Geo-anomaly: The Extreme Value in Geology and Its Application in Quantitative Assessment of Mineral Resources

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1. Introduction

Variations of chemical composition, texture and genesis are uninterruptedly taking place during the evolution of geospheres and the process of their interaction. The variations could be recorded in geological objects such as rocks, strata, and tectonics formed in past geological periods. Such variations can be characterized in quantity through quantitative or digitized research into their anomalous features, including statistical, spatial, textural and genetic features etc. According to their digital features, the variations caused by globally geological factors can be differentiated from ones by regionally geological factors, locally geological factors, and micro- geological factors. To sum up, geological background caused by the regional factors can be distinguished from geo-anomaly caused by local factors. A geo-anomaly refers to such a geological body or a combination of geological bodies that their composition, texture-structure and genesis are significantly different from those of their surroundings. Extreme value, anomalous value and " outlier " in geology may be regarded as a geo-anomaly (or geological extreme variation) protruding from relatively smooth background. Therefore, from the viewpoint of statistics we can define the geological objects with the digital features higher or lower than a given threshold as geo-anomalies.

Geo-anomaly is a result of geological process evolving within some special sectors of the crust in particular geological historical times (D. A.Gorelov, 1982), and it is an origin of causing both geological disasters and various ore-forming processes. For instance, earthquakes and volcanoes directly have connection with the activities of deep-large faults. Mineralization is a typical geological anomalous event.

This paper emphatically elucidates relationships between geo-anomaly and the formation and distribution of mineral resources; and puts forward a new quantitative method for delineating and assessing ore targets in the basis of ore-forming geo-anomaly principle.

2. Classification of geo-anomaly related to mineral deposits

Geo-anomaly can be classified into different categories according to different purposes and rules. Different types of geo-anomalies have different connotations. According to their scales (or sizes), geo-anomalies can be classified into four categories: (a) global geo-anomaly; (b) regional geo-anomaly; (c) local geo-anomaly; (c) micro-geo-anomaly (Zhao and Wang et al, 1995; Zhao and Chen, 1998). From the viewpoint of assessment of mineral resources, geo-anomaly can be classified into the following categories (table1).

Table1 Classification of Geo-anomaly

Basis of classification	Type of anomaly	Name of anomaly and example
Structure of anomaly	Single geo-anomaly	Geo-anomaly of strata, structure, magmatic rock, and litho- face etc.
	Comprehensive geo-anomaly	Combination of geo-anomaly

Displaying form	Visible geo-anomaly	Geo-anomaly of fracture, geological bodies and their boundaries
	Hidden geo-anomaly	Geo-anomaly of combination entropy, geological complexity, and ore-forming favorability etc.
Scale	Global geo- anomaly	Geo-anomaly of tectonic plate margin etc.
	Regional geo-anomaly	Geo-anomaly of ore-forming province and ore-forming belt etc.
	Local geo-anomaly	Geo-anomaly of orefield, oredeposit, and orebodies etc.
	Micro- geo-anomaly	Geo-anomaly of mineral and element etc.
Ore-forming factor	Anomaly of ore sources	Strata anomaly, magmatic rock anomaly etc.
	Anomaly of passageway	Ore-accumulating fracture anomaly etc
	Anomaly of ore accumulation	Ore-hosting fracture anomaly etc.
	Anomaly of ore preservation	Trap anomaly etc.
	Medium anomaly	Porosity anomaly, lithoface anomaly etc.
Evolution of anomaly	Static anomaly	Single stage of anomaly and single genetic anomaly etc.
	Dynamic anomaly	Multi-stage superimposition anomaly and multi-genetic anomaly etc.

3. Quantitative Delineation and Assessment of Ore Targets Step by Step in the Basis of Geo-anomaly

A new method we put forward for quantitative delineation and assessment of ore targets in the basis of geo-anomaly, is called the way of progressively approaching ore objects through delineation of "5P" ore-finding areas step by step. The flow chart of the method is shown in Figure2. What is called"5P" ore-finding areas means (a) probable ore-forming area, (b) permissive ore-finding area, (c) preferable ore-finding area, (d) potential mineral resources area; (d) perspective ore body area.

