Solovov, Boyle, and others improved the theory and technology of the soil geochemical survey method. They conducted in-depth research on soil geochemical survey methods and made great contributions. Since then, the soil geochemical survey method has gradually developed into a flawless exploration of geochemical methods and technology[6]. Norwegian scholar Goldschmidt first used the method of emission spectroscopy to analyze trace elements, thus creating a modern exploration of geochemistry. In 1941, Russian scholars published the " geochemical prospecting method " . In this book, the theory and method of geochemical exploration are systematically expounded for the first time, which is of epoch-making significance[8].

China began to use geochemical prospecting in the 1950s, later than the Soviet Union, Northern Europe, and other countries. In 1951, Xie Xuejin et al. collected stream sediment and soil samples in Yueshan, Anhui Province, and found a copper indicator, which was the first experiment in China. In 1956, the Ministry of Metallurgy established the geochemical exploration group of the General Team of Metallurgical Features. In the 1960 s, Guilin Institute of Geology, Beijing Institute of Geology, and other domestic colleges and universities successively established geochemical exploration majors. By the 1980 s, this method had become an important prospecting method. And with the continuous development of geological technology, the method has been well applied. It has been proved in many years of practice and production that this method has a remarkable prospecting effect[3]. It has played a vital role in the discovery, survey, evaluation, and exploration of many large deposits in China. Using the soil geochemical survey, prospecting method we found a number of deposits or spots, such as Shandong Penglai area of Heilangou gold mine; the gold belt outside the Sandaowanzi gold deposit in Heilongjiang Province has expanded the scale of the deposit; the Modola copper-gold mining area in the southern section of the Gangdise, Tibet, discovered the II copper-gold mineralization zone; a silver and copper polymetallic ore body has been discovered in Chaganchulu area, Inner Mongolia. Several gold ore bodies were found in the exploration of the Puqing antimony gold deposit in Guizhou. Lead-zinc ore bodies were found in Huize area on the western margin of the Yangtze platform; 10 gold mineralization belts and 4 gold spots have been found in Longbao area of the west end of North Qinling. Copper polymetallic ore bodies were found in the Xiangutai area, Ruichang City, Jiangxi Province. Four gold deposits have been found in the Boxzizhai-Tongqianxia area of Shaanxi Province. Mazongshan Gongpoquan East Gold Mine, a number of gold ore bodies were newly discovered; a copper ore body with industrial scale was found in the Guoqing mining area to the northern margin of Hengyang Basin. Two better industrial copper ore bodies were found in the Biaoshanbei area of Ejina Banner, Inner Mongolia. Jilin Daheishan large platinum mine; Liaoning Hongtoushan Copper Mine; Xinjiang Huangshan copper-nickel ore, etc., The above cases show that a soil geochemical survey is a fast and effective prospecting method[5].

In the past thirty years, although scholars at home and abroad have summarized a variety of geochemical prospecting methods, soil geochemical survey still has a very significant effect on the specific prospecting work and has achieved certain economic value and social value[6]. In general, a soil geochemical survey is very effective for prospecting. Especially now with the mining value of the deposit is increasingly difficult to find the situation, the use of soil geochemical survey methods for prospecting and deep metallogenic prediction is increasingly subject to the attention of domestic and foreign governments, enterprises and researchers, and through soil geochemical survey methods, the found deposits and increased reserves are also excellent. It is worth noting that soil geochemical survey has not only made great contributions to geological prospecting, but also been widely used in various fields, and has achieved satisfactory results. For example, the soil geochemical survey method was used to analyze the quality of water resources in the Ethiopian Valley of Africa. Surface soil analysis and valley strait sediment analysis were carried out in Oslo, Norway, northern Europe, by soil geochemical survey method. Using soil pollution assessment to analyze urban diversified environment. These cases show that soil geochemical survey methods have developed in a diversified direction[7].

