

Volumetric geochemical model of Chortovo Koryto gold-ore deposit (Patom range)

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Abstract. Core sampling analysis from vertical exploration wells was conducted by the statistical methods. Assayable gold samples were analyzed by the atomic absorption method, while trace elements- emission-spectral semi-quantitative method. It was determined that the grade distribution of gold and trace elements within the deposit itself does not match one of the partition laws. Applied complex mode of processing of geochemical data provided the interpretation of anomaly geochemical field structure. The analysis of geochemical association distribution showed that their structure is concentric-zonal within bulk-metasomatic halo. The geochemical association distribution, in general, is related to hydrothermal minerogenesis stages in a deposit. Based on the mining-geological Datamine studio 3 program 3-D geochemical deposit model was plotted.

1. Introduction

An important investigation stage in forecasting and prospecting ore deposits includes exploration and modeling by applying sophisticated mining-geological programs. Not only are familiar methods updated, but also new advanced ones are introduced in processing geochemical data.

Future ore forecasting is based on previously developed prognostic exploration models: geological-geochemical, geological-geophysical, geological-structural and others. By applying developed models comparative analysis of these models to perspective areas and bodies of industrial mineralization can be used.

Previous geochemical studies within Chortovo Koryto ore field involved not only the geological history remodeling of chemical elements in ore-hosting metasomatic haloes, but also the identification of bulk-geochemical halo structure. It was determined that the ore-hosting geochemical gold-silver-arsenic deposit halo has a flat cubic configuration oriented along the ore-controlling and solution-feeding fault and dipping westward.

The research aim was to plot a 3D geochemical deposit model to develop forecasting-exploration criteria for gold mineralization. This model was plotted on the basis of obtained interpretation results of anomaly geochemical field structure (AGFS) [1].

2. Regional setting

The geological characteristics of the deposit are particularized in [3].

The deposit is in the north of Irkutsk oblast in Patom range (figure 1) and is confined to the ore-grade gold of black-shale formation. The deposit is located in the brachyfold syncline, composed of early Proterozoic carbonaceous rocks of Mikhailovskoe suite (figure2). The dip angle of formation rocks is from 0 to 10-20°. There are high-order step folds within the fold itself. The formation is



composed of rocks metamorphosed to epidot-amphibolitic facies: poorly sorted arkose, fine-grained sandstones, siltstones and mudstones. Carbon content in rocks of mineralized zones varies from hundred to 2 % volume. Metasomatic rock alterations are superimposed by propylitization and brecciation forming gold-sulphide-carbonate-quartz veins and veinlets.

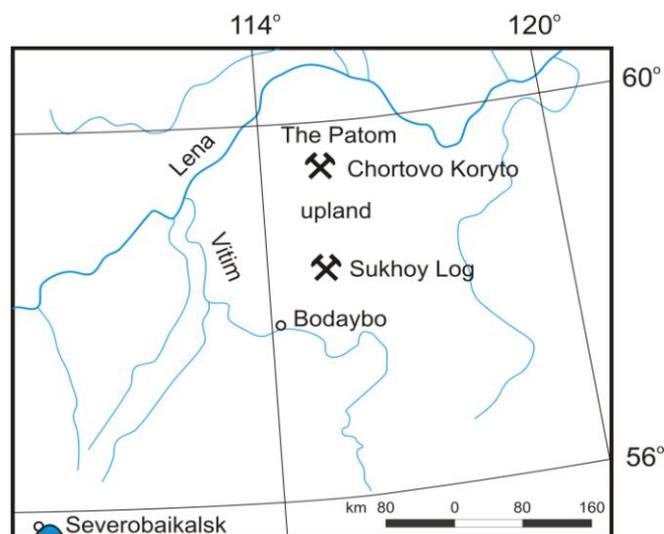


Figure 1. Map of Chortovo Kuryto deposit.