Probable ore-forming area is delineated based on ore-causing geo-anomaly. The geo-anomalies that are associated with mineralization, and can be delineated by some methods with basic ore-forming conditions may be probable ore-forming areas, like various kinds of ore-bearing formations and deep-large ore-bearing fracture zones etc.. Through finding out the ore-forming specialty of various geological factors as well as their combination and analyzing the property that different genetic kinds of ore deposits select different ore-forming conditions, determine the geo-anomalies where the expected types of ore deposits can be found. The ore targets delineated based on the geo-anomaly is regards as permissive ore-finding areas. For example, the contact zone between mid-acidic granites and carbonate rock is a permissive ore-finding area for skarn ore deposits. According to geochemical, geophysical, and remote sensing anomaly related the geo-anomaly and integrating the geo-anomaly with more direct as well as indirect ore-finding information like concentrated mineral anomaly and alteration halo etc., further determine ore-finding areas within the permissive ore-finding area. This ore-finding area delineated using integrated ore-finding information is called preferable ore-finding area. Within the preferable ore-finding area, the ore-finding areas with direct mineralization trace delineated using integrated ore-finding information mapped at 1:50000-1:10000 scale is called potential ore resources areas. Within the potential ore resources area the ore targets with commercial mineralization delineated using ore-finding information mapped at 1:10000-1:2000 scale is called perspective ore body areas.

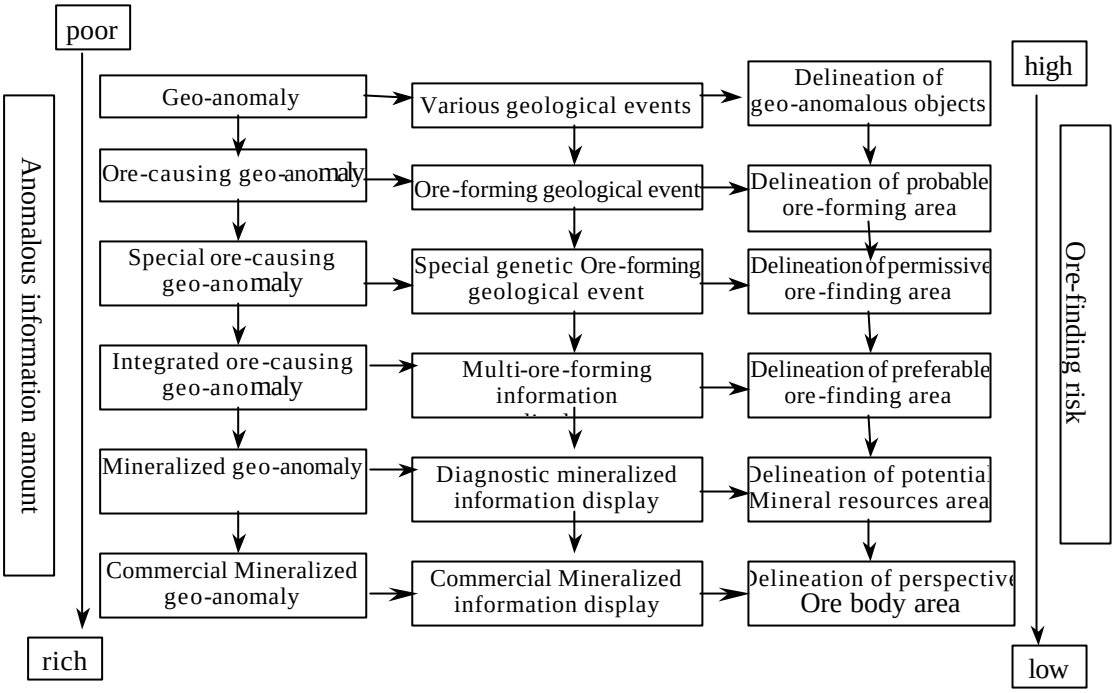

Figure1 The flow chart of the method of progressively approaching ore objects through delineation of "5P" ore-finding areas.

