

Methodological approaches in estimating anomalous geochemical field structure

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Abstract. Mathematical statistic methods were applied to analyze the core samples from vertical expendable wells in Chertovo Koryto gold ore field. The following methods were used to analyse gold in samples: assay tests and atomic absorption method (AAS), while emission spectrum semiquantative method was applied to identify traces. The analysis of geochemical association distribution in one central profile demonstrated that bulk metasomatic aureoles are characteristic of concentric zonal structure. The distribution of geochemical associations is correlated to the hydrothermal stages of mineral formation identified in this deposit. It was proved that the processed geochemical data by factor and cluster analyses provided additional information on the anomalous geochemical field structure in gold-bearing black-shale strata. Such methods are effective tools in interpreting specific features of geochemical field structures in analogous potential ore-bearing areas.

Introduction

Limited reserves of cropping-out deposits significantly impedes the exploration of new ore bodies. Nowadays, the existing processing methods for geochemical information [1-4] for grading geochemical anomalies and interpretation of anomalous geochemical field structure (AGFS) are being updated. These factors enhance for potential undiscovered ore bodies during the geological-exploration stage. It is obvious that an accurate interpretation of anomalous geochemical field structure in early geological survey stages is labor-saving and material resource efficient, and is time-consuming in identifying of ore bodies.

Prognostic prospecting models of mineral deposits plotted in accordance with the analysis and generalization of geological, structural, geochemical, geophysical and other data provide a basis for ore mineralization. Such a profound analysis enables to compare these models to potentially existing ore-bearing areas, ore occurrences and ore zones.

One forecasting element involves the mathematical modeling of ore bodies based on the results of lithogeochemical survey in secondary and primary dispersion aureoles. The method development in identifying the ore mineralization zone erosion and its prospectivity assessment was and is still being promoted (L Ovchinnikov and S Grigoryan [5]). The attempts to evaluate the integral configuration of an ore deposit are not necessarily successful, due to the influence of various natural processes (denudation, weathering, etc.). More critical becomes that obtained information on conventional targets, such as structural accumulations, mineralized zones, stockworks and different morphological bodies, which were investigated within total thickness, along strike and down-dip.



This research aim is to develop those methodological approaches in interpreting anomalous geochemical field structure of Chertovo Koryto gold -ore deposit that would identify additional exploration criteria for gold-ore targets in black-shale strata. Two principal approaches were applied in the spatial mapping of anomalous geochemical field structure: the first is based on the identification of chemical element associations and their spatial distribution analysis, while the second - the identification of spatial domain according geochemical attributes.

Regional Setting

In previous papers [6] data on the geological position and deposit structure have been presented and described. However, in this present article the author gives only a summary of the target under discussion.

The deposit is situated in north Irkutsk Oblast, in northern Patom highland (Fig. 1), which is a typical example of mesothermal gold mineralization in black-shales.

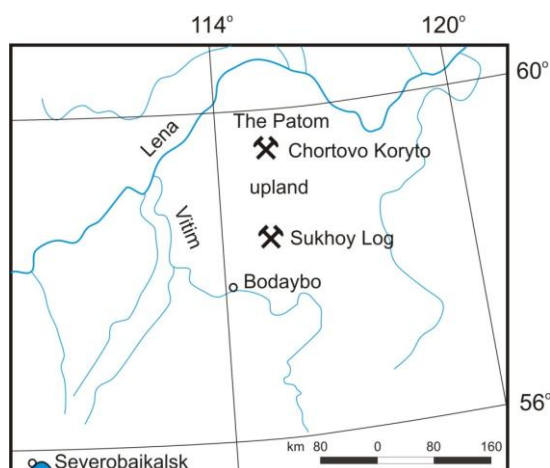


Figure 1. Map of Chertovo Koryto deposit

Ores hosted in Early Proterozoic formation of Mikhailovsk suite carbonaceous terrigenous shales formed a brachysyncline fold with a low angle (from 10 to 20°) of layers, i. e. southward dip to the north changing westward and further to north-NW in the south of the deposit. Brachyfold is dissected by a north -NW-trending tectonic wedge, associated to the Amandrask deep-seated fault. The suite itself is comprised of metamorphized to epidote-amphibolite facies of sandstones, aleurolites, argillites being subjected to hydrothermal metasomatism effect of propylite-beresite profile. Ore-hosting metasomatites include numerous sulfide-quartz veins and sulfide impregnated pyrite, pyrrhotine, arsenopyrite and other minerals. The ore deposit contour, tracked along the fault up to 1800m., was identified by continuous sampling data. The maximum deposit thickness near the fault is up to 140 meters and gently dipping westward and gradually pinching-out. The contour width of commercial mineralization is about 500 meters.