Ore deposit, with contoured cut-off grade of 0.5 gr/tonne and westward dipping at an angle of 0 – 20°, extends 1800m in length and about 500m in width. Its maximum thickness of 140m is in the central part of the ore body. Gold concentration varies from $n \times 0.01$ to $n \times 100$ gr/tonne. The ore deposit size and its reserves can change depending on cut-off grades.

3. Research methodology

Chortovo Koryto was investigated by applying core sampling boring. Based on the exploration results the relevant reserve categories were estimated. Assaying included: section-type core- to determine gold grade and section-type chip to determine trace elements in gold –ore grade and their behavior within the ore zone. Core sample length is in average 1m., section-type chip sample- 3m. 3D plotted geochemical model is based on detailed study of 6 exploration well profiles.

Gold samples were analyzed by assaying and atomic-absorbent methods in laboratory environment in Lensk gold-ore company. Method sensitivity is 0.1 gr /tonne and 0.01 gr/tonne, respectively.

The trace-element content in mineralization was analyzed by the emission-spectral semi-quantitative method in the laboratory of Bodaibinsk geo-exploration expedition. The following elements were determined Ag, As, Pb, Co, Cu, Ni, Zn. While the remaining elements were found in limited amount and could not be used in statistic calculations.

Integrated indicator calculations were based on analytical data obtained from section-type chip samples ($n > 4000$). Background is determined by the analysis results of 170 samples, retrieved from those wells located outside the ore-metasomatic zones.

To plot 3D geochemical model and interpret anomaly geochemical field structure (AGFS) calculations of grade correlation, mineralization energy, dispersion and geochemical spectrum variations were conducted, as well as cluster and factor analyses.