4. Case Study : Quantitative Delineation and Assessment of Perspective Gold Ore Body Area in Western Shangdong Uplifted Terrain, Eastern China

Quantitative delineation and assessment of perspective gold ore body area was implemented within the preferable gold ore-finding area of VIII based on the result of the quantitative delineation and assessment of preferable gold deposits – finding area in western Shangdong uplifted terrain, eastern China(Chen and Zhao, 2001). The data used in the project include data of gold, silver, and copper contents from soil survey mapped at 1:10000 scale, data from magnetic survey with high precision at 1:10000 scale and the latest geological map of gold deposits at the 1:10000 scale. Through a series of data- processing procedures such as extraction, transformation and integration of ore-causing information for the aforementioned data, the digital pattern for quantitative delineation and assessment of perspective gold ore body area is given below:

$$\mathbf{O_f = Ln\,(C_X + 1) + Ln\,(M_I + 1)}(1)$$

Where O_f stands for comprehensive ore-forming favorablity of integrated ore-causing geo-anomaly, C_x stands for the complexity, M_I represents the anomalous intensity of the associated elements. The map of integrated ore-causing geo-anomaly can be compiled by O_f values (Figure 2). Taking the value that isopleth vary from the sparse to dense as the threshold of delineating the perspective gold ore body area on the map of integrated ore-causing geo-anomaly, for example, 7 as the threshold, five perspective gold ore body areas are delineated; among them the ore target V contains a large gold deposit (Chen and Zhao, 1997). Exploration detailed in recent years demonstrates that more gold deposits have been discovered within the above- mentioned five perspective gold ore body areas (Chen and Liu, 2000).

5.Conclusion

The digital features of geo-anomaly like extreme value, anomalous value and outlier etc. in geology may characterize profoundly some processes of greatly geological events, especially geo-anomalous events that had taken place and developed in past geological times, as well as are taking place and developing now. It has great significance not only to ore-forming prognosis, but also to disaster forecast.

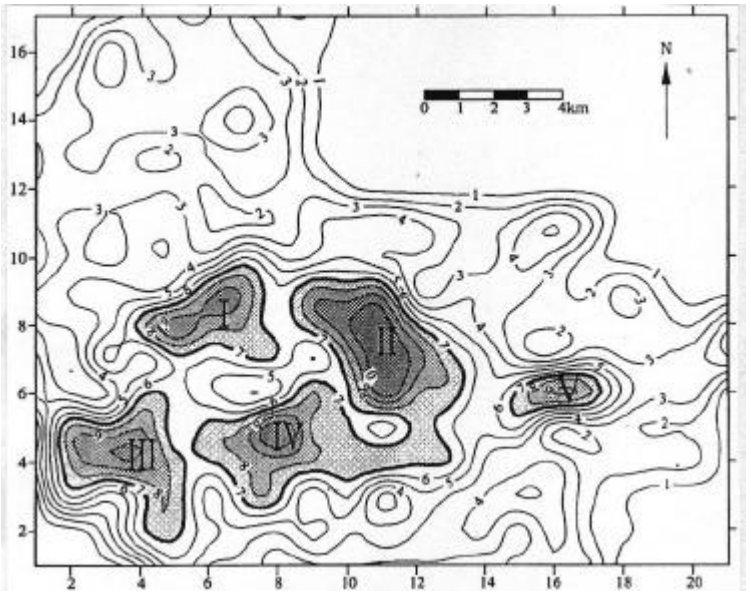

Figure 4 Perspective gold ore body area delineated by geo-anomaly method in the western Shandong uplift terrain. More details can be seen in the text

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Resume: Extreme value, anomalous value and " outlier " in geology may be regarded a geo-anomaly (or geological extreme variation) protruding from relatively smooth background. Therefore, from the viewpoint of statistics we can define the geological objects with the digital geological features higher or lower than a given threshold value as geo-anomalies. This paper emphatically elucidates relationships between geo-anomaly and the formation and distribution of mineral resources; and puts forward a new quantitative method for delineating and assessing ore targets in the basis of ore-forming geo-anomaly principle

Keywords Geo-anomaly outlier "5p" ore-finding area assessment of ore target Eastern China