Research Methods

Exploration drilling involved not only vertical core hole at 50x50m. grid, but also the estimation of C_1+C_2 reserves in Chertovo Koryto deposit. This research is based on the results of drill-hole core sampling: sectional-coring to determine gold content and sectional chip sampling to determine traces of gold mineralization and their behavior within the ore zone. The average length of sectional core samples was one meter, while sectional chip samples vary from 1 to 9 meters, although in average- 3

meters. The first estimation stage of anomalous geochemical field structure (AGFS) included one of the central exploration profiles (BL 15).

Gold samples were analyzed by the assaying method in the laboratories of Lensk Gold Mining Company-subsidaries: OOO Tonoda and OJSC Pervenets. In this case, the test sensitivity was 0.1 g/t. The gold content was also determined by the atomic absorption method, where the test sensitivity was 0.01 g/t., and this method was used in controlling assaying results. The content of 28 elements was analyzed by the emission spectrum semiquantative analysis in the laboratory of Bodaibin geological survey expedition. The analysis showed results in determining Ag, As, Pb, Co, Cu, Ni and Zn. Other elements were neither detected, nor their content was less than the background concentrations.

The analysis of more than 4000 sectional chip sampling was applied to calculate the statistic factors of gold mineralized traces. The estimation of element background concentrations is conducted by the standard procedure, including the analysis of 170 samples from two drill holes located at the deposit periphery.

To plot the geochemical cross-section zoning statistic calculations of grade correlation, mineralization energy, dispersion and geochemical spectrum variation were applied, as well as cluster and factor analyses.

The differences in the assaying methods for gold and gold traces excluded determining their correlation by the mathematical statistic method. The correlation of the gold content in rocks and statistic index of trace distributions is performed in diagrams.

Results and Discussion

The analysis of AGFS is based on the obtained sampling data of primary litho-geochemical halo dispersion from exploration core wells in one of the central exploration profiles (BL 15). As mentioned above, the difference in analysis methods, chemical element concentration level and assaying methods for gold and gold traces precludes their correlation by the mathematical statistic method. Their correlation could be plotted only by applying content distribution diagrams.

The distribution of ore-genetic elements within the deposit does not correspond with the normal and logarithmically normal laws. The gold content in an ore body varies from milligrams to hundreds of grams per ton.

Depending on the cut-off grade within the ore deposit, the amount of reserves significantly varies. The cut-off grade contouring the ore deposit is 0.5 g/t (Fig. 2). In the central zone there is a maximum ore body thickness with rather enriched remnant ores. At the deposit periphery there are single narrow pinching-out lens of ore with rather low metal content.

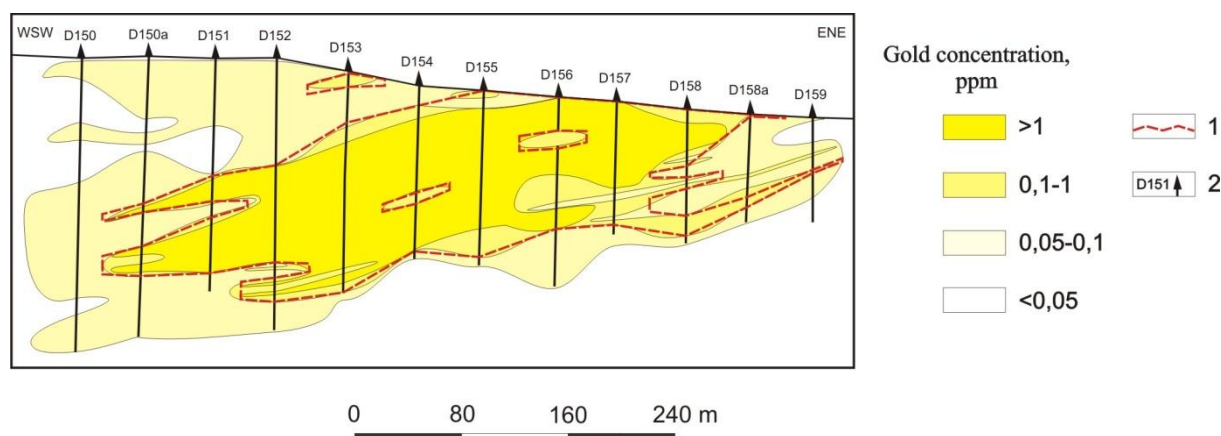


Figure 2. Diagram of gold distribution in the cross-section (BL 15) of the deposit ore-hosting metasomatic aureoles

1) ore deposit contour and lens-satellite; 2) exploration wells and their corresponding numbers

The following gold mineralization traces As, Ag and Pb produce the most contrasting anomalies in bulk metasomatic aureoles. The high-contrasting aureole As is incomparably to that of background values and spatially coincides with the ore deposit contour. Anomalous Ag concentrations partially coincide with the high-contrasting gold aureoles. In this case, contrasting Ag aureoles even exceed the background values hundreds of times and correlate well with remnant ores. The aureole Pb is partially superimposing the ore body contour itself, whereas its maximum value is 300 times higher than the background values.