3. Determination Method and Principle of Abnormal Lower Limit

The determination of the lower limit of the anomaly is an important part of the extraction of anomaly information in soil geochemical surveys, and it is also a key step in the application of exploration geochemistry for mineral exploration. In geochemical exploration, the lower limit of anomaly is an important parameter to distinguish the background area and the anomaly area[7]. Its value is directly related to the size of the anomaly range and the distribution of anomalies, and determines the direction of the next work and the metallogenic prospect of this area. In this paper, the principles and applicable data characteristics of the four methods of histogram method, traditional statistical method, EDA technology, and fractal theory will be briefly clarified, and the advantages and disadvantages of the four methods in the data processing of soil geochemical survey will be analyzed through the data processing flow of these four methods, and then a more suitable method for determining the lower limit of anomaly can be adopted for certain soil geochemical data characteristics.

3.1. Histogram Method

The application of histogram method to determine the abnormal lower limit value must meet the normal distribution or lognormal distribution of elements in geological bodies. The specific steps and diagrams (Figure 1) are as follows:

1) The geochemical exploration data are grouped from low to high according to a certain logarithmic interval of content. The number of groups is generally 5-7 or more, and the frequency or frequency of each group of samples is counted.

2) Drawing histogram: the logarithm of the content is the abscissa, and the frequency of the sample is the ordinate;

3) In the square column with the largest frequency, the left vertex angle is connected with the corresponding vertex angle of the right adjacent square column, and the right vertex angle is connected with the corresponding vertex angle of the left adjacent square column. The projection of

the intersection point of the connection line on the abscissa is the logarithm of the background value;

4) Make a bell-shaped curve through each square cylinder, so that the logarithmic sides of the background curve are basically symmetrical;

5) A straight line parallel to the abscissa is drawn from 0.6 times the maximum value of the frequency and intersects with one side of the curve, the length of which is σ or lgσ. The logarithm of the background value is measured on the right by 2-3 times σ (usually 2σ), where the indicated logarithm is the logarithm of the lower limit of the anomaly[10].

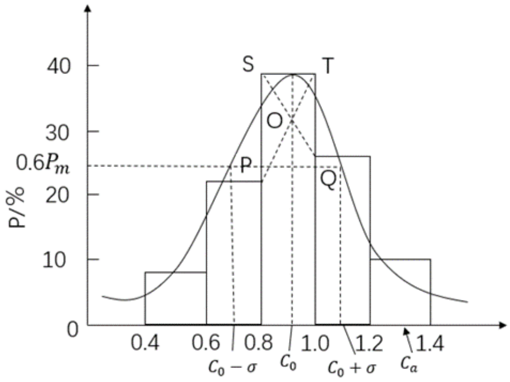

Figure 1: Histogram diagram.

3.2. Traditional Statistical Method-Iterative Method

Method principle: The premise of an iterative method to calculate the lower limit of an anomaly is to ensure that the original variable data or its logarithm conforms to a normal distribution, but the data measured in the actual soil geochemical survey can hardly meet this condition. Therefore, it is necessary to iteratively eliminate the extreme outliers in the data until it satisfies the normal distribution so that the abnormally lower limit can be calculated. For data with a normal distribution, the background value and the lower limit of the anomaly are calculated by:

$$C_0=\frac{1}{n}\sum_{i=1}^{n} x_i=\bar{x};\ \ T=C_0+1\sim 3S \tag{1}$$

Analysis of the formula for obtaining background values and anomaly lower limits:

1) Calculate the average value X and standard deviation S of the analysis data of all sampling points laid out in the survey area, and eliminate extreme outliers higher than X + 3S or lower than X-3S;

2) Calculate the mean and standard deviation of the remaining data after elimination, and eliminate the extreme outliers again. Repeat the cumulative elimination until there are no extreme outliers, and the data obey the normal distribution;

3),The final mean value X and standard deviation S are obtained, and the abnormal lower limit is A = X + 2S[5].