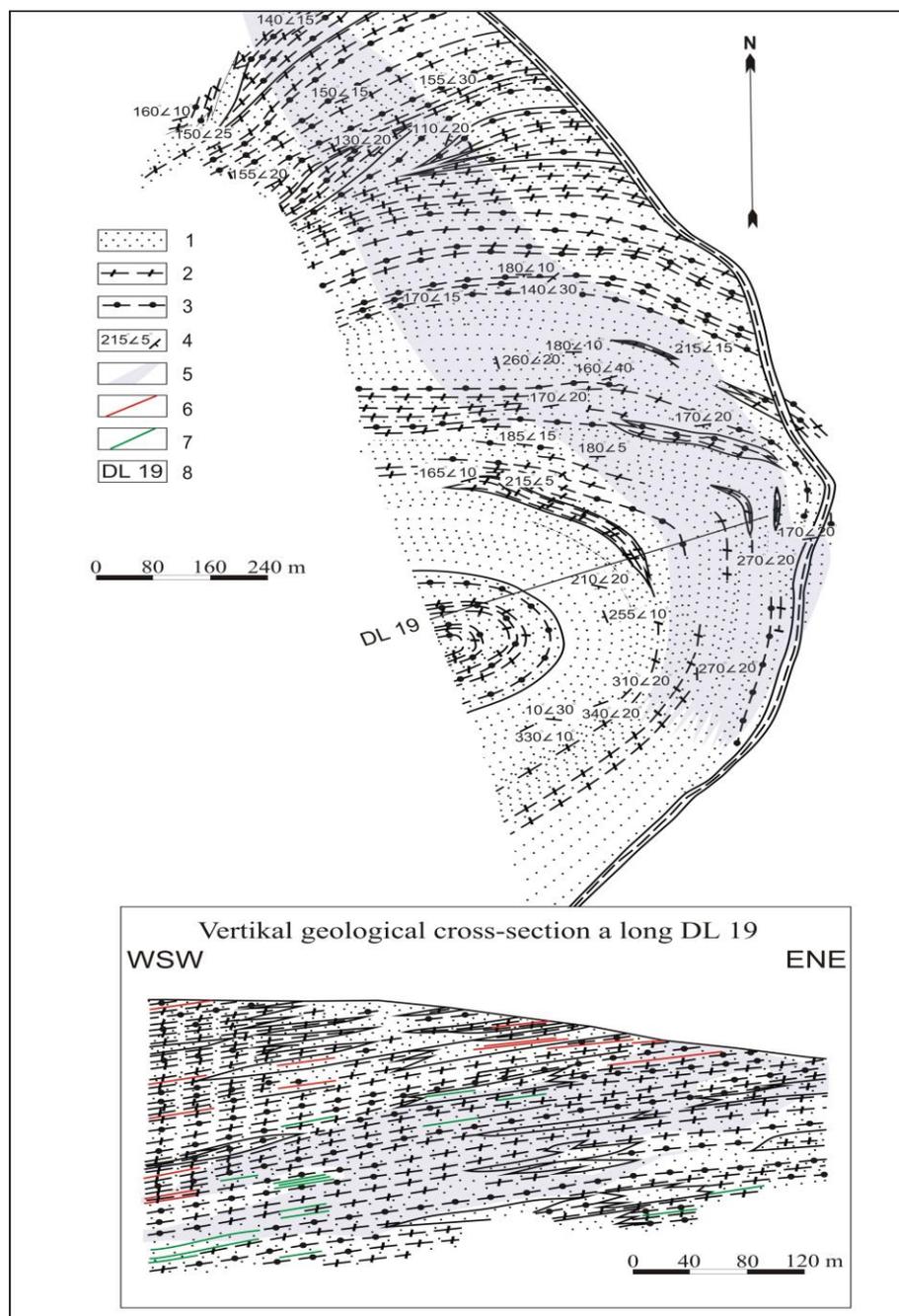


Figure 2. Geological map of Chortovo Koryto deposit structure: 1) generally, poorly- sorted grey to dark grey, from fine-grained to medium-grained, indistinct layered to coarsely stratified feldspar-quartz sandstones, silty sandstones, carbon and carbon free; 2) generally, poorly sorted dark- grey anisometric, from fine-grained to coarse-grained finely-stratified to coarse-stratified feldspar-quartz siltstones, sandstone siltstones, carbon and carbon free; 3) sericitic mudstones with insignificant content (up to 25 volume %) and / or lack of fragmental fraction of sand and / or silt size, carbon and carbon free; 4) azimuth and layer angle of penetration; 5) sulphide mineralization zone; 6) zones of thin cleavage and rock breaking; 7) back zones (chlorite, albite and beresite) of ore-hosting metasomatic halo [3].

4. Spatial distribution of gold and trace elements

Grade distribution of gold and trace elements within the deposit itself does not match one of the partition laws.

High-contrast gold halo is presented by a large-volume body extending N- S. The internal halo structure is characterized by pipe-like, acicular and tabular bodies. Within the ore zone the element concentration incomparably exceeds the clarke (percentage abundance) level. In the south direction there is a significantly decrease of halo areas and ore zones.

Within the deposit sub-clarke silver concentrations are predominate. Silver halo is characterized by a nest-like structure. Most of the halo volume includes moderate-contrast concentrations. Moderate and high-contrast haloes are pipe-like and acicular bodies.

Field allowable of the high-contrast arsenic halo shows an oval -shaped elongated body which covers practically all the ore zone. The inner halo includes pipe-like, acicular and flame-shaped bodies. Most of the ore zone embraces haloes with elements incomparably exceeding high clarke concentration. Increased arsenic concentration is due to its mineral -carrier – arsenic pyrite and insignificant amount of other sulphides.

The basic deposit bulk is sub-clarke lead concentration. Moderate contrast haloes have nest-like distribution which are pipe-like and acicular. Increased lead concentration is due to basic mineral-carrier- galenite found in the ore zone.

