UDC 553.311

QUANTATIVE ESTIMATION OF ABNORMAL GEOCHEMICAL FIELD PARAMETERS AND FORECAST OF GOLD MINERALIZATION

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The construction of abnormal geochemical fields accompanying gold mineralization is investigated; criteria of its quantitative estimation are developed. Orderliness estimation methods of geochemical field abnormal structures and intensity of hydrothermal process are offered. Dependence between quantitative parameters of these structures and scales of gold mineralization is established. Estimation possibility of deposits and ore fields erosive section by parameter values of abnormal geochemical fields is shown.

The quantitative estimation of radical mineralization on the basis of geochemical data traditionally relies on metal resources direct calculation on the basis of its concentration in aureoles and dispersion streams [1–3]. Unfortunately, this method does not always give the desired result concerning gold. Exclusive non-uniformity of gold distribution in primary aureoles, complexity of its behavior at formation of secondary aureoles and streams of dispersion lead to ambiguity of mineralization scale estimation under content of gold in aureoles. Additional uncertainty is also brought by problems of analytical character. At the same time, hydrothermal deposits of gold are always accompanied by the wide range of the elements-satellites forming complex abnormal structures of geochemical fields (ASGF) of various rank. These structures are well enough kept in secondary geochemical accumulations [4]. Anyway, in a secondary geochemical field deposit and large ore body ASGF is confidently identified and in streams of dispersion – rank structures of ore fields and large deposits. The quantitatively-morphological estimation of these ASGF gives objective enough information on scales of hydrothermal process and can serve as an additional criterion for updating resources of radical gold and ranging of the perspective areas.

Complex character of geochemical fields is widely used in forecast estimation of territories [5], but usually it the case with the general efficiency metal-bearing objects regardless of morphological features of accompanying them ASGF. Quantitative modeling of volumetric figures ASF is also applied for level estimation of mineralization erosive section [6]. Quantitatively-morphological analysis of ASGF for forecasting is performed for golden-ore deposits of Far East by S.V. Sokolov [7]. Parities of the centrifugal and centripetal (in S.V. Sokolov's understanding) element productivity are the basis of forecast which has allowed for localization of the perspective areas as much as possible and specification of their resources.

As a whole, it is possible to state that the question of ASGF quantitative estimation has not been solved yet completely which is caused, first of all, by uncertainty of criteria of their geometrization. The variety of approaches to the solution of this problem defines incomparability of results obtained by various authors and dictates the necessity of development of the general technique depending on standardized parameters. As it was repeatedly emphasized by many authors, abnormal geochemical fields zoning of hydrothermal deposits occurs, first of all, in polar behavior of concentrating and deconcentrating (in relation to golden-ore bodies) elements [8–10]. Their set depending on conditions of mineralization formation cannot be set a priori and is defined by variable deposit clusterization methods for specific gelologo-industrial types. Intensity of addition and subtraction of the revealed element associations in such a way is suggested to geometrize as a sum of their concentration clarks. The minimal-abnormal values of these parameters are calculated by the standard technique [2], therefore, contours of obtained anomalies do not depend on subjective predilections of the exesectionor. As an additional criteria of correct ASGF geometrization of various ranks serves distribution of coefficient values of element relative concentration: anomalies RC Pb:Zn gravitate to supra-ore levels, and RC Co:Ni – to lower-ore-sub-ore.

The next stage is the estimation of orderliness degree of the revealed abnormal structures. As the main attribute of ASGF orderliness we consider presence of zoning focus – areas of space where zoning vectors originate at its centrifugal character or where they converge in case of centripetal zoning. As orderliness is expressed through contrast of distinctions in structure of ASGF focal and intermediate zones it is suggested to use standard criteria for hypothesis check about equality of two unknown averages for its quantitative characteristics. Average concentration clarks of deconcentrating elements in ASGF focal and intermediate zones are compared among themselves. At the normal law the Student criterion is used, at lognormal – the D.A. Rodionova's criterion, at the unknown law of distribution – the rank criteria. For convenience of use numerical value of orderliness coefficient (C_{ord}) is accepted equal to fractile of normal distribution corresponding to calculated significance level of the criterion. As a boundary value (C_{ord})=2 (for confidential probability 0,95) is accepted. Parameter values depend on sample volume; therefore, at the same density of approbation they are proportional to scales of abnormal structures. Theoretically, the range of (C_{ord}) values is not limited, in fact, for middle-ore shears it is within the limits of 30...35, and in process of mineralization pinching out gradually decreases to an insignificant level.

The scale of the revealed mineralization is functionally connected with general intensity of hydrothermal process. The quantitative expression of which is the parameter of ore-formation energy [11]: $E=\Sigma \ln(KK_i)$, where KK_i is concentration clark of the *i-th* element.