Although the principle and steps of traditional statistical methods are relatively simple, the data of soil geochemical surveys are large, ranging from thousands to tens of thousands. If manually processed, it is still a very large workload and easy to cause unnecessary errors due to human reasons. Therefore, the traditional statistical methods rely on data analysis software, combined with its principles and data processing methods for soil geochemical survey data analysis to determine the lower limit of the anomaly. The following two software DGSS and Excel example, detail its specific steps, detail its specific steps:

(1) Completed in the integrated data processing module of DGSS software, the specific steps are as follows:

1) After the original data processing is completed, the soil point (WT) file is loaded into the engineering edit box of DGSS.

2) Open the comprehensive data processing module, select the field attributes of the corresponding elements, and calculate their digital features;

3) The extreme abnormal values except X ± 3S are eliminated circularly until the data characteristics conform to the normal distribution.

4) At this time, the numerical characteristics of the normal distribution are obtained, and X + 2S is selected as the abnormally lower limit of the element[3].

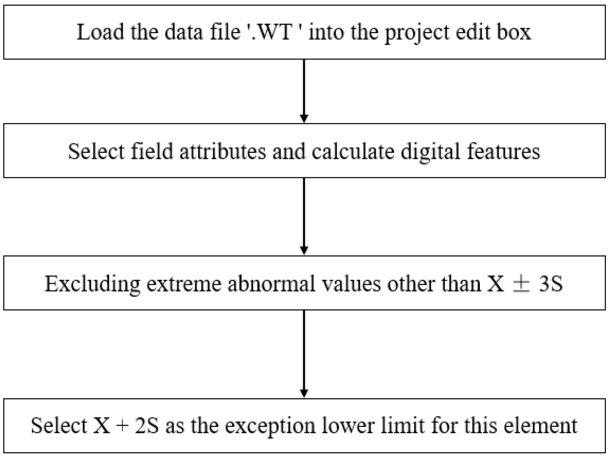

Figure 2: Data processing step diagram of traditional statistical methods in DGSS.

(2) Completed in the ‘formula, data’ function area of Excel software, the specific steps and flowchart (Figure 2) are as follows:

1) Obtain the maximum, minimum, mean, and mean square error of all samples by Excel data table;

2) Remove the outliers according to certain conditions until there are no outlier, and then calculate the maximum, minimum, mean, and mean square error of the new data.

3) Here, “three” is selected as the deviation multiple of this iteration method to obtain the abnormal lower limit of this element[8].

3.3. EDA Technology (Box Whisker Method)

Principle: EDA technology, also known as the box whisker method and box diagram method, is a statistical graph describing data distribution. It can be used to describe the characteristics of the data center, extension, and distribution from a visual perspective. It mainly represents the five percentile points of the variable value: the maximum value of the data, the minimum value of the data, the first quartile (25 %) Q_1 of the data, the median (50 %) Q_2 of the data, and the third quartile (75 %) Q_3 of the data[3]. The above five parameters and box plots can be calculated in SPSS software, and the operation is simple and convenient, as shown in Figure 3.