The highest volume in ore-hosting metasomatic halo embraces sub-clarke zinc concentrations. Poor contrast haloes are oval-shaped. Ther halo structure is characterized by oval-shaped, pipe-like and isometric nests, rarely acicular shaped. Most likely, increased element content is associated with sphalerite.

In deposit volume the contrast cobalt halo is oval-shaped. The inner halo structure is characterized by pipe-like, tabular and isometric bodies. In most of the ore zone the element concentration is significantly higher than the clarke level itself. Such contrast haloes are conditioned by cobalt arsenic and other sulphide minerals within the large-volume metasomatic haloes.

Within the metasomatic halo the presence of contrast nickel halo is conditioned by the presence of its mineral carrier- pyrrhotine, as well as cobalt arsenic and some other minerals, containing it as an impurity. Haloes with different intensity are located within the ore zone contour. In cases of the coupling of the most contrastive haloes with high-contrast gold haloes is rather rare.

Moderate-contrast copper concentrations occupy most of the ore-hosting metasomatic halo. The inner halo structure includes a pipe-like, isometric and acicular body system.

Thus, the most contrast anomalies in large-volume metasomatic halo are produced by Au, As, Ag and Pb.

5. Discussion

The interpretation of anomaly geochemical field structure (AGFS) was performed by applying the mathematical statistics method.

According to the grade correlation method it was defined that relevant positive correlation is distinctive for all oregenetic elements. However, in this case, it was practically impossible to classify these elements into separate groups.

Intensive hydrothermal-metasomatic ore formation is described by the integrated indicators of ore-formation energy [4] and dispersion and the variations of geochemical spectrum [2].

Ore formation energy is calculated on the basis of the total product of element concentration clarkes by their logarithms. Background value changes from –1 to 2 units within the mineralization zone are rarely observed. Indicator values could be up to 10^4 units and even more. Ore formation energy values demonstrate a direct dependence from As content value.

The method to estimate the substance separation degree according to geochemical spectrum of all specific chemical elements in a spot sample was firstly used by I Biborov and S Bistrov [2]. Dispersion spectrum indicators and geochemical spectrum variations (DSI and CSV respectively) are calculated on the basis of the standard formula of variance and variations of use element concentrations.

In the volume mineralized zone the DSI value increases significantly. Maximum concentration indicators are 10^5 units or more. Anomaly arsenic content of insignificant amount affects the integrated indicator value. It is this fact that explains the spatial overlapping of the haloes.

The DSI and CSV values throughout the deposit are distributed differently. Mineralization zone contours are distinguished by the high-contrast CSV halo, which, in its turn, is conditioned by the significant difference in element concentrations in the mineralized zone itself and its borders. It has been determined that the irregular distribution pattern of ore-genetic element content is plotted as indicator values $CSV > 140\%$.

It is obvious that these indicators characterizing intensive ore formation processes could determine the zone borderlines of hydrothermal-metasomatic alterations, but, in this case, impede the CSV interpretation of ore features.

Based on the specific features of the geochemical spectrum and cluster analysis 5 sample groups were identified.

In the first and fourth sample clusters there were no elements that could have significantly influenced their geochemical spectrum. The second cluster is characterized by Cu, Zn, Ag, and Pb associated with the galenie-chalcopyrite-sphalerite mineral association. The third sample cluster shows high Co and Ni content found as a result of pyrite-pyrrhotite association accumulation. The last cluster (fifth) is characterized by the dominating As which actively interacts in the formation of arsenic pyrite-pyrite-prryholite association. Identified geochemical associations correlate to mineral formation stages determined on their basis of previous geological surveys [3]. The limited amount of analyzed elements made it impossible to define a concise concept of the zonal structure of geochemical associations.

To determine the ore-genetic element associations with identical behavior during the geochemical process, the factor analysis was applied. Three associations were distinguished, i.e. 64% of total dispersion.