Parameter values reflect total balance of substance of each point of approbation; therefore, it is appropriate to calculate them separately for concentrating and deconcentrating elements. For each of these parameters the background and minimal-abnormal values and productivity in ASGF borders are calculated. At estimation of mineralization scale the $E_{conc.}$ and $E_{deconc.}$ productivity is used as the independent parameters reflecting the different parties of one process. It is empirically stated by us that $E_{conc.}$ and $E_{deconc.}$ productivity, differing from each other in 1–2 orders, are directly proportional to resources of gold in ASGF corresponding ranks. In logarithmic scale these dependences are well approximated by direct lines and can be used for scale estimation of the revealed mineralization (Fig. 1). For concentrating elements the averaging straight lines have converging character which reflects a high degree of mineralization concentration in large and huge deposits. Productivity of deconcentrating elements in a much greater degree is defined by the rank (i. e., area) of structures which specifies their borrowings from containing rocks. The dependence of redistribution scales of deconcentrating elements from substratum structure, especially distinctly shown in ASGF rank of ore bodies, indicates the same fact.

Geochemical resources of gold in abnormal fields, being an industrial reflection of industrial mineralization scale, nevertheless, are connected with them by complex dependence. Conditionality of ores depends on concentration degree which, in its turn, is inversely proportional to the ASGF rank, which follows from the postulate on prevalence of the dispersed condition over concentrated for all elements [1]. For the ASGF rank of ore bodies the direct proportional dependence of balance ore coefficient (α) on mineralization scales is stated, in this case parameter values change from 0,2 up to 0,9 [1, 12]. With application to golden-ore deposits of Far East S.V. Sokolov [7] estimated average values for ASGF ranks of ore bodies (0,52), deposits (0,21) and ore fields (0,14). For even larger divisions the value α consistently decrease and in structures of global level make $n\cdot(10^{-4}...10^{-7})$ [1], where n=1,2,...,10. The presented data were taken into consideration by us at estimation of gold resources when there was no opportunity of direct definition of balance ore coefficient according to approbation of mountain developments and well core.

Estimation of the mineralization erosive section level is one of the main tasks of geochemical research. For ASGF rank of ore bodies and deposits the technique of such estimation depending on a number of vertical geochemical element zoning is well approved and in detail elucidated in literature [1, 12, etc.]. Application of this technique to golden-ore deposits often becomes complicated by centripetal character of volumetric zoning of ore columns and, as consequence, by change stage character with zoning coefficient depth. Change on a vertical of relative concentration (RC) of related elements is more sustained. The Fig. 2 shows a typical picture of change with depth of ASGF quantitative characteristics (in the form of productivities corresponding to parameters in horizon-oriented sections) by the example of the Tsentralnie Shtoki depoit of the Kazskiy ore field (Mountainous Shoria). The interval of gold mineralization development is characterized by maximal values of ore-formation energy, factor of orderliness, sums of concentrating and deconcentrating elements. At the same time maximum RC of Co:Ni is dated to the sub-ore area, and RC of Pb:Zn and the sum (Ba+Mn) – to supra-ore.

For dispersed mineralization zones concentration of fluid stream is not typical, therefore, a distinctive feature of such sites is the absence of the concentric zonal ASGF in within them. Hence, the orderliness coefficient for any section of such structure does not fall outside the limits of statistically insignificant level (Fig. 3).

For dispersed mineralization zones a low-contrast and irregular change with productivity depth of all geochemical parameters is also characteristic. At the same