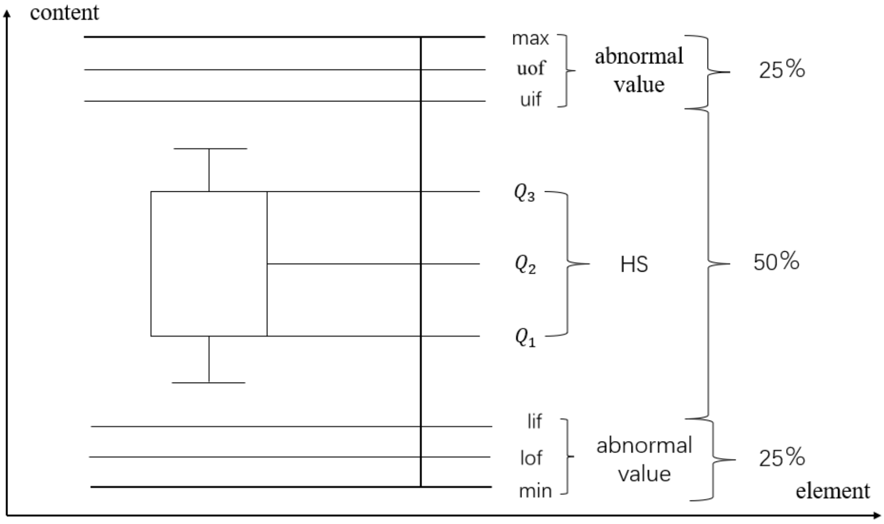

Figure 3: Box whisker diagram schematic diagram.

The specific steps and flow chart of the box whisker method for finding the lower limit of the exception are as follows(Figure 4):

1) Using SPSS software, import the initial data of elements, set the variable window ‘type’ and ‘measure’;

2) Select the graphic box whisker in the menu;

3) In the pop-up window, select the variables that need to be analyzed: the elements to be analyzed by soil geochemistry;

4) Output results: In the output data results, the spacing between the first quartileQ_1, the median Q_2, the third quartile Q_3 and the quartile of the analysis element can be obtained IQR = Q_3-Q_1. The range of Q_3 + 1.5 IQR and Q_1-1.5 IQR is called the internal limit, that is, the normal value interval of the data. In the interval other than this, it is the abnormal value in the data, and Q_3 + 1.5IQR can be selected as the abnormal lower limit[6].

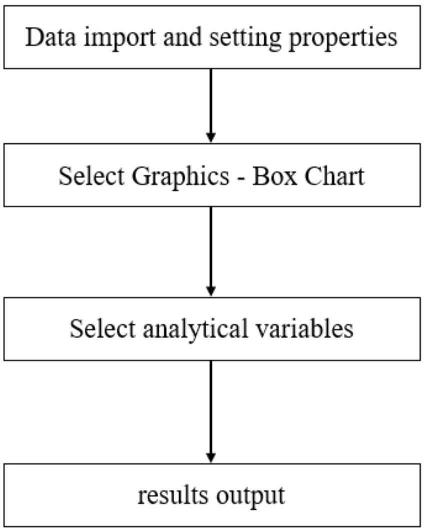

Figure 4: EDA data processing step diagram

3.4. Fractal Theory

For fractal theory, this paper will introduce the content-sum method to establish a fractal model and the formula for fractal processing of soil geochemical data through the calculation formula of the model:

$$N_{(r)}=\sum_{i=1}^{N} x_i(x_i \geq r) \tag{2}$$

$$\lg N_{(r)}=-D\lg r+\lg C \tag{3}$$

In the formula: r is the element content value; N is the number of all element content values satisfying $x_i \geq r$; x_i is the element content value greater than or equal to r; $N_{(r)}$ is the cumulative sum value of all elements that satisfy the element content greater than r; d is the fractal dimension; c is a proportional constant. The r and $N_{(r)}$ are plotted on the double logarithm diagram, and the curve is fitted by the least square method to obtain the slope of the straight line, and the D value (fractal dimension value) can be obtained[9].

As shown in Figure 5, in the fractal analysis of element content, the fractal dimension value D_1 can accurately reflect the content distribution of each element in the background area that is not disturbed by mineralization, and the fractal dimension values D_2 and D_3 can accurately reflect the content change and abnormality of each element in the abnormal area disturbed by mineralization. In the fractal feature map of element content, the intersection of fractal dimension D_1 and D_2 represents an inflection point of the transition from the background zone to different normal zones, and the corresponding content change value can also be regarded as the background of an element. On the basis of this method, the element background value C_0 can be determined on the fractal feature map of element content in this area[11], and the anomaly lower limit of each element can be calculated according to formula 2-4.