Investigating the interrelations between ore genetic elements by the grade correlation method, the results indicated that this interrelation is significantly positive for all the elements. The following interrelation of Ni with Co, Pb, Cu, Zn and Pb-Cu-Zn triads showed the highest values. The contrasting Ag and As anomalies within the deposit have a rather low correlation relationship value (0.21). However, the grade correlation method did not distinctly separate the elements into different groups, which most probably, is connected with the low interrelation threshold value for the enormous processed samples.

To interpret the deposit anomalous geochemical field structure the following indexes characterizing the intensity of hydrothermal-metasomatic mineralization processes were applied: mineralization energy [7], dispersion and variation of the geochemical spectrum [8].

Mineralization energy background values vary from - 1 to 2 units and are rarely detected throughout the ore deposit. The index value reaches 10^4 units and more. So, the mineralization energy depends on the dominant element - As. In the case of excluding this dominant from the calculation equation, the index values incomparably decrease leading to further reduction of the ore-hosting substance volume, which is characterized by the maximum mineralization energy.

The method to estimate the substance differentiation degree according to the geochemical spectrum of one sample was proposed by S Vyborov and I Bystrov. The index calculations of geochemical (GSD) spectrum dispersion and geochemical (GSV) spectrum variations is based on standard dispersion equations and normalized chemical element content variations. Background GSD values do not exceed 0, fraction unit within the surrounding extensive metasomatic aureoles. However, the index values substantially increase reaching the maximum for certain samples up to 10^5 units and even more within the ore zone. The element As significantly influences the anomalous GSD values which is governed by the interrelation in the distribution of their aureoles.

GSV background values at the periphery of extensive metasomatic aureoles do not exceed 40%. These value indexes vary from n to 250% within the ore deposit. In spite of the fact that Despite this variation is the derived function of dispersion, whereas both indexes embrace different genetic information. Anomalous GSV values do not always coincide with the GSD anomalies. Chertovo Koryto deposit is an evident example of this fact. High-contrasting aureole indexes coincide in mineralized zone cross-section, which is obviously conditioned by the sharp difference in element concentrations within the ore body and along its margin. It should be stated that the mineralized deposit zone is characterized by a random content distribution of ore- genetic elements with $GSV > 140\%$. Excluding the GSD and GSV indexes of As from the calculation equation incomparably results in their value decline and significant dimension reduction of high-contrasting aureoles.

Thus, the intensive mineralization indexes are excellent indicators in plotting the volume of metasomatic aureoles within which is located the mineralized zone. However, without additional operations (such as, chemical element breakdown into associations according to a specific principle), these indexes preclude the possible interpretation of the anomalous geochemical field structure of the deposit.

The cluster analysis of mineralized zone dimension identified distinguish 5 sample clusters. There is no distinct interrelation between ore-genetic elements in the first and the fourth clusters. The second cluster unites Cu, Zn, Ag and Pb that characterize a galena-chalcopyrite-sphalerite association. The third sample cluster is characteristic of a considerable Co and Ni content that are involved in the generation of pyrite-pyrrhotine association. In the last (fifth) cluster the dominant is As that is an

active element in the arsenopyrite-pyrite-pyrrhotine association. Identified chemical element associations closely match the minerogenesis stage, defined during structural, petro- geochemical investigations in the Chertovo Koryto deposit [6]. Nevertheless, the limited number of chemical elements that are includes in the calculations affected the distribution of clusters within the deposit dimension. A distinct configuration of the zonal geochemical aureole structure was not identified on the basis of the above-mentioned cluster analysis.

The factor analysis was also applied in defining the chemical element associations to interpret the anomalous geochemical field structure. The following three factors incorporate 64% of the total dispersion. The first factor - Pb, Zn and Ag incorporate 30% of total dispersion. The second most significant factor, being 20% of total dispersion, is characterized by Co, Cu and Ni. The third factor includes only one element - As. This proves the fact of the introduction into hydrothermal solutions of elements and their precipitation as native minerals and element- impurities. Identified chemical element associations are also an integral part in the minerogenesis stage [6]. Thus, classifying the close ore-genetic elements into three geochemical associations indicate different conditions and time formation of ore mineralization within large metasomatic aureoles.

Based on processed geochemical data by mathematical statistics methods, a diagram of the deposit geochemical zoning cross-section BL 15 was plotted (Fig. 3).