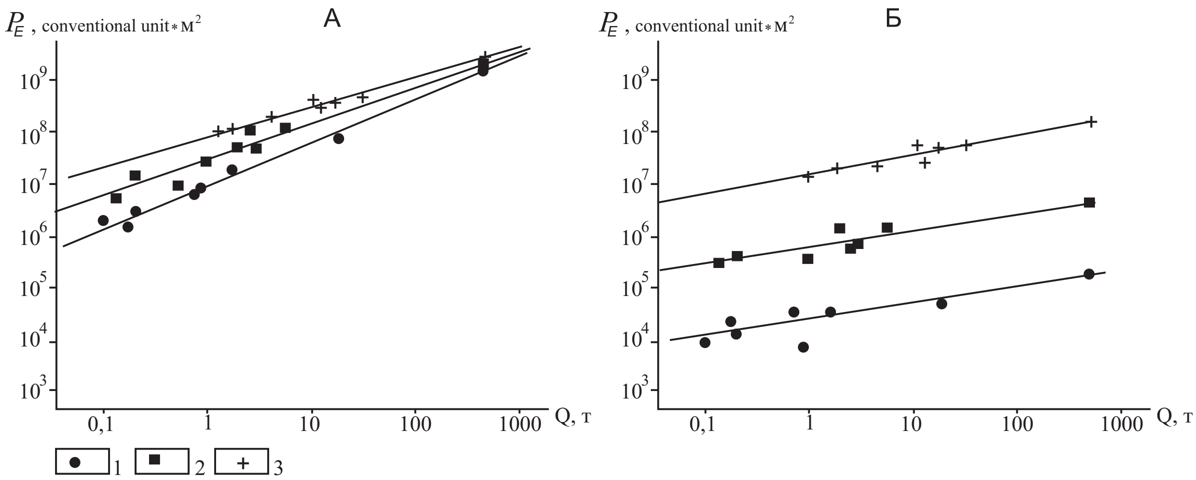

Fig. 1. *Dependence between the scale of gold mineralization Q and efficiency of the energy ore-formation parameter P_E for elements: A) concentrating, Б) deconcentrating. ASGF ranks: 1 – ore body; 2 – deposits; 3 – ore field*

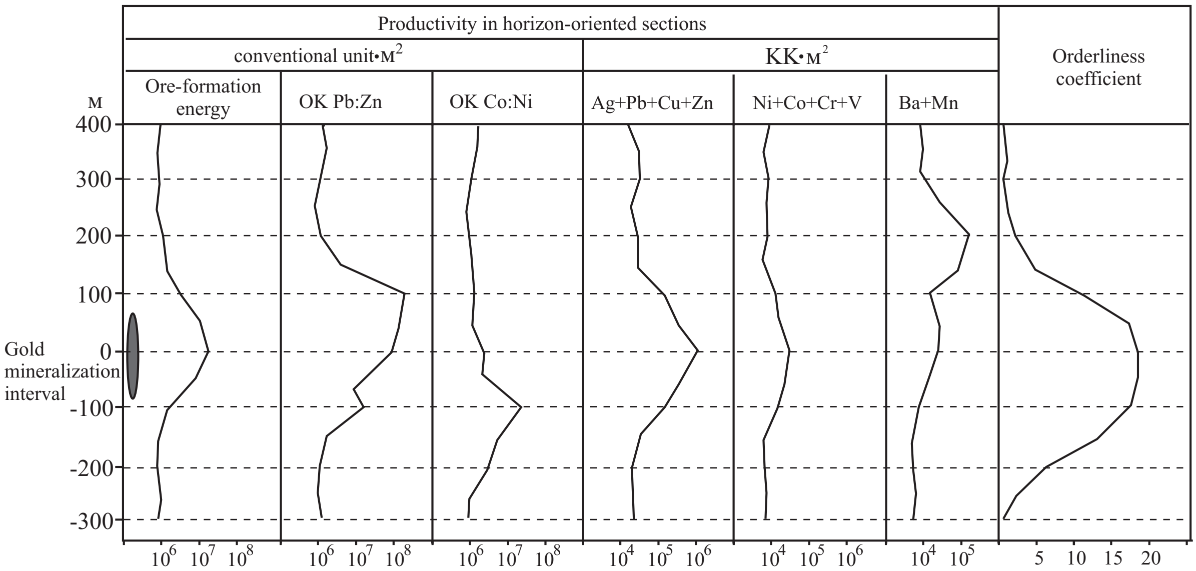

Fig. 2. *Change with depth of ASGF parameters of the Tsentralnie Shtoki deposit of the Kazskiy ore field (Mountainous Shoria)*

time, the general level of deconcentrating elements accumulation corresponds to industrial ore bodies which specify high enough energy potential of hydrothermal system. However, in conditions of adverse tectonic environment concentration of fluid streams did not occur and ore (concentrating) elements dispersed rather equally together with deconcentrating in great volume without formation of contrast zonal structures.

The estimation of ASGF erosive section level of ore fields rank represents a separate problem. Research in vertical zoning of such level on master objects is possible only at subhorizontal position of zoning vector. However, such situations occur seldom. In most cases we deal with cross-sections of hydrothermal systems and have to restore vertical zoning of ore fields by separate fragments or by the analogy principle. The analysis of the data published and obtained by us shows that subore and supra-ore sections of ore fields are characterized by similarity of some ASGF parameters (degree of orderliness, ore-formation energy, spectrum of concentrating elements, ASGF morphology), but have certain differences. At sustained set of concentrating elements their parity during filtration of fluids naturally varies, therefore, for frontal zones of ore fields positive anomalies RC Pb:Zn are peculiar at their absence in indigenous zones. RC anomalies Co:Ni, on the contrary, are usual for indigenous zones and are absent in frontal. For indigenous zones higher concentration in metasomatites and pyrite Co, Ni, Cr, V are also characteristic. For some golden-ore fields of the Far East, besides, relative accumulation in indigenous zones Ba and Mn [7] is stated, but the data obtained by us does not confirm this conclusion.