The first factor, embracing 30% of total dispersion, is characterized by significant Pb, Zn and Ag load. The second factor is maximal influenced by Co, Cu and Ni, where the total dispersion is 20%. The third factor is characterized by the significant load of only one element- As. Thus, this fact indicates the ore-genetic element input process during hydrothermal metasomatic ore formation. The identified geochemical associations correlate with the mineral formation stages [3]. It is obvious that the formation of all three described associations indicate the different conditions and time period in the formation of ore solutions within the mineralized zone.

The processed geochemical data by statistics methods allowed plotting a 3D geochemical model of the ore-gold deposit in black shale formation made it possible to (Figure 3).

Later Ag-Pb-Zn-Cu associations are also spatially overlapping the borderlines of mineralized zones, however, Co-Ni geochemical association is found within these zones.

Based on the results of previous investigations it was determined that the basic metal mass accumulates during the galenite- chalcopyrite-sphalerite stage of mineral formation.

Mineralized zone is located in the centre of the bulk metasomatic halo, spatially matching with the high-contrast Co-Ni, Ag-Pb-Zn-Cu and As geochemical associations. At the same time, the mineralized zone contours are plotted on Co-Ni and Ag-Pb-Zn-Cu geochemical associations.

Contrast association halo Co-Ni corresponds spatially with the contours of ore bodies, fragmentarily with Ag-Pb-Zn-Cu associations, occupying the farthest peripheral areas of the mineralized zone. Co and Ni supply of early hydrothermal solutions and deposited with pyrite-prryholite mineralization. The second group is characterized by the presence of only one element –

As. Its accumulation, basically as arsenopyrite, occurs during the arsenopyrite-pyrite-prryholite mineralization.

It has been determined that the concentric-zonal structure of geochemical associations within the bulk metasomatic halo (from central to periphery) is the following: As → Ag-Pb-Zn-Cu → Co-Ni. Identified behavior in the spatial distribution of geochemical associations could be applied not only insurface (areal lithochemivcal survey) but also depth (wells, mining) investigations of perspective areas.

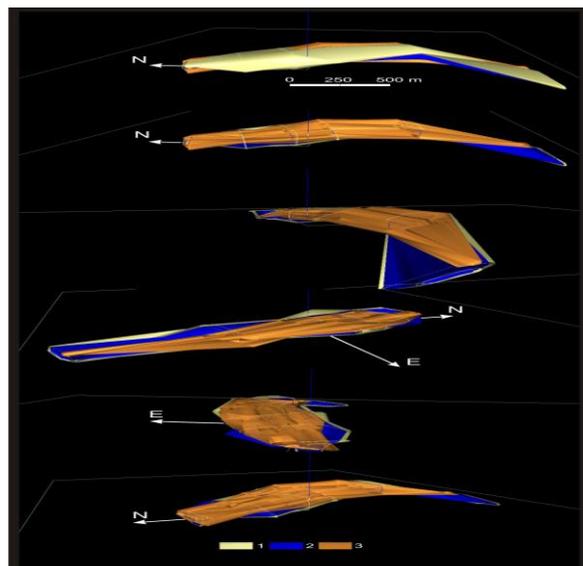


Figure 3. 3D geochemical model of Chortovo Koryto gold-ore deposit 1 – Co-Ni association; 2 – Ag-Pb-Zn-Cu association; 3 – As association.

6. Summary and conclusions

Applied set of processing methods for geochemical data made it possible to interpret the anomaly geochemical field structure (AGFS) and to determine its concentric-zonal structure. The most important results in processing geochemical data from Chortovo Koryto deposit was obtained through such methods as nonparametric statistics, i.e. cluster and factor analysis.

Based on the processed geochemical data obtained by the mathematical statistical method the AGFS in Chortovo Koryto deposit was interpreted and a 3D geochemical model was plotted. This localized the border contours of gold-ore mineralization within investigated mineral resources.

Designed 3D geochemical gold-ore deposit model would stipulate the potential targets in licensed areas.

References

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