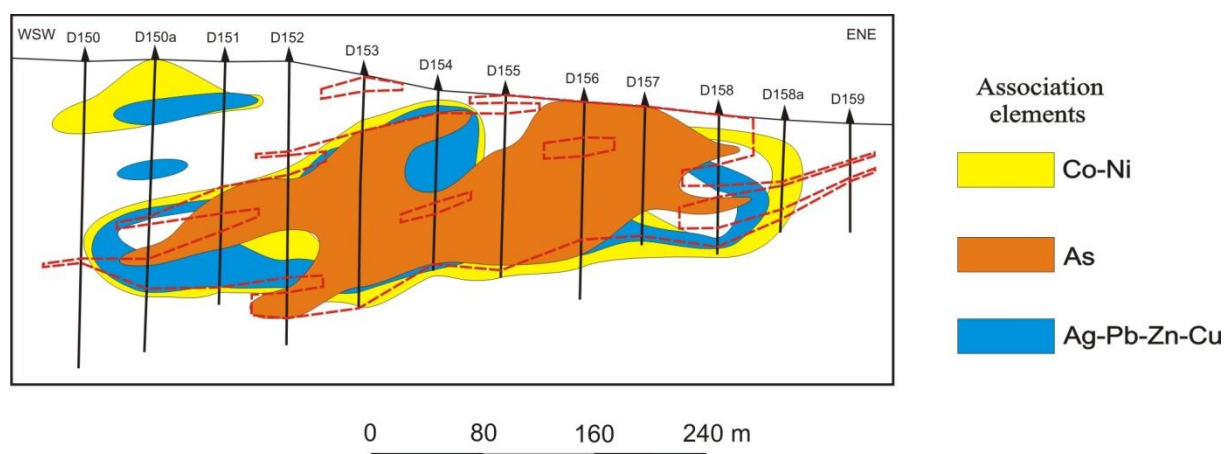


Figure 3. Geochemical zoning of Chertovo Koryto gold deposit in cross- section BL 15 (Ref. to legend in figure 2.)

The high-contrasting Co and Ni aureole correlates to the ore deposit section plane, partially with Ag-Pb-Zn-Cu associations and embraces a rather peripheral location in the mineralized zone. Both these metals have been educed from early hydrothermal fluids accumulated after pyrite-pyrrhotine mineralization. The second group includes only one element - As, found in arsenopyrite , which, in its turn, was a component of late arsenopyrite-pyrite-pyrrhotine association. Due to most extensive spatial superposition of high-contrasting As aureole and mineralized zone, there is limited isolation in the distribution of its aureoles and gold aureoles. The high-contrasting aureoles of the late Ag-Pb-Zn-Cu associations also coincide not only with the ore deposit and its periphery, but also is located more closely to the inner zone, relative to the early Co-Ni geochemical association.

Summary and Conclusions

Methods in interpreting the geochemical field of different targets should be performed by applying all available tools. In this case, the complex analysis of investigated targets are based on those proven methods and approaches that could be used in prospecting-exploration activities. The identification factor for ore bodies is a geochemical field structure. As it has been proven gold anomalies identified

in the geochemical studies could not be a precise indicator for ore bodies. An additional criterion could be the zonal structure of the geochemical field itself.

In reality, the application of conventional and non-conventional methods in analyzing the geochemical field can significantly differ depending on the geologic survey stage, goals and objectives of conducted studies. For some cases, it is sufficient to identify the distribution law, background and minimal anomalous content of ore-forming elements and plot their distribution diagrams. However, in most cases to identify ore-genetic element associations and determine combined statistic geochemical zoning indexes, more complex analysis methods and further graphical plotting is a required factor.

Defined geochemical zoning with a rather wide element spectrum of ore associations should be applied for areal lithogeochemical survey in potential deposits and for the data interpretation from mining and single wells.

Grade correlation of chemical element associations is not identified due to the distribution features of ore-genetic elements within the Chertovo Koryto deposit, for example. The intensive mineralization indexes without preliminary identification of element clusters excludes the possibility of obtaining further knowledge on the nature and structure of deposit geochemical field. The geochemical zoning sequence of the deposit metasomatic aureoles was determined by factor and cluster analyses. Three ore-genetic element associations (from the earliest to the latest): Co-Ni, As and Ag-Pb-Zn-Cu were identified. The plotted diagram of geochemical zoning in hydrothermal ore-hosting metasomatic aureoles demonstrates its concentric zoning structure. The diagram shows the correlation of the results obtained in gold fields from other regions (S Grigorov (2007) and V Voroshilov (2009))

Thus, some of the discussed methods in geochemical data processing provide additional information about the anomalous geochemical field structure in gold-bearing black-shale layers. These methods are effective tools in interpreting specific geochemical field structure within ore-bearing areas under similar conditions. The localization of potential areas and the forecasting of ore deposits could be based on the results of areal lithogeochemical mapping and obtained data from mining and single wells. Information on the specific features of the anomalous geochemical field structure and location of ore bodies in such geochemical fields in correlation with other data is significant for accurate gold-ore deposit forecasting.

Acknowledgements

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