$$T= C_0+ k\sigma \tag{4}$$

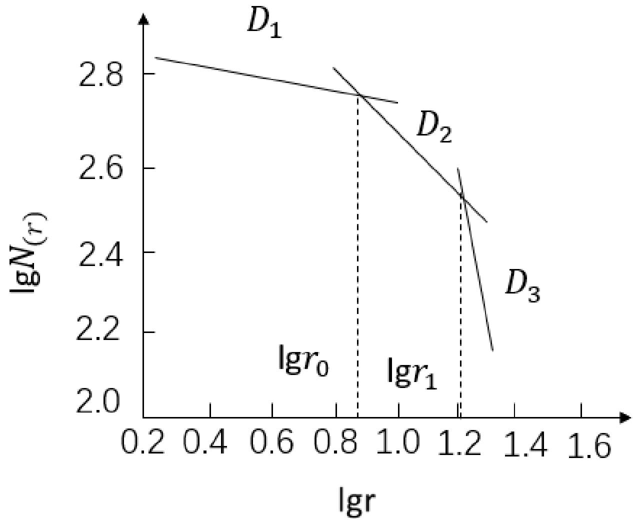

Figure 5: Fractal theory output result diagram.

4. Advantages and Disadvantages

Through the observation of the specific steps of the histogram solution, it can be seen that the advantage is that the calculation principle is simple and the operation is convenient. It is only about the drawing of the histogram, and the background value and the lower limit of the anomaly are read directly through the histogram and the bell curve[3], but its disadvantage is also very obvious. This method has specific requirements for data characteristics and must meet the normal distribution or logarithmic normal distribution of elements in geological bodies. Otherwise, the histogram was drawn and the bell curve being drawn according to the histogram will not show a normal distribution. In statistics, skewness and kurtosis are generally used to represent the degree of data deviating from the normal distribution, that is, the degree of dispersion. If the data does not meet the normal distribution, this histogram drawing can not accurately read the abnormal lower limit value, and the histogram solution is not applicable.

As one of the most commonly used methods to calculate the lower limit of anomaly, the traditional iterative method has the advantages of simple operation and classic. At the same time, it is actually an improved version of the histogram solution, marking the progress of geochemical data processing methods. Although it still requires the original variable data or the logarithm to conform to the normal distribution, the data that does not meet the normal distribution will be iteratively eliminated from the extreme outliers, to achieve the data conforming to the normal distribution characteristics. This way, the lower limit of the anomaly will not be affected by the data itself as the histogram solution, resulting in great deviation, but also giving the data a great acceptance space. Iterative processing is an advantage of the traditional iterative method and a disadvantage that cannot be ignored. It can be imagined that in the process of eliminating useful data points, it is likely to eliminate useful data points, reduce the number of original data samples, and reduce the accuracy of anomalies. The abnormal lower limit obtained by this method deviates from the real data results, and the results are not accurate. The range used to delineate anomalies will also be small and scattered[5].

From the histogram solution to the traditional iterative method, we can indeed see the progress of the method, but they have not got rid of the data feature premise that the original data is normally distributed or lognormally distributed. Therefore, the EDA technology, namely, the box-and-whisker diagram method, is introduced. In the process of using the box-and-whisker diagram method to calculate the lower limit of the anomaly of the element, there is almost no requirement for the data, the basic data set is not destroyed, and the data is not missing. The integrity and authenticity of the retained data can more truly and effectively reflect the distribution characteristics of the actual elements. And it can avoid the tedious process of using iteration to eliminate outliers and possible systematic errors in the traditional iterative method. The data set can basically reflect the structural characteristics of the original data, which is more significant for the identification of smaller anomalies[3].