The objective estimation of ASGF parameters on primary aureoles is in most cases possible only for ore bodies and in detail studied deposits. The density of the approbation network of indigenous rocks at search-estimated works, as a rule, is insufficient for a correct quan-

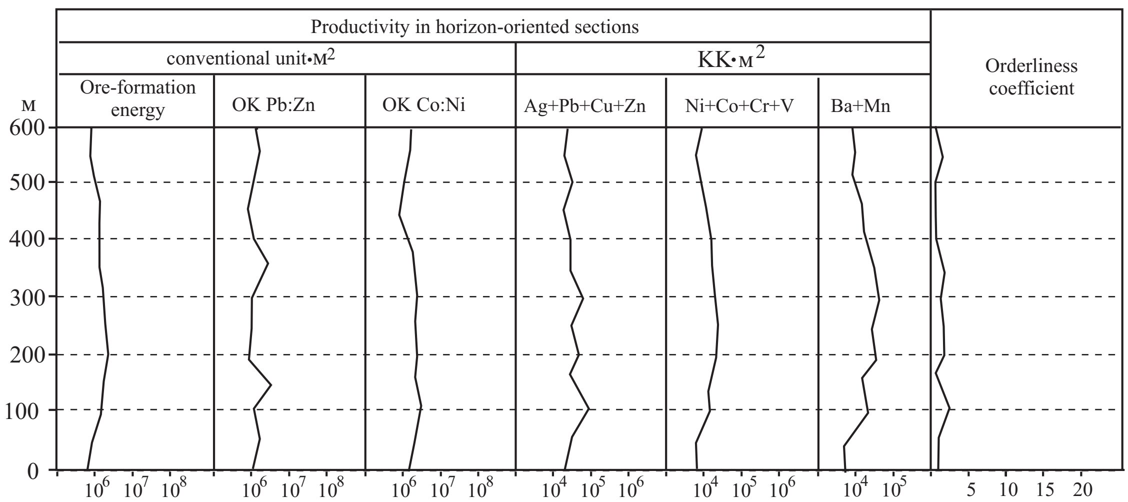

Fig. 3. *Change with depth of ASGF parameters of the dispersed mineralization zone (the Sinuhinskiy ore field, Mountainous Altai)*

titative estimation of ASGF parameters of ranks of deposits and ore fields; therefore, use of results of secondary geochemical fields mapping for these purposes is an obviously necessary element of researches. The parity of element concentration in primary and secondary aureoles is supervised by the whole set of coefficients to predict the total influence of them is practically impossible. Coefficients of residual efficiency are usually calculated on each object during special researches. At the initial stage of works it is possible to use factors deduced for similar landscape-geochemical conditions in other areas.

The data about average values of these coefficients for golden-ore fields of Siberia generated in the alumosilicate environment are shown in the Table. For carbonaceous rocks the essential (in few times) enrichment of secondary auras Ni, Co, Cr, V, Pb, Zn, Ba is stated, therefore, the experimental-methodical works are necessary for such deposits.

Table. *Average coefficient values of residual productivity in golden-ore fields of Siberia generated in the alumosilicate environment (according to N.A. Rosljakov's data [15])*

Element	Au	Ag	Pb	Cu	Zn	Mo	Bi	Ba	Mn	Sr	Ni	Co	V	Cr
$\bar{k}$	1,5	0,5	2,2	0,7	1,4	1,7	0,7	0,9	1,0	0,6	1,1	0,9	0,9	1,4

The involved data and data obtained by us indicate that ASGF revealed in primary fields keep the morphology in secondary accumulations in general. The quantitative parameters of ASGF, at the same time, in the certain degree are deformed and should be corrected according to calculated for each element coefficients of residual productivity. Correlation connections in primary aureoles are also impaired and new ones arise, therefore, associations of concentrating and deconcentrating elements should be allocated in terms of the results of investigation in primary fields or by analogy with the master object.

Conclusion

The technique of quantitative estimation of abnormal geochemical field parameters is offered, which includes:

- Geometrization of concentrating and deconcentrating anomalies concerning ore body elements;
- Calculation of geochemical field abnormal structures orderliness coefficient;
- Calculation geochemical parameters productivity (ore-formation energy, coefficients of element relative concentration, sums of concentrating and deconcentrating elements).

The dependence of quantitative parameters of geochemical field abnormal structures on scales of gold mineralization accompanied by them is revealed. The opportunity of erosive section of deposits and ore fields estimation on values of these parameters is shown, the criteria of difference between industrial ore bodies and zones of the dispersed (nonindustrial) mineralization are determined.

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Received on 07.09.2006