The improvement of the first three methods is only carried out around the integrity of the data and the convenience of data processing. The fractal theory does hit the essence through the phenomenon. The fractal theory is to overcome the randomness of the traditional geochemical determination of the lower limit of the anomaly. The method can effectively improve the recognition accuracy, and the use of the fractal characteristic curve to calculate the background value, and the lower limit of the anomaly can also avoid the impact of eliminating the original data[11]. However, the fractal theory is extremely strict on the data, and the data applicable to the fractal theory must meet the following three conditions:

1) Irregular on the whole

2) The regularity at different scales is the same, that is, the local shape and the overall shape have self-similarity

3) Uncharacteristic scale and scale

Only the data that meets the above three characteristics are suitable for processing with fractal theory. If the measured soil geochemical data does not meet the above characteristics and the forced use of the thinking and methods of fractal theory to process, the data can only lead to the analysis of the abnormal lower limit value. Deviation or even running counter to the correct abnormal value will cause certain difficulties and losses to the next step of mineral exploration and prediction.

5. Conclusion

Determining the lower limit of geochemical anomalies is the most basic problem in soil geochemistry. There are many ways to determine the lower limit of geochemical anomalies, and each has its own advantages and disadvantages. From the previous content, the histogram solution of the traditional iterative method, to the box whisker diagram method, and finally the fractal theory, it can be seen that the method of obtaining the lower limit value of the anomaly can be divided into two categories, one is the drawing method, one is the calculation method, and the shortcomings of these four methods focus on two aspects, one is whether the method has strict requirements for the characteristics of geochemical data, and the other is whether the data still has integrity and authenticity after data processing. In summary, in the four methods described in this paper, the three aspects of applicable conditions, basic principles, and processing steps are discussed. EDA technology is a better method to determine the lower limit of the exception, but the specific situation still needs to be analyzed.

In addition, in addition to the four methods listed in this paper, there are other methods to determine the abnormal lower limit, such as long profile method, probability grid paper method, trend surface analysis method, contrast value filtering method and so on. No matter which method is used, it is necessary to study the distribution structure of data variables, geological background conditions, and regional geochemical characteristics of the study area before determining the specific value method[11]. The accuracy of the anomaly lower limit is directly related to the control of the anomaly range and the implementation of the next prospecting work, which is particularly important. No matter what a method is just a tool, we should learn to make good use of tools rather than being limited by tools.

References

[1] Liu Yingjun, Qiu Detong et al., 1987, Exploration Geochemistry Beijing: Science Press, 12-25.

[2] Xiao Junjun.Soil geochemical anomaly and gold prospecting prediction in Jiufeng mining area, Tonggu County, Jiangxi Province. Nanjing University, 2020.

[3] ZHANG Can. Analysis of soil geochemical characteristics and metallogenic geological conditions in area, Geji County, Tibet. Chengdu University of Technology, 2021.

[4] Tian Fan, Zhu Jieyong, Bai Guangshun, Sun Bin. Soil geochemical anomaly evaluation and prospecting of Shuihekou gold deposit in Funing, Yunnan. Geophysical and geochemical exploration, 2016, 40 (04): 661-666.

[5] Liu Yang. Soil geochemical characteristics and prospecting prediction of Namugang gold-copper deposit in Dibao, Tibet. Chengdu University of Technology, 2017.

[6] He Zukang. Soil geochemical anomaly and prospecting prediction in Nandanna near lead-zinc mine area, Guangxi. Kunming University of Science and Technology, 2016.

[7] Han Peng. Soil and rock geochemical characteristics and prospecting target delineation of Xiongcun ore concentration area in Tibet. Chengdu University of Technology, 2019.

[8] Liu Huanming. Soil geochemical characteristics and metallogenic prediction of the Baburongxi Pb-Zn deposit in Anduo County, Tibet. Chengdu University of Technology, 2017.

[9] Wu Xiang. Application of soil geochemical survey in prospecting in the Shiquanhe power station area of Tibet. Chengdu University of Technology, 2019.

[10] Gong Yushuang. Soil geochemical characteristics and metallogenic prediction of Changtangling tungsten polymetallic deposits in Hainan Province. Central South University, 2012.

[11] Wu Yanbin. Soil geochemical characteristics and prospecting prediction of Luoboling mining area in Zijinshan, Fujian. Guilin University of Technology, 2021.